TWO RIVERS RESERVOIR PROJECT

WATER CONTROL MANUAL

PECOS RIVER, NEW MEXICO

APPENDIX A

TO

PECOS RIVER BASIN

MASTER WATER CONTROL MANUAL

DEPARTMENT OF THE ARMY

ALBUQUERQUE DISTRICT, CORPS OF ENGINEERS

ALBUQUERQUE, NEW MEXICO

OCTOBER 1995

DIAMOND A DAM

ROCKY DAM

NOTICE TO USERS OF THIS MANUAL

Regulations specify that this Water Control Manual be published in loose-leaf form, and only those sections or parts thereof requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that inserts can be made to keep the manual current.

All elevations referred to in this manual, unless noted otherwise, are in feet, NGVD (National Geodetic Vertical Datum).

EMERGENCY REGULATION ASSISTANCE PROCEDURES

During duty hours, contact Corps of Engineer (Corps) personnel in the Reservoir Control Section of the Albuquerque District Office by telephone (Comm) 505-342-3381 or 505-342-3383. Assistance during non-duty hours can be obtained by contacting one of the following Corps personnel at home. Table 5-1 contains a more complete list of personnel who can provide assistance. The Emergency Regulation Schedule is presented in Table 7-2, page 7-3.

NAME	RESIDENCE TELEPHONE
Marc S. Sidlow Hydraulic Engineer, Reservoir Control Section	505-899-0087
Richard D. Kreiner Chief, Reservoir Control Section	505-865-0244
Roberta Ball Hydraulic Engineer, Reservoir Control Section	505-828-0860

TWO RIVERS RESERVOIR PROJECT WATER CONTROL MANUAL

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LISTS OF TABLES

EXHIBITS

LIST OF PLATES

PERTINENT DATA

LOCATION

Two Rivers Reservoir Project is located in Chaves County, New Mexico about 14 miles southwest of Roswell on the Rio Hondo. The project consists of two dams, Rocky Dam and Diamond "A Dam, that form a common reservoir. Diamond "A" Dam is located on the Rio Hondo and is approximately 34 miles upstream of the confluence of the Rio Hondo with the Pecos River. Rocky Dam is located on Rocky Arroyo about 10 miles above its confluence with the Rio Hondo.

Latitude: 33° 17'55" N   Longitude: 104° 43'20" W

DRAINAGE AREA

The Two Rivers project controls 1,027 square miles of which 963 square miles are in the Rio Hondo watershed and 64 square miles are in the Rocky Arroyo watershed. The uncontrolled drainage area below Two Rivers Reservoir project is 31 square miles.

EMBANKMENT

Diamond "A" and Rocky Dams are rolled-fill structures with upstream impervious-fill zones and downstream random-fill zones. Diamond "A" Dam has a crest length of 4,885 feet, a crest width of 26 feet and the height above streambed is 98 feet. The embankment for Rocky Dam has a crest length of 2,940 feet, crest width of 20 feet and the height above streambed is 118 feet.

OUTLET WORKS

The outlet works consist of two reinforced concrete conduits, one in each embankment. The conduits are rectangular in shape with transition structures upstream and downstream and are set in rock cuts. The Diamond "A" conduit is a 4- X 7-foot gated structure located in the right abutment. The control structure has a 38-foot gate section in length with a 4- X 7-foot single slide gate, located 25 feet upstream from the dam axis. The Rocky Arroyo outlet is an uncontrolled 3.5-foot square conduit located in the left abutment of Rocky Dam.

SPILLWAY

The spillway consists two uncontrolled saddle spillways located at the right and left abutments of Rocky Dam. Except for 400 feet of the left spillway, both spillways are in limestone; a portion of the left saddle dips about 4 feet below the crest elevation at 4,032 feet, NGVD, a concrete weir is located at this low area.

RESERVOIR DATA

Reservoir Features	Elevation (ft NGVD)	Area (acres)	Reservoir Capacity (acre ft)	Total Runoff (inches)	Release Capacity (cfs)		
					Outlet Rocky	Outlet Diamond	Spillway
Top of Dam	4054.0	7270	294,000	5.37	465	1270	348,000
Max Pool	4048.9	6654	260,319	4.75	455	1220	233,500
Top Flood Control	4032.0	4834	163,775	2.99	425	1120	0
Saddle Dike	3988.0	1706	23,950	0.44	305	750	0
Sediment Reserve	3982.3	1222	15,624	0.29	280	655	0
Diamond A	3957.0	154	549	0	175	0	0

Invert							
Rocky Invert	**3945.0**	**0**	**0**	**0**	**0**	**0**	**0**

NOTE: Additonal project data is given in Exhibit A, Supplementary Pertinent Data.

PERTINENT FLOW DATA
RIO HONDO AND PECOS RIVER

STATION	AREA (mi^2)	YEAR BEGAN	AVERAGE ANNUAL VOLUME (acre-ft)	MAX FLOW (cfs)	DATE	MIN FLOW (cfs)	DATE
PECOS RIVER NR ACME, NM	11,380	1937-	129,400	45,000	23 Sep 41	0	Many
RIO RUIDOSO AT HOLLYWOOD, NM	120	1953	22,430	2,120	11 Aug 84	0.3	01 Jan 62
EAGLE CREEK BLW SOUTH FORK, NR ALTO, NM	8.14	1988	2,280	206	19 Dec 78	0	Many
RIO HONDO AT DIAMOND A RANCH, NR ROSWELL, NM	947	1939	19,230	54,800	18 Jun 65	0	Many
RIO HONDO BLW DIAMOND A DAM, NR ROSWELL, NM	963	1963	12,530	659	29 Jul 65	0	Many
RIO HONDO AT ROSWELL, NM	1,070	1981	16,510	378	18 Jul 91	0	Many
PECOS RIVER NR LAKE ARTHUR, NM	14,760	1938	162,300	49,600	24 Sep 41	0	Many
PECOS RIVER NR ARTESIA, NM	15,300	1909	171,600	51,500	30 May 37	0	Many

RECORD STORAGES

TWO RIVERS PROJECT BEGAN OPERATION IN JULY 1963

RIO HONDO RESERVOIR			ROCKY RESERVOIR		
DATE	W.S. ELEVATION	STORAGE (acre-ft)	DATE	W.S. ELEVATION	STORAGE (acre-ft)

	(ft NGVD)			(ft NGVD)	
29 Jul 65	3985.70	1,260	18 Jun 65	3970.70	6,090
23 Aug 66	3983.60	964	06 Jul 68	3965.90	3,589
06 Nov 86	3986.70	922	27 Jun 86	3969.63	4,881
15 Jul 91	3989.21	1,153	15 Jul 91	3970.84	5,484

WATER CONTROL MANUAL
TWO RIVERS RESERVOIR PROJECT
ALBUQUERQUE DISTRICT

I - INTRODUCTION

1-01. Authorization. This manual has been prepared in compliance with the following:

EM 1110-2-3600, "Management of Water Control Systems," dated 30 November 1987.

ER 1110-2-240, "Water Control Management," dated 8 October 1982.

ER 1110-2-8156, "Preparation of Water Control Manuals," dated 31 August 1995

1-02. Purpose and Scope. The purpose of this manual is to document the plan of water control for Two Rivers Reservoir Project and to provide a reference source for those who are concerned with control of lake levels throughout the life of the project. Other information contained in the manual supporting the water control plan consists of a detailed description of the project, including its history since authorization for construction; a description of the watershed covering such features as topography, climate, floods, economic data, and flood forecasting procedures employed for the project including storm and run-off data collection. Effects of project control on stream flows are presented and the interest of local agencies and organizations are discussed. It should be noted that elevations mentioned are in feet and are referenced to the National Geodetic Vertical Datum (NGVD). Since this manual is an appendix to the Pecos River Basin Master Water Control Manual (MWCM), numerous references will be made to that manual.

1-03. Related Manuals and Reports. Water control manuals which are pertinent to the Pecos River Basin are:

"Master Water Control Manual-Pecos River Basin," dated August 1977.

Appendix B, "Santa Rosa Dam and Lake, Water Control Manual," dated April 1979.

Appendix C "Sumner Dam and Lake Sumner, Water Control Manual," dated March 1991.

Appendix D, "Brantley Dam and Reservoir, Water Control Manual," dated September 1995.

Appendix E, "Drought Contingency Plan, Pecos River Basin," dated May 1989.

Reports which are pertinent to this manual are:

"The Pecos River Master's Manual," River Master of the Pecos River, dated November 30, 1987.

"Reconnaissance Report for Dam Safety Assurance Program, Two Rivers Reservoir," dated March 1995.

1-04. **Project Owner.** Two Rivers Reservoir Project is owned by the U.S. Army Corps of Engineers (Corps).

1-05. **Operating Agency.** Chaves County Flood Control Commission (CCFCC) operates Two Rivers Project through a cooperative agreement with the Corps (Exhibit B). Mr. Kenneth Barbe is the commissioner, his office telephone number is 505-622-6613 and his home telephone number is 505-622-4291. Mr. Dick Smith is the superintendent, his office telephone number is 505-623-9722 and his residence telephone number is 505-622-5297. Mr. Gary Smith is the foreman, his office telephone number is 505-623-9722 and his residence telephone number is 505-623-5033.

1-06. **Regulating Agencies.** The Albuquerque District Corps is responsible for regulation of the project (see Chapter IX, Water Control Management) for details.

II - DESCRIPTION OF PROJECT

2-01. Location. Two Rivers Reservoir Project is located in Chaves County, New Mexico about 14 miles southwest of Roswell on the Rio Hondo. The project consists of two dams, Rocky Dam and Diamond A Dam, that form a common reservoir. Diamond A Dam is located on the Rio Hondo and is approximately 34 miles upstream of the confluence of the Rio Hondo with the Pecos River. Rocky Dam is located on Rocky Arroyo about 10 miles above its confluence with the Rio Hondo. The reservoir location is shown on Plate 2-1, and the Two Rivers Watershed Map is shown on Plate 2-2.

2-02. Purpose. The Two Rivers Reservoir Project regulates Rio Hondo and Rocky Arroyo flows for flood control and sediment retention.

2-03. Physical Components. Two Rivers Reservoir Project is an earthfill structure with two conduit outlets, one in each embankment (one controlled by a gate), and an emergency spillway. Plate 2-3 shows the General Project Plan for Two Rivers Reseroir Project.

a. Embankment. The embankments for Diamond A and Rocky Dams are rolled-fill structures with upstream impervious-fill zones and downstream random-fill zones. Diamond A Dam has a crest length of 4,885 feet, a crest width of 26 feet. It has a maximum height above the streambed of 98 feet and contains 2.03 million cubic yards of fill material. The embankment for Rocky Dam has a crest length of 2,940 feet and a crest width of 20 feet with the height above streambed of 118 feet. It contains 3.69 million cubic yards of fill material. The crest elevation of the embankments is 4,054.0 feet, National Geodetic Vertical Datum (NGVD). A service road crosses the tops of both dams. Slope protection for the embankments consists of 18 inches of selected cobbles on the upstream slope. Details of the Diamond A embankment are shown on Plate 2-4A and details of the Rocky embankment are shown on Plate 2-4B.

The lower part of the reservoir is divided by an 8-foot dike and separate pools are formed behind each dam when the water surface elevation is below 3,988 feet, NGVD, in either reservoir. The dike is constructed in a natural saddle in the low ridge between the Rio Hondo and Rocky Arroyo watersheds. When the reservoir elevation on either side exceeds 3,988 feet, NGVD, the dike will breach, permitting flow from one reservoir to the other. A common pool is formed when both reservoirs are above elevation 3,988 feet, NGVD.

b. Outlet Works. The outlet works consist of two reinforced concrete conduits, one in each embankment. The conduits are rectangular in shape with transition structures upstream and downstream and are set in rock cuts. The intake structures consist of trash racks, side and wing walls, transition sections and stop log slots. Deflector buckets are used for energy dissipators; each will operate as a flip bucket until the tailwater rises above the bucket lip, after which they will function as deflector buckets. The Diamond A conduit is a 4- X 7-foot gated structure located in the right abutment with an upstream invert elevation of 3,957.0 feet, NGVD. The control structure has a 38-foot gate section in length with a 4- X 7-foot single slide gate, located 25 feet upstream from the dam axis. The concrete access shaft is a 90-foot high, wet well structure, with an inside diameter of 9.5 feet. The gate-control machinery is on the operating deck located at the top of the access shaft. The Diamond A outlet works are shown on Plate 2-5A.

The Rocky Arroyo outlet is an uncontrolled 3.5-foot square conduit located in the left abutment of Rocky Dam and has an invert elevation of 3,945.0 feet, NGVD. The outlet works for Rocky Dam are shown on Plate 2-5B.

c. Spillway. The spillway consists two uncontrolled saddle spillways located at the right and left abutments of Rocky Dam. The right and left spillways have crest lengths of 400 and 730 feet, respectively. Except for 400 feet of the left spillway, both spillways are in limestone; a portion of the left saddle dips about 4 feet below the crest elevation at 4,032 feet, NGVD. A concrete weir, with a crest elevation of 4,032 feet, NGVD, is located at this low area. Discharges through the spillways flow along natural channels and enter Rocky Arroyo 2,000 feet downstream. The total spillway capacity, at maximum water surface elevation of 4,048.9 feet, NGVD, is 233,000 cubic feet per second (cfs). Spillway plan, profile and typical sections are shown on Plate 2-4B.

d. Reservoir. The reservoir is approximately 4.2 miles long and 3.5 miles wide at elevation 4,032 feet, NGVD (top of flood control), which contains a volume of 163,775 acre-feet and a surface area of 4,834 acres. Initial storage allocations were 150,000 acre-feet for flood control and 18,000 acre-feet for sediment space.

2-04. Related Control Facilities. None.

2-05. Real Estate Acquisitions. Two Rivers Reservoir lands are shown on Plate 2-6.

2-06. Public Facilities. Facilities at Two Rivers Reservoir include a picnic site. Recent visitation records show about 500 visitors per annum.

III - HISTORY OF PROJECT

3-01. Authorization. Congressional authority for the Two Rivers Reservoir project is contained in the Flood Control Act of 1954 (Public Law 780, 83rd Congress, 2nd Session, approved September 3, 1954).

3-02. Planning and Design. Definite project studies were authorized by Advice of Allotment No.C-55, dated 20 July 1956, Appropriation 96x3122 Construction, General, Corps of Engineers. Design was completed and construction started in 1960. Two Rivers Reservoir Project was completed in July 1963, essentially as described in paragraph 3-03.

Due to the revision of the probable maximum precipitation by the National Weather Service in the early 1980's, a reconnaissance report was prepared in March 1995 that recommends widening the Rocky Dam left abutment spillway by 1,170 feet.

3-03. Construction. The existing dam and related structures were initiated in May 1960 and completed in July 1963.

3-04. Related Projects. Sections VI and VII of the Pecos River Basin Master Water Control Manual (MWCM) describe the system regulations for all related projects in the basin. The following is a brief description of each individual project in downstream progression.

a. Santa Rosa Dam and Lake. Santa Rosa Dam and Lake (formerly Los Esteros Dam and Lake) provides the first inviolate flood control on the main stem of the Pecos River. The dam is located on the Pecos River about seven miles upstream of Santa Rosa, New Mexico. It controls runoff from the upper 2,434 square miles of the Pecos River Basin. Conservation storage is 200,000 acre-feet; flood control, 167,000 acre-feet; and sediment space, 82,000 acre-feet. The Water Control Manual for Santa Rosa Dam and Lake is Appendix B to the MWCM.

b. Sumner Dam and Lake Sumner. Summer Dam (formerly Alamogordo Dam)is located 55.6 river miles downstream from Santa Rosa Dam. All but 20,000 acre-feet of irrigation space in Sumner Lake was transferred to Santa Rosa Lake upon its completion. This resulted in 85,500 acre-feet of flood control space in Sumner Lake, of which 52,500 acre-feet, between elevations 4,261 and 4,275 feet, NGVD, is available for flood regulation with controlled releases. The remaining 33,000 acre-feet, between elevations 4,275 and 4,282 feet, NGVD, offer only partial flood control because of automatic spillway releases when the lake level exceeds elevation 4,275 feet, NGVD. Flood operations at Santa Rosa and Sumner projects will be balanced so that each project will maintain proportional available flood control space. The Water Control Manual for Sumner is Appendix C to the MWCM.

c. Hondo Reservoir. Hondo Reservoir was a Reclamation Service (now the U.S. Bureau of Reclamation) irrigation project essentially completed in 1907, and is located about 3 miles downstream of Diamond A Dam. A sink hole developed in the bottom of the reservoir due to porous gypsum and limestone formations which underlies the floor. This reduced the available water by a substantial amount. The inadequate water supply combined with excessive maintenance costs, and in 1915, when the intake canal was washed out during a flood, led to the abandonment of the project and no water has been diverted for irrigation purposes since that time.

After the disastrous floods of 1941, the city of Roswell sought to convert the abandoned Hondo Reservoir to a flood control facility. The upper diversion works were renovated sufficiently to partially divert flood flows into Hondo Reservoir. Construction of Two Rivers Reservoir Project eliminated the need to use Hondo Reservoir as a facility for flood control. The diversion structure to Hondo Reservoir was breached in 1975 by CCFCC.

d. McMillan Dam and Lake. This project was located 5.5 miles upstream from Brantley Dam and was primarily used for irrigation storage. It has been replaced by Brantley Dam and Reservoir and was breached in January 1991. The dam embankment remains within the reservoir area of Brantley Reservoir. A 200 foot breach allows Pecos River flows to pass into Brantley Reservoir at low reservoir stages.

e. Brantley Dam and Reservoir. Brantley Dam is located on the Pecos River about 13 miles upstream from the city of Carlsbad, New Mexico. The primary purpose for Brantley is for dam safety (replaces Mcmillan Dam which was declared unsafe) with additional benefits derived from irrigation, flood control, fish and wildlife enhancement, and recreation. Total storage is approximately 348,000 acre-feet, at elevation 3,283 feet, NGVD. The Water Control Manual for Brantley Dam and Reservoir is Appendix D to the MWCM.

f. Avalon Dam and Lake. This project is located on the Pecos River 10 miles below Brantley Dam. It is operated primarily as a diversion structure for irrigation flows and provides only incidental benefits in the event of minor floods. Total storage is approximately 4,200 acre-feet.

g. Red Bluff Dam and Lake. Red Bluff Dam is located on the Pecos River about 10 miles below the New Mexico-Texas state line. Flood control and power production provided by the project are incidental to the operations for irrigation. The lake capacity is approximately 290,000 acre-feet at elevation 2,842 feet, NGVD.

3-05. Modification to Regulations. There have been no modifications to the regulations.

3-06. Principal Regulation Problems. The channel capacities of 1,000 cfs and 900 cfs on the Rio Hondo and Rocky Arroyo, respectively, have not been properly maintained. Significant overbank flooding problems are expected when flows exceed 600 cfs in the city of Roswell (Roswell), due to poor channel alignment at Deming Avenue and Kentucky Street. Roswell is responsible for maintaining the channel capacities under a resolution dated April 14, 1960 (Exhibit E). The regulations in this manual are based on restoring the capability to a 1,000 cfs release from Two Rivers Reservoir Project.

Mile 12 on the Rio Hondo, as referenced in Roswell's resolution and other documents, is located about 2 miles east of Roswell. The location of mile 12 was based on the river mileage shown on the Index Map, and described within the text in House Document 436 (HD 436) of the 83d Cogress, 2d Session, dated June 14, 1954. References to river mileage contained in this Water Control Manual are from U.S. Geological Water Resources Data reports, they do not necessarily correlate with those given in HD 436 and other documents prepared prior to the construction of Two Rivers Project.

IV - WATERSHED CHARACTERISTICS

4-01. General Characteristics. The Pecos River watershed is located in the states of Texas and New Mexico, in the Rocky Mountains and Great Plains physiographic region, in the southwestern United States, between latitudes 29° 40'N and 36° 00'N and longitudes 101° 04'W and 105° 50'W. The river has its source in Mora County, New Mexico, and flows in a general southeast direction through eastern New Mexico and western Texas to its confluence with the Rio Grande at the International Boundary between the United States and Mexico. Plate 2-1 shows the Pecos River Basin. The total area of the Pecos River watershed is 44,535 square miles. Of the total 25,473 square miles in New Mexico, 8,160 square miles are considered noncontributing and 17,313 square miles contributing. Of the total 19,062 square miles in Texas, 3,153 square miles are considered noncontributing and 15,909 square miles contributing. The largest of the noncontributing areas is located along the eastern limit of the basin, and the others are located in the northwestern portion. The watershed, which extends approximately 500 miles northwest from the confluence of the Pecos River and the Rio Grande, has a maximum width of about 130 miles near Pecos, Texas. The principal tributary drainage areas and river miles above the mouth for the Pecos River system are given in Table 4-1.

The Rio Hondo watershed is located in southeastern New Mexico and comprises 1,716 square miles of the Pecos River Basin. The Rio Hondo lies between latitudes 33° 09'N and 33° 39'N and longitudes 104° 24'W and 105° 51'W. It is about 82 miles long and has a maximum width of about 32 miles. The western boundary of the Rio Hondo basin is defined by the crests of Sierra Blanca and the northern end of the Sacramento Mountains which are both part of the general broken mountain ranges extending along the western edge of the Pecos River Basin. The northern limit of the Rio Hondo Basin is defined by the crest of the Capitan Mountains and an easterly extension thereof along a low divide across the plains to Pecos River. The southern limit of the Rio Hondo Basin consists of a series of low divides extending easterly from the Sacramento Mountains across the foothills and plains to Pecos River. The Rio Hondo and Rocky Arroyo flow in a general easterly direction to the confluence with the Pecos River. The Rio Hondo watershed is shown on Plate 2-2.

4-02. Topography. A broken chain of mountain ranges extends along the western divide from the northern headwaters south into Texas. Elevations of these ranges vary from more than 13,000 feet, NGVD, in the north to less than 5,000 feet, NGVD, in the southern part. From the foothills of the mountains, a steeply sloping plain scored by shallow drainage channels extends eastward to the Pecos River. Elevations increase gradually east of the Pecos River to the escarpment which marks the limit of the contributing area. East of the escarpment the land surface is an undulating plain rising gradually to the eastern boundary of the watershed.

The headwater reaches of the 2,434 square mile area above Santa Rosa Dam drain a rugged, mountainous region from the source of the river to the vicinity of Dilia (river mile 811.7). Along the western divide, Truchas Peak, elevation 13,100 feet, NGVD, marks the most northern point in the basin. From Truchas Peaks, the Sangre de Cristo Range extends south about 30 miles to Glorieta Mesa, the general elevation of which is about 7,500 feet, NGVD. The divide continues southward traversing a high plain to the Pedernal Hills at the headwaters of Pintada Canyon, which enters the Pecos River 39 miles upstream from Sumner Dam. From Truchas Peak east, the eastern watershed decreases in elevation from 13,100 feet, NGVD, to about 7,000 feet, NGVD, due north of Las Vegas, New Mexico. From this location, the divide extends southeast along the high plain which decreases to about 4,800 feet, NGVD, east of Santa Rosa Dam. The main valley decreases in elevation to about 5,200 feet, NGVD, at Dilia (river mile 811.7) and to about

4,500 feet, NGVD, at Santa Rosa Dam.

The major tributaries in the basin above Santa Rosa Dam are Cow Creek, Gallinas River, Canyon Blanco and Tecolote Creek. Pintada Canyon and Alamogordo Creek are the primary tributaries between Santa Rosa Dam and Sumner Dam. Pertinent data for the tributaries are given in Table 4-1.

TABLE 4-1

PERTINENT DATA, PECOS RIVER, AND TRIBUTARIES

TRIBUTARY	Miles Upstream from Mouth	Length (mi)	Contributing Drainage Area (sq mi)	Percent of Contributing Drainage Area (%)	Drainage Area of Pecos River at Location (Sq Mi)	
					Noncontributing	Contributing
Cow Creek	866.5	28	128	0.4	0	484
Tecolote Creek	826.5	40	282	0.8	0	1,001
Gallinas River	797.6	87	619	1.9	0	2,393
Pintada Canyon	749.7	63	488	1.5	383	3,156
Alamogordo Creek	711.6	34	353	1.1	644	3,749
Taiban Creek	675.6	64	591	1.8	2,292	4,871
Salt Creek	595.0	52	2,988	9.0	2,574	9,338
Rio Hondo	571.2	87	1,716	5.2	2,574	11,244
Rio Felix	545.1	92	938	2.8	2,574	12,552
Eagle Creek	504.0	45	143	.4	2,574	13,200
Rio Penasco	496.5	108	1,075	3.2	2,574	14,605
Seven Rivers	481.0	56	624	1.9	2,574	15,578
Dark Canyon	459.0	60	442	1.3	2,574	16,504
Black River	436.4	54	362	1.1	2,574	17,139
Delaware River	405.6	60	971	2.9	8,160	18,502
Toyah Creek	296.1	55	3,729	11.2	8,160	23,928
Coyanosa Creek	277.5	74	1,569	4.7	8,160	25,608
Comanche Creek	188.2	46	946	2.8	1.313	27,268
Mule Creek	166.4	25	926	2.8	1,313	28,603
Independence Creek	94.6	56	759	2.2	1,313	30,981
Howards Creek	59.8	68	1,224	3.7	1,313	32,521
Pecos River	0.	926.4		100.0	1,313	33,222

The topography between Santa Rosa Dam and Sumner Dam is mostly rolling hills, plains and prairie land with hills, mesas and mountains forming the borders on both the east and west. There are numerous low basins and sink holes. Most of these sink holes are dry; however, some form deep lakes, and a few are springs producing clear water. Elevations vary from about 6,300 feet, NGVD, in the headwaters of Pintada Canyon in the west to about 4,600 feet, NGVD, at the Pecos and 5,300 feet, NGVD, east of the Pecos in the headwaters of Alamogordo Creek. The watershed is shown on Plate 2-1.

The western portion of the middle basin, which extends from Sumner Dam to Red Bluff Dam, is delineated by a contributing area commencing at the Pedernal Hills. From this location, a series of mountain ranges form the western divide for the contributing areas of the middle basin. From north to south these ranges are known as the Gallinas, Jicarilla, Sierra Blanca, Sacramento, and Guadalupe

Mountains. In these mountains, crest elevations range from 9,390 feet, NGVD, in the Jicarillas, 12,000 feet, NGVD, on Sierra Blanca, and 9,190 feet, NGVD, in the Sacramentos to 8,750 feet, NGVD, in the Guadalupes. The eastern divide, beginning at elevation 5,000 feet, NGVD, traverses the high plains southeast to the New Mexico-Texas state line between Lea County, New Mexico, and Andrews County, Texas, where the elevation is approximately 3,600 feet, NGVD. The watershed of the contributing area on the eastern bank generally follows the escarpment a few miles east of the Pecos River. The river valley is comparatively narrow with steep marginal bluffs through most of the middle basin. The widest areas of the valley proper are in the vicinity of Fort Sumner and between Roswell and Carlsbad, New Mexico. Elevations along the valley decrease to about 2,840 feet, NGVD, at the head of Red Bluff Reservoir just above the New Mexico-Texas state line. The major tributaries in the middle basin are Salt Creek, Rio Hondo, Rio Felix, Rio Penasco, Dark Canyon, and Delaware River.

From the Guadalupe Mountains, the western divide of the lower basin is aligned along the Delaware, Apache, Davis, Del Norte, and Glass Mountains for about 175 miles to the Edwards Plateau. Elevations in these ranges vary from about 8,750 feet, NGVD, to about 5,400 feet, NGVD. Along the eastern boundary of the lower basin, the contributing area on the left bank from Red Bluff Dam to the vicinity of Girvin, Texas, is delineated by a low escarpment. Downstream from Red Bluff Reservoir the river valley widens, and the main stream meanders through gently rolling hills to the vicinity of Girvin, Texas. Below Girvin, the river has cut a canyon through the rough Edwards Plateau. At the confluence with the Rio Grande, elevation 1,000 feet, NGVD, the canyon is more than 300 feet deep.

The Rio Hondo begins in the Sierra Blanca Mountains with the elevation varying from about 12,000 feet, NGVD, down to 6,000 feet, NGVD, and is characterized by steep slopes and narrow valleys. The watershed narrows as it reaches the foohill region then widens some but remains comparatively narrow to Roswell. Topography from the town of Hondo gradually changes from steep rocky foothills to gently rolling hills above the project. The lower end of the Rio Hondo Basin in the Pecos River flood plain is nearly flat. The lower basin varies in elevation from about 6,000 feet, NGVD, in the foothills to 3,440 feet, NGVD, at the confluence with the Pecos River.

4-03. Geology and Soils of the Pecos River Basin. Exposed rock formations in the Pecos River Basin range in age from Precambrian to Quaternary. In the upper portion of the watershed (above Las Vegas, New Mexico) the exposed strata consist of Precambrian granites and metaphoric materials. Carboniferous beds and Pennsylvanian limestone are also exposed in the northwestern part of the watershed. Cretaceous and Jurassic sandstone, along with variegated shales and limestones, are exposed in a limited area in the vicinity of Las Vegas, New Mexico. From the area of San Jose (approximately 19 miles southwest of Las Vegas, New Mexico) to the confluence of the Pecos River and the Rio Grande, Permian, Triassic, and Cretaceous rocks consisting of anhydrite, gypsum, salt, sandstone, shale, and limestone are exposed in spots, but in most areas they are mantled by extensive deposits of sand, gravel, silt, and clay of Tertiary and Quaternary age. Exposed igneous rocks of post-Carboniferous age are found along the western edge of the Pecos Basin in Lincoln County, New Mexico. Tertiary and/or late Cretaceous igneous rocks are exposed in the lower Pecos River Basin in Jeff Davis County, Texas. New Mexico's Lincoln County has exposed strata of post-Carboniferous igneous rocks and intrusive rocks consisting mostly of porphyries. Jeff Davis County in Texas contains exposed strata of either Tertiary or late Cretaceous igneous rocks, in addition to materials consisting largely of extrusive lava, tuff, ash, and agglomerate. From the vicinity of San Jose south to the confluence with the Rio Grande, the basin is underlain by Permian, Triassic, and Cretaceous strata. The Permian materials consist of anhydrite, gypsum, salt, sandstone, shale, and limestone. The Triassic materials consist of gypsum, sandstone, and shale while the Cretaceous materials consist of sandstone, shale, and limestone. Cambrian, Ordovician, Silurian, and Devonian strata are present beneath the surface in southeastern New Mexico and west Texas.

The formations underlying the Pecos River Basin have a shallow general dip to the east and southeast. This general dip is interrupted only by minor warping which accompanied a regional uplift and tilting of the area at the close of the Cretaceous period. Soluble beds are found nearly everywhere beneath the land surface in the Pecos Valley. The surficial rock layers have been distorted through slumping caused by the removal of large quantities of soluble material from the underlying formations. As a result, trains of sink holes (depressions) occupied by playas and perennial ponds are in evidence over much of the watershed area. The trains of depressions were integrated by overflow from high to lower basins or by tapping of successive depressions by streams working headward from the lower depressions. These depressions were eventually captured by a tributary of the Rio Grande working headward (northward), fixing the Pecos River in approximately its present position.

The rock outcroppings in the Rio Hondo watershed range in age from Carboniferous to Quartenary. The greater part of the area is underlain by deposits of Permian, Triassic and Quartenary age with Permian as the generally dominant age. Rocks of Quartenary age formations are found in the extreme eastern portion of the basin, with spotted representation in the mountains of the western part of the watershed. Along a line, roughly designated as being between the high mountains and the foothills in the western part of the basin, strata of Triassic age are evident. Exposures of igneous rocks of post-Carboniferous age, intrusive rocks, mostly porphyries, are found in the western portion and along the northwestern limit of the basin.

The United States Department of Agriculture has grouped the soils of the watershed as deep alluvial; deep soils, upland; medium depth, upland; shallow depth, upland; deep loose sand; and shallow gravelly and stony soils. The depth to an impervious layer governed the classification. Shallow soils are less than 10 inches in depth, medium-depth soils are 10 to 40 inches in depth, and deep soils are more than 40 inches in depth. The percent of the contributing drainage area occupied by each of these classifications and their general topographic position in the basin are given in Table 4-2.

Latitude and precipitation are the governing factors controlling native vegetation in the Pecos River Basin. In general, annual precipitation in the drainage area increases with elevation. The water requirements of the major vegetative types are indicators of the average amounts of precipitation. From the higher altitudes, as elevations decrease, coniferous forest merges to woodland followed by grasses and desert shrub. Broad vegetative types and the percent of the watershed they occupy are: Short grass, 31 percent; desert shrub-grassland, 31 percent; desert grass, 18 percent; sandhill grass, one percent; woodland, 14 percent; and coniferous forest, 5 percent.

4-04. Sediment. The 2,000-square mile mountainous source area of the Pecos River produces little sediment. The remaining watershed area, according to the Soil Conservation Service, is susceptible to erosion at rates ranging from 0.4 acre-foot per square mile per year to 3.5 acre-feet per square mile per year. The greatest erosion occurs in the alluvial valleys along the main stem and major tributaries where fine-textured soils are exposed to bank caving and gully erosion.

Between Santa Rosa Dam and Santa Rosa, New Mexico, the river bed is mostly gravel with some boulders and large rocks from the canyon walls. Talus material from the canyon sides lines the banks. Below Santa Rosa, soil depths vary from

TABLE 4-2

SOIL GROUPS, PECOS RIVER BASIN

Soil Group	Percent of Contributing Drainage Area	Topographic Position
Deep alluvial	4	Recent overflow or first bottom land
Deep soils, upland	15	Second bottom or low outwash plains
Medium depth, upland	24	Undulating to rolling hills and river terraces
Shallow depth, upland	43	Mountains, foothills, and steeply rolling plains area
Deep loose sand	2	High plains east of Pecos River
Shallow gravelly and stony	12	Steep hills and mountainous areas

shallow to deep, and there are some areas of blow sand. Erosion is greatest in a strip four to ten miles wide along the Pecos River and in a narrow strip along each side of the major tributaries. Erosion varies greatly with the vegetal cover and rainfall. Bank caving is common along the main stem and for considerable distances up some of the tributaries. Short, steep sided arroyos are common in the bluff areas and produce coarse material in the main stem. The size of sediment particles derived from this area varies greatly. Suspended samples secured from the main stem show about 25 percent of the total load coarser than silt which indicates a heavy total coarse material load.

According to the Natural Resources Conservation Service (NRCS) classification, the Rio Hondo watershed is moderately susceptible to erosion. The upper portion of the watershed is comprised of moderate to high rates of sediment production. The lower portion has a low rate of sediment production.

4-05. Climate. Climatic conditions vary considerably within the Pecos River watershed. These variations are due principally to the geographical location and topography of the drainage area. Generally, the summers are warm in the upper part and hot in the lower portion of the basin, and the winters are moderate with occasional cold waves of short duration. Within the watershed, maximum and minimum observed temperatures of 116° Fahrenheit (F.) and -35° F. have been recorded at Artesia, New Mexico, elevation 3,350 feet, NGVD. The average 230-day growing season at the lower elevations in Texas extends from late March to the middle of November. The period shortens with increase in latitude and elevation to about 100 days, from the first 10 days in June to the second 10 days in September, at the higher elevations in the mountainous northern part of the drainage area. The prevailing winds are from the south or southwest. The maximum recorded wind velocity within the watershed was 75 miles per hour at Roswell, New Mexico. Relative humidities are low and reflect the diurnal and nocturnal temperatures.

a. Temperature. A wide range of temperature is experienced in the watershed as evidenced by the difference between mean, maximum and minimum monthly temperatures at all stations of nearly 40° F. Average annual temperatures do not differ significantly; however, the maximum and minimum temperatures during record periods vary as much as 132°. In the mountains, much colder daily temperatures are experienced as listed in Table 4-3. Las Vegas, New Mexico, averages 170 days per year below 32° F. and only 8 days above 90° F., while Sumner Dam averages only 100 days per year below 32° F. and 91 days above 90° F.

TABLE 4-3

TEMPERATURE DATA

Station	Elevation (feet)	Years of Record	Temperature-Degrees F. Average Annual	Max.	Min.	Days/Yr. Above 90	Days/Yr. Below 32
Las Vegas AP	6,886	48	49.3	100	-31	8	169
Santa Rosa	4,620	67	57.7	108	-25	86	113
Vaughn	6,050	39	52.8	110	-25	39	141
Sumner Dam	4,306	46	58.4	106	-24	91	100
Roswell	3,649	87	59.5	110	-29	86	107

Data Taken from USWB Publication No's. 86-25, 86-36 and Anuual Summaries of Climatological Data published by NOAA. Record through 1988.

b. Precipitation. The average annual precipitation over the Pecos Basin above Sumner Dam is about 15 inches. About one-half of it occurs during July, August and September and three-fourths during the growing season from May through September. It varies from 23.89 inches at Cowles to 12.74 inches at Vaughn, New Mexico. Annual and extreme precipitation data for representative stations are listed in order from north to south in Table 4-4. Average annual precipitation is shown on Plate 4-1.

TABLE 4-4

PRECIPITATION DATA

Station	Elev. (feet)	Annual Precipitation (In.) Years of Record	Max.	Min.	Avg.	Precipitation Max. 24-Hour In.	Date
Cowles	8,100	60	37.25	11.77	23.89	2.61	15 Sep 31
Las Vegas AP	6,886	48	32.29	6.33	16.29	3.87	1 Sep 42
Santa Rosa	4,620	89	34.97	6.63	14.27	3.52	22 Sep 41
Vaughn	6,050	64	29.95	3.21	12.64	4.40	31 Aug 42
Sumner Dam	4,306	49	40.97	3.95	13.26	7.11	22 Sep 41

Roswell	3,649	87	32.90	4.35	12.44	5.65	01 Nov 01

Data taken from USWB Publications No's. 86-25, 86-36 and Annual Summaries of Climatological Data published by NOAA. Record through 1988.

c. Snow. Average annual recorded snowfall in the basin mountainous areas varies from 81.4 inches at Cowles to 6.5 inches at Sumner Dam. A maximum annual recorded snowfall of 215.5 inches occurred at Harvey's Upper Ranch Station in the Gallinas watershed above Las Vegas in 1911. Over most of the basin, snowfall constitutes only a minor portion of the total precipitation. In the mountains, snowfall is significant and it remains on the ground in the higher elevations until spring. In the lower elevations, snow seldom remains on the ground more than a few days. Snowfall for four stations are listed in Table 4-5.

TABLE 4-5

SNOWFALL DATA

		Average Monthly in Inches								
Station	Elevation (feet)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Season
Fort Sumner	4,306	0	1.0	2.3	1.9	2.3	0.6	0.2	0	8.3
Santa Rosa	4,620	0.1	1.4	4.4	2.1	2.0	0.7	0.4	0	12.4
Las Vegas	6,470	1.6	4.1	7.6	4.6	5.1	7.1	3.7	0.6	35.3
Ruidoso	6,839	1.4	4.5	9.8	9.6	8.4	8.0	1.5	0.2	43.4

From: USWB 1951-80

d. Evaporation. Average annual evaporation in, and adjacent to, the Pecos River Basin varies from 92.05 inches at Portales to 119.54 inches at Lake Avalon in New Mexico. The highest monthly evaporation occurs in the month of June and is about 14 percent of the annual. The lowest rates occur in December and January, each of which is about three percent of the annual. Monthly and annual evaporation data for Lake Sumner are shown in Table 4-6. Comparison of evaporation for several stations is presented in the Pecos River Master Manual. The evaporation in Table 4-6 is for a period about 17 years and is from a Pecos River Commission study. Winter months were estimated from comparison with adjacent stations.

TABLE 4-6

EVAPORATION DATA

Average Evaporation in Inches												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
3.68	4.91	8.62	10.86	13.01	14.97	13.88	12.92	10.49	7.38	4.82	3.78	108.69

e. Wind. According to observations made during the 51 years of record at Roswell, the greatest wind activity is in the spring with the maximum monthly average velocity of 10.2 miles per hour (mph) occurring in March. A maximum velocity of 75 mph was recorded during April 1953. All months of the year have, at some time, experienced velocities greater than 50 mph. Wind data are listed in Table 4-7.

TABLE 4-7

WIND DATA

	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Hourly Speed (mph)	**51**	**7.8**	**8.6**	**10.2**	**10.1**	**9.4**	**8.7**	**7.4**	**7.2**	**7.3**	**7.7**	**7.4**	**7.4**	**8.3**
Prevailing Direction		**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Fastest Mile:														
Speed (mph)		**60**	**65**	**65**	**75**	**57**	**57**	**66**	**72**	**54**	**52**	**65**	**60**	**75**
Direction		**NW**	**NW**	**W**	**W**	**SW**	**NE**	**SW**	**W**	**NW**	**S**	**W**	**NW**	**W**
Year		**53**	**52**	**49**	**53**	**50**	**40**	**53**	**53**	**52**	**54**	**53**	**51**	**APR 53**

Data taken from Roswell, New Mexico Stations, 1941-70

4-06. <u>Storms and Floods.</u> General precipitation may produce a large volume of runoff and high peak discharges throughout the Pecos Valley. Thunderstorm precipitation may cause local floods of high peak discharges and comparatively small flood volume. However, this type of flood wave is soon dampened by channel storage. Upstream from Anton Chico, floods may result from snowmelt or precipitation occurring upon a melting snow blanket. Snowmelt does not cause high flows below Anton Chico unless supplemented by runoff from rain storms occurring below the snowmelt area. Spring snowmelt volumes average about 45,000 acre-feet and are regulated at Santa Rosa Lake. Snowmelt from the various tributaries with headwaters in the Sacramento Mountains and Sierra Blanca seldom reaches the Pecos River with magnitudes that cause flooding problems. The average Spring snowmelt volume on the Rio Hondo at Ruidoso is 6,500 acre-feet.

a. <u>Historical Floods</u>. Historical evidence, prior to the establishment of stream gaging stations, includes reference to five major floods in the Pecos Basin prior to 1904. Accounts beginning in 1865 indicate that major floods occurred in 1871, 1874, 1886, 1893, and 1900.

b. <u>Major Floods of Record</u>. Recorded data of major floods cover the period from 1904 to date. During that period, there have been 12 major and moderate floods in the main stream of which 11 were caused by general precipitation and only one by local rainfall. The maximum peak discharge in the basin occurred at Comstock, Texas, near the confluence of the Pecos River with the Rio Grande, during the flood of 27, 28 June 1954 when a discharge of 948,000 cfs was observed. The largest tributary discharge in the Sumner area had an estimated peak of 21,800 cfs and occurred in Alamogordo Creek above Sumner Dam, on 3 June 1937. Maximum peak discharges on the Pecos River and its tributaries are listed in Table 4-8.

TABLE 4-8

PECOS BASIN MAXIMUM PEAK DISCHARGES

Location	Years of Record	Date	Peak Discharge (cfs)
Pecos River:			
Pecos (New Mexico)	69	Sep 21, 1929	4,500
Anton Chico	75	Jun 1, 1937	40,300
Santa Rosa	77	Jun 2, 1937	55,200
Puerto de Luna	50	Sep 1, 1942	48,600
Sumner	76	Sep 1, 1942	42,800
Acme	50	May 28, 1937	53,300
Lake Arthur	50	Sep 24, 1941	49,600
Artesia[1]	83	May 30, 1937	51,500
McMillan Dam	47	Oct 2, 1904	60,000
Avalon Dam	38	Aug 23, 1966	55,500
Malaga	68	Aug 23, 1966	120,000
Red Bluff	51	Aug 23, 1966	111,000
Orla	51	Sep 29, 1941	23,700
Girvin	49	Oct 5, 1941	20,000
Major Tributaries:			
Gallinas River near Montezuma	72	Aug 2, 1966	7,120
Alamogordo Creek above Sumner Dam[3]	0	Jun 3, 1937[4]	21,800
Cienega del Macho near confluence with Salt Draw[3]	0	May 28, 1937[4]	49,500
Salt Creek at Roswell[3]	0	Oct 1904[4]	12,400
Berrendo Creek near Roswell[3]	0	Jun 1, 1937[4]	37,700
Rio Hondo:			
Riverside[3]	0	May 29, 1937[4]	24,900
Diamond A Ranch	50	Jun 18, 1965	54,800
Rio Felix at Hagerman	49	Oct 7, 1954	74,000
Eagle Creek at Diversion[3]	0	Jul 24, 1911[2]	26,000
Rio Penasco at Dayton	37	Aug 23, 1966[4]	29,800
Rocky Arroyo near Carlsbad	25	Aug 23, 1966[4]	31,600
Dark Canyon at Carlsbad[3]	15	Aug 23, 1966	66,000
Hackberry Draw at mouth[3]	0	Sep 7, 1932	3,000

/1 Includes records published as Pecos River near Dayton.

/2 Estimated.

/3 Non established gaging station.

/4 From miscellaneous discharge measurements.

The following paragraphs discuss major storms in the basin for which substantial information was available.

Pecos Mainstem:

(1) September-October 1904. This flood originated in the upper Pecos River Basin and in the headwaters of major tributaries upstream from Carlsbad, New Mexico. Major flood stages were experienced throughout the Pecos River with maximum peak flows of record at Roswell and McMillan Dam. Peak flows at pertinent stream gage stations on the Pecos River were: Santa Rosa - 46,500 cfs, Fort Sumner - 45,200 cfs, Roswell - 55,700 cfs, McMillan Dam - 82,000 cfs, and Red Bluff - 52,000 cfs. Major damages occurred throughout the entire reach of the Pecos River with the Carlsbad area experiencing the greatest because of the affected residential and commercial areas of the city. Crops and pastures were damaged throughout the river's length but especially in the reach from the mouth of the Rio Hondo to McMillan Reservoir.

(2) May-June 1937. The first rise of the May-June 1937 flood had a momentary peak of 13,900 cfs in the Pecos River at Santa Rosa on May 27. Peak flows in the tributaries did not synchronize with high flows on the main stem as indicated by the peaks of 26,500 cfs in Rio Felix at Hagerman on may 29; 24,900 cfs in Rio Hondo at Riverside, just upstream from Diamond A Ranch gage, on June 1; and 37,700 cfs in Berrendo Creek near Roswell on June 1. This rise was followed by maximum flows of record at Anton Chico - 40,300 cfs and Santa Rosa - 55,200 cfs on June 1 and June 2, respectively. Subsequently, a flow of 21,800 cfs occurred in Alamogordo Creek on June 3. These momentary peaks were regulated by Sumner Dam to a peak discharge of 23,200 cfs. On May 28 and 30, record breaking flows of 53,300 cfs and 51,500 cfs passed Acme and Artesia gages, respectively. These flows resulted principally from the Cienega del Macho watershed, a tributary of Salt Creek. Red Bluff Reservoir, with about 285,000 acre-feet of available storage capacity, reduced the flood peak to 5,530 cfs on June 9. This flood, although occurring in late May, was not augmented by snowmelt. Major damages to crops and pasture occurred from Anton Chico downstream to McMillan Dam. Lesser damages occurred in the remainder of the basin. Crops, pasture lands and transportation facilities experienced the most damage.

(3) August-September 1942. This flood originated in the basin above Sumner Dam. Flows in excess of flood stage were recorded from Santa Rosa to below McMillan Dam. Maximum flows were 9,850 cfs at Anton Chico; 40,600 cfs at Santa Rosa; 48,600 cfs at Puerto de Luna; and 37,000 cfs at Acme. Maximum outflow through the spillway at Sumner Dam was 42,800 cfs on 1 September. Damages occurred to crops, pastures, rural improvements such as irrigation facilities, utilities and transportation facilities.

(4) June 1954. The flood that occurred on the Lower Pecos and Devils River on 27-28 June 1954 was from a small hurricane that began on 24 June in the Gulf of Mexico. The storm crossed the coast about 50 miles south of Brownsville, Texas, about noon on 25 June. The storm moved slowly up the Rio Grande Valley and stalled over the Pecos and Devils River watershed during the night of 26 June. As the storm progressed over the relatively flat terrain below Del Rio, rain was moderate. Above Del Rio the storm encountered narrowing of the valley between Serranias del Burro in Mexico and the tip of the Balcones Escarpment in Texas. Lift imparted by the ground slope was sufficient to initiate and maintain vast ascending columns of air in the saturated atmosphere.

When the center of the decaying hurricane reached this orographically favorable region, heavy rains began near Langtry, Texas. Detailed information on the wind is lacking, but it is reasonable to suppose that the prevailing wind into the area was from the southeast with the heaviest rain tending to be up slope. The flow on the Pecos at the site of the Sheffield, Texas gaging station (abandoned) was estimated to be about 17,500 cfs.

(5) August 1966. This flood occurred during 20-23 August 1966, producing a prolonged steady rain over southeastern New Mexico and southwestern Texas. The areal extent of the flooding was from Roswell, New Mexico south to Red Bluff, Texas. A number of maximum peak flows of record were experienced in the middle portion of the Pecos River Basin. Pecos River at Avalon Dam, Malaga and Red Bluff had estimated peak flows of 55,500 cfs, 120,000 cfs and 111,000 cfs, respectively, all occurring on August 23. Three tributaries, Rio Penasco at Dayton, Rocky Arroyo near Carlsbad and Dark Canyon near Carlsbad had estimated peak flows of 29,800 cfs, 31,600cfs and 66,000 cfs, respectively. Most of the damage caused by this flood was in the Carlsbad area.

Rio Hondo:

(6) September 1941. The heavy rainfall of September 20-24, 1941, over eastern New Mexico extended into the headwaters of Rio Hondo. This storm produced a peak discharge of 26,500 cfs at the Rio Hondo at Diamond A Ranch gage. The estimated peak discharge at Roswell was 35,800 cfs, and caused considerable damage to Roswell.

(7) October 1954. On October 5-7, relatively heavy rains fell in the Pecos River Basin in the area from Lake Sumner to Carlsbad. From Roswell and south the rains occurred mostly west of the Pecos River. Very little runoff developed in the upper reaches of the Rio Hondo, most of it concentrated below the confluence of the Rio Bonito and Rio Ruidoso. Downstream from the heavy rain at Diamond A Ranch, the peak discharge on the Rio Hondo was 23,000 cfs. Rocky Arroyo near Roswell produced a peak discharge of 6,620 cfs. The effects of channel and overbank storage, and flood fighting greatly reduced the amount of flooding damage to Roswell.

(8) June 1965. During the period of June 16-17, a front aloft created by an inflow of cold air from the Gulf of Alaska, via the southwest Pacific route, coupled with plentiful moisture from the Gulf of Mexico, resulted in highly unstable atmospheric conditions over eastern New Mexico. This synoptic situation resulted in intense showers centered near Raton in northern New Mexico, and in the Ruidoso-Hondo area. On June 17-18, severe flooding occurred in the Rio Hondo valley and in tributary valleys west of Roswell. The floods resulted from intense rainfalls in the upper reaches which moved downstream. The peak discharge on the Rio Hondo at Picacho was 115,000 cfs. In the 30-mile meandering river reach from Picacho to Daimond A Ranch, the peak discharge was reduced to 54,800 cfs. All the floodwater in Rio Hondo was intercepted and easily contained in the Two Rivers Project.

(9) July 1991. Mid and upper level winds organized into a southwesterly flow beginning July 9 and by the 11th, this flow had become an axis of moist air streaming out of the eastern Pacific over northern Mexico and across southcentral and eastern New Mexico where scattered heavy rain showers began producing amounts of 1 to 2 inches. On the 12th, a surface trough of low pressure extending from central Oklahoma into southeastern New Mexico began a weak intensification as a 500mb low formed near the Texas Big Bend region. Locally heavy rains then became focussed over southeast areas of the state with early morning storms producing street flooding at Roswell, New Mexico on the 13th. As the upper low over Mexico drifted slowly northward, persistent heavy

rains began to focus along the mountains west of Roswell and Carlsbad. Rainfall estimated at 4 to 6 inches over the Rio Hondo and Rocky Arroyo watersheds on the 13th produced heavy runoff. A one-hour peak inflow into Rocky Reservoir was estimated at 9,500 cfs and a one-hour peak inflow into Rio Hondo Reservoir was estimated at 1,700 cfs, both ocurring on the 13th. The gate at Diamond A Dam was closed early on the 13th, and there were uncontrolled releases from Rocky Dam. This event resulted in maximum historical pool elevations at Rio Hondo and Rocky Reservoirs, 3989.21 feet, NGVD, and 3970.84 feet, NGVD, respectively.

4-07. <u>Runoff Characteristics</u>. Stream flow in the Pecos River is perennial except for a short reach between Anton Chico and Colonias and from Sumner Dam to the vicinity of Acme gage. Floods in the basin are characterized by rapid rises and short durations. Synchronization of flood flows from the various tributaries has seldom been experienced in the basin downstream from Sumner Dam. Hydrologic studies of storms and resultant runoff show that infiltration rates varied from 0.13 to 0.44 inch per hour with an average rate of 0.25 inch per hour for the area between Santa Rosa and Sumner Dams. No initial loss was indicated for the watershed, primarily because of the shallow soils and sparse vegetation. Peak flood flows are found to occur from 24 to 30 hours after the beginning of storms. The largest peak flows and flood volumes typically occur during the months of May through October.

Rio Ruidoso and Rio Bonito, which, at their confluence form Rio Hondo, are perennial throughout most of their lengths. Rio Hondo is perennial to about the Lincoln-Chaves county line. From this point it is intermittent to the Two Rivers Project and continues as an intermittent stream down to the mouth.

Stream flow records are available for 35 streamgaging stations on the Pecos River and for 48 stations on tributary streams. Records were first obtained at Avalon Dam, New Mexico, in 1891, but records for the main stem are continuous at only eight stations from 1915 to date. The records for the station near Comstock, Texas, are unbroken from 1900. Fragmentary data prior to 1915 are available for the seven other long-record stations. Records of tributary streams are meager prior to 1932 with the exception of the station at Montezuma, New Mexico, on the Gallinas River. Plates 4-2 and 4-3 show stream gaging stations for the entire basin and for the Sumner Dam to Brantley Dam area, respectively. Plates 4-4A through 4-4C show profiles of the riverbed, low and high waters, and bank heights from Girvin, Texas, to the Pecos headwaters. A flow duration curve for the Rio Hondo at Diamond A Ranch near Roswell gage is shown on Plate 4-5.

Stream flow records are available for 18 stream gaging stations in the Rio Hondo Basin. Periods of record for these stations vary from a few months to about 56 years; and of the 18 stations only five are maintained at the present time, three on the mainstem Rio Hondo and two on tributaries.

Consumptive use in the drainage basin has varied with irrigation developments and changed vegetative cover, and these depletions are reflected in the records. The records show the general surface runoff contributions for different portions of the watershed. The maximum, minimum, mean, average annual runoff, the period of record, and drainage area for selected stations are shown in Table 4-9. Tables 4-10, 4-11 and 4-12 lists the recorded monthly flows at the Rio Hondo at Diamond A Ranch, Rio Hondo below Diamond A Dam and Pecos River at Artesia gages, respectively.

Stream flow data on the main stem and on tributaries in irrigated areas are reasonably adequate except that some gaging stations are not capable of recording stages of major floods. Tributaries not affected by irrigation developments are generally not gaged, although some have drainage areas of over 1,000 square miles. Therefore, many floods originating on tributaries are not recorded until after they enter the main stem.

4-08. <u>Water Quality</u>. The quality of Pecos River water has traditionally been poor and continues to be so today. In general, the quality of water deteriorates downstream because it gains soluble minerals from surface water runoff, irrigation and municipal return flow, and ground water discharge. In addition, water that is high in dissolved solids is contributed to the Pecos River from springs located below Colonias, near Bitter Lake, and in the Lake Arthur area. The discharge of natural brine from aquifers near the Malaga Bend area are largely responsible for inflows of highly saline water to the Red Bluff Reservoir.

Flow of the Pecos River in Texas consists principally of releases and some seepage from Red Bluff Reservoir. Flow continues to increase in dissolved solids content from irrigation return flows, evaporation, and ground water seepage until tributaries below Girvin contribute better quality water.

TABLE 4-9

<u>STREAM FLOW DATA AT SELECTED STATIONS ON THE PECOS RIVER</u>

	Contributing Drainage Area (Square Miles)	Complete Water Years of Record	Annual Runoff (acre-feet) Maximum	Minimum	Mean	Average Annual Runoff (Inches)
Mainstem:						
Anton Chico, NM	1,052	71	354,400	16,950	90,020	1.60
Santa Rosa, NM	2,652	64	480,200	18,200	94,100	0.67
Artesia, NM	13,256	84	997,600	47,050	171,600	0 24
Malaga, NM	17,150	62	1,196,000	12,200	110,500	0.12
Rio Hondo:						
Diamond A, NM	947	53	149,400	946	12,530	0.25

Dissolved solids from irrigation return and ground water seepage are the major source of salinity in the Pecos River. In general, irrigated farming results in the consumptive use, by evaporation and transpiration, of about two-thirds of the water diverted from the river. Return flow from irrigation transports essentially all the dissolved solids from the consumed supply back to the stream or to the ground water system.

4-09. <u>Channel and Floodway Characteristics</u>. From its mountainous headwaters to Dilia (river mile 811.7), the Pecos River flows through precipitous canyons. From Dilia to Sumner Dam (river mile 710.8), stream slopes are approximately nine feet per mile and the average width of the river in this reach is about 400 feet. The Gallinas River, the major tributary in this area, has a capacity of 8,000 cfs through the city of Las Vegas. From Sumner Dam to the Acme gage (river mile 591.2), the fall per mile decreases to about five feet and the streambed is approximately 500 feet in width. From Acme to Brantley Dam (river mile 478.5), the gradient decreases to 2.4 feet per mile with a channel width of about 300 feet. Channel capacity through the Fort Sumner Irrigation District is about

18,000 cfs. Through the Roswell Artesian Basin it is approximately 8,500 cfs. The stream slope between Brantley Dam and Red Bluff Dam (river mile 390.8) increases to 5.3 feet per mile, the average channel width lessens to 260 feet, and the channel capacity is about 20,000 cfs. Below Red Bluff Dam to Girvin, Texas (river mile 178.4), the stream gradient is only 2.3 feet per mile and the average channel width is less than 150 feet. The channel capacity through the irrigated areas is approximately 3,000 cfs. In the canyon section below Girvin to the mouth, the fall is about seven feet per mile. The principal characteristics of the Pecos River channel for selected reaches are given in Table 4-13.

Rio Ruidoso and Rio Bonito flow through deeply cut, narrow valleys from their headwaters to their confluence, the start of the Rio Hondo. The Rio Hondo flows through a precipitous canyon in the upper reaches and is confined to a relatively narrow valley from about the Lincoln-Chaves county line to Two Rivers Project. River slopes in the reaches above Two Rivers project vary from 15 feet per mile to 25 feet per mile in the upper reaches. These reaches have channel capacities of about 25,000 cfs. Rocky Arroyo drains 74 square miles above Rocky Reservoir and is confined by a relatively narrow canyon.

TABLE 4-13

PRINCIPAL CHARACTERISTICS OF THE PECOS RIVER CHANNEL

Reach From-	Reach To-	Channel Fall (ft per mile)	Channel Avg. Width (ft)	Channel Avg. Depth (ft)	Channel Capacity (cfs)
Source (river mile 926.4)	Cow Creek (river mile 866.5)	98.0			
Cow Creek	Dilia (river mile 811.7)	19.4	130	6	2,000
Dilia	Santa Rosa Dam (river mile 766.4)	9.9	400	8	2,000
Santa Rosa Dam	Sumner Dam (river mile 710.8)	8.6	400	8	13,000
Sumner Dam	Taiban Creek (river mile 675.6)	6.5	411	17	15,000
Taiban Creek	Acme gage (river mile 591.2)	4.9	570	8	15,000
Acme gage	Artesia gage (river mile 503.9)	2.42	290	15	8,500
Artesia gage	Brantley Dam (river mile 478.5)	3.57	290	13	8,500
Red Bluff Dam	Girvin (river mile 178.4)	2.3	125	14	3,000
Girvin	Mouth (river mile 0)	7.0			

Below Two Rivers Project, Rio Hondo and Rocky Arroyo are confined to relatively narrow valleys and then emerge onto a common alluvial fan. Below the confluence, only a small low-water channel is incised in the alluvial slope. The floodplain is 6,000 feet at the western city limits. Because of past attempts to make the Rio Hondo channel conform to the grid pattern of Roswell streets, there are many abrupt turns in the channel where high flows frequently enter the overbank areas. The Rio Hondo channel is perched in comparison to the adjacent overbank areas, with a limited channel capacity of 1,000 cfs. Thus, any flows which escape the channel have great difficulty in flowing back into the Rio Hondo. The floodplain is still over 4,000 feet wide as it passes through downtown Roswell. The river slopes from the mouth to Two Rivers Project vary from 4 feet per mile to 10 feet per mile.

4-10. Upstream Structures.

a. Santa Rosa Dam and Lake. Santa Rosa Dam and Lake is a Corps project which is located on the Pecos River at mile 766.4, about 55 miles upstream from Sumner Dam, and about 7 miles north of Santa Rosa in Guadalupe County, New Mexico. The project provides 449,000 acre feet of storage, of which 167,000 is allocated to flood control, 200,000 to irrigation, and 82,000 to sediment reserve. The embankment consists of rolled earth and rockfill. It is about 1,900 feet long and 210 feet high at the maximum section and has a top width of 36 feet. An uncontrolled spillway 1,050 feet long is located in the left abutment and the outlet works consist of a 10-foot diameter concrete-lined tunnel. Maximum discharge through the outlet works is 5,760 cfs at the top of flood control pool (elevation 4,797 feet, NGVD). Santa Rosa Water Control

Manual, which is Appendix B to the MWCM, has detailed information on the project.

b. Sumner Dam and Lake Sumner. Sumner Dam, a Reclamation project, is located on the Pecos River at mile 710.8 about 21 miles upstream from the City of Fort Sumner in DeBaca County, New Mexico. The project provides 132,000 acre-feet of storage of which 48,000 is allocated to flood control, 20,000 to irrigation, and 64,000 to sediment reserve. The embankment consists of rolled earthfill and rockfill. It is approximately 3,000 feet long, averages 30 feet wide at the crest, and is 164 feet high at the maximum section. The outlet works consists of a combination pressure tunnel and a 10-foot diameter penstock upstream of the gates and two penstocks, 5.5 feet in diameter, downstream. Releases are controlled by two 48-inch diameter jet flow valves, with a capacity up to 1,740 cfs at top of flood control pool. Irrigation releases, up to 100 cfs, may be made through a 20-inch jet flow valve. There is a service spillway constructed near the west end of the dam through which larger releases are made. It is a tainter-gated chute-type structure with three 45-foot openings and an invert elevation at 4,259 feet, NGVD,. An emergency spillway consisting of a fuse plug type embankment is located in the left abutment. A 500-foot concrete sill, with a crest elevation of 4,275 feet, NGVD, is covered with earth and rock fill forming four individual sections at elevations 4,282, 4,283, 4,284, and 4,285 feet, NGVD,. The respective lengths of these individual sections are 130 feet, 130 feet, 118 feet, and 118 feet. The initial project was completed in 1937, and the dam was raised and the emergency spillway added in 1955. The Sumner Water Control Manual, which is Appendix C to the MWCM, has detailed information on the project.

4-11. Downstream Structures.

a. Brantley Dam. Brantley Dam, a Reclamation project built to replace Mcmillan Dam, is located approximately 13 miles upstream from the city of Carlsbad, New Mexico. The dam is situated at mile 478.5, approximately 10 miles upstream from Avalon Dam and 25 miles downstream from Artesia. The dam consists of a central concrete gravity section across the Pecos River with earth sections built on either side. The concrete section contains the outlet works and gated spillway. Total dam length is about 4 miles. The concrete section is 730 feet long and 143.5 feet high. The east wing dam is 12,059 feet long with a crest width of 24 feet. The west wing dam is 8,720 feet long with a crest width of 24 feet. The main outlet works consist of two 4 foot X 4 foot conduits passing through the concrete section with tandem hydraulic-operated slide gates. A low flow structure is located to the left of the spillway on the downstream side, and consists of a 36-inch diameter concrete pipe between the stilling basin and the old Pecos River channel. The spillway has six gated bays totaling 300 feet in length, with the discharge controlled by six radial arm gates (tainter gates) which are 50 feet wide by 25.24 feet high. The project provides 348,000 acre-feet of storage, of which 189,700 is allocated to flood control, 40,000 to irrigation, 2,000 is inactive and 116,300 is for sediment retention. The WCM for Brantley Dam and Reservoir, Appendix D to the MWCM, has detailed information on the project.

b. Avalon Dam. Avalon Dam is located on the Pecos River about 10 miles downstream from Brantley Dam and about 6 miles north of Carlsbad. It is an earth and rockfill structure 1,360 feet long and 53 feet high. The dam was built by the Pecos Irrigation and Improvement Company in 1893. Following several floods and extensive damages, the dam was rebuilt in 1906-07 by the U.S. Reclamation Service. In 1938, Reclamation raised the dam to its present level, elevation 3,194 feet, NGVD. Appurtenant works include three spillways and an outlet works. The original capacity of the reservoir was approximately 7,600 acre-feet. Due to sediment deposition, present capacity is about 4,334 acre-feet. The location of Avalon Dam is shown on Plate 2-1.

c. Red Bluff Dam. The Red Bluff Water Power Control District constructed the Red Bluff Dam at river mile 390.8 on the Pecos River. Total capacity is 290,000 acre-feet and it functions as a power and irrigation project. Project location is shown on Plate 2-1. Section IV in the MWCM for the Pecos River has additional information on Red Bluff Dam.

4-12. Economic Data. The economy of the Pecos River Valley has been expanding. The following subparagraphs discuss the various aspects of the basin's economy.

a. Population. Population density in the Pecos River Basin is low. The basin is largely mountainous and the valley is primarily composed of large farms and cattle ranches. Population has been gradually incresing through most of the basin, but not at a significant rate. Table 4-14 shows the change in basin population since 1950.

b. Agriculture and Industries. Agriculture and ranching play a significant role in the local economies within the basin and consists of irrigated farming along the Pecos River and livestock grazing over most of the watershed. The basin has some of the prime agricultural area in the state of New Mexico. Much of the industry is located in the cities of Roswell, Artesia, and Carlsbad.

Roswell is the most populous city in Chaves County. Having diversified over the years, Chaves County has also developed a manufacturing base. As Walker Air Force Base was phased out, the area has redeveloped into Roswell Air Industrial Center and is contributing substantially to growth in the population and economy of the area. Chaves County employment follows the state of New Mexicos pattern except that manufacturing makes up 18% of the workforce compared to a state average of 8%, and services represent 21% of the workforce compared to a state average of 33%. Water is fully appropriated and in order for major developments to occur water must be obtained by acquisition and transfer of water rights. Roswell is the Chaves County seat of government and the county's largest urban center. Gross receipts from agriculture have been first in the state, leading the state in milk, hay and sheep production. Additionally, oil and gas extraction is a major economic factor throughout the region.

c. Flood Damages. Historical flooding from the Rio Hondo have been gathered in conjunction with flood control studies. Interviews with long-time residents, and newspaper accounts indicate numerous flood occurences prior to the establishment of stream gages and reliable records. The floods of 1937, 1941, and 1954, produced damages of $195,000, $693,000 and $816,000, respectively. The June 1965 flood is considered the maximum flood on record for Rio Hondo. Intense showers centered near the Ruidoso-Hondo area and produced a peak discharge of 54,800 cfs on Rio Hondo near Hondo, approximately 45 miles west of Roswell. Two Rivers Reservoir caught all of the flood runoff, and prevented any major damages in Roswell.

Two Rivers Project is estimated to have prevented almost $84,000,000 in damages through 1995. A large portion of the benefits were captured during 1991 when flows were greater than a 50 year event on the upper Rio Hondo and Rocky Arroyo. It was estimated that a peak flow 9,000 cfs would have hit the city of Roswell without Two Rivers Project in place, and $75 million of damages were prevented.

TABLE 4-14

POPULATION STATISTICS

Name	Population				
	1950	1960	1970	1980	1990
Counties:					
Chaves	40 605	57 649	43 335	51 103	57 849
De Baca	3 464	2 991	2 547	2 454	2 252
Eddy	40 640	50 783	41 119	47 855	48 605
Guadalupe	6 772	5 610	4 969	4 496	4 156
Lincoln	7 409	7 744	7 560	10 997	12 219
San Miguel	26 512	23 468	21 951	22 751	25 743
Communities:					
Artesia	8 244	12 000	10 315	10 385	10 610
Carlsbad	17 975	25 541	21 297	25 496	24 952
Roswell	25 738	39 593	33 908	39 676	44 654

V - **DATA COLLECTION AND COMMUNICATION NETWORKS**

5-01. Hydrometeorological Stations.

a. Facilities. The locations of precipitation and stream gages in the entire Pecos Basin are shown on Plate 4-2, while locations of gages between Sumner Dam and Red Bluff Dam are shown on Plate 4-3. The term "DCP Equipped", as shown on Plate 4-3, refers to remote stations (gages) which are automated with data collection platforms (DCP's) which transmit to the Geostationary Operational Environmental Satellites (GOES).

(1) Precipitation Gages. There are 73 precipitation gages in or near the Pecos Basin. Sixteen of these gages in the Basin are automated. Plate 4-2 shows the location of precipitation gages. Paragraph 5-01b describes reporting methods of hydrometeorological stations while Paragraph 5-04 gives information on retrieval of this data from the appropriate agency.

(2) River Gages. There are 49 river gaging stations in the Pecos Basin with 25 of these stations located on the mainstem of the Pecos River. Currently, 10 gages on the mainstem of the Pecos River between Pecos and Carlsbad, and 3 gages on the Rio Hondo are equipped with DCP's. The Rio Hondo at Diamond A Ranch gage is the inflow gage for Rio Hondo Reservoir.

(3) Snowpack Data. The National Resources Conservation Service (NRCS) operates and publishes data for two snow measurement stations in the Rio Hondo drainage basin. These are Sierra Blanca and Buggs Cienegita Creek. Snow measurements are made once a month during the winter months. When snow measurements are made, they are available by the fifth of each month from January through May.

(4) Two Rivers Project. DCP automated stage gages at Two Rivers Project include inflow and outflow gages on the Rio Hondo and a gage for each reservoir level (Rio Hondo and Rocky Arroyo Reservoirs). In addition, precipitation data is recorded and transmitted at the Diamond A Dam (Rio Hondo Reservoir) station.

b. Reporting. The Reservoir Control Section (RCS), Albuquerque District, has established a Water Control Data System (WCDS) for receiving, decoding, evaluating, and storing real-time meteorologic and hydrologic data for its water management activities and responsibilities. All DCP's in the Pecos Basin on the WCDS transmit data to the GOES satellite, which is then received by a downlink to a central computer operated by the National Oceanic Atmospheric Administration (NOAA). The data is then transmitted to a domestic satellite (DOMSAT) and is received by a downlink directly into the computer network located in the Reservoir Control Section at the Albuquerque District Office. Most of these stations are reservoir elevation and streamflow gages.

The National Weather Service (NWS) receives rainfall data from automated stations continuously and from observer stations when precipitation exceeds specified amounts. The NWS disseminates this information along with weather forecasts over the Automation of Field Operations and Services (AFOS) system to its various offices. Selected AFOS information is accessible through the WCDS in Dallas, Texas. Any data collected by Corps personnel is forwarded to the NWS by phone.

(1) Normal Conditions. The hydrometeorological data required for reservoir regulation, under normal conditions, consists of daily reports on stage, storage, outflow, inflow and precipitation. The Chaves County Flood

Control Commission (CCFCC) office in Roswell, New Mexico, is able to obtain most of the above information by computer, via telephone line connection to RCS's WCDS real-time data base. The information which is not available through automated reporting methods, will be obtained by the damtender in the field and transmitted to the RCS by telephone, radio, facsimile or computer. Reporting criteria and methods are described in Standing Instructions to Damtender, Exhibit F.

(2) Flood periods. During flood periods, information on downstream conditions and precipitation over the basin will be required in addition to normal data. The RCS will monitor reservoir and weather data through the WCDS in Albuquerque, New Mexico. Supplemental information on conditions at Two Rivers Project will be transmitted from the CCFCC to the RCS as necessary on a daily basis.

c. Maintenance. Lake level monitoring devices and stream gages, including reservoir inflow and outflow gages, are operated and maintained by the U.S. Geological Survey (USGS). Personnel from the USGS conduct scheduled visits to each gage to insure proper operation.

5-02. Water Quality Stations. The USGS collects water quality data at gaging stations in the Pecos Basin. The station applicable to Two Rivers is Rio Ruidoso at Hollywood, New Mexico. The USGS operates and maintains the water quality stations and publishes the data in USGS publications.

5-03. Sediment Stations.

a. Facilities. The transport and deposition of sediment, which affects the operation of Two Rivers Project, are monitored by periodic ground and aerial surveys of the reservoir area.

(1) Suspended Sediment Sampling. Suspended sediment samples have been taken on the Pecos River at Puerto de Luna for a period of about 10 years, from January 1949 to September 1958. Also, records are available for Pecos River flows near Anton Chico since July 1974 and at Santa Rosa since September 1958. Prior to 1958, sediment samples were secured for short periods (12 to 18 months) at Anton Chico, Santa Rosa, and Puerto de Luna. On the Rio Hondo, sediment samples have only been collected at Diamond A Ranch during Water Year 1962. The USGS collected most of these samples and the sediment loads are published in USGS publications.

(2) Reservoir Sediment Ranges. The original system of reservoir sedimentation ranges was established in 1963. The system consisted of two transverse and two longitudinal sediment ranges on the Rio Hondo and six transverse and one longitudinal sediment ranges on Rocky Arroyo; some of these ranges were extended in 1971. Eight cross-sections were developed for the resurvey conducted in 1988. The original and new reservoir sediment ranges are shown on Plate 5-1.

(3) Degradation Ranges. There are three degradation ranges located in the channels below the reservoir. The end points of the ranges are marked with permanent survey monuments.

b. Reporting. Sedimentation resurveys are normally scheduled on a fifteen year basis. Resurveys at Two Rivers Reservoir were made in 1971 and 1988.

c. Maintenance. The RCS is responsible for the sedimentation and degradation range line monuments with the assistance of CCFCC who periodically inspects the monuments.

5-04. Recording Hydrologic Data. Daily summaries of Rio Hondo and Rocky Reservoirs data, including stage, storage, outflow, inflow, and precipitation are available from the RCS. The RCS developed a Morning Report Computer System which uses data received from DCPs with addtional data gathered by project personell to generate a daily reservoir report for each project within the district. Monthly tabulations of this information are retained indefinitely as the official recoed of operation. Monthly and annual summary data are available from the RCS.

5-05. Communication Network. The Corps Albuquerque District radio network is part of the Southwestern Division network which includes the Division Office at Dallas, Texas, and the five District Offices at Albuquerque, New Mexico; Fort Worth and Galveston, Texas; Little Rock, Arkansas; and Tulsa, Oklahoma. Each District has fixed stations at field offices and several mobile units. The Southwestern Division network consists of twelve single side-band (SSB) frequencies ranging from 3346.4 KHZ to 16383.4 KHZ. The Albuquerque District network includes the same twelve single side-band (SSB) frequencies plus a five channel UHF network using 413.55/408.05 MHZ tone controlled frequencies. Mobiles, base stations, repeaters, and portables are available in the UHF network. The UHF network is utilized for day-to-day communication while the SSB network is reserved for emergencies. Plate 5-2 shows the Albuquerque District communications network.

The District Office and reservoir project offices of Conchas, John Martin, Trinidad, Abiquiu, Cochiti, Jemez Canyon, and Santa Rosa have four channel base station voice radios. A repeater on Sandia Crest uses channel three for a local communications net. Other repeaters are required to relay to the other district projects. Channel one and two are the primary net link through repeater stations. The District has a contract with the state of New Mexico to use the state microwave net. Three of the twenty state repeater sites are utlized as the backbone of the UHF systems.

The Albuquerque District Radio Control Center is located in the Information Support Services Branch Division Office. Under normal conditions, the radio network is operational from 0730 to 1600 hours, Monday through Friday. During times of emergency, the network may be operated 24 hours a day. The Albuquerque District's ground communications consist of commercial telephone service, including facsimile service. Two Rivers Project is not on the Albuquerque District radio net.

The District has implemented wide area network capabilities, which allow communications to project data on a real-time basis with other districts, division offices, as well as, many military installations worldwide.

CCFCC personnel are available to take instructions, by telephone, for gate changes during the normal 5-day work week between the hours of 0800 and 1530, and at any other times required during flood emergencies. During off-duty hours the CCFCC Commissioner or superintendent can be reached at their residences. The project is under the supervision of the Santa Rosa Lake Project Manager. The Santa Rosa Lake Project Manager can also be reached at his residence during off-duty hours.

Table 5-1 lists telephone numbers of pertinent organizations and personnel.

5-06. Communication with Project. Under normal conditions, the CCFCC will be in contact with RCS at least once per week to provide a full readout of the project gaging equipment to assure the accuracy of the data. During flood periods, communications between CCFCC and RCS will be extended as necessary. The RCS is responsible for collecting and recording hydrologic data, making flood predictions, and issuing instructions for the storage and release of water from the reservoir during flood control operations. During flood periods, the RCS and CCFCC personnel will be in contact with each other every workday in order to transmit data and instructions. Communications between RCS and CCFCC personnel will be extended up to a 24-hour, 7 day-a-week basis as necessary. Contact between CCFCC and RCS will be by commercial telephone, facsimile or computer.

5-07. Reporting Instructions. The damtender normally reports pertinent data at least once per week to the RCS in Albuquerque, New Mexico, while weekend and holiday reports are transmitted the next workday. Daily reports during flood periods are also made to the RCS. These daily reports will consist of lake elevation, storage, inflow and release rates, and weather data as required to supplement automated data collection. Unusual weather conditions or inflow will be reported immediately to the RCS via telephone.

When changes in the release have been made in compliance with RCS instructions, CCFCC personnel are required to confirm the release change and give the downstream river gage reading to RCS after the flow has stabilized. Unanticipated conditions which arise will be reported immediately to the RCS and the RCS will issue new instructions. Details of reporting instructions are contained in Exhibit F, Standing Instructions to Damtender.

5-08. Warnings. The RCS is responsible for collecting hydrologic data for making flood predictions. The RCS will issue the necessary instructions for flood warnings.

When flows greater than 600 cfs are to be released the RCS will notify the CCFCC, Santa Rosa Reservoir Manager and other appropriate officials, agencies, and individuals listed in Table 5-1. CCFCC will warn the general public in the vicinity of the dams and officials in the City of Roswell and Chaves County.

TABLE 5-1

TELEPHONE DIRECTORY FOR RESERVOIR CONTROL AND FLOOD EMERGENCIES

NAME	TITLE	OFFICE NUMBER	HOME NUMBER

VI - HYDROLOGIC FORECASTS

6-01. General. The responsibility of forecasting flows in the Pecos River Basin rests with the Corps of Engineers and the National Weather Service (NWS). The NWS is the recognized federal agency responsible to the public for forecasts of flood flows. The Corps of Engineers makes estimates of flows which are used to forecast the effects of flood regulation in accordance with the flood control plan. For these purposes, it is essential that close coordination of efforts within the two agencies be maintained. Any significant snowmelt runoff in the Pecos Basin is normally regulated at Santa Rosa Lake, and therefore, flood forecasting will generally be restricted to rainfall runoff events.

a. Role of the Corps of Engineers. Albuquerque District personnel utilize precipitation and flow data from various sources in the Pecos Basin to prepare forecasts of expected pool elevation and estimated reservoir releases. Reports and forecasts from the NWS are also used in preparing volume forecasts which, in turn, are used to project impacts within the reservoir.

b. Role of the NWS. The NWS forecast office in Albuquerque receives precipitation reports from automated gages in the Basin. In addition, local observers report readings of non-automated gages when rainfall exceeds 0.5 inches. An Automatic Hydrologic Observing Station (AHOS) gage at Clines Corners, New Mexico, is also used in monitoring climatic data. All of this information is used in forecasting peak flood flows at most Pecos River gages in the Basin as needed.

6-02. Flood Condition Forecasts.

a. Requirements. Flood condition forecasts are necessary when substantial rainfall occurs within the Pecos River Basin. The type of forecast required will depend on the nature and aerial extent of the storm. Upon notification, the RCS will initiate procedures to collect and process precipitation, streamflow, and reservoir data required for flood forecasting. The majority of this data is obtained at regular intervals (usually every four hours) by automated methods (DCP's) for use in computer forecasting programs. Depending on the timing of the data transmission and initiation of forecasting procedures, the time required to make flood forecasts will vary from two to six hours.

Key streamflow forecasts for Two Rivers project include the reservoir inflow and the uncontrolled runoff between the dam and the river gage on the Rio Hondo at Roswell. Observed reservoir storage and intervening downstream runoff are used to determine current and near future flood control releases in accordance with criteria in paragraph 7-05. The RCS will use forecasted flood flows on a case by case basis. The reliability of flood forecasts is often diminished by insufficient data, the inability of numerical techniques to model a particular rainfall event, and the limited time available to calibrate computer hydrologic parameters. Therefore, judgement must be used when applying forecasted flows in determining reservoir releases.

b. Methods. The RCS has developed both computerized and manual procedures for making flood condition forecasts for Two Rivers Project. The numerical calculations required are essentially the same for both procedures. In general, the procedure consists of a numerical model which simulates the physical processes of sub-basin rainfall, infiltration, and runoff; the combination of this runoff with river flows; and the movement and attenuation of these flows down the Pecos River. This information is used along with reservoir storage information for determining release schedules. For the purpose of flood forecasting, the Pecos River Basin between Sumner and Red Bluff Dams has been divided into 31 sub-basins, including the Rio Hondo watershed. These sub-basins are shown on Plate 6-1. Unit hydrographs, the numerical model for sub-basin runoff, for these sub-basins are shown on Plate 6-2.

Because of the generally limited time available and the large number of computations needed to make flood forecasts, computerized methods are emphasized. Hopefully, manual methods will only be necessary for short periods of time when computer facilities are unavailable. Contingency plans have been developed by SWD to provide duplicate data and forecasting programs on two different computers. The hydrologic data and computer programs necessary to make flood forecasts for the Pecos River Basin are maintained on the RCS water control computer in Albuquerque, New Mexico and on SWD's computer in Dallas, Texas. If RCS's computer is "down", the RCS will access the forecasting software on SWD's computer.

(1) <u>Computerized Methods</u>. Computerized flood forecasting methods developed for the Pecos Basin are built around the Water Control Software System developed by the Corps' Hydrologic Engineering Center (HEC). This system includes software which automates the retrieval and processing of meteorologic and hydrologic data, forecasting rainfall runoff, and simulation of reservoir system operation. Information on gage, sub-basin, and reservoir locations; hydrologic loss, runoff, and routing parameters; and flood control release criteria for the entire Pecos Basin is stored in files on RCS's and SWD's water control computers. This input information along with current rainfall and streamflow data is used with the HEC software to make forecasts and schedule future reservoir releases.

Details on hydrologic methods used by the computer programs is provided in Exhibit D along with instructions on how to access and run these programs. The procedures and the HEC software, which comprise the forecasting system, are described briefly in the following paragraphs.

(a) Retrieve current rainfall, streamflow, and reservoir data from the master database. The master database contains the most recent three months of hydrometeorologic data collected by RCS for New Mexico, Colorado and Texas. The program EXTRCT is used to extract the data for the Pecos Basin from the forecast master database and place it into a special forecast data file.

(b) Compute sub-basin average rainfall from point precipitation by the normalized inverse squared distance method. The program PRECIP uses measured rainfall at precipitation gages from the forecast data file and calculates the hourly average areal rainfall over defined sub-basins for the Pecos Basin.

(c) Estimate initial and uniform infiltration coefficients based on qualitative analysis of current soil moisture conditions. Apply these losses to the sub-basin average rainfall. Initial values of loss rates for wet soil moisture conditions are given in the input files for the forecasting system. These values assume sufficient rainfall has occurred over the Basin prior to the forecast (in the past week for example) to saturate the soil. If this is not the case, the loss rates should be increased based on starting soil moisture conditions. These values will be adjusted later as more information becomes available.

(d) Compute sub-basin runoff hydrographs with the Snyder Unit Hydrograph method. See Plate 6-1 for initial values of the unit hydrograph parameters. The program HEC-1F is used to compute sub-basin runoff hydrographs based on these parameters and excess rainfall (sub-basin average rainfall minus losses).

(e) Route runoff hydrographs with Modified Puls method.

Combine hydrographs to obtain total river flows. The program HEC-1F routes and combines runoff hydrographs concurrent with step (d) above.

(f) Review streamflows computed above with available measured streamflows. Adjust loss (and perhaps unit hydrograph and routing) parameters by graphically comparing computed streamflow with observed flows. Repeat above steps with calibrated parameters to obtain best forecast. The computerized forecasting system includes five HEC-1F models and a graphical display program (DSPLAY) to facilitate checking and adjusting these hydrologic parameters.

(g) Determine optimal reservoir release schedules based on streamflow forecasts and flood control criteria. The program HEC-5 is used to determine hourly reservoir releases based on forecasted river flows, forecasted reservoir storages, and reservoir operational criteria based on project purposes and physical constraints.

(2) Manual Methods. If Corps WCDS computer systems are unavailable, hand computations may be required to determine future reservoir releases. These repetitive calculations as well as data acquisition may be automated to some degree with microcomputer based spreadsheet and communications software. However, the procedures shown are developed to provide a simplified streamflow forecasting capability without computer assistance.

In order to minimize the number of computations and simplify calibration of hydrologic parameters, only the within the Rio Hondo Basin is forecasted with the manual method presented here. If conditions require manual computation of sub-basin runoff on the mainstem Pecos River, see The Santa Rosa Dam, Sumner Dam, and/or Brantley Dam Water Control Manuals for the procedures for the area of concern.

(a) The NWS, Reclamation, and USGS each collect and store real-time hydrologic data on their own computer systems. If the Corps' computer database is "down", rainfall and streamflow data can be obtained by telephone or micro computer from these agencies. This process will be cumbersome since the transfer process is not automated. In general, the specific information required for manual forecasting is as follows:

River hydrographs at the Rio Hondo at Diamond A gage.
Precipitation hyetographs for all available gages in and around the Rio Hondo watershed. The locations of automated gages are shown on Plate 4-3.
Two Rivers Project storage and release data.

The time step used for these time-series data is one hour.

(b) Sub-basin average rainfall hyetographs will be computed for the drainage areas (1) above Two Rivers Project, and (2) between Two Rivers Project and the mouth. The best method used to compute the area-average rainfall will depend on the precipitation data available and the location, movement, and extent of the storm. Computation of the sub-area average hyetographs should be done in such a manner that the assumption of uniform rainfall over the area represented is reasonable. The average rainfall is the weighted average of the nearest precipitation gages within the drainage area. The weight assigned to each gage is the inverse of the distance between the gage and the centroid of the subarea squared and normalized by the station mean annual rainfall. Refer to Plate 4-1 for mean annual rainfall in the Pecos Basin.

(c) Assume preliminary initial and uniform precipitation infiltration rates of 0.25 and 0.17 inches per hour, respectively. These values represent wet soil moisture conditions for this area of the Basin and will be revised as information on observed runoff becomes available for comparison to computed runoff. Apply these loss rates to the subarea hyetographs to obtain the rainfall excess hyetographs.

(d) Unit hydrographs for each of 31 sub-basins between Sumner and Red Bluff Dams are shown on Plate 6-2. These unit hydrographs are used by both the computerized flood forecasting and manual methods.

Computation of the runoff hydrograph at each point will be accomplished using a spreadsheet format. Plates 6-3A and 6-3B show examples of runoff computations for the subareas above Two Rivers Project (12W) and from Two Rivers Project to the mouth (subarea 12.1W) using a microcomputer spreadsheet program. Unit hydrograph ordinates are listed vertically on the left side on the table. The rainfall excess hyetograph is entered horizontally across the top of the worksheet. The rainfall amount is multiplied by the unit hydrograph ordinate lagged by the time from the start of the rainfall. The numbers in the columns are added horizontally to get the total runoff hydrograph shown in the right most column. This method is limited based on a uniform rainfall over the entire subarea. If the actual rainfall is not uniform, this procedure may need to be modified based on judgement when comparing observed and computed flows.

(e) Add the ordinates of the runoff hydrographs to the flow already in the river. Travel times for flood peaks along the Pecos River and Rio Hondo are shown in Table 6-1. The flow in the river at the concentration points for the runoff hydrographs will be determined using the upstream automated river gage lagged by the travel time.

(f) Compare computed river flows to observed flows from automated gages up to the current time. The reservoir inflow can be computed using the reservoir release and the change in reservoir storage. If the computed streamflows are unreasonably different, adjust the infiltration rates, sub-basin average rainfall, unit hydrographs, and travel times as necessary to improve the forecast. The parameters are dependent on the rainfall pattern and intensity, soil moisture conditions, and magnitude of the flood flow. As with any complex physical process, numerical methods must be supplemented with human judgement and experience. This is the case with both manual and computerized methods.

(g) Determine the optimal release schedule for Two Rivers Project based on best available forecast and in accordance with the criteria in paragraph 7-05.

6-03. Conservation Purpose Forecasts. The National Resource Conservation Service (NRCS) makes forecasts of spring runoff on the first of each month, beginning 1 January. Forecasts are based on snow water content and projected normal conditions. Supplemental measurements are made on 15 May and 15 June whenever conditions warrant.

6-04. Long Range Forecasts. The longest range forecasts with a degree of reliability are the spring snowmelt runoff forecasts discussed in paragraph 6-03. The NWS provides 30- and 90-day qualitative long range forecasts of precipitation potential. These forecasts do not provide sufficient accuracy or reliability to be of benefit for flood control operations. However, in combination with current basin conditions such as cumulative rainfall and availability of irrigation water storage, long range precipitation forecasts may benefit irrigation operations.

TABLE 6-1

FLOOD PEAK TRAVEL TIMES

Location	River Miles Between Locations	Average Travel Time Between Locations (Hours)
Pecos River:		
Santa Rosa Dam		
	9	1
Santa Rosa Gage		
	46	5
Sumner Dam		
	120	34
Acme Gage		
	84	24
Artesia Gage		
	25	8
Brantley Dam		
	19	6
Carlsbad Gage		
	69	34
Red Bluff Dam		
Rio Hondo:		
Two Rivers Dam		
	22	6
Roswell gage		
	12	3
Mouth, Rio Hondo		
	64	21
Artesia Gage		

6-05. <u>Drought Forecasts</u>. Appendix E to the MWCM, "Drought Contingency Plan, Pecos River Basin," provides information on historical droughts in the Basin and methods used to compute the drought severity of current Basin conditions. In general, the three factors used to estimate the potential for drought are the current irrigation water available, the volume of spring snowmelt runoff forecasted, and a NWS index known as the Palmer Drought Severity Index (PDSI). The PDSI is published monthly by the NWS and provides a measure of current soil moisture conditions. A large negative number indicates abnormally dry conditions have prevailed up to the time of measurement. Consideration of current conditions, qualitative forecasts of precipitation potential, and characteristics of the Basin in regard to droughts and irrigation demands provides sufficient information to regulate the irrigation operations on a seasonal basis and may provide some idea of problems which could occur during the following season.

VII - **WATER CONTROL PLAN**

7-01. General Objectives. Two Rivers Reservoir Project is operated to provide sediment retention and flood control in accordance with the Flood Control Act of 1954.

7-02. Major Constraints. The channel capacities of 1,000 cfs and 900 cfs on the Rio Hondo and Rocky Arroyo, respectively, have not been properly maintained. Significant overbank flooding problems are expected when flows exceed 600 cfs in Roswell due to poor channel alignment. The City of Roswell is responsible for maintaining the channel capacities under a resolution dated April 14, 1960 (Exhibit E). The regulations in this manual are based on restoring the capability to a 1,000 cfs release from Two Rivers Reservoir Project.

7-03. Overall Plan for Water Control. Normal Rio Hondo and Rocky Arroyo flows are passed through the reservoir(s) with minimal regulation, so the reservoir(s) will remain dry except during periods of flood control operation. Flood flows are briefly detained and released as rapidly as downstream conditions permit. Two Rivers Project is operated in conjunction with Santa Rosa and Sumner Dams, located upstream on the Pecos River, for optimum flood control benefits on the Rio Hondo and Pecos River. Flood control releases plus uncontrolled flows will not exceed 1,000 cfs.

7-04. Standing Instructions to Damtender. Flood control operations will be in accordance with paragraph 7-05 and Exhibit F of this manual. Instructions for flood releases are issued by the Reservoir Control Section (RCS), Engineering and Planning Division, Albuquerque District. In the event of a communications disruption between RCS and Chaves County Flood Control Commission (CCFCC), regulation will be in accordance with paragraph 7-05b and Exhibit F of this manual. Communications will be re-established as rapidly as possible.

7-05. Flood Control. Flood control begins at Two Rivers Reservoir when the existing or forecasted flow in the Rio Hondo or Pecos River approaches channel capacity. Flood control procedures are described below.

a. Normal Flood Control Regulations. Flood control regulation begins when the existing or forecasted flow in the Rio Hondo at Roswell approaches 1,000 cfs, or Pecos River flow approaches 8,500 cfs at the Acme or Artesia stream gages. Sumner Dam regulates flows on the Pecos River to 8,500 cfs at the Artesia gage. The flood control operation will minimize storage and evacuate flood storage as rapidly as downstream conditions permit within the operating constraints at Two Rivers Reservoir, Santa Rosa Lake and Lake Sumner. Flood control releases will limit flows at Roswell to 1,000 cfs and Pecos River flow to 8,500 cfs at the Acme and Artesia gages below Sumner Dam. The normal regulation schedule is shown in Table 7-1.

b. Emergency Flood Regulations. In the event communications are disrupted during a flood and information concerning stream-flow conditions is not available, the following procedures will be followed:

(1) Continue last release rate

(2) Re-establish communications

(3) If communications cannot be re-established follow the **EMERGENCY REGULATION SCHEDULE** given in Table 7-2. CCFCC personnel, or the designated Operations and Maintenance contractor, will make every effort to reestablish communications. This effort will continue through the period of disrupted communications. The emergency regulation schedule is also in Exhibit F, Standing

Instructions to the Damtender.

TABLE 7-1

NORMAL REGULATION SCHEDULE
TWO RIVERS PROJECT

Rio Hondo Flow Condition	Reservoir Condition	Reservoir and Control Station Stages	Operation
A. Low or normal flows	Rising, steady or falling	1. Pool below elev. 3,980 ft., NGVD	1. Maintain the Diamond A gated conduit opening of 3.0 ft. (1)
		2. Pool below elev. 4,032 ft., NGVD (spillway invert) and Pecos River flow predicted to equal or exceed 8,500 cfs at Acme	2. Close gated conduit until flows at Acme fall below 8,500 cfs.
B. Flooding	Rising	1. Pool predicted to crest below elev. 4,032 ft., NGVD	1. Make releases at such rates that, when combined with releases from the uncontrolled conduit and runoff below the dam, flows of 1,000 cfs at Roswell or 8,500 cfs at Artesia on the Pecos River will be maintained insofar as possible. No change in excess of 500 cfs per hour.
		2. Pool predicted to exceed elev. 4,032 ft., NGVD	2. Operate in accordance with condition B.1, above, until inflow forecasts indicate greater releases necessary to effect maximum possible downstream stage reductions. All gates must be fully opened in the event the pool rises to

			elev. 4,033 ft., NGVD.
	Falling	3. Pool above elev. 4,032 ft., NGVD	3. Hold maximum gate opening attained until pool falls to 4,032 ft., NGVD, then operate in accordance with condition B.1, above.
	Falling	4. Pool below elev. 4,032 ft., NGVD	4. Operate in accordance with condition B.1, above, until the pools are emptied then place gate in the normal open position of 3.0 ft.

(1) Gate opening to be set by Albuquerque District Office. The objective of this operation is to assure that the conduit will always be slightly open to pass normal flows.

NOTE: In reference to above schedule, at elevation 3,980 feet, NGVD, a release of approximately 600 cfs will be made (335 cfs through the gated conduit with a 3.0-foot opening, and 275 cfs from the uncontrolled Rocky Dam conduit).

TABLE 7-2

EMERGENCY REGULATION SCHEDULE
TWO RIVERS PROJECT

Reservoir Condition	Reservoir Stage	Operation
A. Rising, falling or steady	1. Pool below elev. 3,980 ft., NGVD.	1. Maintain gated conduit in the same position it was in at the time communications were lost.
B. Rising	1. Pool below elev. 4,014 ft.(flood control storage 50 percent used).	1. Same as A.1, above.
	2. Pool between elevations 4,014 ft. and 4,032 ft., NGVD	2. Regulate gated conduit so that releases combined with release from uncontrolled conduit do not exceed 1,000 cfs (note - no change in excess of 500 cfs per hour).

Rising	**3. Pool above elev. 4,032 ft., NGVD**	**3. Fully open gated conduit.**
Falling	**4. Pool above elev. 4,032 ft., NGVD**	**4. Leave gated conduit fully open until pool falls to elev. 4,032 ft., NGVD then operate in accordance with condition B.2, above.**
Falling	**5. Pool below elev. 4,032 ft., NGVD**	**5. Make releases as per condition B.2, above. When pools are emptied, place gate in normal open position in accordance with condition A.1, Table 7-1, Normal Regulation Schedule.**

NOTE: Under any conditions a delay period of 6-12 hours is to be observed after communications are lost before any regulation is made by the Dam Tender except when the pool is approaching or above elevation 4,032 ft., NGVD. In this case, action in accordance with B.3 above should be taken. Throughout the emergency every possible effort will be made to again establish communications with the Albuquerque District Office.

c. Rating Tables and Curves. Elevation versus area and capacity values for one-foot increments are shown in Table 7-3. Elevation versus area and capacity to one-hundredths foot is published under separate cover and maintained at CCFCC, Santa Rosa Project Office and the COE Albuquerque District offices. Elevation versus area and capacity curves are shown on Plate 7-1. Outlet works rating curves are shown on Plate 7-2. Spillway rating curves are shown on Plate 7-3. Flood peak travel times are shown on Plate 7-4. Gage rating curves for the Rio Hondo and the Pecos River are shown on Plates 7-5A and 7-5B, respectively.

7-06. Recreation. There are no operations made specifically for recreation.

7-07. Water Quality. There is no specific operation for water quality control.

7-08. Fish and Wildlife. There is no specific operation for fish and wildlife propagation.

7-09. Water Supply. Two Rivers Project has no water supply storage.

7-10. Hydroelectric Power. There are no power facilities at Two Rivers Project.

7-11. Navigation. Flows in the Rio Hondo and Pecos River are insufficient to support navigation.

7-12. Drought Contingency Plans. The purpose of the Drought Contingency Plan for the Pecos River Basin is to provide a basic reference for water management decisions and responses to water shortages induced by climatological droughts. As a water management document it is limited to those drought concerns relating to water control management actions. Refer to Appendix E of the Pecos River

Basin Master Water Control Manual for more information.

7-13. Flood Emergency Action Plans. The purpose of the Flood Emergency Plan is to outline and define procedures to be followed in the event that critical conditions develop which could lead to the failure of or uncontrolled release of water from Two Rivers Project. This plan further assigns responsibilities of CCFCC personnel in the degree necessary to take prompt remedial action to prevent dam failure and to prevent or minimize loss of life and property damage. Refer to Two Rivers Reservoir Initial Reservoir Filling Plan/Flood Emergency Plan dated March 1986 for additional information.

7-14. Sediment Control. No operation will be made specifically for control of sediment in the Rio Hondo. However, significant quantities of suspended sediment will be removed from river flows as they pass through the reservoir(s).

7-15. Deviation from Normal Regulations. The District Engineer may be requested to deviate from the water control plan. Prior approval of deviations is obtained from Southwestern Division Office (SWD) with the exception of minor deviations as discussed in subparagraph a, below.

a. Emergencies. CCFCC personnel, or the designated Operations and Maintenance contractor, at Two Rivers Project have the authority to make emergency deviations in matters of life and death. Some emergencies that can be expected are: drownings, other accidents or failure of operation facilities. Necessary action under emergency conditions is taken immediately unless such action would create equal or worse conditions. The Southwestern Division is informed as soon as practicable. A written confirmation showing the deviation and conditions will be furnished to CESWD-ED-WR on Form SWD 898.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviations from the normal regulation of Two Rivers Reservoir Project, although they are not considered emergencies. Construction accounts for the major portion of the incidents and includes utility, stream crossing, bridge work, and major construction contracts. Changes in release rates are sometimes necessary for maintenance and inspection. Request for changes of release rates are generally for a few hours to a few days. Each request is analyzed on its own merits. Consideration is given to upstream watershed conditions, potential flood threat, conditions of downstream reservoirs, and possible alternative measures. In the interest of maintaining good public relations, the requests are complied with providing there are no adverse effects on the overall operation of Two Rivers Reservoir Project. Approval for these minor deviations will normally be obtained from SWD by telephone. A written confirmation showing the deviation and conditions will be furnished CESWD-ED-WR on Form SWD 898. The following example is provided on the use of Form SWD 898.

✓ Mail to: **Southwestern Division**
ATTN: SWDED-WR

RECORD OF DEVIATION FROM APPROVED WATER CONTROL PLAN

DATE 23 Feb 95

DEVIATION Two Rivers Reservoir
(~~Lake, Reservoir, or System~~)

1. This is to confirm the following verbal request from

Marc Sidlow to Patty Taylor via telephone for approval for a deviation from the approved water control plan.

2. The city of Roswell is requesting a shut down of releases from Two Rivers Reservoir to repair a semi collapsed sewer line in the Rio Hondo from 23 February to 27 February 1995. At present, the flow through the project is less than 10 cfs. There is a chance of scattered showers and a few thunderstorms through the period. Less than 100 acre-feet is expected to be stored and then immediately released upon completion of the repaired sewer main. The states of New Mexico and Texas have been notified of the situation.

SWD 898
1 Nov 77

c. Planned Deviations. Planned deviations provide the mechanism to modify the water control plan to obtain greater flood control benefits. Each situation should be analyzed on its merit. Sufficient data on flood potential, reservoir and watershed conditions, possible alternative measures, benefits to be expected, and probable effects on other authorized and useful purposes will be presented, by letter or telephone, to SWD along with recommendations for review and approval.

7-16. Rate of Release Change. Change in release rates during flood operations will normally be limited to 500 cfs per hour. Unusual conditions that can occur may require the limiting flow rate change to be exceeded.

VIII - EFFECTS OF WATER CONTROL PLAN

8-01. General. Two Rivers Project provides flood control from Rio Hondo flows for Roswell and sediment retention, which reduces the sediment that the Rio Hondo contributes to the Pecos River. Two Rivers Project in conjunction with Santa Rosa Dam and Sumner Dam control Pecos River flows to channel capacity through the middle Pecos River valley down to Brantley Dam.

8-02. Flood Control.

a. Spillway Design Flood (SDF). The spillway design flood (SDF) used for the spillway sizing was based on estimates of probable maximum precipitation (PMP) furnished by the Hydrometeorological Section of the U.S. Weather Bureau in a memorandum dated December, 1956. It was derived from a storm which produced 6.29 inches of rainfall over the drainage area during a 6-hour period. The flood duration is 2 days and has a loss rate of 0.25 inches per hour for Rio Bonito, 0.20 inches per hour for Rio Ruidoso and 0.17 inches per hour for Rocky Arroyo and Rio Hondo below Hondo. The flood has a peak inflow of 281,400 cfs and a volume of 344,700 acre-feet.

The reservoir level at the beginning of the SDF was selected on the basis of the most severe situation probable of occurance. The pool elevation of the Two Rivers Reservoir at the beginning of the SDF was determined by assuming that the interval between the standard project flood SPF peak and the SDF peak would be five days. The occurance of the SPF prior to the SDF established a water surface elevation of 4,031.3 feet, NGVD, four days after the peak inflow. This reservoir stage, which is 0.7 feet below the crest of the uncontrolled spillway, was used as the beginning point for routing the SDF. The SDF was regulated to an outflow discharge of 1,000 cfs as long as possible by means of the gated outlet. After the flow over the uncontrolled spillway exceeded 1,000 cfs the gate was opened completely. The routing of the SDF through the reservoir resulted in a maximum water surface at elevation 4,048.9 feet, NGVD, equivalent to 16.9 feet of surcharge over the spillway crest with maximum outflow of 233,500 cfs and 1,700 cfs through the conduit. The routing is shown on Plate 8-1.

b. Standard Project Flood (SPF). The SPF for Two Rivers Reservoir Project was developed from a transposition of the August 29-September 1, 1942, storm centered near Anton Chico, New Mexico. This transposition resulted in average rainfall over the drainage area above Two Rivers Reservoir Project of 6.90 inches during a period of 72 hours. The runoff was determined to be 2.76 inches. The SPF has a peak flow of 98,000 cfs and a volume of 151,000 acre-feet. The SPF was routed through Two Rivers Reservoir with the reservoir elevation initially at 4,272.0 feet, NGVD. The reservoir storage space was depleted by 18,000 acre-feet of sediment. The maximum reservoir level reached during this simulation was elevation 4,032.6 feet, NGVD, and the maximum outflow was 2,300 cfs. This routing is shown on Plate 8-2.

c. Other Floods.

(1) 1941 Flood. The largest volume flood of record from the drainage area above Two Rivers Reservoir occurred during the period September 20-30, 1941. This flood had several peaks, the largest being 27,000 cfs, and a volume of 91,600 acre-feet. When routed through Two Rivers Reservoir, it would result in a maximum pool elevation of 4010.3 feet, NGVD, and a maximum discharge of 1,000 cfs. Plate 8-3 shows the September 1941 flood routing.

(2) 1965 Flood. The largest volume flood since the project has been in place occurred June 16-17 1965. This flood produced a peak of 54,800 cfs at

the Diamond A Ranch gage. The historical maximum storage in the combined Rocky Arroyo and Rio Hondo Reservoirs reached 7,400 acre-feet. The maximum release through the two outlet works was 750 cfs.

8-03. Recreation. There is limited recreation at Two Rivers Reservoir Project. There are some picnic facilities at the project. Visitor days at the project average about 900 per annum.

8-04. Water Quality. There is no specific operation for water quality at Two Rivers Reservoir. The retention of a pool for sediment deposition results in reduction of suspended solids.

8-05. Fish and Wildlife. Flood storage is too short term to have a significant impact on fish and wildlife.

8-06. Water Supply. There is no municipal or industrial water supply storage in Two Rivers Reservoir.

8-07. Hydroelectric power. None.

8-08. Navigation. None.

8-09. Drought Contingency Plans. The purpose of the Drought Contingency Plan (DCP) for the Pecos River Basin is to provide a basic reference for water management decisions and responses to water shortages induced by climatological droughts. As a water management document it is limited to those drought concerns relating to water control management actions. Because of the long-term nature of a drought and uncertainties of the specific problems that may result, the DCP details only a limited number of specific actions that can be carried out related to water control. The primary value of the DCP is in providing a framework to facilitate coordination and documenting data needed to manage water resources to insure that they are used in a manner consistent with the needs which may develop during a drought.

8-10. Flood Emergency Action Plans. The Flood Emergency Plan describes the type of emergencies to be encompassed, notification procedures, and accumulation of data and information needed in a flood emergency. The purpose of the plan is to provide procedures, aids, instructions and other provisions for interpreting information and data to assess if remedial actions as listed in the plan are required to correct an existing or potential emergency. Included are flood inundation maps which show the areas likely to be inundated. The Flood Emergency Plan provides technical data required for the development of an evacuation plan for downstream areas which subject to flooding.

8-11. Frequencies.

a. Flow Frequency. Plate 8-4 shows an inflow peak discharge frequency curve derived from the Rio Hondo at Diamond A Ranch, which includes 947 square miles of the total 1,027 square miles above Two Rivers Project. Plate 8-5 shows an outflow peak discharge frequency curve.

(1) Key Control Points. The key control point for determining flood control releases from Two Rivers Project is the Rio Hondo at Roswell gage. Plate 8-6 shows the peak-discharge frequency curve for the Roswell gage.

b. Elevation Frequency. The elevation frequency curves for Rio Hondo and Rocky Reservoirs are shown on Plate 8-7. End of month pool elevations are shown on Plates 8-8A through 8-8C.

8-12. **Other Studies**.

a. Reconnaissance Study. The Corps is completing a Reconnaissance Study to assess the effects of the revised PMF on the operation of Two Rivers Reservoir. This analysis found that the revised PMF will exceed the available capacity of Two Rivers Reservoir. Six alternatives have been evaluated to protect the embankments from failure. The most promising alternative consists of widening the spillway on the Rocky Dam left abutment by 1,170 feet. A draft report was completed in March 1995. A Project Design Memorandum (PDM) is the next step in the process to remedy the undersized emergency spillway.

(1) Probable Maximum Flood (PMF) Routing through Proposed Modification. The probable maximum flood (PMF) was based on new rainfall criteria presented in a 1977 National Weather Service memorandum "Probable Maximum Precipitation Estimates for Two Pecos River Drainages and the Las Cruces Drainage, New Mexico" that revised the procedure for estimating the PMP. It was derived from a storm which produced 19.7 inches of rainfall over the drainage area during a 72-hour period. The flood has a peak inflow of 500,000 cfs and a volume of 610,800 acre-feet.

The reservoir level at the beginning of the PMF was selected on the basis of the most severe situation probable of occurance. The pool elevation of the Two Rivers Reservoir at the beginning of the PMF was determined by the analysis of two events; an antecedent flood to determine the starting pool elevation followed five days later by a flood of such magnitude as to fill the existing structure to its maximum pool. Computer runs executed for an empty reservoir at various percentages of the PMF indicated that five days later the reservoir would still be filled to a level greater than 50% of flood control pool. Because of this, the antecedent event was set equal to an event that left the reservoir full to the spillway crest (elevation 4,032 feet, NGVD) after five days. The routing of the PMF through the reservoir, based on the most promising alternative, increasing the spillway crest length by 1,170 feet, resulted in a maximum water surface at elevation 4,048.7 feet, NGVD, with maximum outflow of 470,000 cfs. The routing is shown on Plate 8-9.

b. Flood Plain Management Study. The Corps is assisting the city of Roswell and Chaves County to determine the channel capacity of Rocky Arroyo and Rio Hondo from Two Rivers Project to the confluence with the Pecos River.

IX - **WATER CONTROL MANAGEMENT**

9-01. **Responsibilities and Organization.**

a. Corps of Engineers. The Corps of Engineers own Two Rivers Project and have direct regulatory responsibility for flood control operations. The Contruction-Operations Division (Con-Ops) of the Albuquerque District (AD) is responsible for overseeing project operation and maintenance performed on contract by Chaves County Flood Control Commission (CCFCC) under a cooperative agreement implemented on July 20, 1987. The Engineering and Planning Division is responsible for prescribing regulations to effect optimum benefits for the purposes which the project was authorized and constructed.

(1) The Albuquerque District Engineer has responsibility for formulating and maintaining the flood control plan and monitoring flood control operations at Two Rivers Project. The Chief of Planning Branch, Engineering and Planning Division, of the Albuquerque District is responsible for:

(a) Formulating a flood control plan.

(b) Coordinating with other agencies.

(c) Directing activities of the Reservoir Control Section (RCS).

(2) The RCS is responsible for issuing instructions for the regulation of the Two Rivers Project. The RCS works closely with the Hydrology and Hydraulics Section (H & H). Both sections are in the Planning Branch of Engineering and Planning Division, Albuquerque District. The function of the RCS is to issue instructions for regulation at Two Rivers Project, maintain a continuous record of pertinent river and reservoir data, maintain contact with the National Weather Service on climatic conditions, and for collecting information for establishing current conditions and forecasting future conditions.

During flood conditions, the Chief of the RCS is responsible for:

(a) Keeping officials informed of current and forecasted flows, storage conditions at the reservoir, weather conditions and the nature and extent of damages.

(b) Providing reservoir and flow data for flood situation reports in accordance with EM 500-1-1 and Appendices.

(c) Directing activities for gathering and analyzing weather and stream flow data, and for preparing runoff forecasts.

(d) Maintaining liason with other agencies engaged in data collection and/or operation of reservoirs in the basin.

(e) Following the Water Control Plan.

(3) The Chief of Con-OPs Division is responsible for overseeing the operation and maintenance of Two Rivers Project performed by Chaves County Flood Control Commission (CCFCC) under a cooperative agreement. Operation of Two Rivers Project is under the direct supervision of the Santa Rosa Reservoir Manager. CCFCC maintains equipment and provides weather data, reservoir data, and flow data as specified in the Memorandum of Agreement - Operation and Maintenance of Two Rivers Reservoir, Chaves County, NM, (Exhibit B), to the RCS.

During flood conditions, the Santa Rosa Reservoir Manager is responsible for:

(a) Providing project data in a timely manner.

(b) Making gate changes.

(c) Operating on a 24-hour basis, when required.

(d) Assuring personnel are on duty 24 hours per day, when required.

(e) Notifying authorities.

(f) Notifying people upstream and downstream.

(4) The District organization chart pertaining to the regulation of Two Rivers Project is shown on Plate 9-1. The telephone directory of officials is shown in Table 5-1. The duties at the project site, related to regulation of flows, are performed by the CCFCC and are outlined in the Standing Instructions to Damtender, Exhibit F. The CCFCC shall be available to take instructions on project gate changes during the normal 5-day work week between the hours of 8:00 am and 3:30 pm. At other times (nights and weekends), CCFCC personnel may be reached at their homes. The principal duties performed by CCFCC pertaining to regulation of flow at Two Rivers Project are outlined as follows:

(a) Carry out instructions for operation of the gates as required . Maintain the reservoir elevation gages. Check the reservoir automatic stage recorders at least weekly to assure that they are reporting consistent with the staff gages. Note the time and gage readings on the chart, when it is checked.

(b) Perform emergency operations during critical flood periods in the event communications with the District office fail.

b. State of New Mexico. The State Engineer's Office is responsible for the administration of water rights in the Rio Hondo and Pecos Basins.

9-02. Inter-agency Coordination. The Corps of Engineers cooperates with local, state and other federal agencies in the area. It is the duty of the Albuquerque District (AD) to keep local and state authorities advised as to flood conditions and to furnish advice and information that will enable them to perform their functions to the greatest advantage.

a. Local Press and Corps Bulletins. The AD Public Affairs Office coordinates with the local press for release of information of public interest.

b. National Weather Service (NWS). The AD cooperates with the National Weather Service (NWS) in operating a network of hydrometeorological stations throughout the Pecos River Basin. The NWS office in Albuquerque furnishes meteorological data and forecasts regularly to the AD on a 24-hour basis. When the meteorological situation indicates general area precipitation, quantitative forecasts are furnished. During periods of flooding, the NWS also receives daily readings at selected gaging stations along the Rio Hondo And Pecos River. The AD reports climatological and stream flow data collected at the projects to the NWS. The NWS is responsible for forecasting streamflows, and only those forecasts issued by them are passed to others. Reports of planned releases from reservoirs aid the NWS forecasted flows.

The NWS publishes coordinated NWS/NRCS water-supply forecasts about the 10th of each month, from January through May, indicating the spring runoff volume expected in Rio Ruidoso at Hollywood gage.

c. U.S. Geological Survey (USGS). The USGS operates stream and precipitation gages on a cooperative basis with State and Federal agencies. They make measurements, provide maintenance service, and publish records from stream gage stations, regularly. They also provide preliminary flow data upon request. If the USGS receives word of flooding or potential flooding, they notify the RCS, or if the RCS receives word of high water, they notify the USGS.

The AD contracts with the USGS for the maintenance and servicing of the recording gages and DCP's for the Two Rivers Project and for publication of the data.

d. Natural Resources Conservation Service (NRCS). The NRCS, Department of Agriculture, operates snow courses in cooperation with State and Federal agencies. Snow courses are sampled the first of each month beginning in February and continue into June. Advance publication of snow depth and water content at each site is available by the fifth of each month. The official publication, "Water Supply Outlook for New Mexico," is available by the tenth of each month. It contains snow course measurements and runoff volume forecasts by basins. In 1978 the NRCS began operating automated stations so daily readings are obtained from these sites. This operation is known as the SNOTEL system, and the data (air temperature, snow-water content, accumulated precipitation and time) is available to the Corps.

9-03. Inter-agency Agreements. A copy of the Memorandum of Understanding (MOU) between the Corps and the CCFCC for the operation and maintenance of Two Rivers Reservoir Project is contained in Exhibit B.

9-04. Pecos River Compact. The Pecos River Compact was finalized on 3 December 1948 by Commissioners for the States of New Mexico and Texas and approved by the Congress of the United States of America shortly thereafter. Article III of the Compact provides for the division of waters between the two states. A copy of the Compact is contained in Exhibit C. New Mexico's obligation to deliver Pecos River water at the Texas state line is determined by the Pecos River Master based on procedures described in the Pecos River Master's Manual, dated November 30, 1987 (Appendix D).

9-05. Reports. Four recurring reports are prepared by the RCS. These reports are as follows:

a. A daily report of reservoir operations is transmitted to Southwestern Division (SWD) by 1000 hours each working day.

b. A monthly regulation report is prepared for submission to the SWD by the tenth of each month. This report summarizes the monthly regulation of the reservoir.

c. An Annual Report of Reservoir Regulation Activities is prepared for the Division Annual Report.

d. A summary of Project Operations is prepared as part of the Annual Report of Chief of Engineers.

Additional reporting is required during a flood event. Refer to EM 500-1-1 for details. Flood reports normally will be made initially by telephone to assure that information on flood situations is provided as rapidly as possible.

TABLES

PLATES

TABLE 4-10

RIO HONDO AT DIAMOND A RANCH NR ROSWELL, NEW MEXICO
RECORDED MONTHLY FLOWS IN ACRE-FEET

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1940	77	2.8	0	6.3	0	2.4	0.20	768	72	943			
41	0	5.4	12	137	0	1018	7077	31918	6996	7976			
42	28191	11843	7043	4955	3665	2745	9844	6212	1067	1938			
43	2446	1620	1484	1404	963	599	286	136	1420	3253			
44	165	763	1434	1757	1476	904	284	75	17	930			
45	696	1224	1390	1112	647	300	127	224	18	319			
46	276	71	32	552	492	88	0	23	188	542			
47	1438	1086	689	1069	591	100	0	1148	817	347			
48	1755	44	778	284	139	38	2.4	372	10559	888			
49	34	0	50	329	825	1208	4237	2902	1347	8781			
1950	793	1228	760	492	18	0	0	4.0	125	7960			
51	1934	16	34	232	89	0	0	0	0	6.0			
52	0	0	56	0	4.0	0	115	119	0	3794			
53	0	0	0	6.0	0	20	0	137	1178	2598			
54	0	105	125	0	0	0	0	2073	288	452			
55	8717	0	0	7.9	0	0	60	42	0	10013			
56	1456	7.9	14	0	0	4.0	0	1212	4.0	371			
57	0	2.0	0	24	0	0	4.0	875	81	2844			
58	1396	1158	972	252	85	1874	8218	6220	28	61			
59	3199	1470	966	327	0	0	0	0	32	266			
1960	0	0	0	0	0	0	0	0	1559	1922			
61	0	0	56	9.9	0	0	0	0	81	268			
62	0	0	0	0	317	0	1882	484	105	3168			
63	579	204	323	129	182	9.9	0	6.0	296	46			
64	0	0	0	0	0	0	0	0	315	44			
65	119	208	4.0	0	0	0	0	244	10852	6678			
66	589	0	14	848	0	986	1591	158	0	82			
67	0	1.3	0	10	0.06	0.44	0	0	465	162			
68	0	0	0	0	0	89	3433	2563	0.16	8579			
69	00	0	0	0	0	1.5	0	1.8	579	344			
1970	318	788	48	158	0	0	0	0	8.3	30			
71	0	0	0	0	1.3	0	0	0	0	1059			
72	313	58	0	0	0	0	0	0	73	113			
73	3130	2694	1146	1521	663	1756	4560	7793	490	501			
74	0	0	0	0	0	0	0	0	0	8.5			
75	4869	3420	595	424	1024	273	639	1078	0	0			
76	0	0	0	0	0.56	2.2	1.0	543	83	308			
77	0	0	0	0	0	0	8.5	127	0	27			
78	0	0	0	0	0	0	1813	544	615	685			
79	5.2	6422	13636	5786	3338	3782	4655	1828	6272	0			
1980	0	0	12	8.8	0	0	15	2.0	0	0			
81	432	0	0	0	0	0	0	0	0	282			
82	0	0	5.8	19	35	0	0	0	0	29			
83	2320	17	209	217	23	149	3876	4756	716	0			
84	915	1623	910	247	0	9.9	9.3	4.9	1471	0			
85	150	914	11240	9860	5343	6538	6964	4881	759	0			
86	12031	2344	1577	1595	1077	738	1199	0.93	19852	6839			
87	9187	11532	7371	5637	5415	9418	11825	9156	5373	375			
88	251	1270	2632	3066	3245	2043	1218	844	63	1629			
89	1217	1012	2202	2261	2337	1734	582	0	0.56	0			
1990	80	87	1783	1704	391	19	10	0	3.8	982			
91	2804	876	1575	3418	2178	3846	4848	1672	61	5385			
92	258	897	2965	4746	4022	4703	8644	8646	5185	466			
93	317	1139	2271	3519	2836	2378	2327	2208	184	52			
94	303	1150	1820	2120	861	24	12	3900	484	0			

TABLE 4-11
RIO HONDO BLW DIAMOND A DAM NR ROSWELL, NEW MEXICO
RECORDED MONTHLY FLOWS IN ACRE-FEET

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Aug	Sep	Annual								
1964	0	0	0 0	0 0	0 0	0 0	0 0	[illegible]	[illegible]	[illegible]
65	[illegible]	[illegible]	0	0	0	0	0	[illegible]	[illegible]	[illegible]
66	0	0	0	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
67	0	0	0	0	0	0	0	0	[illegible]	[illegible]
68	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
69	0	0	0	0	0	0	0	0	[illegible]	[illegible]
1970	[illegible]	[illegible]	0	0	0	0	0	0	[illegible]	[illegible]
71	0	0	0	0	0	0	0	0	0	[illegible]
72	[illegible]	[illegible]	0	0 0	0 0	0 0	0 0	0	[illegible]	[illegible]
73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
74	0	0	0	0	0	0	0	0	0	0
75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	0	[illegible]
76	0	0	0	0	0	0	0	[illegible]	0	[illegible]
77	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]
79	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
1980	0	0	0	0	0	0	0	0	0	0
81	[illegible]	0	0	0	0	0	0	[illegible]	0	[illegible]
82	0	0	0	0	0	0	0	0	0	0
83	[illegible]	0	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	0
84	[illegible]	[illegible]	0	[illegible]	0	0	0	0	[illegible]	0
85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
86	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]
1990	0	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	[illegible]
91	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
93	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	0

TABLE 4-12

PECOS RIVER NEAR ARTESIA, NEW MEXICO
RECORDED MONTHLY FLOWS IN ACRE-FEET

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1906	13170	38590	40380	27020	18980	11960	31520	38500	18300	39550			
07	11660	23240	36830	28860	21960	8530	12500	21660	33440	28540			
08	27400	24910	26120	22920	15920	4840	6480	8670	5440	29400			
09	2790	9210	22240	21240	10350	6670	2930	3420	6390	---			
1910	6840	7910	22270	18330	12760	6730	4860	10470	11030	3890			
11	5720	9020	14380	19200	14130	11040	9690	24950	10960	90500			
12	22000	19530	18910	16580	13810	10330	9990	30490	52460	9750			
13	9800	7520	15250	24360	16770	8690	9790	5910	105300	17990			
14	13260	11680	18890	16800	14080	9840	9620	101800	44850	81260			
15	21080	17990	22350	24290	20940	20300	219900	40630	31650	43950			
16	17220	11380	16570	20340	16660	14870	26380	49700	13210	2750			
17	17190	15470	18280	21530	14240	9030	5270	7930	4620	2280			
18	5320	7550	11410	19710	12590	7360	5820	6570	15510	4620			
19	33190	14430	19120	18960	13100	127100	66660	74460	70750	84670			
1920	60350	23410	23350	26750	20650	13650	9640	41250	44830	18500			
21	5710	12300	14310	17450	12880	9990	5580	55890	169200	70550			
22	5930	9500	12030	14480	11170	11720	8230	18090	29240	13480			
23	3840	8600	10060	11610	14920	12150	19870	11970	16920	9940			
24	97040	27070	30940	25770	17070	12680	23280	29330	21190	28060			
25	8780	9220	15810	16790	9330	5710	3260	4350	3900	43510			
26	17030	13670	12050	13660	9820	10790	17730	60960	48050	32230			
27	16540	13490	17200	16400	11400	8010	6600	7440	15810	13880			
28	6690	4260	8020	11270	9260	6740	4420	33240	16030	17780			
29	43590	26700	18480	14480	13840	11630	5610	22670	16350	9170			
1930	16050	14070	11590	13630	9330	6780	6910	9690	22190	24690			
31	113100	14140	15140	16560	13820	8640	30460	62010	18970	11760			
32	20120	14180	19400	17540	13550	11720	14070	44890	17850	22280			
33	62680	18740	17380	16820	13350	9880	4420	2700	16600	14770			
34	8210	9820	9340	9570	9730	9370	7500	7820	2870	579			
35	4210	11130	8970	9050	9560	6990	3510	30140	19870	8400			
36	7090	9090	12310	12570	13010	9360	4420	21540	26670	32100			
37	15370	11190	17090	17950	13000	14020	23980	182700	208000	38370			
38	8710	8990	8320	7850	6590	23360	4920	3690	35580	22560			
39	17140	8480	7090	8230	6690	25140	15890	27590	24340	23850			
1940	5270	5020	7160	7090	6470	33050	19110	20560	22930	13340			
41	3940	5780	6430	5680	5190	47240	54460	235800	150200	89320			
42	258400	73760	37750	30690	27980	13600	76900	67100	19160	17560			
43	23820	62210	20010	21670	9740	9180	19180	5160	31880	15870			
44	6150	7520	11840	12790	8410	34420	5400	4530	30540	9910			
45	14800	9390	9220	8190	6070	4950	34600	3700	13710	3050			
46	7240	6650	6220	6900	5390	4330	23920	2830	5070	10090			
47	17290	10060	9860	8800	4740	8440	23120	10540	927	20610			
48	2010	4400	6090	4960	5680	3500	31660	4500	28720	15960			
49	2650	5140	5530	5780	5620	2600	26590	11480	40010	35180			
1950	25880	10720	9370	10860	8740	6610	13530	4590	26650	64110			
51	14240	5640	5560	5380	4810	24130	5760	16650	14840	37630			
52	2450	5820	5980	4740	2990	3560	22520	2440	9780	18410			
53	2740	3590	4210	3210	2880	3070	19770	2130	1420	9450			
54	1390	3390	3600	3200	2380	2430	15680	19170	991	47			
55	152700	12460	8660	7200	5990	4490	3210	6820	14950	38880			
56	32180	6020	6420	5120	6660	3780	2530	5210	9480	24070			
57	1130	4220	3610	3850	2940	10990	1940	6680	5440	10620			
58	5460	4380	4140	4590	3570	20760	22350	70740	23290	11610			
59	12470	8950	8720	6080	6590	3890	2400	15980	4010	28410			
1960	1570	3510	4180	5360	4010	15580	7160	18760	20030	89330			
61	26090	10630	12190	12480	9670	7470	5450	7320	18700	31210			
62	2150	7480	6380	5460	3780	25390	2820	4170	29940	10850			
63	3990	3580	4130	4190	3770	22170	1600	2710	20830	21780			
64	1300	2750	3290	2710	2670	1890	17810	1110	3430	10070			
65	139	2170	2100	2130	1690	17380	5310	4040	8510	32960			
66	928	2760	2700	2680	2450	23360	3290	1450	24130	17420			
67	2700	2890	2070	2830	2760	1410	634	40790	5850	1270			
68	818	1870	2560	3810	3190	20890	8850	1700	10810	31360			
69	1230	2250	2590	2610	2380	21710	18080	2250	22260	17420			
1970	10340	6670	5390	4600	3140	2220	1560	8810	20640	15570			
71	4550	2760	2910	3000	1650	1350	15300	18540	448	75			
72	2640	3220	3210	2650	1640	5380	27710	1360	1100	32740			
73	5430	4660	4230	5100	3530	3400	20710	76410	24420	11480			
74	17620	2990	2790	2970	2000	20310	4080	19490	4690	10900			
75	22050	7910	5550	4660	4310	2820	1970	972	33190	19000			
76	1230	2270	2310	2400	2330	22080	2750	1910	392	3430			
77	2380	3250	2910	2810	1830	16420	4890	3820	323	9800			
78	5610	3560	2810	3020	2980	10770	24600	1350	22170	21040			
79	2620	6900	9120	8120	5740	2840	1030	18700	30300	4680			
1980	16240	4900	3810	3960	4180	2050	25020	5120	7900	41980			
81	4150	3750	3160	2840	2160	1330	1050	4200	18710	3700			
82	6310	4070	3580	4160	3010	2150	24490	9290	606	29090			
83	7610	3160	3890	3970	3040	2060	2100	28560	1520	40770			
84	7710	9870	4190	3750	2040	1570	883	30750	6520	2760			
85	5740	5740	11090	11840	7000	5620	3260	3950	31290	4360			
86	17560	5900	3990	3720	3930	2640	748	38450	49000	15350			
87	21430	19300	16840	19190	16330	26610	29860	44600	32480	9260			
88	7820	6540	6340	6840	7260	4420	2330	23240	6940	25340			
89	12280	4270	3960	3490	5700	3520	23380	46630	11960	843			
1990	1460	2640	2410	3090	3000	2510	2480	7590	22290	269			
91	6360	4910	3970	3900	3810	2650	2400	38880	2620	39950			

92	10730	7560	9420	11240	8750	24940	14210	32330	33520	5120
93	19550	6070	5830	7820	5580	4220	26160	8440	9660	39040
94	22210	6060	5520	5560	7410	19710	4230	12890	28910	2090

TABLE 7-3

ELEVATION - AREA - CAPACITY TABLE

ELEV. (FT NGVD)	AREA (ACRES)		CAPACITY (AC-FT)		ELEV. (FT NGVD)	AREA (ACRES)		CAPACITY (AC-FT)	
	ROCKY ARRYO	RIO HONDO	ROCKY ARROYO	RIO HONDO		ROCKY ARROYO	RIO HONDO	ROCKY ARROYO	RIO HONDO
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
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NOTE: A common reservoir forms above elevation 3,988 feet NGVD, the common reservoir values are listed under Rio Hondo Reservoir.

EXHIBITS

EXHIBIT A

SUPPLEMENTARY PERTINENT DATA

SUPPLEMENTARY PERTINENT DATA

Item	Description
	GENERAL INFORMATION
Other Names for Project:	None
Location:	Rio Hondo, New Mexico, river mile (RM) 34
Type of Facility:	Dam and Reservoir
Objectives of Regulation:	Flood control, sediment control
Project Owner:	U.S. Army Corps of Engineers (Corps)
Operating Agency:	Corps
Regulating Agency:	Corps
Code of Federal Regulations, Title 33:	N/A
Inter-Agency Agreements:	(1) Memorandum of Understanding between CCFCC and Corps, 1990 (2) Memorandum of Agreement between CCFCC, Roswell, Chaves County and Corps, 1995
Water Rights:	New Mexico State Engineer
Construction Completion Dates:	See paragraph 3-03 in text
Real Estate Acquisitions:	See Plate 2-7
Reservoir Clearing:	None
Minimum Pool Level for release of maximum non-damage flow:	3,286.0 feet, NGVD - 1,000 cfs 295 cfs - Rocky Dam 705 cfs - Diamond A Dam
Shoreline length at top of conservation pool:	N/A

[illegible]

EMERGENCY DRAWDOWN

(FULL RELEASE FROM SPILLWAY AND/OR OUTLET WORKS)

Max Pool (elev. 4,048.9) to Spillway Crest (elev. 4,032.0):	46 Hrs.
Spillway Crest to empty reservoir:	75 days
Pertinent Reservoir Areas:	See Reservoir Data Above, and Plate 2-7.

HYDROLOGY

Drainage Area:	963 sq mi above Diamond A Dam 64 sq mi above Rocky Arroyo Dam

Reservoir Data - Design Floods:

Flood	Duration (days)	Runoff (ac-ft)	Max. Inflow (cfs)	Max. Outflow (cfs)	Max. Pool (ft.)
SDF	2	344,700	281,400	235,200	4,048.9

Climate:	Semi-Arid
1" of runoff:	54,770 for 1,027 sq mi

Storm Types: Frontal, Tropical, and Thunderstorm

Flood Season: May through October

Low flow season: November through April

Reservoir Inflow Data:

Diamond A Ranch, near Roswell gage (1940-1993)

Item	Value	Date
Minimum Daily	0 AF	Many
Minimum Monthly	0 AF	Many
Minimum Annual	945 AF	1964
Average Annual	19,230 AF	1940-1993
Maximum Annual	149,400 AF	1941
Maximum Monthly	78,390 AF	Sep 1941
Maximum Daily	25,590 AF	22 Sep 1941
Maximum Instantaneous	57,800 cfs	18 Jun 1965
Maximum Flood Volume	91,600 AF	1941

Pertinent Stream Flow Stations: At Diamond A Ranch, Near Roswell
Rio Hondo RM 44.7
Below Diamond A Dam, Near Roswell
Rio Hondo RM 33.3
At Roswell, Rio Hondo RM 11.7
Near Acme, Pecos RM 591.2
Near Artesia, Pecos RM 506.8

Water control data recorded at dam: Precipitation, lake elevation, inflow, releases, storage

Number of precipitation stations used in hydrologic forecasting: Automatic DCPs - 16 existing

DAM DATA

EMBANKMENT

Purpose: Impoundment

Type: Non-overflow

Type of fill: Rolled earth fill and rock fill

Slope Protection: Rock riprap upstream and downstream

	Rocky	Diamond A
Height - maximum:	118 ft	98 ft
Length - at crest:	2,940 ft	4,885 ft
Width - at top of dam:	20 ft	26 ft

Top elevation: 4,054.0 ft, NGVD

Freeboard: 5.1 ft

Seepage: Yes

Roadway: Gravel surface on crest of embankments

SPILLWAYS

Location:	Left and Right Abutments of Rocky Dam
Purpose:	Flood Control releases
Type:	Uncontrolled
Crest elevation:	4,032.0 ft, NGVD
Length, net:	Rocky Dam: Right Abutment - 400 ft Left Abutment - 730 ft
Number and size of gates:	None
Type of gates:	N/A
Elev - bottom of gates	N/A
Design Head:	16.9 ft
Maximum Discharge:	233,500 cfs

OUTLET WORKS

	Rocky	Diamond A
Location:	In left abutment	In right abutment
Purpose:	Flood releases	Flood releases
Type:	Uncontrolled square concrete conduit	Controlled rectangular concrete conduit
Size:	3.5 X 3.5 foot	4 X 7 foot
Type of service gate:	N/A	Motor operated slide gate
Number and size of gates:	N/A	1 - 4 x 7 foot
Minimum time required to open/close gate:	N/A	1 Hr 45 min
Type emergency closure and time required:	N/A	1 - Slide gate (4 X 7 ft), 6 hr
Entrance invert elevation:	3,945.0 ft, NGVD	3,957.0 ft, NGVD

Conduit discharges:

	Elevation (ft, NGVD)	Discharge (cfs)	
Maximum Pool	4,048.9	455	1220
Spillway Crest	4,032.0	425	1120
Saddle Dike	3,988.0	305	750
Sediment Reserve	3,982.3	280	655

Energy dissipator:	Deflector bucket	Deflector bucket

RIVER CONTROL REACHES

Location:	The control points for releases from Two Rivers Reservoir Project are the Rio Hondo at Roswell (RM 11.7), Pecos River near Acme (RM 585.3) and Pecos River Artesia (RM 506.8) gages
Purpose of Control:	Potential flood damage
Channel Description:	Rio Hondo: Poorly defined in some sections and fairly well dell defined in the remaining sections Pecos: Generally well defined
Uncontrolled Drainage Area:	Rio Hondo: 43.2 sq mi above Roswell gage Pecos: Approximately 8,300 sq mi above Artesia gage
Target flow rate:	Rio Hondo: 1,000 cfs Pecos: 8,500 cfs
Flood peak travel times:	Rio Hondo at Roswell: 6 hrs Pecos near Artesia: 1 day
Stage and discharge:	@ Rio Hondo at Roswell gage; max non-damaging stage = 10.0 ft; regulating discharge = 1,000 cfs discharge of record = 378 cfs (regulated) @ Pecos near Artesia gage; max non-damaging stage = 13 ft; regulating discharge = 8,500 cfs; discharge of record = 51,500 cfs (33,600 cfs regulated, estimate)
Monitoring Provisions:	River stages are reported to the NWS and are received in AD by satellite transmission and/or by telephone
Related Control Structures:	Santa Rosa Dam and Lake, Sumner Dam and Lake Sumner, Brantley Dam and Reservoir, Avalon Dam and Reservoir, and Red Bluff Dam and Reservoir (irrigation storage only)

EXHIBIT F

STANDING INSTRUCTIONS TO DAMTENDER
TWO RIVERS RESERVOIR PROJECT
PECOS RIVER, NEW MEXICO

STANDING INSTRUCTIONS TO DAMTENDER
TWO RIVERS RESERVOIR PROJECT
RIO HONDO, NEW MEXICO

1. General. The following paragraphs cover project duties which are the responsibility of the damtender. These instructions cover daily routine operations and responsibilities during flood emergencies and when communications between Chaves County Flood Control Commission (CCFCC) and the Albuquerque District (AD) are disrupted. The term "damtender" in the following paragraphs refers to an employee of CCFCC or the designated Operations and Maintenance contractor.

2. Operation Requirements. Operation of Two Rivers Reservoir Project is accomplished by the damtender under the direct supervision of the Santa Rosa Lake Reservoir Manager. Instructions for normal daily and flood regulation are received from the Reservoir Control Section (RCS), Albuquerque District.

The damtender is responsible for:

a. Accomplishing the physical operation of the project in accordance with instructions contained in this manual and issued by the RCS. During flood periods, this may require 24-hour attendance at the dam.

b. Each Monday morning (or the next regular workday, if a holiday), the damtender will report the following data to the RCS:

1) Two Rivers Reservoir Project Hydrologic Data:

a) Reservoir elevations from staff and DCP readings; Rocky and Rio Hondo reservoirs - 0800.

b) Downstream Stage and flow from staff and DCP readings - 0800.

2) Climatic Data:

a) Precipitation (rain or snow).

c. Reporting to the RCS any unusual conditions in the reservoir(s) or along the downstream channel(s) which might interfere with the regulation of flow from the reservoir.

d. Keep trash rack maintained so the outlets will operate efficiently.

e. Making emergency changes when communication with the AD is disrupted and a clearly defined change occurs that warrants immediate action. Refer to Paragraph 7-05b and Table 7-1.

3. Limitations on Changing Release Rates. Changes in release rates during flood control regulation will be limited to 500 cfs per half hour. Releases are generally restricted to a maximum of 1,000 cfs depending on downstream channel conditions on the Rio Hondo and Pecos River.

4. Gate Operations.

a. The gate on Diamond A dam is normally set at 3.0 feet.

b. Gate settings for flood control regulation will normally be provided by the RCS.

5. **Regulation Reports**.

a. The RCS developed a morning report system to use data received from Data Collection Platforms (DCP's) with additional data gathered by the damtender, when necessary, to generate a daily reservoir report for each project. Included in the daily report are the following:

1) Reservoir and downstream stage for midnight and 0800 hours.

2) Reservoir and downstream stage and time for gate changes are made the previous day.

3) Precipitation data as of 0800 hours each morning. Refer to Federal Meteorological Handbook No. 2, operation and procedures for making observations.

b. When the RCS cannot access the data on the AD water control data system, the RCS will request the required project data from the damtender via telephone or facsimle.

6. Special Weather and Flood Reports. The damtender will report occurrences of precipitation at Two Rivers in excess of one-half inch or more during any 6-hour period.

7. **Computation of Project Hydrologic Data**.

The required data, as specified in paragraph 5, for the operation of Two Rivers Reservoir Project and for official record purposes may be computed by the damtender as indicated in the following paragraphs.

a. Reservoir Stage and Contents:

1) Reservoir stage is obtained from the staff gage and/or other instrumentation available at the dam. Reservoir storage is obtained from the current area-capacity table.

2) The change in reservoir storage is the difference between the present and previous day's midnight storage in acre-feet. To convert acre-feet into an average daily flow in cubic feet per second, multiply change in storage (acre-feet) by a factor of 0.5042.

b. Mean daily outflow computation.

1) At the downstream gage, check the recording chart against the staff gage for errors in time and automated gage height reading. Time should be correct to the nearest (current) 15 minutes; automated gage reading should be correct to the nearest .01 foot.

2) Tabulate correct gage height readings one hour after a gate change. Recording chart correction, if any, should be noted.

3) Using most recent rating table, with shifts as applicable, determine and list flow, using the procedure as indicated below.

4) When using the gage rating table with a negative (-) shift correction, subtract the absolute value of the shift correction from the gage reading, then obtain the discharge from the rating table. For a positive (+)

shift correction, add the absolute value of the shift to the gage reading.

5) To use the downstream gage and rating tables to obtain a desired flow, the following procedures are to be followed:

a) Add amount of (-) shift to gage height obtained from table. This is required gage height for desired discharge.

Example: Shift = (-.05) and desired discharge = 275 cfs. Rating table shows gage height of 3.40 = 275 cfs. Required gage height for 275 cfs is 3.40-(-.05) = 3.45.

b) For (+) shift, use the same procedure except subtract amount of shift to obtain correct gage heights.

Example: Shift = (+.05) and desired discharge = 275 cfs. Rating table shows gage height of 3.40 = 275 cfs. Required gage height = 3.40-(.05) = 3.35.

6) Multiply the previous day's release readings by the number of hours at each setting and then total the products; divide this total by 24 hours which will give the average daily release.

7) Average daily flows will be listed to the nearest 0.1 cfs for flows up to 10 cfs and to the nearest cfs for flows above 10 cfs.

c. Average Daily Inflow.

1) Average inflow to the reservoir is the sum of the average outflow, and storage change. Total average daily outflow (cfs) + change in storage (cfs) = average inflow (cfs). The daily average inflow will be computed in acre-feet for the daily report.

TABLE 1

TWO RIVERS RESERVOIR PROJECT
DAILY REPORT
(FOR 24-HOUR PERIOD FROM 0000 TO 2400 ON 13 JUL 91)

(1) TIME* HOURS	(2) ELEV.* FEET	(3) STOR* AC-FT	(4) DS*	(5) Q* CFS	(6) TIME INC HOURS (_1)	(7) CHG STOR AC-FT (_3)	(8) DIFF CFS (3x12.1) / (_1)	(9) OUTFLOW CFS (5)⇘	(10) INFLOW CFS (8)+(9)
0000	3965.00	0	1.64	10					
					7	140	242	10	252
0700	3979.95	140	1.08	0.20					
					17	541	385	0.20	385
2400	3985.54	681	1.10	0.20					

* INPUT DATA SUPPLIED BY PROJECT PERSONNEL

TABLE 2

24 HR
OPERATION SUMMARY

(1) RELEASE CFS	(2) EVAPORATION CFS	(3) UNID. LOSSES CFS	(4) STOR. CHANGE CFS	(5) COMP. INFLOW CFS (1)+(2)+(3)+(4)
3.00	N/A	0	343.00	346.00

SWD - Morning Report Data

0000 Elev	0800 Elev	Precip	Evap	24 hr Release	24 hr Losses	0800 Release
3965.00	3985.54	4.66	0.00	3.00	0	346.00

Note: Column (3) Table 2 - If inflow computes negative it is set to zero and the unidentified losses balance the equation.

8. Computation of Gate Opening. In order to obtain a desired flow using the previous gate opening use the following procedure:

a. Divide present flow by gate setting, then divide desired flow by the result.

Example: Present flow is 320 cfs and one gate is set at 3.00 feet and the desired flow is 500 cfs: 320/3.00 = 106.67 then 500/106.67 = 4.69 feet.

4.69 feet is the gate opening for a flow of 500 cfs.

Gate settings are normally rounded to the nearest tenth or half tenth for all but very low flows.

9. Standing Instructions During Flood Emergency.

a. Normal Flood Control Operation shall be in accordance with instructions from the Reservoir Control Section. During storm periods, close contact will be maintained between CCFCC and district personnel on a 24-hour per day basis or as otherwise required.

b. In the event communications are disrupted during a flood and information concerning stream-flow conditions is not available, the following procedures will be followed:

(1) Continue last release rate

(2) Re-establish communications

(3) If communications cannot be re-established follow the **EMERGENCY REGULATION SCHEDULE** given in Table F-3. CCFCC personnel, or the designated Operations and Maintenance contractor, will make every effort to reestablish communications. This effort will continue through the period of disrupted communications.

10. Modification of Instruction. The operating rules contained herein are subject to temporary modification by the Albuquerque District Engineer during storms or other emergencies. Refer to paragraph 7-13 for information on types of deviations and steps required to initiate and approve these deviations.

TABLE F-3

EMERGENCY REGULATION SCHEDULE
TWO RIVERS PROJECT

Reservoir Condition	Reservoir Stage	Operation
A. Rising, falling or steady	1. Pool below elev. 3,980 ft., NGVD.	1. Maintain gated conduit in the same position it was in at the time communications were lost.
B. Rising	1. Pool below elev. 4,014 ft.(flood control storage 50 percent used).	1. Same as A.1, above.
	2. Pool between elevations 4,014 ft. and 4,032 ft., NGVD	2. Regulate gated conduit so that releases combined with release from uncontrolled conduit do not exceed 1,000 cfs (note - no change in excess of 500 cfs per hour).
Rising	3. Pool above elev. 4,032 ft., NGVD	3. Fully open gated conduit.
Falling	4. Pool above elev. 4,032 ft., NGVD	4. Leave gated conduit fully open until pool falls to elev. 4,032 ft., NGVD then operate in accordance with condition B.2, above.
Falling	5. Pool below elev. 4,032 ft., NGVD	5. Make releases as per condition B.2, above. When pools are emptied, place gate in normal open position in accordance with condition A.1, Table 7-1, Normal Regulation Schedule.

NOTE: Under any conditions a delay period of 6-12 hours is to be observed after communications are lost before any regulation is made by the Dam Tender except when the pool is approaching or above elevation 4,032 ft., NGVD. In this case, action in accordance with B.3 above should be taken. Throughout the emergency every possible effort will be made to again establish communications with the District Office.

EXHIBIT B

B-1	B-2	B-3	
E-1	E-2	E-3	E-4

MEMORANDUM OF AGREEMENT

OPERATION AND MAINTENANCE OF TWO RIVERS RESERVOIR

EXHIBIT D

AUTOMATED FLOOD FORECASTING MODEL
FOR THE PECOS RIVER BASIN

EXHIBIT D
Automated Real-Time Flood Forecasting for
the Pecos River Basin

1. General. This exhibit describes the functions and usage of the Pecos River Basin Real-Time Flood Forecasting System (RTFFS). This system consists of generalized computer software developed by the Hydrologic Engineering Center (HEC) and a set of data models developed by the Albuquerque District Reservoir Control Section (RCS). The HEC programs perform data management functions and standard surface water hydrology computations. The data models describe the particular characteristics of the Pecos River Basin, the flood control criteria, and the data collection networks. The purpose of the water control system is to aid the RCS in operating the Pecos River flood control reservoirs through the acquisition and display of real-time hydrologic and meteorologic data, forecasting rainfall runoff, and deriving a reservoir system regulation plan.

a. Hydrologic Data Management. The data retrieval and processing component provides for automatic collection of satellite telemetered field measurements and conversion to hydrologic quantities. The data management component provides organized storage and retrieval of real-time meteorologic and hydrologic data. In addition, the RCS has full control to check and edit this data in either graphical or tabular formats.

b. Stream Flow Forecasting. The stream flow forecasting component forecasts future stream flows based on observed flows, observed and future precipitation, and basin runoff and routing parameters. The system uses observed data as fully as possible. The modular structure of the forecasting component allows user interaction with the system at key points. This facilitates model calibration and intermediate computations through add-on programs.

c. Reservoir Regulation. The operations simulation component provides the capability to evaluate the effects of alternate regulation plans for the flood control reservoir system. The computer model can compute optimum flood releases based on the given criteria, or the user can set some or all releases. The operations simulation model computes hydrographs of future reservoir releases and storage levels as well as downstream control point flows. The RCS uses this information to determine the best flood control operation.

2. System Overview

a. General. The Pecos River RTFFS is a series of computer programs and their data models. Executed in a coordinated manner, the system acquires, analyzes, stores, and displays real-time water control data, generates rainfall runoff forecasts, and determines alternate reservoir release schedules. The following is an example of a typical use of the system.

(l) Seeing that significant rainfall is approaching the Basin, the RCS will prepare for a possible flood control event. The RCS will alert the appropriate personnel from other federal and state agencies, reservoir project personnel, and other elements within the Albuquerque District Office to the flood potential. The RCS will work with the NWS Albuquerque Office to develop an estimate of future rainfall. A Quantitative Precipitation Forecast (QPF) for the United States is available from the National Weather Service (NWS) as a graphics product on the Automation of Field and Operations Services (AFOS). The program VUENWS provides access to the QPF.

(2) Once rainfall begins, the RCS transfers stream flow, reservoir, and rainfall data from RCS's master database into the Pecos River RTFFS master data file (DSSPEC) with the program DSSMATH. The RCS checks and edits these data in a

graphical format (DSPLAY, DATCHK and DATVUE programs) or tabular format (DSSUTL, DWINDO, and DATAST programs). The RCS manually enters rainfall data from the NWS's observer stations into a separate file called MISCPPT. The PRECIP program computes sub-basin average precipitation from point rainfall measurements from automated and observer stations. The RCS manually enters future precipitation into the RTFFS through the MODCON program.

(3) Once runoff begins to occur, the RCS will monitor stream flow and reservoir conditions with data collected via satellite and through other agencies such as the NWS and the USGS. If these data are not sufficient, the RCS will request dam tenders to report hourly water surface elevation and release. The DSSMATH program screens for missing and erroneous data, computes reservoir inflow, total outflow, and storage and writes these data the data file DSSPEC. The RCS verifies the DSSMATH output and manually checks the processed data.

(4) At this point, the RCS begins making regular runoff forecasts. The RCS prepares the RTFFS for each forecast by setting forecast time and zonal hydrologic loss parameters. Then, the RCS executes a group of programs to generate a forecast specific subset database, evaluate the existing conditions of the basin, produce the runoff forecast, and reservoir operation plan.

The first set of programs includes DSSMATH and EXTRCT. Together, these programs retrieve data from the RCS master database, convert it into hourly interval time-series data, and place it into a forecast specific subset database. The program PREFOR modifies the HEC-1F stream flow forecasting input files (g-model and F-model) to reflect the current forecast session. The RTFFS requires two separate applications of the HEC-lF program. The first step estimates hydrologic parameters and calculates "best fit" discharge hydrographs for gaged headwater sub-basins using the observed real-time data and the HEC-1F E-model input file. The second HEC-1F application calculates discharge hydrographs for all ungaged sub-basins and derives forecast hydrographs at all control points in the watershed model by routing, combining and blending the calculated sub-basin hydrographs using the HEC-1F F-model input file.

Finally, HEC-5 program simulates the reservoir operations using the forecasted hydrographs and any future predetermined release schedules and produces a reservoir system regulation plan. Supplemental programs include the PREOP and MOD5 programs. The PREOP program modifies the skeleton HEC-5 input file to reflect the current forecasting session. The program MOD5 is an interface between the RCS and the extensive list of reservoir operation features available with HEC-5. The RCS can modify the operation criteria interactively through MOD5 and thereby adapt the computer model's decision making to a particular flood situation.

b. The remainder of this Exhibit expands further on the topics already discussed. Sections 3, 4 and 5 provide greater detail on each computer program and how each fits into the forecast process. Section 6 provides step-by-step instructions for using the RTFFS to tie together the information in the HEC water control software manuals listed in the reference section at the end of this Exhibit. Section 7 lists the known problems which are bound to surface during the use of this system during a flood event. Since the system has not been tested, this listing is far from complete. The last section provides a summary of this Exhibit and explores some areas where the RTFFS could be improved as more information and capabilities become available. A listing of the programs, input files, and output files used in the RTFFS is provided at the end of this Exhibit.

3 <u>Data Acquisition and Preparation Programs</u>

a. DSSMATH. The Pecos River RTFFS transfers hydrologic data between the various programs using a standardized database system written by HEC called the

Data Storage System (DSS). The program DSSMATH is a HEC general purpose program which performs typical water control computations with time-series data. DSSMATH processes data collected from DCPs, and copies the data required to generate flood forecasts in the Pecos Basin from the master database (MASTDB) into a forecast master database file called DSSPEC, for later use by the HEC-1F and HEC-5 programs. WCINF is the input file for DSSMATH, and the output file is WCRPT. The DSSMATH program computes inflow, release, and storage for the reservoirs in the Pecos Basin and stores these data in the subset database. In addition to performing reservoir calculations, DSSMATH generates summaries of calculations and reports of current reservoir status. The RCS uses the output from DSSMATH to verify the automated DCP data.

b. DATAST. The DATAST program checks for the existence of data for specified records in a DSS file. The input and output files for DATAST are DLIST and DSRPT, respectively. The DATAST program checks the forecast master database file DSSPEC. The file DLIST contains the pathnames for the raw DCP data and the data processed with the DSSMATH program. The RCS reviews the output file DSRPT before transferring data to the forecast subset database.

c. DSPLAY and DSSUTL. The programs DSPLAY and DSSUTL provide access to data stored in both the forecast master database file DSSPEC and the forecast subset database. With the DSPLAY program and a Tektronics compatible graphics terminal, the RCS displays and checks time-series hyetographs and hydrographs. The DSSUTL program provides the same access to these data in a tabular format as well as other data management functions such as data archiving and transfer with other computer systems.

d. DATCHK and DATVUE. The programs DATCHK and DATVUE are used to view, check and edit the data in the forecast master database (DSSPEC). The input files for DATCHK are FLOCRIT.TX and PPTCRIT.TX. The input files for DATVUE are SVPLMAC.FLO and SVPLMAC.PPT.

e. DWINDO. The DWINDO is a generalized program which provides entry and editing of DSS data in a spreadsheet format. The RCS will use DWINDO to enter reservoir data for Red Bluff Reservoir manually into the master data file DSSPEC.

f. EXTRCT. The HEC program EXTRCT copies stream flow, reservoir storage, and rainfall data within a given forecast time window from the forecast master database, DSSPEC, to a forecast specific subset database, DSSdhh (d-letter code of the forecast day hh-hour of forecast in military time). EXTLIST is the input file for EXTRCT. EXTLIST contains a listing of the DSS record pathnames identifying the appropriate data sets and a fixed time window starting 70 hours relative to prior the forecast time. The HEC water control software manual Forecast and Operations contains complete documentation of the EXTRCT program.

4. <u>Watershed Modeling Programs</u>

a. PRECIP. The HEC program PRECIP develops regular interval sub-basin average hyetographs using gaged time series cumulative precipitation data. The hyetographs are written as DSS records and stored in the subset database (DSSdhh). The RCS executes the PRECIP program as batch-job using the MODCON program during a real-time water control forecasting session. The input file for PRECIP is SUBPPT.

b. Stream flow Forecasting (HEC-1F). The program HEC-1F performs the stream flow forecasting for the RTFFS. HEC adapted the program HEC-1 Flood Hydrograph Package for use in real-time flood forecasting. Like HEC-1, the HEC-1F program calculates runoff from complex watersheds using a unit hydrograph approach and hydrologic routing methods.

Flood forecasting with HEC-1F in a multi-sub-basin watershed requires two separate applications of the program. The first step is to estimate hydrologic parameters (e.g., loss rates, unit hydrograph and baseflow) and calculate discharge hydrographs for gaged headwater sub-basins. The input file for this step is named IPECAE.

The input file for the second step is called IPECAF. The F-model retrieves E-model headwater hydrographs, and routes and combines them with the estimated runoff hydrographs calculated for the intervening sub-basins. This combined hydrograph is the "estimated" hydrograph. Estimated hydrographs at each automated stream gage are blended with observed stream flows before subsequent routing and combining operations. Blending consists of replacing the calculated hydrograph ordinates with observed hydrograph ordinates up to the time of forecast, and providing a smooth transition to the calculated hydrograph over six future time periods following the time of forecast. The resultant of a blending procedure is a "forecasted" hydrograph. The estimated and forecasted hydrographs are written to the subset data file with an "E" or a "F", as the fifth character of the F-part of their pathnames, respectively.

The input files to HEC-1F, which define the sub-basin network and the runoff parameters, are "base files". The base files are not input directly to HEC-1F. Instead, the preprocessor PREFOR alters the base files to reflect the forecast time, loss rates, base flow, and the precipitation alternative. The HEC-1F input files created by PREFOR have names of the form IdhhpE and IdhhpF, where "d" is the symbol for the forecast day, "hh" are the first two numbers of the military time of forecast, and "p" is the precipitation alternative. For example, IHO9AF is the input file to the HEC-1F forecast model for Thursday, at 900 a.m., using the precipitation alternative "A".

The RCS specifies the loss rate and base flow parameters used in the calculation of local hydrographs on a zonal basis. PREFOR uses the zonal values passed from MODCON to replace the values in the base files. In addition to zones for loss rate and base flow parameters, the RCS must specify zones for future precipitation. A MODCON input file, BASNZONE, lists the HEC-1F sub-basins and their loss rate, baseflow, and future precipitation zone designations. The RCS can modify the BASNZONE file through MODCON to change the grouping of the sub-basins to reflect the current flood forecast situation.

c. Reservoir System Simulation (HEC-5). The HEC program HEC-5 simulates the sequential operation of the reservoir system. HEC-5 determines reservoir releases in accordance with constraints at the reservoirs as well as at downstream control points. Reservoir inflow hydrographs and hydrographs of uncontrolled runoff at downstream control points are obtained from previously completed HEC-1F applications. Output from HEC-5 such as hydrographs of discharge, reservoir elevation and storage is written to the subset database with a "3", as the fifth character of the F-part of their pathnames.

The HEC-5 base file, IPECA5, contains the data describing the reservoir system both physically and operationally. The preprocessor program PREOP modifies the base file to reflect the current forecast dates and times, specified runoff forecasts, and operation alternative. PREOP creates the HEC-5 input file called Idhhp5o. The "d" is the symbol represents the forecast day, "hh" the first two numbers of the military time of forecast, and "p" and "o" the precipitation and operation alternatives. For example, IHO9A5B is the input file to the HEC-5 operations model for Thursday, at 900 a.m., using the precipitation alternative "A" and operations alternative "E".

The RCS defines pre-determined future releases and temporary modifications in operating criteria through the program MOD5. Both HEC-5 and MOD5 run interactively from the MODCON program. A complete discussion of the use of HEC-5 in real-time applications is contained in the HEC-5 Training Manual.

5. Model Control

a. MODCON. MODCON is an interactive, executive program designed to integrate the components of the RTFFS. The RCS uses the MODCON program to specify the magnitude of input parameters for PRECIP, HEC-1F and HEC-5. Input parameters include values for loss rates, baseflow rates, future precipitation or specified future reservoir releases. The MODCON program can create and send off (for execution) batch jobs that involve the sequential execution of a series of modeling programs. The RCS can review input parameters, job status, and program output through MODCON. It is also possible to execute the DSPLAY and DSSUTL programs to view plots or tabular displays of any time-series data of interest, including observed and computed data. Refer to the Forecast and Operations Manual for complete information on the MODCON program. Section 8 of this Exhibit provides specific instructions for MODCON use for the RTFFS.

b. Model Control Files (Functions, Macros, Screens, and Menus). The documentation for PREAD describes the use and the format of function, macro, screen, and menu files. PREAD connects the many programs of the RTFFS and provides a friendlier interface between the RTFFS user and the command line of other HEC programs.

(1) Function File. The PREAD function key capability enables the user to identify specific keys on the keyboard with alphanumeric information. When the key is used, the information is inserted into the overall flow of information in place of the function key. Function definitions are unique in that the same function definitions are used by several programs. Because of this property, function keys are used to pass information between programs in the water control software system. The function file is called GENFUN.

(2) Macro Files. PREAD macros enable a user to save and reuse a series of input lines for interactive programs. Macros for a particular program are named and stored in a single file. Since MODCON and DSPLAY are the main interactive programs in the RTFFS, macros are provided for frequently used command groups for each program. The DSPLAY macro file is DSPMAC, and CONMAC for MODCON

(3) Menu File. The menu allows the user to invoke commands, execute programs and display data by touching appropriate areas of the menu on a graphics tablet with a graphics pointer. GENMEN is the data input file which defines the menu.

(4) Screen File. A screen file is provided for the DSPLAY program to allow easy access to predefined reservoir and stream gage hydrographs. The screen file for DSPLAY is DSPSCN. Screens are very rigid compared to menus. In general, the DSPLAY screen is provided for interested parties and not the RCS flood forecaster.

6. Model Control User's Guide

This section serves as a guide for operating the Pecos River RTFFS. Its purpose is to supplement the HEC water control software manuals by describing how the HEC software is applied to the Pecos River RTFFS. The RCS should become thoroughly familiar with the HEC water control software manuals to understand the model control techniques that are available in generating stream flow forecasts and reservoir operation plans.

a. In general, the RCS forecasts floods with the Pecos River Forecast Models by:

(1) Developing a comprehensive real-time data set in the master data file (DSSPEC) consisting of observed precipitation, stream flow and reservoir data. Data in this file is utilized in several forecasts as the storm progresses. Therefore, the RCS must check and edit the data in this file before continuing with the forecast.

(2) Developing a forecast subset database from the checked and corrected data in the data file DSSPEC.

(3) Developing stream flow forecasts and rainfall-runoff parameter estimates of gaged headwater sub-basins using the HEC-1F E-model.

(4) Adjusting zonal loss rate parameters to reflect current conditions in the watershed and generating stream flow forecasts for all ungaged sub-basins and control points using the HEC-1F F-model.

(5) Developing reservoir operation plans using the HEC-5 reservoir simulation model.

(6) Generating graphical displays and forecast summary tables to aid in making water control decisions.

The RCS controls the forecasting procedure through an executive model control program called MODCON. From MODCON, the RCS initiates commands to perform data entry, data edit, data display, forecasting, operations, and other functions necessary to manage the Pecos River forecasting procedure. The available commands are listed in the HEC water control software manual, Forecast and Operations.

Various functions, macros, an interactive menu and screen aid the RCS in operating MODCON to develop forecasts and display results. A list of the functions used in the RTFFS are listed in Table D-1. Table D-2 shows the name and function of the predefined macros in the CONMAC (MODCON) and DSPMAC (DSPLAY) files. The menu developed for the Pecos River RTFFS is Figure D-1. Model control commands to set up, and execute the forecasting programs are located on the left hand side of the menu. Located on the right hand side and along the bottom of the menu are commands and macros to develop graphical displays of observed data and model results using the DSPLAY program. Regular keyboard input and JCL commands are located along the bottom of the menu. A schematic of the Pecos River Forecasting System is the center of the menu.

In general, the functions and macros are not accessed directly (although they certainly can be). Instead, the user issues commands through menus or screens to run macros or change function references. A screen is provided for the DSPLAY program to facilitate access to hydrologic data. This screen is shown in Figure D-2. Because of the flexibility of menus over screens, the RCS flood forecaster will use the menu and the general users will use the DSPLAY screen.

b. RTFFS and Real-time Data Preparation. RTFFS preparation is conducted using the executive model control program MODCON. Once in the MODCON program, the RCS can enter commands directly with the keyboard at the command line prompt "MC>" The menu must be initialize before the RCS can use it to control the modelling process. Type in "MENU Pecos R" at the command line prompt and register the origin and X and Y axis when prompted. Commands can be entered through the keyboard with the menu activated. The following paragraphs provide specific instructions for executing the forecasting steps outlined previously.

(1) The first step in running the RTFFS is to create a master data file containing current real-time hydrometeorological data, check these data for existence and accuracy, and select a forecast time. The PREAD macro GETDATA runs the programs DSSMATH and DATAST. The DSSMATH program retrieves data from the master database for the previus 75 hours and places into the forecast master database with an F-part of TS1.

Table D-1

Functions Character Definitions

Function Character	Description
^b	Basin name. Always PECOS.
^d	D-part of the pathname for the specific forecast
^e	E-part of the pathname. Always 1HOUR.
^h	Fraction of pathname for observed data which includes the D-, E-, and F-parts. Always ^d/^e/OBS/.
^j	Fraction of pathname for forecasted data which includes the D-, E-, and F-parts. Always ^d/^e/^r^s^pF/.
^l	Fraction of pathname for estimated data which includes the D-, E-, and F-parts. Always ^d/^e/^r^s^pE/.
^m	Forecast time
^n	Fraction of pathname for data generated by HEC-5 which includes the D-, E-, and F- parts. Always ^d/^e/^r^s^p5^o/.
^o	Operating alternative currently set in MODCON.
^p	Precipitation alternative currently set in MODCON.
^r	The single character code for the day of the week for the current day of forecast where S = Sunday, M = Monday, T = Tuesday, W = Wednesday, H = Thursday, F = Friday, A = Saturday.
^s	The first two digits of the current time of forecast.
^u	Time and date of the start of the current forecast time window.
^v	Time and date of the end of the current forecast time window.
^z	Name of the current subset database. Always DSS^r^s

Table D-2

Pecos River RTFFS Macros

MODCON Program

GETDATA	Retrieves data from master database and processes it to place in forecast master database DSSPEC.
DSSUTL [f]	Chains to the DSSUTL program with the proper file assignment. The [f] designates the DSS file to open (DSSPEC or DSSdhh).
DSPLAY (f)	Chains to the DSPLAY program with the proper file assignment. The [f] designates the DSS file to open (DSSPEC or DSSdhh).
DWINDO [f] [p]	Chains to the DWINDO program. The [f] designates the DSS file to open (DSSPEC or DSSdhh3)and the (p) designates the project (SRL, SUM, RRR, RWR, BRT, or RBF).
NOW	Generates a report on the current (time of forecast) reservoir and stream flow data.
DATASTAT	Chains to the DATASTAT program and displays a table showing status of gage availibility in the master data base.
DATCHK	Chains to the DATCHK and DATVUE programs to check,view and edit the data.
DATVUE	Chains to the DATVUE program to view and edit the data.

DSPLAY Program

AUTO	Configures DSPLAY for this forecast specific subset database by opening the data file, setting the time window, forecast time marker, and other graphical format settings.
VIEWMAST	Plots of raw data.
VIEWCHK	Plots of raw and processed data.
STRM5PL	Plots observed, regulated, natural, local cumulative, and space remaining hydrograph for a stream gage. Function reference ^b defines the B-part of the pathname.
ATS	Runs macro STRM5PL for the Artesia gage.
ACM	Runs macro STRM5PL for the Acme gage.
CPD	Runs macro STRM5PL for the Carlsbad gage.
RHR	Runs macro STRM5PL for the Roswell gage.
RES5PL	Plots reservoir inflow, outflow, and storage computed by HEC-5 of a specified project. Function reference ^b defines the B-part of the pathname.
SRL	Runs macro RES5PL for Santa Rosa.
LAK	Runs macro RES5PL for Sumner.
RRR	Runs macro RES5PL for Rio Hondo.
RWR	Runs macro RES5PL for Rocky.
CBL	Runs macro RES5PL for Brantley.
RBF	Runs macro RES5PL for the Red Bluff.
ALL	Cycles through macros SRL, SUM, RRR, RWR, BRT, and RBF.

Figure D-1

Figure D-2

DSPLAY Screen

```
              PECOS RIVER REAL TIME FLOOD FORECASTING SYSTEM
*******************************************************************

RESERVOIR I, O, & S              RIVER GAGES (1 EACH)
--------------------    -----------------------------------------
SRL - SANTA ROSA (3)    PCO - PECOS               ATS - ARTESIA
LAK - SUMNER (3)        PEC - CANON DEL UTA       PSB - BLW BRANTLEY
RRR - TWO RIVERS (3)    SRD - BLW SANTA ROSA      CPD - CARLSBAD
CBL - BRANTLEY (3)      PUE - PUERTO DE LUNA
RBF - RED BLUFF (3)     PSD - BLW SUMNER          __________________
                        ACM - ACME               | FORECAST TIME:    |
                        DAR - DIAMOND A RANCH    | 13AUG1989 1200    |
                        RRH - BLW DIA A DAM      | FORECAST WINDOW:  |
RESERVOIR ELEV          RHR - ROSWELL            | ST 10AUG1989 1400 |
-----------------                                | EN 22AUG1989 0600 |
SRLE, SUME, RRRE,                                | PREC ALT:  A      |
  BRTE, RBFE                                     | OPER ALT:  A      |
                  X   -  Exit                    |___________________|

SELECT UP TO 7 PLOTS THEN P TO PLOT >
```

Then, the program DSSMATH checks the raw data for missing and erroneous values, fills in missing data, converts 15-minute hydrologic data into hourly data, and computes reservoir total inflows, outflows and reservoir storage. The output file for the DSSMATH program is WCRPT. The DATAST program checks hourly data for missing values and generates a report called DSRPT that is displayed to the screen. Run the DSPLAY program after the GETDATA macro. The DSPLAY macro VIEWMAST runs to plot the data that was converted, processed and placed into the forecast master database (DSSPEC) with the F-part of TS1. The RCS then run DATCHK and DATVUE (calling macro DATCHK) to edit the data, if necessary, and to write the data into the data file DSSPEC with an F-part of OBS. The DSPLAY macro VIEWCHK runs to plot the "raw" (F-part - TS1) and the edited (F-part - OBS) data. The data can be edited again, if necessary, by calling the DATVUE macro at the MODCON prompt.

(2) Select Time of Forecast and Forecast Time Window. The forecast time reflects the available real-time data in the master data file. The forecast time is not necessarily the current time, although it should be close. Select a forecast time where approximately 70 to 80 percent of the stations have reported. The RCS enters the MODCON command TIME followed by the date and time in the form of TIME ddmmmyyyy hh00 to set the forecast time to the nearest hour.

MODCON uses the time of forecast to define the forecast DSS subset database name and its pathnames. The letter d defines the day of the week (S = Sunday, M = Monday, T = Tuesday, W = Wednesday, H = Thursday, F = Friday, A = Saturday), and the letter symbol hh defines the military hour of the time of forecast (01 through 24).

The MODCON command SIMTIME sets the forecast time window. The SIMTIME parameters represent the lookback time in hours for the HEC-1F models, the lookback time in hours for the HEC-5 model, the lookahead time in hours for both the HEC-1F and HEC-5 models, and the computation period in minutes. For the Pecos RTFFS, the computation time interval is always 60 minutes. The lookback and lookahead default times are 70 and 210 hours, respectively. The lookback time is the average time-to-peak for runoff for the sub-basins in the Basin of 10 hours times 7. Refer to the HEC-1F documentation in the Forecasts and Operations manual for information on the significance of this calculation. The lookback time for the DSSMATH, DATAST, and EXTRCT programs is 70 hours. HEC-1F limits the total time window to a total of 300 hours. Unless these parameters require changing, the user should not have to reenter the simulation time window. To reset the default settings, enter the command SIMTIME 70 70 210 60.

(3) Select Precipitation Alternative. A precipitation alternative identifies a particular forecast session with respect to the precipitation used in the forecast. The available precipitation alternatives are A, B, C, D, Q, R and S. Alternative A represents only observed precipitation is desired for the forecast. Select alternatives E, C, and D when ad-hoc modifications are made to the observed precipitation using the MODCON command PASTPPT and/or zonal future precipitation is input using the MODCON command FUTURPPT. After choosing a precipitation alternative, do not change it until the entire forecasting process (through HEC-5) is complete. When the precipitation alternative is changed, start over with the HEC-1F E-model.

Alternatives Q, R and S are predefined future precipitation alternatives stored in the MODCON file STATUS. Alternative Q designates using the Quantified Precipitation Forecast (QPF) developed by the RCS in conjunction with the SWD meteorologist and the NWS. Alternatives R and S designate using predetermined ratios of the QPF information stored in the master database (0.5 for Alternative R and 1.5 for Alternative S). Once determined, the RCS enters these values by first changing the precipitation alternative to Q (or R or S) by entering PPTALT Q (or R or S), and then entering the forecasted precipitation with the FUTURPPT command.

(4) Create Forecast Subset Database. With the time of forecast, forecast time window, and precipitation alternative defined, create a forecast subset database by executing the HEC program EXTRCT. Issue the MODCON command "RUN X" to submit the EXTRCT program for execution. EXTRCT copies the appropriate data from the master data file (DSSPEC) into the forecast subset database (DSSdhh) and assigns each record a Pathname F-part specific to that forecast. The default master database is DSSPEC. To reset this default value, use the MODCON command MASTERDB to reset the master database to DSSPEC.

(5) Generate Sub-basin Average Hyetographs. Most of the real-time data in the file DSSPEC is received via satellite telemetry. The automated precipitation gages in place now (see Figure D-1 and Plates 6-1 and 6-2) will not cover the Basin sufficiently to generate accurate rainfall runoff forecasts. The NWS volunteer observers report rainfall amounts to the NWS. The RCS enters these miscellaneous readings along with the station latitude, longitude, and station identification into a file called MISCPPT.

PRECIP program computes sub-basin average hyetographs based on regular time-series (automated) rainfall in the data file DSSPEC and miscellaneous rainfall entered into the file MISCPPT. Run the PRECIP program with the MODCON command "RUN P". The sub-basin average hyetographs are written back to the subset database with an F-part of dhhp (where d = day of forecast, hh = military hour of forecast, and p = precipitation alternative). Review summary of tables of gaged precipitation, sub-basin precipitation, and precipitation gage usage with the MODCON command SUMMARY (e.g., SUM PG, SUM PS, and SUM PU). Small errors in the sub-basin average precipitation can cause large errors in the runoff computations. Use MODCON command GAGE to "ignore" bad gage data for a specified period. The PRECIP program must be rerun if the GAGE command is executed.

(6) Designate Starting Loss Rates for Parameter Estimation. Set the loss rates before initiating the HEC-1F program to estimate rainfall-runoff parameters and calculate hydrographs at gaged headwater sub-basins (E-model) by

using the MODCON command LOSS. These loss rate estimates act as starting points for the optimization procedure employed in the HEC-1F E-model analysis. Accurate estimates of the loss rate starting units improve the optimization results. Zonal loss rates from MODCON are passed to the individual sub-basins by the program PREFOR using the data file BASNZONE.

The BASNZONE file contains baseflow values for each zone. Unless additional information exists, use the initial baseflow parameters values for forecasting.

c. Real-time Hydrologic Parameter Estimation (HEC-1F E-Model). Stream flow forecasts for the gaged headwater sub-basins are calculated by HEC-1F using the E-Model data input file. Use the optimized rainfall, runoff parameters to estimate the condition of the watershed and choose zonal parameters for use in stream flow forecasting with the HEC-1F F-model data input file. Default values of the constant and uniform loss rates (stored in the base files) represent wet soil moisture conditions. Increase these parameters for drier conditions.

Before initiating the HEC-1F program, review the forecast session setup with MODCON command STATUS. If the default value for the E-model is not IPECAE, issue the MODCON command "INPFILE E PEC". Run the HEC-1F program using the E-model with the RUN command (e.g., RUN E). MODCON creates a forecast specific input data file called IdhhpE through the interface with program PREFOR using the base file IPECAE. The HEC-1F E-model runs and creates the output file named OdhhpE. HEC-1F creates an E-model forecast summary table called TdhhpE. This file is displayed from MODCON with the command SUMMARY (e.g., SUM E).

d. Model Preparation for Real-time Runoff Forecasting

(1) Specify Zonal Loss Rates. Before initiating the HEC-1F program to develop stream flow forecasts for the remaining ungaged sub-basins in the watershed using the F-model input data file, set the zonal loss rates for these sub-basins. Use the results of the HEC-1F E-model application to reflect current watershed conditions. The RCS specifies the zonal loss rates with the MODCON command LOSS and is automatically passed to the individual sub-basins by the program PREFOR using the data file BASNZONE. If zonal loss rates are not specified, then the model uses loss rates set previously.

(2) Determine Reservoir Operation Alternative. Future predetermined releases from reservoirs can be specified from the model control program MODCON. These releases should not be input into the forecast subset database before running the HEC-1F F-model. HEC-1F assumes all future reservoir outflows are zero in developing forecasted hydrographs at downstream control points. HEC-5 computes reservoir releases and the corresponding downstream flows. Each set of user-specified future reservoir release are identified by an operation alternative. The available operation alternatives are A, B, C, and D and are set with the MODCON command OPERALT. Set future releases for each alternative with the MOD5 program accessed through the MODCON command IA5.

(3) Specify Starting Storage for Red Bluff Reservoir. Red Bluff Reservoir is not telemetered with DCP's as are the other projects in the Basin. Reservoir storage at the beginning of forecast simulation needs to be input into the HEC-5 model data file before program initiation. This can be done with the text editor COED by editing the appropriate portions of the HEC-5 model input file IPECAF. In general, the conditions at Red Bluff Reservoir will not impact the flood control operations upstream. If a particular flood event requires intensive analysis at Red Bluff, the RCS will manually enter reservoir data through the DWINDO program.

e. Real-time Runoff Forecasting (HEC-1F F-Model). HEC-1F develops stream flow forecasts for control points and ungaged sub-basins in the Pecos River Basin using a F-model input data file and current forecast parameters. The HEC-1F program is initiated with the RUN command (e.g., RUN F). A forecast specific input data file is then automatically created by the interface program PREFOR using the data file IPECAF and current forecast parameters and is named IdhhpF (where d = day of forecast, hh = military hour of forecast, and p = precipitation alternative). The HEC-1F F-model is then executed and the output file is named OdhhpF. A F-model forecast summary table is generated and written to TdhhpF by HEC-1F and can be displayed from MODCON with the command SUMMARY (e.g., SUM F).

Extensive review the summary table and hydrograph plots is required at this point. If the forecasted flows vary greatly from known observed flows or otherwise seem unreasonable, there is no point in running the reservoir simulation model. The possible errors incorporated into the forecast are numerous. Additional errors in the time-series data tend to appear and must be corrected, if possible. If not, the MODCON command GAGE can be used to "ignore" bad precipitation and stream flow data. It is relatively easy to adjust loss rates by changing the zonal values or by moving sub-basins into another zone. Correcting errors in unit hydrograph and routing parameters requires direct editing of the base files and so are much harder to correct. Note that the routing parameters in the HEC-1F F-model and HEC-5 models must match.

f. HEC-5 Reservoir System Simulation. Forecasted reservoir operations are computed by the HEC program HEC-5 using an input data file and current forecast parameters. The HEC-5 data file is IPECA5 for the Pecos River Basin. The execution of HEC-5 is very different from the other programs in the RTFFS. A HEC-5 sub-menu is accessed with the IA5 command from MODCON. At this point, the RCS can provide additional input information to the model such as pre-defined future releases or run the HEC-5 program to simulate reservoir system response to the forecasted flood.

The MOD5 program allows the RCS to change the operational rules in the reservoir model as well as set future releases. Minor changes might reflect deviations from the flood control plan such as reducing maximum channel capacity. Some of the information in the data file or the model can not be changed during real-time use of MOD5. Examples include releases prior to the time of forecast and storage amounts at each level. MOD5 is designed to "know" the types of parameters which could change in a real-time flood situation. Refer to the draft training manual titled Flood Control Simulation Using HEC-5 and the MOD5 Users Manual for more information.

After running the MOD5 program, run HEC-5 interactively from the IA5 menu. The first time HEC-5 runs for a given precipitation alternative, HEC-5 computes local incremental flows at each control point and stores these in a binary file. The binary file name is Qdhhp5, following the form of other files generated by the RTFFS. Subsequent reservoir simulation runs with the same forecast time and precipitation alternative will access the binary file. If the HEC-1F E- and F-models are rerun for the same forecast time and precipitation alternative after the binary file is generated, delete this file prior to running HEC-5.

After HEC-5 runs through the reservoir operation, it stops to allow the RCS to review the results before generating an output file or writing time-series data to the forecast subset database. The RCS has the option to complete the execution of HEC-5 or to abandon this run and start over. If the run is stopped, the HEC-5 generated data will be lost. The HEC-5 output file is named Odhhp5o.

7. Potential Problems Modelling the Pecos River Basin. The following paragraphs briefly discuss the Pecos River real-time flood forecasting models in respect to the potential shortfalls of modelling real-world physical systems with a computer. This listing is far from complete. The problems specific the Pecos Basin RTFFS are discussed in this section and not the common problems associated

with rainfall runoff flood forecasting.

a. Measuring Uncontrolled Releases. Spillway releases at Santa Rosa and Sumner Dams flow directly at or just upstream of the automated downstream river gages causing potentially large inaccuracies in flow measurement. Flow from the Rocky Arroyo side of Two Rivers Reservoir is not gaged below the dam and is not measured until it reaches the Rio Hondo gage in Roswell. If water is flowing

from the Rio Hondo side to Rocky Reservoir there is no way to measure the flows above Roswell until the two reservoirs join and stabilize.

b. Two Rivers Reservoir. With the complex physical configuration of Two Rivers Reservoir, the HEC-5 model does not accurately represent the project.

c. Brantley Dam and Reservoir. As specified in the water control plan for Brantley Dam and Reservoir, a surcharge operation is followed by the Corps when the pool elevation is below but forecast to exceed 3,283. Reclamation does not use a surcharge operation above elevation 3,283. The HEC-5 model will operate for a surcharge operation below and above elevation 3,283 leading to errors when the Reclamation specifies the releases.

d. Reservoir regulation. Based on flood control criteria, the HEC-5 model specifies Santa Rosa and Sumner Dams operate together down to the Artesia gage. The travel time from Sumner to the Artesia gage is longer then the "foresight" of HEC-5, and therefore, Santa Rosa and Sumner Dams in fact do <u>not</u> operate for the Artesia gage. The foresight time can be increased <u>if</u> the forecasted intervening flows are reliable for this period.

e. The channel routing parameters used in the RTFFS were obtained from the PMF model for the Basin. These parameters were developed for large flows and may be inadequate for the smaller floods. Since little or data was available, neither the routing or unit hydrograph parameters in these models have been calibrated with historical floods.

f. Limited headwaters basins. There are only two true headwaters basins in the Pecos River RTFFS: the Pecos River at Pecos, NM and the Rio Hondo at Diamond "A" Ranch.

8. <u>Conclusions and Recommendations</u>

a. Conclusions. A real-time flood forecasting and reservoir operations simulation system has been developed for the Pecos River Basin. The system consists of generalized computer software developed by the Albuquerque District and the Hydrologic Engineering Center and a set of data models describing the particular characteristics of the Pecos River Basin, the flood control system, and the data collection and reporting networks. The flood forecasting system includes data retrieval and processing, hydrologic data management, stream flow forecasting and simulation of reservoir operations.

The data retrieval and processing component provides for automatic collection and conversion to hydrologic quantities of field measurements.

The data management component provides systematic, organized storage and retrieval of real-time reservoir and hydrologic data. Utility programs are provided to edit, purge, plot and tabulate data. Capabilities are provided to easily invoke routine complex data plots with minimal user interaction, including use of a graphics tablet to select desired plots.

The stream flow forecasting component provides forecasts of future stream flows based on recently observed stream flows, observed and future precipitation, user defined basin loss and baseflow rates, and expected reservoir releases. Observed information is used as fully as possible. Stream flow forecasting data models were developed, calibrated and verified under forecast conditions using historical runoff events.

The operations simulation component provides the capability to rapidly evaluate the effects of alternative plans of operating the reservoir flood control system assuming future stream flows given by the stream flow forecasting component. Future regulated flows at control points and future storage levels can be anticipated using the operations simulation model. The reservoir operation models were developed, calibrated, and verified under simulated forecast conditions using historical runoff events.

The Pecos River Real-Time Flood Forecasting System provides a coherent set of tools to increase the effectiveness of the RCS in identifying future flood problems and evaluating alternative measures for mitigation.

b. Recommendations. The effectiveness of the Pecos River Real-Time Flood Forecasting System depends heavily on the accuracy and reliability of the stream flow forecasting component. The accuracy of the stream flow forecasting in turn relies on the hydrologic procedures and model parameters and the availability of data to adequately and accurately represent the actual basin rainfall-runoff process. The rainfall-runoff parameters and routing coefficients in the Pecos River stream flow forecasting models were estimated using data from historical events, but sufficient data is not available to calibrate and verify accurate simulation. It is therefore recommended that as flood events occur adequate hydrologic data be collected in order to calibrate stream flow forecasting models.

GLOSSARY

AFOS - AFOS stands for Automation of Field Operations and Services. This is the system on which the National Weather Service disseminates weather and forecast information to all of its offices. The Corps is tied into this system and thereby receives this data as soon as it is put on AFOS. Refer to the HEC Water Control Software Manual, Data Acquisition, for more information.

BASNZONE - BASNZONE is a text file which lists the precipitation, loss rate, and baseflow zones assigned to each sub-basin in the HEC-1F models. The program PREFOR uses the BASNZONE file to modify the HEC-1F input files with the zonal loss rates, future precipitation amounts, and baseflows set with the MODCON program. Refer to the HEC Water Control Software Manual, Forecast and Operations, for more information.

CONMAC - The text file CONMAC is the PREAD macro file for the MODCON program. Refer to the HEC Water Control Software Manual, Implementation and Management, for more information.

DATAST - The DATAST program checks a DSS file for a specified time window to see if data is present. Refer to the HECDSS Users Guide for more information.

DATCHK - The DATCHK program performs screening tests with user-specified criteria and optionally generates replacement values for flagged data.

DATVUE - The DATVUE displays data flagged by DATCHK and allows the user to edit replacement values.

DCP - In the context of this Exhibit, a data collection platform is a programmable electronic component located at remote field sites attached to a hydrologic or meteorologic gaging site. The DCP is programmed to periodically measure a hydrometeorologic parameter (usually every 15 minutes), store this measurement, and then transmit (generally every four hours) these data to the Geostationary Operational Environmental Satellites (GOES). These satellites retransmit these data to ground receive sites which in turn send these data to the WCDS computer in Dallas for use in the Pecos RTFFS.

DLIST - DLIST is a text file which lists the DSS record names which the program DATAST checks. Refer to the HECDSS Users Guide for more information.

DSPLAY - The program DSPLAY graphically displays data in the database. The SWD WCDS provides two versions of the DSPLAY program to access data in the TOTAL database and also HEC DSS files. Refer to the HECDSS Users Guide for more information.

DSPMAC - The text file DSPMAC is the PREAD macro file for the DSPLAY program. Refer to the HEC Water Control Software Manual, Implementation and Management, for more information.

DSS - DSS refers the HEC Data Storage System.

DSSdhh - Form taken by the forecast specific subset data file name. The "d" character indicates the day of the week for the forecast where d is S for Sunday, M for Monday, T for Tuesday, W for Wednesday, H for Thursday, F for Friday, and A for Saturday. The "hh" characters indicate the time of the forecast in 24-hour clock time (e.g., for 0100 or 1:00 am. hh is 01).

DSSMATH - The DSSMATH program is a general purpose program for performing computations with time-series and paired data in DSS files.

DSSPEC - The master DSS data file for the Pecos River RTFFS.

DSSUTL - The program DSSUTL is a HECDSS utility program for editing, deleting, archiving, and otherwise managing DSS records and files. Refer to the HECDSS Users Guide for more information.

DWINDO - The program DWINDO is a data entry and editing program for DSS data files. Through pre-defined forms, data records are displayed in a columnar format and accessed in a crude "spreadsheet" fashion. Refer to the HECDSS Users Guide for more information.

EXTLIST - EXTRCT is a text file containing a time window and a listing of pathnames which the program EXTRCT transfers from the master data file DSSPEC to the forecast specific subset database DSSdhh.

EXTRCT - The EXTRCT program transfers DSS data from the master data file DSSPEC to the forecast specific subset database DSSdhh. It is run from MODCON. Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

GENFUN - GENFUN is a text file containing the PREAD function key definitions. Refer to the HEC Water Control Software Manual, Implementation and Management, for more information.

GENMEN - GENMEN is a text file containing the definition of the PREAD menu for the Pecos River RTFFS. Refer to the HEC Water Control Software Manual, Implementation and Management, for more information.

HEC - The U.S. Army Corps of Engineers Hydrologic Engineering Center: a Corps lab located in Davis, California.

HEC-1F - The HEC-lF program is a modified version of the general purpose rainfall-runoff modelling program HEC-1 designed for real-time flood forecasting. Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

HEC-5 - The HEC-5 program is HEC's general purpose reservoir system simulation program. The full title is Simulation of Flood Control and Conservation Systems. Refer to the following manuals for more information: HEC-5 Users Manual; Exhibit 8 to the HEC-5 User Manual, Description of Program Input, and the draft Training Document, Flood Control Simulation Using HEC-5.

IPECA5 - IPECA5 is a text file containing the base file for the HEC-5 model.

IPECAE - IPECAE is a text file containing the base file for the HEC-1F E-model.

IPECAF - IPECAF is a text file containing the base file for the HEC-1F F-model.

JCL - Job Control Language.

MISCPPT - MISCPPT is a text file containing miscellaneous precipitation measurements manually entered by the user. The PRECIP programs uses this information to compute sub-basin average rainfall.

MOD-5 - The MOD5 program is a menu driven editor for HEC-5 input files. Refer to the Users Manual for MOD5 for more information.

MODCON - The MODCON program is a shell program for HEC real-time flood forecasting programs. Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

NWS - National Weather Service

PREAD - PREAD is a preprocessor of user input to most interactive HEC programs. PREAD features include functions, macros, screens, and menus. Refer to the HEC

Water Control Software Manual, Implementation and Management, for more information.

PRECIP - The PRECIP program computes sub-basin average hyetographs from point rainfall data. Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

PREFOR - The PREFOR programs transfers time, loss rate, baseflow, and precipitation parameters from MODCON to HEC-1F by generating forecast specific input files.   Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

PREOP - The PREOP program transfers time, release, and inflow information from MODCON to HEC-5 by generating forecast specific input files. Refer to the HEC Water Control Software Manual, Forecasts and Operations, for more information.

QPF - Quantitative Precipitation Forecast

RCS - The U. S. Army Corps of Engineers, Albuquerque District Reservoir Control Section.

RTFFS - Real-time Flood Forecasting System

SUBPPT - SUBPPT is a text file containing precipitation gage and sub-basin, locations for input to the PRECIP program.

SWD - The U. S. Army Corps of Engineers, Southwestern Division.

USGS - U. S. Geological Survey

VUENWS - The VUENWS program provides a method for viewing NMS AFOS products. Refer to the HEC Water Control Software Manual, Data Acquisition, for more information.

WCINF - WCINF is a text file containing instructions for the DSSMATH program to perform computations required for the RTFFS.

WCRPT - WCRPT is a text file containing text output from the DSSMATH program.

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EXHIBIT E

RESOLUTION NO. 1039 BY THE CITY OF ROSWELL, COUNTY CHAVES, STATE OF NEW MEXICO, PLEDGING COOPERATION WITH THE UNITED STATES OF AMERICA IN FLOOD CONTROL, RIO HONDO RIVER