STATE OF NEW MEXICO

MIDDLE RIO GRANDE CONSERVANCY DISTRICT

REPORT OF THE CHIEF ENGINEER

JOSEPH L. BURKHOLDER

SUBMITTING A PLAN FOR FLOOD CONTROL, DRAINAGE AND IRRIGATION OF THE MIDDLE RIO GRANDE CONSERVANCY PROJECT

IN THREE VOLUMES
VOLUME I

THE OFFICIAL PLAN
APPROVED AUG. 15, 1928

Middle Rio Grande
Conservancy District
1930 (S. 2nd)
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CH 3-6796

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MIDDLE RIO GRANDE CONSERVANCY DISTRICT

Albuquerque, New Mexico

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VOLUME I

VOLUME II

VOLUME III

(Volume III and 22 volumes of exhibits, containing 5 special reports and 290 drawings accompany this report and are a part of it, but have not been published in form available for distribution).

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Albuquerque, New Mexico,

March 19, 1929.

The Honorable Board of Commissioners,
Middle Rio Grande Conservancy District,
Albuquerque, New Mexico.

Gentlemen:

I have the honor of transmitting herewith Volumes I and II of the Report of the Chief Engineer submitting a plan for flood control, drainage and irrigation of the Middle Rio Grande Valley Project, revised to include the Modification of the Plan, as approved by the Court August 15, 1928.

In revising the manuscript of the original report, as submitted to you May 1, 1928, it has been the aim to keep the original report intact, but to note all changes due to the modification ordered by the Court. Volume I, as now submitted, is therefore intended as a record of the Official Plan of the Middle Rio Grande Conservancy District. No important changes have been made in Volume II, Contract Forms and Specifications.

There have been added to the report as appendices a recent water supply study of the Project by R. G. Hosea, and also a brief description and record of the evaporation experiments obtained at the Los Griegos Station under the cooperative agreement between this District and the United States Bureau of Reclamation.

Respectfully,

J. L. BURKHOLDER,
Chief Engineer.

SYNOPSIS OF THE REPORT

This report is presented for the express purpose of outlining a plan for flood control, drainage and irrigation of the Middle Rio Grande Conservancy Project in accordance with the requirements of Chapter 45 of the Session Laws of the State of New Mexico for the year 1927. It consists of three volumes and certain exhibits. The exhibits contain the following: Five volumes of special reports marked Exhibits R-1, R-2, R-3, R-4, R-5, and 17 volumes of drawings marked Exhibits P-1, P-2, P-3, P-4, P-5, P-5a, M-1, M-1a and M-2, and R-3a and R-3b, which are a part of Special Report R-3.

The recommended Plan is described in Section V of Volume I. It consists of flood control and river improvement work, a comprehensive system of drainage and a modern system of irrigation, including a storage reservoir and four diversion dams. The proposed work is all believed to be necessary at this time for the material improvement and development of the middle Rio Grande valley. The total estimated cost of the Plan as modified is $10,337,000 which includes the share of the United States of America, on behalf of the Indian lands within the project, estimated as $1,593,311. This cost estimate includes liberal provisions for contingencies and it is believed to be ample for the completion of the Plan.

The report includes a description of the early history of the area involved, an outline of present conditions and the need for the proposed work, and a record of the investigations and studies made by the engineers of the District during the development of the Plan. In this latter part an attempt has been made to set forth the important features studied and finally rejected as a part of the recommended Plan, and the reasons for this exclusion.

Attention is directed to the special reports included as exhibits to this report. There are five of these, all dealing directly with the recommended Plan. Of these the report entitled "Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico," by the United States Bureau of Reclamation, deals with the water supply of the proposed project and reaches the conclusion that the supply is adequate, as developed by the Plan, for the irrigation of 140,000 acres.

The report entitled "Erosion and Control of Silt on the Rio Puerco, New Mexico", by Kirk Bryan and George M. Post, is an interesting description of the causes of excessive erosion. It fixes the responsibility on the Rio Puerco for over 40 per cent of the silt entering the Rio Grande, and outlines methods and cost estimates for ameliorating this condition.

President E. H. Wells, of the New Mexico State School of Mines, had made a study of the geology of the El Vado reservoir for the Dis-

trict, and his report is entitled "The Geology of the El Vado Dam Site and Reservoir".

Dean Philip S. Donnell, of the University of New Mexico, has collected and studied the extensive data on water table conditions in the middle Rio Grande valley. His report entitled "Report on Ground Water Determinations" is accompanied by one volume of maps and one volume of profiles.

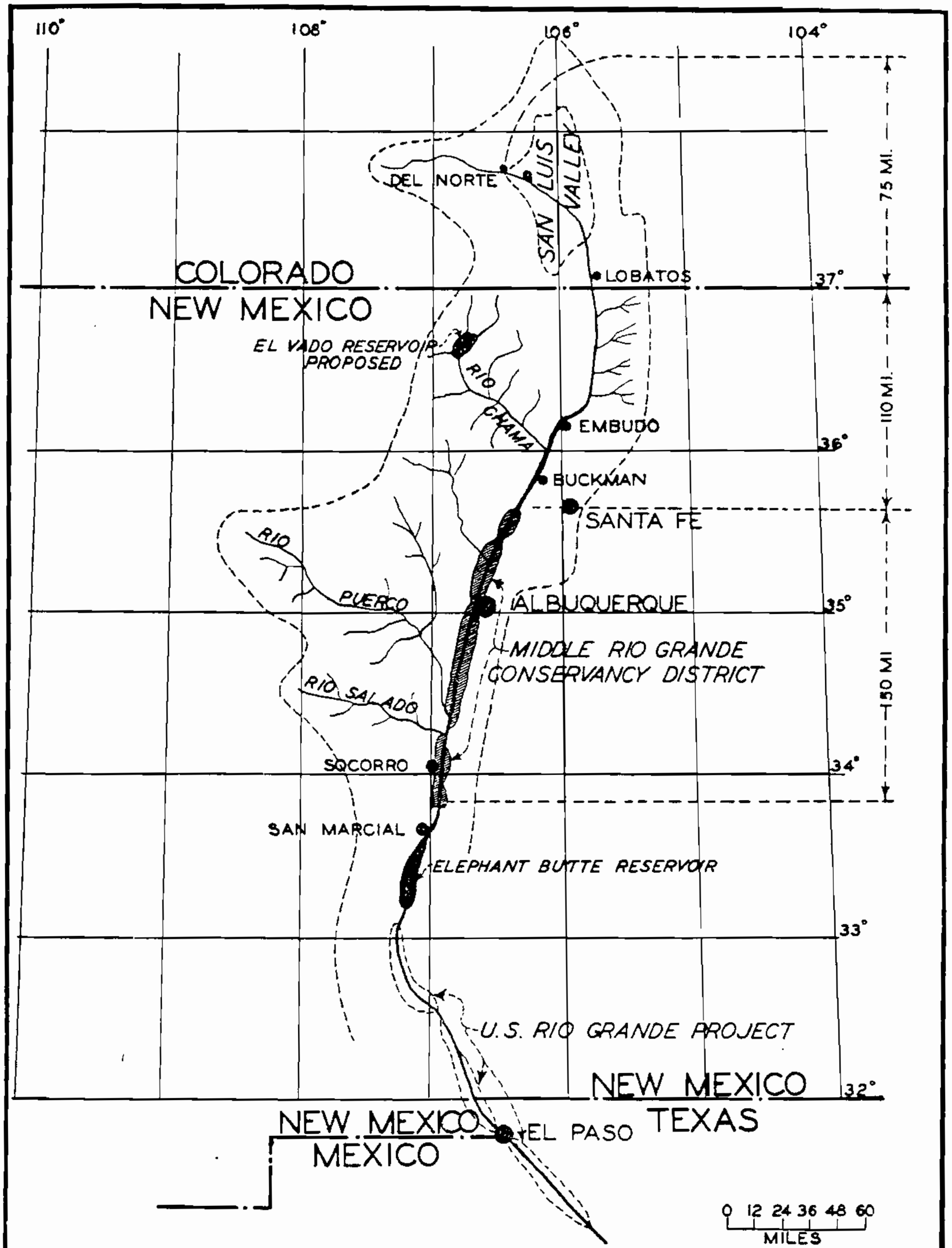
The Board of Consulting Engineers has rendered several reports to the District which are included as a volume of the exhibits. A summary of this report is included in paragraph 118 to 122.

PART I

THE PLAN

SECTION I

CHRONOLOGICAL DEVELOPMENT OF THE RIO GRANDE BASIN



SKETCH MAP OF
RIO GRANDE VALLEY
SHOWING
RELATIVE LOCATION OF PROJECTS

SECTION I

CHRONOLOGICAL DEVELOPMENT OF THE RIO GRANDE BASIN

The Middle Valley

The Middle Valley Prior to Spanish Exploration.

✓1. The middle Rio Grande valley in New Mexico is probably one of the oldest irrigated areas in the United States. Long before the first explorations of the Spaniards in 1539, the Indians in this valley were irrigating their lands, and traces of ancient canals are found in many localities.

✓2. These prehistoric Indians left no written records from which to determine the time when they first settled in the Rio Grande valley. Their own traditions and the studies of archaeologists seem to indicate that it was about the beginning of the Christian era, though some scholars place the date still earlier.

✓3. Antonio de Espejo, writing of the Rio Grande valley as seen by him about 1582, says in his "relaciones", "They (the Indians) have fields of maize, beans, gourds, and piciete in large quantities which they cultivate like the Mexicans. Some of the fields are under irrigation, possessing very good diverting ditches, while others are dependent upon the weather."

✓4. Archaeologists and historians differ widely in their estimates of the number of these earlier inhabitants. Benavidez says that the Rio Grande valley was quite densely populated, one "city" alone having 3000 inhabitants. Other investigators think his estimates exaggerated, but there is positive proof of the existence of a number of towns or "pueblos", and it is thought that a very conservative estimate of their population would be something like 25,000 people.

✓5. If they cultivated one acre of land per inhabitant (which is about the present area cultivated per capita on some of the pueblo grants), there must have been about 25,000 acres of cultivated land in the valley prior to the coming of the Spaniards.

The Middle Valley from 1539 to Date.

✓ 6. The first Spaniards to visit New Mexico were treasure seekers under Coronado. They accomplished little in the way of developing

the country and, disappointed in their quest for the fabulous wealth of "Cibola", returned to Mexico in 1542.

✓ 7. It was not until 1598 that a real colonizing expedition under Don Juan de Onate came into the valley and founded a settlement near the mouth of the Rio Chama at the Indian pueblo of Yugewinge. This settlement was christened San Juan de los Caballeros and was the first capital of the new empire. Here, with the assistance of 1500 Indians, Onate built a canal or "acequia" which was probably the first Spanish ditch in the country.

✓ 8. A few years later (probably 1609) this settlement was abandoned and a new capital was established at the Ciudad Real de la Santa Fe de San Francisco de Assizi, where it remains today under the shorter name of Santa Fe.

✓ 9. Exploration and colonization was carried on from Santa Fe for a period of about 75 years, but in 1680 the Indians rose in revolt and drove the Spaniards out of the country. They retired to Paso del Norte (the El Paso of today) and remained there for 12 years. In 1692, under Don Diego de Vargas, they put down the Indian rebellion and returned to Santa Fe and the Rio Grande valley.

10. At this time many vast Spanish land grants were made, in recognition of services rendered during the pueblo rebellion, and the real development of the country began. Perhaps because of the location of Santa Fe, which was the capital and headquarters for the entire country, this development took place generally from north to south, the country near Santa Fe being settled first.

11. In almost regular progression down the river to the south, settlement and development followed. Bernalillo was founded about 1700 on a land grant from the Spanish Crown.

12. The Villa de San Felipe de Alburquerque, named for King Philip of Spain and his Viceroy the Duke of Alburquerque, was settled in 1706 on the site of the old "hacienda" of Don Luis Carbajal, which had been destroyed by the Indians during the uprising of 1680.

13. In 1739 certain residents of Albuquerque, dissatisfied with conditions there, moved a few miles to the southward and established the settlement known as Nuestra Senora de la Concepcion de Tome Dominquez. This settlement still exists under the shorter name of Tome, and it is interesting to note that one of the reasons for the dissatisfaction of the original settlers with Albuquerque was the shortage of water for their fields.

14. In 1716 a grant of land known as the San Clemente Grant was made to Ana Sandoval y Manzanares, daughter of Mateo Sandoval y Manzanares, one of the original colonists driven out by the pueblo

rebellion of 1680. The present town of Los Lunas, some 20 miles south of Albuquerque, is located on this grant.

15. The Belen area developed from another land grant made in about 1642 and the La Joya grant to the south followed.

16. The Socorro area was developed many years later. There were Indian pueblos in this locality in pre-Spanish time and the Spaniards established several missions at these pueblos, but after the rebellion of 1680 these few small settlements were exposed to continual attack by the hostile Apaches who murdered or drove off the settlers, and it was not until the building of the railway down the Rio Grande valley some 200 years later that the real development of this country took place.

17. The above historical sketch outlines roughly the history of the settlement of the middle Rio Grande valley in New Mexico. As each community was settled it built its own irrigating ditch or "acequia", since all of these settlements were agricultural communities, dependent upon irrigation, without which no crops could be grown in this country. Today there are nearly 70 ditches in the middle valley resulting in much duplication of effort and waste of water (see paragraph 66).

✓ 18. From the date of discovery by the Spanish Conquistadores in 1539, the middle Rio Grande valley was claimed by Spain and was ruled by Spanish governors under the jurisdiction of the colonial government of Mexico until 1821, when Mexico established her independence.

19. When Mexico revolted and became independent, this upper country became Mexican territory and so remained until it was ceded to the United States of America under the treaty of Guadalupe Hidalgo in 1848. This treaty, which marked the end of the Mexican war, guaranteed to the inhabitants of the ceded area the same rights and privileges to which they had been accustomed. Consequently the customs of the Spanish colonies have been preserved to a considerable extent in New Mexico, and this becomes important in any consideration of the irrigation canals and of the use of water.

The Valley from San Marcial to Fort Quitman

Brief Historical Statement.

20. In the southern Rio Grande valley, in the early days of Spanish rule, there was only one important settlement. This was at Paso del Norte (the present El Paso) where a ford or pass across the river gave access to the northern country.

21. Otermin and his fugitives from Santa Fe stopped in El Paso in 1680 and remained until 1692, but no colonization on any large scale was attempted on account of the constant raids of the hostile

Apaches. Numerous attempts were made to cultivate that portion of the Rio Grande valley from El Paso to Palomas during the last of the 18th and the first of the 19th centuries, but the inhabitants were driven off or murdered.

22. On August 4, 1853, Mexico made a grant of land to certain Mexican families known as the Civil Colony of Mesilla, the lands being on the west side of the Rio Grande near Mesilla. This area was then part of the Republic of Mexico and was later acquired by the United States as a part of the Gadsden purchase.

23. There were no Indian pueblos south of the present San Marcial at the time of the Spanish conquest. This is definitely stated in the memorial of Fray Alonzo de Benavidez, and also in the "relaciones" of Antonio de Espejo, both of whom traveled up the Rio Grande from Mexico without finding any Indian pueblos south of the present San Marcial.

The Rio Grande Valley in Colorado

First Settlements.

24. A number of exploring expeditions into Colorado were made by the Spaniards from Santa Fe in the days of Spanish rule in New Mexico, but it was not until after 1850 that actual colonization began. For ten or twelve years thereafter, a number of Spanish settlements were made in the Costilla, Culebra and Conejos valleys which are tributary to the Rio Grande in Colorado, but it was not until about 1873 that Americans began to move into the San Luis valley in numbers.

Rapid Development after 1880.

25. About 1880 the Denver & Rio Grande Western Railroad built into the valley. A number of huge canals were constructed and large areas of land were brought under cultivation until the normal flow of the river was practically exhausted. Reservoirs were then constructed and development continued. Today the greater part of the water which crosses the interstate line into New Mexico is flood water, drainage return flow, or water which cannot be utilized in Colorado.

Effect on Lower River.

26. This progressive increase in the use of water in Colorado has had a two-fold effect in the middle river valley in New Mexico. The flow of the river has decreased and at the same time the irrigated area has decreased, by reason of the rising river bed and the increasing seeping of adjacent lands. The one effect has to a great extent concealed the other. As the irrigable area decreased the demand for water decreased and tended to conceal the increasing shortage, but this condi-

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tion did not hold true below the middle Rio Grande valley where the shortages became more and more apparent as time went on.

The U. S. Rio Grande Project

The Mexican Protest.

27. In 1895 a protest was made by Mexico on behalf of certain citizens of Juarez against the alleged immoderate use of the waters of the Rio Grande in Colorado and New Mexico, and the construction of an international dam and the appointment of a commission to distribute the waters of the Rio Grande equitably between the United States and Mexico was proposed.

Investigation by International Commission.

28. This protest resulted in the appointment of an international commission, and a study of the whole Rio Grande situation was made under its direction. The part of this study dealing with the flow of the river, the diversions therefrom, and the existing storage sites thereon, was made by W. W. Follett, Civil Engineer of El Paso, and appears in Senate Documents Vol. 21, No. 229, 55th Congress, 2nd Session, pp. 47-177.

Ditches in the Rio Grande Valley in New Mexico in 1896.

29. Table 1 shows the ditches which were found by Mr. Follett in the Rio Grande valley in 1896, taken from the above mentioned report.

Treaty with Mexico.

30. The outgrowth of the whole matter was the negotiation of a treaty between the United States and Mexico, wherein the United States guaranteed to Mexico the delivery of 60,000 acre feet of water per annum at the heads of the Mexican canals.

Location and Construction of Elephant Butte Reservoir.

31. To insure the ability to carry out the provisions of this treaty, the United States Bureau of Reclamation constructed the Elephant Butte Reservoir with a capacity of 2,600,000 acre feet. This reservoir not only guarantees the delivery of water to Mexico, but also makes possible the irrigation of some 155,000 acres of land in New Mexico and Texas, which constitutes the Rio Grande Project of the United States Bureau of Reclamation. The reservoir, which has been completed and in operation since 1915, is located on the Rio Grande just below the lower end of the middle valley and extends south from San Marcial for a distance of about 45 miles to the site of the Elephant Butte Dam.

Table 1

LIST OF DITCHES IN RIO GRANDE VALLEY, NEW MEXICO

(See paragraphs 28 and 29)

Number of Ditches	Number on Stream	Name	Stream	When built	Approximate Location of head	Capacity	Total Capacity	Acres Irrigated	Acre Feet of Water used			Remarks
									1894	1895	1896	
					Sec. T. R.	S.F.	S.F.					
2	19, 20	Cochiti Pueblo	E. & W. side Rio Grande	Pueblo, very old	18 16N. 6E.	a12	24	450	1,800	1,800	1,800	
1	21	Pena Blanca	E. side Rio Grande	Before 1800	18 16N. 6E.	22	22	850	3,400	3,400	3,400	
1	22	Santo Domingo	E. side Rio Grande	Pueblo, very old	36 16N. 6E.	6	6	200	800	800	800	
2	23, 24	Santo Domingo Lower	E. side Rio Grande	Pueblo, very old	23 15N. 5E.	a 4	8	200	800	800	800	
1	25	Sili	W. side Rio Grande	About 1820	35 16N. 5E.	5	5	200	800	800	600	
2	26, 27	San Felipe	E. & W. side Rio Grande	Pueblo, very old	3 14N. 5E.	a10	20	500	2,000	2,000	1,500	
1	28	Algodones	E. side Rio Grande	Before 1800	19 14N. 5E.	10	10	250	1,000	1,000	750	
1	29	Santa Ana	W. side Rio Grande	Probably about 1810	25 14N. 4E.	13	13	330	1,320	1,320	990	
1	30	Santa Ana	E. side Rio Grande	Probably about 1810	1 13N. 4E.	13	13	330	1,320	1,320	990	
1	31	Bernalillo	E. side Rio Grande	1700	15 13N. 4E.	25	25	620	2,480	2,480	1,860	
1	32	Sandia Pueblo	E. side Rio Grande	Pueblo, very old	31 13N. 4E.	18	18	450	1,350	1,800	1,120	
1	33	Upper Corrales	W. side Rio Grande	Before 1800	23 12N. 3E.	24	24	600	1,800	2,400	1,500	
1	34	Alameda	E. side Rio Grande	Before 1800	35 12N. 3E.	25	25	630	1,890	2,520	1,530	
1	35	Los Ranchos	E. side Rio Grande	Before 1800	3 11N. 3E.	22	22	550	1,650	2,200	1,380	
1	36	Lower Corrales	W. side Rio Grande	Before 1800	8 11N. 3E.	8	8	200	600	800	500	
1	37	Los Griegos de Candelaria	E. side Rio Grande	Before 1800	18 11N. 3E.	21	21	530	1,590	2,120	1,360	
1	38	La Barela	E. side Rio Grande	Before 1800	30 11N. 3E.	20	20	500	1,500	2,000	1,250	
1	39	Duranes	E. side Rio Grande	1706	36 11N. 2E.	11	11	280	840	1,120	680	
1	40	Albuquerque	E. side Rio Grande	1706	1 10N. 2E.	16	16	400	1,200	1,600	1,000	
22		Total Cochiti to Albuquerque.					311	8,070	28,140	32,280	23,860	

a—Each.

Table 1 (Continued)

1	41	Ranches de Atrisco	W. side Rio Grande	Before 1800	11	10N. 2E.	9		140	420	560	280	
1	42	Upper Atrisco	W. side Rio Grande	Before 1800	12	10N. 2E.	36		540	1,620	2,160	1,080	
1	43	Middle Atrisco	W. side Rio Grande	Before 1800	13	10N. 2E.	20		300	900	1,200	600	
1	44	Lower Atrisco	W. side Rio Grande	Before 1800	13	10N. 2E.	63		950	2,850	3,800	1,900	
1	45	Acequia de Pajarito	W. side Rio Grande	Before 1800	12	9N. 2E.	65		980	2,940	3,920	1,960	
1	46	Los Padillos	W. side Rio Grande	Before 1800	24	9N. 2E.	40		600	1,800	2,400	1,200	
1	47	Isleta Pueblo	W. side Rio Grande	Pueblo, very old	12	8N. 2E.	40		600	1,800	2,400	1,200	
1	48	Chical	E. side Rio Grande	Pueblo, very old	13	8N. 2E.	21		320	960	1,280	640	
1	49	Picuri	E. side Rio Grande	Pueblo, very old	24	8N. 2E.	30		420	1,260	1,680	840	
1	50	Romero	E. side Rio Grande	Before 1850	24	8N. 2E.	40		600	1,800	2,400	1,200	
1	51	Peralta	E. side Rio Grande	Before 1850	35	8N. 2E.	21		320	960	1,280	640	
1	52	Valencia	E. side Rio Grande	Before 1850	35	8N. 2E.	31		460	1,380	1,840	920	
1	53	Los Lentes	W. side Rio Grande	Before 1850	35	8N. 2E.	40		600	1,800	2,400	1,200	
1	54	Los Lunas	W. side Rio Grande	Before 1850	10	7N. 2E.	48		720	2,160	2,880	1,440	
1	55	Huning's Mill & irrigation	W. side Rio Grande	1872	23	7N. 2E.	80		1,000	3,000	4,000	2,000	
1	56	San Fernandez	E. side Rio Grande	Old	23	7N. 2E.	8		130	330	390	200	
1	57	Upper Tome	E. side Rio Grande	Old	26	7N. 2E.	9		150	380	450	230	
1	58	Los Chavez	W. side Rio Grande	Old	33	7N. 2E.	30		500	1,250	1,500	750	
1	59	Lower Tome	E. side Rio Grande	Old	3	6N. 2E.	36		600	1,500	1,800	900	
1	60	Belen	W. side Rio Grande	Old	4	6N. 2E.	36		560	1,400	1,680	840	
1	61	La Sausal	W. side Rio Grande	Old	9	6N. 2E.	30		500	1,250	1,500	750	
1	62	La Constancia	E. side Rio Grande	Very old	21	6N. 2E.	36		600	1,500	1,800	900	
1	63	Acequia de los Innocentes	W. side Rio Grande	Old	29	6N. 2E.	36		600	1,500	1,800	900	
1	64	Casa Colorado	E. side Rio Grande	Old	16	5N. 2E.	36		600	1,500	1,800	900	
1	65	Jarales	W. side Rio Grande	Old	8	5N. 2E.	55		850	2,120	2,550	1,270	
1	66	Del Bosque	W. side Rio Grande	Old	29	5N. 2E.	36		600	1,500	1,800	600	
1	67	Sabinal	W. side Rio Grande	Old	8	4N. 2E.	30		600	1,500	1,800	600	
1	68	San Jose No. 1	E. side Rio Grande	Old	8	4N. 2E.	65		800	2,000	2,400	800	
1	69	San Jose No. 2	E. side Rio Grande	1888	20	4N. 2E.	30		400	1,000	1,200	400	All this land form watered by San Jose
1	70	Las Nutrias	E. side Rio Grande	Old	20	4N. 2E.	27		500	1,250	1,500	500	
1	71	Picacho	W. side Rio Grande	1868	7	3N. 2E.	21		300	750	900	300	
1	72	Los Ranchos	E. side Rio Grande	Old	18	3N. 2E.	27		400	1,000	1,200	400	
1	73	La Joya	E. side Rio Grande	Old	25	3N. 1E.	36		600	1,500	1,800	600	
33		Total Albuquerque to La Joya					1168		17,840	48,880	62,070	28,940	

Table 1 (Continued)

Number of Ditches	Number on Stream	Name	Stream	When built	Approximate Location of head	Capacity	Total Capacity	Acres Irrigated	Acre Feet of Water used 1894	1895	1896	Remarks
1	74	San Geronimo	W. side Rio Grande	Old	32 2N. 1E.	6		90	270	270	220	
1	75	San Acacio	W. side Rio Grande	Old	31 1N. 1W.	14		650	1,950	1,950	1,580	
1	76	Polvadera	W. side Rio Grande	Old	31 1N. 1W.	12		500	1,500	1,500	1,250	
1	77	Lemitar	W. side Rio Grande	Old	12 1S. 1W.	42		1,000	3,000	3,000	2,500	
1	78	Socorro	W. side Rio Grande	Old	2 2S. 1W.	40		600	1,800	1,800	1,200	
1	79	Publicito	E. side Rio Grande	Old	28 2S. 1E.	5		150	380	450	300	
1	80	Lotiller	W. side Rio Grande	Old	29 2S. 1E.	22		600	1,500	1,800	1,200	
1	81	Cuba	W. side Rio Grande	Old	8 3S. 1E.	8		200	500	600	400	
1	82	San Antonio	W. side Rio Grande	Before 1855	8 4S. 1E.	36		450	1,120	1,350	900	
1	83	Bosquecito	E. side Rio Grande	Before 1855	8 4S. 1E.	15		200	250	600	400	
1	84	San Pedro	E. side Rio Grande	Before 1855	8 4S. 1E.	28		400	1,000	1,200	800	
1	85	San Antonito	W. side Rio Grande	1881	32 4S. 1E.	12		150	370	450	300	
1	86	Val Verde	E. side Rio Grande	Before 1869	10 7S. 1W.	16		200	500	600	400	
1	87	San Marcial	W. side Rio Grande	Before 1869	17 7S. 1W.	16		200	500	600	400	
1	88	La Mesa	E. side Rio Grande	Before 1869	20 7S. 1W.	14		200	500	600	400	
1	89	Contidero	E. side Rio Grande	1863	19 7S. 1W.	14		200	500	600	400	
16		Total San Acacio to San Marcial				300		5,790	15,640	17,370	12,650	
1	90	Paraje	E. side Rio Grande	1863	28 8S. 2W.	21	21	300	750	900	600	
1	91	Fort Craig	W. side Rio Grande	1887	21 8S. 2W.	4	4	50	120	150	100	
1	92	Cautaricio	W. side Rio Grande	1869	6 9S. 3W.	11	11	200	500	600	400	
1	93	San Jose Plaza	W. side Rio Grande	Before 1864	4 10S. 3W.	14	14	300	750	900	600	
1	94	San Albino	E. side Rio Grande	Before 1864	10 10S. 3W.	10	10	200	500	600	400	
1	95	Mitchell	W. side Rio Grande	1884	8 11S. 3W.	11	11	250	620	750	200	But 100 acres watere[d in] 1896.
2	96, 97	Gonzales	E. & W. side Rio Grande	1884	5 12S. 3W.	a 3	6	90	220	270	180	
2	98, 99	Polomitas and Hot Springs	W. side Rio Grande	1870	— 14S. 4W.	a18	—	900	—	—	—	Washed out and a[ban]doned in 1884.
1	100	Greenhorn	W. side Rio Grande	1895	6 16S. 4W.	10	10	60	—	180	120	Failure.
1	101	Sierra	W. side Rio Grande	1895	18 16S. 4W.	10	10	200	—	600	—	Failure.
1	102	Arroyo Bonito	W. side Rio Grande	1895	35 16S. 5W.	24	24	400	—	600	800	Good ditch; 200 a[cres] watered in 1895.
1	103	Loma Padre	E. side Rio Grande	1893	29 17S. 5W.	100	100	3,600	2,500	7,500	7,200	200 acres in 1893; 1,0[00 in] 1894; 2,500 in 1895.

Table 1 (Continued)

1	104	Colorado Plaza	W. side Rio Grande	1870	27 18S. 4W.	60	60	4,000	10,000	12,000	6,000	
1	105	East Colorado	E. side Rio Grande	1870	31 18S. 3W.	10	10	100	250	300	150	Watered 250 acres to 1889.
1	106	Private	W. side Rio Grande	1895	17 19S. 2W.	4	4	100	—	150	150	Watered 50 acres in
17		Total San Marcial to Leasburg					295	9,850	16,210	25,500	16,900	
	a—Each.											
1	107	Dona Ana	E. side Rio Grande	1844	24 21S. 1W.	70		4,600	11,500	11,500	11,500	About 7,000 acres wa prior to 1882; then ually fell to 4,600 in 1888.
1	108	Las Cruces	E. side Rio Grande	1849	4 22S. 1E.	125		6,000	13,750	13,750	13,750	Has same head as water divided ec since 1884.
1	109	La Mesilla	E. side Rio Grande	1850	4 22S. 1E.	125		5,000	13,750	13,750	13,750	4,000 acres watered in Increase has been gra
1	110	Picacho	W. side Rio Grande	1850	4 23S. 1			2,500				Abandoned 1880; now vacant.
1	111	San Miguel	W. side Rio Grande	1857	19 24S. 2	66		1,500	3,750	3,750	3,000	
1	112	Santa Tomaz	W. side Rio Grande	1857	20 24S. 2	10		500	1,250	1,250	1,000	Washed out in 1884 not used until 1890. 1890 takes water San Miguel. Pri 1884 served 1,200 .
1	113	Mesquite	E. side Rio Grande	About 1875	36 24S. 2	10		500	1,250	1,250	1,000	Poor ditch.
1	114	La Mesa	W. side Rio Grande	1857	28 24S. 2	60		1,500	3,750	3,750	3,000	Until 1869 part of Miguel.
1	115	Chambarino	W. side Rio Grande	1864	13 25S. 2	75		3,000	7,250	7,500	4,500	Prior to 1884, 3,000 a 1885 to 1888, 2,000 ; Then increase gra
1	116	Anthony	E. side Rio Grande	1887	7 25S. 3	30		500	1,250	1,250	750	1,000 acres served 188 90.
1	117	Old La Union	W. side Rio Grande	1852	8 26S. 3	18		400	1,000	1,000	600	Prior to 1884, 4,000 watered; since 188 to 400 in 1890.
1	118	New La Union	E. side Rio Grande	1892	8 26S. 3	90		3,600	6,500	9,000	5,400	1892, 600 acres; 1893, acres; 1894, 2,600 a 1895, 3,600 acres; increasing.
12		Total Leasburg to New Mexico-Texas Interstate Line				679		27,100	65,000	67,750	58,250	

Progress and Decline of Irrigation Development in the Middle Valley

Conclusions of C. R. Hedke.

32. In a report made to the New Mexico Interstate Compact Commission by C. R. Hedke, Civil Engineer, in December 1924, entitled "A Report on the Irrigation Development and Water Supply of the Middle Rio Grande Valley, N. M., as it Relates to the Rio Grande Compact", on pages 19 and 20 appears the following data, Table 2:

Table 2

Middle Rio Grande Developments

Time of Construction	Number of Ditches	Second Feet Capacity	1910 Irrigation (Acres)	Additional Possible (Acres)	Total Under Ditch (Acres)
Ancient and very old	15	405	11,100	7,830	18,930
Old	40	946	20,285	25,815	46,100
About 1700	2	40	1,300	1,300	2,600
Before 1800	6	221	4,500	7,400	11,900
Before 1850	5	143	3,000	5,350	8,350
To 1880	6	184	3,500	10,000	13,500
To 1910	5	197	1,535	21,885	23,420
Totals	79	2,145	45,220	79,580	124,800

(This table is given by Mr. Hedke as a summary of an investigation made in 1910 by Mr. H. W. Yeo of the United States Reclamation Service, at present State Engineer of New Mexico.)

Mr. Hedke goes on to say (p. 20, paragraph 5):

33. "The above table received excellent confirmatory data through the drainage survey made by the State of New Mexico in 1918 under the direction of Mr. G. M. Neel (later State Engineer), who found 65 ditches with a carrying capacity of 1,957 second feet, irrigating 47,007 acres during the war period of maximum production, and calculating 115,000 acres as the area with suitable soil and surface topography for irrigation."

34. This data is also corroborated by the surveys of the Middle Rio Grande Conservancy District (see paragraph 57) which show an area of about 45,000 acres under cultivation in 1926 and 1927.

35. On page 22 in the aforementioned Hedke report, appears the following data, Table 3:

Table 3

"Table Showing the Progress of Irrigation Developments in the Middle Rio Grande Valley based on the reports of: W. W. Follett, Engineer, International Boundary Commission; H. W. Yeo, Engineer, United States Reclamation Service; State of New Mexico, 1918 Drainage Survey."

Time Up to	No. of Ditches	Sec. Ft. Capacity	Acres Under Development	Acres Failed	Remarks
1600	22	537	25,555		Indian development.
1700	61	1,445	73,580		Indian with Spanish.
1800	70	1,808	100,380		Above with Spanish grants.
1850	80	2,099	123,315		Natural increase.
1880	82	2,145	124,800		Transcontinental traffic and civil war demand, completed developments.
1896	71	1,779	50,000	74,800	Due to short water supply, rising water table, R. R. supply competition and R. R. labor demand.
1910	79	2,121	45,220	79,580	Further shortage and further rising water table.
1918	65	1,957	47,000	77,800	War period.
1925	60	1,850	40,000	84,800	Estimated present condition.

Maximum and Present Development.

36. Table 3 shows that the maximum development of the middle valley of about 125,000 acres was reached in about 1880 after which a great retrogression took place, until in 1925 only 40,000 acres were cultivated. This latter figure is corroborated by the Conservancy District surveys which show approximately 45,000 acres in cultivation, including Indian lands, during 1926 and 1927.

Construction of Ditches.

37. As shown in the above tables of "irrigation development", most of the ditches in the middle Rio Grande valley are very old. The Indian ditches date back to prehistoric time and no one knows how long they had been in use before they were first seen by the Spaniards in 1539.

38. As Spanish colonies were founded, ditches were built, since irrigation was essential to the agriculture by means of which these early pioneers existed. No records exist, so far as known, which fix the exact dates of construction of these Spanish acequias, but the dates of the various land grants are probably a close approximation of some of the earlier ones.

39. Since each ditch was constructed to serve its own little community or area, there was no attempt to construct a comprehensive irrigation system for the valley as a whole. It was inevitable that a great duplication should result with a consequent waste of effort, excessive cost of maintenance, and loss of water. This condition continues to exist at the present time.

Causes of Decrease in Cultivated Area.

40. The principal causes of the decrease in the cultivated area in the middle valley are two in number:

1. Increasing height of water table.
2. Increasing water shortage.

41. The most casual inspection of the middle Rio Grande valley is sufficient to reveal the fact that over large areas the water table is at, or near, the surface. Swamps, salt grass, and alkali offer mute testimony of the retrogression of what were once cultivated fields. Some of the causes which have produced this result are:

(a) The increasing use of water in Colorado has reduced the flow of the river in New Mexico and consequently the silt transporting capacity of the stream. The result has been a building up of the river bed and an increase in the seepage from the river to the lands.

(b) There is some evidence to support the theory that there has been a climatic change in the southwestern part of the United States, and that the rainfall and streamflow is less now than it once was. The effect of such a change would be a decrease in flow and silt carrying capacity, and a building up of the stream bed.

(c) The amount of silt brought into the Rio Grande has materially increased in recent years because of the increase in the amount of erosion on tributary streams.

(d) Many of the ditches in the Rio Grande valley have been diverting water for 200 years without restraint or regulation and have doubtless contributed to the rising water table of the lands through which they pass.

The Flood of 1874 and Other Floods.

✓42. Throughout the history of the Rio Grande valley is found frequent reference to more or less disastrous floods. Many Indian villages have been swept away at one time or another, and the pueblo of Santo Domingo has been moved several times to higher ground. A flood in Santa Fe Creek in 1767 cost many lives and caused much property damage.

✓43. Many men still living in the valley north of Albuquerque clearly remember the flood of May 1874 when the river overflowed its

banks at the bend north of Alameda, and poured its muddy torrent through the valley to a point below where Albuquerque now stands. For days the inhabitants of the flooded area went about in boats trying to salvage what they could from the wreckage of their homes. The following men were interviewed and remember one or more of these earlier floods which occurred prior to 1889:

Jose Garcia y Gallegos—Alameda.
Max Chavez—Alameda.
Pedro Garcia—North of Alameda on Sandia Grant.
Carlos Armijo—Near Albuquerque Indian School.
Jose Domingo Gurule—Alameda.
Ramon Borboa—Los Padillas.
Jesus Padilla—Los Padillas.

✓ 44. This disaster made such an impression on the minds of the native population that they composed a song about it, fixing the date of the occurrence in the first two lines—May 21, 1874. However, the evidence that such a flood occurred is not based entirely upon recollections of fifty years ago, but is corroborated by an authentic written record.

✓ 45. In the diary of the Jesuit Priests at the Church of San Felipe de Neri in Old Albuquerque, under date of May 21, 1874, may be found an entry to the effect that the river overflowed its banks at the bend above Alameda. For several days thereafter the entries show that the priests were busy helping people to fight the rushing waters, and moving the valuables of the church to a safe place in the hills. This flood was probably considerably greater than the largest measured flood of 33,000 second feet.

✓ 46. Among the older residents of the valley there are also vague recollections of other floods, one of which probably occurred in or about the year 1865. Another may have taken place in the early eighties, before the first stream measuring station on the river was established at Embudo in 1889. The floods which have occurred since stream flow records were kept are considered in Section IV.

PART I

THE PLAN

SECTION II

GENERAL AND STATISTICAL DATA

SECTION II

GENERAL AND STATISTICAL DATA

The Project

Location and General Description.

✓47. The reclamation and flood control project of the Middle Rio Grande Conservancy District, herein described, is located in the counties of Sandoval, Bernalillo, Valencia and Socorro, State of New Mexico, in the middle valley of the Rio Grande. The middle valley extends along the Rio Grande from the Indian village of Cochiti at the mouth of White Rock Canyon, on the north, to San Marcial at the upper end of the United States Reclamation Bureau's Elephant Butte Reservoir, on the south, a distance of over 150 miles. It is long and narrow and consists of a number of strips of land, from one to five miles wide, through which the river meanders from one side to the other, forming a series of natural units or districts.

✓48. In general, the project includes lands in Townships 1 to 7 South, Ranges 1 West and 1 East, and Townships 1 to 17 North, Ranges 2 to 6 East, of the New Mexico Principal Meridian. The average longitude is about 107° west and the latitude varies from 34° to 36° north, approximately.

Area and Ownership.

49. The gross area of the valley floor to the base of the hills is about 210,000 acres of which the larger portion is in private ownership. Title to most of this land came originally through land grants made by the Kings of Spain. Subsequent bequests and transfers have reduced the original grants to a very large number of small irregular-shaped tracts of which some 12,500 lie within the boundaries of the Conservancy District.

50. In addition to the lands referred to in the preceding paragraph, there are a number of Indian grants lying wholly or in part in the middle valley. These grants were made to the Indians by the Spanish Crown shortly after the suppression of the pueblo rebellion in 1692, and were confirmed by the United States Government after this country was acquired from Mexico under the treaty of Guadalupe Hidalgo in 1848. Six tribes of pueblos hold lands in the middle valley, namely, Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta. The total area of Indian land included in the Middle Rio Grande Conservancy District is about 28,500 acres, exclusive of the river channel area.

Principal Cities and Towns.

51. The principal cities and towns located within the boundaries of the Middle Rio Grande Conservancy District are as follows:

Albuquerque—County Seat of Bernalillo County, the largest city in New Mexico, population 35,000.
Bernalillo—County Seat of Sandoval County, population 1,500.
Los Lunas—County Seat of Valencia County, population 1,000.
Belen—Important railway center, population 4,000.
Socorro—County Seat of Socorro County, population 1,500.

There are also numerous other small towns and communities both American and Spanish, and the total population of the middle valley is estimated at about 55,000 people, including some 3,000 Indians.

Assessed Valuations.

52. The assessed valuation of the middle Rio Grande valley, including lands and improvements, is about $40,000,000 on a basis of 50 to 60 per cent of actual value, of which about $20,000,000 is in the City of Albuquerque.

Transportation.

53. This area is served by the Atchison, Topeka and Santa Fe Railway, which traverses the entire length of the valley, and by numerous Federal Aid, State and County highways, so that transportation facilities are first-class.

Climate.

54. The middle Rio Grande valley lies at an elevation ranging between 4,460 feet at San Marcial and a little over 5,200 feet at Cochiti, and is protected by hills and mountains on both sides.

(a) The rainfall is light. At Albuquerque the 40-year mean is 7.59 inches, and at Socorro the 28-year mean is 11.09 inches.

(b) At Albuquerque the mean annual temperature is 55.7° with a mean maximum of 70.1° and a mean minimum of 41.6°. Winters are mild and open, and in summer the evenings are cool.

(c) The average growing season varies from about 189 days in the northern end to 198 days in the southern end of the valley.

(d) As a matter of fact, the wonderful climate of the middle Rio Grande valley is so well known that this country has become a mecca for health seekers, who come here in increasing numbers each year.

Soils.

55. The soils of the middle Rio Grande valley are of river bottom alluvium, usually of sandy texture and extremely fertile when properly drained and irrigated. (For detailed discussion of these soils see "Soil Survey of the Middle Rio Grande Valley Area, New Mexico", by the United States Bureau of Soils, 1912.)

Crops.

56. The principal crops grown in the valley are alfalfa, corn, grain, fruits, celery and garden truck. Some cotton is grown in the southern part, and recent experiments indicate that certain varieties of tobacco are well adapted to local conditions. A factory has been built near Albuquerque for the extraction of nicotine for commercial purposes, and a large area is planted to tobacco each year.

Classification of Valley Lands.

57. Table 4 shows the classification of the lands of the middle Rio Grande valley as of date 1926-1927.

Table 4

Classification of Valley Lands

Areas shown are total lands under constructed canals or possible extensions of existing canals. All roads and ditch rights of way excluded. Date from survey and inspection by District Engineers.

Classification 1926-27	Acres	Total Acres	Per Cent	Per Cent
Orchard and Garden	3,408		2.28	
Alfalfa and Grain	40,001		26.69	
Pasture and Hay	1,355		.90	
Homesites	820		.55	
Total Irrigated		45,584		30.42
Salt Grass	48,603		32.43	
Bosque	37,821		25.24	
Swamp and Lake	3,324		2.21	
River Wash and Arroyo Wash	1,290		.86	
Barren Alkali	275		.18	
Sand Dunes and Gravel	4,400		2.94	
Fallow Land	4,980		3.32	
Homesites	3,588		2.40	
Total Non-Irrigated		104,281		69.58
Totals	149,865	149,865	100.00	100.00

Note: Above areas include about 28,500 acres of Indian lands located in 6 different pueblos.

Lands Included in the District

Areas.

58. The tabulation, Table 5, shows the total irrigable area and the total benefited area included in the District. The District boundaries, as shown on the maps, include a total area of 277,760 acres, but this includes the river bed and a considerable acreage which will not be benefited by the proposed Plan. The net irrigable area under the proposed Plan as originally prepared is 128,787 acres and the total benefited area is estimated at 132,724 acres, including some land which it is proposed to drain but not to irrigate, and including also all lands in Indian ownership. Final estimates of the benefited areas based on complete appraisal data, under the Plan as modified and approved, are included in Table 5.

Areas Excluded.

59. Certain small tracts or areas of valley land have been left out of the benefited area of the District for the reason that their location is such that they can only be irrigated by canals or laterals passing under the river, or diverting from the river directly. Either of these methods of irrigating such areas would be very costly, in view of the relatively small acreage involved, and improvements for such areas have consequently been omitted.

60. Lands of this character include the small tract west of and across the river from Bernalillo, locally known as Los Montoyas, small areas lying east of and across the river from San Acacia and Escondida, and the area lying on the east side of the river from a point a few miles north of Bosquecito, south to the northerly end of the Val Verde District. (See Section VI, paragraphs 374, 375 and 376 for areas eliminated in plan approved by Court Aug. 15, 1928.)

Indian Lands.

61. The gross area within Indian grants is 28,509 acres, of which 24.329 acres is estimated to be irrigable. Of this amount 1,595 acres are shown by reports of the Pueblo Lands Board as being extinguished to the Indians, leaving a net irrigable area in Indian ownership of 22,734 acres. The reports of the Lands Board on the pueblos of Cochiti and Isleta have not yet been secured, and these may show a slight difference in ownership as between Indians and non-Indians. In the meantime, non-Indian holdings within these pueblos are considered a part of Indian lands.

Table 6 shows in detail the available data in regard to Indian lands:

Table 5

MIDDLE RIO GRANDE CONSERVANCY DISTRICT

Summary of Irrigable Areas

Dec. 28, 1928.

Division	Areas Under Present Ditches: *Gross Area Includ-ing River Bed	Areas Under Present Ditches: Net Area Sur-veyed	Areas Under Present Ditches: Less Deduc-tions	Areas Under Present Ditches: **Net Irrigable Under Plan	Additional Irrigable Areas: Gross	Additional Irrigable Areas: Net	Net Irrigable Areas Under Plan: Non-Indian	Net Irrigable Areas Under Plan: Indian	Net Irrigable Areas Under Plan: Total Irrigable	Areas Drained Only	Total Lands Bene-fited
Cochiti	14,269	10,796	530	10,266	2,537	2,408	1,423	11,251	12,674		12,674
Albuquerque	51,491	43,578	8,053	35,525	2,036	1,904	26,700	7,875	34,575	2,854	37,429
Belen	69,886	58,272	8,435	49,837	6,272	5,626	50,746	4,481	55,227	236	55,463
Socorro	47,199	37,219	10,061	27,158			26,311		26,311	847	27,158
Totals as per Original Estimates	182,845	149,865	27,079	122,786	10,845	9,938	105,180	23,607	128,787	3,937	132,724
Deductions due to Modified Plan and Final Check of Areas from Appraisal Data		14,479	8,272	6,207			4,647	873	5,520	687	6,207
Totals	182,845	135,386	18,807	116,579	*10,845	9,938	100,533	22,734	123,267	3,250	126,517

* Represents total area in valley floor, under present ditches or possible extensions thereof. River bed covers 26,822 acres. Present rights of way on non-Indian land 6,158 acres.

** Includes areas of cities and towns to be drained only.

Deduct River 26,822
Pres. R/Ws 6158
32980

182,845
32980
149,865

22734 123,267
20,084 - 2650
2650 120,617

or

100,533 + 20,084 = 120,617

Table 6

INDIAN LANDS AFFECTED BY THE MIDDLE RIO GRANDE CONSERVANCY DISTRICT

**Data Compiled from Records of U. S. Indian Irrigation Service,
U. S. Pueblo Lands Board and this District.**

Aug. 10, 1928.

Grant	Total Area Under Proposed System	Deducted for Roads, RR and Present and Future Rights of Way	Net Area Under Proposed System	*Less Net Area Privately Owned	Net Total Indian Lands	Net Total Indian Lands made up as follows: Claimed by Non-Indians			In Hands of Indians			
						Cultivated	Non-Cultivated	Total	Cultivated	Non-Cultivated	New Irrigable Area	Total
Cochiti	2,243	133	2,110		2,110	529	91	620	705	449	336	1,490
Santo Domingo	5,484	723	4,761	214	4,547				1,440	2,684	423	4,547
San Felipe	6,636	1,245	5,391	460	4,931				1,111	2,051	1,769	4,931
Santa Ana	1,339	250	1,089	84	1,005				636	369		1,005
Sandia	5,217	867	4,350	837	3,513				532	2,981		3,513
Isleta	7,590	962	6,628		6,628	146	80	226	2,555	3,488	359	6,402
Totals	28,509	4,180	24,329	*1,595	22,734	675	171	846	6,979	12,022	2,887	21,888

* Lands, title to which has been declared to be extinguished to the Indians by the U. S. Pueblo Lands Board. Reports on Cochiti and Isleta have not yet been secured and adverse holdings therein are shown as "Claimed by Non-Indians."

Seeped Areas

General Statement.

62. The middle Rio Grande valley has long been a notorious example of a badly seeped and alkalied irrigated area. The seepage and alkalinity has increased from year to year and, at the present time, there is only about 2,000 acres of land which is entirely unaffected within the entire valley. The total area in alkali, salt grass and swamp is over 50,000 acres. A large portion of the area now under cultivation is seriously affected by alkali, the salt concentration on such lands being sufficient to reduce crop production without entirely preventing the germination of seeds. Likewise, seepage becomes a menace to agriculture whenever the water table is less than about 4 feet below the surface. Crop production is frequently reduced by seepage and alkali without the farmer fully understanding the cause of the difficulty.

63. As early as 1917, the State established a large number of test wells throughout the valley for measuring periodically the elevation of the water table. Additional test wells were installed by the U. S. Department of Agriculture, and the readings of these test wells were systematically taken and recorded from March, 1918 to December, 1921. In July, 1926, the collection of data on water table conditions was begun under the District's supervision and, since that date, additional test wells have been installed and the entire system of wells has been read at intervals of about 2 months. During this period data was collected from over 1,000 wells. The data collected since 1918 has been brought together in a report entitled "Report on Ground Water Determination", by Philip S. Donnell, Exhibit R-3 of the Official Plan.

Areas Classified by Depths to Ground Water.

64. A careful study has been made from the test well readings to determine the present average condition of the valley lands, in respect to water table conditions. This data is summarized in Table 7, which shows the various districts within the valley classified by depths to the water table. The condition shown is the average for one full year—1926 to 1927. About 72 per cent of the entire area of the valley has a water table from 0 to 4 feet below the surface.

Table 7
SEEPED AREAS IN MIDDLE RIO GRANDE VALLEY
(1926-27 Average Condition on Gross Area)

DISTRICT		Water Above Surface	Depth to Ground Water Below Surface 0'–1'	1'–2'	2'–4'	4'–6'	Over 6 Ft.	Un-deter-mined	Totals
Algodones	%	7.46	9.61	10.91	24.19	14.86	29.55	3.42	100%
	Ac	429	552	627	1390	854	1698	197	5747
Bernalillo	%	2.22	7.71	20.57	35.21	21.64	12.65	0.00	100%
	Ac	143	496	1323	2265	1392	814		6433
Corrales	%	8.36	22.12	17.81	25.02	23.83	2.86	0.00	100%
	Ac	254	672	541	760	724	87		3038
Alameda	%	4.05	25.33	32.88	31.88	3.87	1.99	0.00	100%
	Ac	211	1317	1710	1658	201	103		5200
Albuquerque	%	15.60	26.23	21.21	19.67	5.86	11.43	0.00	100%
	Ac	1478	2485	2010	1864	555	1083		9475
Atrisco	%	3.94	9.86	18.66	61.41	6.13	0.00	0.00	100%
	Ac	171	428	810	2665	266			4340
Barr	%	8.82	18.59	31.54	33.45	7.60	0.00	0.00	100%
	Ac	369	778	1320	1400	318			4185
Pajarito	%	2.52	6.79	17.34	52.23	17.03	4.09	0.00	100%
	Ac	184	495	1265	3810	1242	298		7294
Isleta (Partially	%	3.20	6.45	12.80	24.87	29.13	19.30	4.25	100%
drained)	Ac	140	282	560	1088	1274	844	186	4374
Peralta	%	9.10	31.91	26.80	26.17	4.33	1.69	0.00	100%
	Ac	914	3206	2693	2630	435	170		10048
Los Lunas	%	0.03	7.94	25.10	50.06	7.10	8.71	1.06	100%
	Ac	3	691	2184	4355	618	758	92	8701
Tome	%	4.54	15.86	16.50	42.32	4.15	16.63	0.00	100%
	Ac	474	1665	1731	4442	435	1746		10493
Belen	%	0.16	4.40	15.42	54.27	14.30	11.45	0.00	100%
	Ac	27	724	2535	8920	2350	1882		16438
San Juan	%	3.02	5.62	23.02	46.35	20.09	1.51	0.39	100%
	Ac	200	372	1525	3070	1331	100	26	6624
San Francisco	%	24.52	23.57	12.65	13.61	14.13	11.52	0.00	100%
	Ac	1132	1088	584	628	652	532		4616
La Joya	%	10.30	5.95	5.03	4.18	2.35	6.68	65.51	100%
	Ac	561	324	274	228	128	364	3570	5449
San Acacia	%	18.78	16.06	17.84	25.04	8.19	1.06	3.03	100%
	Ac	477	408	453	636	208	27	331	2540
Lemitar	%	6.12	11.32	11.32	29.72	16.98	19.34	5.20	100%
	Ac	364	673	674	1768	1010	1150	309	5948
Socorro	%	11.92	19.09	26.05	27.14	6.89	8.91	0.00	100%
	Ac	666	1067	1456	1517	385	498		5589
San Antonio	%	1.71	7.68	17.32	30.35	12.25	3.51	27.18	100%
	Ac	165	740	1669	2924	1180	338	2620	9636
Elmendorf	%	5.27	9.40	15.70	36.86	8.79	0.00	23.98	100%
	Ac	436	778	1299	3050	727		1985	6275
Val Verde	%	1.46	0.57	0.83	13.23	71.40	12.51	0.00	100%
	Ac	51	20	29	463	2500	438		3501
San Marcial	%	5.33	15.88	10.04	35.23	25.97	0.00	7.55	100%
	Ac	103	307	194	681	502		146	1933
TOTALS	%	5.97	13.06	18.32	34.84	12.87	8.63	6.31	100%
	Ac	8952	19568	27466	52212	19287	12930	9462	149877*
RUNNING	%	5.97	19.03	37.35	72.19	85.06	93.69		100%
TOTALS	Ac	8952	28520	55986	108198	127485	140415		149877

* Area in river-bed, 26,800 acres, is excluded.

The Present Irrigation System

Location and Capacity of Ditches, 1896.

65. Table 1 shows the number, location and capacity of the ditches diverting water from the Rio Grande between Cochiti and the lower end of the Mesilla Valley in 1896, as found by W. W. Follett.

Discharge and Capacity of Ditches, 1927.

66. Table 8 gives the number and capacity of the ditches serving the middle Rio Grande valley in 1927 as reported by C. C. Elder, Assistant Engineer, United States Bureau of Reclamation. It will be seen that this table lists 67 ditches between Cochiti and San Marcial in 1927, while the Follett report shows 71 ditches serving the same area in 1896.

Table 8

Discharge and Capacity of Ditches, 1927

	Ditch	Discharge in Sec. Ft. Apr. 1-11	June 13-22	Estimated Capacity in Sec. Ft.
1	Cochiti West Side	5.0	4.0	10
2	Cochiti East Side	7.0	9.4	15
3	Pena Blanca	22.7	37.4	60
4	Sili and Domingo	10.0	39.1	50
5	San Felipe West Side	0.5	0.0	2
6	Domingo East Side	5.0	8.8	10
7	San Felipe East Side	4.0	0.0	10
8	San Felipe West Side	8.7	6.0	20
9	Algodones	18.9	5.7	20
10	Bernalillo	19.9	20.3	40
11	Santa Ana	9.5	23.9	25
12	Olguin	3.1	2.5	5
13	Sandia	25.9	12.0	30
14	Corrales	78.0	52.3	100
15	Alameda	42.6	39.0	75
16	Ranchos	23.6	44.0	50
17	Las Gallegos	0.0	16.0	20
18	Las Griegos	22.3	20.6	30
19	Barelas	7.3	0.0	15
20	Los Duranes	27.5	5.9	40
21	Albuquerque	11.9	15.3	20
22	Lopez	3.9	5.0	8
23	Los Ranchos de Atrisco	14.4	17.6	20
24	Arenal	32.9	27.8	40
25	Atrisco	13.2	10.1	20
26	Armijo	5.6	0.0	10
27	Barr	5.0	10.0	12
28	Pajarito	48.0	0.0	50
29	Isleta	51.7	37.6	70
30	Los Padillas	17.7	14.1	30
31	Cacique	29.9	22.0	40
32	Chical	27.8	19.3	35

Table 8 (Continued)

	Ditch	Discharge in Sec. Ft. Apr. 1-11	June 13-22	Estimated Capacity in Sec. Ft.
33	Peralta No. 1	33.4	20.5	40
34	Peralta No. 2	42.7	28.8	50
35	Bosque de los Pinos	29.5	38.8	40
36	Otero	7.5	9.2	12
37	Los Lunas	27.3	27.2	35
38	Belen	95.4	57.1	100
39	San Fernandez	10.2	18.6	25
40	Las Cercas	24.1	17.5	30
41	Valencia	25.4	18.4	30
42	La Constancia	29.5	26.1	35
43	Los Endames	19.7	8.3	25
44	Tome	18.5	21.7	25
45	Los Chavez	24.6	22.4	30
46	Old Belen	34.1	24.6	40
47	Sausal	29.9	15.4	35
48	Garcia	17.2	19.1	25
49	Jarales No. 1	4.7	17.3	20
50	Los Inocentes	10.5	25.1	30
51	Jarales No. 2	13.7	45.1	50
52	Jarales No. 3	10.2	16.6	20
53	Sabinal	9.8	17.8	20
54	Rincon	21.3	15.2	25
55	San Francisco	5.0	4.3	5
56	Casa Coloradá	6.5	0.1	10
57	San Juan	32.7	29.6	40
58	Las Nutrias	13.1	9.2	14
59	La Joya	11.7	6.9	20
60	San Acacia	0.0	2.4	5
61	Polvadera	6.0	20.0	20
62	Lemitar	53.9	46.1	90
63	Socorro	21.8	6.3	35
64	San Pedro	0.0	3.0	5
65	Luis Lopez	0.0	8.9	15
66	San Antonio	3.5	19.1	30
67	Val Verde	21.7	13.5	25

PART I

THE PLAN

SECTION III

THE NEED FOR FLOOD PROTECTION, DRAINAGE AND IRRIGATION

SECTION III

THE NEED FOR FLOOD PROTECTION, DRAINAGE AND IRRIGATION

The Need for Flood Protection

Albuquerque Located in Channel of 1874 Flood.

67. It has been definitely established that a disastrous flood occurred in the area just North of Albuquerque, in 1874, before the city occupied its present location. (See Section I, paragraphs 42 to 46.) The business district of the present City of Albuquerque occupies the channel of the flood of 1874, and an entirely inadequate dike serves to maintain the river in its channel at the danger point above Alameda. At various times in more recent years the river overflowed at this point and once the water reached the outskirts of Albuquerque.

River Channel Capacity above Alameda.

68. Hydraulic computations indicate that the capacity of the river channel at the critical point above Alameda (8 miles north of Albuquerque) is not more than 25,000 second feet, up to the elevation of the top of the present dike; an amount likely to be exceeded at any time. Should such a flood occur, the present dike would offer little resistance to the water and the valley would be inundated again. The damage would be infinitely greater than it was in 1874, as this area is thickly settled, and the business district of the City of Albuquerque is directly in the path of the flood. The railway has been constructed since the flood of 1874.

Effect of Ditches Across the Valley.

69. Each ditch crosses the valley in a generally southeasterly direction and the high banks of these ditches would tend to deflect the water toward the east, against the railway, and to prevent the return of the water to the river. It is probable that a large flood would wash out the railway more or less completely from about Mile Post 891 to Mile Post 902, a distance of 11 miles just north of Albuquerque, and in addition would inundate the yards, the shops, the roundhouse and the Alvarado Hotel in the city. This flood would not be merely an overflow of still water, but would be a rushing torrent impelled by a fall of 5 feet to the mile through the eleven miles of valley above the city, and it would probably inundate all of that part of town lying west of the railway.

San Marcial in Dangerous Location.

70. At San Marcial the flood menace is ever present and only perpetual vigilance and the expenditure of large sums of money by the A. T. & S. F. Ry., which has a large investment to protect, has averted disaster.

Maximum Recorded Floods.

71. At other places the need for flood protection, while not so spectacularly apparent, is nevertheless imperative. Stream flow records kept since 1889 indicate that the peak flow since that time was reached in May 1920 with a volume of 28,800 second feet at Buckman (some 25 miles above the middle valley), and at San Marcial the maximum flow of 33,000 second feet was recorded in 1904. Studies of flow records, drainage areas and meteorological data indicate that the recorded peak flows of the last 40 years have been relatively small and may be greatly exceeded at any time. Yet, many of these relatively small floods very nearly caused serious damage and even disaster.

Causes of Floods.

72. While most of the high water of recent years has been caused by melting snow in the mountains, almost any one of several different tributaries of the Rio Grande could, under proper climatic conditions, cause a flood which would rival in size and effect that which devastated Pueblo, Colorado, in June 1921.

Rising River Bed.

73. In the middle Rio Grande valley the present river bed is from 2 feet to 4 feet higher than the low point of the valley floor in many places, while at San Marcial, New Mexico, the river bed has raised about 12 feet since 1880. The raising of the stream bed is greatest at San Marcial, decreases with distance upstream therefrom and is probably changing very slowly at Albuquerque.

Shifting River Channel.

74. The present river has a distinct tendency to widen its channel as a natural consequence of the rising bed. This tendency is manifest throughout the river course from Belen to San Marcial, where the normal flow channel is nearly a mile wide in several places. In recent years the construction of bridges, railroads, and river protection work throughout the valley has held the river channel in place and this work has prevented major shifts in channel locations such as took place in former years. The water surface elevation in the stream has gradually

raised and this has resulted in increasing water-logged and alkalied areas, and in decreasing the flood carrying capacity of the river channel.

Peak Flows and Drainage Areas.

75. The watershed of the Rio Grande above San Marcial is approximately 26,000 square miles. The largest flood recorded at the San Marcial gage in thirty years of record is 33,000 second feet. The drainage area of the Rio Grande above Buckman, New Mexico, is about 14,000 square miles and the maximum flood discharge recorded at this point is 28,000 second feet. The Pueblo Flood of June 3, 1921, was about 100,000 second feet, originating from a drainage area of less than 500 square miles.

Flood Menace at Albuquerque.

76. It is evident that the river channel is becoming less and less able to pass floods without serious damage to lands and property. The high water peak in May 1926 was about 12,000 second feet at Albuquerque and this discharge appeared to be about all the channel could carry without serious overflow.

77. A large part of the business district of Albuquerque and a considerable area of the residential portion is built in a former bed of the Rio Grande. This fact is established beyond question by the statements of persons living at the time when the river ran through the area now occupied by the City and is further confirmed by recent surveys. Experience with floods, especially those of 1904 and of 1920, has demonstrated that the City of Albuquerque is dependent upon the dikes above Alameda and upon the banks of irrigation ditches for protection against even the normal floods which occur every few years. This protection, such as it is, will be wholly inadequate in the case of exceptional floods such as may sweep through the valley. Indeed, due to the tendency of the river bed to rise, the flood menace is increasing from year to year.

Flood Menace at San Marcial and Other Points.

78. The danger from floods is not peculiar to the City of Albuquerque. San Marcial is in grave danger from overflow, being located several feet below the present river bed. Protective dikes built by the A. T. & S. F. Ry. hold the normal flow of the river from the town, but discharges of even 12,000 second feet are a source of danger and a large flood would do great damage. Practically all of the towns and villages located in the valley floor are subject to the flood menace and are dependent for relief upon a comprehensive plan of general river improve-

ment. It is therefore evident that the need for flood prevention is imperative.

Silt Content of Tributary Streams North of Rio Puerco.

79. Closely allied to flood control is the control of silt in the Rio Grande, which enters the State of New Mexico a comparatively clear stream and remains clear until the mouth of the Rio Chama is reached, below which point the river is never clear. The Rio Chama carries comparatively little silt during its spring flood, but is often heavily charged from the run off of rainfall in the lower part of its watershed below the El Vado Reservoir. Other tributaries to the Rio Grande contribute but little water except during floods when vast quantities of silt, sand and debris are carried into the main stream.

Silt Content of the Rio Puerco.

80. The Rio Puerco is the largest producer of silt, being the tributary having the largest drainage area and being subject to frequent silt-laden floods. In the report by Kirk Bryan and George M. Post on the "Erosion and Control of Silt on the Rio Puerco, New Mexico", (Exhibit R-1 Part V.), it is stated that nearly 400,000 acre feet of valley soil has been carried away by the erosion of streams and arroyos in the Rio Puerco valley during the last 40 to 50 years. It is also estimated that some 9,000 acre feet of silt is brought to the Rio Grande annually from the Rio Puerco, which is therefore held responsible for almost one-half of the 20,000 acre feet of silt which is annually deposited in the Elephant Butte Reservoir.

The Need for Silt Control.

81. It is, therefore, evident that there is a two-fold need for silt control on the Rio Puerco and other tributaries: first, to conserve the soil of the valleys themselves and, second, to decrease the amount of silt brought into the river and into the Elephant Butte Reservoir by the tributary streams. It is estimated that under present conditions the capacity of the Elephant Butte Reservoir will be so descreased in 50 years that additional storage will be necessary for the United States Rio Grande Project.

The Atchison, Topeka and Santa Fe Railway*

82. Another phase of the need for improvement closely related to flood control is the protection of the A. T. & S. F. Ry. which enters the middle Rio Grande valley near its northern end, at the pueblo of

* The modification of the plan approved by the Court Aug. 15, 1928, eliminated proposed improvements at San Marcial. See Section VI.

Santo Domingo, and follows it to a point below the southern boundary of the Conservancy District near San Marcial. From Santo Domingo to a point near Bernalillo (16 miles north of Albuquerque) the railway is generally above danger from flood in the Rio Grande. The railway is in general lower than the top of the proposed levees south of Bernalillo, but in a few places the topography of the valley is such that the railway has had to adopt a location along the banks of the river, and in these places the levees cannot be carried through. In the narrow canyon extending from a point just south of La Joya station, nearly to San Acacia, a distance of about 10 miles, the railway follows the river closely and is not sufficiently above it to be safe against even moderate-sized floods. This was demonstrated in September, 1927, when a flood estimated at 20,000 second feet, originating in the Rio Puerco, washed out the railway in one place and reached practically to the base of rail at several other points.

83. At other points there is not room to carry the levees through between the tracks and the river, and at such places it is proposed to raise the track in approximately its present location to an elevation sufficiently high to be above danger from floods of 50,000 second feet, protecting the river side of the road bed with rock riprap. The location and extent of these changes, as determined by a cooperative study made by the A. T. & S. F. Ry. and the District's engineers, is not included in the Plan as a part of the work of the District, but is considered as a part of a betterment program to be undertaken by the railway. Such changes affect only the railway and, in general, create no benefits to agricultural lands or other interests.

84. At San Marcial the situation is different. In order to provide a river channel of capacity sufficient to pass floods of 50,000-60,000 second feet, it is necessary to raise A. T. & S. F. Ry. bridges Nos. 1005-A and 1006-A and their approaches a maximum of about 8 feet in elevation. The cost of this work, as estimated by the A. T. & S. F. Ry. Engineering Department, is included in the Plan as a part of the protection work for San Marcial. No detailed plans of the bridges have been prepared, as this work is to be done by the railway in accordance with its own standards.

The Need for Drainage

Seepage Reported by Hedke.

85. The need for drainage in the middle Rio Grande valley is so self evident and so well known that little need be said in regard to it. It is brought out in a spectacular manner in Mr. Hedke's "Table Showing the Progress of Irrigation Developments in the Middle Rio Grande Valley" (See Section 1, paragraphs 35 and 36), in which it is

stated that the irrigated area in this valley was 124,800 acres in 1880, while today it is only 45,000 acres.

Well Readings.

86. Test wells have been maintained throughout the valley since 1918 and the data collected is shown in detail in Exhibit R-3. Studies of over 1,000 test wells show that in 72 per cent of the area of the valley floor the water table is less than four feet below the ground surface. (See paragraph 64.) Since most crops require at least four feet of unsaturated soil, the high water table strikingly illustrates the need for drainage.

Drainage Imperative.

87. It seems self evident that drainage of the valley is absolutely imperative. Not only is it necessary to reclaim areas already waterlogged and abandoned, but to prevent the spreading of that condition and the further reduction of the relatively small area of "dry" land yet remaining. Without drainage this area will decrease year by year until the middle Rio Grande valley will become a vast swamp and the population will be forced to seek homes elsewhere. Property values will shrink or disappear, not only those of farm lands, but those of cities and towns as well, since urban values are dependent, to a great extent, upon the agricultural interests of the surrounding country.

The Need for Irrigation

Present Irrigation System.

✓ 88. The ditches forming the present irrigation system of the middle Rio Grande valley were constructed at different times, each one to serve some small community or area, and with no thought of forming a part of a comprehensive system of irrigation for the valley as a whole. As a result there is a great deal of duplication of effort and of maintenance expense, and a large loss of water. Structures are primitive and inadequate, where any at all exist, and there are no adequate diversion dams on the river in the entire middle valley. Sand dams, which wash out with every rise, furnish the usual means of diverting water from the river, and every flood in an arroyo forces the rebuilding of the ditch which crosses it. A large amount of labor and money can be saved the farmers by the construction of an adequate consolidated irrigation system.

Necessity for Storage.

89. Another phase of the need for a comprehensive system of

irrigation is the regulation and stabilization of water supply which such a system will afford. About 70 per cent of the annual flow of the river occurs during the spring rise, while during the late summer the river is frequently dry as far up as Albuquerque. In the lower end of the valley water shortage is frequent and acute. Consequently reservoir storage is imperative to regulate the flow of the river and to make water available at the ditch headings during the entire irrigating season. It is evident that another part of the reclamation problem is the building of a modern comprehensive irrigation system, including an adequate storage reservoir.

Summary of Improvements Needed

Drainage.

90. About seventy-two per cent of the area in the valley floor has a water table ranging from above the surface to 4 feet below the ground surface. Four feet is about the minimum depth of unsaturated soil required for successful cultivation with diversified crops. The total area in alkali, salt grass, and swamp is over 50,000 acres. Excessive alkalinity is a common cause of poor crops and a large portion of the area now under cultivation is seriously affected by alkali. Drainage is absolutely imperative and is perhaps the most urgent need of the valley.

Irrigation.

91. The present irrigation works are inadequate for the area now being cultivated. The ditch headings in the river are expensive to maintain and are frequently incapable of delivering water to the ditches. The ditches are poorly located; often two or three ditches command an area which could be served by one. The water supply for irrigation is frequently inadequate for all the lands south of Albuquerque. In 1926 the river was dry at Belen for nearly sixty days during the season of greatest demand. At San Marcial the river is dry an average of about thirty-nine days each year. The need for a storage reservoir and for a complete modern irrigation system is readily apparent.

Flood Protection.

92. The flood menace is an ever present danger, threatening cities, towns, agricultural lands, roads, railways and other public utilities through almost the whole of the middle Rio Grande valley. While no large flood has occurred in recent years, conditions clearly indicate the possibility of a great disaster due to the increase in urban and suburban population in areas where the flood menace is imminent.

93. It must be borne in mind that the drainage, irrigation and flood control systems are correlated undertakings and to exclude any one

would throw large added costs upon the others. The drain ditches not only drain the land, but they also develop water for irrigation, and the excavated material partly builds the levees which protect against floods.

94. The need to check the rising of the river bed by means of channel work, the need of silt control on tributary streams, and matters of protection involving all the resources of the District might be included as a part of the larger subject of flood protection.

PART I

THE PLAN

SECTION IV

DEVELOPMENT OF THE PLAN

SECTION IV

DEVELOPMENT OF THE PLAN

Early Efforts to Reclaim the Middle Valley

Previous Organizations and Associations.

✓ 95. As early as the late Nineties plans for the improvement of the old acequia systems in the middle Rio Grande valley were considered by various organizations and individuals, and about fifteen years later two small drainage districts were attempted south of Albuquerque. All of these early plans failed, but as the seeped areas of the valley continued to increase, drainage became more and more the important subject of discussion in meetings of the various civic bodies and voluntary associations interested in the agricultural welfare of the various river communities. The spirit of these pioneers culminated in the enactment of a law in 1921 creating The Rio Grande Valley Survey Commission. That Commission entered into a contract with the United States, through the Reclamation Service, dated March 31, 1922, for an investigation and report on the Middle Rio Grande project. In 1922 a voluntary association known as the Middle Rio Grande Reclamation Association was formed and fostered through the Chamber of Commerce and many interested individuals.

Previous Reports.

96. Prior to the formation of the Middle Rio Grande Conservancy District, a number of engineering reports were made dealing with proposed reclamation and drainage for the middle valley. Some of these are listed in Table 9 for convenient reference and are on file in the District offices.

Table 9

Partial List of Previous Reports

Reference	Name of Report	Author	Date
1	Middle Rio Grande Reclamation Project.	U. S. B. of Rec. by H. J. Gault	1923
2	Reclamation of the Middle Rio Grande Valley of New Mexico.	Vernon L. Sullivan	1924
3	Drainage Investigations, Middle Rio Grande Valley.	State of N. M. J. A. French	1919
4	Water Supply for, and Possible Development of Irrigation and Drainage Projects on the Rio Grande.	U. S. B. of Rec. Conkling and Debler	1919
5	Floods and Drainage at San Marcial, New Mexico.	U. S. B. of Rec. C. T. Pease	1925
6	Study of the Use of Water for Irrigation on the Rio Grande Del Norte.	W. W. Follett	1896
7	Irrigation Development and Water Supply of the Middle Rio Grande Valley.	C. R. Hedke	1924
8	Review of Water Supply, Drainage, Irrigated Areas, etc., Rio Grande Basin above Ft. Quitman, Texas.	R. L. Meeker	1924
9	Rio Grande Water Supply.	Debler and Walker	1924
10	Soil Survey of the Middle Rio Grande Valley Area, N. M.	U. S. Dept. of Agriculture	1912
11	12th Annual Report, U. S. Geological Survey, pages 240-278.	U. S. Geological Survey	1890

The Middle Rio Grande Conservancy District

The Original Conservancy Act.

97. Notwithstanding this pioneer work no adequate legal machinery had yet been provided to carry out plans for drainage, storage, flood control, river protection and adequate irrigation in the middle Rio Grande valley. With the spirit fostered by the voluntary reclamation association, aided by the many civic bodies and individuals interested, a conservancy act was passed by the New Mexico Legislature in 1923, known as Chapter 140 of the Session Laws of that year. In September 1923 the first petitions for the organization of the Conservancy District were filed in the District Court of the Second Judicial District, sitting within and for the County of Bernalillo.

98. These first petitions were inadequate from a legal standpoint as they contained no survey descriptions, and in August 1924 amended petitions were filed containing adequate descriptions, and the case for the Conservancy District was from that time forward carried through to a successful decree of organization, which was duly entered by the Court on August 26, 1925. In order to test the many constitutional questions involved, an appeal was expedited to the Supreme Court of

the State of New Mexico, and a decision was rendered by that tribunal on December 12, 1925, upholding the constitutionality and legality of the District in all phases.

The Amended Conservancy Act.

✓99. No important changes have been made in the legal status of the District since its organization, other than those provided for by Chapter 45, Session Laws of the State of New Mexico for the year 1927. This last mentioned Act is largely a reenactment of the former conservancy law, but broadened the application of the former act and made clear the powers of the District regarding preliminary finances; increased the Board of Directors to five members and generally strengthened certain administrative provisions contained in the law. Its most important provisions improving the old law are those relating to the assessment of benefits for irrigation, provisions regulating the use of water in the District, provisions relating to hearings on appraisals, and enlarging the preliminary financing powers of the District by changing the original assessment powers of 50c an acre, giving the District preliminary assessment powers on the ad valorem basis of not to exceed eight (8) mills. Fortunately, at the time the Legislature was in session, Mr. James H. Pershing of the firm of Pershing, Nye, Tallmadge & Bosworth, bond attorneys of Denver, Colorado, and Mr. Arthur E. Morgan, President of the Dayton Morgan Engineering Company of Dayton, Ohio, were able to be present in Santa Fe and to give their experience and technical knowledge in drawing or adapting many provisions of the law. Both the bond attorneys and authorities on irrigation, who have examined the New Mexico Conservancy Act, consider it a model legal instrument for carrying out the flood control, drainage, irrigation and other purposes contemplated by the Middle Rio Grande Conservancy District. Under the provisions of this law the Middle Rio Grande Conservancy District, as originally organized, was not affected but its status was confirmed and approved. The North boundary of the District was fixed as the North line of Sandoval County, the South boundary as the Elephant Butte Reservoir, and its East and West boundaries restricted to lands capable of drainage, flood control or irrigation; or not more than two miles distant from any such lands.

Board of Commissioners.

✓100. The Board of Commissioners is appointed jointly by the Judges of the two Judicial Districts lying within the exterior boundaries of the Middle Rio Grande Conservancy District. Their tenure of office is for a period of six (6) years dating from March 16, 1927, and they are removable only for cause. Such Board has the general powers of a corporate Board of Directors. The District itself is a political subdi-

vision of the State of New Mexico and a body corporate with all the powers of a public or municipal corporation. The first important duty of the Board of Commissioners is the preparation of an Official Plan for the reclamation and flood protection of the middle valley. If no objections are made to the Official Plan the Board may adopt the same, but if any objections are made thereto the Court holds hearings, and after such hearings the Plan is either adopted, modified, rejected or referred back to the Board. After the Plan is adopted the Board has broad authority to execute the same and carry all of the details thereof into effect.

Board of Appraisers.

101. A Board of Appraisers was appointed by the Judges of the Judicial Districts having lands within the exterior boundaries of the District. The duty of the Board of Appraisers is to appraise benefits and damages to all land and property, within or without the District, which will result from the execution of the Official Plan. Provision is made in the law for hearings on appraisals. When the Court approves and confirms the report of the appraisers this approved appraisal becomes the basis for assessment.

Outline of Engineering Investigations

General Features.

102. The Middle Rio Grande Conservancy District engaged an engineering force in the spring of 1926, with instructions to prepare plans for flood control, drainage and irrigation of District lands. The first field surveys were begun in June 1926 and work has progressed steadily since that time. About $300,000 has been expended, to date of submitting the Plan, on investigations and work appurtenant to the establishment of these plans. The principal items of work accomplished and the conclusions reached from study of the data gathered will be described in the following paragraphs.

Property Surveys and Maps.

103. Valley lands have been surveyed to establish ownerships and areas, and property maps have been prepared on the scale of 1 inch equals 200 feet. In general this surveying was done by planetable, with control traverses run with transit and steel tape. The maps cover all property within the District exclusive of Indian lands. The tracts mapped are about 23,600 in number aggregating approximately 110,000 acres, and some 20,000 acres not included in the present Plan were also surveyed and mapped. On the Indian lands, property maps have been

prepared of all property in the hands of non-Indians, comprising approximately 2,440 acres. The Cochiti, Santo Domingo and San Felipe Pueblo lands have been surveyed, scale 1 inch equals 400 feet, and the lands have been classified.

Classification and Listing of Properties.

✓ 104. All property within the District, exclusive of Indian lands, has been inspected, listed and classified for appraisal purposes, and an appraisal data sheet has been prepared for each tract or parcel of land in the District for the informtion of the Board of Appraisers.

Reservoir Surveys.

✓ 105. Three reservoir sites have been surveyed on the Rio Grande and three on tributary streams. Extensive reconnaissance work has been accomplished at several other sites. The surveying has been topographic, for the purpose of obtaining areas and capacities by means of five-foot contour lines, and was done by planetable. Table 10 shows the reservoir sites which were surveyed.

Table 10

Reservoir Sites Surveyed

Reservoir Site	Location	Area	Capacity
State Line	Rio Grande	14,000 acres	225,000 acre feet (previously surveyed)
Buckman	Rio Grande	12,100 acres	540,000 acre feet
San Felipe	Rio Grande	18,500 acres	1,000,000 acre feet
El Vado	Rio Chama	5,300 acres	200,000 acre feet
Embudo	Embudo Creek	660 acres	36,000 acre feet
Rio Puerco No. 1	Rio Puerco	7,500 acres	200,000 acre feet

Foundation Testing.

✓ 106. Extensive foundation testing has been carried on at the El Vado, San Felipe and State Line sites, and geological investigations and reports have been made at all sites which appear favorable.

Water Supply Studies.

107. Studies have been carried on since June 1926 by the United States Bureau of Reclamation under a cooperative contract with the District. This work consists of the installation and care of a soil evaporation station, monthly measurements of an extensive system of test wells for measuring the elevation of the ground water, stream gaging work and silt sampling. A report has been made on this work by the United States Bureau of Reclamation and is included in the Official Plan as Exhibit R-4.

✓ 108. In addition to the above studies by the Government engineers, the District has carried on its own independent water supply investigations including studies of flood flow and necessary storage requirements, flood detention storage and, in general, all phases of the flood protection, drainage and irrigation problem.

River Protection.

✓ 109. Cross sections, profiles and special studies have been made of the river channel. Comparative methods of river protection work have been laid out and their costs estimated.

Topography.

✓ 110. The topographic maps made by the State Engineer in 1918, scale 1 inch equals 1000 feet, have been used for base maps. Detailed topography on scale 1 inch equals 200 feet has been taken to the extent of about 30,000 acres. The area mapped covers important canal locations, major structure studies, railroad relocations and new lands which may be susceptible of irrigation under the proposed method.

Rio Puerco Silt Studies.

111. A reconnaissance survey of the Rio Puerco watershed has been made for the purpose of securing data on the silt problem. A special report has been made on this subject and is included in the Official Plan as Exhibit R-1.

Irrigation System Studies.

✓ 112. Many of the present irrigation ditches have been profiled and their location and grades have been studied. A new irrigation system has been designed consisting of main canals and laterals to cover the entire area of the valley lands.

Drainage System Studies.

113. The seeped areas have been determined and plotted on project maps and a drainage system has been designed to serve all the lands.

Designs and Estimates.

✓ 114. Designs have been prepared for 18 different storage and flood detention dams for the purpose of comparing types and cost. Six designs have been prepared for diversion dams; and all major and minor structures on canal, lateral and drainage systems have been designed.

Detailed estimates have been prepared for the proposed reclamation and flood protection works, and comparative designs and estimates have been made in many cases.

Railroad Relocations.

115. Special studies of railroad relocations and grade changes which would be necessary with the various systems of flood control under investigation have been made, and maps, profiles and cost estimates of such changes have been prepared.

Other Office Studies.

116. A great deal of time has been spent in office studies which do not appear in the Plan as they had to do with alternative plans since discarded. Of this nature were the studies of all recorded floods through various combinations of detention reservoirs at the State Line and at San Felipe.

117. Investigation of various degrees of flood protection at San Marcial and elsewhere, probability studies, and the studies of a great number of books, reports, pamphlets, etc., which do not appear directly in the Plan, nevertheless required a great deal of time.

Reports of the Board of Consulting Engineers.

118. The Board of Consulting Engineers of the District consists of the following members:

Dr. Arthur E. Morgan,
President of Antioch College, Ohio and
President of the Dayton Morgan Engineering Co.

W. M. Reed,
Chief Engineer of the United States Indian
Irrigation Service.

D. C. Henny,
Consulting Engineer, Portland, Oregon.

A. J. Wiley,
Consulting Engineer, Boise, Idaho.

119. This Board met at Alamosa, Colorado, September 12, 1927, together with the Chief Engineer and other representatives of the District, the Acting Chief Engineer and the Chief Engineer of Western Lines of the A. T. & S. F. Ry., and others, and went over the entire conservancy project in the field. They then went over the maps, plans

and estimates of the District engineers in Albuquerque, devoting several days to the task.

120. The original studies presented to the Board contemplated the building of three reservoirs: the El Vado, State Line and San Felipe. The last two were for the purpose of flood detention. Drainage, irrigation and silt control were provided substantially as described herein. The estimated cost of the entire improvement under this method is about $16,000,000.

121. The Consulting Board recommended a careful balancing of the various features of the Plan and further study of all details, the omission of all reservoirs except the El Vado, the protection against floods of 50,000 second feet by means of levees, and the limiting of the total cost of the project to not over $10,000,000 exclusive of the share of the United States Government on behalf of Indian lands.

122. The Plan was thereafter amended along the lines of the proposed changes and resubmitted to the Consulting Board, who on November 17, 1927, expressed their opinion of the amended Plan in the following words:

"The degree of river protection afforded by the Plan as above explained is reasonable and well balanced; the projected system of drainage and irrigation is of a permanent character and follows the best practice; the water supply of the project is deemed sufficient, provided it is rigorously protected against upstream encroachments: and the estimates are comprehensive and conservative. We recommend procedure under the Plan as now outlined."

Special Studies and Reports.

123. In the development of the Plan many studies and informal reports were prepared on special features of the project. Some of these have been made a part of the Plan. All are listed in the following Table 11.

Table 11

Special Studies and Reports by District

Title	Author	Date
The Situation at San Marcial	C. H. Howell	1- 7-27
The Situation at San Marcial (Revision)	C. H. Howell	9-20-27
The Situation at San Marcial (3rd Revision)	C. H. Howell	5- 1-27
Rio Grande Channel Improvement	C. H. Howell	9- 1-26
Channel Improvement and Flood Protection	C. H. Howell	11- 8-27
Water Supply Studies	R. G. Hosea	9- 1-27
District Lands and Irrigable Areas	C. A. Anderson	11- 3-27
Ground Water Determinations	P. S. Donnell	9- 1-27
Erosion and Control of Silt on the Rio Puerco, New Mexico	Kirk Bryan and George M. Post	9- 1-27
El Vado Reservoir Geology	E. H. Wells	9- 1-27
San Felipe Reservoir Geology	Kirk Bryan	9- 1-27
State Line Reservoir Geology	Kirk Bryan	9- 1-27
Preparation of Cost Estimates	J. L. Burkholder and Staff	10-15-27
Economic Survey and Agriculture Report, Middle Rio Grande Valley	Pearce C. Rodey collaborating with State College and County Agricultural Agents	Nov. 1927
Modified Plan for Flood Protection at San Marcial	R. G. Hosea	May, 1928
Special Work Required to Protect the A. T. & S. F. Railway	R. G. Hosea	1-25-28

Summary of Flood Studies

The River Channel.

124. The Rio Grande runs in a comparatively direct southerly course through the entire District from the mouth of White Rock Canyon to San Marcial, a distance of about 167 miles measured along its meanderings. Above Bernalillo the channel of the river is relatively well defined, and the stream does not overflow its banks during ordinarily high water. The fall of the river is about 8 feet per mile through this section, and the channel width varies from 400 to 800 feet. Below Bernalillo the channel is not well defined and floods of more than about 12,000 second feet overflow the adjacent lands. The fall varies from about 5 feet per mile near Bernalillo to some 4 feet per mile near San Marcial, and the width of the channel also varies from 1,200 to 1,500 feet near Bernalillo to some 2,000 feet at San Marcial.

Drainage Areas.

125. The drainage area of the Rio Grande and its tributaries is shown in Table 12.

✓

Table 12

Drainage Area Tributary to Rio Grande Above San Marcial, New Mexico

Name	Elevation	Square Mile
Area in Colorado	7500—14000	7700
New Mexico area above Embudo		
East Side:		
Rio Costilla	13000— 7500	335
Rio Colorado	13000— 7500	131
Rio Hondo	13000— 7000	91
Rio Taos	13000— 7000	485
Arroyo Hondo	12500— 6500	65
Rio Embudo	12500— 6500	270
Intermediate areas (approximate)	7000— 6000	194
West Side:		
Interstate line to Embudo (approximate)	8000— 6000	797
New Mexico area above Embudo		2369
Total area above Embudo		10069
Embudo-Buckman		
East Side:		
Rio Truchas	12000— 6000	86
Rio Medio	12000— 6000	166
Rio Pojoaque	11000— 6000	156
Intermediate areas	7000— 6000	121
West Side:		
Rio Chama	10000— 5500	3150
Intermediate area (approximate) (drainage of a part of Pajarito Plateau)	7000— 6000	165
Total area Embudo-Buckman		3844
Total area above Buckman		13914
Buckman-San Felipe		
East Side:		
Rio Santa Fe	11000— 5500	372
Rio Galisteo	10000— 5200	769
Intermediate areas	6000— 5000	200
West Side:		
Intermediate area	6000— 5000	330
Total area Buckman-San Felipe		1671
Total area above San Felipe		15585
San Felipe-Albuquerque		
East Side:	10000— 5000	500
West Side:		
Rio Jemez	10000— 5000	986
Intermediate area	6000— 5000	200
Total area San Felipe-Albuquerque		1686
Total area above Albuquerque		17271
Albuquerque-mouth of Rio Puerco		
East Side:		
Tijeras Creek	10000— 5000	202
Intermediate area	9000— 4500	864
West Side: (no large streams)		
Intermediate area	6000— 4500	388
Total Albuquerque-Rio Puerco		1454

✓ Table 12 (Continued)

Name	Elevation	Square Mile
Total area above Rio Puerco		18725
Rio Puerco-San Marcial		
East Side:		
Alamillo Creek	9000— 4500	410
Intermediate area	9000— 4500	314
West Side:		
Rio Puerco	8000— 4500	5170
Rio Salado	8000— 4500	1148
Intermediate area	5500— 4500	929
Total area Rio Puerco-San Marcial		7971
Total area above San Marcial		26696

✓ 126. *Colorado Area.*—The drainage basin in Colorado comprises 7700 square miles, of which 1400 square miles is mountain area above Del Norte on the main stream at elevations ranging from 14000 feet down to 8000 feet.

✓ 127. *New Mexico Area, East Side.*—The drainage basin in New Mexico (East Side) comprises 2600 square miles (south to and including Rio Santa Fe) draining the west slopes of the Sangre de Cristo range from elevation 13000 to 5500 feet, approximately. An area of about 2400 square miles (Rio Santa Fe to San Marcial) drains the Sandia and Manzano ranges up to about 10000 feet elevation. This area is subject to violent floods in any of the numerous arroyos.

✓ 128. *New Mexico Area, West Side.*—The drainage basin in New Mexico (West Side) comprises an area drained by four principal streams from north to south as follows:

(a) Rio Chama.

The Rio Chama drains an area of 3150 square miles located between the Continental divide on the west, at elevations exceeding 10000 feet, and the Rio Grande on the east at elevations from 7500 to 5500 feet. The snowfall is heavy and the run off is large, but floods from summer and fall rains are small and infrequent.

(b) Rio Jemez.

The Rio Jemez drains about 1000 square miles of area located south of the Rio Chama drainage and at somewhat lower elevations. The run off from this area is less proportionally than from the Rio Chama drainage and floods due to storms are more frequent.

(c) Rio Puerco.

The drainage basin of the Rio Puerco is very large, perhaps 5700 square miles, though it is difficult to determine definitely from any available map. The greater part of the area lies at elevations of 5000

to 6000 feet, and is relatively unprotected by high mountain ranges. The Rio Puerco is usually dry but is subject to violent floods from summer and fall storms. Such floods bring down vast quantities of silt and the stream has cut a canyon 35 to 50 feet deep through the soil of the valley.

(d) Rio Salado.

The Rio Salado drainage basin is very similar to that of the Rio Puerco but is somewhat smaller in area and has steeper slopes. It drains an area of about 1150 square miles, and its floods are probably nearly as large as those of the Rio Puerco.

Floods.

129. The present capacity of the Rio Grande channel is about 12,000 second feet, and such a volume of water will cause no material overflow of banks or damage to structures. As mentioned in the historical data, it has been established from authentic sources that a flood occurred in 1874 which did a large amount of damage. This occurred prior to the time when stream flow measuring stations were installed, and we have no definite knowledge of its volume. Estimates might be made but they would of necessity be based on recollections of very old inhabitants as to high water marks or depths, and would probably mean little. There are also vague recollections of other floods occurring within the time of men now living, but the flood of 1874 seems to have been the largest.

130. The greatest measured flood in the valley occurred in October 1904 when 33,000 second feet passed San Marcial. Over 15,000 second feet of this flood originated below Buckman.

131. Other floods occurred in 1903, 1905 and 1920, that of 1920 giving the maximum recorded flow of 28,800 second feet at Buckman near the upper end of the middle valley.

132. An analysis of the flow record at Buckman will be of value to show the frequency and volume of flood peaks which have passed through the middle valley during the period of record, viz. 1895-1905, 1910-1914, and 1916 to 1925, a total of 26 years. While the Buckman record is broken and the record for certain years is missing, an indication of the flow during these missing years may be obtained from the records of Embudo and Lobatos stations.

The Ten Largest Floods at Buckman.

133. Examination of the Buckman record discloses that there have been ten flood peaks of more than 12,500 second feet (the approximate present capacity of the river channel) during the 26 years of record, viz. 1895-1905, 1910-1914, and 1916 to 1925. The ten maximum floods at Buckman are shown in Table 13.

Table 13

Ten Maximum Floods at Buckman

Number	Month	Year	Second Feet
1	May	1920	28800
2	May	1912	23800
3	May	1905	19500
4	June	1903	19300
5	October	1904	17700
6	June	1921	17400
7	May	1924	16910
8	May	1916	15900
9	October	1911	15600
10	May	1897	15300

134. Since the drainage area tributary to the river above Buckman is roughly 14000 square miles, it would seem that past floods have been comparatively small in volume. Two possible conclusions follow, either:

(a) The valley of the Rio Grande above Buckman is so protected by mountains that physical and meteorological conditions render excessive precipitation and consequent floods unusual, or,

(b) No excessive storms and floods have occurred during the period of record.

135. Table 14 shows the progress of the 10 flood peaks referred to above, from Del Norte to San Marcial.

Table 14

Progress of 10 Flood Peaks in Rio Grande From Del Norte to San Marcial

Station	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
	S.F.	S.F.	S.F.	S.F.	S.F.	S.F.	S.F.	S.F.	S.F.	S.F.
Del Norte	7580	6940	7460	6025	3100	9630	5590	4690	14000*	5234
Lobatos	9320	8680	11700	12780	3198	12200	7380	5910	7510	No record
Embudo	15000	No record	No record	15860	No record	14900	8767	9790	No record	8745
Buckman	28800	23800	19500	19300	17700	17400	16910	15900	15600	15300
San Marcial	22500	15270	29070	18880	33000	19360	12400	15145	11780	21750

136. *Flood Peak No. 1 at Buckman, May 1920.*—The maximum peak of record at Buckman (May 1920) is analyzed as follows: A flow of 7580 second feet originated in the mountain area above Del Norte and, since it occurred in May, was probably due to melting snow. This flow increased to 9320 second feet at the Interstate Line. Between the

* Believed to be in error.

Interstate Line and Embudo, about 5680 second feet was contributed by streams in New Mexico, making a total of 15000 second feet at Embudo. About 13800 second feet entered the river between Embudo and Buckman, and must have come very largely from the Rio Chama. The Rio Chama record at Chamita (not given above) shows that the Rio Chama actually did contribute 11000 second feet. The discharge at El Vado at that time was only 3740 second feet, showing that 7260 second feet originated in the Rio Chama below El Vado. Between Buckman and San Marcial the peak flattened out somewhat and reached only 22500 second feet at the latter point. This peak of 28800 second feet was therefore the result of 9320 second feet or 33 per cent from Colorado, 5680 second feet or 20 per cent from New Mexico above the Rio Chama, 1000 second feet or 40 per cent from the Rio Chama, and 7 per cent from other smaller areas.

137. *Flood Peak No. 2 at Buckman.*—Flood peak No. 2 (next below the maximum) occurred in May 1912. The flow of 6940 second feet at Del Norte was increased to 8640 second feet at the Interstate Line, and to 23800 second feet at Buckman. The Embudo and Chamita records are missing, so this peak cannot be distributed in as much detail as Peak No. 1, but it is probable that several thousand second feet originated in the Rio Chama. At San Marcial the peak reached only 15270 second feet, indicating either a flattening out, or a loss through the valley, or both.

138. *Flood Peak No. 3 at Buckman.*—Flood peak No. 3 occurred in May 1905 with discharges of 7460 second feet at Del Norte, 11700 second feet at the Interstate Line, 19500 second feet at Buckman and 29070 second feet at San Marcial. (Embudo report missing.) This record indicates a flood similar to both No. 1 and No. 2, but added to by tributaries between Buckman and San Marcial, and probably the Rio Puerco and the Rio Salado.

139. *Flood Peak No. 4 at Buckman.*—Flood peak No. 4 occurred in June 1903 with discharges of 6025 second feet from above Del Norte, 12780 second feet at the Interstate Line, 15860 second feet at Embudo and 19300 second feet at Buckman; indicating a contribution of 3080 second feet from tributaries in New Mexico north of the Rio Chama, and 3440 second feet from the Rio Chama itself. The discharge of 18880 second feet at San Marcial indicates that no tributaries below Buckman were contributing.

140. *Flood Peak No. 5 at Buckman.*—Flood peak No. 5 occurred in October 1904 with a discharge of 3100 second feet at Del Norte, 3198 second feet at the Interstate Line, 17700 second feet at Buckman, 33000 second feet at San Marcial. (Embudo record missing.) Here is a flood of a different character. Since it came in October, it was evidently caused by rain which fell on the watershed between the

Interstate Line and Buckman, and also on the watersheds tributary below Buckman. The 33000 second feet recorded at San Marcial is the maximum flood of record for that station, and testimony of local residents gives most of the credit for the flood to the two lower tributaries, the Rio Puerco and the Rio Salado.

141. *Flood Peak No. 6 at Buckman.*—Flood peak No. 6 occurred in June 1921 with a discharge of 9630 second feet from above Del Norte, 12200 second feet from Colorado at Lobatos, 14900 second feet at Embudo, 17400 second feet at Buckman and 19360 second feet at San Marcial. Here is a flood similar to No. 1 and No. 4, except that the Rio Chama contributed only 2500 second feet and more of the total flow came from Colorado.

142. *Flood Peak No. 7 at Buckman.*—Flood peak No. 7 occurred in May 1924 with a discharge of 5590 second feet at Del Norte, 7380 second feet at the Interstate Line, 8767 second feet at Embudo, 16910 second feet at Buckman and 12400 second feet at San Marcial. Here is a flood whose characteristics are similar to Peak No. 1, but of a lesser magnitude. The Rio Chama contributed 8143 second feet as shown by the difference between Buckman and Embudo, or 7810 second feet as shown by the Rio Chama record at Chamita. The flattening of the flood peak through the valley is shown by the peak of only 12400 second feet at San Marcial.

143. *Flood Peak No. 8 at Buckman.*—Flood peak No. 8 occurred in May 1916 with discharges of 4690 second feet from above Del Norte, 5910 second feet at the Interstate Line, 9790 second feet at Embudo and 15900 second feet at Buckman. (6110 second feet from Rio Chama.) This flood was similar to peaks Nos. 1, 4, 6, and 7.

144. *Flood Peak No. 9 at Buckman.*—Flood peak No. 9 occurred in October 1911 with discharges of 14000 second feet at Del Norte (probably an error, though possibly due to a dam failure above), 7510 second feet at the Interstate Line, 15600 second feet at Buckman, (no record at Embudo) and 11780 second feet at San Marcial. This record is similar to Peak No. 5 except that tributaries below Buckman were not active.

145. *Flood Peak No. 10 at Buckman.*—Flood peak No. 10 occurred in May 1897 with discharges of 5234 second feet at Del Norte, (no record at the Interstate Line) 8745 second feet at Embudo, 15300 second feet at Buckman, 6555 second feet from Rio Chama, and 21750 second feet at San Marcial. The tributaries below Buckman were evidently active.

Most Flood Peaks Due to Melting Snow.

146. It is interesting to note that of the ten maximum flood peaks listed, eight occurred in the spring and only two in the fall. The fall peaks are evidently due to rainfall, and the spring peaks to melting snow. Of the two fall peaks, the larger was only 17700 second feet (October 1904). This same point is further emphasized by a detailed study of the peaks at various stations particularly on the Rio Chama, and tends to the verification of conclusion (a) stated above, paragraph 134, since it is evident that if the high flood peaks in the river are caused by the spring run off of the mountain snows no enormous flood peaks are likely. The snow melts slowly at high altitudes and will produce water over a considerable period of time, rather than a vast quantity all at once as happens in case of a cloud burst. So far as the upper river is concerned, i. e. the Rio Grande above Buckman, New Mexico, it would seem from the record that the maximum flood peaks are caused by the maximum snowfall in the mountains melting in the minimum of time in the spring. On the lower river the maximum flood may be caused by spring rains on the tributaries contributing to a river already carrying the spring freshet due to melting snow.

The Ten Largest Floods at San Marcial.

147. The ten largest flood peaks at San Marcial may be tabulated as follows:

No. 1	October	1904	33000 second feet	corresponding to peak No. 5 at Buckman
No. 2	May	1905	29070 second feet	corresponding to peak No. 3 at Buckman
No. 3	May	1920	22500 second feet	corresponding to peak No. 1 at Buckman
No. 4	May	1897	21750 second feet	corresponding to peak No. 10 at Buckman
No. 5	June	1921	19360 second feet	corresponding to peak No. 6 at Buckman
No. 6	June	1903	18880 second feet	corresponding to peak No. 4 at Buckman
No. 7	July	1898	16775 second feet	
No. 8	October	1897	15500 second feet	
No. 9	May	1912	15270 second feet	corresponding to peak No. 2 at Buckman
No. 10	May	1916	15145 second feet	corresponding to peak No. 8 at Buckman

This tabulation shows that the ten largest peaks at Buckman produced eight of the ten largest peaks at San Marcial. The other two peaks at San Marcial were both caused by storms on the tributaries entering below Buckman, probably the Rio Puerco and the Rio Salado.

Flood Probabilities.

148. The application of probability methods to studies of flood flow and run off data is of comparatively recent date. Their use in actuarial work has been much more common and is perhaps better understood, but the recent work of Mr. H. Alden Foster (see Transac-

tions American Society of Civil Engineers, 1924) and others, has simplified the involved mathematics of such studies.

149. Probability studies for both flood peaks and run off have been made for all of the main Rio Grande stations and for the stations at Chamita and El Vado on the Rio Chama, and for the Rio Puerco at the mouth. The conclusions reached from these studies were:

(a) That they may be of some value in extending a short time discharge record, provided that record contains either very high or very low terms, or both.

(b) That in the case of the Rio Grande and Rio Chama stations, where we have a record of approximately 36 years duration, probability methods are of more value in determining minimum stream flow expectation than as a guide to maximum flood peaks. The apparent reason for this is that the period of record includes a series of very dry years (1898-1902) but no large flood peaks.

(c) That the high or low flow of the river is not a matter of chance, as is assumed in the extension of records by means of probability curves, but, through this valley at least, depends very largely upon the time and distribution of the mountain snowfall and the melting of that snowfall in the spring, which in turn depends directly upon temperature. Temperature, it seems logical to believe, may well be affected by sun spots or other solar phenomena, which many scientists believe follow certain laws and recur at certain definite intervals. Hence we may expect cycles of extreme temperatures affecting the fall and the melting of snow in the mountains and the resulting run off of the river. More study may succeed in correlating the stream flow records of the Rio Grande with the tree ring studies of Professor Douglas in Arizona sufficiently to determine the "wave length" of these climatic cycles and the amplitude of the waves.

Flood Control by Means of Flood Detention Reservoirs.

150. Several reservoir sites exist on the main river above Albuquerque which would be of some value for flood detention, either singly or combined. The District has made comprehensive studies of this situation, and its early studies contemplated the construction of the State Line Reservoir, capacity 200,000 acre feet, together with a flood detention reservoir at San Felipe with a capacity of 400,000 acre feet. By means of these reservoirs the maximum flow of the river below San Felipe could be regulated to about the present channel capacity of some 12,000 second feet. During periods of flood the water would back up behind the San Felipe Dam, the extent of the impounding being determined by the intensity and duration of the run off. Such backing up of water would occur only in years of abnormally large flow.

151. This type of control has several obvious advantages, prob-

ably the most important one being the definite limitation of river flow below the reservoir and the fact that only small levees would be needed along the river. The principal disadvantage is the excessive cost of the San Felipe Dam and appurtenances. The outlet works for limiting the outflow to 12,000 second feet, and the spillway to carry 50,000 second feet or more around the dam, make this reservoir very expensive. The cost of the detention reservoir plan for 12,000 second feet regulation exceeds that for flood protection by levees, as provided in the Plan, by three to four million dollars.

152. Other disadvantages of the detention reservoirs would be the more or less infrequent flooding of Indian lands on the San Felipe and Santo Domingo Grants, and the remote possibility of a very large spillway discharge which would exceed the channel capacity of the river and cause flooding of property. This latter objection might be serious because, with detention reservoirs, the river channel would become more and more obstructed through disuse by high floods.

153. The Board of Consulting Engineers advised against flood detention reservoirs, and the original idea was therefore modified as to flood protection. Under the Plan flood protection is to be obtained by means of levees and other river improvements.

Flood Control by Means of Channel Dredging.

154. The proposal has been advanced in some of the earlier reports, and has had more or less popular backing, that the river channel might be dredged to any required size and depth, through the entire middle valley, providing both drainage and flood protection. It was claimed that drain ditches and levees would then be superfluous, and that the large acreage of land necessary for rights-of-way for such ditches and levees would be saved for agricultural purposes. Experience on silt-carrying rivers has demonstrated that often a dredged channel rapidly refills with silt and does not maintain its depth. It is often necessary to repeat the operation of dredging so that it becomes continuous. Floods from all tributary streams from the Rio Chama down stream to San Marcial bring more or less silt into the Rio Grande, and this silt, which is deposited in the river bed, is washed by successive floods into the Elephant Butte Reservoir.

155. The elevation of the water surface in the Elephant Butte Reservoir controls the height of the water surface in the river at the lower end of the middle valley. Also the water surface of the river at the mouth of White Rock Canyon is practically fixed. The total fall through the valley is therefore definitely limited. If the river can be straightened, the distance through which the water flows can be reduced, and consequently the slope per unit of distance will be increased. The

result will be an increase in velocity of flow and in silt transporting capacity.

156. Theoretically, the river channel, to be effective in lowering the water table to a depth of four feet below the surface, would need to be at least 20 feet deeper than at present. This estimated theoretical depth is based upon the prevailing condition of the present river bed which is from 2 to 4 feet above the lowest part of the valley, the normal slope of the water table as experienced on similar lands when drained, and assuming 2 miles as the distance between the deepened river and the most remote farmland. A channel of this depth would probably not effectively drain the entire area of the valley floor. In practice, drainage ditches are usually spaced about 1¼ miles apart to maintain the water table slope as estimated above. If the river channel were deepened to provide one effective drain through the entire valley, a depth of 10 feet below the land surface could be expected to provide drainage for a strip of land from ½ to ¾ mile wide on both sides of the channel. Greater depth of channel would not increase proportionately the width of area drained. With a greatly deepened channel, a system of lateral drainage would still be necessary in parts of the valley, dut to the width of the area and the efficient drainage required in leaching alkali soils.

157. A river channel 175 miles long and 500 feet wide, dredged to a depth of 20 feet, would require the excavation of about 340 million cubic yards of material. This is about fourteen times the total amount of earthwork required in executing the Plan. The dredging required from year to year for maintenance of depth would necessitate a large continuing expense. At San Marcial and in the upper end of Elephant Butte Reservoir the maintenance of such a deep channel would be especially difficult and expensive. Where a river is building up its flood plain, as in the case with the Rio Grande, a very delicate balance of forces exists, and the interference with these forces by artificial works and structures is likely to have a far-reaching and often an unforseen effect. The various studies made for channelizing the river have not offered an attractive solution of the river problem.

Channel Control by Jetties.

158. The proposed channel regulation by means of permeable jetties or retards has been successfully employed to a limited extent on the Missouri, Kansas, Canadian and Colorado rivers, and on a small scale locally. Such jetties are known to be effective in depositing silt for filling at predetermined places. It is proposed to place these jetties so that the resulting silt deposits will define a narrowed channel for the low water flow. The flow, instead of dissipating its scouring effort over the valley, will be confined between banks of deposited silt where,

with its increased velocity, it will be effective in scouring the narrow inner channel and in keeping it free from further deposits of silt. The decision to adopt the method of flood portection using levees and jetties resulted from the gradual elimination of other methods which were studied as outlined herein and found to be less desirable. Of the methods studied the levee method with jetties and certain other improvements, as described in paragraphs 279-283, is believed to afford the greatest measure of protection for the money expended. Regardless of cost, it is the only method which is considered feasible, except a detention reservoir plan, or a combination of levees and jetties with one or more detention reservoirs.

Summary of Water Supply Studies

Climatic Characteristics of the Rio Grande Valley.

159. The general air movements which determine the climate of the country originate mainly in differences of temperature which cause differences in air pressure and consequent wind movements from high pressures to low. In winter the water of the oceans is warmer than the land of the continents, and the interior continental plateaus become areas of high pressure, from which the air movement is down, and toward the low pressure areas of the oceans.

160. New Mexico is somewhat south of these high pressure areas, and the Rio Grande Valley is exposed to the cold winds from the north with the result that late frosts are common in the spring. The usual warm weather of this latitude is apt to be interrupted by a "norther", after the early fruits like apricots and peaches have blossomed, and very often these blossoms are nipped, as they were in April of 1927, and again in April of 1928.

161. In summer the conditions are reversed and the land areas become warmer than the ocean areas. The resulting air movement from high pressure to low takes place from ocean to land and here again the climate of the Rio Grande Valley is influenced by peculiar local topographical conditions.

162. When an air current passing over the land encounters an obstruction like a mountain range, the air is deflected upward where it cools in the higher altitudes, and its moisture is precipitated. The obstruction past, the cooler drier air again descends, is heated, and absorbs moisture. As a consequence the windward side of the mountain range receives the precipitation while the leeward side is arid.

163. This influence is operative on the mountain slopes surrounding the Rio Grande valley. There are three areas with a mean an-

nual precipitation of over 35 inches, located in the high mountain areas of the San Juan and Sangre de Cristo ranges in which the Rio Grande heads. The principal area of this type is the San Juan Mountain area west of the San Luis Valley. Here the winter snowfall is very large (often in excess of 30 feet) and the mean annual precipitation probably exceeds 40 inches on the highest peaks. Thirty to 50 miles to the east, in the San Luis Valley, the precipitation drops to from 6 to 8 inches annually.

164. North and east of the San Luis Valley the precipitation on the high peaks of the Sangre de Cristo probably reaches 35 to 40 inches, but it falls largely on the eastern side of the range and drains through areas, like the Wet Mountain Valley, into the Arkansas River. On the San Luis Valley side the run off is small and very little of it reaches the Rio Grande.

165. The third high precipitation area is in the southern extension of the Sangre de Cristo Range, north and east of Santa Fe. Here the mountains are so near the Rio Grande that the drainage areas of the streams are small and the runoff is not large.

166. Aside from the San Juan mountain area, the most prolific source of runoff is the Rio Chama area in New Mexico. This stream drains the southern end of the San Juan area and also a large area having a moderately high precipitation of from 10 to 25 inches per annum.

167. South of the mouth of the Rio Chama there is no dependable source of runoff. A few small local areas of high precipitation exist in the Sandia and Manzano Mountains east and south of Albuquerque, but they do not produce perennial streams flowing as far as the Rio Grande.

168. It is apparent, then, that the Rio Grande basin is a narrow, north and south valley protected above Buckman by mountain ranges on both the east and the west, and by a lower range on the north. The effect of this protection is to produce an arid valley with an annual precipitation of 6 to 8 inches, while on the high ranges to the east and west the rainfall averages over 35 inches per year.

169. The lower valley (below Buckman) is wider and it also is protected by the lower mountains of the Jemez, Datil and Mimbres Ranges on the west, and Sandias, Manzanos, Oscuros, and San Andres Mountains on the east. The whole area included in the middle valley is in the belt of less than ten-inch rainfall; in fact, the average rainfall for the middle valley is probably from 7 to 8 inches per annum.

Gaging Stations.

170. Records of flow of the Rio Grande are available for several stations in Colorado of which two are of particular interest:

(1) Del Norte:

This station measures the flow of the Rio Grande into the San Luis Valley above most of the irrigated area. The station is well located and has been in operation since October 1889. The accuracy of this record is considered to be good.

(2) Lobatos:

This station is nearly at the Interstate Line and measures the flow of the Rio Grande from Colorado into New Mexico. It has been in operation since June, 1899 and its record is considered good.

Records from three stations in New Mexico are available:

(1) Embudo:

Located a few miles above the mouth of the Rio Chama. Records are available from January, 1889 to December 1903, and from September, 1912 to date.

(2) Buckman:

Located some 30 miles downstream from Embudo, and below the mouth of the Rio Chama. Records are available from February, 1895 to December, 1905, and from June, 1909 to date.

(3) San Marcial:

Located at the town of San Marcial a few miles above the upper end of the Elephant Butte Reservoir. Records are available from January 1895 to date.

Records of flow of the Rio Chama are available at:

(1) Chamita:

Located at the mouth of the Rio Chama near the point where it empties into the Rio Grande. Records available from November, 1913 to date.

(2) El Vado:

Records kept at various stations near El Vado for period September, 1912 to September, 1916, and from February, 1920 to date.

A condensed tabulation of flow records follows:

Table 15

Flow Records

Station	Period of Record	Mean Annual Flow in A.F.	Max. Flow in A.F.	Min. Flow in A.F.
Lobatos Colo.-New Mex. Interstate Line	1899—date	627,000	1,040,600 (1920)	98,700 (1902)
Embudo	1899—date	855,000	1,579,000 (1920)	281,000 (1902)
Buckman	1895—date	1,400,000	2,359,000 (1920)	425,000 (1902)
San Marcial	1895—date	1,180,000	2,422,000 (1905)	201,000 (1902)
Chamita	1914—date	525,000	787,000 (1920)	258,000 (1918)
El Vado	1912—1916, 1920 to date	315,000	530,000 (1916)	89,000 (1904)

171. The records of Buckman and San Marcial stations are of particular interest because they measure the water at the head and foot respectively of the middle valley. Buckman measures the water supply of the middle valley and San Marcial measures the remaining water which flows into the Elephant Butte Reservoir of the United States Bureau of Reclamatoin just below San Marcial.

172. The Buckman record includes the three periods 1895-1905, 1910-1914, and 1916-1925, and parts of the record at Embudo and Lobatos are missing, but, by plotting monthly curves of relationship between Lobatos, Embudo and Buckman, it is possible to fill in the gaps in the records and obtain a reasonably accurate record for all three stations covering the 38-year period 1889-1926.

Hydrographs.

173. Hydrographs of the stream flow at all of the Rio Grande stations and at all of the principal tributaries have been plotted. Study of these records and hydrographs shows that generally about 70 per cent of the flow of the Rio Grande above the middle valley occurs during the three months of April, May and June. In late summer there is a shortage of irrigation supply almost every year. The hydrographs show a very dry series of years occurring during the period 1898-1902.

Colorado Depletions.

174. Because of the fact that the irrigated area of the San Luis valley in Colorado and the use of water thereon has increased greatly since 1890, it is necessary in estimating the future water supply for the

middle valley to take into account this depletion of flow. The Debler-Elder Report (Exhibit R-4 of the Official Plan) includes detailed studies of this depletion and a compensated record of middle valley demands based thereon. The water supply studies, taking account of the low flow years and Colorado depletions, show that a storage of about 190,000 acre feet is essential to regulate the erratic river flow and to supplement the irrigation supply during the summer when the spring flood has passed.

Summary of Reservoir Investigations

General Statement.

175. The conclusions resulting from the reservoir investigations and studies described in paragraph 105, may be summarized as follows:

(a) There are no reservoir sites on tributaries to the Rio Grande, other than the Rio Chama, of sufficient size or with adequate water supply to supply the requirements of the middle valley.

(b) There are sites on the Rio Chama where reservoirs of some 200,000 acre feet capacity can be constructed at reasonable cost, and where an adequate water supply seems assured. The best of these sites appears to be the one at El Vado, in Rio Arriba County, New Mexico.

(c) Several reservoir sites exist on the main Rio Grande above the District, but most of these sites are of insufficient capacity to be of great value. The following three sites are not open to this objection:

The State Line Site.

176. At the State Line site a reservoir of nearly 200,000 acre feet capacity is economically feasible, without inundating drain outlets in the San Luis Valley, Colorado. Being located just North of the Interstate Line, it is above the principal New Mexico tributary, the Rio Chama, and is consequently dependent upon the run off from the Colorado area of the Rio Grande watershed for its water supply. Under present conditions this supply is inadequate and uncertain and, should certain proposed storage reservoirs in Colorado be built, this reservoir would be of small value for irrigation. Its value for flood protection would be appreciable, but it is too far away from the middle valley to be very effective, unless developed in combination with a lower detention reservoir.

The Buckman Site.

177. This site has a capacity of some 600,000 acre feet and is located on the Rio Grande just below the mouth of the Rio Chama. Its

water supply is adequate, but economic reasons forbid its construction. A reservoir at this location would inundate the Rio Grande valley from Otowi to a point above Espanola, and would destroy a large acreage of very valuable land. In addition it would inundate the Indian pueblos and lands of San Ildefonso, San Juan, and Santa Clara, and a part, at least, of the town of Espanola.

The San Felipe Site.

178. This site is in some ways the best site on the river between the State Line and Elephant Butte Reservoir. Its economic capacity would be about one million acre feet, with a dam about 150 feet high. In this location, its water supply would be assured and, lying directly above the middle valley, its value for flood protection would be very great.

179. On the other hand the development of the San Felipe site would cause inundation of a large acreage of Indian land and would either force the removal of the pueblo of Santo Domingo to higher ground, or, if developed for a smaller capacity, the protection of the pueblo in its present location by means of a high dike or levee would be necessary.

180. In combination with the El Vado Reservoir and the State Line Reservoir, the San Felipe site would afford an ideal system of irrigation, storage and flood protection. In such a plan it would be simply a flood detention basin, which would retard and regulate flood flows to a predetermined volume, capable of being safely conducted through the valley. The development of this reservoir for 400,000 acre feet storage was a part of one plan considered. However, any development of this site for capacity of less than one million acre feet would necessitate provision for large spills. The site is not easily adapted to spillways of large capacity and this provision greatly increased the estimated cost.

The El Vado Reservoir.

181. As set forth in paragraph 114, nine different designs have been made for the dam at the El Vado Reservoir site, covering dams of various types and heights. These designs were based on detailed topographic surveys of the site, deep drilling tests in the bed of the river, and a series of 5 open shafts sunk in the broken rock of the easterly abutment.

182. Preliminary water supply studies indicated that a storage capacity of 200,000 to 225,000 acre feet would be required. After the completion of the United States Bureau of Reclamation water supply report, the capacity of 190,000 acre feet was decided upon and was approved by the Board of Consulting Engineers. In the final design, the

crest of the dam has been raised slightly increasing the capacity of the reservoir to 198,000 acre feet, because this higher elevation of maximum water surface simplifies the design and increases the capacity of the emergency spillway. The elevation of this structure is controlled by a "saddle" in the hills located about a mile away from the dam.

183. The dam site is located in a narrow canyon with walls of massive sandstone and hard shale. The side walls are almost vertical and are less than 100 feet apart and a casual inspection of the site immediately suggests the use of a concrete arched dam. Test shafts, however, demonstrated an unusual geologic condition of the east abutment which seems to prohibit the use of a concrete arch.

184. The geology of the site is described in detail in a report by Mr. E. H. Wells, President of the New Mexico School of Mines, entitled "The Geology of the El Vado Damsite and Reservoir, Rio Arriba County, New Mexico", (Exhibit No. R-2 of the Official Plan). Briefly this condition may be summarized as follows: On the east side of the river at the El Vado damsite the strata dip to the west, toward the river. As originally formed these strata consisted of alernate layers of sandstone separated by strata of clay or poorly cemented material. At a later time the soft material has been either squeezed out or eroded by percolating water. The result has been a breaking and letting down of the rock strata to a considerable depth near the river, but to lesser depths as the distance from the river increases, so that the east abutment affords no stable water-tight foundation above the river bed and is in effect a loose rock fill.

185. The type of dam has therefore been determined by the broken condition of the east abutment and a gravel and loose rock embankment with a concrete cut-off wall and a concrete face has been selected for the site. The dam is described in paragraphs 268-275.

The Situation at San Marcial*

General Statement.

186. The situation at San Marcial has been studied intensively and several solutions of the problem have been suggested. Since 1880 the river bed has raised from 12 to 14 feet at San Marcial and the channel is almost obliterated. The capacity of the channel has been so reduced that a discharge of 12,000 second feet in 1926 caused a water surface 3 feet higher than a flood of 12,700 second feet in 1919, and 4.7 feet higher than the flood of 33,000 second feet in 1904. The water

* The Plan approved by the Conservancy Court on Aug. 15, 1928, eliminates all proposed improvements south of the north line of the Bosque del Apache Grant, including San Marcial, with the sole exception of certain channel improvements.

surface in 1926 was about 6 feet above the railroad track, and the track and town are from 2 to 3 feet lower than the bottom of the river.

187. The A. T. & S. F. Ry. has a levee along its tracks from a point about 6400 feet north of the station to a point about 3500 feet south thereof. Joining the south end of the railroad levee the town has a levee extending southwesterly about 4500 feet to the higher ground south of "Old Town". Roughly paralleling this levee, there is a second levee about 3500 feet long, also built by the town, and these levees form the only protection to the town and the railroad against direct overflow during high water. They are not capable of withstanding large floods, and they have been breached frequently. Continuous raising of the river bed will require continuous raising of the levees at continuous expense and with increasing hazard. Ultimately this system must be abandoned.

188. Ground water in San Marcial is at or above ground surface most of the time, and the problem of drainage is difficult because the river is higher than the land. Drains must be carried a long distance down stream to find an outlet offering sufficient fall for the lowering of the water table in the town. Drawing K-9, Exhibit P-4 of the Official Plan, shows diagramatically the present condition of the river channel and the rate of filling in of that channel in the vicinity of San Marcial. It shows the silt delta or "plug" which is believed to be the cause of most of the river trouble at this point. It seems necessary to get the river either through or around this silt plug, and various plans for doing so have been studied. Three methods have been considered for this purpose.

Flood Protection at San Marcial—Method A.

189. Method A was based on the fact that clear water has much more erosive power than silty water. With the ordinary flow of the river controlled by flood detention reservoirs (as was first proposed) and with a silt detention program being carried out on the tributary streams, it was thought that the situation at San Marcial might be improved. It was concluded, however, that such a method was impractical and that the time required could not be predicted. The condition at San Marcial is acute and needs an immediate remedy. Method A was consequently discarded.

Flood Protection at San Marcial—Method B.

190. Method B proposed to improve the present flood channel by levees from a point about 2 miles above town to A. T. & S. F. Ry. Bridge No. 1005A about 1 mile below. This bridge, a steel truss, spanned the channel of 1920, which has since filled in up to the floor of the bridge. It is proposed to reopen this channel and extend it along the

west side of the valley to a point opposite Old Ft. Craig, where it will empty into the present channel. Where the reopened channel leaves the present channel, a drop structure 500 feet wide is proposed at a point about 150 feet east of A. T. & S. F. Ry. Bridge No. 1005A. The construction of this drop would be such as to induce scour in the channel above. A spillway channel with a capacity of 10,000 second feet would be made of the present river channel under Bridge 1006A, and the main channel under Bridge 1005A would be constructed to a capacity of 20,000 second feet. The combined capacity is therefore 30,000 second feet.

191. Levee protection would be provided above the drop by means of jetties made of channel irons and wire fencing, and by means of trees and wire fence where practicable. At the lower end of the sand plug it is proposed to prevent the formation of sand bars by the extension of these permeable jetties, spaced so as to form a narrow channel which will have a scouring velocity Drainage will be provided either by increasing the depth and grade of the present drain or by constructing a new system. Method B is considered to be practical, economic and permanent, but more expensive than a similar plan which includes the raising of the track and bridges at San Marcial.

Flood Protection at San Marcial—Method C.

192. Method C proposed to make a complete channel change of the river and divert it over to the west side of the valley past San Marcial. This method is practical, but would cost about twice as much as method B, on account of additional bridges, length of channel and right-of-way expense.

Flood Protection at San Marcial—Method D.

193. Method D was similar to method B, except that the railway bridges and the tracks approaching them are raised about 6 feet to provide a greater waterway. A channel would be excavated from the present river bank just above bridge 1005A to Ft. Craig in a slope of .000615. At and above the bridge the width will be 500 feet. Below the bridge there will be a transition from 500 feet to 100 feet and the last 3000 feet of channel will be only 50 feet wide. The idea of this channel is to excavate only for the small and ordinary discharges and confine the floods between the high ground on the west and a longitudinal retard of woven wire on the east. A flood channel about 600 feet wide would be so determined. This arrangement, due to the raising of Bridge 1005A, has a greater flood capacity than 30,000 second feet, so that the spillway channel is not needed. Otherwise, it is similar to method B without the drop. Drainage conditions are not quite as good as in

method B, on account of higher water surfaces in the flood channel, but the cost is much less for method D.

194. When the Board of Consulting Engineers advised the elimination of all flood detention reservoirs from the Plan, it was no longer possible to count upon a predetermined, regulated river flow, and it seemed necessary to provide protection for San Marcial against a greater flood than the 30,000 second feet previously considered.

195. Again it became necessary to revise the San Marcial protection plan and three more methods G, E and F were considered, to protect against 30,000 second feet, 50,000 second feet and 100,000 second feet, respectively. These three methods worked out in detail, with cost estimates, established the relationship between the degree of flood protection to be obtained and cost, and indicated that the maximum degree of protection obtainable at a reasonable cost is about 50,000 second feet. In other words, the cost of protection against floods of much more than 50,000 second feet would be excessive and would result in an unbalanced Plan.

Flood Protection at San Marcial—Method E.

196. Method E, providing protection against 50,000 second feet, was therefore decided upon. This plan provides for the protection of San Marcial by high levees, the raising of bridges 1005A and 1006A, with their approaches a maximum distance of about 8 feet, the replacing of present pile bridge 1006A with a new steel truss bridge, the drainage of the San Marcial area by means of an open drain ditch outletting in the river opposite Old Fort Craig, and the maintenance of a flood channel through the silt plug by means of permeable jetties. This method is described in detail in Part V, Paragraphs 352-359. Exhibit R-1 should be studied in connection with the San Marcial situation. This report sets forth, on pages 165 to 167, the serious nature of the engineering problem at the upper end of Elephant Butte Reservoir.

River Bridges

Provisions of Conservancy Act Relating to Removal of Structures.

197. The Conservancy Act gives the District very broad powers. Under the general heading "Removal of Structures", Section 313 of the Act, reads in part as follows:

"Sec. 313.—Removal of Structures.

(1) For the accomplishment of the Official Plan, the Board of Directors of any district shall have full power and authority to improve in alignment, section, grade, location or in any other manner, any water

course, and they may remove, widen, lengthen, lower, raise or otherwise change any public or private road-bridge or railroad bridge or any other construction, over, across, in, into, under or through any such water course, or may require the same to be done, and the foregoing shall apply to all such changes specified by the Official Plan, or reasonably necessary for the accomplishment of the same; provided, however, that whenever any such change is made necessary in any construction because of the failure of the same to permit the free flow of the water in such stream in time of flood, or to permit the necessary enlargement or protection of the channel, then the owner of such construction shall make such change and all adjustments of grade, road-way, track, approach or other construction incidental thereto, without cost to the District, and without any claim for damages against the District; * * * *"

Discussion of Various Bridges.

198. Fifteen bridges span the Rio Grande between Cochiti and San Marcial, at the following points:

Table 16

Bridges Spanning the Rio Grande Between Cochiti and San Marcial

	Location	Kind	Type	Length
1	Cochiti	Highway	Steel Truss	246
2	San Felipe	Highway	Steel Truss	428
3	Bernalillo	Cuba Railway	Pile Trestle	850 Approximately
4	Bernalillo	Highway	Pile Trestle	1252
5	Alameda	Highway	Pile Trestle	862
6	Barelas	Highway	Steel Truss	1565
7	Isleta	Railway	Plate Girder	638
8	Isleta	Highway	Pile Trestle	948
9	Los Lunas	Highway	Pile Trestle	880
10	Belen	Highway	Pile Trestle	680
11	Belen	Railway	Plate Girder	800 Approximately
12	San Acacia	Highway	Pile Trestle	292
13	Escondida	Highway	Combination Pile Trestle and Steel Truss	516
14	San Antonio	Highway	Combination Pile Trestle and Steel Truss	749
15	San Marcial	Highway	Steel Truss	455

199. It will be seen from the above table that the lengths of these bridges vary greatly. The narrower ones in the northern end of the district are, generally speaking, considerably higher above the stream, and the stream itself has more fall than is the case lower down, so that the channel capacity under these bridges is greater than in some of the longer ones. Cochiti and San Felipe are considered to be safe against very considerable floods, perhaps 50,000 second feet, and the new Barelas Bridge, it is understood, will provide sufficient waterway for this amount.

200. The A. T. & S. F. Ry. engineers do not consider the railway bridges at Isleta and Belen to be capable of withstanding 50,000 second feet of water, and propose to lengthen each bridge about 200 feet.

201. The various other highway bridges do not create any additional flood menace but are very likely to be washed out, or have their approaches washed out during exceptionally high water. At San Acacia the highway bridge is located across a very narrow river channel at the lower end of the canyon between La Joya and San Acacia. High water scours out the bottom of the river under the bridge to great depths, but approximately 20,000 second feet during September 1927, brought the water up to the floor of the bridge, and indicated about the limit of the channel capacity at this point.

202. At Escondida about 12,000 second feet inundates the low fill which forms the approach to the bridge on the east side. A flow much in excess of this amount would probably wash out this approach and render the bridge impassable. Were this approach to be raised and strengthened, the bridge itself would probably wash out.

203. At San Antonio an old makeshift wooden truss does duty both for the branch railway to the Tokay coal mines and for a highway. This structure will probably be washed out during the first large flood.

204. It is not considered necessary to replace these bridges at the present time, since they do not create an additional flood menace, and they may continue to serve their purpose for years. Should they be washed out in some subsequent flood, they should be replaced with more substantial structures designed to provide waterways for at least 50,000 second feet.

205. It should be the policy of the District to prevent the narrowing of the flood channel of the river by the construction of high fills approaching river bridges in order to shorten the bridges themselves. In fact, it should be the ultimate aim to have all bridges long enough and high enough to provide a clear flood channel of at least 50,000 second feet, but it is believed that this ultimate goal can be approached gradually by replacing present structures as they wear out or become inadequate.

Power Possibilities

General Statement.

206. Power possibilities in connection with the proposed reclamation and flood protection plan of the District are considered to be of much future value. In general four types of site where power might be developed exist. These are:

(a) At the El Vado Reservoir.

(b) At the diversion dams.
(c) At small drops in the irrigation canals.
(d) At a few points where canals are considerably higher than valley floor.

Types (a), (b), and (c) Unsuitable.

207. Detailed investigation of power possibilities at sites of types (a), (b) and (c) disclose the fact that such sites are unsuitable for the following reasons:

El Vado reservoir is essentially a reservoir for the storage of irrigation water. It is an insurance against shortage of water in the river and in general will be drawn upon only when such shortage exists. Under normal conditions of river flow, this reservoir is likely to be drawn down during the months of July, August and September and, in periods of extreme drought, it may be emptied during the summer months. During the winter and spring it must be refilled and during the refilling no water will pass the dam except the relatively small amount necessary to supply prior rights below the dam. It is evident that the necessities of operation as a storage reservoir conflict with those of a power reservoir and no continuous, dependable flow of water for the generation of power can be counted upon.

Of the four diversion dams, only the Cochiti dam can be built of sufficient height to be of any value in the development of power. A design for a combination diversion and power dam was made for this site but was found to be so costly that the idea was abandoned.

The main canals are located through the low part of the valley except in the case of the Belen High Line Canal. Such locations necessitate the use of drops, since the valley slope is greater than the grade of the canal. As a rule these drop structures provide a fall of four feet or less; in fact, no drops of more than four feet are contemplated While no development of power on a large scale could be made at these drop structures, it is thought that small individual installations might be of some value.

Type (d) Suitable at a Few Locations.

208. At several places where the irrigation canals of the District attain a considerable elevation above the valley floor, it is possible to construct a power drop and a by-pass or wasteway back to the river. Several such power sites have been investigated.

Cochiti Power Site.

209. A possible power development exists at a point on the proposed Cochiti Main Canal, just north of the village of Cochiti, some 20 miles north of Bernalillo, and 23 miles southwest of Santa Fe. This

development will require the enlargement of the Cochiti Main Canal to a capacity sufficient to carry the entire winter season flow of the river from the diversion dam to a point 6,000 feet below; the construction of 11,800 feet of new power canal; the construction of the power house itself; and the excavation of a tailrace 4000 feet long back to the river.

An effective head of 28 to 30 feet is available and a power development of 884 K. W. is estimated as possible at all times. This estimate is based on a minimum river flow of 500 second feet at the Cochiti diversion dam, which is apparently very conservative.

Power Sites on Belen High Line Canal.

210. At two or three places on the Belen High Line Canal, it would be possible to drop from the canal down into the valley and install a power plant at the foot of the drop. It is necessary to carry water from the main west side canal across the valley and across the river to serve the San Juan area, in any event. If the main canal were to be built with an excess capacity from the head down to the power drop, and a wasteway were to be provided back to the river, a certain amount of continuous flow could be counted upon during the irrigation season, and during the winter months the whole flow of the canal could be turned through the power drop.

Summary of Investigations of Two Sites on Belen High Line Canal.

211. Two power sites on the Belen High Line Canal were studied in some detail:

(a) The first is located west of the village of Los Chavez, about 16 miles below the head of the Belen High Line Canal, where a drop of about 50 feet is available in a distance of 600 feet or less. The irrigation demand below this drop would amount to some 200 to 250 second feet, and an excess of 150 second feet in the main canal above the power drop would give a total of about 400 second feet through the drop. Roughly, the power development here would amount to about 1220 H. P. for the 400 second foot total flow. As indicated above, it would be necessary to provide a wasteway to the river for the excess of 150 second feet, and a wasteway from the San Juan Lateral to the river for the 250 second feet or irrigation water.

(b) The second site investigated is located at a point on the Belen High Line Canal, about three miles south of Belen, where the canal is 10,900 feet west of the river and about 74 feet above it. Irrigation requirements below this point, together with diversion of 400 to 500 second feet of river water during the non-irrigation season, assure the development of 1490-1690 K. W. of power at this point.

No Power Plants Included in Plan.

212. It was decided to omit these possible power developments from the present Plan, though it is realized that they should be kept in mind as rather attractive future possibilities. Their principal disadvantage lies in the combination of power development, which involves continuous canal operation, during twelve months of the year, with irrigation operation, which is only continuous during eight months. It would be difficult to clean canals, repair them, or renew structures during continuous operation. With the present demand for power, such developments do not appear very attractive, but it is possible that in the future, with the country more thickly settled, a greater power demand might be created, possibly sufficient to absorb the entire output. In this case, the estimated financial returns appear attractive enough to warrant the construction of one or more of these power plants by the District, and this can be done at any time with very little change in the irrigation system as now proposed.

General Features of Design

Drainage System.

213. The drain ditches have been projected upon the 1000-foot scale contour maps of the valley, with particular reference to the topographic features of the lands. They were then transferred to the 200-foot scale property maps by pantograph and adjusted as far as possible to existing property lines. Because of the fact that the 12,000 or more tracts of land in private ownership in the valley are very small and very irregular in shape, it is impossible to avoid the cutting of many such tracts. The details of location of drains may be improved perhaps in some cases by field locations, but modifications of this kind will be of a minor character and will have little effect upon the Plan as a whole, either as to location or cost.

214. From carefully kept records on the Government Rio Grande Project, the effectiveness of open ditch drainage can be closely predicted both from the standpoint of lowering of the water table and of recovery of water. These records are particularly applicable here in the middle valley where conditions are so similar to those of the lower valley.

215. The design and spacing of the proposed drain ditches has been based upon results actually obtained in the lower valley. Drain ditches are located with the expectation that they will be effective for from half a mile to three-quarters of a mile on each side, and they are spaced accordingly within this limit and as controlled by the topography and irrigation canals.

216. The water reclaimed by the drainage ditches is a very essential part of the water supply for the District lands, and the estimates of the amount of such reclaimed water are set forth in Exhibit R-4 of the Official Plan. The project drains must provide capacity for this reclaimed water and also for additional water resulting from direct seepage from the river into adjacent drains. The drainage system has been designed for carrying capacity in accordance with discharge measurements made on drains below Elephant Butte Reservoir, adjusted to meet local conditions, as follows:

(a) Riverside drains, 2.5 second feet per mile of drain.

(b) Interior drains in valley floor, 1.5 second feet per mile of drain.

(c) Interior drains near foot of side hills and below irrigation canals, 1.75 second feet per mile of drain.

217. Studies by the District and by the United States Bureau of Reclamation demonstrate that the saving of water which will be accomplished by drainage will more than offset the increased use of water for irrigation of District lands, so that an actual saving of water for the Government Rio Grande Project will result.

Water Supply Developed from Water Reclaimed by Drainage.

218. The Plan proposes to develop a water supply for the irrigation of District lands by means of the drainage of these lands as outlined in the foregoing section on drainage. This is possible because of the great loss of water by evaporation from the valley lands under present water table conditions. Drainage, as provided by the Plan, will lower the water table a sufficient distance below the surface to reduce greatly the present loss of water, thus effecting an actual development of water now lost to all beneficial use. This water will be made available to the lands of the District partly by direct diversions from the natural and augmented flow of the Rio Grande, and partly by the release of stored water from the El Vado Reservoir.

219. In this connection the following is quoted from Exhibit R-4 "Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico", by E. B. Debler, Hydrographic Engineer, and C. C. Elder, Assistant Engineer, United States Bureau of Reclamation, December 15, 1927, as follows:

"Water Supply

"Of surface waters entering the middle valley through the Rio Grande and its tributaries, including also the gain from Buckman to Bernalillo, 582,000 acre feet of water, on the average, is annually lost through the valley to San Marcial, being somewhat larger in years of high run off and very much smaller in years of extremely low run off,

due to fluctuating water table on the valley lands and variation in irrigation supply. With developments planned by the District, such losses will be relatively much more uniform and it is estimated will average 535,000 acre feet annually, including the use of stored waters. Adding to this loss, an average evaporation loss at El Vado reservoir of 9,000 acre feet annually, makes a total loss of 544,000 acre feet annually. In the years of low run off, when under present conditions such losses are relatively small, the losses with the valley reclaimed will also be smaller by reason of lack of divertible water resulting from insufficient storage capacity to provide a full supply. It is concluded that middle valley development will, therefore, not infringe on the water supply for lands dependent on Elephant Butte Reservoir."

220. This feature of the Plan is of utmost importance and is of an unusual nature. It means that sufficient water can be saved by drainage to more than supply the additional needs of the District without in any way interfering with the rights of other appropriators on the river.

Irrigation System.

221. Each of the four divisions will derive its supply of water from a main canal heading in the river at one of the four diversion dams. The Belen Division will have two such canals, one on each side of the river. These main canals might be designed in either of two ways:

(a) As "high-line" canals which would run on light supported grade lines without drops. Such canals would follow the side hills bordering the valley, and since their grades would be much less than the slope of the valley floor, they would gain elevation over the valley lands as they extended downstream. They would, therefore, make possible the irrigation of some new land lying above the present irrigation system.

(b) As "low-line" canals running through the valley floor. Such canals would require drops at more or less frequent intervals, since the canal grades would of necessity be less than the general downstream slope of the valley.

222. In three of the four divisions the Plan proposes low-line canals, chiefly for the reason that they avoid the extra first cost and the extra maintenance cost of carrying large canals across the many large arroyos which empty into the valley from the side hills. Since it is believed that the adequacy of the water supply for large areas of new land would be very questionable, the extra land which might be irrigated by more expensive high line canals is not an important consideration of canal location.

223. In the Belen Division, however, the west side main canal has been loctaed as a high-line canal for the reason that little cross drainage is encountered on the west side of the river between Belen and La Joya. The Rio Puerco practically parallels the Rio Grande at no great distance, and consequently the drainage areas tributary to the Rio Grande are small.

224. Some very fine land above the present ditches will thus be brought under the new irrigation system, in the area west of Los Lunas and Belen as far south as Mile Post 943 on the A. T. & S. F. Ry., where it is proposed to drop the water from the high-line canal down to about the limits of present irrigation ditches.

Rio Puerco Unit.

225. A study was made contemplating the extension of the Belen High Line Canal around the hills and up the Rio Puerco valley, crossing the Rio Puerco at a point about 10 miles above its mouth and extending down the south and west side of this valley. This extension would have brought under cultivation about 10,000 acres of new land in the Rio Puerco valley and is considered to be entirely feasible. The necessity for economizing in the total cost of the project has caused this unit to be excluded from the Plan. However, the Belen High Line Canal has been designed with sufficient excess capacity to carry the water necessary for these Rio Puerco lands, if at some time in the future it should be deemed desirable to construct this part of the project.

Canal Capacities.

226. Records of water deliveries on the Rio Grande Project show an average of 2.57 acre feet per acre per annum delivered at the farms, with .44 acre feet per acre delivered in June, the month of maximum use. This figure has been somewhat increased in designing the canals for the District. Canal capacities have been computed on the basis of a delivery of 3 acre feet per acre per annum, with a maximum 30-day delivery of 20 per cent, or 0.6 acre feet per acre. Expressed in terms of second feet this becomes 0.01 second-foot capacity per acre of land to be irrigated, with an added capacity for seepage and regulation losses.

Seepage Losses.

227. Seepage losses have been computed from the Moritz formula $s=0.2\ C \frac{Q^{1/2}}{V^{1/2}}$ where:

s=loss in second feet per mile of canal.

Q=discharge of canal in second feet.
V=mean velocity of flow in feet per second.
C=depth in feet lost per day over wetted perimeter of canal.
C=1.5 for high line canals.
C=1.0 for valley canals.

Regulation Losses.

228. Regulation losses have been estimated at 10 to 20 per cent of the canal capacity, depending upon the canal discharge, and these amounts of additional capacity have been added to all canals between headworks and wasteway points.

Canal Velocities.

229. Canal sections and grades have been based upon Kutter's formula with special consideration of the relation of velocity to erosion and silting. The soil survey of 1912 shows that the soils of the valley vary from the Gila fine sandy loam, with a surface soil 24½ per cent clay and silt, to the Gila clay, with a surface soil 88½ per cent clay and silt. It is evident that, as a general rule, the canals of the District will be constructed in soils which contain a large percentage of clay and silt, and particularly will this be true for the low line valley canals.

230. The studies of Fortier and Scobey of "Permissible Canal Velocities" (Transactions American Society of Civil Engineers, 1926, Vol. 89) indicate that in soils containing considerable clay, with water carrying silt in suspension, rather high velocities may be safely used. In addition to the above considerations the Kennedy studies on erosion and silting of canals in India have been kept in mind and the Kennedy formula for non-silting, non-scouring velocity, viz., $V=0.84d^{0.64}$ has been used as a criterion of the relationship between velocity and depth to some extent. In general, the following values for "n" and "v" have been used in canal design:

Valley Canals

Capacity	"n"	"v"
40 s.f. or less	0.025	2.25 ft. per sec.
40—75	0.0225	2.50 ft. per sec.
75—300	0.020	3.00 ft. per sec.
300—1000	0.020	3.25—3.50 ft. per sec.

High Line Canals

Capacity	"n"	"v"
40 s.f. or less	0.025	2.0 ft. per sec.
40—75	0.0225	2.25 ft. per sec.
75—300	0.0225	2.6 ft. per sec.
300—1000	0.020	2.85—3.00 ft. per sec.

Side Slopes, Depths and Curvature.

231. In general, trapezoidal canal sections having side slopes of 1½ to 1 have been used. The minimum width of base is 6 feet. As a rule a suitable velocity was considered more important than the depth of channel. No depths greater than 8 feet have been used. No curves whose radius is less than ten times the width of base have been introduced. A freeboard of at least ¼ the depth has been provided. Crowns are flat and are 4 or more feet wide.

Scope of Irrigation System.

232. The attempt has been made to include in the Plan the construction of an irrigation system which will bring water to a point within at least half a mile of each farm or tract in the middle valley. Where the farms are under irrigation at the present time, the present farm distributaries will serve the land without the additional construction of small ditches. In the case of tracts which are not improved, the small ditches connecting such farms with canals and laterals constructed by the District must be built by the landowner.

Drops.

233. All drops have been designed as concrete-lined chutes with a drop or fall of 4 feet or less. The velocity generated by this fall is dissipated by the principle of the hydraulic jump which is created by the change of grade at the lower end of the chute. Typical drawings for drops of various sizes are included in the exhibits of Part V of the Plan.

River Siphons.

234. Certain areas can be reached only by carrying laterals across the river. Since the river banks are low at all such crossings, flumes cannot be used and it is necessary to carry the laterals under the river in inverted siphons. The Plan contemplates the construction of six reinforced concrete siphons as follows:

Cochiti	60-inch diameter 400 feet long
Sili	40-inch diameter 1200 feet long
Corrales	46-inch diameter 1200 feet long
Atrisco	72-inch diameter 1200 feet long
Casa Colorado	60-inch diameter 1200 feet long
*Val Verde	52-inch diameter 1500 feet long

235. Experience in the construction of similar siphons on the Rio Grande Project, near El Paso, has demonstrated the efficiency and

*Note: The Val Verde Siphon has been eliminated from Plan, see Section VI, Paragraphs 374, 375, and 376.

economy of a system of unwatering by means of well-points and pumps, so that the construction of the siphon barrel can be accomplished "in the dry". Concrete was chosen in preference to wood stave or steel pipe, because it is thought that the bands of the one and the steel shell of the other would soon rust under conditions to which these pipes would be subjected.

Arroyo Crossings.

236. Arroyo crossings will be of two general types determined by local topography; the first a reinforced concrete pipe siphon, the second a reinforced concrete culvert crossing on grade. In both cases the arroyo will be carried over the canal.

Railway Crossings.

237. Where canals cross railways, existing bridges will be used and, where new bridges are necessary, the A. T. & S. F. Ry. standard open deck creosoted pile trestles are contemplated.

Road Crossings.

238. Crossings of main roads and highways have been determined from property maps, and standard creosoted timber bridges have been indicated at all such points. Due to the very great number of small tracts, it has been impossible to forecast the exact number of farm bridges which will be needed and consequently such structures have been estimated on a mileage basis, one for each half mile of canal.

Drain Ditch Crossings and Under Drains.

239. Where drains cross canals or laterals, structures will consist in general of one or more lines of 36-inch to 48-inch diameter reinforced concrete pipe. A similar class of structure will be utilized for passing surface water under canals.

Farm and Lateral Turnout Gates.

240. Farm turnouts have been estimated on the basis of one turnout for each quarter mile of lateral, plus 15 per cent, and of one turnout for each half mile of main canal in places where irrigation takes place directly from the main canal.

241. Turnout gates from laterals will consist of metal gates, sliding in steel frames, discharging into metal pipes of 12, 15 or 18-inch diameter. Some 3000 such gates are contemplated, so that as far as possible a standard design is desirable. The drawings of the design proposed are E-29 and E-36 Exhibit P-3 of the Official Plan.

Kutter's "n" for Flood Channels.

242. Flood channel capacities have been computed from surveyed or projected river sections using water surface slopes obtained from surveys or from topographic maps. The factor "n" in Kutter's formula has been taken as,

(1) .025 for clear, low water channels with sand and silt bottom and no vegetation or trees,

(2) .030 for clear channels immediately adjacent to low water channels subject to frequent overflow and with little or no vegetation except a few weeds,

(3) .035 for overflow channels, subject to overflow at occasional intervals, with cleared bosque or brush; such channels to be cleared and kept cleared by the district.

Alternative Studies and Locations

General Statement.

243. The Plan is the outgrowth of a comprehensive study and comparison of various alternatives, and the elimination of those which proved to be impractical or excessively costly. Two types of comparative studies have been made; the first dealing with details such as the location of canals and drains and the choice of types of structures, and the second dealing with the broader aspect of choosing the most economical and efficient general plan for the development of the project as a whole.

244. The irrigation and drainage systems have not offered a wide range of comparative studies, because the configuration of the valley has, in a large measure, fixed the location of diversion dams and these have in turn controlled the position of both canals and drains. However, two possible sites were available for the diversion dam serving the Albuquerque Division, and a comparative study has indicated that the lower site situated at Angostura is more economical than the upper site near San Felipe Pueblo.

245. In designing drainage and irrigation layouts, costs were computed on an acreage basis for each natural unit of the project, and several of the less feasible smaller units were eliminated from the area proposed to be benefited. Also many alternative canal and drain locations were compared as to cost and efficiency in order to select the best. In considering the second phase of the alternative studies, that of choosing the best general method for developing the project as a whole, it has been necessary to take into account the economic situation of the District.

Cooperative Agencies

The United States Government.

246. In accordance with the provisions of an Act of Congress approved February 14, 1927, the United States Government appropriated $50,000 on behalf of the Indian lands included in the Conservancy District, toward the preliminary expense of the preparation of the District Plan of reclamation and flood protection. The Indian Department designated General H. F. Robinson of Albuquerque, Supervising Engineer of the United States Indian Irrigation Service, as the local representative of the Indian Department in matters pertaining to cooperation with the Conservancy District, and he has rendered the District valuable service in furnishing maps, plans and data on matters within his jurisdiction.

247. Mr. W. M. Reed, Chief Engineer of the United States Indian Service, has acted as one of the Board of Consulting Engineers which has reported favorably upon the proposed conservancy project.

Act of Congress Authorizing Contract with District.*

248. An Act of Congress approved March 13, 1928, provides an appropriation not to exceed $1,593,311, on behalf of Indian lands, which constitute about 18 per cent of the area of the District, for the construction of the proposed reclamation and flood control works. This act provides for an agreement between the Secretary of the Interior and the Conservancy District, covering the details of procedure in regard to determination of areas, designation of the Secretary's local representative, and in general specifies in some degree how the money shall be spent. The following is a copy of the Act:

"(Public-No. 169-70th Congress)

(S. 700) Approved March 13, 1928

An Act Authorizing the Secretary of the Interior to execute an agreement with the Middle Rio Grande Conservancy District providing for conservaiton, irrigation, drainage, and flood control for the Pueblo Indian lands in the Rio Grande Valley, New Mexico, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior is hereby authorized to enter into an agreement with the Middle Rio Grande Conservancy District, a political subdivision of the State of New Mexico, providing for conservation, irrigation, drainage, and flood control for the Pueblo Indian lands situated within the exterior boundaries of the said Middle Rio Grande Conservancy District, as pro-

* The Secretary of the Interior executed this contract on behalf of the United States on Dec. 14th, 1928.

vided for by plans prepared for this purpose in pursuance to an Act of February 14, 1927 (Forty-fourth Statutes at Large, page 1098). The construction cost of such conservation, irrigation, drainage, and flood-control work apportioned to the Indian lands shall not exceed $1,593,-311, and said sum, or so much thereof as may be required to pay the Indians' share of the cost of the work herein provided for, shall be payable in not less than five installments without interest, which installments shall be paid annually as work progresses: Provided, That should at any time it appear to the said Secretary that construction work is not being carried out in accordance with plans approved by him, he shall withhold payment of any sums that may under the agreement be due the conservancy district until such work shall have been done in accordance with the said plans: Provided further, That in determining the share of the cost of the works to be apportioned to the Indian lands there shall be taken into consideration only the Indian acreage benefited which shall be definitely determined by said Secretary and such acreage shall include only lands feasibly susceptible of economic irrigation and cultivation, and materially benefited by this work, and in no event shall the average per acre cost for the area of Indian lands benefited exceed $67.50: Provided further, That all present water rights now appurtenant to the approximately eight thousand three hundred and forty-six acres of irrigated Pueblo lands owned individually or as pueblos under the proposed plans of the district, and all water for the domestic purposes of the Indians and for their stock shall be prior and paramount to any rights of the district or of any property holder therein, which priority so defined shall be recognized and protected in the agreement between the Secretary of the Interior and the said Middle Rio Grande Conservancy District, and the water rights for the newly reclaimed lands shall be recognized as equal to those of like district lands and be protected from discrimination in the division and use of water, and such water rights, old as well as new, shall not be subject to loss by nonuse or abandonment thereof so long as title to said lands shall remain in the Indians individually or as pueblos or in the United States, and such irrigated area of approximately 8,346 acres shall not be subject by the district or otherwise to any pro rata share of the cost of future operation and maintenance or betterment work performed by the district. The share of the cost paid the district on behalf of the Indian lands under the agreement herein authorized, including any sum paid to the district from the funds authorized to be appropriated by the Act of February 14, 1927 (Forty-fourth Statutes at Large, page 1098), shall be reimbursed to the United States under such rules and regulations as may be prescribed by the Secretary of the Interior: Provided, That such reimbursement shall be made only from the proceeds of leases of the newly reclaimed pueblo lands whether leased by Indians or others, Indians, however, to be given the preference in the making of such leases, and the proceeds of such leases to be applied, first, to the reim-

bursement of the cost of the works apportioned to said irrigated area of approximately 8,346 acres: Provided further, That as to not to exceed 4,000 acres of such newly reclaimed lands if cultivated by Indians no rentals shall be charged the Indians: Provided further, That there is hereby created against the newly reclaimed lands a first lien for the amount of the cost of the works apportioned to such newly reclaimed lands which lien shall not be enforced during the period that the title to such lands remains in the pueblo or individual Indian ownership: Provided further, That said Secretary of the Interior, through the Commissioner of Indian Affairs, or his duly authorized agent, shall be recognized by said district in all matters pertaining to its operation in the same ratio that the Indian lands bear to the total area of lands within the district, and that the district books and records shall be available at all times for inspection by said representative."

Agreement with the U. S. Bureau of Reclamation.

249. An agreement was entered into between the United States Bureau of Reclamation and the District in the Spring of 1926, which provided for an investigation and report by the Reclamation Bureau on the following points:

(a) Stream gaging.
(b) Evaporation and transpiration losses.
(c) Measurement of ground water levels.
(d) Consumptive use of water.
(e) Determination of water storage requirements of the District.
(f) Silt Measurements.

250. By the terms of this agreement the investigations were carried on and the report was made by the engineers of the United States Bureau of Reclamation, the District paying half of the cost. This report, entitled "Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico", by E. B. Debler, Hydrographic Engineer and C. C. Elder, Assistant Engineer, United States Bureau of Reclamation, is included in the Official Plan as Exhibit R-4.

State of New Mexico.

251. By an Act of the state legislature approved March 15, 1927, a fund was created for the purpose of investigating reservoir sites in the State of New Mexico, and $7,625.00 of this fund was spent in cooperation with the District in drilling and exploring foundations at several reservoir sites investigated by the District, notably at El Vado and at San Felipe.

The Counties Within the District.

252. The Counties of Sandoval, Bernalillo, Valencia and Socorro have purchased property maps from the District for all District lands lying within their boundaries.

PART I

THE PLAN

SECTION V

STATEMENT OF THE PLAN

SECTION V

STATEMENT OF THE PLAN

General Features

Plan Includes Flood Control, Drainage and Irrigation.

253. The lands and property to be improved by the proposed works of the District are located in the middle Rio Grande valley, between the Indian village of Cochiti on the north and the town of San Marcial on the south. The Plan proposes the construction of flood control and river improvement works, a comprehensive and modern system of irrigation, a drainage system, and a reservoir for the partial stabilization of the discharge of the Rio Grande.

Existing Ditches to be Used Where Feasible.

254. These works will be built with as little disturbance as possible to the service of the present irrigation ditches. The existing ditches will be utilized in the Plan wherever feasible. In some cases these smaller ditches will be adapted to the new Plan without material change, except to supply the necessary headgates to feed water from new main canals to the existing ditches. In other cases the old ditches will be enlarged and supplied with modern structures. New main canals will be provided for each area proposed to be improved, and these will be regulated by modern diversion dams and headworks.

Water to be Carried Within Half a Mile of Every Farm.

255. It is not proposed to construct farm laterals or small distributaries, but the District works will generally carry the irrigation water to within half a mile of each farm.

River Improvement.

256. The river improvements will consist in the main of levees on each side of the river, a system of permeable jetties designed to straighten and narrow the low flow channel, and the clearing and protection work necessary to make the channel efficient and safe for flood discharges.

Degree of Flood Protection.

257. The degree of flood protection provided under the Plan will afford reasonable protection and security based on the present knowledge of the past history of the river. It will permit growth and

promote substantial increases in value of all the property under the District. A system of detention reservoirs combined with certain channel improvements would have been somewhat more desirable than the recommended Plan. The cost of such a system is believed to be impracticable under present conditions. It may be considered as the ultimate protection desired after values have increased sufficiently to warrant and make possible such further improvements. At that future time, with the channel improvements completed as contemplated by the Plan, and values greatly increased, the building of one or more reservoirs on the Rio Grande above Albuquerque will be a relatively easy accomplishment. Moreover, experience may demonstrate that the river work proposed under the Plan is more effective than can be definitely predicted at this time. The important fact is that the work now proposed will fit in, without alteration or waste, with any additional protection which may be deemed desirable in the future.

Type of Drainage.

258. Drainage will be accomplished by a system of deep open drains similar to the Isleta Drainage Ditch.

Portions of Valley Not Included.

259. Certain small isolated portions of the valley are not included in the area covered by the proposed improvements because of the excessive cost of irrigation and the impossibility of securing adequate drainage without pumping. These areas are Bolenguin, Pueblito and San Pedro in the Socorro Division, San Geronimo in the Belen Division and Los Montoyos in the Albuquerque Division. (See Section VI, paragraphs 372 to 377 for other areas eliminated under Plan approved by Court.)

Cost Estimates.

260. The proposed Plan is believed to be the best and cheapest method of providing the necessary improvements described herein. The cost estimates have been prepared with knowledge of the cost of similar improvements constructed at El Paso and elsewhere. These are believed to be ample, provided reasonable care and economy are exercised in supervising construction. The total estimated cost of the Plan as approved is $10,337,000.

Adaptation of Details of Plan to Conditions.

261. Conditions relating to the project were closely studied in outlining the Plan. Information relating to the physical features was sufficiently accurate to permit plans and estimates to be made. In carry-

ing out the Plan, it will be desirable to adapt the details of the work to each condition as further disclosed in order to obtain the most advantageous combination of cost and results. Such adaptation will entail minor increases and decreases in quantities and modifications in the details of the designs and the position of structures. The Plan does not attempt to forecast and define conditions beyond reasonable limits, and such adjustments to actual detail conditions are understood to be within the limits of the Official Plan and are not to be construed as changes in or additions to the Official Plan. The same is true concerning variations made necessary in order to avoid unnecessary interference with existing works and structures, and concerning other conditions which become apparent on the various parts of the work as construction or preparation for construction progresses. The Official Plan also provides, subject to approval by the Board of Commissioners, for major changes in the size and type of individual structures when such change is plainly advantageous; does not reduce the efficacy of the project as a whole or to individual beneficiaries; does not cause increased damages for which compensation is not provided; and does not add to the project more than 10 per cent of the original estimated cost of the affected structural unit.

Coordination of Features.

262. While the proposed work is referred to frequently as consisting of various features or parts, it should be understood that these parts are coordinated and that each feature of the Plan depends upon other parts for its proper functioning as a whole. The coordinated Plan is comprised of these separate parts, each fulfilling an important function itself, but acting also to supplement other features to the end that the entire Plan will produce the fullest measure of benefit.

263. Dut to this interlocking of functions of the various parts of the Plan, it will be impracticable to separate the various features of the Plan either in the practical accomplishment of the work or as to the benefits to be derived from the work.

264. The El Vado Reservoir is primarily for irrigation purposes, but it will also be helpful in the flood control problem. The riverside drains will supply the major portion of the material for the construction of levees without materially adding to the cost of these drains. Likewise it may be pointed out that the spoil banks of the interior drains will provide levees which may be useful, in the case of major floods, for secondary defense purposes. Also that the drainage of the land will afford an immense "soil reservoir" which may be filled during floods, by seepage of hill or river water, before damage is wrought at the surface.

265. The estimated cost of the Plan is predicated upon the construction of all the features comprising it, and not upon the construction of any one of these features taken separately. If any single feature of the Plan were to be constructed by itself, the cost of this part would necessarily be higher than has been estimated herein. The order of accomplishment will be undertaken with due regard for the most pressing need of immediate benefit and to the most efficient method of completing the Plan as a whole. The following description of the features and parts of the Plan should be considered in the light of this paragraph. The classification of the work by features, as followed hereinafter, is an arbitrary division of the work contemplated, made for the purpose of clarifying the description.

Water Development an Essential Feature of the Plan.

266. The execution of the Plan will cause the development of large quantities of water now lost by evaporation to all beneficial use. One of the express purposes of the drainage system is to reclaim water and make it available to the lands of the District. Exhibit R-4, "Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico", sets forth the estimated amount of water which will be thus reclaimed. Title to all water so reclaimed or saved by the works of the District is hereby asserted for the irrigable lands within the District.

Classification of Improvements.

267. The improvements proposed by the Plan may be segregated according to the seven main features listed below, each of which is described in succeeding paragraphs.

(1) Storage Reservoir.
(2) Flood Control and River Improvements.
(3) Silt Control on Tributaries.
(4) The Drainage System.
(5) The Irrigation System.
(6) Diversion Dams.
(7) Improvements at San Marcial.*

Storage Reservoir

Location.

268. The storage of water for irrigation purposes and partial regulation of the flow of the Rio Grande through the District will be accomplished by the construction of a reservoir on the Rio Chama at El Vado, 16 miles southwest of Tierra Amarilla, Rio Arriba County, New

* Eliminated; see Section VI, paragraphs 380, 381 and 382.

Mexico, and about 75 miles above the confluence of the Rio Chama and Rio Grande. The reservoir is about 175 miles northeasterly from Albuquerque.

Dimensions of Dam.

269. The proposed dam is located in a narrow gorge cut through the sandstone and shale formation. It will have a height of 175 feet above bed rock and will be built of gravel and loose rock, both of which are found near the site. The dam will have a total length of 1,300 feet at the crown line and a bottom length of about 140 feet. The steep slope of the easterly abutment breaks at a height of 100 feet above the river and extends out in a flat slope, thus accounting for the length of crown. The westerly abutment is continuously steep. The crown width will be 20 feet, and the maximum bottom width of the base will be 600 feet. The upper face will have a slope of 1¾ to 1 and the lower face 1½ to 1. A concrete parapet wall will be provided at the crown.

East Abutment.

270. An important feature of the site is the broken condition of rock in the east abutment. This is fully described in Exhibit R-2 "The Geology of the El Vado Damsite and Reservoir, Rio Arriba County, New Mexico" by E. H. Wells. The construction of the dam provides for a reinforced concrete cut-off wall extending through the broken rock into solid sandstone.

Slope Paving and Cutoff Wall.

271. The upstream slope of the dam will be provided with a reinforced concrete face increasing in thickness from 8 inches at the top to 13 inches at the bottom. At the base of the dam the concrete face will join a heavily reinforced cut-off wall extending vertically into the bed rock. Below the cut-off wall it is proposed to pressure grout the rock through drill holes provided for this purpose.

Outlet Works.

272. The outlet works will consist of two 60-inch steel pipes, extending through the dam in two conduits of reinforced concrete, and controlled by needle valves at the lower end. The combined capacity of the two operating valves at full head is 2,300 second feet. Emergency valves of the "butterfly" type are located at the inlet end of the conduits and provided with manual and remote electrical control. A small electric generator will be provided and operated from the outlet conduits to furnish current for lighting the dam and operators' quarters and for operating the emergency valves.

Area and Capacity.

273. The reservoir will have a capacity of 198,000 acre feet at the elevation of the top edge of the spillway gates, which is 9 feet below the top of the dam or 13 feet below top of parapet wall. At this elevation the water surface of the reservoir will have an area of about 3,600 acres. Only about 250 acres of improved land will be inundated at high water.

Operating Spillway.

274. The drainage area of the Rio Chama above El Vado reservoir is approximately 650 square miles. Two spillways will be provided having a combined capacity of approximately 58,000 second feet. The operating spillway, with a capacity of 6,000 second feet, is located at the westerly end of the dam. It is controlled by radial gates which discharge into a concrete chute. The chute is supported by the solid sandstone and shale of the west abutment of the dam, and it will discharge the overflow into the river at a safe distance below the dam.

Emergency Spillway.

275. An emergency spillway, with a capacity of about 52,000 second feet, is located in a saddle about one mile westerly from the dam. Water will be discharged at this point only at very infrequent intervals after the capacity of the operating spillway is exceeded. The discharged water will flow back to the Rio Chama through an arroyo which enters the river over a mile below the dam. This spillway consists of a concrete weir 700 feet in length. Below the weir three cross walls will be built across the arroyo with proper spacing to prevent scour and undermining of the weir.

Flood Control and River Improvements

Capacity of Flood Channels.

276. It is proposed to construct levees on each side of the Rio Grande of sufficient height and at a proper distance apart to permit the safe passage of 40,000 cubic feet per second measured at the upper end of the levees above Albuquerque, and increasing to 50,000 cubic feet per second measured at San Marcial. The Plan provides for extra height of levees to give increased security against flooding at Albuquerque and lands in its immediate vicinity, with the expectation that this highly valuable area may be safe aganst floods of 75,000 cubic feet per second.

Low Flow Channels.

277. A system of permeable jetties will be provided within the levee lines. These will be arranged in such manner as to afford the

maximum protection to the levees and at the same time define a narrow, low flow channel which is expected to scour its bottom, due to increased velocity of flow, sufficiently to overcome the present tendency of the river to raise its bed.

Area Between Levees to be Acquired by District.

278. The land within the levee lines including the river bed is to be acquired by the District. This area will be cleared where necessary to remove obstructions to the free flow of water. Some channel excavation will be accomplished in order to straighten the low flow channel at bad bends; however, a general program of river dredging is not contemplated.

Levees.

279. The general height of levees will be 8 to 9 feet above normal ground surface through the agricultural area. From the bend north of Alameda to a point below Albuquerque, the east side levee will have a height of 10 feet. At the critical points this stretch of levee will be reinforced and provided with special protection against erosion and breaching. At San Marcial the river levees will have a height ranging from 10 feet to a maximum of 14 feet. Proper clearing, roughening or scarifying of the ground under all levees is contemplated.

280. All river levees will have crowns of 8 feet and 10 feet respectively, varying with the height. Their slopes will be 1½ to 1 on the land side, and 2½ to 1 on the river side. They will be spaced a minimum distance of 1,200 feet apart at the northerly end of the project, increasing gradually in a downstream direction to approximately 1,500 feet at Albuquerque and 2,000 feet at points below the Rio Puerco.

Jetties.

281. The proposed jetties will be of the "permeable" type, constructed of materials which will cause a slowing down of the velocity of flow and thus cause a gradual deposition of silt. The top of the jetties will be generally 6 feet or more below the crown of the levees, permitting flow over the top in cases of major floods.

282. In general, it is proposed to construct the jetties of galvanized woven wire fencing held in place by steel piling or by other devices which may prove more effective for the purpose. The approximate location of the jetties is shown on maps A-7, A-8, A-9 and A-10 Exhibit M-1, and types of construction are shown on Drawing K-44.

Levee Protection.

283. The protection of the levees against erosion will be accomplished gradually as and where the need becomes apparent, and in accordance with experience to be gained during construction. A portion of the protection work will consist of the planting of grasses, shrubs and trees on the river side slopes of the levees, and immediately in front thereof. Bends and curves subject to erosion during floods will be protected by jetties or other suitable protective work. No trees shall be left standing within thirty feet of levees.

Silt Control on Tributaries

General Statement.

284. The Rio Grande carries a high proportion of silt and the proportion increases markedly below the mouth of the Rio Puerco. The deposition of silt in the channel at San Marcial has been especially injurious. The Plan provides for combating this silt deposition in the Rio Grande by the river improvement works previously described. The effect of the river improvement work in this direction will be rendered more certain by combating the excessive erosion on the Rio Puerco watershed, thus preventing the delivery of a large portion of the silt to the Rio Grande. The effectiveness of silt retention and erosion prevention works on the Rio Puerco seems more certain when it is understood that this stream is believed to be responsible for over 40 per cent of the total silt now entering the Elephant Butte Reservoir, although its watershed comprises but about 20 per cent of the total Rio Grande watershed.

Silt Retarding Works.*

285. The Plan proposes the construction of silt retardation works on the Rio Puerco and its tributaries, as described in more detail in Exhibit R-1, "Erosion and Control of Silt on the Rio Puerco, N. M.", by Kirk Bryan and Geo. M. Post. The general method consists of small check dams built across the arroyos and small washes, and the planting and care of grasses, shrubs and trees to prevent side erosion.

286. It is expected that silt will be deposited back of the checks extending upstream for a considerable distance. In the larger arroyos it is planned to add a second series of checks, after the first series is filled with silt, thus accomplishing the required filling in two lifts. It is not planned to entirely fill the existing channels of large arroyos in this manner, but only the depth in excess of that required for the largest floods. Drawing B-21 shows a typical installation of one of the larger checks.

* This program has been modified, see Section VI.

The tentative locations are shown on sheets 1, 2, 3 and 4 of B-10. In the smaller arroyos only one series of checks will be installed. In many cases these may be constructed entirely of brush and rock found near the site.

Drainage

General Features.

287. The proposed drains are of two general types, riverside drains which will closely parallel the river and provide the outlets for interior drains, and interior drains branching from the riverside drains and following generally the lower portions of the valley. Drains will all be of the open type similar to the Isleta Pueblo drains, and to those constructed on the Rio Grande Project near El Paso, Texas, by the United States Bureau of Reclamation.

288. The drains will require many structures in passing highways, irrigation canals, and railroads. These are planned to be constructed of permanent materials, wherever practicable, and in accordance with approved modern design practice.

289. The drainage system is not designed to control floods from the side arroyos. Such floods will occur in the future as in the past whenever a torrential rainfall occurs on the steep slopes of the valley. Due care will be taken to protect the drains against damage from such floods, and whenever it is possible to do so, the arroyo waters will be afforded an entrance into the drains through restricted openings which will pass off the water in such a gradual manner as not to damage or overflow the drains.

290. In general, the drainage system is designed to provide a normal water table under all the irrigated land varying from a minimum of 4 feet under lands distant from drains to about 6 feet below the lands adjacent to the drains. Construction of drains will proceed in all cases from the outlet toward the upper end in such a manner as to provide drainage when the lower portion of each drain is completed. Drains will be built with draglines or similar excavating machinery.

Riverside Drains.

291. The material excavated from riverside drains will be deposited toward the river and utilized in the construction of the levee system. These drains will have a depth of 6 to 8 feet below the normal ground surface, except at points near the outlets where the grades will be flattened to meet the elevation of the river bed. They will have widths at the bottom varying from a minimum of 10 feet to a maximum of about 20 feet, governed by the quantity of water to be discharged. The side slopes are planned 1½ to 1 in all cases but, because of the

unstable and saturated condition of the materials forming the banks, this slope will not be attainable in many places.

Structures on Riverside Drains.

292. The land on the river side of the riverside drains is to be acquired by the District and dedicated to use as a part of the river channel. Due to this condition the only permanent structures required on such drains will be highway bridges at approaches to bridges over the Rio Grande. Such bridges will be constructed in accordance with Drawing No. E-26, Exhibit P-3, except where the drain can be carried under the road in one or more lines of concrete pipe.

Interior Drains.

293. The interior drains will discharge through the riverside drains into the Rio Grande at selected outlets. They will have depths of about 10 feet below normal ground surface, except at points near outlets in riverside drains where the grades will be flattened to meet that of the shallower drains. They will have widths at the bottom of from 8 to 14 feet, depending upon the quantity of water to be carried. The side slopes are estimated at 1½ to 1 in all cases but, due to the unstable condition of the material forming the banks, this slope will not be attainable in all places.

294. Interior drains will be located as shown in Exhibit M-1, in accordance with the water table and soil conditions which have been studied for this especial purpose. In general, the drains will be so spaced that the greatest distance from any point to a drain will be approximately half a mile.

Structures on Interior Drains.

295. A great many structures will be required on the system of interior drains for purposes of passing roads, irrigation ditches, and railroads over the drains, and for taking surface water into the drains. Drawings showing the general type of structures proposed to be built have been prepared and are included in Exhibit P-3 of the Plan.

296. Bridges are planned over the drains at all existing State, County and privately owned roads. In addition to the bridges required at such points, other private bridges are included in the Plan to serve farms which may be cut by the drains.

297. Substantial metal flumes will be provided across the drains, wherever necessary, in order to preserve the established irrigation layouts on farms cut by drains. In so far as possible, however, the drains will be located in the swales and water will be made available on each side of the drains, so that an excessive number of flumes will not be required.

298. A permanent class of structures will be provided at all places where drains cut the main canals or main laterals. Such structures will generally be of the culvert type and be constructed of concrete.

Surface Water.

299. The waters entering the valley from side arroyos and washes will be permitted to enter the drains through pipe structures designated as "Drainage Inlets," which will pass under the spoil banks and enter the drains near the bottom. Exceptions to this rule exist in the case of arroyos which discharge very large quantities of water. In such cases the river levees may be turned and extended a short distance along the sides of the arroyo in order to confine the floods and guide the water direct to the river. This may necessitate passage of the riverside drain underneath the arroyo in a closed culvert or siphon.

300. In general, the surface water condition will be greatly improved, due to the construction of drains, because drainage will provide a "soil reservoir" which may be temporarily filled from the arroyo floods without damage at the surface. Also, the smaller surface discharges may be taken directly into drains.

Areas Having Partial Drainage.

301. At the outlets of the riverside drains certain areas will have only partial drainage due to the flattening of grade in the drains to meet the river bottom. The drains have been located to restrict such areas to the smallest acreage possible.

302. An estimate has been made of the size of the various tracts which will have incomplete drainage under the Plan. Each tract has been divided into two classes to represent the degree of drainage to be provided, and the results are shown in the following tabulation:

Table 17

Summary of Partially Drained Areas

Division	Riverside Drain	Area in Acres Water Depth 0′ to 2′	Area in Acres Water Depth 2′ to 4′
Albuquerque	Corrales	113	106
Albuquerque	Albuquerque	90	100
Belen	Peralta	22	76
Belen	Sabinal	35	29
Belen	San Francisco	0	14
Socorro	Limitar	228	186
Socorro	Socorro	76	202
Total		564	713
Combined Total		1,277 Acres	

Irrigation System

General Features.

303. The Plan provides for a comprehensive system of main canals and laterals, together with modern structures for the regulation and use of the water. These works are located in four divisions from north to south as follows:

(1)	Cochiti Division	Irrigable Area	12,674 acres
(2)	Albuquerque Division	Irrigable Area	34,575 acres
(3)	Belen Division	Irrigable Area	35,227 acres
(4)	Socorro Division	Irrigable Area	26,311 acres
	Total Estimated Irrigable Area (Original Plan)		128,787 acres

On the basis of deductions due to the modifications of the Plan as approved, and by final check of appraisal data, the irrigable area is as follows:

Cochiti Division	13,000 acres
Albuquerque Division	37,205 acres
Belen Division	57,399 acres
Socorro Division	15,663 acres
Total Irrigable Area Official Plan	123,267 acres

304. It is not proposed to construct farm laterals or the smaller distributaries. However, the District canals are arranged to carry water generally to within a distance of about half a mile from the most remote farm, and connections will be made from the new canals to existing ditches.

305. In many cases it is proposed to take over existing canals and incorporate them as part of the new system. Such canals will be enlarged, if necessary, and suitable structures will be installed so that adequate water service can be maintained for all the lands served.

306. Each of the four divisions will be served by a diversion dam in the Rio Grande and suitable headgates for regulating the water supply.

Description of Main Canals.

307. The locations of the main canals to be constructed under the Plan are shown in Exhibits M-1 and M-2. With the exception of the San Juan canal, they will head at the diversion dams and will extend the entire length of the division or district to be irrigated, decreasing in size as the various laterals and farm turnouts are supplied. Modern irrigation structures will be provided on each canal to facilitate and make safe their operation and use. The main canals are all planned to be constructed by draglines or similar excavating equipment.

Length, Capacity and Earthwork of Main Canals.

308. The main canals, together with their length, capacity, and required earthwork, are shown in the following tabulation:

Table 18

Proposed Main Canals

Name of Canal	Length in Miles	Earthwork Cu. Yds.	Capacity Sec. Ft.
Cochiti	24.8	391,400	200
Albuquerque	34.3	864,131	550
Belen High Line	32.2	1,834,000	1000
Peralta	15 7	200,000	300
San Juan	17.7	259,000	170
*Socorro	43.9	926,078	680
Totals	168.6	4,474,609	

Cochiti Main Canal.

309. The Cochiti Main Canal will supply water to the Cochiti Division. It diverts from the Rio Grande at the westerly end of the Cochiti Diversion Dam and follows the river to a point below the Cochiti Bridge, where it passes under the river in an inverted siphon of reinforced concrete. From the easterly or downstream end of the siphon the canal follows the foothills in a southerly direction, passing the village of Pena Blanca and the Indian Pueblos of Santo Domingo and San Felipe. Below the "narrows" at San Felipe this canal commands a strip of excellent bench land in the vicinity of Algodones and ends near the village of Angostura. The canal is planned with a maximum section as follows: Base 10 feet, Water Depth 4.2 feet, Slopes 1½ to 1, Crown 12 feet.

Structures on Cochiti Canal.

310. The important structures on the Cochiti Canal are the siphons and culverts under the many large arroyos and the Rio Grande. Eleven structures of this type are required. These will all be constructed of reinforced concrete in general accordance with drawing numbers E-40 and E-43, Exhibit P-3.

311. The minor structures required, consisting of bridges, farm turnouts, lateral headgates etc. will be provided and installed in accordance with the standard plans shown in Exhibit P-3.

Albuquerque Main Canal.

312. The main canal of the Albuquerque Division heads at

*Revised length 28.0 miles; Earthwork 628,500 c.y.; Capacity 276 Sec. ft. (See Section VI paragraphs 369 to 375 inclusive.)

the easterly end of the Angostura Diversion Dam about 24 miles north of Albuquerque. The canal has a maximum section as follows: Base 20 feet, water depth 5.8 feet, Slopes 1½ to 1, Crown 12 feet. The location of the canal is in the valley floor, approximately midway between the river and the edge of the valley. West of Albuquerque the canal passes under the Rio Grande in an inverted siphon of reinforced concrete and continues through the Atrisco and Pajarito Districts, terminating on the Isleta Pueblo lands.

Structures on Albuquerque Main Canal.

313. The Albuquerque Main Canal requires drops at approximately mile intervals to maintain safe velocities of flow. Such structures will be built of reinforced concrete in accordance with drawings E-30, E-31, E-32, E-33 and E-34, Exhibit P-3.

314. The general plan of the Atrisco Siphon under the Rio Grande is shown on drawing E-43, Exhibit P-3. The inside diameter of the siphon will be 72 inches and its length 1,200 feet.

315. Minor structures consisting of bridges, farm turnouts, lateral headgates etc. will be built wherever necessary for the proper operation and use of the canal and in accordance with the plans shown in Exhibit P-3.

Belen High Line Canal.

316. The Belen High Line is the main canal for the lands on the west side of the Rio Grande and the San Juan area on the east side, in the Belen Division. The canal heads at the westerly end of the Isleta Diversion Dam and continues in a southerly direction on a very light grade, passing Los Lunas, Belen, Jarales, Sabinal, and ends at a point near Mile Post 943 on the A. T. & S. F. Ry. In this location the canal cuts no improved property and may be constructed without interference with existing canals and without crossing proposed drains.

317. The maximum section of this canal is as follows: Base 30 feet, Water Depth 8.0 feet, Side Slopes 1½ to 1, Crown 18 feet. With a maximum capacity of 1000 cubic feet per second, the Belen High Line will be the largest canal on the project. It will have sufficient capacity as designed to irrigate all the lands included in the proposed Plan and, in addition thereto, to carry a supply for approximately 10,000 acres of excellent land which may be irrigated in the Rio Puerco valley by a future extension of the canal. It is not proposed to construct such an extension at this time, but canal capacity will be available if required in the future.

Structures on Belen High Line Canal.

318. Due to its location along the side of the valley the Belen High Line Canal will require no drop structures and very few other structures of major importance. A wasteway and sand trap is provided about 3½ miles below the Isleta Diversion Dam. Numerous culverts will be required to pass surface drainage under the canal. These are shown on drawing E-39, Exhibit P-3. Minor structures of the usual types including farm turnouts, bridges and lateral headgates will be installed as required for proper use and operation of the canal. These structures are shown in Exhibit P-3.

Peralta Main Canal.

319. The main canal for the Peralta District in the Belen Division heads at the easterly end of the Isleta Diversion Dam and follows through the approximate center of this unit passing the villages of Peralta, Valencia and Tome and terminates below Cerro Tome. The canal has a maximum section as follows: Base 12 feet, Water Depth 4.8 feet, Slopes 1½ to 1, Crown 14 feet.

Structures on Peralta Main Canal.

320. No major structures are required on the main canal of the Peralta District. Drops will be necessary at approximately one-mile intervals to compensate for differences in grade between the canal and the supporting ground. These will be installed in accordance with drawings E-33, E-34 and E-35, Exhibit P-3.

321. Minor structures consisting of farm turnouts, lateral headgates, bridges, etc. will be built as required for the proper operation and use of the canal. Drawings of these structures are shown in Exhibit P-3.

San Juan Main Canal.

322. The main canal for the Casa Colorado and San Juan Districts in the Belen Division will divert from the Belen High Line Canal at Mile 22.2, approximately 2½ miles below Belen. The canal will cross the Belen District lands in a southeasterly direction serving this area en route, and passing under the Rio Grande in an inverted siphon of reinforced concrete above the village of Casa Colorado. From the easterly or downstream end of the river siphon the canal will continue down the valley, passing the villages of Casa Colorado, San Juan and Las Nutrias, terminating 3 miles below Las Nutrias.

Structures on San Juan Canal.

323. The San Juan Canal will require several relatively impor-

tant structures. The first of these is a series of concrete drops, at a point near its heading, which are required to drop the canal from the elevation of the Belen High Line Canal to the level of the valley. At mile 1.7 it is proposed to provide a wasteway to the Rio Grande which will serve the San Juan Canal and also assist in the operation of the Belen High Line Canal. The Jarales Siphon under the Rio Grande, located at Mile 4.2, will be similar to the other river siphons but will have an inside diameter of 48 inches and a length of 1,200 feet.

324. The minor structures will consist of farm turnouts, lateral headgates, bridges and drainage culverts which will be installed where required, in accordance with standard plans as shown in Exhibit P-3.

Socorro Main Canal.

325. The main canal of the Socorro Division is planned to divert from the westerly end of the San Acacia Diversion Dam. This canal will command the entire irrigable area of the Socorro Division. It will have a maximum section as follows: Base 16 feet, Water Depth 6.5 feet, Slopes 1½ to 1, Crown 16 feet. The canal is located as a valley canal, approximately in the center of the irrigable area, with laterals diverting at required intervals to irrigate the sloping sides of the valley. The canal passes under the Rio Grande on the Elmendorf Tract in an inverted siphon and continues on the easterly side of the river through the Val Verde District. It ends opposite the town of San Marcial.*

Structures on Socorro Main Canal.

326. Due to the location as a valley canal, the main canal of the Socorro Division will require numerous drops, located at approximately one-mile intervals. Three important culverts are planned to pass the canal under the larger arroyos. These are located as follows: The San Lorenzo about a mile north of the village of Chamisal, an unnamed arroyo at Mile Post 973 on the A. T. & S. F. Ry., and another about half a mile north of the village of San Antonio. At mile 10 the canal will be lined with concrete for a length of 1,900 feet, where it passes between the hill and the A. T. & S. F. Ry.

327. The Val Verde Siphon, at mile 33, is planned to be built in accordance with the standard design drawing E-43, with an inside diameter of 52 inches, and a length of 1,500 feet. (Eliminated in plan. See Section VI Paragraphs 374 and 384.)

328. The minor structures will consist of bridges, farm turnouts, lateral headgates and drainage culverts, as may be required for

*Due to modification of Plan this canal will end at the North line of the Bosque del Apache grant. See Section VI.

safe and efficient use and operation of the canal. Designs of these structures are shown in Exhibit P-3.

Laterals.

329. The location of the laterals to be constructed under the Plan is shown in Exhibits M-1 and M-2. The laterals are the branches of the main canals and larger laterals. They will head in the main canals or in other laterals and will be controlled by suitable headgates. Many of the laterals shown as part of the Plan utilize the site of existing ditches. In such cases the old ditch is to be rebuilt, if this is necessary to secure the required capacity, and provided with suitable structures of modern design. Whenever necessary to prevent interference with the usual operations of the old ditches, their reconstruction will be accomplished during the non-irrigation season.

330. The construction of the larger laterals will be accomplished by machine excavators, while the smaller laterals may be built by teams and scrapers, as governed by conditions.

Length and Earthwork of Laterals.

331. The following list of laterals shown in Table 19, to be built as located in the various divisions of the project, shows the lengths and earthwork required for their construction.

Table 19

Laterals by Divisions

Division	Length Miles	Earthwork Cubic Yards
Cochiti Laterals	38.7	186,805
Albuquerque Laterals	114.3	873,560
Belen Laterals	147.5	926,078
*Socorro Laterals	77.7	311,909
Totals	378.2	2,298,352

Structures on Laterals.

332. Laterals will require structures of the same general type as the main canals, but of smaller size and less cost. The minor structures are therefore numerous, and very few structures of major importance will be required.

333. Only three major structures are planned on laterals. Two of these are siphons under the Rio Grande, and the third is a long flume on the Arenal Lateral. The Sili Siphon is located at mile 0.6 on the

*Revised: Length 55.8 miles; Earthwork 226,712 c. y. (See Section VI, paragraph 385.)

Sili Lateral in the Cochiti Division, and it will have an inside diameter of 40 inches, and a total length of 1,200 feet. The Corrales Siphon is located at Mile 1.7 on the Corrales Lateral, and it will have an inside diameter of 54 inches, and a total length of 1,200 feet. Both of these structures will be built in accordance with the standard plans included in Exhibit P-3.

334. The flume on the Arenal Lateral will have a length of 3,500 feet and a capacity of 36 cubic feet per second. It will be installed in accordance with drawing E-25, Exhibit P-3.

335. The minor structures consist of farm turnouts, bridges, drainage culverts and flumes. These will be constructed wherever required for the safe and efficient operation and use of the laterals, and in accordance with standard plans shown in Exhibit P-3.

Special Features on Lateral System.

336. The laterals have been described as heading in the main canals or larger laterals. There are two exceptions to this in the Plan. In the Cochiti Division a small lateral diverts from the Rio Grande directly below the San Felipe Pueblo, on the west side of the river. This lateral is to be reconstructed and enlarged to divert and transport water for the irrigation of approximately 300 acres which comprises all the irrigable land in this unit. A concrete headgate will be provided at the intake to regulate the flow of the canal.

337. In the Albuquerque Division the irrigation of the Barr District south of Albuquerque is planned to be served from a lateral diverting from the Albuquerque Riverside Drain. The water delivered to the Barr District lands in this manner will be discharged from the main canal in proper quantities to dilute the excess alkalinity of the drainage water.

338. In the City of Albuquerque it is proposed to purchase the water rights from the Barelas Ditch for all lands south of Marquette Avenue. The purpose of this is to permit abandoning the present ditch through the city.

Diversion Dams

General Features.

339. Four diversion dams on the Rio Grande are included in the Plan, located and named as follows: Cochiti, at the mouth of White Rock Canyon near Cochiti Pueblo; Angostura, about 24 miles north of Albuquerque near the village of Angostura; Isleta, at Isleta Pueblo, 12 miles south of Albuquerque; San Acacia, about 16 miles north of So-

corro near San Acacia. These four structures are of somewhat similar design, each being a low weir or a barrage of gates with headworks for regulating the flow into canals and sluiceways for clearing the control gates.

Cochiti Diversion Dam.

340. The Cochiti Diversion Dam is a concrete Ogee weir structure founded on heavy gravel. It has a crest length of about 300 feet and a height of 7 feet. The total width of the base slab is 80 feet. The diversion works are located at the westerly end of the dam. These consist of two concrete conduits leading to the Cochiti Division Main Canal, controlled by two 3.6-foot by 4.5-foot slide gates, and a sluiceway through the dam in front of the gates controlled by one 10-foot by 7-foot radial gate. The dam is designed to divert a maximum of 200 cubic feet per second for irrigation of the Cochiti Division. The detailed design of this dam is shown on Drawing Dc1, Exhibit P-2.

Angostura Diversion Dam.

341. The Angostura Diversion Dam is a low flat "Indian" type weir founded on sand and gravel. It has a total length of 938 feet, including the sluiceway. The river section of the dam is to be constructed of loose rock held in place by sheet piling and concrete walls. The top slope will be paved with hand laid rock. This section is 520 feet long, and it has a maximum height of about 6 feet above river bed and a base of about 70 feet.

342. The central section of the dam is located on a gravel bar, and it consists of a sloping concrete deck with sheet piling at the crest and toe. The toe will be further protected by loose riprap.

343. The sluiceway section, located at the easterly end of the dam, consists of five openings each 20 feet wide, controlled by five radial gates 20 feet wide by 6.4 feet high. This section is supported by round piling. A concrete floor extends 57 feet upstream and 40 feet downstream from the gates.

344. The headworks consist of a skimming weir 149 feet long, designed to exclude the heavier sand and gravel from the canal. The canal is regulated by one radial gate 20 feet wide by 6.4 feet high, set about 150 feet downstream from the skimming weir. The headworks is designed to divert a maximum of 550 cubic feet per second for irrigation of the Albuquerque Division. The detailed design of this dam is shown on Drawing Da2, Exhibit P-2.

Isleta Diversion Dam.

345. The Isleta Diversion Dam consists of a flat crested concrete slab 692 feet long, supported on sheet piling and terminating at both ends in sluiceway sections each 127.5 feet long. The foundation is silt and fine sand, requiring supports of round piling and sheet piling for all concrete work. The structure is designed to divert 300 cubic feet per second at the easterly end for the Peralta District, and 1,000 cubic feet per second at the westerly end for the other lands of the Belen Division.

346. The concrete slab forming the crest is 40 feet wide, and its downstream toe will be protected against scour by a blanket of heavy riprap 20 feet wide and from 5 to 10 feet thick. The sluiceway is controlled by 6 radial gates, each 20 feet wide by 6.4 feet high.

347. The headworks consist of similar structures at each end of the dam designed to exclude the heavier sand and gravel from the canals by "skimming" the surface of the stream. These structures have lengths of 170.5 feet and 84.5 feet respectively. The canals leading from the headworks are controlled in each case by radial gates. Drawings Di3, Exhibit P-2 show the details of the design of this dam.

San Acacia Diversion Dam.

348. The San Acacia Diversion Dam consists of a barrage of 30 radial gates, each 20 feet wide by 6.4 feet high, located in a gorge of the Rio Grande at the village of San Acacia. The foundation at this point is silt and fine sand, necessitating the use of round piling supports and sheet piling cut-offs for all concrete work.

349. The dam has a total length of 643.6 feet. The pier section supporting the gates has a base 18 feet wide resting on round piling. Concrete aprons extend 60 feet upstream and 18.6 feet downstream from the gate sections, with sheet piling at the upper and lower edge of concrete. A heavy blanket of loose rock 20 feet wide will be placed at the downstream edge of the concrete apron to prevent scour.

350. The gates will be operated by suitable hoists from a concrete deck supported on the gate piers and extending the length of the dam. Counter weights are provided on each gate to facilitate rapid opening in the case of floods.

351. The headworks consist of a "skimming" arrangement designed to exclude sand and gravel from the canal. This is located at the westerly end of the dam, controlling the intake to the Socorro Division Main Canal which has a maximum capacity of 276 cubic feet per second. The detailed design of this structure is shown on Drawing Dsa3, Exhibit P-2.

Improvements at San Marcial*

General Features.

352. At San Marcial the river channel is almost obliterated by silt. Since 1880 the river bed has raised from 12 to 14 feet, and in consequence of this raise the channel capacity has been greatly reduced and is decreasing from year to year. At the present time the average elevation of the town and railroad yards is from 2 to 3 feet below the bottom of the river channel opposite. Floods are controlled by small and wholly inadequate levees on each side of the river. A detailed description of the studies made of this condition may be found in paragraphs 186 to 196.

353. The proposed improvements consist of levees, jetties and channel work, the raising of the A. T. & S. F. Ry. tracks and structures, and drainage.

Work Affecting the Atchison, Topeka and Santa Fe Railway.

354. The Plan provides a raise of grade on the A. T. & S. F. Ry. extending from Station 8056+75 to Station 8190+00. The maximum height of the required raise is about 8 feet. Suitable connections will be provided from the raised main track to the necessary yard tracks. The water crane and crane pit, the coal chute and trestle, and the depot will be raised to meet the revised grade of the tracks.

355. It is proposed to replace the present pile trestle bridge No. 1006-A by a through steel truss 45° skew span bridge about 465 feet in length. It is also proposed to raise bridge No. 1005-A to meet the revised grade, and to maintain this bridge as a spillway for major floods. Drawing K-30, Exhibit P-6, shows profile of the railroad and the proposed grade raise.

Levees.

356. The Plan provides levees on both sides of the Rio Grande about 14 feet in height, and of a section similar to the standard levee. A levee will be built westerly from the north end of bridge No. 1005-A to the hills, to protect San Marcial from backwater. The levees will be protected from river erosion by woven wire supported on steel channels along the toe of slopes.

Scour Through the Silt Plug.

357. Below the railroad tracks, on land belonging to the Elephant Butte Reservoir of the United States Bureau of Reclamation,

*All improvements at San Marcial, with the exception of certain channel work, were eliminated from the Plan. See Section VI.

the river has deposited a silt delta extending generally across the river valley. This delta is now acting as a "plug" to flatten the slope of the river opposite San Marcial.

358. In order to ameliorate this condition, it is proposed to straighten and confine the normal flood flow between two lines of woven wire supported by steel piling. This work will extend to a point near Old Fort Craig, and is intended to induce a scouring of the channel between the lines of retards. Major floods will in part find an outlet into the reservoir through the upstream bridge 1005-A. Drawing K-9, Exhibit P-6 shows the silt delta referred to above. Drawing K-27, Exhibit P-6 shows the plan of the proposed channel improvements.

Drainage.

359. The San Marcial Drainage Ditch is planned to discharge into the improved channel about 3.4 miles below railroad bridge 1006-A. It will follow the westerly side of the valley and come to an end north of the town. A headgate will be provided at the point where the drain crosses the "Old Town" levee, and above this point a levee will be constructed on the west side of the drain to protect the town and levee from arroyo floods.

Execution of Project Works

Order of Construction.

360. The work will follow an order of construction formulated to correlate the various controlling factors to the best advantage. One object is to extend and add to the areas of productive land as rapidly as possible. Land now supplied with irrigating water, but seeped and unfit for use in its present condition, will be the first drained, so far as such program can be arranged. Following this, other land will be drained and made ready for the preliminary conditioning operations of clearing and plowing in order that it can become productive without unnecessary delay when the irrigating water becomes available.

361. Parts of the work embracing flood protection for Albuquerque, San Marcial, and other important localities will be given preference, furnishing protection of the more highly developed sections at the earliest possible date.

362. The El Vado Dam will be commenced as soon as arrangements can be made, and pushed to completion, making irrigation water available when needed. The diverting dams on the Rio Grande will likewise be pushed to an early completion for use in supplying water to the canals, some of which may be used before being completed.

363. The canals, laterals and interior drains, involving some

16,000,000 cubic yards of excavation, must be scheduled according to two governing factors. The work must of necessity be done almost entirely by draglines, and it must therefore be apportioned somewhat uniformly over the construction period in order to minimize the amount of equipment needed on the work, at any one time, and to obtain in this way the lowest costs for doing the work. On the other hand, such work as is to be done each year will be so chosen that it will be of most use to the greatest possible amount of land.

364. The exact location of the river levees and adjacent riverside drains will depend upon the results accomplished with the permeable jetties, placed in advance, along the river for the purpose of filling bends and the straightening of the river. Construction of the levees and riverside drains must therefore fit into the program for river improvement which, owing to its nature, must be done gradually, commencing at the most advantageous places and progressing as conditions will warrant. Also, in order to keep the present ditches in operation without entailing the wasteful expense of providing temporary structures, construction of some parts of the riverside drains will be postponed until the ditches can be fed from new canals of the District.

Time Required to Complete Project.

365. The excavation items control the time needed to complete the project. It seems that five years should be allotted to the work in order to secure normal costs, but this estimate of time may be somewhat modified upon a detailed development of the construction program which would take into account both costs and the other requirements of the situation.

Exhibits Accompanying the Plan

366. The following exhibits consisting of five volumes of special reports and 17 volumes of drawings (not in form available for distribution) are included as a part of the Plan:

Summary	Exhibit	Sheets
Erosion and Control of Silt on the Rio Puerco, N. M.	R-1	
The Geology of the El Vado Damsite and Reservoir	R-2	
Report on Ground Water Determination	R-3	
Profiles and Cross Sections Showing Ground Water	R-3a	1
Topographic Maps Showing Seeped Areas	R-3b	35
Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico	R-4	
Reports of Board of Consulting Engineers	R-5	
El Vado Dam and Reservoir	P-1	6
Diversion Dams	P-2	5
Plans for Minor Structures, Irrigation and Drainage System	P-3	20
River Improvements and Silt Control	P-4	16
Profiles of Canals and Drains	P-5	14
Plan of Modifications, Socorro Main Canal	P-5a	1
Division Maps, Scale 1″ equals 1000′	M-1	4
Plan of Modifications Near San Marcial	M-1a	1
Property Maps (9 Volumes)	M-2	189
Total		292

SPECIAL REPORTS

Title	Author	Exhibit	Sheets
Erosion and Control of Silt on the Rio Puerco, N. M.	Kirk Bryan and George M. Post	R-1	
The Geology of the El Vado Damsite and Reservoir	E. H. Wells	R-2	
Report on Ground Water Determination	Philip S. Donnell	R-3	
Profiles and Cross Sections Showing Ground Water		R-3a	1
Topographic Maps Showing Seeped Areas		R-3b	35
Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico	E. B. Debler and C. C. Elder—U. S. Bureau of Reclamation	R-4	
Reports of Board of Consulting Engineers		R-5	

EXHIBIT P-1—El Vado Dam and Reservoir

Title	Drawing	Sheets
El Vado Dam—General Layout and Sections	Cv25	1
El Vado Dam—Section "M" Outlet Works	Cv26	1
El Vado Dam—Emergency Spillway	Cv27	1
El Vado Dam—Operating Spillway	Cv23	1
El Vado Damsite—Topography, Logs of Shafts, Test Pits and Drill Borings	Cv4	1
El Vado Reservoir—Topography	Cv7	1

EXHIBIT P-2—Diversion Dams

Title	Drawing	Sheets
Cochiti Diversion Works—General Plan and Sections	Dc1	1
Angostura Diversion Works	Da2	1
Isleta Diversion Works	Di3	2
San Acacia Diversion Works	Dsa3	1

EXHIBIT P-3—Plans for Minor Structures

Irrigation and Drainage System

Title	Drawing	Sheets
Four Foot Standard Drops:		
800 Sec. Ft. Capacity 28 Ft. Base Canal	E-37	1
700 Sec. Ft. Capacity 22 Ft. Base Canal	E-38	1
600 Sec. Ft. Capacity 20 Ft. Base Canal	E-30	1
500 Sec. Ft. Capacity 16 Ft. Base Canal	E-31	1
400 Sec. Ft. Capacity 14 Ft. Base Canal	E-32	1
300 Sec. Ft. Capacity 12 Ft. Base Canal	E-33	1
200 Sec. Ft. Capacity 12 Ft. Base Canal	E-34	1
100—10 Sec. Ft. Capacity less than 12 Ft. Base Canal	E-35	1
Standard Metal Flumes	E-25	1
Standard Bridges over Drains and Canals	E-26	1
Surface Water Pipe Inlet to Open Drains	E-27	1
Standard Bridges and Culverts for Small Laterals	E-28	1
Typical Lateral Turnouts	E-29	1
Typical Farm Turnouts	E-36	1
Typical Under Drain	E-39	1
Typical Cut and Cover Sections	E-40	1
Typical Drain Outlet	E-41	1
Standard Drainage Culverts	E-42	1
Typical River Siphon	E-43	1
Typical River Siphon Wasteway	E-44	1

EXHIBIT P-4—River Improvements and Silt Control

Title	Drawing	Sheets
Proposed Railroad Grade Change at San Marcial	K-30	1
River Profile Angostura to San Marcial	K-37	1
River Sections and Capacity Curves, Belen Division	K-38	1
River Sections and Capacity Curves, Socorro Division	K-39	1
River Sections and Capacity Curves, Albuquerque Division	K-40	1
Permeable Jetties	K-44	1
Profile River Bed and Railroad Sub-grade at San Marcial	K-45	1
River Bed Conditions at San Marcial	K-9	1
Filling Under Santa Fe Railway Bridge 1005-A	K-10	1
Water Surface Conditions at San Marcial	K-11	1
Flood Protection at San Marcial	K-27	1
Rio Puerco Silt Control Structures	B-21	1
Rio Puerco Watershed Maps	B-10	4

EXHIBIT P-5—Profiles of Canals and Drains

Title	Drawing	Sheets
Cochiti Main Canal	Ep1	1
Albuquerque Main Canal	Ep2	1
San Juan Main Canal	Ep4	1
Socorro Main Canal	Ep5	1
Socorro and Peralta Main Canals	Ep8	1
Belen Main Canal	Ep14	1
Sabinal-Belen Riverside Drain	Ep3	1
Socorro-Lemitar Riverside Drain	Ep6	1
San Francisco-San Juan Riverside Drain	Ep9	1
Peralta Riverside Drain	Ep12	1
Isleta-Atrisco-Corrales Riverside Drain	Ep7	1
Albuquerque Riverside Drain	Ep10	1
Val Verde-San Antonio Riverside Drain	Ep11	1
Bernalillo Riverside Drain	Ep13	1

EXHIBIT P-5a—Plan of Modifications, Socorro Main Canal

Title	Drawing	Sheets
Socorro Main Canal—Modified Plan		1

EXHIBIT M-1—Division Maps, Scale 1″=1000′

Title	Drawing	Sheets
Cochiti Division	A-7	1
Albuquerque Division	A-8	1
Belen Division	A-9	1
Socorro Division	A-10	1

EXHIBIT M-1a—Plan of Modifications Near San Marcial

Title	Drawing	Sheets
Modifications Near San Marcial		1

EXHIBIT M-2—Property Maps (9 Volumes)

Volume	Map Numbers	County	Sheets
1	1 to 19	Sandoval	19
2	20 to 40	Bernalillo	21
3	41 to 61	Bernalillo	21
4	62 to 83	Valencia	22
5	84 to 100	Valencia	17
6	101 to 117	Valencia	17
7	118 to 145	Socorro	28
8	146 to 168	Socorro	23
9	169 to 189	Socorro	21

PART I

THE PLAN

SECTION VI

MODIFICATION OF THE PLAN

SECTION VI

MODIFICATION OF THE PLAN

The Plan as Submitted to the Court.

367. The report of the Chief Engineer of the Middle Rio Grande Conservancy District, submitting a plan for flood control, drainage, and irrigation of the Middle Rio Grande Conservancy Project, was filed with the Secretary of the District on May 3, 1928. The Plan, as submitted, includes improvements for an area of 133,000 acres within the District for an area extending along the Rio Grande from White Rock Canyon on the north, to the head of Elephant Butte Reservoir, below San Marcial, New Mexico, on the south.

368. The Board of Commissioners adopted this Plan on June 12, 1928, after holding a legally advertised hearing thereon. Only one exception to the Plan as adopted, that of J. Fred Schoellkopf, was taken before the Board.

Protests to Plan as Submitted.

369. Protests to the Plan were filed by J. Fred Schoellkopf of Dallas, Texas, in behalf of 8,300 acres of land located in the lower end of the Socorro Division of the project on the lands of the Bosque del Apache Grant, and by 26 property owners residing in the Val Verde-La Mesa area situated in the extreme southern end of the Socorro Division. Also, certain petitions have been filed in the Court requesting consideration for a modification of the Plan to include the deepening of the channel of the Rio Grande.

370. The two protests first mentioned request the elimination of areas from the District, or an elimination of the contemplated improvements on the land of the protestants. Due to the fact that these areas are in the extreme southern portion of the District, such an elimination is possible without disturbing, to any great extent, the improvements contemplated for other areas within the District.

Proposed Modification.

371. The Board of Commissioners of the District directed the Chief Engineer, by resolution of the Board dated July 6, 1928, to prepare a complete report on the possibility of eliminating improvements from the lands of the two protestants first above mentioned. This report made in accordance with the Board's resolution does not consider the proposed deepening of the channel of the Rio Grande, but is confined entirely to the effect on the District of eliminating improvements in so

far as possible from all lands south of the north line of the Bosque del Apache Land Grant.

Areas Affected by Proposed Modification.

372. The area from which improvements are proposed to be eliminated is situated entirely in Socorro County and covers the extreme south end of the project as originally planned. It lies on both sides of the Rio Grande and extends southerly from the north line of the Bosque del Apache Grant in Sections 16, 17 and 18, T. 5 N., R. 1 E., New Mexico Principal Meridian, to the south boundary line of the Middle Rio Grande Conservancy District just below San Marcial, a distance along the river of about 16.5 miles. Through this area the valley varies in width from 1¼ to 2½ miles.

373. All lands involved lie within two large land grants, the Bosque del Apache Grant and the Pedro Armendaris Grant No. 33. The entire area is traversed on the west side by the A. T. & S. F. Railway from about 750 feet north of Mile Post 991 to about 1500 feet south of Mile Post 1006, approximately 15.4 miles.

374. The meanderings of the river from hill to hill divide the area generally into four natural bodies of land, two on each side of the river. Those on the north contain land in the Bosque del Apache Grant known as the Elmendorf Tract, and also a few private claims adjacent to the south boundary of the grant on the east side of the river. At the south end are the areas or districts of San Marcial and Val Verde-La Mesa, the former being west of the river and the latter on the east side thereof.

375. Practically the entire area is unimproved. The only agricultural land is located in the Val Verde-La Mesa area which is served by the single irrigation ditch of the entire area. This ditch, the Val Verde, takes out from the river in Section 18, T. 6 N., R. 1 E. and irrigates approximately 1100 acres. The Town of San Marcial occupies about 50 acres in the south part of the San Marcial area. The balance of the area is occupied mainly by salt grass and bosque, and its use is limited to cattle grazing.

376. The entire area, exclusive of the river bed, roads, present ditches and railroad right-of-way, contains 14,479 acres within the limits of the valley floor, and within the limits of the proposed improvement. This land is classified as follows:

Irrigated		Non-Irrigated	
Orchard and Garden	75	Salt Grass	4245
Alfalfa and Grain	1037	Bosque	7723
		Swamp	137
Total Irrigated	1112	River Wash	36
		Sand Dunes	258
		Mesa and Upland	203
		Fallow	596
		Homesites	119
		Town of San Marcial	50
		Total Non-Irrigated	13,367

Irrigated	1,112
Non-Irrigated	13,367
Total Acres	14,479

The original Plan affected this acreage in the following manner:

Lands Benefited	11,795 acres
Lands taken by District for Rights-of-way and Floodway	1,619 acres
Lands not affected by Plan	1,065 acres
Total	14,479 acres

377. Approximately 524 separate parcels of land are included in the entire area. They include 495 small tracts distributed about evenly between small agricultural holdings in the Val Verde-La Mesa area, and homesites and platted lots in the Town of San Marcial. The remaining 29 tracts are owned by two separate owners who hold the majority of the acreage involved in the area proposed to be eliminated. The amount and percentage of the area held by the several owners are as follows:

	Total Lands in Area (Acres)	(%)	Lands Benefited (Acres)	(%)
J. Fred Schoellkopf et. al.	9,413	65.0	8,300	70.4
Victorio Land and Cattle Co.	2,291	15.8	914	7.8
Other Owners	2,775	19.2	2,581	21.8
Totals	14,479	100.0	11,795	100.0

Conditions at San Marcial.

378. At San Marcial, New Mexico, river conditions have become almost intolerable due to the silting of the river channel. To remedy or ameliorate this condition the District engineers have made various studies and have prepared a plan for improvements. (See Section IV, Paragraphs 186 to 196.) The degree of success of this plan depends upon the results obtained with silt control on tributary streams, notably the Rio Puerco. (See Exhibit R-1, pp. 165-166.)

379. The Santa Fe Railway, with its division terminal facilities at San Marcial, would be one of the chief beneficiaries of the im-

provements at this point. However, there has recently been a material reduction in the railroad's forces at San Marcial and it seems probable that the Railway may contemplate a partial abandonment of its terminal there. No definite commitment on this matter has been made by the Railway, so far as is known. The attitude of the Railway Company has a material bearing on the problem of the proposed modification of the Plan because, if San Marcial is to become of less importance as a terminal, the Railway Company's benefits under the original Plan will be decreased. The Company has been advised of the proposed elimination of improvements, as outlined herein, and it has not objected to the change in plans.

The Modified Plan.

380. Studies have been made of the effect of eliminating all the improvements contemplated by the Plan located below the north line of the Bosque del Apache Grant. In so far as the construction of jetties is concerned, it seems that it will be necessary to retain these as contemplated by the Plan, extending to the head of the Elephant Butte Reservoir. This seems necessary because the river bed is now filling with silt and, unless corrective measures are taken, it is only a question of a short time until serious trouble can be expected at the north line of the Bosque del Apache Grant. It seems preferable to construct river improvements continuously to the Elephant Butte Reservoir, rather than to be forced to make large and uncontemplated expenditures at a future date in order to protect the improvements of the District.

381. Likewise it may be stated that silt control on the Rio Puerco is a feature which the District, as a whole, cannot afford to entirely eliminate without seriously jeopardizing the entire project. The Modified Plan contemplates reducing the silt program to an expenditure of $100,000. With this sum of money and the possibility of interesting the Federal Government in this problem, it seems that sufficient work may be accomplished to protect the improvements remaining under the Modified Plan. This seems especially true because the effect of silt is naturally greatest directly at the head of the reservoir at San Marcial. San Marcial, under the Modified Plan, will be some 15 or 16 miles south of the improved agricultural lands of the District.

382. In order to properly drain all the lands north of the north line of the Bosque del Apache Grant, it is necessary to extend the outlet of the San Antonio Riverside Drain approximately 2½ miles southerly into the grant lands.

383. The Modified Plan, as considered herein, therefore includes a full program of river jetties, as contemplated by the original Plan, a partial program of silt control and the extension of a drain out-

let, together with levees some distance south on the lands of the Bosque del Apache Grant. All other improvements south of the north line of the Bosque del Apache Grant described in the Plan, including drains, irrigation canals, levees, etc., would be eliminated under the proposed Modified Plan. The works retained will be necessary in order to fully improve the lands north of the grant line and to insure their full productivity under farming conditions. The Modified Plan, as described above, is shown on map Exhibit M-1a, and Exhibit P-5a shows revised profile and sections of the Socorro Main Canal.

Cost of the Plan as Modified.

384. The cost of the Modified Plan, as described above, is shown by cost estimates herein to be $10,357,000. (See Table No. 22.) This is a saving of $1,491,000 under the estimated cost of the original Plan. In order to determine what proportion of this saving results in a gain of revenue to the District, it is necessary to consider the loss of revenue which may occur because of the elimination of improvements contemplated by the Modified Plan.

Loss of Revenue to District by Elimination of Improvements.

385. While definite figures of benefit have not been placed against individual tracts within the area, a rough estimate of the revenue lost to the District by the proposed elimination of improvements in this area follows:

Table 20

Total Revenue Expected from Area Under the Original Plan.

Source	Acres Benefited	Total Expected Revenue
Bosque del Apache (Schoellkopf et. al.)	8,300.00	$445,711
S. H. Claims in Bosque del Apache	492.50	25,917
Val Verde-La Mesa	2,366.81	118,340
San Marcial	635.39	42,771
Total (Exclusive of Ry.)	11,794.70	$632,739
A. T. & S. F. Railway through elimination of railroad reconstruction at San Marcial		325,127*
Totals	11,794.70	$957,866

386. The above table estimates a total revenue to the District of $957,866 to accrue through the execution of the District Plan. This is based in part upon the assumption that the proposed railway reconstruction at San Marcial will offer benefits to the Railway Com-

* Railway Company's estimate of cost of railway improvements at San Marcial under District's Plan.

pany exactly corresponding to the cost of the work. This may not be the fact. However, on the basis of the estimate, that is, after deducting from the total saving made by the Modified Plan, $1,491,000, the total expected revenue as estimated above, $957,866, there remains a sum of $533,134 which represents the estimated net saving to the District by the elimination of the improvements as contemplated herein.

Future Maintenance.

387. In addition to the direct saving in cost made by the proposed Modified Plan, it is pointed out that the exclusion from the Plan of the San Marcial silt problem eliminates the most uncertain engineering problem within the District. The responsibility of the District to maintain farming conditions directly above Elephant Butte Reservoir is eliminated by the Modified Plan, and this may result in reduced future maintenance cost for the entire project.

Probable Sources of Future Revenue.

388. The elimination of the major program of improvement from this area still leaves features which may be utilized by certain portions of the area to their benefit.

389. The channel improvements to be carried on under the Modified Plan will be beneficial to the lands, but if Elephant Butte Reservoir becomes filled with silt agriculture cannot be maintained in the vicinity of San Marcial. With the existing uncertainties in regard to silting and in view of the proposed reduction in silt control work, it is believed best that the District should assume no responsibility for maintaining farming conditions south of the north line of the Bosque del Apache Grant. This can probably only be done by eliminating all assessments for river improvement work.

390. It is expected that the river will at all times discharge water past the north line of the Bosque del Apache Grant. During the period of heaviest irrigation use, it is estimated that a minimum discharge of 50 second feet will be developed from the drainage works of the Socorro Division alone. This discharge will be augmented by regulation losses at the San Acacia Diversion Dam which may normally amount to about 30 second feet.

391. The river is often dry under present conditions and it is obvious that such a stabilized discharge during the summer months will be of value to the lands of the Bosque del Apache and to those of the Val Verde-La Mesa area. Further, additional water can be delivered from the District's irrigation works into the river so as to provide an amount sufficient for ample irrigation needs of these areas.

392. The development of such increased supply in the river will be due to the District's works and such water will be available to the lands now being irrigated or which might be placed under irrigation in the future. Any relief obtained during periods of drought from the augmented and stabilized flow of the river, which the proposed Modified Plan will provide, constitutes benefits to the lands from which the District might anticipate future revenue. This can be secured through the sale of water or dealt with by appraisal according to such benefits as may be decided at the time the Appraisal Report is filed.

The Bosque Del Apache Grant.

393. While irrigation and drainage improvements are generally excluded south of the north line of this tract, certain improvements must of necessity be carried through a portion of the tract. The Elmendorf Drain and a levee along its east side are carried across the northeast portion of the large tract between the river and the railroad. These join with the west bank of the river at a point about 2½ miles below the north line of the grant. The operation of these structures will render certain portions of the land available for cultivation, if water is supplied through the District's irrigation works or otherwise.

394. The installation of such District improvements would appear to convey full or partial benefit from irrigation, drainage, and flood protection to a portion of the lands in Sections 16, 17, 18, 19, 20, 21, 29 and 30. The acreage involved in such possible improvement is roughly estimated at 600 to 800 acres.

395. No benefits may be expected from other lands within the grant, except as such lands are considered by the Appraisers to have a general benefit, or are given advantage of irrigation water obtained from the increased river flow provided by the District.

The Val Verde-La Mesa Area.

396. No improvement is conveyed to this area except as may be conveyed to the lands from increased river flow. Lands which now experience serious periods of shortage in irrigation water may be greatly benefited by the availability of water maintained in the channel by the District works above.

Advantages of the Modified Plan.

397. The direct advantages to be gained by modification of the Plan, as herein outlined, may be summarized as follows:

(1) Reduction in total cost of project from $11,828,000 to $10,337,000.

(2) The estimated net saving to the District, considering loss in revenue due to the Modified Plan, is $533,000.

(3) The Modified Plan eliminates the most difficult engineering problem, the San Marcial silt problem, from the Plan and reduces future uncertainties in regard to maintenance of agriculture in the lower end of the District.

(4) The Bosque del Apache lands constitute the largest single area of unsettled lands within the District. Their elimination from the improved area should generally strengthen the security of the remaining area to be improved.

(5) With District improvements discontinued at the north line of the Bosque del Apache Grant, the distance between the flow line of Elephant Butte Reservoir and improved District lands becomes about 16 miles. The fall in this distance is about 60 feet. This distance and difference in elevation is a safeguard to the future existence and maintenance of District works.

Disadvantages of the Modified Plan.

398. If the Plan of the District is modified, as outlined herein, the areas from which the improvements are eliminated will probably continue to become more and more adversely affected due to the silt delta forming at the head of Elephant Butte Reservoir. (See Exhibit R-1, Erosion and Control of Silt on the Rio Puerco, New Mexico, pp. 165-166). A continuation of agriculture within these areas, now restricted to 1,100 acres, cannot be maintained indefinitely without checking the inflow of silt into the reservoir.

399. With the full silt control program as contemplated by the Plan, and the probability of arousing Governmental interest and assistance in the work of checking excessive erosion on tributary streams, agriculture might be prolonged many years. With drainage and a full water supply these areas could then prosper.

400. The Town of San Marcial is now located on land which is lower than the bed of the Rio Grande. Its existence depends upon wholly inadequate dikes. Without the help of a comprehensive plan of improvement, it cannot exist much longer. The citizens of this town have been looking to the District for correction of their problems for many years.

401. The Modified Plan will cause a loss in water to the river, due to the high evaporation losses from swamped and water-logged areas which would have been saved by drainage under the original plan. This loss is estimated at 6,900 acre feet per annum. Under full irrigation and drainage, the water consumption on the 11,800 acres proposed

to be improved under the Plan would average 6,900 acre feet per annum less than the water consumption under present conditions.

The Modified Plan Approved by the Court.

402. The district court of the 2nd Judicial District set a day for the hearing of protests to the Conservancy District plan as submitted, and after consideration of the evidence introduced handed down a decree, approving the plan, modified by the elimination of the areas south of the north line of the Bosque del Apache Grant, as described in Section VI herein. This decree was rendered on August 15, 1928.

Table 21

Canals, Laterals, Levees and Works. Revised by Modified Plan.

Structure or Work	Length in Original Plan	Length in Modified Plan	Remarks
Socorro Main Canal	44 Miles	28 Miles	Ends in modified plan at north boundary line of Bosque del Apache Grant.
Elmendorf Lateral	5.3 Miles	None	Eliminated from the plan.
Apache Lateral	4.7 Miles	None	Eliminated from the plan.
Herrick Lateral	3.4 Miles	None	Eliminated from the plan.
Olguin Lateral	4.7 Miles	None	Eliminated from the plan.
La Mesa Lateral	3.8 Miles	None	Eliminated from the plan.
San Antonio Riverside Drain	26.5 Miles	4.5 Miles	Part south of north boundary line of Bosque del Apache Grant eliminated from the plan. Location revised to outlet into Elmendorf Drain.
Val Verde Riverside Drain	10.1 Miles	None	Eliminated from the plan.
Elmendorf Drain	8.9 Miles	5.7 Miles	Relocated to outlet into the river east of M.P.993 of the A. T. & S. F. Railway.
Herrick Drain	3.8 Miles	None	Eliminated from the plan.
Salome Drain	3.9 Miles	None	Eliminated from the plan.
La Mesa Drain	3.2 Miles	None	Eliminated from the plan.
San Marcial Drain	4.0 Miles	None	Eliminated from the plan.
San Marcial Levees	3.2 Miles	None	Eliminated from the plan.
King's Levee	1.0 Miles	None	Eliminated from the plan.
Flood Protection & River Control			Levees to north boundary line of Bosque del Apache Grant. Permeable jetties in river to a point below San Marcial.
Silt Control on Tributaries			Reduced to jetties on main side arroyos and Rio Puerco.

PART I

THE PLAN

SECTION VII

ACKNOWLEDGMENTS

SECTION VII

ACKNOWLEDGMENTS

403. Among the many pioneers who labored during the early years to promote drainage and reclamation in the middle Rio Grande valley, the names of the late Coney T. Brown of Socorro, the late Eugene Kempenich of Peralta, the late Clark M. Carr and the late A. B. McMillen of Albuquerque, should receive prominent mention. These men, together with A. B. Stroup, F. S. Donnell, B. C. Hernandez, James Bezemek, Don J. Rankin and W. C. Reid of Albuquerque, George W. King of San Marcial, John Becker, Jr., of Belen, and others, did much to arouse public interest to the needs of the valley.

404. The creation of the Rio Grande Survey Commission, under a legislative enactment of 1921, was the first definite step toward a comprehensive study of the entire middle valley. The Board of Commissioners under the act, appointed by Governor Merritt C. Mecham, were Coney T. Brown, A. B. McMillen, and W. C. Reid. With the assistance of Mr. Herman Mohr and Mr. R. P. Barnes, this commission made a special study and investigation of the Conservancy Act of Ohio and, in conjunction with the Middle Rio Grande Reclamation Association, succeeded in obtaining the legislation known as The Conservancy Act of New Mexico, passed by the State Legislature in 1923.

405. In March 1922 at a mass meeting held in the Albuquerque Chamber of Commerce, the Middle Rio Grande Reclamation Association was organized and funds were collected to promote the organization of a Conservancy District. The officers of the association were Coney T. Brown, President, James Bezemek, Vice President, J. C. Smith, Secretary, and Chas. S. White, Treasurer.

406. Under the leadership of this association and with the assistance of Messrs. R. P. Barnes and Pearce C. Rodey as attorneys, the organization of the Middle Rio Grande Conservancy District was carried through to a successful completion. In this organization work many individuals and civic organizations gave material assistance. General H. F. Robinson, Messrs. George M. Neel, Edmund Ross, Jay Turley and Ira N. Sprecher all gave technical guidance and assistance to the various petitions and court hearings.

407. The first officers of the District were Messrs. George E. Cook of Socorro, President of the Board of Directors, Robert E. Dietz of Albuquerque, Ramon Baca y Chavez of Belen, Directors; J. C. Smith, Secretary and Treasurer, and Pearce C. Rodey, Attorney. The original Board of Appraisers were James Bezemek, Chairman, Ira N. Sprecher and Alejandro Gonzales.

408. The above is an incomplete record of the many individuals and organizations who have given valuable time and study to the earlier problems of reclamation. The organization work of the Conservancy District was in itself a task of magnitude and of great importance to the future. The earlier organizations are to be commended for the comprehensive engineering data gathered. which has been of material assistance to the present studies.

409. Acknowledgments are due the following organizations and individuals, as well as many others not mentioned here, who have assisted the District engineers in the development of the Plan:

The United States Bureau of Reclamation through its Denver, Colorado, and El Paso, Texas, offices has supplied valuable data and information and has studied and reported upon the water supply of the project. Mr. C. C. Elder, Assistant Engineer, United States Bureau of Reclamation, has been in charge locally of the cooperative water supply studies until recently, and his excellent work in this connection is appreciated.

410. General H. F. Robinson, Supervising Engineer, United States Bureau of Indian Affairs, who for many years has studied irrigation problems of the Southwest, has offered all his files of data and has cooperated with the District in matters pertaining to Indian lands.

411. Mr. Herbert W. Yeo, State Engineer of New Mexico, has supplied the District with copies of reports and maps. His report of early irrigation conditions in the middle Rio Grande valley, made for the United States Bureau of Reclamation, has been of especial value.

412. The District has made full use of the excellent topographic maps and water table data of the middle Rio Grande valley taken under the direction of Mr. George M. Neel, former State Engineer. This work has saved the District considerable expense.

413. Mr. J. C. Smith, Flood Commissioner of Bernalillo County, and Mr. Phillip Campredon, Flood Commissioner of Socorro County, have made their experience with the Rio Grande flood problem available for the District.

414. The Engineering Department of the A. T. & S. F. Ry. has made available their flood records and other data. The officials of this railway have taken an active interest and have cooperated in the work of the District in many ways.

415. The technical schools of the State have rendered material assistance to the work. The State College of Agriculture and Mechanic Arts at Mesilla Park has made numerous tests of silt samples and alkali waters and soils. The agricultural experts of this school, and of the various counties in the District, have given valuable information.

416. The District has been very fortunate in being able to secure engineering consultants of experience in similar problems and high standing in their professions. The Dayton Morgan Engineering Company has been retained throughout the progress of the investigations. Mr. Arthur E. Morgan has served with a Board of Consulting Engineers, consisting of Messrs. D. C. Henny of Portland, Oregon, A. J. Wiley of Boise, Idaho, and W. M. Reed of Washington, D. C. The able counsel and advice of these engineers has been of particular value to the Chief Engineer.

417. Expressions of sincere appreciation are due the entire engineering force of the District for the loyal support and earnest service given. This report could not have been forthcoming at this time if the District engineers had not given more effort than just the day's work to its completion.

418. The able and active assistance rendered by the division chiefs, Mr. C. H. Howell, former designing engineer, Mr. R. G. Hosea, present designing engineer, Mr. Edmund Ross, engineer in charge of property surveys, Mr. George M. Post, engineer in charge of reservoir investigations, and Mr. C. A. Anderson, engineer in charge of appraisals, has been of especial value.

419. The preparation of this report is the work of the entire engineering staff, with the assistance of Mrs. E. G. Watson, District Secretary. Mr. R. G. Hosea has given much time to research of the early history of the middle Rio Grande valley and to water supply and flood studies, and is responsible for these phases of the report. Mr. Barton M. Jones, Chief Engineer of the Pueblo Conservancy District, has prepared the volume of "Contract Forms and Specifications" and rendered other valuable assistance. Mr. Edmund Ross has had in charge the preparation of the volume on "Property Affected by the Plan."

420. The engineering force has had full cooperation and constant support from both the present and the former Board of Commissioners, and from the Attorney and the Secretary of the District. This is acknowledged with grateful appreciation of the assistance that such cooperation has been in the development and preparation of the Plan.

PART II

ESTIMATES OF QUANTITIES AND COSTS

SECTION I

ARRANGEMENT AND PREPARATION OF THE ESTIMATES

SECTION I

ARRANGEMENT AND PREPARATION OF THE ESTIMATES

General Statement.

421. In the following pages are tabulations of estimates of quantities and cost of the work required in the prosecution and completion of the Plan. All estimates have been prepared on the basis of performance by contract. The field cost items include the estimated contractor's profit and an allowance for superintendency, plant depreciation and camp expense where necessary. Because of the nature of the work to be performed, the length of the construction period, and the necessary work which may have been inadvertently omitted from estimates, it has been deemed advisable to add liberal contingent allowances to the estimated field costs.

Arrangement of Estimates.

422. The estimates of quantities are grouped under main headings covering work which might naturally be included in a group of contracts, or one contract covering work that is inclusive of a natural division or geographical location; as, El Vado Dam, Angostura Diversion Dam, Belen Main Canals, Socorro Riverside Drains, etc. These main headings are subdivided according to structures, features and the class of work to be done to complete each structure, group of structures, or feature, and are listed separately under subheadings, together with the numerical designation of the specification item under which each kind of work falls.

423. The summary of cost is grouped under main headings covering all items necessary to complete a definite principal part of the Plan; as "El Vado Dam and Appurtenances," and "Irrigation Including Diversion Dams."

Preparation of the Estimate.

424. Cost estimates in general are based on actual costs of similar construction on the Rio Grande Project near El Paso, and on other reclamation projects in the West which have been constructed in recent years. Railroad construction features have been estimated with the assistance of the A. T. & S. F. Ry. engineers.

425. Quantities for El Vado Dam and the four diversion dams on the river are prepared from detail designs. Unit costs used are taken from similar structures recently constructed, due allowance being made for difference in location, cost of materials, freight, and labor.

426. Earthwork quantities are computed from profiles plotted from projected locations of canals, drains, and levees on the topographic maps of the District, and increased 10 to 15 per cent to allow for inaccuracies in elevation. The topography maps have in general a two-foot contour interval, and are drawn on scales of 200 feet and 1000 feet to the inch.

427. The number of Railroad, State Highway and County bridges has been estimated by counting the actual number of such crossings shown on the maps. Quantities are based on the design and length of the bridge required. Costs are computed on the following general basis:

Railroad bridges ..$40.00 to $50.00 per foot
State Highway bridges.......at $1000 each
County bridges.............at $ 550 each

428. Increases and allowances are made to this cost depending on the location and character of the crossing. The cost of farm bridges is estimated at $500 per mile of drain, canal, or lateral, with adjustments where necessary as noted for other bridges. Quantities and costs of the river siphons are based on actual work being carried on near El Paso, under similar conditions at the present time. The river is to be diverted to one side; the excavation and construction of the reinforced concrete pipe structure is to be accomplished "in the dry" by a well point predrainage system. Cost of arroyo siphons and other arroyo crossing structures are computed on a similar basis, except that no unwatering is required.

429. Minor structures are estimated as follows: Drain inlets are computed at $100 per mile; farm turnouts are placed at ½-mile intervals on main canals and at ¼-mile intervals on laterals, plus a contingency of 15 per cent, double this number if the topography of the country permits irrigation on both sides of the canal or lateral; temporary structures or flumes are based on the crossing of present ditches by the proposed irrigation and drainage system during construction; measuring devices, weirs or rating flumes are placed near the head of all main canals; minor flumes are computed at $500 per mile of drain; minor drops are estimated directly from the profiles or laterals. The unit prices used in computing the cost of these structures are based on contractors' prices on similar work, the cost of materials being furnished by reliable manufacturers and dealers.

430. The number and size of major drops, laterals, headgates, flumes, sandtraps, wasteway structures on canals and drains, underdrains and crossing culverts, are estimated directly from the profiles and maps of the District. Quantities and costs of these structures are computed from preliminary designs, with allowances for contengencies of an unforeseen character. The costs and quantities of the railroad reconstruc-

tion work near San Marcial are taken directly from the A. T. & S. F. Ry. engineers' estimates.

431. The location and length of permeable jetties are shown on the maps. Costs are computed from the designs of these structures, allowing an ample contingency for unforeseen obstacles.

432. In general, all materials such as cement, reinforcing steel, corrugated metal pipe, timber, piling, radial gates, slide gates, etc. are to be purchased by the District.

433. Allowances are made for the operation of the present system of ditches during the construction of the proposed canals and drains. The cost of rebuilding parts of farm ditches destroyed by drains is estimated at $125 per mile of the proposed drains. This work will be done by teams, and is placed in the estimate of quantities as team excavation.

434. Experience on similar projects shows that new canals require a short period of light operation before they will carry water in a satisfactory manner. To cover this, an estimate is made for priming and puddling at $100 per mile of canal and lateral.

435. Prior to turning the completed project over to the maintenance department, operation probably will be carried on for an initial period by the construction force. This cost is estimated at 75 cents per acre, and is taken account of in the estimates of cost of the main irrigation canals.

PART II

ESTIMATES OF QUANTITIES AND COSTS

SECTION II

SUMMARY OF QUANTITIES

EL VADO DAM AND APPURTENANCES

Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	4,658
	EXCAVATION:		
1	River diversion during construction		Lump Sum
2	Clearing foundation		Lump Sum
17-18-19-47	Preliminary test borings or test pits		Lump Sum
19	Solid rock—upstream toe open trench, exca. (All classes)	Cu. Yd.	44,167
19	Solid rock—in cut-off trenches at toe of paving (All classes)	Cu. Yd.	7,621
19	Solid rock—outlet works	Cu. Yd.	1,940
19	Solid rock—operating spillway	Cu. Yd.	1,000
17-18	Earth and loose shale in emergency spillway (Machine excavation, no haul)	Cu. Yd.	7,865
17-18	Earth and loose shale in emergency spillway (Machinery excavation and haul)	Cu. Yd.	24,877
17-18	Loose shale in emergency spillway (Hand excavation and no haul)	Cu. Yd.	2,610
17-18	Earth and loose rock in operating spillway (No haul)	Cu. Yd.	2,500
18	Shale in operating spillway (No haul)	Cu. Yd.	13,500
17-18	Earth and loose rock on conduit area for outlet works	Cu. Yd.	850
19a	Stripping below El. 6740 (river bed)	Cu. Yd.	2,000
17-18	Earth and loose rock-stripping abutments	Cu. Yd.	3,000
17	Trimming for paving (6")	Cu. Yd.	2,450
	BACKFILL: (Emergency Spillway)		
37	Operating spillway and outlet	Cu. Yd.	4,000
	EMBANKMENT:		
34	Loose rock on downstream face (Charged to rock excavation)	Cu. Yd.	76,650
33	Gravel fill	Cu. Yd.	315,030
	PAINTING:		
55	Water proofing on concrete face		Lump Sum
	DRILLING AND GROUTING HOLES:		
47	Holes not over 20 feet deep	Lin. Ft.	3,380
47	Holes 20 ft. to 40 ft. deep	Lin. Ft.	7,840
48	Providing and placing connections	Number	365
48	Pressure grouting	Cu. Yd.	727
	CONCRETE: (Dam)		
41	Slope paving face of dam	Cu. Yd.	5,000
40	Parapet	Cu. Yd.	560
39	Cut-off walls	Cu. Yd.	7,621
	CONCRETE IN OUTLET WORKS: (Trash Rack)		
39	Floor and footings	Cu. Yd.	71
40	Posts, cross beams, splitter wall and roof	Cu. Yd.	224
	CONCRETE IN CONDUIT:		
40	Barrels, stair cover and cut-off collars	Cu. Yd.	3,315
40	Pipe cradles, anchors, stairs and walkways	Cu. Yd.	106
40	Butterfly valve housing	Cu. Yd.	427

El Vado Dam and Appurtenances (continued)
Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	CONCRETE IN NEEDLE VALVE HOUSING UNDER ELEVATION 6755:		
39a	Bottom, sides, splitter wall and top of square conduit, bottom and sides of needle valve setting Gantry foundation; stairs, landing, coping and control house floor	Cu. Yd.	323
	ABOVE ELEVATION 6755:		
40	Walls of control house	Cu. Yd.	23
39-40-41	Emergency spillway footings, cut-offs and apron for weir section retaining wall footings and slope paving	Cu. Yd.	1,293
	STRUCTURAL CONCRETE:		
40	Slope wall and cutoffs for weir section, vertical walls, copings, cutoffs for retaining walls	Cu. Yd.	457
39	Sills (Lean concrete)	Cu. Yd.	1,440
	CONCRETE IN OPERATING SPILLWAY:		
39 & 40	Floors	Cu. Yd.	960
39 & 40	Retaining walls	Cu. Yd.	750
39 & 40	Cutoffs	Cu. Yd.	30
39 & 40	Warps	Cu. Yd.	60
39 & 40	Piers	Cu. Yd.	175
39 & 40	Bridge	Cu. Yd.	100
39 & 40	Handrail posts	Cu. Yd.	5
39 & 40	Protection wall	Cu. Yd.	26
	WATER PROOF JOINT: (Toe of Slope)		
56	Providing and placing	Lin. Ft.	1,600
	REINFORCING STEEL:		
46	Bending and placing (Face of dam)	Lb.	522,500
46	Bending and placing (Other concrete)	Lb.	1,600,900
	METAL WORK:		
75	Installing 2-20'x10' radial gates and hoists	Lb.	20,000
75	Installing trash rack metal	Lb.	55,940
75	Installing 6' diameter butterfly valves	Lb.	100,000
75	Installing 6' diameter steel pipe	Lb.	353,000
75	Installing 60" balanced valves	Lb.	165,000
75	Installing handrail	Lin. Ft.	125
75	Installing Gantry crane	Lb.	10,000
75	Installing miscellaneous metal in outlet, stairs, roofing, sash, roof trusses, etc.	Lb.	4,000
75	Installing turbine generator, wiring and conduit for lighting tunnel and control of butterfly valves, lighting system for top of dam		Lump Sum
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	31,200
45	Reinforcing steel	Lb.	2,123,400
	Paint.		
55	Water proofing for concrete face		Lump Sum
	Metal Work.		
61	Radial gate hoists		2
62	20'x10' radial gates (2)	Lb.	18,000
65	Trash rack metal	Lb.	55,940
58	Steel pipe 6' diameter	Lb.	353,000
60	Butterfly valves (6' diam.)	Number	2

El Vado Dam and Appurtenances (continued)
Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT: (con't)		
59	60″ balanced needle valves	Number	2
65	Handrail	Lin. Ft.	125
65	Gantry crane	Lb.	10,000
65	Miscellaneous metal outlet, stairs, roofing, sash roof trusses, etc.	Lb.	4,000
76	Turbine, generator, wiring and conduit for lighting tunnel and control of emergency valves, lighting system for top of dam		Lump Sum
	PERMANENT IMPROVEMENTS:		
20-21-22	Roads		Lump Sum
91	Buildings		Lump Sum

COCHITI DIVERSION DAM
Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	Lump Sum
	EXCAVATION:		
1	Diversion of river during construction		Lump Sum
17a	Sand and gravel below El. 5242	Cu. Yd.	1,500
17	Sand and gravel above El. 5242	Cu. Yd.	1,000
18	Loose rock above El. 5242	Cu. Yd.	3,000
	EMBANKMENT:		
33	Sand and gravel	Cu. Yd.	2,400
29	Riprap	Cu. Yd.	700
	CONCRETE:		
39	Cutoffs	Cu. Yd.	180
39	Aprons	Cu. Yd.	760
39	Ogee	Cu. Yd.	630
39	Slope pavement	Cu. Yd.	220
40	Radial gate piers and deck	Cu. Yd.	26
40	Outlet culvert piers and portal	Cu. Yd.	100
	METAL WORK: (Installing)		
75	3.6′x4.5′ slide gates and hoists	Lb.	3,800
75	10′x7.0′ radial gates and hoists	Lb.	1,700
75	Steel foot bridge	Lb.	3,000
75	Handrail	Lin. Ft.	24
50-51	Wooden bridge floor	F.B.M.	300
46	Reinforcing steel	Lb.	45,000
33	Backfill	Cu. Yd.	500
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	2,400
45	Reinforcing steel	Lb.	45,000
	Metal Work.		
62	3.6′x4.5′ slide gates and frames	Lb.	2,600
62	Stems	Lb.	600
62	Guides and couplings	Lb.	100
63	Hoists	Lb.	500
61	10′x70′ radial gate	Lb.	1,300
61	Pins and bearings	Lb.	100
61	Hoist	Lb.	300
65	Handrail	Lin. Ft.	24
65	Steel foot bridge	Lb.	3,000
	PERMANENT IMPROVEMENTS:		
91	Buildings		Lump Sum

COCHITI DIVISION

Summary of Quantities

Main Canal

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	152
3	Removal of buildings and structures	Mile	25
6	Fence alterations	Mile	25
	CANAL EXCAVATION:		
8	Excav. earth machine	Cu. Yd.	383,300
9	Excav. loose rock	Cu. Yd.	7,600
10	Excav. solid rock	Cu. Yd.	500
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	5
50-51	Timber	M.Ft.B.M.	8.5
52	Piling	Lin. Ft.	720
82	Steel guard rail	Lin. Ft.	270
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	1,378
50-51	Timber	M.Ft.B.M.	54.5
52	Piling	Lin. Ft.	1,310
	RIVER SIPHONS:		
23-24-25	Excavation and backfill	Cu. Yd.	15,635
29	Riprap	Cu. Yd.	300
40	Reinforced concrete	Cu. Yd.	330
45-46	Reinforcing steel	Lb.	33,000
44	Cement	Bbl.	413
	ARROYO SIPHONS:		
17	Excavation and backfill	Cu. Yd.	17,729
29	Riprap	Cu. Yd.	1,020
40	Reinforced concrete	Cu. Yd.	1,307
44	Cement	Bbl.	1,634
45-46	Reinforcing steel	Lb.	130,700
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	1,378
39	Plain concrete	Cu. Yd.	25
40	Reinforced concrete	Cu. Yd.	143
44	Cement	Bbl.	217
45-46	Reinforcing steel	Lb.	10,700
50-51	Timber	M.Ft.B.M.	63
71	24″ Rein. conc. pipe	Lin. Ft.	643
71	36″ Rein. conc. pipe	Lin. Ft.	450
61-63-75	Radial gate with hoists	Lb.	10,246
	MAJOR DROPS:		
17	Excavation and backfill	Cu. Yd.	143
39	Plain concrete	Cu. Yd.	66
40	Reinforced concrete	Cu. Yd.	165
44	Cement	Bbl.	286
45-46	Reinforcing steel	Lb.	12,500
50-51	Timber	M.Ft.B.M.	1.75
	SAND TRAPS AND WASTEWAYS:		
17	Excavation and backfill	Cu. Yd.	875
40	Reinforced concrete	Cu. Yd.	211
44	Cement	Bbl.	264

Cochiti Main Canal (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	SAND TRAPS AND WASTEWAYS: (con't)		
45-46	Reinforcing steel	Lb.	16,600
61-63-75	Radial gate with hoists	Lb.	6,517
50-51	Timber	M.Ft.B.M.	7
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	1,511
40	Reinforced concrete	Cu. Yd.	700
44	Cement	Bbl.	875
45-46	Reinforcing steel	Lb.	70,000
29	Riprap	Cu. Yd.	500
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	24.8
98	Operation	Acre	10,300

COCHITI DIVISION

Summary of Quantities

Laterals

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	210.24
2	Clearing and grubbing	Acre	15.
3	Removal of buildings and structures	Mile	33.72
6	Fence alterations	Mile	33.72
	CANAL EXCAVATION:		
8	Excav. earth machine	Cu. Yd.	186,805
	COUNTY BRIDGES:		
17	Excavation and backfill	Cu. Yd.	257
50-51	Timber	M.Ft.B.M.	45.7
	RIVER SIPHON:		
23-24-25	Excavation and backfill	Cu. Yd.	1,858
40	Reinforced concrete	Cu. Yd.	418
44	Cement	Bbl.	523
45-46	Reinforcing steel	Lb.	41,800
	ARROYO SIPHONS:		
17	Excavation and backfill	Cu. Yd.	70
40	Reinforced concrete	Cu. Yd.	83
44	Cement	Bbl.	104
45-46	Reinforcing steel	Lb.	8,300
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	12,003
39	Plain concrete	Cu. Yd.	9
40	Reinforced concrete	Cu. Yd.	94
45-46	Reinforcing steel	Lb.	7,890
44	Cement	Bbl.	128
50-51	Timber	M.Ft.B.M.	237.2
71	24" Rein. conc. pipe	Lin. Ft.	140
66	12" Corrugated metal pipe	Lin. Ft.	1,070

Cochiti Laterals (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	MINOR STRUCTURES: (con't)		
66	15" Corrugated metal pipe	Lin. Ft.	704
66	18" Corrugated metal pipe	Lin. Ft.	814
62-63-75	Slide gates with hoists	Lb.	34,004
	MAJOR DROPS:		
17	Excavation and backfill	Cu. Yd.	157
40	Reinforced concrete	Cu. Yd.	463
45-46	Reinforcing steel	Lb.	30,800
44	Cement	Bbl.	579
50-51	Timber	M.Ft.B.M.	4.6
	LATERAL HEADGATE:		
17	Excavation and backfill	Cu. Yd.	133
29	Riprap	Cu. Yd.	346
40	Reinforced concrete	Cu. Yd.	26
44	Cement	Bbl.	33
45-46	Reinforcing steel	Lb.	2,500
52	Piling	Lin. Ft.	420
61-63-75	Radial gates with hoists	Lb.	2,200
80	Woven wire	Lin. Ft.	200
	FLUMES:		
17	Excavation and backfill	Cu. Yd.	28
29	Riprap	Cu. Yd.	300
40	Reinforced concrete	Cu. Yd.	4.5
44	Cement	Bbl.	6
45-46	Reinforcing steel	Lb.	340
50-51	Timber	M.Ft.B.M.	9.82
52	Piling	Lin. Ft.	1,040
67	Metal flume	Lin. Ft.	350
	CONCRETE LINING:		
17	Excavation and backfill	Cu. Yd.	75
39	Plain Concrete	Sq. Yd.	1,446
44	Cement	Bbl.	150
	SANDTRAPS AND WASTEWAYS:		
17	Excavation and backfill	Cu. Yd.	43
40	Reinforced concrete	Cu. Yd.	25
44	Cement	Bbl.	32
45-46	Reinforcing steel	Lb.	2,500
50-51	Timber	M.Ft.B.M.	0.5
61-63-75	Radial gate with hoists	Lb.	931
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	53
40	Reinforced concrete	Cu. Yd.	67
44	Cement	Bbl.	84
45-46	Reinforcing steel	Lb.	6,700
71	36" Rein. conc. pipe	Lin. Ft.	1,015
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	33.71
98	Operation	Acre	3 875

ANGOSTURA DIVERSION DAM

Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	140
	EXCAVATION:		
1	Diversion of river during construction		Lump Sum
17a	Sand and gravel below El. 5076	Cu. Yd.	2,000
17	Sand and gravel above El. 5076	Cu. Yd.	8,500
18-18a	Loose rock all elevations	Cu. Yd.	500
	EMBANKMENT:		
34	Loose rock in main channel	Cu. Yd.	5,000
34	Hand placed pavement	Cu. Yd.	2,000
33	Sand and gravel from excavation	Cu. Yd.	4,500
	BACKFILL:		
33	Selected gravel	Cu. Yd.	450
33	Puddle	Cu. Yd.	1,000
	PILING:		
52	Round timber piles	Number	70
52	Round timber piles driving	Lin. Ft.	1,750
52	Timber sheet piling in place	M.Ft.B.M.	193
	CONCRETE:		
39	Floors (sluice, headgate and inclined concrete crest)	Cu. Yd.	1,500
39	Piers (sluice and headgate sec.)	Cu. Yd.	130
40	Decks (sluice and headgate sec.)	Cu. Yd.	100
39	Slope pavement	Cu. Yd.	40
40	Retaining walls and warps	Cu. Yd.	520
39	Cutoff walls rockfill section	Cu. Yd.	750
39	Cutoff walls concrete section	Cu. Yd.	250
	RIPRAP:		
29	Loose rock	Cu. Yd.	5,000
	REINFORCING STEEL:		
46	Bending and placing	Lb.	270,000
	METAL WORK: (Installing)		
75	6-20'x6.4' radial gates	Lb.	33,000
75	7-20'x2' slide gates	Lb.	7,000
75	Radial gate hoists	Number	6
75	Slide gate hoists	Number	7
75	Pipe handrail	Lit. Ft.	575
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	4,100
45	Reinforcing steel	Lb.	270,000
	Metal Work.		
61	6-20'x6.4' radial gates	Lb.	33,000
62	7-20'x2' slide gates	Lb.	7,000
63	Radial gate hoists	Number	6
63	Slide gate hoists	Number	7
65	Pipe handrail	Lin. Ft.	575
	PERMANENT IMPROVEMENTS:		
91	Buildings		Lump Sum

ALBUQUERQUE DIVISION

Summary of Quantities

Main Canal

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	412.1
2	Clearing and grubbing	Acre	10
3	Removal of buildings and structures	Mile	34.24
6	Fence alterations	Mile	34.24
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu. Yd.	864,131
14	Excavation earth team	Cu. Yd.	21,460
	HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	2,000
50-51	Timber	M.Ft.B.M.	90
52	Piling	Lin. Ft.	1,200
89	Woven wire guard rail	Lin. Ft.	800
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	853
50-51	Timber	M.Ft.B.M.	36.5
52	Piling	Lin. Ft.	876
	RIVER SIPHON:		
23-24-25	Excavation and backfill	Cu. Yd.	17,897
29	Riprap	Cu. Yd.	300
40	Reinforced concrete	Cu. Yd.	864
44	Cement	Bbl.	1,080
45-46	Reinforcing steel	Lb.	86,400
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	14,122
39	Plain concrete	Cu. Yd.	37.5
40	Reinforced concrete	Cu. Yd.	460
44	Cement	Bbl.	622
45-46	Reinforcing steel	Lb.	34,500
50-51	Timber	M.Ft.B.M.	208
71	24" Rein. conc. pipe	Lin. Ft.	1,840
61-62-63-75	Radial gate and slide gate with hoists	Lb.	26,404
	MAJOR DROPS:		
17	Excavation and backfill	Cu. Yd.	2,921
40	Reinforced concrete	Cu. Yd.	1,736
45-46	Reinforcing steel	Lb.	130,000
50-51	Timber	M.Ft.B.M.	56.
61-63-75	Radial gate with hoists	Lb.	39,960
44	Cement	Bbl.	2,170
	CONCRETE LINING:		
17	Excavation and backfill	Cu. Yd.	254
39	Plain concrete	Sq. Yd.	4,900
44	Cement	Bbl.	510
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	255
40	Reinforced concrete	Cu. Yd.	61
45-46	Reinforcing steel	Lb.	4,600

Albuquerque Main Canal (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	WASTEWAY STRUCTURES: (con't)		
50-51	Timber	M.Ft.B.M.	2
61-63-75	Radial gate with hoists	Lb.	1,862
44	Cement	Bbl.	76
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	10,125
29	Riprap	Cu. Yd.	132
39	Plain concrete	Cu. Yd.	460
40	Reinforced concrete	Cu. Yd.	360
44	Cement	Bbl.	1,025
45-46	Reinforcing steel	Lb.	36,000
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	34.24
98	Operation	Acre	33,930

ALBUQUERQUE DIVISION

Summary of Quantities

Laterals

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	473
2	Clearing and grubbing	Acre	18
3	Removal of buildings and structures	Mile	114.2
6	Fence alterations	Mile	114.2
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu. Yd.	873,560
14	Excavation earth team	Cu. Yd.	12,625
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	6
50-51	Timber	M.Ft.B.M.	6.2
52	Piling	Lin. Ft.	526
82	Steel guard rail	Lin. Ft.	198
	STATE HIGHWAY BRIDGES:		
17	Excavation and backfill	Cu. Yd.	300
50-51	Timber	M.Ft.B.M.	50
52	Piling	Lin. Ft.	1,200
89	Woven wire guard rail	Lin. Ft.	750
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	1,402
50-51	Timber	M.Ft.B.M.	248.2
52	Piling	Lin. Ft.	None
	RIVER SIPHON:		
23-24-25	Excavation and backfill	Cu. Yd.	12,107
40	Reinforced concrete	Cu. Yd.	612
44	Cement	Bbl.	765
45-46	Reinforcing steel	Lb.	61,200

Albuquerque Laterals (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	11,380
40	Reinforced concrete	Cu. Yd.	497
44	Cement	Bbl.	625
45-46	Reinforcing steel	Lb.	38,750
50-51	Timber	M.Ft.B.M.	461.3
61-62-75	Slide gates with hoists	Lb.	99,400
66	12″ Corrugated pipe (metal)	Lin. Ft.	2,800
66	15″ Corrugated pipe (metal)	Lin. Ft.	3,300
66	18″ Corrugated pipe (metal)	Lin. Ft.	1,590
	LATERAL HEADGATES:		
17	Excavation and backfill	Cu. Yd.	1,491
40	Reinforced concrete	Cu. Yd.	234
44	Cement	Bbl.	292
45-46	Reinforcing steel	Lb.	17,550
61-63-75	Radial gates with hoists	Lb.	15,964
	FLUMES:		
17	Excavation and backfill	Cu. Yd.	241
40	Reinforced concrete	Cu. Yd.	41.5
44	Cement	Bbl.	60
45-46	Reinforcing steel	Lb.	3,060
50-51	Timber	M.Ft.B.M.	90
52	Piling	Lin. Ft.	10,432
67	Metal flume	Lin. Ft.	3,550
39	Plain concrete	Cu. Yd.	6.4
	CONCRETE LINING:		
17	Excavation and backfill	Cu. Yd.	98
39	Plain concrete	Sq. Yd.	1,530
44	Cement	Bbl.	160
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	255
40	Reinforced concrete	Cu. Yd.	61
44	Cement	Bbl.	76
45-46	Reinforcing steel	Lb.	4,600
50-51	Timber	M.Ft.B.M.	2.0
61-63-75	Radial gates with hoists	Lb.	1,862
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	4,316
39	Plain concrete	Cu. Yd.	55
40	Reinforced concrete	Cu. Yd.	165
44	Cement	Bbl.	275
45-46	Reinforcing steel	Lb.	16,500
71	36″ Rein conc. pipe	Lin. Ft.	1,760
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	114.17

ISLETA DIVERSION DAM

Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase		Lump Sum
	EXCAVATION:		
1	Diversion of river during construction		Lump Sum
17a	Sand, gravel and clay below elevation 4883.0	Cu. Yd.	13,000
17	Sand, gravel and clay above elevation 4883.0	Cu. Yd.	2,500
18-18a	Loose rock all elevations	Cu. Yd.	200
19-19a	Solid rock all elevations	Cu. Yd.	100
	BACKFILL:		
33	Sand, gravel or clay	Cu. Yd.	7,800
33	Selected gravel	Cu. Yd.	700
	PILING:		
52	Round timber piles	Number	146
52	Round timber piles driving	Lin. Ft.	3,650
52	Timber sheet piling in place	M.Ft.B.M.	203
	CONCRETE:		
39	Floors (river section, headgates and transitions)	Cu. Yd.	3,200
40	Piers (river section and headgates)	Cu. Yd.	210
40	Decks (river section and headgates)	Cu. Yd.	140
39	Retaining walls	Cu. Yd.	320
	RIPRAP:		
29	Loose rock	Cu. Yd.	5,800
	REINFORCING STEEL:		
46	Bending and placing	Lb.	305,000
	METAL WORK: (Installing)		
75	15-20'x6.4' radial gates	Lb.	82,500
75	12-20'x2' slide gates	Lb.	12,000
75	Radial gate hoists	Number	15
75	Slide gate hoists	Number	12
75	Pipe handrail	Lin. Ft.	1,300
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	4,900
45	Reinforcing steel	Lb.	305,000
	Metal Work.		
61	15-20'x6.4' radial gates	Lb.	82,500
62	12-20'x2' slide gates	Lb.	12,000
63	Radial gate hoists	Number	15
63	Slide gate hoists	Number	12
65	Pipe handrail	Lin. Ft.	1,300
	PERMANENT IMPROVEMENTS:		
91	Buildings		Lump Sum

BELEN DIVISION

Summary of Quantities

Main Canals

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	862.2
2	Clearing and grubbing	Acre	10
3	Removal of buildings and structures	Mile	66
6	Fence alterations	Mile	66
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu. Yd.	2,283,400
8	Excavation earth team	Cu. Yd.	12,820
9	Excavation loose rock	Cu. Yd.	8,000
10	Excavation solid rock	Cu. Yd.	2,000
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	14
50-51	Timber	M.Ft.B.M.	31.1
52	Piling	Lin. Ft.	2,622
82	Steel guard rail	Lin. Ft.	988
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	800
50-51	Timber	M.Ft.B.M.	46
52	Piling	Lin. Ft.	600
89	Woven wire guard fence	Lin. Ft.	400
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	708
50-51	Timber	M.Ft.B.M.	29.2
52	Piling	Lin. Ft.	696
	RIVER SIPHON:		
23-24-25	Excavation and backfill	Cu. Yd.	3,480
40	Reinforced concrete	Cu. Yd.	506
44	Cement	Bbl.	632
45-46	Reinforcing steel	Lb.	50,600
	RAILROAD AND DRAIN SIPHONS:		
17	Excavation and backfill	Cu. Yd.	5,549
39	Plain concrete	Cu. Yd.	70
40	Reinforced concrete	Cu. Yd.	360
44	Cement	Bbl.	538
45-46	Reinforcing steel	Lb.	4,500
71	36″ Rein. conc. pipe	Lin. Ft.	252
95	Maintenance of railway traffic		Lump Sum
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	29,691
39	Plain concrete	Cu. Yd.	90
40	Reinforced concrete	Cu. Yd.	1,050
44	Cement	Bbl.	1,425
45-46	Reinforcing steel	Lb.	78,750
50-51	Timber	M.Ft.B.M.	415
71	24″ Reinforced concrete pipe	Lin. Ft.	4,200
61-63-75	Radial gates with hoists	Lb.	60,270
	MAJOR DROPS:		
17	Excavation and backfill	Cu. Yd.	2,080
39	Plain concrete	Cu. Yd.	500
40	Reinforced concrete	Cu. Yd.	825

Belen Main Canals (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	MAJOR DROPS: (con't)		
44	Cement	Bbl.	1,656
45-46	Reinforcing steel	Lb.	62,000
50-51	Timber	M.Ft.B.M.	305
61-63-75	Radial gates with hoists	Lb.	24,062
	HEADGATES:		
17	Excavation and backfill	Cu. Yd.	914
40	Reinforced concrete	Cu. Yd.	108
44	Cement	Bbl.	135
45-46	Reinforcing steel	Lb.	10,800
61-63-75	Radial gates with hoists	Lb.	9,500
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	4,486
39	Plain concrete	Cu. Yd.	164
40	Reinforced concrete	Cu. Yd.	581
44	Cement	Bbl.	1,035
45-46	Reinforcing steel	Lb.	56,600
50-51	Timber	M.Ft.B.M.	13
61-63-75	Radial gates with hoists	Lb.	30,143
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	12,363
39	Plain concrete	Cu. Yd.	170
40	Reinforced concrete	Cu. Yd.	500
44	Cement	Bbl.	838
45-46	Reinforcing steel	Lb.	50,000
71	36" Reinforced concrete pipe	Lin. Ft.	5,600
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	66
98	Operation	Acre	55,905

BELEN DIVISION

Summary of Quantities

Laterals

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	934
2	Clearing and grubbing	Acre	33
3	Removal of buildings and structures	Mile	148
6	Fence alterations	Mile	148
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu. Yd.	926,078
14	Excavation earth team	Cu. Yd.	74,650
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	15
50-51	Timber	M.Ft.B.M.	35.8
52	Piling	Lin. Ft.	3,030
82	Steel guard rail	Lin. Ft.	1,136

Belen Laterals (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	310
50-51	Timber	M.Ft.B.M.	50.5
52	Piling	Lin. Ft.	1,200
89	Woven wire guard rail	Lin. Ft.	750
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	700
50-51	Timber	M.Ft.B.M.	129
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	32,729
40	Reinforced concrete	Cu. Yd.	305
45-46	Reinforcing steel	Lb.	26,940
44	Cement	Bbl.	381
50-51	Timber	M.Ft.B.M.	824.8
66	12″ Corrugated metal pipe	Lin Ft.	5,104
66	15″ Corrugated metal pipe	Lin. Ft.	4,070
66	18″ Corrugated metal pipe	Lin. Ft.	3,670
62-63-75	Slide gates with hoists	Lb.	163,424
	DROPS:		
17	Excavation and backfill	Cu. Yd.	1,647
40	Reinforced concrete	Cu. Yd.	1,218
44	Cement	Bbl.	1,522
45-46	Reinforcing steel	Lb.	74,950
50-51	Timber	M.Ft.B.M.	21.6
61-63-75	Radial gates with hoists	Lb.	17,530
	LATERAL HEADGATES:		
17	Excavation and backfill	Cu. Yd.	2,316
40	Reinforced concrete	Cu. Yd.	324
44	Cement	Bbl.	405
45-46	Reinforcing steel	Lb.	21,600
61-63-75	Radial gates with hoists	Lb.	14,040
	CONCRETE LINING:		
17	Excavation and backfill	Cu. Yd.	247
39	Plain concrete	Sq. Yd.	4,720
44	Cement	Bbl.	491
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	574
40	Reinforced concrete	Cu. Yd.	130
44	Cement	Bbl	162
45-46	Reinforcing steel	Lb.	13,000
50-51	Timber	M.Ft.B.M.	4.6
61-63-75	Radial gates with hoists	Lb.	4,430
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	16,283
39	Plain concrete	Cu. Yd.	763
40	Reinforced concrete	Cu. Yd.	167
45-46	Reinforcing steel	Lb.	16,660
44	Cement	Bbl.	1,162
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	134.93

SAN ACACIA DIVERSION DAM

Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	Lump Sum
	EXCAVATION:		
1	Diversion of river during construction	Acre	Lump Sum
17a	Sand, gravel and clay below elevation 4661.30	Cu. Yd.	3,000
17	Sand, gravel and clay above elevation 4661.30	Cu. Yd.	18,000
18-18a	Loose rock all elevations	Cu. Yd.	500
19-19a	Solid rock all elevations	Cu. Yd.	200
17	Culvert excavation under railroad	Cu. Yd.	Lump Sum
	BACKFILL:		
33	Sand, gravel or clay	Cu. Yd.	1,000
33	Selected gravel	Cu. Yd.	250
	PILING:		
52	Round timber piles	Number	210
52	Round timber piles driving	Lin. Ft.	5,300
52	Timber sheet piling in place	M.Ft.B.M.	146
	CONCRETE:		
39	Floors (river section, headgates flume and transition)	Cu. Yd.	2,800
40	Piers (river section and headgates)	Cu. Yd.	400
40	Decks (river section and headgates)	Cu. Yd.	230
39	Retaining walls	Cu. Yd.	125
40	Culvert under railroad	Cu. Yd.	115
39	Slope pavement	Cu. Yd.	60
39	Counter weights	Cu. Yd.	50
	RIPRAP:		
29	Loose rock	Cu. Yd.	4,300
	REINFORCING STEEL:		
46	Bending and placing	Lb.	300,000
	METAL WORK: (Installing)		
75	31—20'x6.4' radial gates	Lb.	170,500
75	8—20'x2' slide gates	Lb.	8,000
75	Counter weight supports	Lb.	117,000
75	Radial gate hoists	Number	31
75	Slide gate hoists	Number	8
75	Pipe handrail	Lin. Ft.	1,700
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	4,800
45	Reinforcing steel	Lb.	300,000
	Metal Work.		
61	31—20'x6.4' radial gates	Lb.	170,500
62	8—20'x2' slide gates	Lb.	8,000
63	Counter weight supports	Lb.	117,000
63	Radial gate hoists	Number	31
63	Slide gate hoists	Number	8
65	Pipe handrail	Lin. Ft.	1,700
	PERMANENT IMPROVEMENTS:		
91	Buildings		Lump Sum

SOCORRO DIVISION

Summary of Quantities

Main Canal

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	338
2	Clearing and grubbing	Acre	94
3	Removal of buildings and structures	Mile	28
6	Fence alterations	Mile	28
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu .Yd.	626,000
9	Excavation loose rock	Cu. Yd.	2,500
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	4
50-51	Timber	M.Ft.B.M.	26
52	Piling	Lin. Ft.	2,195
82	Steel guard rail	Lin. Ft.	824
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	200
50-51	Timber	M.Ft.B.M.	9
52	Piling	Lin. Ft.	120
89	Woven wire guard rail	Lin. Ft.	80
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	990
50-51	Timber	M.Ft.B.M.	40
52	Piling	Lin. Ft.	960
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	7,381
39	Plain concrete	Cu. Yd.	87.5
40	Reinforced concrete	Cu. Yd.	980
44	Cement	Bbl.	1,335
45-46	Reinforcing steel	Lb.	73,575
50-51	Timber	M.Ft.B.M.	204
71	24" Reinforced concrete pipe	Lin Ft.	1,060
61-62-63-75	Slide and radial gates with hoists	Lb.	61,875
	MAJOR DROPS:		
17	Excavation and backfill	Cu. Yd.	2,609
40	Reinforced concrete	Cu. Yd.	608
44	Cement	Bbl.	761
45-46	Reinforcing steel	Lb.	45,600
50-51	Timber	M.Ft.B.M.	19.5
61-63-75	Radial gates with hoists	Lb.	13,579
	CONCRETE LINING:		
17	Excavation and backfill	Cu. Yd.	200
39	Plain concrete	Sq. Yd.	5,000
44	Cement	Bbl.	695
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	242
40	Reinforced concrete	Cu. Yd.	91
44	Cement	Bbl.	121
45-46	Reinforcing steel	Lb.	6,825
50-51	Timber	M.Ft.B.M.	2.8
61-63-75	Radial gates with hoists	Lb.	4,584

Socorro Main Canal (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	10,067
39	Plain concrete	Cu. Yd.	183
40	Reinforced concrete	Cu. Yd.	1,175
44	Cement	Bbl.	2,037
45-46	Reinforcing steel	Lb.	89,700
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	28
98	Operation	Acre	16,000

SOCORRO DIVISION

Summary of Quantities

Laterals

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	340.8
2	Clearing and grubbing	Acre	101.8
3	Removal of buildings and structures	Mile	55.73
6	Fence alterations	Mile	55.73
	CANAL EXCAVATION:		
8	Excavation earth machine	Cu. Yd.	226,712
	RAILROAD BRIDGES:		
50-51	Timber	M.Ft.B.M.	9.9
52	Piling	Lin. Ft.	835
82	Steel guard rail	Lin. Ft.	312
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	698
50-51	Timber	M.Ft.B.M.	25.5
52	Piling	Lin. Ft.	680
89	Woven wire guard rail	Lin. Ft.	240
	ARROYO SIPHONS:		
17	Excavation and backfill	Cu. Yd.	53
40	Reinforced concrete	Cu. Yd.	52
44	Cement	Bbl.	65
45-46	Reinforcing steel	Lb.	5,200
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	2,850
40	Reinforced concrete	Cu. Yd.	277
44	Cement	Bbl.	337.25
45-46	Reinforcing steel	Lb.	21,365
50-51	Timber	M.Ft.B.M.	165.3
66	12" Corrugated metal pipe	Lin. Ft.	1,620
66	15" Corrugated metal pipe	Lin. Ft.	260
66	18" Corrugated metal pipe	Lin. Ft.	1,296
61-62-75	Slide gates with hoists	Lb.	41,152
	LATERAL HEADGATES:		
17	Excavation and backfill	Cu. Yd.	1,063
40	Reinforced concrete	Cu. Yd.	85

Socorro Laterals (continued)

Specification Item	Description of Work or Material	Unit	Quantity
	LATERAL HEADGATES:		
44	Cement	Bbl.	106
45-46	Reinforcing steel	Lb.	6,375
61-63-75	Radial gates with hoists	Lb.	4,305
71	24″ Reinforced concrete pipe	Lin. Ft.	300
	WASTEWAY STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	39
40	Reinforced concrete	Cu. Yd.	9
44	Cement	Bbl.	11
45-46	Reinforcing steel	Lb.	675
50-51	Timber	M.Ft.B.M.	0.10
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	333
40	Reinforced concrete	Cu. Yd.	131
44	Cement	Bbl.	164
45-46	Reinforcing steel	Lb.	9,825
71	36″ Reinforced concrete pipe	Lin. Ft.	472
	OPERATION DURING CONSTRUCTION:		
92	Priming and puddling	Mile	55.73

COCHITI DIVISION

Summary of Quantities

Riverside Drains and Levees

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	43.5
2	Clearing and grubbing	Acre	20.
3	Removal of buildings and structures	Mile	2
6	Fence alterations	Mile	10.
	DRAIN AND LEVEE EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	536,350
14	Excavation earth team	Cu. Yd.	5,400
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	3,113
40	Reinforced concrete	Cu. Yd.	2.2
44	Cement	Bbl.	3
45-46	Reinforcing steel	Lb.	215
50-51	Timber	M.Ft.B.M.	12.
28	Dry rubble paving	Sq. Yd.	22
66	18″ Corrugated metal pipe	Lin. Ft.	65
66	24″ Corrugated metal pipe	Lin. Ft.	65
	WASTEWAY STRUCTURES:		
66-71	36″ Corrugated metal pipe or reinforced concrete pipe with flap gate	Lin. Ft.	600
	UNDERDRAINS AND CROSSING CULVERTS:		
71	36″ Reinforced concrete pipe	Lin. Ft.	300
29	Riprap	Cu. Yd.	500

COCHITI DIVISION

Summary of Quantities

Interior Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	88.7
2	Clearing and grubbing	Acre	15.0
3	Removal of buildings and structures	Mile	9.73
6	Fence alterations	Mile	9.73
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	350,359
14	Excavation earth team	Cu. Yd.	2,210
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	7
50-51	Timber	M.Ft.B.M.	9.1
52	Piling	Lin. Ft.	772
82	Steel guard rail	Lin. Ft.	290
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	400
50-51	Timber	M.Ft.B.M.	18
52	Piling	Lin. Ft.	240
89	Woven wire guard fence	Lin. Ft.	160
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	4,551
39	Plain concrete	Cu. Yd.	42
40	Reinforced concrete	Cu. Yd.	25.5
44	Cement	Bbl.	84.5
45-46	Reinforcing steel	Lb.	1,900
50-51	Timber	M.Ft.B.M.	69.2
52	Piling	Lin Ft.	210
67	Metal flume	Lin. Ft.	328
28	Dry rubble paving	Sq. Yd.	25
66	18″ Corrugated metal pipe	Lin. Ft.	78
66	24″ Corrugated metal pipe	Lin. Ft.	78
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	10,260
39	Plain concrete	Cu. Yd.	200
50-51	Timber	M.Ft.B.M.	5.2
71	36″ Reinforced concrete pipe	Lin. Ft.	1,440.0
44	Cement	Bbl.	250

ALBUQUERQUE DIVISION

Summary of Quantities

Albuquerque Riverside Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
6	Fencing alterations	Mile	59.4
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	1,979,934
14	Excavation earth team	Cu. Yd.	3,715
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	11
50-51	Timber	M.Ft.B.M.	20.7
52	Piling	Lin. Ft.	1,758
82	Steel guard rail	Lin. Ft.	658
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	655
40	Reinforced concrete	Cu. Yd.	50
44	Cement	Bbl.	62.5
45-46	Reinforcing steel	Lb.	5,000
50-51	Timber	M.Ft.B.M.	20
52	Piling	Lin. Ft.	320
89	Woven wire guard rail	Lin. Ft.	160
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	800
50-51	Timber	M.Ft.B.M.	36
52	Piling	Lin. Ft.	480
89	Woven wire guard rail	Lin. Ft.	320
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	20,226
28	Dry rubble paving	Sq. Yd.	130
39	Plain concrete	Cu. Yd.	6.5
40	Reinforced concrete	Cu. Yd.	17.0
44	Cement	Bbl.	29.5
45-46	Reinforcing steel	Lb.	1,300
50-51	Timber	M.Ft.B.M.	86.5
52	Piling	Lin. Ft.	152
66	18″ Corrugated metal pipe	Lin. Ft.	405
66	24″ Corrugated metal pipe	Lin. Ft.	375
67	Metal flume	Lin. Ft.	50
	WASTEWAY STRUCTURES:		
66-71	36″ Corrugated metal or reinforced concrete pipe with flap gates	Lin. Ft.	900
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	12,528
39	Plain concrete	Cu. Yd.	250
44	Cement	Bbl.	312.5
50-51	Timber	M.Ft.B.M.	5.28
71	36″ Reinforced concrete pipe	Lin. Ft.	1,440

ALBUQUERQUE DIVISION

Summary of Quantities

Interior Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	732
2	Clearing and grubbing	Acre	none
3	Removal of buildings and structures	Mile	55.34
6	Fence alterations	Mile	55.34
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	2,926,042
14	Excavation earth team	Cu. Yd.	34,600
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	23
50-51	Timber	M.Ft.B.M.	26
52	Piling	Lin. Ft.	2,196
82	Steel guard rail	Lin. Ft.	794
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	655
40	Reinforced concrete	Cu. Yd.	50
44	Cement	Bbl.	62.5
45-46	Reinforcing steel	Lb.	5,000
50-51	Timber	M.Ft.B.M.	20
52	Piling	Lin. Ft.	320
89	Woven wire guard rail	Lin. Ft.	160
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	7,686
50-51	Lumber	M.Ft.B.M.	305
52	Piling	Lin. Ft.	7,320
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	29,589
28	Dry rubble paving	Sq. Yd.	138
39	Plain concrete	Cu. Yd.	354
40	Reinforced concrete	Cu. Yd.	207.8
44	Cement	Bbl.	702.5
45-46	Reinforcing steel	Lb.	15,506
50-51	Timber	M.Ft.B.M.	423.2
52	Piling	Lin. Ft.	1,770
67	Metal flume	Lin. Ft.	2,777
66	18" Corrugated metal pipe	Lin. Ft.	415
66	24" Corrugated metal pipe	Lin. Ft.	415
	WASTEWAY STRUCTURE:		
66-71	36" Corrugated metal pipe or reinforced concrete pipe with flap gates	Lin. Ft.	300
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	10,398
39	Plain concrete	Cu. Yd.	250
44	Cement	Bbl.	312.5
50-51	Timber	M.Ft.B.M.	44
71	36" Reinforced concrete pipe	Lin. Ft.	1,200

BELEN DIVISION

Summary of Quantities

Belen Riverside Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
3	Removal of buildings and structures	Mile	29.6
6	Fence alterations	Mile	74.0
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	2,581,086
14	Excavation earth team	Cu. Yd.	940
	RAILROAD BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	1,200
50-51	Timber	M.Ft.B.M.	13
52	Piling	Lin. Ft.	1,440
82	Steel guard rail	Lin. Ft.	400
95	Maintenance of Railway traffic		Lump Sum
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	600
50-51	Timber	M.Ft.B.M.	27
52	Piling	Lin. Ft.	360
89	Woven wire guard rail	Lin. Ft.	240
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	756
50-51	Timber	M.Ft.B.M.	30
52	Piling	Lin. Ft.	720
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	39,924
28	Dry rubble paving	Sq. Yd.	155
40	Reinforced concrete	Cu. Yd.	16
44	Cement	Bbl.	20
45-46	Reinforcing steel	Lb.	1,240
50-51	Timber	M.Ft.B.M.	184.9
66	18" Corrugated metal pipe	Lin. Ft.	465
66	24" Corrugated metal pipe	Lin. Ft.	465
	WASTEWAY STRUCTURES:		
66-71	36" Corrugated metal or reinforced concrete pipe with flap gates	Lin. Ft.	1,500

BELEN DIVISION

Summary of Quantities

Interior Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	1,080
2	Clearing and grubbing	Acre	55.5
3	Removal of buildings and structures	Mile	74.73
6	Fence alterations	Mile	82.26
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	3,798,589
14	Excavation earth team	Cu. Yd.	46,015
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	8
50-51	Timber	M.Ft.B.M.	15.5
52	Piling	Lin. Ft.	1,320
82	Steel guard rail	Lin. Ft.	495
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	600
50-51	Timber	M.Ft.B.M.	27
52	Piling	Lin. Ft.	360
89	Woven wire guard rail	Lin. Ft.	240
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	8,694
50-51	Timber	M.Ft.B.M.	345
52	Piling	Lin. Ft.	8,280
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	53,986
39	Plain concrete	Cu. Yd.	524.8
40	Reinforced concrete	Cu. Yd.	308
44	Cement	Bbl.	1,041
45-46	Reinforcing steel	Lb.	23,000
50-51	Timber	M.Ft.B.M.	680.26
52	Piling	Lin. Ft.	2,654
67	Metal flume	Lin. Ft.	4,100
28	Dry rubble paving	Sq. Yd.	210
66	18″ Corrugated metal pipe	Lin. Ft.	630
66	24″ Corrugated metal pipe	Lin. Ft.	630
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	21,614
39	Plain concrete	Cu. Yd.	450
44	Cement	Bbl.	565
50-51	Timber	M.Ft.B.M.	8.8
71	36″ Reinforced concrete pipe	Lin. Ft.	2,400

SOCORRO DIVISION

Summary of Quantities

Socorro Riverside Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
2	Clearing and grubbing	Acre	12
6	Fence alteration	Mile	28
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	1,043,124
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	7
50-51	Timber	M.Ft.B.M.	13.2
52	Piling	Lin. Ft.	1,080
82	Steel guard rail	Lin. Ft.	405
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	200
50-51	Timber	M.Ft.B.M.	9
52	Piling	Lin. Ft.	120
89	Woven wire guard rail	Lin. Ft.	80
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	6,231
28	Dry rubble paving	Sq. Yd.	88
40	Reinforced concrete	Cu. Yd.	8.8
44	Cement	Bbl.	11
45-46	Reinforcing steel	Lb.	660
50-51	Timber	M.Ft.B.M.	12.5
66	18" Corrugated metal pipe	Lin. Ft.	265
66	24" Corrugated metal pipe	Lin. Ft.	265
	WASTEWAY STRUCTURES:		
66-71	36" Corrugated metal pipe or reinforced concrete pipe with flap gates	Lin. Ft.	900
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	2,080
39	Plain concrete	Cu. Yd.	50
44	Cement	Bbl.	62.5
50-51	Timber	M.Ft.B.M.	8.8
71	36" Reinforced concrete pipe	Lin. Ft.	240

SOCORRO DIVISION

Summary of Quantities

Interior Drains

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	386.6
2	Clearing and grubbing	Acre	108.3
6	Fence alterations	Mile	31.1
	DRAIN EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	1,348,664
14	Excavation earth team	Cu. Yd.	5,120
	RAILROAD BRIDGES:		
17	Excavation and backfill	Cu. Yd.	22
50-51	Timber	M.Ft.B.M.	40.8
52	Piling	Lin. Ft.	3,480
82	Steel guard rail	Lin. Ft.	1,300
	STATE HIGHWAY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	1,600
50-51	Timber	M.Ft.B.M.	144
52	Piling	Lin. Ft.	1,920
89	Woven wire guard rail	Lin. Ft.	1,280
	COUNTY BRIDGES:		
17-20	Excavation and backfill	Cu. Yd.	480
50-51	Timber	M.Ft.B.M.	21.6
52	Piling	Lin. Ft.	288
89	Woven wire guard rail	Lin. Ft.	192
	MINOR STRUCTURES:		
17	Excavation and backfill	Cu. Yd.	12,560
28	Dry rubble paving	Sq. Yd.	142
39	Plain concrete	Cu. Yd.	193
40	Reinforced concrete	Cu. Yd.	120.3
44	Cement	Bbl.	392
45-46	Reinforcing steel	Lb.	9,000
50-51	Timber	M.Ft.B.M.	196
52	Piling	Lin. Ft.	968
67	Metal Flume	Lin. Ft.	1,512
66	18" Corrugated metal pipe	Lin. Ft.	423
66	24" Corrugated metal pipe	Lin. Ft.	423
	UNDERDRAINS AND CROSSING CULVERTS:		
17	Excavation and backfill	Cu. Yd.	11,720
39	Plain concrete	Cu. Yd.	253
44	Cement	Bbl.	316
50-51	Timber	M.Ft.B.M.	4.8
71	36" Reinforced concrete pipe	Lin. Ft.	1,315

FLOOD PROTECTION AND RIVER CONTROL

Summary of Quantities

Cochiti, Albuquerque, Belen, and Socorro Divisions

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	9,000
2-4	Clearing and grubbing	Acre	2,510
	CHANNEL AND LEVEE EXCAVATION:		
11	Excavation earth machine	Cu. Yd.	340,000
30	Borrow earth machine	Cu. Yd.	1,797,200
30	Finishing	Lin. Ft.	924,800
65-75	Permeable jetties	Lin. Ft.	493,670
11-30-65-75	Maintenance of levees and jetties 4 years		Lump Sum

SILT CONTROL ON TRIBUTARIES

Summary of Quantities

Silt Control

Specification Item	Description of Work or Material	Unit	Quantity
	SILT CONTROL STRUCTURES:		
50-65-75	Permeable jetties on side arroyos	Number	299
50-65-75	Permeable jetties on Rio Puerco	Number	24
	Experimental structures		Lump Sum
	Planting, supervision and care of plantations		Lump Sum

Reference: "Erosion and Control of Silt on the Rio Puerco, New Mexico," by Kirk Bryan and George M. Post, Exhibit R-1.

LIST OF STRUCTURES AND WORK

Description of Work or Material	Feature	Unit	Quantity
DAMS:			
Storage	Irrigation system	Number	1
Diversion	Irrigation system	Number	4
CANALS			
Main	Irrigation system	Mile	153
Lateral	Irrigation system	Mile	356
DRAINS:			
Riverside	Drainage system	Mile	206
Interior	Drainage system	Mile	183
EXCAVATION:			
Main canals	Irrigation system	Cu. Yd.	4,211,711
Laterals	Irrigation system	Cu. Yd.	2,300,430
Riverside drains	Drainage system	Cu. Yd.	5,667,834
Interior drains	Drainage system	Cu. Yd.	8,511,099
Channel and levees	Flood control & river protection	Cu. Yd.	2,137,200

List of Structures and Work (continued)

Description of Work or Material	Feature	Unit	Quantity
RIGHT-OF-WAY:			
Canals and drains	Irrigation and drainage systems	Acre	6,194
River	Flood protection	Acre	9,000
Clearing and grubbing	Irrigation and drainage systems	Acre	492
Clearing and grubbing	Flood protection & river control	Acre	2,510
STRUCTURES:			
Railroad bridges	Irrigation and drainage systems	Number	32
Highway bridges	Irrigation and drainage systems	Number	64
County bridges	Irrigation and drainage systems	Number	323
Farm bridges	Irrigation and drainage systems	Number	1,418
River siphons	Irrigation system	Number	5(L.F.5200)
Arroyo, railroad and other siphons	Irrigation system	Number	8(L.F.3600)
Farm turnouts (main canals)	Irrigation system	Number	507
Farm turnouts (laterals)	Irrigation system	Number	2,786
Major drops	Irrigation system	Number	155
Minor drops	Irrigation system	Number	55
Lateral headgates	Irrigation system	Number	85
Flumes (major)	Irrigation system	Number	2(L.F.3850)
Flumes (minor)	Irrigation and drainage systems	Number	180(L.F.8100)
Sandtraps and wasteways	Irrigation system	Number	26
Underdrains and crossing culverts	Irrigation and drainage systems	Number	208
Measuring devices	Irrigation system	Number	8
Drain inlets	Drainage system	Number	172
Temporary	Irrigation and drainage systems	Number	170
Wasteway	Drainage system	Number	12
Permeable jetties	Flood control & river protection	Lin. Ft.	493,670
Permeable jetties	Silt control on tributaries	Number	323

DIVERSION DAMS

Condensed Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	RIGHT OF WAY:		
96	Purchase	Acre	Lump Sum
	EXCAVATION:		
1	Diversion of river during construction		Lump Sum
17a	Sand and gravel below specified elevation. Wet excavation	Cu. Yd.	19,500
17	Sand and gravel above specified elevation. Dry excavation	Cu. Yd.	30,000
18-18a	Loose rock all elevations	Cu. Yd.	4,200
19-19a	Solid rock all elevations	Cu. Yd.	300
	EMBANKMENT AND BACKFILL:		
29	Riprap	Cu. Yd.	15,800
33	Selected gravel, sand, or clay	Cu. Yd.	18,600
34	Loose rock in main channel and hand placed pavement	Cu. Yd.	7,000

DIVERSION DAMS
Condensed Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
	CONCRETE:		
39	Plain concrete	Cu. Yd.	1,841
40	Reinforced concrete	Cu. Yd.	11,015
	PILING:		
52	Round timber piles	Number	425
52	Round timber piles driving	Lin. Ft.	10,700
52	Timber sheet piling in place	M.Ft.B.M.	542
	REINFORCING STEEL:		
46	Bending and placing	Lb.	920,000
	METAL WORK: (Installing)		
75	Radial gates	Lb.	287,700
75	Slide gates	Lb.	30,800
75	Radial gate hoists	Number	52
75	Slide gate hoists	Number	27
75	Pipe handrail	Lin. Ft.	3,599
75	Steel foot bridge	Lb.	3,000
75	Counter weight supports	Lb.	117,000
50-51	Wooden bridge floor	F.B.M.	300
	MATERIALS FURNISHED BY CONSERVANCY DISTRICT:		
44	Cement	Bbl.	16,200
45	Reinforcing steel	Lb.	920,000
	Metal Work.		
61	Radial gates	Lb.	287,700
62	Slide gate	Lb.	30,800
63	Radial gate hoists	Number	52
63	Slide gate hoists	Number	27
63	Counter weight supports	Lb.	117,000
65	Steel foot bridge	Lb.	3,000
65	Pipe hand rail	Lin. Ft.	3,599
	PERMANENT IMPROVEMENTS:		
91	Buildings		Lump Sum

IRRIGATION SYSTEM

Condensed Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
96	Purchase of R. O. W.	Acre	3,722.34
2	Clearing and grubbing	Acre	281.80
3	Removal of buildings and structures	Mile	504.89
6	Fence alterations	Mile	504.89
8	Excavation earth machine	Cu. Yd.	6,369,986
9	Excavation loose rock	Cu. Yd.	18,100
10	Excavation solid rock	Cu. Yd.	2,500
14	Excavation earth team	Cu. Yd.	121,555
	Total Canal Excavation....................	....	6,512,141
*17-20	Excavation and backfill	Cu. Yd.	224,012
23-24-25	Excavation and backfill—river siphons	Cu. Yd.	50,977
29	Riprap	Cu. Yd.	2,398
39	Plain concrete	Cu. Yd.	2,686
39	Plain concrete	Sq. Yd.	17,596
40	Reinforced concrete	Cu. Yd.	18,610
44	Cement	Bbl.	29,078
45-46	Reinforcing steel	Lb.	1,533,030
50-51	Timber	M.Ft.B.M.	4,090.5
52	Piling	Lin. Ft.	30,662
61-62-63-75	Radial and slide gates with hoists	Lb.	688,244
66	12" pipe	Lin. Ft.	10,594
66	15" pipe	Lin. Ft.	8,334
66	18" pipe	Lin. Ft.	7,370
67	Metal flume	Lin. Ft.	3,900
71	24" Reinforced concrete pipe	Lin. Ft.	8,183
71	36" Reinforced concrete pipe	Lin. Ft.	9,549
80	Woven wire	Lin. Ft.	200
82	Steel guard rail	Lin. Ft.	3,728
89	Woven wire guard rail	Lin. Ft.	3,020
92	Priming and puddling	Mile	491.58
95	Maintenance of railway traffic		Lump Sum
98	Operation	Acre	120,010
96	Purchase of R. O. W.	Acre	2,331
2	Clearing and Grubbing	Acre	210.8
3	Removal of buildings and structures	Mile	171.4
6	Fence alterations	Mile	375.33
11	Excavation earth machine	Cu. Yd.	14,080,933
14	Excavation earth team	Cu. Yd.	98,000
	Total Drain Excavation....................	....	14,178,933
*17-20	Excavation and backfill	Cu. Yd.	263,184
28	Dry rubble paving	Sq. Yd.	910
29	Riprap	Cu. Yd.	500
39	Plain concrete	Cu. Yd.	2,573.3
40	Reinforced concrete	Cu. Yd.	805.6
44	Cement	Bbl.	4,227
45-46	Reinforcing steel	Lb.	62,821
50-51	Timber	M.Ft.B.M.	2,882.34
52	Piling	Lin. Ft.	38,528
66	18" pipe	Lin. Ft.	2,746
66	24" pipe	Lin. Ft.	2,716

*Excavation and backfill for structures.

DRAINAGE SYSTEM
Condensed Summary of Quantities

Specification Item	Description of Work or Material	Unit	Quantity
66-71	36″ pipe or reinforced concrete pipe with flap gate	Lin. Ft.	4,200
71	36″ Reinforced concrete pipe	Lin. Ft.	8,335
67	Metal flume	Lin. Ft.	8,767
82	Steel guard rail	Lin. Ft.	4,342
89	Woven wire guard rail	Lin. Ft.	2,833
95	Maintenance of Railway traffic		Lump Sum

PART II

ESTIMATES OF QUANTITIES AND COSTS

SECTION III

SUMMARY OF COST

TABLE 22

COMPARATIVE GENERAL SUMMARY OF COST

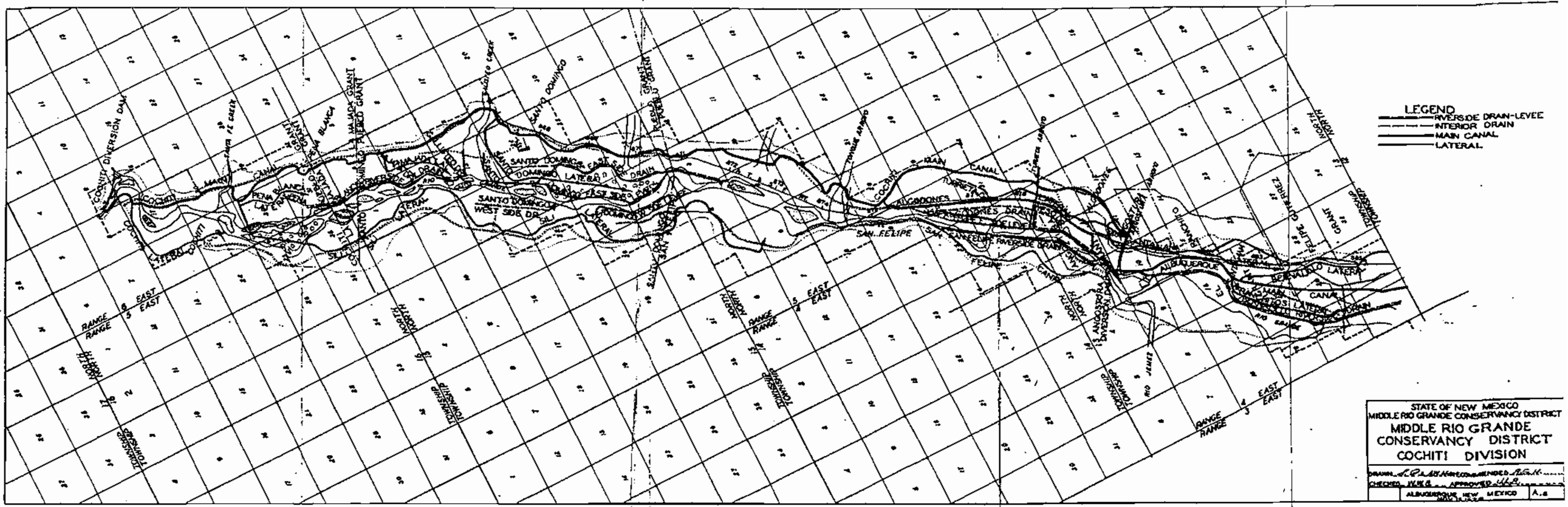
(See paragraph 384)

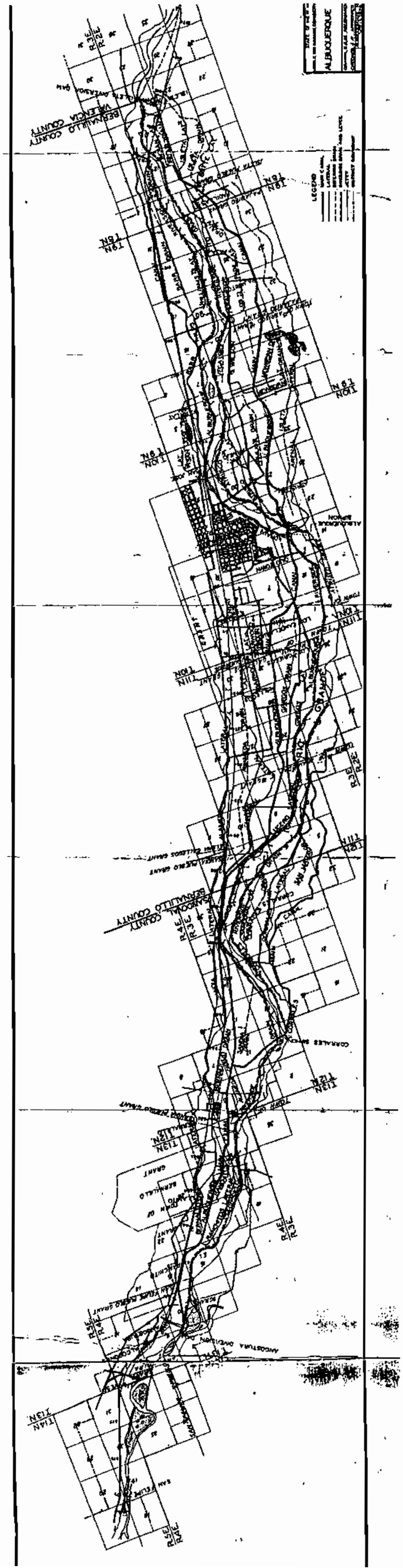
	Summary of Cost with Original Plan		Summary of Cost with Modified Plan		Decrease in Cost
El Vado Dam & Appurtenances		$ 1,317,560		$ 1,317,560	
Contingencies		164,303		164,303	
Irrigation.					
Cochiti Diversion Dam	$ 62,485		$ 62,485		
Cochiti (Division) Main Canal	190,313		190,313		
Cochiti (Division) Laterals	141,501		141,501		
Angostura Diversion Dam	154,707		154,707		
Albuquerque (Division) Main Canal	381,056		381,056		
Albuquerque (Division) Laterals	377,768		377,768		
Isleta Diversion Dam	182,541		182,541		
Belen (Division) Main Canal	648,740		648,740		
Belen (Division) Laterals	459,778		459,778		
San Acacia Diversion Dam	190,856		190,856		
Socorro (Division) Main Canal	459,357		265,457		
Socorro (Division) Laterals	152,084		110,313		
TOTAL COST OF IRRIGATION INCLUDING DIVERSION DAMS		3,401,186		3,165,515	$ 235,671
Contingencies		347,727		319,047	28,680
Drainage.					
Cochiti (Division) Riverside Drains and Levees	65,643		65,643		
Cochiti (Division) Interior Drains	72,990		72,990		
Albuquerque (Division) Riverside Drains	256,886		256,886		
Albuquerque (Division) Interior Drains	483,238		483,238		
Belen (Division) Riverside Drains	312,509		312,509		
Belen (Division) Interior Drains	604,320		604,320		
Socorro (Division) Riverside Drains	181,273		122,007		
Socorro (Division) Interior Drains	343,421		225,231		
TOTAL COST OF DRAINAGE		2,320,280		2,142,824	177,456
Contingencies		272,259		247,886	24,373
Flood Protection and River Control		1,461,745		1,322,554	139,191
Contingencies		359,092		323,453	35,639

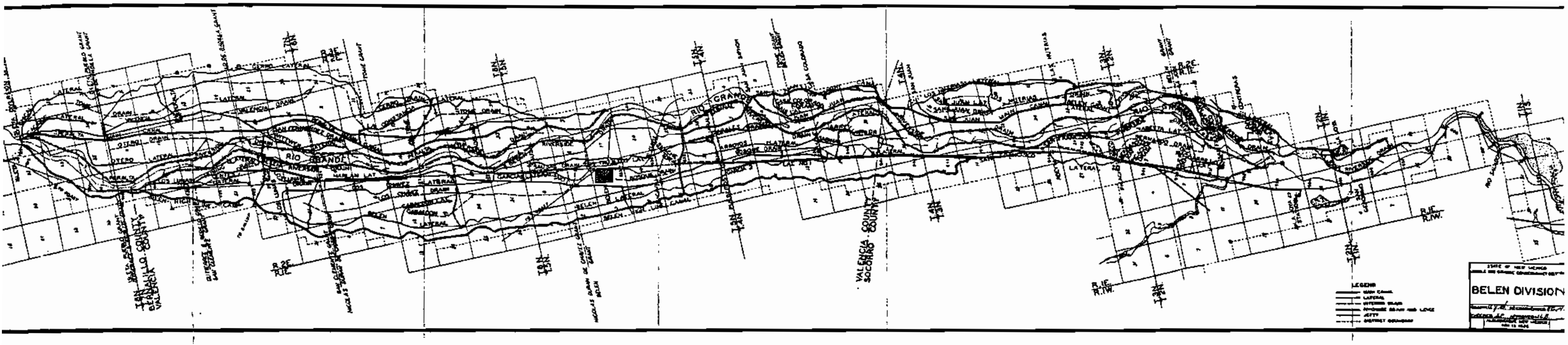
Table 22 (continued)

	Summary of Cost with Original Plan	Summary of Cost with Modified Plan	Decrease in Cost
Railroad Reconstruction (San Marcial)	268,700	None	268,700
Contingencies	56,427		56,427
Silt Control on Tributaries	444,935	86,956	357,979
Contingencies	46,936	8,239	38,697
Purchase and Protection of Water Rights	80,000	80,000	
Permanent Improvements (Telephone system, construction quarters, etc.)	50,000	50,000	
Preliminary Expense Including Organization to be Re-funded	325,000	325,000	
Field Engineering	367,156	315,878	51,278
General, Administrative and Legal	544,694	467,785	76,909
GRAND TOTAL COST	$11,828,000	$10,337,000*	$ 1,491,000

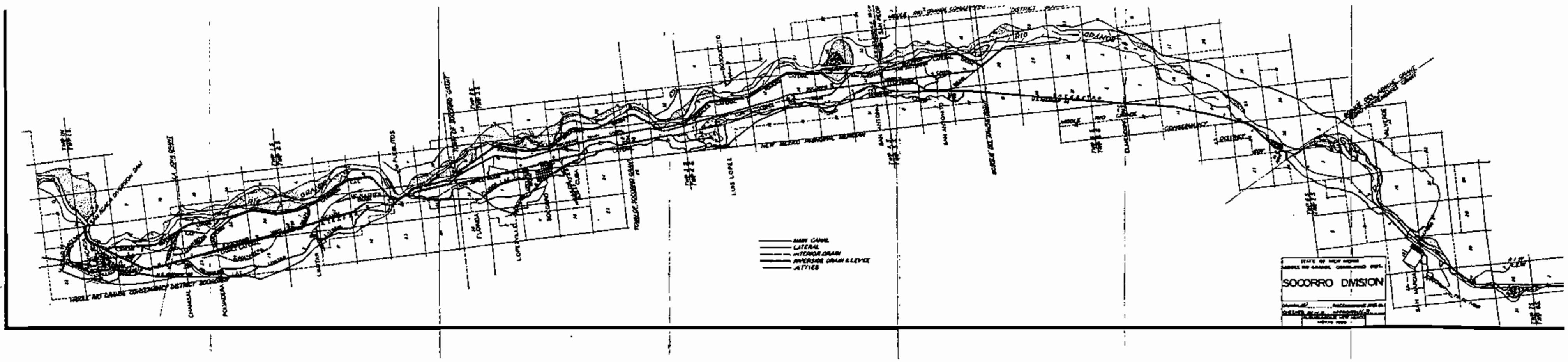
* Approved by the Court Aug. 15, 1928.


LEGEND
RIVERSIDE DRAIN-LEVEE
INTERIOR DRAIN
MAIN CANAL
LATERAL
STATE OF NEW MEXICO
MIDDLE RIO GRANDE CONSERVANCY DISTRICT
MIDDLE RIO GRANDE
CONSERVANCY DISTRICT
COCHITI DIVISION
ALBUQUERQUE, NEW MEXICO
A.6
COCHITI DIVERSION DAM
SANTA FE CREEK
PENA BLANCA
LA MAJADA GRANT
SANTO DOMINGO PUEBLO GRANT
GALISTEO CREEK
SANTO DOMINGO
SANTO DOMINGO WEST SIDE DR.
SAN FELIPE
ALGODONES
ANGOSTURA DIVERSION DAM
RIO JEMEZ
ALBUQUERQUE
BERNALILLO LATERAL
FELIPE GUTIERREZ GRANT
RANGE 6 EAST
RANGE 5 EAST
RANGE 4 EAST
RANGE 3 EAST
TOWNSHIP 17 NORTH
TOWNSHIP 16 NORTH
TOWNSHIP 15 NORTH
TOWNSHIP 14 NORTH
TOWNSHIP 13 NORTH





BELEN DIVISION
LEGEND
RIO GRANDE
VALENCIA COUNTY
SOCORRO COUNTY
BERNALILLO COUNTY
VALENCIA


SOCORRO DIVISION
MAIN CANAL
LATERAL
INTERIOR DRAIN
RIVERSIDE DRAIN & LEVEE
JETTIES
LUIS LOPEZ

STATE OF NEW MEXICO

MIDDLE RIO GRANDE CONSERVANCY DISTRICT

REPORT OF THE CHIEF ENGINEER

APPENDIX "A"

WATER SUPPLY STUDIES

by

R. G. Hosea

SUMMARY

The net irrigable area of the project as it appears in the Official Plan of the Conservancy District, as approved by the Court August 15, 1928, is as follows:

Cochiti Division	13,000 Acres
Albuquerque Division	37,205 Acres
Belen Division	57,399 Acres
Socorro Division	15,661 Acres
Total	123,265 Acres

Based on records of the Mesilla Valley (a part of the U. S. Rio Grande Project) the following assumptions are made:

(a) Total Annual Consumptive use of river water 3.9 acre feet per acre irrigated (includes river losses).

(b) Drainage return 2.4 acre feet per acre. (Except in Cochiti Division where drainage is not so necessary, and where the assumed return is less.)

(c) Delivery on lands 3.0 acre feet per acre.

(d) River losses, considered in addition to above, both by evaporation from water surface and by seepage to lands not included in District.

Irrigation season demand on Rio Grande at Buckman is estimated as follows:

March	10,000 Acre Feet
April	83,000 Acre Feet
May	91,000 Acre Feet
June	93,000 Acre Feet
July	98,000 Acre Feet
August	70,000 Acre Feet
September	34,000 Acre Feet
Total	479,000 Acre Feet

(October demand more than offset by return flow from drainage.)

For the purposes of this study the Buckman record is modified for Colorado irrigation conditions of 1927, as determined by Messrs. D. C. Henny, R. G. Hosea and A. W. Newcomer, engineers for New Mexico and Texas at the Rio Grande Compact Conference, Santa Fe, New Mexico, January 21 to February 14, 1929. This study was made under the direction of Mr. D. C. Henny, Consulting Engineer of Portland, Oregon.

Deficiencies of Buckman flow below project demands are made up by release from El Vado storage usually in July, August and September, as follows.

Year	Release from El Vado	
1897	74,000 Acre Feet	
1898	71,000 Acre Feet	
1899	176,000 Acre Feet	
1900	112,000 Acre Feet	—Shortage 58,000=12% of demand
1901	82,000 Acre Feet	
1902	61,000 Acre Feet	—Shortage 172,000=36% of demand
1903	79,000 Acre Feet	
1904	305,000 Acre Feet	—Shortage 186,000=39% of demand
1905	120,000 Acre Feet	
1906	18,000 Acre Feet	
1907	0	
1908	83,000 Acre Feet	
1909	33,000 Acre Feet	
1910	159,000 Acre Feet	
1911	25,000 Acre Feet	
1912	57,000 Acre Feet	
1913	135,000 Acre Feet	
1914	0	
1915	44,000 Acre Feet	
1916	23,000 Acre Feet	
1917	59,000 Acre Feet	
1918	113,000 Acre Feet	
1919	2,000 Acre Feet	
1920	24,000 Acre Feet	
1921	27,000 Acre Feet	
1922	107,000 Acre Feet	
1923	48,000 Acre Feet	
1924	98,000 Acre Feet	
1925	102,000 Acre Feet	
1926	114,000 Acre Feet	
1927	17,000 Acre Feet	

No depletion of the river is indicated by reason of middle valley project operations, even during a very dry series of years, such as that of 1898-1904. In years of full water supply for the middle valley a gain of about 57,000 acre feet to the river is estimated.

The inclusion of 10,000 acres of Rio Puerco valley land has the effect of increasing the El Vado shortages by about 5 per cent, but does not introduce additional shortages in other years and does not deplete the river at San Marcial below the amount which has been recorded.

The Rio Grande Compact between the States of Colorado, New Mexico and Texas, recently signed at Santa Fe, New Mexico, while temporary in its nature, may be of decided benefit to the middle valley particularly if the "Closed Basin Drain" and the "State Line Reservoir", therein contemplated, should be constructed.

WATER SUPPLY AND FUTURE OPERATING CONDITIONS OF MIDDLE RIO GRANDE CONSERVANCY DISTRICT

Foreword.

On April 16, 1926, the Middle Rio Grande Conservancy District entered into a contract with the United States Bureau of Reclamation, pursuant to which contract the Bureau carried on certain "studies of water supply, silt deposit and other problems affecting the Rio Grande."

On December 15, 1927, a report to the Chief Engineer of the Bureau was made by Engineers E. B. Debler and C. C. Elder under the title "Preliminary Report on Middle Rio Grande Valley Investigation—New Mexico". This report, hereinafter referred to as the Debler-Elder report, was filed with the District Court as Exhibit R-4 of the Official Plan of the Middle Rio Grande Conservancy District.

The Debler-Elder report, inter alia, considers the questions of water supply of the Conservancy District project and the effect of the future operations of the project upon the water supply of the Elephant Butte Reservoir. The latter consideration is naturally paramount with the Reclamation Bureau and with the District as well, since no material depletion of water supply of the Elephant Butte Reservoir could be allowed.

Since the Debler-Elder report was made, more data have become available with respect to:

(1) Consumptive use and drainage return in the Mesilla Valley.

(2) River depletions in Colorado.

(3) Area of Middle Rio Grande project, as determined by the Official Plan of the District, approved by the Court in August, 1928.

In order to make use of this additional information and to bring estimates of water supply, canal diversions, drainage return, reservoir operation and river depletions up to date, the following study and report is herewith submitted.

This study considers the subject from two different points of view:

(1) That of the water requirements of the project in connection with river flow at Buckman and storage at El Vado.

(2) That of the future effect of the middle valley project upon the river flow at San Marcial, and the water supply for the Elephant Butte Reservoir.

PART I

WATER REQUIREMENTS

Areas.

The Official Plan of the Middle Rio Grande Conservancy District, as approved by the Court August 15, 1928, contemplates the irrigation and drainage of 123,267 acres distributed among the four divisions as follows:

Cochiti Division	13,000 Acres
Albuquerque Division	37,205 Acres
Belen Division	57,399 Acres
Socorro Division	15,663 Acres
Total	123,267 Acres

The decision of the court fixing the southern limit of the District irrigation and drainage works at the north line of the Bosque del Apache Grant (except for an outlet drain extending a few miles south of this point) excludes areas south of this line. A few other areas are also excluded where the cost of irrigation and drainage would be prohibitive. The following tabulation lists the valley areas included in the District, as determined by District surveys and computations made in 1926, 1927 and 1928.

Table 23

Classification of areas included in District
(Data from Appraisal Dept. as of date Dec. 28, 1928)

Classification	Division				Total Acres
	Cochiti	Albuq.	Belen	Socorro	
Orchard, garden, alfalfa and grain	969	13,410	18,319	4,583	37,281
Pasture and hay	8	2,200	6,309	474	8,991
Total Irrigated	977	15,610	24,628	5,057	46,272
Salt grass	180	5,462	16,438	2,230	24,310
Bosque	176	3,239	4,340	7,274	15,029
Swamp and lake	5	772	899	873	2,549
Sand dunes	1	2,753	1,853	44	4,651
Gravel	18	350	50	110	528
Mesa and upland	41	1,560	4,631	47	6,279
Platted rural homesites	14	736	138	26	914
Total Unirrigated	435	14,872	28,349	10,604	54,260
*Indian Lands Cultivated	4,441	1,955	1,274	0	7,670
Not Cultivated	7,147	4,769	3,148	0	15,064
Total Indian Lands	11,588	6,724	4,422	0	22,734
Total Net Irrigable Area	13,000	37,205	57,399	15,661	123,266

The distribution and classification of Indian lands (*as shown in Table 23) is approximate only, but the total figure of 22,734 acres is considered to be correct. No data on other classification of Indian lands are available.

The areas shown are net areas and do not include rights-of-way for ditches, drains, roads, etc.

Table 24

Classification of all Valley Areas

Classification	Division				Total Acres
	Cochiti	Albuq.	Belen	Socorro	
Net Irrigable Area	13,000	37,205	57,399	15,661	123,266
(1) River channel—Cochiti to San Marcial	4,250	6,000	8,700	7,850	26,800
Bosquecito Area (excluded):					
Irrigated				114	
Salt grass and bosque				2,001	2,115
Pueblito Area (excluded):					
Salt grass and bosque				756	756
Bosque del Apache Grant, Val Verde and San Marcial Areas (excluded):					
Irrigated				1,095	
Non-irrigated				13,385	14,480
Area in cities and towns	0	2,850	240	160	3,250
(2) Rights-of-way, ditches, flood channel, etc.	1,000	3,656	5,380	4,512	15,048
(3) Areas between present high line ditches and hills	4,000	12,000	18,300	5,033	24,285
Total Valley					210,000

Notes: (1) "River channel" distributed by districts in proportion to length of river channel in each district. Assume 75% of channel in Socorro Division to be included in District (5,888 acres).
(2) Distribution by districts approximate only—total correct.
(3) Distribution by districts approximate only—total correct.

From the foregoing tabulation it is apparent that the project demand on the river at Buckman must include water for 1,200 acres of irrigated land, not included in the District; for losses from 24,838 acres of river channel above the south line of the district; for losses from 2,757 acres of salt grass and bosque situated above the south line of the District in excluded areas; and for losses from 15,048 acres listed as rights-of-way. Losses from land above present ditches assumed to be supplied from rainfall.

(In predicting the future effect of the project on the Elephant Butte Reservoir, it is necessary to take account also of the 13,385 acres of land, largely bosque and salt grass, lying between the north line of the Bosque del Apache Grant and San Marcial.)

Comparison Middle Rio Grande Valley with Mesilla Valley.

The middle Rio Grande valley is very similar to the Mesilla Valley in physical and climatic characteristics. The Mesilla Valley lies along the Rio Grande about 100 miles south of the lower end of the Middle Valley and forms part of the Federal Reclamation Bureau's

Rio Grande Project. It is irrigated by means of water from the Elephant Butte Reservoir and is drained by means of a system of open drainage ditches, similar to the system proposed for the Middle Valley. Very complete records of drainage return flow are available and records of river flow at both ends of the Mesilla Valley have been kept for many years.

It is, therefore, possible to compute the consumptive use of water in the Mesilla Valley and the amount of water returned to the river through the drains, and it seems fair to assume that in the Middle Valley these items will be proportional, or at least similar.

Table 25

Comparison of Mesilla and Middle Rio Grande Valleys

	Mesilla Valley	Middle Rio Grande Valley
Total Valley Area	109,000 Acres	210,000 Acres
Irrigated Area (av. 1923-1927)	66,300 Acres	123,600 Acres (Proposed)
Irrigated Area in per cent of Total Valley Area	62.3	59%
Mean Annual Temperature	60°	56°
Principal Crop	Cotton	Alfalfa(?)
Rainfall	8″ to 10″	8″ to 10″

The following tabulation (Table 26) summarizes the total annual consumptive use of river water in the Mesilla Valley during the last five years (1924-1928).

Table 26

Annual Consumptive Use of River Water in Mesilla Valley (Data from U. S. Bureau of Reclamation)

(1924)

Rio Grande at Leasburg	991,935 A. F.	
Rio Grande at Courchesne	799,070 A. F.	
Depletion	192,865 A. F.	
Irrigated Area	61,966 A.	
Consumptive Use		3.1 Acre Feet per Acre.

(1925)

Rio Grande at Leasburg	856,218 A. F.	
Rio Grande at Courchesne	633,622 A. F.	
Depletion	222,596 A. F.	
Irrigated Area	67,356 A.	
Consumptive Use		3.3 Acre Feet per Acre.

(1926)

Rio Grande at Leasburg	820,463 A. F.	
Rio Grande at Courchesne	556,836 A. F.	
Depletion	263,627 A. F.	
Irrigated Area	76,222 A.	
Consumptive Use		3.4 Acre Feet per Acre.

Table 26 (continued)

(1927)		
Rio Grande at Leasburg		873,522 A. F.
Rio Grande at Courchesne		619,566 A. F.
	Depletion	253,956 A. F.
Irrigated Area	73,314 A.	
Consumptive Use		3.5 Acre Feet per Acre.
(1928)		
Rio Grande at Leasburg		912,132 A. F.
Rio Grande at Courchesne		623,637 A. F.
	Depletion	288,495 A. F.
Irrigated Area	76,057 A.	
Consumptive Use		3.8 Acre Feet per Acre.

Average consumptive use of river water per acre irrigated during period 1924-1928 3.42 acre feet per acre. (Note that this figure includes all river losses.)

It is believed that with modification to allow for one dissimilar condition, this figure is also applicable to the middle Rio Grande valley. The dissimilar condition is the difference in the kind of crop and its possible greater use of water. In the Mesilla Valley the principal crop is cotton, while in the Middle Valley it is doubtful if much cotton will be raised, except perhaps in the southern part. Alfalfa and grains, which will probably be the preponderant crops of the Middle Valley, require more water than cotton. The figure of 3.42 acre feet per acre consumptive use for the Mesilla Valley has, therefore, been increased 15 per cent, making 3.9 acre feet per acre per annum as the estimated future consumptive use of river water in the middle Rio Grande valley. With an irrigated area of 123,265 acres, the river depletion should amount to 480,740 A.F. per year. (Compare with 478,296 as shown in Table 40.)

The monthly distribution of the irrigation demand is also based on the use of water in the Mesilla Valley, modified to take account of the somewhat shorter season in the Middle Valley. This distribution is the same as that assumed in the Debler-Elder report and is as follows:

January	0	March	3%	July	19%
February	0	April	17%	August	14%
November	0	May	19%	September	8%
December	0	June	19%	October	1%

Other Estimates of Consumptive Use and Losses.

In connection with the assumed figures for consumptive use it may be noted that in the Conkling-Debler report of 1919, in discussing use of water and losses on the Rio Grande Project, the following assumptions were made:

Plant Consumption	1.0 Acre Foot per Acre
Evaporation incidental to irrigation.	1.5 Acre Feet per Acre
Evaporation from uncultivated areas	0.35 Acre Feet per Acre
Consumptive use	2.85 Acre Feet per Acre

The figure for evaporation from uncultivated areas was based on the following assumptions:

Uncultivated Areas............ 10% of total
Waste Areas.................. 6% of total
Water Table.................. 6 ft. below surface
Evap. from water table 25% of evap. from free water surface.
Evap. from free water surface 7 ft. per year.
Annual evap. from uncultivated and waste areas 1.75 ft. per yr.
Same prorated on acreage basis—0.35 acre feet per acre.

Return flow through drains was estimated at 1.5 acre feet per acre. Recent records indicate about 2.4 acre feet per acre drainage return from the Mesilla Valley.

Headgate diversion was assumed to equal the consumptive use, 2.85 plus the drainage return, 1.5, or 4.35 acre feet per acre.

Transmission loss in the Franklin Canal and Laterals for the year 1918 was found to be 27 per cent of the diversion.

Loss from evaporation in the river was assumed to be 66.000 acre feet for the period February-November from a channel of 10,000 acres. Seepage loss from the river was assumed to be entirely recovered by the drains.

In the Debler-Walker report of 1924 and in the Hedke report of 1924, net consumptive use of water was estimated at 2.5 acre feet per acre per year for lands under the Rio Grande Project above El Paso, Texas.

Table 27

Mesilla Valley Drainage Discharge in Acre Feet
(Data from U. S. Rio Grande Project Office, El Paso, Texas)

Month	1923	1924	1925	1926	1927	Average	% of total
January	11,565	9,174	10,249	9,995	9,941	10,185	5.4
February	11,335	9,324	10.146	9,080	9,436	9,864	5.2
March	14,414	12,155	15,123	13,304	14,148	13,829	7.3
April	16,239	14,412	18,993	14,262	17,613	16,304	8.6
May	18,803	18,994	21,196	19,001	20,309	19,661	10.4
June	19,357	18,815	22,260	19.836	20,230	20,099	10.6
July	19,509	19,306	23,999	22,930	22,037	21,556	11.4
August	20,218	20,359	21,316	19,656	19,776	20,265	10.8
September	15,614	19,471	19,999	19,207	20,028	18,864	9.9
October	14,467	16,264	14,720	14,321	15.034	14,961	7.9
November	12,002	12,750	12,231	12,708	13,238	12,586	6.6
December	11,707	11,847	10,805	11,183	10,655	11,239	5.9
Total	185,230	182,871	201,037	185,174	192,446	189,413	100.0
Acres irrigated	51,801	61,966	67,356	76,222	73,314	66,330	
Second ft. per mile of drain	1.55	1.40	1.56	1.44	1.30	1.45	

Miles of drain Jan. 1, 1923—153.8, Jan. 1, 1928—201.4.
Total Valley Area—Mesilla Valley 109,000 acres.
Total Irrigable Area—Mesilla Valley 78,000 acres.
Based on total valley area, drain return=av. 1.75 Acre Feet per Acre.
Based on irrigable area, drain return=av. 2.4 Acre Feet per Acre.

Drainage return distribution, round figures:

January	5%	March	7%	July	11%
February	5%	April	9%	August	11%
November	7%	May	10%	Sept.	10%
December	6%	June	11%	Oct.	8%
	23% = Total Non-Irrigating Season.				77% = Total Irrigating Season.

Based on the above data the future drainage return from the middle Rio Grande valley has been estimated as follows:

Table 28

Estimated Drainage Return Middle Rio Grande Valley

Cochiti Division—20 miles of drain @ 1.5 A. F. per mile=30 Second Feet		
30 second feet =21,900 acre feet per year		21,900
Albuquerque Division—37,205 acres @ 2.4 A.F. per A.	=	89,292
Belen Division —57,399 acres @ 2.4 A.F. per A.	=	137,757
Socorro Division —15,663 acres @ 2.4 A.F. per A.	=	37,591
Estimated Total Annual Drainage Return		286,540

Of this amount the entire drainage return from the Socorro Division comes in below the lowest diversion dam and is, therefore, not subject to re-diversion and re-use on the project. This water will go to the Elephant Butte Reservoir, together with the winter flow of the drains of the other three divisions, as follows:

Table 29

Total Drainage Water to Elephant Butte Reservoir

Cochiti Division	Nov.-Feb.	23% of 21,900	5,037 Acre Feet
Albuquerque Division	Nov.-Feb.	23% of 89,292	20,537 Acre Feet
Belen Division	Nov.-Feb.	23% of 137,757	31,684 Acre Feet
Socorro Division	All	100% of 37,591	37,591 Acre Feet
Total			94,849 Acre Feet

River Channel Losses.

In accordance with evaporation losses from open water surfaces, as determined at the Los Griegos Station near Albuquerque during 1926 and 1927, river channel evaporation losses have been assumed at 4.6 feet per year. This includes average rainfall of 0.7 feet and, therefore, actual evaporation loss of river water will be as follows:

Cochiti Division	4250 A. @ 3.9	equal	16,575 A.F.
Albuquerque Division	6000 A. @ 3.9	equal	23,400 A.F.
Belen Division	8700 A. @ 3.9	equal	33,930 A.F.
Socorro Division	5888 A. @ 3.9	equal	22,963 A.F.
Below District and above San Marcial	1962 A. @ 3.9	equal	7,652 A.F.
Total	26,800 A.		104,520 A.F.

Losses from Salt Grass and Bosque Areas.

The evaporation losses from bosque and salt grass areas, as determined by the Los Griegos evaporation experiments, were as follows:

Bosque, water table 2′—4′ below surface—3.6
Salt grass, water table 1′—2′ below surface—3.5

Assuming the 2,757 acres excluded from the District above the Bosque del Apache Grant to be 50 per cent bosque and 50 per cent salt grass, with an average evaporation rate of 3.6 feet. (of which 0.7′ is supplied by rainfall) gives a water loss of 8,000 acre feet, all of which occurs in the Socorro Division.

Losses from Rights-of-Way, Towns, Etc.

Losses from rights-of-way, towns, roads, flood channels, etc., have been estimated at 3 acre feet per acre and are approximately distributed by divisions as follows:

Cochiti	1,000 A. @ 3.0	equal	3,000 A.F.
Albuquerque	6,506 A. @ 3.0	equal	19,518 A.F.
Belen	5,620 A. @ 3.0	equal	16,860 A.F.
Socorro	4,672 A. @ 3.0	equal	14,016 A.F.
Total	17,798 A.		53,394 A.F.

Consumptive Use.

The following tabulation shows the estimated future consumptive use of river water in the middle Rio Grande valley (rainfall deducted):

Table 30

Estimated Consumptive Use of River Water (Annual)

Acre Feet Per Year

Classification	Division				Total
	Cochiti	Albuq.	Belen	Socorro	Acres ft.
Conservancy District Lands 123,267 acres @ 3.0	39,000	111,615	172,197	46,989	369,801
Other Irrigated Lands 1,200 acres @ 3.0	....	....	....	3,600	3,600
River Channel Evaporation Losses 24,838 acres @ 3.9	16,575	23,400	33,930	22,963	96,868
Excluded areas 2,757 acres @ 2.9	....	....	....	8,000	8,000
Rights-of-Way, Etc. 17,798 acres @ 3.0	3,000	19,518	16,860	14,016	53,394
Total Project	58,575	154,533	222,987	95,568	531,663
Excluded Areas between project and San Marcial, 13,385 acres @ 2.9	....	....	....	....	38,817
River Channel between project and San Marcial, 1,963 acres @ 3.9	....	....	....	....	7,656
El Vado Reservoir Evaporation	....	....	....	....	9,000
Total Valley					587,136
Less Drainage Return (Socorro Div. entire year, Cochiti, Albuquerque and Belen Division Nov.-Feb. See Table 7)					94,849
Net Annual Consumptive Use, Entire Valley					492,287

(Compare with Debler-Elder figure of 544,000—See Debler Elder report page 108, par. 3)

Future valley losses determined by a somewhat different method are shown in Table 31.

Table 31

Estimated Future Losses Middle Rio Grande Valley

Classification	Av. Depth Water Table	Area Acres	Loss Feet	Loss Acre Feet Per Year
Irrigated Area	6′	123,600	3.0	370,800
River banks and bars	0′-2′	18,920	3.8	71,900
River open water	0	10,000	4.6	46,000
Unbenefited Area (Pueblito, Bosquecito, Val Verde and San Marcial)				
Irrigated	2′-4′	2,200	3.0	6,600
Unirrigated				
Bosque	2′-4′	5,600	3.6	20,100
Salt Grass	1′-2′	1,500	3.5	5,250
Swamp	0	70	7.0	500
Sand Dunes	0	200	1.0	200
*Other areas	Variable	43,910	3.0	131,730
Total Valley		206,000		653,080
Deduct rainfall of 0.71′ over 206,000 A.=				146,000
				507,080

*Including sand bars, mesa or upland, fallow, unirrigated homesites, road and ditch rights-of-way, areas above ditches and below foot of mesa slopes, etc.

Project Demand on River.

Assume application of 3 acre feet per acre on the lands for the irrigated areas and a transmission loss of 33 1/3 per cent. This gives a headgate diversion of 4.5 acre feet per acre for 123,267 acres=554,700 acre feet.

(The transmission loss of 1.5 acre feet per acre, or 184,900 acre feet will be partly lost by evaporation from rights-of-way, etc., and will be partly recovered through the drains.)

Assuming the headgate diversion for other irrigated lands not in the District to be 4.5 acre feet per acre gives 5,400 acre feet which must be carried in the river to supply such lands.

Channel and other losses shown in Table 30 are assumed to occur in the same monthly distribution as the evaporation rates found at the Los Griegos Station, viz.:

Jan.	1.8%	Mar.	7.8%	May	12.8%	July	13.9%	Sept.	9.6%	Nov.	4.6%
Feb.	4.1%	Apr.	9.8%	June	13.7%	Aug.	13.2%	Oct.	6.7%	Dec.	2.0%

(Debler-Elder report Table 32, p. 89)

From Table 30 and the above data, Table 32 is derived as follows:

Table 32

Irrigation Season Demand on River

(March-October)

Acre Feet

Diversions for District lands	554,700	Acre Feet
Diversions for lands not in District	5,400	Acre Feet
River channel losses	84,760	Acre Feet
Losses in excluded areas	7,000	Acre Feet
Losses in flood channel and other rights-of-way	46,720	
	698,580	
Redivertible Drainage (77% of total annual drainage return from Cochiti, Albuquerque and Belen Divisions)	191,730	
Net Demand	506,850	Acre Feet

Assuming a gain to the river between Buckman and the Middle Valley of 36,500 acre feet per year (see next paragraph), or 31,750 acre feet during the irrigation season, reduces the project demand on the river at Buckman to 475,100 acre feet.

Compare with Debler-Elder figure of 578,000 acre feet (See Debler-Elder report Table 18, p. 44, also this report Table 39.)

Return Flow Buckman to Bernalillo.

A number of measurements have indicated a considerable gain to the river between Buckman and Bernalillo, but the numerical amount of this gain has not been definitely determined, nor has it been fully identified as surface or sub-surface inflow. It seems likely that much of it may be surface drainage from the Pajarito Plateau to the west of White Rock Canyon.

For the purposes of this study an annual inflow of 36,500 acre feet (the equivalent of an average inflow of 50 second feet) is assumed to accrue to the Rio Grande between Buckman and the Middle Valley, distributed monthly in proportion to the monthly distribution of river flow at Buckman, as follows:

Table 33

Estimated Gain in Rio Grande between Buckman and Middle Valley

Month	Per Cent of Total	Acre Feet
January	3	1,095
February	3	1,095
March	6	2,190
April	13	4,745
May	28	10,220
June	20	7,300
July	7	2,555
August	4	1,460
September	4	1,460
October	5	1,825
November	4	1,460
December	3	1,095
Total		36,500

The following tabulations summarize future diversions, losses, drainage returns and river depletions by divisions.

Table 34

Diversions, River Loss, Drainage Return and River Depletion
Cochiti Division

(Irrgaible area—13,000 A. Delivery on lands 3 A. F. per acre. Headgate diversion 4.5 A. F. per acre. Net consumptive use—3 A. F. per acre. Drainage return 1.7 A.F. per acre. River channel and other losses 19,575 A. F.)

Month	Diversions		River Channel and Other Losses		Diversions plus Losses		River Gain Buckman to Middle Valley		Drainage Return		River Gain plus Drain. Return		River Depletion at head Albuq. Div.		Remarks
	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F	A.F.	S.F.	
March	1755	29	1527	25	3282	54	2190	36	1533	25	3723	61	–441	7	Gain
April	9945	166	1918	32	11863	198	4745	79	1971	33	6716	112	5147	86	Loss
May	11115	185	2506	42	13621	227	10220	170	2190	36	12410	207	1211	20	Loss
June	11115	185	2682	45	13797	230	7300	122	2409	40	9709	162	4088	68	Loss
July	11115	185	2799	46	13914	231	2555	42	2409	40	4964	82	8950	149	Loss
August	8190	136	2584	43	10774	179	1460	28	2409	40	3869	64	6905	115	Loss
September	4680	78	1879	31	6559	109	1460	28	2190	36	3650	61	2909	48	Loss
October	585	10	1312	22	1897	32	1825	30	1752	29	3577	60	–1680	–28	Gain
Nov.-Feb.	0	0	2368	10	2368	10	4745	20	5037	21	9782	41	–7414	–31	Gain
Total	58500		19575		78075		36500		21900		58400		19675		

Note: This table, by taking account of river gain between Buckman and the Middle Valley, makes depletion column and the demand apply to river at Buckman.

Table 35

Diversions, River Loss, Drainage Return and River Depletion

Albuquerque Division

Irrigable Area 37,205 acres.

Delivery on lands	3.0 A.F. per A. equals	111,615 A.F.
Headgate diversion	4.5 A.F. per A. equals	167,422 A.F.
Drainage return	2.4 A.F. per A. equals	89,292 A.F.
Net Consumptive use	3.0 A.F. per A. equals	111,615 A.F.
River channel and other losses		42,918 A.F.

Month	Diversions		River Channel and Other Losses		Diversions plus Losses		Drainage Return		River Depletion at head Belen Div.		Remarks
	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	
March	5022	84	3346	56	8368	140	6251	104	2117	35	Loss
April	28458	474	4210	70	32668	544	8037	134	24631	410	Loss
May	31806	530	5500	92	37306	622	8930	149	28376	473	Loss
June	31806	530	5900	98	37706	628	9823	164	27883	465	Loss
July	31806	530	5960	99	37766	629	9823	164	27943	466	Loss
August	23436	390	5670	95	29106	485	9823	164	19283	321	Loss
September	13392	223	4120	69	17512	292	8930	149	8582	143	Loss
October.	1696	28	2875	48	4571	76	7144	119	—2573	—43	Gain
Nov.-Feb.	0	0	5337	22	5337	22	20531	85	—15194	—63	Gain
Total	167422		42918		210340		89292		121048		

Table 36

Diversions, River Loss, Drainage Return and River Depletion

Belen Division

Irrigable Area 57,399 acres.

Delivery on lands	3.0 A.F. per A. equals	172,197 A.F.
Headgate diversion	4.5 A.F. per A. equals	258,295 A.F.
Drainage return	2.4 A.F. per A. equals	137,758 A.F.
Net consumptive use	3.0 A.F. per A. equals	172.197 A.F.
River channel and other losses		50,790 A.F.

Month	Diversions		River Channel and Other Losses		Diversions plus Losses		Drainage Return		River Depletion at head Socorro Div.		Remarks
	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	
March	7749	129	3962	66	11711	195	9646	160	2065	35	Loss
April	43911	732	4978	83	48889	815	12402	207	36487	608	Loss
May	49077	818	6502	108	55579	926	13780	229	41799	697	Loss
June	49077	818	6960	116	56037	934	15158	253	40879	681	Loss
July	49077	818	7062	118	56139	936	15158	253	40981	683	Loss
August	36162	603	6706	112	42868	715	15158	253	27710	462	Loss
September	20664	345	4877	81	25541	426	13780	229	11761	196	Loss
October	2578	43	3404	57	5982	100	11024	184	—5042	—84	Gain
Nov.-Feb.	0	0	6339	26	6339	26	31652	132	—25313	-106	Gain
Total	258295		50790		309085		137758		171327		

Table 37

Diversions, River Loss, Drainage Return and River Depletion

Socorro Division

Irrigable Area 15,663 acres.

Delivery on lands	3.0 A.F. per A. equals	46,989 A.F.
Headgate diversion	4.5 A.F. per A. equals	70,484 A.F.
Drainage return	2.4 A.F. per A. equals	37,590 A.F.
Net consumptive use	3.0 A.F. per A. equals	46,989 A.F.
River channel and other losses		50,379 A.F.

Month	Diversions		River Channel and Other Losses		Diversions plus Losses		Drainage Return		River Depletion in Socorro Division		Remarks
	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	
March	2100	35	3930	65	6030	100	2632	44	3398	56	Loss
April	11985	200	4937	82	16922	282	3384	56	13538	226	Loss
May	13395	223	6448	107	19843	331	3760	63	16083	268	Loss
June	13395	223	6902	115	20297	338	4136	69	16161	269	Loss
July	13395	223	7003	117	20398	340	4136	69	16262	271	Loss
August	9870	164	6650	111	16520	275	4136	69	12384	206	Loss
September	5640	94	4836	80	10476	175	3760	63	6716	112	Loss
October	704	12	3375	56	4079	68	3008	50	1071	18	Loss
Nov.-Feb.	0	0	6298	26	6298	26	8638	36	—2340	10	Gain
Total	70484		50379		120863		37590		83273		

Table 38

Annual Project Demand on River at Buckman

(From Tables 34, 35, 36, 37)

Month	River Depletion in Cochiti Div.		River Depletion in Albuq. Div.		River Depletion in Belen Div.		Diversions plus Losses in Socorro Div.		Demand on River at Buckman		Remarks
	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	A.F.	S.F.	
March	—441	7	2117	35	2065	35	6030	100	9771	163	Loss
April	5147	86	24631	410	36487	608	16922	282	83187	1386	Loss
May	1211	20	28376	473	41799	697	19843	331	91229	1520	Loss
June	4088	68	27883	465	40879	681	20297	338	93147	1552	Loss
July	8950	149	27943	466	40981	683	20398	340	98272	1638	Loss
August	6905	115	19283	321	27710	462	16520	275	70418	1173	Loss
September	2909	48	8582	143	11761	196	10476	175	33728	562	Loss
October	—1680	—28	—2573	—43	—5042	—84	4079	68	—5216	—87	Gain
Nov.-Dec.	—7414	—31	—15194	—63	—25313	-106	6298	26	—41623	-174	Gain
Total	19675		121048		171327		120863		432913		

Table 39

Irrigation Season Demand at Buckman

This Report			Debler-Elder Report Table 18, p. 44		
Month	% of Total	Acre Feet	Month	% of Total	Acre Feet
March	2	9,771	March	3	17,000
April	17	83,187	April	17	97,000
May	19	91,229	May	19	109,000
June	19	93,147	June	19	110,000
July	20	98,272	July	19	110,000
August	14	70,418	August	14	82,000
September	7	33,728	September	8	47,000
October	2	....	October	1	6,000
Total	100	479,752		100	578,000

(479,752—5,216 gain in Oct. = 474,536, Compare Table 32 this report)

Table 40

River Depletion Buckman to San Marcial

Month	Depletion Cochiti D.	Depletion Albuq. D.	Depletion Belen Div.	Depletion Socorro Div.	Depletion below Socorro Div.	River Gain	Net River Depletion
March	—441	2,117	2,065	3,398	3,625	2,190	12,954
April	5,147	24,631	36,487	13,538	4,554	4,745	89,102
May	1,211	28,376	41,799	16,083	5,948	10,220	103,637
June	4,088	27,883	40,879	16,161	6,366	7,300	102,677
July	8.950	27,943	40,981	16,262	6,459	2,555	103,150
Aug.	6,905	19,283	27,710	12,384	6,134	1,460	73,876
Sept.	2,909	8,582	11.761	6,716	4,461	1,460	35,889
Oct.	—1,680	—2,573	—5,042	1,071	3,113	1,825	—3,286
Nov.-Feb.	—7,414	—15,194	—25,313	—2,340	5,813	4,745	—39,703
Total	19,675	121,048	171,327	83,273	46,473	36,500	478,296

Add 9,000 acre feet estimated annual evaporation loss from El Vado reservoir gives 487,296 acre feet annual loss of water to the river compared with Debler-Elder figure of 544,000 acre feet (see Debler-Elder Report p. 108, par. 3).

(Note discrepancy of 5,000 acre feet between the total annual depletion of 487,296 acre feet, as shown in Table 40, and 492,287 acre feet, as shown in Table 30, due to excess of drainage over demands in October.)

PART II

WATER SUPPLY

Records.

A stream gaging station has been maintained at Buckman, on the Rio Grande, a few miles above the northern end of the middle Rio Grande valley since 1895. This station, for all practical purposes, measures the flow of the Rio Grande into the middle valley. The record covers the period 1895-1927, with the exception of a few breaks which have been filled in by comparison with records at Embudo and San Marcial.

The average flow at Buckman for the 33 years of record (including extensions) is 1,428,000 acre feet, with variations from a minimum of 425,000 acre feet in 1902, to a maximum of 2,359,000 acre feet in 1920.

The seasonal distribution of the average flow is as follows:

Table 41

Monthly Distribution of Flow of Rio Grande at Buckman

Month	Per Cent	Acre Feet	Av. Second Feet
January	3	42,800	713
February	3	42,800	713
March	6	85,600	1,427
April	13	185,600	3,093
May	28	400,000	6,667
June	20	285,600	4,760
July	7	100,000	1,667
August	4	57,100	952
September	4	57,100	952
October	5	71,400	1,190
November	4	57,200	952
December	3	42,800	713
Total	100	1,428,000	

This distribution of flow immediately suggests the necessity of storage for the purpose of regulation, and the large variations in annual flow indicate the necessity for hold-over storage as well.

The following table summarizes the flow of the Rio Grande at Buckman by months.

Table 42

Run-off of Rio Grande at Buckman, New Mexico
(Unit 1000 A. F.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1895	†34	33	84	338	284	276	109	91	43	42	50	44	1428
1896	37	35	81	207	166	32	25	15	18	29	30	30	705
1897	29	30	61	303	702	366	97	27	41	136	72	32	1896
1898	22	25	33	266	200	224	162	39	19	22	36	39	1087
1899	26	36	81	176	118	24	37	22	53	27	45	38	683
1900	37	32	53	52	212	173	18	10	43	24	25	29	708
1901	24	37	46	83	319	131	45	51	35	30	28	29	858
1902	30	27	34	98	74	28	17	34	29	17	18	19	425
1903	23	25	75	172	407	709	137	27	22	22	25	24	1668
1904	21	24	21	27	24	17	15	92	148	253	49	35	726
1905	44	52	158	219	785	573	54	39	23	26	38	38	2049
1906	*35	*34	*49	*161	*539	*476	*167	*66	*58	*112	*69	*50	1816
1907	*51	*49	*96	*334	*531	*754	*610	*197	*137	*74	*45	*41	2919
1908	*41	*41	*85	*145	*167	*128	*48	*78	*47	*44	*34	*33	891
1909	*37	*38	*65	*207	*557	*492	95	90	203	81	29	36	1930
1910	37	31	200	305	426	130	11	22	*17	*11	34	32	1256
1911	48	42	92	150	408	340	350	70	64	336	132	78	2110
1912	49	43	95	139	701	*560	*96	53	38	38	38	33	1883
1913	34	36	49	146	180	112	38	17	26	50	49	35	772
1914	41	43	90	170	373	259	140	117	83	87	56	36	1495
1915	†34	†38	†67	†250	†460	†475	92	71	43	40	36	39	1645
1916	44	50	194	266	551	325	99	132	51	†154	95	56	2017
1917	42	42	65	163	312	455	196	38	28	25	37	35	1438
1918	33	33	68	71	185	136	66	26	†43	†32	†37	45	775
1919	36	34	86	315	570	201	138	89	36	53	54	54	1666
1920	49	78	86	142	860	705	184	60	37	47	63	48	2359
1921	45	47	102	72	259	672	108	192	95	47	50	54	1743
1922	54	50	76	107	401	369	82	21	14	16	35	42	1267
1923	44	47	57	95	397	261	58	82	118	138	98	70	1465
1924	45	61	61	368	684	204	55	31	24	29	42	49	1653
1925	49	52	86	160	114	48	58	60	43	64	60	52	846
1926	50	46	†76	†175	†446	†335	49	20	23	25	34	38	1317
1927	35	40	67	177	436	224	186	53	157	131	72	53	1630

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Modification of Buckman Record to Take Account of Increasing Use of Water by Colorado.

During the period covered by the Buckman record (1895-1927) Colorado has continuously and progressively depleted the flow of the Rio Grande across the Colorado-New Mexico interstate line by reason of increasing diversion and storage of water in Colorado. This fact is of importance in any studies of water supply for projects in New Mexico, for the reason that under present conditions of development in Colorado the river flow would have been less than the records indicate.

The numerical amounts of these depletions are difficult of ascertainment and are somewhat dependent upon the judgment of the indi-

* From Embudo record by means of relation graphs, Plates L. M. N. & P.
† Rio Grande at Embudo plus Chama at Chamita (mouth).
Unmarked quantities from U. S. G. S. water supply paper No. 358 and from compilation by State Engineer.

vidual. A number of determinations have been made by various engineers at different times. The most recent and perhaps the most thorough determination of Colorado depletions was made by Messrs. D. C. Henny, R. G. Hosea and A. W. Newcomer, engineers for New Mexico and Texas at the Rio Grande Compact Conference in Santa Fe, New Mexico, in February, 1929. This study was made under the direction of Consulting Engineer, D. C. Henny.

For the purposes of this study the flow of the Rio Grande at Del Norte plus the flow of the Rio Conejos at Mogote was considered as "inflow" to the San Luis Valley in Colorado. The record of flow at the "Lobatos" or "Interstate Line" station was considered as outflow. Inflow was plotted against outflow, by months, for three periods viz. 1900-1910, 1911-1920, and 1921-1928. While the points so plotted scattered somewhat they, nevertheless, define three curves which were adjusted so that the deviations of the points from the curves balanced.

These three curves indicate a progressive change of relationship between inflow and outflow. By considering each curve as representing this relationship as of the average or mean year of its time period, the rate of change of relationship (depletion or repletion) was obtained and depletions up to 1927 and back to 1900 were computed. From this data and records of inflow the depletions for each month during the period of record have been computed, as shown in the following table.

Table 43

Colorado Depletions, 1927 Condition

(Values marked * to be added, other values to be subtracted)
Unit 1000 A. F.

Year	Total	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900	68	*6	*13	*22	*3	89	51	1	1	4	*4	*19	*11
1901	55	*6	*13	*17	*2	82	32	1	3	7	*4	*18	*10
1902	*37	*6	*12	*17	0	23	1	0	1	4	*4	*17	*10
1903	154	*5	*12	*17	2	81	77	44	6	8	*5	*16	*9
1904	*11	*5	*12	*15	3	19	1	0	19	9	*7	*15	*8
1905	132	*5	*11	*16	6	82	68	20	8	6	*5	*14	*7
1906	162	*4	*11	*15	12	80	61	42	14	9	*7	*12	*7
1907	199	*4	*11	*15	12	62	58	57	54	9	*6	*11	*6
1908	79	*4	*11	*14	15	33	33	15	26	6	*5	*10	*5
1909	141	*4	*10	*12	17	67	44	27	23	9	*7	*9	*4
1910	74	*3	*10	*13	24	66	20	1	2	4	*5	*8	*4
1911	159	*3	*10	*11	24	64	37	43	25	8	*8	*7	*3
1912	110	*3	*10	*10	14	67	24	27	9	6	*6	*6	*2
1913	55	*2	*9	*8	18	43	12	6	2	6	*7	*5	*1
1914	106	*2	*9	*8	13	48	20	25	23	8	*8	*4	0
1915	80	*2	*9	*7	23	23	16	23	16	7	*7	*3	0
1916	132	*2	*8	*7	35	47	14	24	31	7	*8	*2	1
1917	80	*2	*8	*6	22	21	15	23	16	5	*5	*2	1
1918	43	*1	*7	*5	13	23	9	8	4	5	*5	*2	1
1919	88	*1	*6	*5	28	38	8	14	14	4	*4	*2	0
1920	71	*1	*5	*4	9	36	11	16	12	3	*4	*2	0
1921	64	*1	*5	*4	12	24	9	14	16	4	*4	*1	0
1922	54	*1	*4	*3	10	26	7	9	10	3	*2	*1	0
1923	44	*1	*3	*2	9	19	5	8	10	3	*3	*1	0
1924	31	0	*2	*2	10	15	4	5	2	1	*1	*1	0
1925	18	0	*1	*1	7	7	2	3	2	1	*2	0	0
1926	8	0	*1	*1	2	3	1	2	2	0	0	0	0
1927	0	0	0	0	0	0	0	0	0	0	0	0	0
1928	*6	0	1	1	*2	*4	*1	*1	0	0	0	0	0
Total	2153	*74	*222	*256	333	1184	639	457	351	146	*133	*188	*84

Table 44

Run-Off of Rio Grande at Buckman, New Mexico, Corrected for Colorado Depletions as of 1927

Year	Total	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900	640	43	45	75	55	123	122	17	9	39	28	44	40
1901	803	30	50	63	85	237	99	44	48	28	34	46	39
1902	462	36	39	51	98	51	27	17	33	25	21	35	29
1903	1514	28	37	92	170	326	632	93	21	14	27	41	33
1904	737	26	36	36	24	5	16	15	73	141	260	64	43
1905	1917	49	63	174	213	703	505	34	31	17	31	52	45
1906	1654	39	45	64	149	459	415	125	52	49	119	81	57
1907	2720	55	60	111	322	469	696	553	143	128	80	56	47
1908	812	45	52	99	130	134	95	33	52	41	49	44	38
1909	1789	41	48	77	190	490	448	68	67	192	88	38	40
1910	1182	40	41	213	281	360	110	10	20	13	16	42	36
1911	1951	51	52	103	126	344	303	307	45	56	344	139	81
1912	1773	52	53	105	125	634	536	69	44	32	44	44	35
1913	717	36	45	57	128	137	100	32	15	20	57	54	36
1914	1389	43	52	98	157	325	239	115	94	75	95	60	36
1915	1565	36	47	74	227	437	459	69	55	36	47	39	39
1916	1885	46	58	201	231	504	311	75	101	44	162	97	55
1917	1358	44	50	71	141	291	440	173	22	23	30	39	34
1918	732	34	40	73	58	162	127	58	22	38	37	39	44
1919	1578	37	40	91	287	532	193	124	75	32	57	56	54
1920	2288	50	83	90	133	824	694	168	48	34	51	55	48
1921	1679	46	52	106	60	235	663	94	176	91	51	51	54
1922	1213	55	54	79	97	375	362	73	11	11	18	36	42
1923	1421	45	50	59	86	378	256	50	72	115	141	99	70
1924	1622	45	63	63	358	669	200	50	29	25	30	43	49
1925	828	49	53	87	153	107	46	55	58	42	66	60	52
1926	1327	50	47	77	173	443	334	47	18	23	25	34	38
1927	1631	35	40	67	177	436	224	186	53	157	131	72	53
Total	39187	1186	1395	2556	4445	10196	8643	2752	1498	1535	2139	1570	1272

***"Discharge Record at El Vado Reservoir Site.**

"Records of monthly discharges are available at the damsite for eight years of the period 1913 to 1924. A continuous record has been secured on the Chama, at its mouth near Chamita, since 1913. A gaging station is maintained at present at Park View, 15 miles above the damsite, with past records for 1913, 1914, 1915 and 1925. The El Vado record, missing for 1913 and 1925, was estimated by adding to the Park View discharge 15% of the gain between Park View and Chamita, this being the average per cent of the gain shown by the 1914 and 1915 records available at all three stations.

"Other missing records have been estimated by use of the curves on plate 24, which show the relation between the flow at El Vado and at Chamita for the four months periods, November to February, March to June, and July to October. Prior to 1913 it was necessary to use the

* Note: Quotation from the Debler-Elder Report p. 150-151. The diagrams mentioned **are not** reproduced in this report.

gain in the Rio Grande from Embudo to Buckman as the basis of the estimate. The total obtained from the curves on plate 24 was distributed among the months in proportion to the monthly flow at Chamita.

"The use of the Embudo-Buckman gain instead of the Chamita discharge, when the latter is not available, is justified by the curves on plate 25. The annual discharges of the Chama at Chamita are plotted for the period of record in a descending order of magnitude for comparison with the Embudo-Buckman gains also plotted. Several small tributaries enter the Rio Grande between Embudo and Buckman, in addition to the Rio Chama, but their flow is largely offset by diversions from the river.

"As shown, the discharge of the Rio Chama at Chamita is practically the same as the river gains, the only considerable variation having been in 1924.

"The monthly inflows to the El Vado reservoir site, both measured and estimated, are listed in Table 53 from 1898 to 1926. Estimates were not computed for the years 1906 to 1909 as during these years no records were secured at Chamita, Buckman or Embudo. Estimates of the Embudo flow made by comparison with the record at Lobatos show these to have been years of above normal runoff, however, so that no shortage could have occurred at El Vado during these years."

Table 45

Run-Off of Chama at El Vado

Unit 1000 A. F.

(This table is Table 53 p. 148-149 of Debler-Elder Report)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1897	2	3	19	145	265	65	10	3	11	22	2	0	547
1898	0	0	0	93	51	13	3	9	0	4	6	6	185
1899	0	4	29	94	49	8	11	5	21	3	7	5	236
1900	5	3	14	23	62	27	1	0	22	6	2	2	167
1901	1	3	12	39	109	25	12	14	8	6	4	1	234
1902	1	1	1	58	25	2	5	14	11	2	3	2	125
1903	2	2	18	76	176	116	30	3	1	1	1	2	428
1904	1	2	0	2	8	1	0	25	46	48	7	2	142
1905	4	8	57	103	177	0	15	10	3	4	5	4	390
1906													
1907													
1908													
1909							18	20	3	5	0	0	
1910	0	0	72	96	96	31	0	0	0	0	3	1	299
1911	6	4	40	77	165	0	17	6	4	35	24	12	390
1912	3	4	20	32	161	63	13	10	12	5	3	2.0	328
1913	2.0	2.7	5.0	52.3	88.2	28.5	5.5	2.5	3.5	5.1	3.3	3.6	202.2
1914	3.4	3.6	9.4	54.7	132.0	53.6	14.2	7.5	7.6	14.6	6.4	4.4	311.4
1915	4.0	3.3	10.9	78.0	123.0	94.6	18.2	8.0	4.0	2.7	1.3	3	351.0
1916	4	5	80	135	170	86.9	21.7	15.9	6.0	15.	4	4	547.5
1917	4	17	16	62	105	101	27	6	2	1	2	3	346
1918	2	3	20	34	91	32	19	3	4	4	2	3	217
1919	3	2	26	104	153	39	39	12	2	6	3	3	392
1920	3.	10	32.6	59.4	183.0	127.0	56.7	18.0	4.0	4.4	4.5	2.4	505.0
1921	3.1	4.3	13.0	21.9	119.0	68.3	11.7	19.7	7.8	5.8	3.6	2.8	281.0
1922	3.0	4.8	31.4	59.3	197.0	60.5	7.2	4.3	2.9	3.0	4.2	6.1	383.7
1923	7.3	7.8	10.5	36.7	148.8	61.5	12.6	13.7	23.8	15.2	8.5	4.9	351.3
1924	6.8	9.7	36.0	105.1	178.3	47.3	12.4	4.1	2.0	4.2	3.3	3.4	412.6
1925	4.4	3.0	14.6	76.2	57.4	18.7	7.8	11.3	5.8	13.4	8.6	7.7	228.9
1926	5	4	9	75	174	95	15	10	2	2	2	3	396

Record for periods 1898 to Nov. 1912, Dec. 1915 to April, 1916, Oct. 1916 to Feb. 1920, and Jan. to Dec. 1926, estimated by comparison with flow of Rio Chama at Chamita when available (after 1912); otherwise with Rio Grande gain from Embudo to Buckman.

Record for periods Dec. 1912 to Sept. 1913, and Jan. to Dec. 1925, estimated by adding to Park View flow 15% of gain between Park View and Chamita.

Operation El Vado Reservoir.

From Table 39 the project demand on the river at Buckman in round figures is as follows (in 1000 acre foot units):

March	9.8 A.F.	July	98.3 A.F.
April	83.2 A.F.	Aug.	70.4 A.F.
May	91.2 A.F.	Sept.	33.7 A.F.
June	93.1 A.F.		
		Total	479,000 A.F.

Buckman record depleted as of 1927.

Capacity of reservoir 198,000 acre feet.

Reservoir losses 2,000 acre feet per month while filling or full.

Water to be released from El Vado only to extent necessary to maintain flow at Buckman equal to project demand.

Reservoir assumed empty April 1, 1897.

Table 46

Operation El Vado Reservoir

(Unit 1000 A.F.)

Year	Month	Buckman Flow	El Vado Flow	El Vado Release	El Vado Loss	El Vado Content	Shortage	Spill
1897	April	268	145		2	143		
	May	584	265		2	198		208
	June	269	65		2	198		63
	July	70	10	28	0	170		
	Aug.	24	3	46	0	124		
	Sept.	38	11		2	126		
	Oct.-Mar.	378	24		12	138		
1898	April	198	93		2	198		31
	May	133	51		2	198		49
	June	118	13		2	198		11
	July	82	3	16	0	182		
	Aug.	32	9	38	0	144		
	Sept.	17	0	17	0	127		
	Oct.-Mar.	256	49		12	164		
1899	April	160	94		2	198		58
	May	104	49		2	198		47
	June	26	8	67	0	131		
	July	37	11	61	0	70		
	Aug.	22	5	48	0	22		
	Sept.	51	21		2	37		
	Oct.-Mar.	235	32		12	57		
1900	April	55	23	28	0	29		
	May	123	62		2	59		
	June	122	27		2	84		
	July	17	1	81	0	3		
	Aug.	9	0	3	0	0	58=12%	
	Sept.	39	22		2	3		
	Oct.-Mar.	255	26		12	17		
1901	April	85	39		2	17		
	May	237	109		2	124		
	June	99	25		2	128		
	July	44	12	54	0	74		
	Aug.	48	14	22	0	52		
	Sept.	28	8	6	0	46		
	Oct.-Mar.	245	14		12	48		
1902	April	98	58		2	61		
	May	51	25	40	0	21		
	June	27	2	21	0	0	45	
	July	17	5		0	0	81	
	Aug.	33	14		0	0	37	
	Sept.	25	11		0	0	9	
	Oct.-Mar.	242	29		12	17	172= 36%	
1903	April	170	76		2	91		
	May	326	176		2	198		67
	June	632	116		2	198		114
	July	93	30	5	0	193		
	Aug.	21	3	49	0	144		
	Sept.	14	1	20	0	124		
	Oct.-Mar.	199	7	5	12	119		

Note: Figures for Buckman 1897-1899 from Debler-Elder Extensions Table 44, p. 137.

Table 46 (Continued)

Year	Month	Buckman Flow	El Vado Flow	El Vado Release	El Vado Loss	El Vado Content	Shortage	Spill
1904	April	24	2	59	0	60		
	May	5	8	86	0	0	26	
	June	16	1	77	0	0	77	
	July	15	0	83	0	0	83	
	Aug.	73	25		2	1	186=	
	Sept.	141	46		2	45	39%	
	Oct.-Mar.	653	126		12	159		
1905	April	213	103		2	198		62
	May	703	177		2	198		175
	June	505	0(?)		2	196		
	July	34	15	64	0	132		
	Aug.	31	10	39	0	93		
	Sept.	17	3	17	0	76		
	Oct.-Mar.	276	43		12	107		
1906	April	149	61		2	166		
	May	459	154		2	198		120
	June	415	77		2	198		75
	July	125	19		2	198		17
	Aug.	52	12	18	0	180		
	Sept.	49	8		2	186		
	Oct.-Mar.	483	53		12	198		29
1907	April	322	105		2	198		103
	May	469	262		2	198		260
	June	696	131		2	198		129
	July	553	33		2	198		31
	Aug.	143	20		2	198		18
	Sept.	128	13		2	198		11
	Oct.-Mar.	379	90		12	198		78
1908	April	130	26		2	198		24
	May	134	66		2	198		64
	June	95	33		2	198		31
	July	33	8	65	0	133		
	August	52	5	18	0	115		
	September	41	3		2	116		
	Oct.-Mar.	297	23		12	127		
1909	April	190	68		2	193		
	May	490	170		2	198		163
	June	448	85		2	198		83
	July	68	18	30	0	168		
	August	67	20	3	0	165		
	September	192	3		2	166		
	Oct.-Mar.	460	77		12	198		33
1910	April	281	96		2	198		94
	May	360	96		2	198		94
	June	110	31		2	198		29
	July	10	0	88	0	110		
	August	20	0	50	0	60		
	September	13	0	21	0	39		
	Oct.-Mar.	300	54		12	81		
1911	April	126	77		2	122		
	May	344	165		2	198		87
	June	303	0		2	196		
	July	307	17		2	198		13
	August	45	6	25	0	173		
	September	56	4		2	175		
	Oct.-Mar.	774	98		12	198		63

Table 46 (Continued)

Year	Month	Buckman Flow	El Vado Flow	El Vado Release	El Vado Loss	El Vado Content	Shortage	Spill
1912	April	125	32		2	198		30
	May	634	161		2	198		159
	June	536	63		2	198		61
	July	69	13	29	0	169		
	August	44	10	26	0	143		
	September	32	12	2	0	141		
	Oct.-Mar.	261	38		12	167		
1913	April	128	52		2	198		19
	May	137	88		2	198		86
	June	100	28		2	198		26
	July	32	6	66	0	132		
	August	15	2	55		77		
	September	20	4	14		63		
	Oct.-Mar.	340	28		12	79		
1914	April	157	55		2	132		
	May	325	132		2	198		64
	June	239	54		2	198		52
	July	115	14		2	198		12
	August	94	8		2	198		6
	September	75	8		2	198		6
	Oct.-Mar.	348	43		12	198		31
1915	April	227	78		2	198		76
	May	437	123		2	198		121
	June	459	95		2	.98		93
	July	69	18	29	0	169		
	August	55	8	15	0	154		
	September	36	4		2	154		
	Oct.-Mar.	430	96		12	198		40
1916	April	231	135		2	198		133
	May	504	170		2	198		168
	June	311	87		2	198		85
	July	75	22	23	0	175		
	August	101	16		2	189		
	September	44	6		2	193		
	Oct.-Mar.	479	60		12	198		43
1917	April	141	62		2	198		60
	May	291	105		2	198		103
	June	440	101		2	198		99
	July	173	27		2	198		25
	August	22	6	48	0	150		
	September	23	2	11	0	139		
	Oct.-Mar.	250	34		12	161		
1918	April	58	31	25	0	136		
	May	162	91		2	198		27
	June	127	32		2	198		30
	July	58	19	40	0	158		
	August	22	3	48	0	110		
	September	38	4		2	112		
	Oct.-Mar.	288	40		12	140		
1919	April	287	104		2	198		44
	May	532	153		2	198		151
	June	193	39		2	198		37
	July	124	39		2	198		37
	August	75	12		2	198		10
	September	32	2	2	0	196		
	Oct.-Mar.	390	58		12	198		44

Table 46 (Continued)

Year	Month	Buckman Flow	El Vado Flow	El Vado Release	El Vado Loss	El Vado Content	Shortage	Spill
1920	April	133	59		2	198		57
	May	824	183		2	198		181
	June	694	127		2	198		125
	July	168	57		2	198		55
	August	48	18	22	0	176		
	September	34	4	2	2	176		
	Oct.-Mar.	358	32		12	196		
1921	April	60	22	23		173		
	May	235	119		2	198		96
	June	663	68		2	198		66
	July	94	12	4	0	194		
	August	176	20		2	198		14
	September	91	8		2	198		6
	Oct.-Mar.	344	52		12	198		40
1922	April	97	59		2	198		57
	May	375	197		2	198		195
	June	362	60		2	198		58
	July	73	7	25	0	173		
	August	11	4	59	0	114		
	September	11	3	23	0	91		
	Oct.-Mar.	250	38		12	117		
1923	April	86	37		2	118		
	May	378	149		2	198		67
	June	256	62		2	198		60
	July	50	13	48	0	150		
	August	72	14		2	150		
	September	115	24		2	172		
	Oct.-Mar.	481	82		12	198		44
1924	April	358	105		2	198		103
	May	669	178		2	198		176
	June	200	47		2	198		45
	July	50	12	48	0	150		
	August	29	4	41	0	109		
	September	25	2	9	0	100		
	Oct.-Mar.	311	33		12	121		
1925	April	153	76		2	189		
	May	107	57		2	198		46
	June	46	19	47	0	151		
	July	55	8	43	0	108		
	August	58	11	12	0	96		
	September	42	6		2	100		
	Oct.-Mar.	352	48		12	136		
1926	April	173	75		2	198		11
	May	443	174		2	198		172
	June	334	95		2	198		93
	July	47	15	51	0	147		
	August	18	10	52	0	95		
	September	23	2	11	0	84		
	Oct.-Mar.	239	30		12	102		
1927	April	177	96		2	194		
	May	436	166		2	198		160
	June	224	60		2	198		58
	July	186	22		2	198		20
	August	53	9	17	0	181		
	September	157	29		2	198		10
	Oct.-Mar.	350(?)	50(?)		12	198		38

Records for El Vado flow 1906, 1907, 1908, and part of 1909 extended from extended records of Embudo and Buckman. These are merely estimates.

Effect of Middle Valley Project Upon Water Supply for Elephant Butte Reservoir.

In the Debler-Elder report the present water loss in the Middle Valley is estimated by two different methods:

(a) By comparing recorded flows at Buckman and San Marcial and making allowance for tributary inflow. By this method the loss is estimated to be 728,000 acre feet, including rainfall. (See Debler-Elder report p. 106.)

(b) By allowing for evaporation losses on various classes of land in proportion to depths of water table. By this method the loss is computed as 755,900 acre feet, including rainfall. (See Debler-Elder report p. 106.)

The former figure of 728,000 acre feet is used, though there is some question as to which method is the more accurate. Excluding rainfall and allowing for return flow and evaporation from El Vado reservoir gives 544,000 acre feet per year as the total valley loss under present conditions.

Table 40, of this report, shows the annual loss under future conditions as 487,000 acre feet, and indicates that for years of full water supply to the Middle Valley the river will be benefited to the extent of about 57,000 acre feet.

Only three years of shortage are indicated by reason of shortage in El Vado reservoir, viz. 1900—shortage 58,000, 1902—shortage 172,000, and 1904—shortage 186,000 acre feet. In these years the river losses will evidently be diminished by the amounts of the shortages (since the water is not there to supply them) and the drainage return may also be diminished, or the water table drawn down.

To determine the effect on the river of the operation of the Middle Valley project, the following tabulation of present and future losses has been made and is comparable to a similar tabulation shown as Table 38, p. 109 of the Debler-Elder report.

Table 47

Middle Rio Grande Depletion 1898-1904, Project 123,267 Acres
Unit 1000 A. F.
(Compare Debler-Elder report Table 38, p. 109)

	Present Valley Loss			Future Valley Loss				Change at San Marcial	
Year	Surface Run-Off	Percolation Inflow	Total	Irrigation Season	Reservoir Losses	Non-Irrigation Season Drainage	Total	Annual	Cumulative
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1898	472	72	544	479	12	65	426	*118	
1899	394	72	466	479	12	50	441	* 25	*143
1900	395	72	467	426	12	32	406	* 61	*204
1901	457	54	511	479	12	65	426	* 85	*289
1902	346	36	382	321	8	32	297	* 85	*374
1903	491	72	563	479	12	65	426	*137	*511
1904	310	36	346	308	10	32	286	* 60	*571

This tabulation indicates that during the driest period known on the river (1898-1904) the Middle Valley would benefit the river by about 570,000 acre feet, and in no year of the period would the water supply for the Elephant Butte Reservoir be depleted.

Effect of Including 10,000 Acres of Puerco Valley Land in the Middle Valley Project.

The Rio Puerco unit of 10,000 acres, which it is proposed to include in the Conservancy District at some future time, is drained by the Rio Puerco which almost bisects the tract, and which flows through it in a canyon 40 feet deep. This canyon is eroded in the soils of the valley. Some additional drainage is also provided by the plans and it is, therefore, assumed that with the efficient drainage provided the consumptive use of water on this area will not exceed 2.5 acre feet per acre. If the unit is included in the project the total demand of the entire project on the river will be increased by probably 25,000 acre feet. The additional drainage flow developed will be available for re-use in the Socorro Division, but since it cannot all be used, the irrigation season demand at

Notes:
- Col. 2. From Table 22, p. 62 Debler-Elder report.
- Col. 3. Assumes 100 second feet gain to river except in 1901 (75 s.f.), 1902 (50 s.f) and 1904 (50 s f.) same as Debler-Elder.
- Col. 4. Sum Col. 2 and Col. 3.
- Col. 5. Irrigation season demand, less shortages plus decrease in drainage return from Socorro Division. This drainage is assumed to decrease from normal of 38,000 A. F. in proportion to shortages.
- Col. 6. Reservoir losses from Table 46.
- Col. 7. River gain, non-irrigation season assumed as 65,000 A.F. in normal years, 75% of this figure in 1899 and 50% in 1900, 1902 and 1904.
- Col. 8. Sum Col. 5 and Col. 6 and Col. 7.
- Col. 9. Col. 4 minus Col. 8.
- Col. 10. Algebraic sum of quantities in Col. 9.
- * Signifies plus.

Buckman will be increased by some 30,000 acre feet and will be distributed as follows:

Table 48

Irrigation Season Demand at Buckman Including 10,000 Acres of Rio Puerco Valley Land

Month	Per Cent	Acre Feet
March	2	10,180
April	17	86,530
May	19	96,710
June	19	96,710
July	20	101,800
August	14	71,260
September	7	35,630
October	2	10,180
Total		509,000

The effect on El Vado storage of this increased demand through the low water years of 1899-1904 is investigated in the following tabulation:

Table 49

Operation El Vado Reservoir for Project Including 10,000 Acres of Rio Puerco Valley Land

Year	Month	Buckman Flow	El Vado Flow	El Vado Release	El Vado Loss	El Vado Content	Shortage	Spill
1899	April	160	94			198		
	May	104	49		2	198		47
	June	26	8	71	0	127		
	July	37	11	65	0	62		
	August	22	5	49		13		
	September	51	21		2	26		
	Oct.-Mar.	235	32		12	46		
1900	April	55	23	32	0	14		
	May	123	62		2	38		
	June	122	27		2	61		
	July	17	1	61	0	0	24	
	August	9	0		0	0	62	
	September	39	22		2	1	86= 17%	
	Oct.-Mar.	255	26		12	15		
1901	April	85	39	2	0	13		
	May	237	109		2	120		
	June	99	25		2	120		
	July	44	12	58	0	62		
	August	48	14	23	0	39		
	September	28	8	9	0	30		
	Oct.-Mar.	245	14		12	32		
1902	April	98	58		2	41		
	May	51	25	41	0	0	5	
	June	27	2		0	0	70	
	July	17	5		0	0	85	
	August	33	14		0	0	38	
	September	25	11		0	0	11	
	Oct.-Mar.	242	29		12	17	209= 41%	
1903	April	170	76		2	91		
	May	326	176		2	198		67
	June	632	116		2	198		114
	July	93	30	9	0	189		
	August	21	3	50	0	139		
	September	14	1	22	0	117		
	Oct.-Mar.	199	7	5	12	112		
1904	April	24	2	63	0	49		
	May	5	8	49	0	0	43	
	June	16	1		0	0	81	
	July	15	0		0	0	87	
	August	73	25		2	0	211= 41%	
	September	141	46		2	44		
	Oct.-Mar.	653	126		2	168		
1905	April	213	103		2	198		71
	May	703	177		2	198		175
	June	505	0(?)		2	198		
	July	34	15	68	0	130		
	August	31	10	40	0	90		
	September	17	3	19	0	71		
	Oct.-Mar.	276	43		12	102		

No other shortages indicated—see Table 46.

The effect on the El Vado reservoir of including 10,000 acres of Rio Puerco valley land in the project is seen to be to increase the indicated shortages by 5 per cent. This increase is shown as follows:

Table 50

Project Shortages in Water Supply

	Project 123,267 A.			Project 133,267 A.		
Year	Shortage	Demand	% Shortage	Shortage	Demand	% Shortage
1900	58,000	470,000	12	86,000	509,000	17
1902	172,000	479,000	36	209,000	509,000	41
1904	186,000	479,000	39	211,000	509,000	41

To investigate the net effect on the river of including 10,000 acres of Rio Puerco land, the following tabulation is submitted: (Compare Table 47.)

Table 51

Middle Rio Grande Depletion 1898-1904, Project 133,267 Acres
Unit 1000 A. F.

	Present Valley Loss			Future Valley Loss				Change at San Marcial	
Year	Surface Run-Off	Percolation Inflow	Total	Irrigation Season	Reservoir Losses	Non-Irrigation Season	Total	Annual	Cumulative
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1898	472	72	544	509	12	70	450	* 94	
1899	394	72	466	509	12	53	468	* 2	* 96
1900	395	72	467	428	12	35	405	* 62	*158
1901	457	54	511	509	12	70	451	* 60	*218
1902	346	36	382	302	8	35	275	*107	*325
1903	491	72	563	509	12	70	451	*112	*437
1904	310	36	346	302	10	35	277	* 69	*506

The Rio Grande Compact.

On or about February 14, 1929, the Compact Commissioners of the States of Colorado, New Mexico and Texas signed a compact which, if ratified by the legislatures of the signatory states and approved by Congress, will become effective for a six-year period, or until June 1, 1935.

This compact affects the water supply of the middle Rio Grande valley in five major ways:

* Signifies plus.
No river depletion is indicated and a large gain accrues to the Elephant Butte Reservoir during the six-year period.

(a) Colorado agrees not to deplete the flow of the Rio Grande at the Colorado-New Mexico interstate line during the life of the compact.

(b) Should the "Closed Basin Drain" in the San Luis Valley be constructed the Middle Valley may receive the benefit of some additional water.

(c) Should the "State Line Reservoir" be constructed a better regulation of the flow across the interstate line may be obtained with the probable release of more water during the irrigation season.

(d) When spill at Elephant Butte Reservoir takes place, the Middle Valley may divert or store the equivalent of a portion of such spill.

(e) During the life of the compact interstate litigation over the waters of the Rio Grande is avoided.

The compact is in effect a six-year cessation of hostilities, during which time it will be attempted to get Government aid for the construction of the "Closed Basin Drain" and the "State Line Reservoir". At the end of the six-year period a new compact may be drawn in the light of conditions then existing.

STATE OF NEW MEXICO

MIDDLE RIO GRANDE CONSERVANCY DISTRICT

REPORT OF THE CHIEF ENGINEER

APPENDIX "B"

EVAPORATION

EVAPORATION

Foreword.

On April 16, 1926, a contract was entered into between the Middle Rio Grande Conservancy District and the United States Bureau of Reclamation. This contract provided for a cooperative investigation of matters relating to water supply of the proposed Conservancy District and the effect of the operation of the District works upon the water supply of the Elephant Butte Reservoir.

As a part of this investigation, experiments were carried on to determine the rates of evaporation from water surfaces and from seeped lands with the water table near the surface. The results of these experiments are given herewith, the explanatory matter being taken from the "Preliminary Report on Investigations in Middle Rio Grande Valley, New Mexico" by E. B. Debler and C. C. Elder, Engineers of the United States Bureau of Reclamation, said report being included in the Official Plan of the Middle Rio Grande Conservancy District as Exhibit R-4. At the time this report was made (December 1927) records had been obtained for a little over one year. Two full years' records are now available and the tabulations have therefore been extended to include the additional data.

Earlier Records of Evaporation in the Rio Grande Valley.

As the large present loss of water in the Middle Rio Grande Valley is due to excessive evaporation from undrained lands, the determination of rates of evaporation and transpiration losses for the various conditions found there becomes of considerable importance. Satisfactory records showing even the rate of evaporation from open water were not available. Class "A" Weather Bureau pans have been maintained for about ten years at Santa Fe, Elephant Butte Dam and Las Cruces, and good records secured. (See table 52.) Determination of the rate of loss for large open water areas in a very different location and climate from these records is difficult, but the records are of great value in establishing average evaporation rates for other and more applicable short time records.

The only known evaporation records for the Middle Rio Grande Valley were made on the grounds of the University of New Mexico, on the mesa east of Albuquerque, during the years 1900 to 1904. The data were published on pages 5-8, Hadley Climatological Laboratory Bulletin No. 10, Volume III, 1905, by John Weinzirl, and a brief summary is given in U. S. G. S. W. S. Paper 188. As the original bulletin is out of print, a detailed description of the pan has been abstracted and is included here. Pan No. 1 was installed in the spring of 1900 by Dr. G. S. Easterday and records secured from February, 1900 to January, 1901,

inclusive. The pan was 2 feet square, 1 foot deep, of wood lined with zinc sheeting, sunk almost level with the ground surface, on the University campus. The bulletin states that "some sand found its way into the tank but—what is apparently gained in this way is partly balanced by the water consumed by birds and other small animals. Allowance was made for the rainfall, the result being actual evaporation. Measurements were made with a meter stick in all cases." Some doubt arose as to the accuracy of the records due to the shallowness of the pan. Records were, therefore, secured on pan No. 1 again in 1903 and 1904, and in addition pans 2 and 3 were installed. These were cylinders of heavy galvanized iron, 18" in diameter, 54" deep, planted beside pan No. 1. The complete records are listed in table 54. The period July, 1903, to June, 1904, was abnormally dry, the total precipitation being 4.06" as compared with a 50-year mean at Albuquerque of 7.77", and the evaporation from pan No. 1 during this period closely checked by that from pans No. 2 and No. 3, was 24% greater than in 1900. The mean for pan No. 1 for the years 1900 and 1903, which were more nearly normal, although drier than the average, is shown in table 53 by months together with an estimated corresponding evaporation rate from large open water surfaces. Because of the shallowness of the pan, the proper coefficient to be applied for open water evaporation from large areas is rather a matter of guesswork, but the best available data indicate a coefficient of about 76%, which has been applied.

Table 52

Evaporation Records, Rio Grande Valley, New Mexico.
Class "A" Weather Bureau Pans
Evaporation in inches.

Santa Fe — Elev. 7013 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual*
1916						11.71	8.21	6.93	6.48	4.40	2.87	1.72	
1917	3.14	2.88	5.58	7.22	7.64	11.89	9.95	9.04	6.79	5.94	3.36	2.39	75.82
1918	1.08	2.30	3.81	6.13	9.77	10.24	9.29	8.17	6.68	4.29	1.96	1.47	65.19
1919	1.59	1.02	2.70	5.50	8.29	9.38	6.81	7.47	5.43	3.84	2.80	1.57	56.40
1920	1.59	2.10	3.91	5.56	8.51	9.04	8.61	7.50	6.53	4.64	2.01	1.71	61.71
1921	1.38	2.32	4.53	6.44	8.88	8.68	8.13	6.64	6.91	4.93	3.26	1.48	63.58
1922	1.42	2.16	3.60	5.77	10.18	10.45	10.26	8.72	7.12	5.18	1.86	*1.45	68.17
1923	1.81			6.28	8.58	10.60	8.75	6.71	4.77	3.81	1.97	0.62	60.15*
1924	0.93	2.24	2.96	5.64	8.35	11.99	8.81	9.28	7.76	6.15	3.30	1.20	68.61
1925	1.54	2.28	5.08	8.22	9.01	10.29	9.53	7.47	6.75	4.47	2.03	0.77	67.44
1926	0.83	3.01	3.94	4.76	5.92	8.78	9.18	9.44	6.71	4.83	2.93	1.02	61.35
1927	1.72	2.10	4.03	6.70	12.24	9.31	9.31	8.09	5.46	5.29	2.87	1.08	62.20
1928	1.45	1.93	4.31	6.02	6.84	11.21	10.01	7.55	7.51	4.58	1.59	1.67	64.68
Mean	1.54	2.21	4.04	6.18	8.67	10.28	8.98	7.93	6.53	4.79	2.52	1.40	65.07
%	2.4	3.4	6.2	9.3	13.4	15.8	13.8	12.2	10.0	7.4	3.9	2.2	100.0

Las Cruces, (N. M. Agr. College) — Elev. 3863 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual*
1918										6.85	3.62	2.18	
1919	2.65	4.19	7.75	9.91	12.25	13.50	12.89	11.48	7.47	5.53	3.89	2.66	94.17
1920	2.22	4.05	7.47	10.36	11.99	11.62	12.90	9.88	8.94	6.10	3.01	3.13	91.67
1921	3.80	4.58	8.60	10.23	11.64	12.35	10.53	9.60	7.84	6.35	4.38	3.23	93.13
1922	3.30	5.84	8.24	10.11	12.69	13.61	13.24	11.02	8.08	5.72	3.45	2.71	98.01
1923	3.37	2.93	6.88	9.55	12.36	11.27	11.30	8.95	7.09	6.18	3.00	1.85	84.73
1924	2.94	4.39	7.09	8.15	10.11	12.09	9.06	9.72	8.92	7.08	4.18	2.44	86.17
1925	2.73	5.34	8.08	9.39	8.69	10.24	9.14	8.35	6.81	4.99	3.50	2.39	79.65
1926	1.91	4.65	5.15	7.29	9.04	10.56	10.13	9.30	7.24	4.59	3.63	2.09	75.58
1927	3.22	4.42	7.25	9.28	11.64	10.28	10.29	7.89	6.84	5.80	4.38	2.17	83.45
1928	3.03	4.15	8.16	9.08	9.52	11.78	10.82	7.80	6.92	5.22	2.67	2.77	81.93
Mean	2.91	4.46	7.47	9.33	11.00	11.72	11.03	9.40	7.61	5.85	3.61	2.51	86.90
%	3.4	5.1	8.6	10.7	12.6	13.5	12.7	10.8	8.8	6.7	4.2	2.9	100.0

Elephant Butte Dam — Elev. 4475 ft.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual*
1916					15.47	16.87	11.83	9.55	9.11	7.34	4.93	3.35	
1917	2.14	4.13	9.64	12.93	13.50	15.29	13.25	11.81	9.00	8.92	5.12	3.96	109.69
1918	3.18	5.64	8.21	11.32	15.71	14.25	13.54	11.60	10.17	6.72	3.69		107.13*
1919		3.46	7.20	9.19	12.66	12.68	11.14	11.13	7.88	7.82	3.98	2.73	92.68*
1920	1.92	3.91	8.37	10.47	14.16	12.47	13.50	10.66	9.96	8.63	3.66	3.47	101.18
1921	3.56	4.88	8.16	10.98	14.26	13.07	10.24	9.87	9.74	9.41	5.34	3.68	103.19
1922	3.67	5.54	8.06	11.19	14.34	14.09	13.85	12.19	8.97	7.63	3.80	2.75	106.08
1923	3.85	3.31	6.76	11.10	14.49	17.06	12.33	9.10	7.83	7.44	2.76	3.83	99.86
1924	2.55	3.85	7.64	8.76	11.57	14.97	10.74	11.39	10.57	8.65	5.04	2.78	98.51
1925	2.44	4.66	8.24	11.08	11.74	15.38	11.96	10.79	9.29	6.81	4.15	2.51	99.05
1926	1.73	4.90	5.30	6.99	9.83	13.16	12.02	11.01	7.27	5.93	4.15	1.96	84.25
1927	3.09	4.76	7.85	10.22	14.83	13.42	12.38	8.98	7.61	6.61	4.74	2.42	96.91
1928	2.80	2.80	7.71	9.10	9.81	14.48	12.10	9.62	8.32	5.87	2.75	2.81	87.54
Mean	2.81	4.32	7.77	10.28	13.26	14.40	12.22	10.59	8.90	7.52	4.16	3.02	99.25
%	2.8	4.3	7.8	10.4	13.4	14.5	12.3	10.7	9.0	7.6	4.2	3.0	

* Record completed by use of mean for missing months.

Table 53

Evaporation on N. M. University Campus (inches)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Pan No. 1 Mean of 1900 and 1903	1.92	2.35	5.69	8.43	10.53	11.98	12.07	10.97	8.83	5.50	2.97	1.64	82.88
76% of above est. open water rate	1.46	1.79	4.33	6.40	8.00	9.10	9.17	8.35	6.71	4.18	2.26	1.25	63.00
% of annual	2.3	2.8	6.9	10.1	12.7	14.5	14.6	13.3	10.6	6.6	3.6	2.0	100.0

Table 54

University of New Mexico Evaporation Records

Year	1900-1901		1903-1904			
	Evaporation	Precipitation	Evaporation			Precipitation
Month	Pan No. 1	Inches	Pan No. 1	Pan No. 2	Pan No. 3	Inches
Jan.			(1) 1.81			0.08
Feb.	2.63	0.40	(1) 2.07			0.41
Mar.	6.17	0.13	5.21			0.38
April	6.82	0.33	10.05			0.05
May	10.08	0.85	10.98			0.18
June	12.63	0.06	11.33			2.48
July	11.78	0.13	12.36	12.80	12.03	0.32
Aug.	10.21	0.13	11.73	11.45	11.06	0.00
Sept.	8.00	2.09	9.65	9.72	9.92	1.93
Oct.	4.38	0.25	6.62	6.92	7.16	0.00
Nov.	1.73	0.83	4.21	4.40	4.40	0.00
Dec.	1.40	0.00	1.88	2.40	2.60	0.00
			87.90			5.83
Jan.	2.04	0.65	2.28	2.20	2.20	0.20
Feb.			3.92	3.64	3.60	0.10
Mar.			7.48	7.12	6.57	0.00
Apr.			10.71	10.43	10.00	0.00
May			(2)12.53	12.53	12.33	1.19
June			(2)13.03	13.03	13.07	0.32
	77.87	5.85	(4)96.40	96.64	(3) 94.94	(4) 4.06

(1) Water frozen part of time. (2) Estimated from pan No. 2. (3) Given as 96.94 in University Bulletin. (4) July, 1903 to June, 1904.

Evaporation Station at Los Griegos.

At the request of Mr. Robert E. Dietz, then a director of the Middle Rio Grande Conservancy District, Mr. J. P. Jacobson granted the use of a corner of his salt grass pasture for an evaporation experiment station near Los Griegos, five miles northwest of Albuquerque. The site is very satisfactory for the purpose, the soil, vegetation and surroundings being typical of the low-lying undrained lands of the valley, and the permission to use the ground has been appreciated. Instruments

and equipment were installed during August and September, 1926, as rapidly as they could be secured. Meteorological instruments including a raingage, maximum and minimum thermometers, sling psychrometer, and anemometer, were secured from the U. S. Weather Bureau, and the station has therefore been operated as a cooperative one, and all data turned in for publication. Operation of open pans No. 1 and No. 2 was begun on September 1, 1926, when readings of all meteorological instruments were also started. The water table levels in the various soil pans were gradually brought to the desired depths during September and operation of these started on October 1. Stock tanks of 4.0 feet diameter were ordered but the actual diameter of pan No. 2 is 48¼″ and of all others approximately 45½″. All pans are of heavy gage galvanized iron and were thoroughly tested for leaks before installation.

Pan No. 1, open water, 2.0 feet deep, is set 1.75 feet in the ground with water level maintained 3 inches below the rim. A pointed meter gage is fixed in center of pan and water surface brought to this level daily by adding or removing water with rated cup. The pan is more nearly like a floating pan than an ordinary ground pan, as the ground water table is close to the surface, its depth varying from 8 inches to 20 inches during the period of observation.

Pan No. 2, 48″ diameter, 10″ deep, filled to depth of 8 inches, open water class "A" Weather Bureau, standard setting, is placed on a low wooden platform permitting circulation of air below the pan. A regulation gage was not available and evaporation is measured in the same way as in the case of Pan No. 1.

Pans No. 3 to 7, are set in the ground with approximately a 3-inch rim inside and out. The bottom of each was filled with 6 to 8 inches of coarse gravel. Soil was then replaced in pans 4, 5 and 6, which are of 4-foot, 3-foot, and 2-foot depths, respectively, and planted with salt grass sod. Thin layers of soil were tamped into place and the various sorts replaced in the same order and amount as found in digging the holes for the pans. Pans 3 and 7, of 4 foot and 2 foot depths, respectively, were filled with river wash material, hauled from a sand bar on the bank of the Rio Grande, composed of rather fine sand with traces of silt. The water table depth in the pans is held practically constant by automatic feed from storage tanks, the equipment being similar to that used at the Ft. Collins laboratory of the Department of Agriculture. Quantities of water evaporated are read daily on a scale fixed to a glass tube alongside of and connected at both ends to the storage tanks.

Samples were taken of the various soils found and sent to the Agricultural Experiment Station at State College, New Mexico. Mr. H. V. Jordan, Assistant Agronomist, classified the entire profile as that of the Gila Clay loam. The various strata were described as follows:

Ground Surface to 1 ft. 3 in.............................Clay Loam.
1 ft. 3 in. to 2 ft. 7½ in.................................Fine, sandy loam.
2 ft. 7½ in. to 3 ft. 6 in.................................Clay.
3 ft. 6 in. to 4 ft...Sand.

Average results of mechanical analyses for Gila Clay loam soils of the Middle Rio Grande Valley as given in the 1912 Soil Survey Bulletin, are as follows:

Table 55

Soil Analyses.

%	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very fine Sand	Silt	Clay
Soil	0.0	1.3	2.3	15.5	14.7	35.3	30.9
Subsoil	0.3	1.3	4.0	29.8	26.5	17.2	16.2
Lower Subsoil	0.3	4.7	14.6	55.1	17.6	3.7	4.1

An analysis was also obtained of a water sample taken August 28, 1926, from the shallow dug well used as a supply for both open water and soil pans. The report from C. W. Botkin, Chemist at the Agricultural Experiment Station, in parts per 100,000 was as follows:

Total Mineral Matter	44.8
Sodium Carbonate	23.0
Sodium Chloride	8.6
Sodium Sulphate	13.2

Some difficulty was anticipated on account of the high content of sodium salts in the water used, but the salt grass grew vigorously, especially on pan No. 6, which received a full supply of water, and the condition of the soil does not seem to have been affected. Water in pans 1 and 2, however, has been renewed frequently, in order to avoid a concentration of alkaline salts which might influence the observed evaporation rate.

Measured evaporation losses by months, from pans 1 and 2, with a summary of meteorological data, for the period September 1, 1926, to August 31, 1928, are given in table 56.

Table 56

Los Griegos Station Evaporation Record Pans 1 and 2 Open Water Surface

	Evaporation, Feet		Coefficient Pan No. 1 in % of Pan No. 2, Percent	Depth to Water Table below W. S. of Pan No. 1, Ft.	Mean Monthly Air Temperature, Degrees	Monthly Precipitation, Inches	Mean Wind Velocity in Miles Per Hour
	Ground Pan No. 1	Class "A" Pan No. 2					
1926—Sept.	0.465	0.585	79.5	1.2	67.2	1.04	2.7
1926—Oct.	0.314	0.417	75.3	1.4	57.3	1.03	2.4
Nov.	0.240	0.336	71.4	1.3	44.2	T	3.5
Dec.	(1)0.075	(1)0.106	70.7	1.1	35.4	1.01	2.4
1927—Jan.	0.084	0.121	69.4	1.1	38.9	T	2.0
Feb.	0.196	0.269	72.8	1.2	44.0	0.34	3.6
Mar.	0.384	0.519	74.0	1.2	46.5	0.50	4.7
Apr.	0.476	0.697	68.3	0.9	53.8	0.17	4.0
May	0.768	1.103	69.6	1.1	61.8	T	4.6
June	0.569	0.850	67.0	1.1	67.9	1.00	3.1
July	0.650	0.937	69.4	1.5	74.7	.80	2.7
Aug.	0.555	0.760	73.0	1.6	71.3	1.62	2.5
Sept.	0.406	0.558	72.7	1.3	66.3	1.34	2.8
	4.717	6.673	71.1	1.2	55.2	7.21	3.2
1927—Oct.	0.322	0.462	69.7	1.3	54.7	0.19	2.2
Nov.	0.213	0.282	75.5	0.9	46.6	0.04	2.5
Dec.	0.089	0.121	73.5	1.0	31.5	0.06	3.2
1928—Jan.	0.090	0.168	53.5	1.1	33.5	0.00	2.6
Feb.	0.158	0.242	65.4	1.1	38.2	0.32	3.6
Mar.	0.359	0.514	69.8	1.1	47.1	0.06	3.6
Apr.	0.500	0.718	69.7	.8	52.0	0.75	5.1
May	0.445	0.676	65.7	.8	61.5	1.38	3.3
June	0.720	1.060	67.8	1.5	68.5	0.00	3.8
July	0.617	0.917	68.6	2.3	73.5	1.43	2.4
Aug.	0.614	0.699	73.6	2.1	70.2	2.65	2.6
Sept.	0.444	0.611	72.8	2.6	63.6	.15	2.3
	4.571	6.470	68.8	1.4	53.4	7.03	3.1

(1) Pans ice covered during most of December and to Jan. 9, 1927.
(2) Anemometer 2 feet above ground surface.
(3) Elevation 4970, one-half mile east of Rio Grande, 4 miles northerly of Albuquerque.

For purposes of comparison a summary of the record of the Weather Bureau Station at the University of New Mexico is included as Table No. 57.

Table 57

Meteorological Records at University Station, Albuquerque, N. M. Elevation 5196, on mesa east of Albuquerque.

Year	Normal				1926-27				1927-28			
Month	Temperature Degrees (1)	Precipitation Inches (1)	Wind (2) Miles per Hour	Relative (2) Humidity %	Temperature Degrees	Precipitation Inches	Wind (3) Miles per Hour	Relative Humidity %	Temperature Degrees	Precipitation Inches	Wind (3) Miles per Hour	Relative Humidity %
Sept.	67.8	0.77	6.9	49	68.6	1.04	6.8	54	67.4	1.11	6.5	60
Oct.	56.1	0.82	6.9	48	58.8	1.21	5.8	54	57.0	0.22	6.1	40
Nov.	43.5	0.44	6.8	52	45.8	T	7.4	43	48.8	T	5.8	49
Dec.	34.5	0.42	6.8	64	33.8	1.10	5.9	73	31.9	0.16	7.0	66
Jan.	34.2	0.37	6.2	61	39.7	0.03	5.3	59	37.6	0	6.2	50
Feb.	39.6	0.28	9.1	51	44.4	0.42	7.8	57	39.4	0.21	7.8	52
Mar.	47.0	0.32	9.6	46	47.1	0.35	9.7	45	49.2	0.10	6.2	40
Apr.	55.5	0.54	10.3	41	56.2	0.21	8.4	36	53.6	0.57	10.2	38
May	64.5	0.46	8.4	39	66.1	T	8.8	21	62.9	1.63	7.5	52
June	73.3	0.72	8.5	36	71.2	1.61	7.7	38	73.2	T	8.9	27
July	76.9	1.32	7.5	49	77.4	1.93	7.0	46	77.2	2.54	7.0	44
Aug.	74.9	1.30	6.5	52	72.8	1.63	6.5	57	71.8	1.96	6.2	60
Annual	55.7	7.76	7.8	49	56.8	9.53	7.3	49	55.8	8.50	7.1	48

(1) Mean of 51 year record.
(2) Mean of 9 year record.
(3) Anemometer on top of building, 50 feet above ground surface.

Measured evaporation losses and depths to water table for pans No. 3—No. 9 for the period Oct. 1, 1926 to Aug. 31, 1928, are shown in the following Tables Nos. 58-64:

Table 58

Los Griegos Station Evaporation Record
Pan No. 3, River Wash Material, Fine Sand with Traces of Silt

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1926—Oct.	2.42	.09	.19
Nov.	2.32	.00	.10
Dec.	2.10	.08	.12
1927—Jan.	2.11	.00	.02
Feb.	2.33	.03	.10
Mar.	2.36	.04	.17
Apr.	2.38	.01	.17
May	2.49	.00	.16
June	2.40	.08	.16
July	2.50	.05	.11
Aug.	2.43	.14	.20
Sept.	2.24	.11	.14
Year		.63	1.64
1927—Oct.	2.38	.02	.12
Nov.	1.86	.01	.08
Dec.	1.59	.01	.13
1928—Jan.	2.10	.00	.03
Feb.	2.22	.03	.08
Mar.	2.38	.01	.09
Apr.	2.17	.06	.10
May	1.78	.12	.16
June	2.18	.00	.06
July	2.26	.12	.15
Aug.	1.90	.22	.20
Sept.	2.02	.01	.13
Year		.61	1.33

Table 59.

Los Griegos Station Evaporation Record
Pan No. 4, Salt Grass

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1926—Oct.	2.07	.09	.10
Nov.	2.32	.00	.01
Dec.	2.08	.08	.09
1927—Jan.	1.84	.00	.01
Feb.	1.82	.03	.04
Mar.	1.67	.04	.05
Apr.	1.67	.01	.01
May	2.30	.00	.05
June	2.23	.08	.23
July	2.25	.05	.29
Aug.	2.28	.14	.35
Sept.	2.30	.11	.28
Year		.63	1.51
1927—Oct.	2.16	.02	.16
Nov.	2.02	.01	.18
Dec.	1.89	.01	.05
1928—Jan.	2.17	.00	.01
Feb.	2.17	.03	.04
Mar.	2.10	.01	.03
Apr.	2.10	.06	.10
May	2.09	.12	.22
June	2.17	.00	.18
July	2.33	.12	.32
Aug.	2.27	.22	.41
Sept.	2.25	.01	.19
Year		.61	1.89

Table 60

Los Griegos Station Evaporation Record
Pan No. 5, Salt Grass

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1926—Oct.	1.35	.09	.18
Nov.	1.15	.00	.08
Dec.	0.96	.08	.09
1927—Jan.	1.17	.00	.01
Feb.	1.24	.03	.07
Mar.	1.10	.04	.11
Apr.	1.23	.01	.12
May	1.22	.00	.26
June	1.28	.08	.38
July	1.27	.05	.51
Aug.	1.12	.14	.61
Sept.	1.06	.11	.35
Year		.63	2.77
1927—Oct.	1.34	.02	.27
Nov.	1.16	.01	.10
Dec.	1.18	.01	.05
1928—Jan.	1.10	.00	.01
Feb.	1.19	.03	.03
Mar.	1.62	.01	.05
Apr.	1.30	.06	.16
May	1.30	.12	.32
June	1.41	.00	.45
July	1.43	.12	.60
Aug.	1.41	.22	.56
Sept.	1.41	.01	.33
Year		.61	2.93

Table 61

Los Griegos Station Evaporation Record
Pan No. 6, Salt Grass

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1926—Oct.	0.48	.09	.29
Nov.	0.40	.00	.08
Dec.	0.20	.08	.07
1927—Jan.	0.26	.00	.03
Feb.	0.39	.03	.07
Mar.	0.40	.04	.14
Apr.	0.47	.01	.26
May	0.37	.00	.59
June	0.41	.08	.59
July	0.41	.05	.75
Aug.	0.40	.14	.67
Sept.	0.39	.11	.49
Year		.63	4.03
1927—Oct.	0.47	.02	.29
Nov.	0.45	.01	.09
Dec.	0.39	.01	.05
1928—Jan.	0.39	.00	.03
Feb.	0.40	.03	.05
Mar.	0.49	.01	.09
Apr.	0.40	.06	.17
May	0.42	.12	.40
June	0.53	.00	.74
July	0.51	.12	.84
Aug.	0.48	.22	.64
Sept.	0.51	.01	.48
Year		.61	3.87

Table 62

Los Griegos Station Evaporation Record
Pan No. 7, River Wash Material, Fine Sand with Traces of Silt

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1926—Oct.	0.37	.09	.26
Nov.	0.25	.00	.23
Dec.	0.20	.08	.08
1927—Jan.	0.19	.00	.12
Feb.	0.35	.03	.20
Mar.	0.28	.04	.40
Apr.	0.45	.01	.47
May	0.41	.00	.68
June	0.36	.08	.57
July	0.39	.05	.63
Aug.	0.34	.14	.54
Sept.	0.34	.11	.40
Year		.63	4.58
1927—Oct.	0.20	.02	.32
Nov.	0.42	.01	.18
Dec.	0.19	.01	.11
1928—Jan.	0.33	.00	.13
Feb.	0.23	.03	.17
Mar.	0.31	.01	.35
Apr.	0.31	.06	.43
May	0.28	.12	.44
June	0.42	.00	.58
July	0.34	.12	.57
Aug.	0.25	.22	.47
Sept.	0.25	.01	.37
Year		.61	4.12

Table 63

Los Griegos Station Evaporation Record
Pan No. 8, (Started Sept. 1927) Salt Grass

Year and Month	Average Depth to Ground Water in Feet	Precipitation in Feet	Net Evaporation in Feet
1927—Oct.	3.06	.02	.04
Nov.	3.08	.01	.02
Dec.	3.10	.01	.02
1928—Jan.	3.07	.00	.01
Feb.	3.04	.03	.03
Mar.	3.04	.01	.01
Apr.	3.09	.06	.07
May	3.09	.12	.13
June	3.09	.00	.02
July	3.09	.12	.16
Aug.	3.04	.22	.28
Sept.	3.07	.01	.05
Year		.61	.84

Table 64

Los Griegos Station Evaporation Record
Pan No. 9 (Started Sept. 1927)
"Tules"—Water at or Slightly Above Surface

Year and Month	Precipitation in Feet	Net Evaporation in Feet
1927—Oct.	.02	.23
Nov.	.01	.15
Dec.	.01	.08
Jan.	.00	.10
Feb.	.03	.14
Mar.	.01	.30
Apr.	.06	.43
May	.12	.44
June	.00	.89
July	.12	1.09
Aug.	.22	.89
Sept.	.01	.65
Year	.61	5.39

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