TEXAS WATER DEVELOPMENT BOARD

REPORT 22

WATER-DELIVERY AND LOW-FLOW STUDIES

PECOS RIVER, TEXAS

Quantity and Quality, 1964 and 1965

By

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

WATER-DELIVERY AND LOW-FLOW STUDIES

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INTRODUCTION

Purpose and Scope

The water-delivery study was made February 15 to March 31, 1964, and the low-flow study was made May 10-12, 1965, by the U.S. Geological Survey under an agreement with the Red Bluff Water Power Control District, Pecos, through the then Texas Water Commission.

The purpose of these studies was to determine changes in the quantity and the quality of a uniform flow of water from Red Bluff Reservoir in a 188.4-mile reach of the Pecos River between the dam and Girvin, Texas, and to determine the quantity and the quality of the low flow in this same reach of the Pecos River when no water was being released from Red Bluff Reservoir. The capacity of Red Bluff Reservoir at the top of the Tainter gates is 310,000 acre-feet. Water in storage in the reservoir was about 33,000 acre-feet at the beginning of the water-delivery study and 19,750 acre-feet during the low-flow study.

Water is released from Red Bluff Reservoir during the spring and summer months for irrigation of land on both sides of the Pecos River in an area extending from about mile 43.3, the first diversion at Reeves County W.I.D. (Water Improvement District) No. 2 dam, to mile 111.5, the last diversion at Ward County W.I.D. No. 2 dam. Some 28,000 acres of land in this area can be irrigated from the river (Pecos River Commission, 1961, p. 128); however, the actual number of acres irrigated varies from year to year, depending on the quantity and quality of water in Red Bluff Reservoir.

Before releases of water were made for the water-delivery study of February 15 to March 31, 1964, the flow in the Pecos River at the stream-gaging station near Orla (mile 14.3) was only 7.0 cfs (cubic feet per second) and consisted of seepage and leakage through gates from Red Bluff Reservoir and some inflow from Salt (Screwbean) Draw near Orla. There was no flow at the site of the inactive stream-gaging station, Pecos River at Pecos (mile 71.8). The flow at the stream-gaging station, Pecos River near Girvin (mile 188.4) was 24 cfs. In comparison, the flow at Orla during the low-flow study of May 10-12, 1965, was only 0.39 cfs. There was no flow at the Pecos station and 11.5 cfs at the Girvin station.

During February 15 to March 31, 1964, conditions were favorable for determining channel losses of water released from Red Bluff Reservoir. A prolonged

dry period preceded the investigation; there was no surface runoff and the only inflow was from small springs in Salt (Screwbean) Draw. No great water loss could be attributed to evapotranspiration because the salt cedars were dormant. Other than seepage through three headgates, no diversions were being made. Some of the checkgates in the diversion dams on the Pecos River had been opened to decrease storage behind the dams.

The Red Bluff Water Power Control District, which operates Red Bluff Reservoir, released a constant flow from the reservoir during the water-delivery study. The measured release from Red Bluff Reservoir was 129 cfs and this discharge was maintained from February 21 to March 9, 1964. During the period March 3-5, 1964, a series of measurements was made and samples for chemical analyses were collected at sites along the Pecos River (Plate 1).

During the investigation of May 10-12, 1965, conditions were favorable for determining gains and losses in the river when there was no surface runoff and no releases were being made from Red Bluff Reservoir. In May the salt cedars are in full leaf and some water loss can be attributed to evapotranspiration. None of the irrigation districts were taking water from the Pecos River during this period. During the low-flow study a series of measurements was made and samples for chemical analyses were collected at sites along the Pecos River (Plate 2).

Between Red Bluff Reservoir and Girvin the Pecos River is a meandering stream with a channel about 60 feet wide. The banks are low, are generally covered with salt cedars and other brushy vegetation, and have not been overtopped since the floods of September and October 1941. The river channel is characterized by long pools formed by gravel bars, rock outcrops, and low diversion dams. Photographs of the river at several sites in the study area during the investigations are shown in Figures 1 and 2.

Method of Analysis

For both the water-delivery and low-flow studies, water losses or gains between sites usually were determined by differences in measured discharge. The flow released from Red Bluff Reservoir during the study in February and March 1964 was constant; and during the low-flow study in May 1965, no tributaries were flowing and no water was released from the reservoir. Therefore, differences in the measured discharges represent the net gains or losses throughout the study reach.

Total water losses, in acre-feet, between the gaging station on the Pecos River near Orla (mile 14.3) and Pecos River near Girvin (mile 188.4) were determined from streamflow records for February and March 1964. Also, the water lost between Red Bluff Dam near Orla (mile 0) and the Girvin station (mile 188.4) was determined by the salt-dilution method of measuring water discharge. From the composition of the mixture of water at Girvin and the known rate of flow, and the known composition of the salt inflow, the water loss and the rate of salt inflow was computed by using simultaneous algebraic equations.

During the low-flow study of May 10-12, 1965, the continuous records of flow at the gaging stations, Pecos River near Orla (mile 14.3) and Pecos River near Girvin (mile 188.4), indicated that the flow was constant.

A. View upstream toward stream-gaging station, Pecos River near Orla (mile 14.3)

B. Pecos River downstream from Grandfalls-Big Valley diversion dam (mile 93.6)

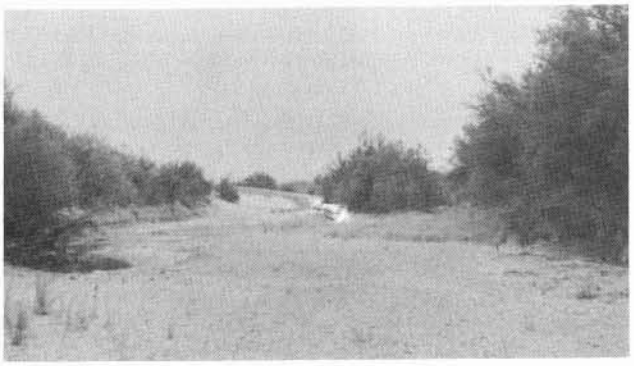
C. Pecos River at stream-gaging station near Girvin (mile 188.4)

Figure 1

Sites Along the Pecos River, March 1964

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District

A. View upstream toward stream-gaging station, Pecos River near Orla (mile 14.3)



B. View upstream toward Reeves County W.I.D. No. 2 dam near Mentone (mile 43.4)

C. View downstream from bridge on State Highway 18 near Grandfalls (mile 127.4)

Figure 2

Sites Along the Pecos River, May 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District

GENERAL GEOLOGY

The study area is a part of the Pecos Plains and Toyah Basin. Alluvium of Cenozoic age is at the surface in most of the study area and unconformably overlies rocks ranging from the Rustler Formation of the Ochoa Series of Late Permian age to rocks of the Gulf Series of Late Cretaceous age. Rocks ranging in age from Permian to Recent crop out in small areas on both sides of the Pecos River. The Cenozoic alluvium consists of unconsolidated to partially consolidated sand, silt, gravel, boulders, clay, gypsum, and caliche. This alluvium is the principal aquifer in Reeves and northern Pecos Counties and is heavily pumped for irrigation in the vicinity of Pecos and Coyanosa.

HYDROLOGY

Discharge was measured and samples for chemical analyses were collected March 3-5, 1964, at 22 sites in the study reach. The results of water discharge measurements and chloride concentrations are given in Table 1, and chemical analyses of samples from 10 of these sites are shown in Table 3. These data, which are also shown graphically on Figure 3, show changes in chemical quality and gains and losses of flow throughout the reach during the period March 3-5, 1964. The flood wave, but not the actual water (as determined by chemical analysis) released from Red Bluff Reservoir, had reached the lower end of the reach (below site 18) at the time samples were collected on March 4-5, 1964. Because the chemical analyses of water samples obtained below site 18 (mile 105.8) were not representative of the released water they are not included in Table 3.

Discharge was measured and samples for chemical analyses were collected May 10-12, 1965, at 26 sites in the study reach. The results of water discharge measurements and chloride concentrations are given in Table 2, and chemical analyses are shown in Table 3. These data, which are also shown graphically on Figure 4, show changes in chemical quality and gains and losses of flow throughout the reach during the study period.

The study reach has been subdivided where significant changes in water discharge and chemical quality occurred.

Reach From Red Bluff Reservoir (Mile 0) To Pecos (Mile 71.8)

Water-Delivery Study

The river channel from Red Bluff Reservoir to Pecos is about 60 feet wide, and the channel bed is sand and gravel. Throughout this reach of the river, salt-cedar growth is very heavy along the low banks and in the flood plain. These water-loving plants have a potential ability to consume as much as 5 acre-feet of water per acre per year (Pecos River Commission, 1955, p. 8). During the period March 3-5, 1964, the plants were dormant and probably consumed no streamflow. During the period May 10-12, 1965, the plants were in full leaf and the quantity of water consumed was probably large.

Before the development of irrigation wells in Reeves County, whose northeastern boundary is the Pecos River, ground water moved toward the Pecos River

along most of the reach between Red Bluff Reservoir and the eastern corner of Reeves County. Hydrologic studies conducted in 1918 (Grover, Gray, and Ellsworth, 1922, p. 103) indicated that during periods of little or no rainfall the flow of the Pecos River increased about 30 cfs between Red Bluff Reservoir and the eastern corner of Reeves County. Ground-water studies in 1958-59 (Ogilbee, Wesselman, and Irelan, 1962, v. 1, p. 33) indicated that little or no ground water was discharged from the Reeves County side of the Pecos River from a point about 15 miles north-northwest of Pecos to a point 7 miles east of Pecos. In 1918, part of this reach was also a losing reach. Along this reach in the central part of the county the water table has been lowered by the withdrawals of ground water for irrigation, and the water table slopes away from, rather than toward, the river.

During the water-delivery study, the released water was measured on March 3, 1964, about 1,500 feet downstream from the dam (site 2, mile 0.35). The amount measured (129 cfs) includes all of the released water and seepage from the reservoir. The chloride concentration of the water at this site was 2,950 ppm (parts per million). An inflow of 0.17 cfs was measured from Salt (Screwbean) Draw (site 3, mile 2.9). This flow was saline and had a chloride concentration of 6,430 ppm. The measured flow at the recording stream-gaging station, Pecos River near Orla at mile 14.3 (site 4), was 124 cfs. In the first 14.3 miles of the river there was a loss in discharge of 5.2 cfs (0.36 cfs per mile), and an increase in chloride concentration from 2,950 ppm to 2,990 ppm. Flow had been constant in this reach of the river since February 21, 1964, and the banks should have been well saturated with water. Thus the loss must be attributed to water entering the alluvium and not returning to the river.

The next measurement of flow was made at mile 43.4 (site 6) just downstream from Reeves County W.I.D. No. 2 brush dam. This brush dam is capped with concrete and is almost water tight. Seepage through the headgates to the canal was 0.15 cfs. The discharge of the river below the dam was 110 cfs, or a loss in discharge of 13.8 cfs in the 29.1-mile reach between sites 4 and 6 (0.47 cfs per mile). The water quality changed very little between sites 4 and 6.

At mile 52.8 (site 8), a short distance downstream from Ward County W.I.D. No. 3 dam (site 7, mile 52.6), the discharge was 102 cfs. No water was diverted at the dam and no other diversions or inflow were found between sites 6 and 8. The channel loss was 0.85 cfs per mile between these sites and the water quality remained unchanged.

The discharge of the Pecos River at Pecos (site 11, mile 71.8) was 77.6 cfs, a loss of 24.4 cfs between sites 8 and 11. Seepage into Ward County Irrigation District No. 1 canal (site 9, mile 61.0) was 0.3 cfs. The water lost in the 19.0 miles of river channel between sites 8 and 11 was 1.27 cfs per mile, the highest loss rate measured. The chloride concentration increased from 2,990 to 3,180 ppm between sites 8 and 11.

During the period March 3-5, 1964, in the 71.8-mile reach of river between Red Bluff Reservoir and the former gaging station on the Pecos River at Pecos, the total loss of flow was about 51 cfs, or 40 percent of the discharge (129 cfs) measured 1,500 feet downstream from the reservoir.

Low-Flow Study

During the investigation of May 10-12, 1965, the Pecos River had a flow of 2.58 cfs and a chloride concentration of 5,970 ppm about 1,500 feet downstream from the dam (site 2, mile 0.35). This flow was seepage from the reservoir and leakage through the gates. Salt (Screwbean) Draw (site 3, mile 2.9) was not flowing. The measured flow at the gaging station, Pecos River near Orla (site 4, mile 14.3), was 0.39 cfs. The water lost between Red Bluff Dam (mile 0) and the Orla station (mile 14.3) was 0.15 cfs per mile. Chloride concentration increased from 5,970 to 7,710 ppm.

The river was dry between Reeves County W.I.D. No. 2 brush dam (site 5, mile 43.3) and Pecos (site 11, mile 71.8).

Prior to the investigation in May 1965, there had been no releases from the reservoir or surface runoff for at least 30 days; therefore, the loss in flow is attributed to seepage into the alluvium and to evapotranspiration (the salt cedars, which consume large quantities of water, were in full leaf at this time).

Reach From Pecos (Mile 71.8) to State Highway 18 Near Grandfalls (Mile 127.4)

Water-Delivery Study

Ground-water studies in 1958 (Armstrong and McMillion, 1961) indicated that the ground-water table was sloping towards the Pecos River in the Coyanosa Draw area of Pecos County. However, the gradient at that time was very low and heavy pumping for irrigation in recent years has probably reversed the gradient in some areas so that water is now being lost from the Pecos River into the Cenozoic alluvium along most of the reach between Pecos and Grandfalls.

During the period March 3-5, 1964, there was an apparent increase in flow of 2.6 cfs between the former gaging station, Pecos River at Pecos (site 11, mile 71.8), and Grandfalls-Big Valley Diversion Dam (site 16, mile 93.6). No visible inflow from creeks or return flow from irrigated lands entered the river. The apparent increase in flow is attributed to accretion of water from the river alluvium.

An abandoned oil well (site 14, mile 93.0), known locally as "The River Well," was discharging about 0.08 cfs of saline water (6,820 ppm chloride) on March 5, 1964. The flow follows a small draw about 1,000 feet to the river. On March 5, 1964, all of the flow from this well was going into the ground before it reached the river, but probably reached the river as ground-water effluent.

On March 4, 1964, the flow decreased from 80.2 cfs at site 16 (mile 93.6) to 74.2 cfs, below the Pecos County W.I.D. No. 2 (upper diversion) canal (site 18, mile 105.8). Outflow from the river to the canal was 1.8 cfs. This decrease in discharge was accompanied by a small increase in the chloride concentration. The increase in chloride concentration from 3,180 ppm at site 11 to 3,280 at site 18 probably resulted from the mixing of release water with the more saline water from pools in the reach and pickup of soluble salts from the channel.

On March 4, 1964, between site 18 (mile 105.8) and the bridge on State Highway 18 near Grandfalls (site 21, mile 127.4), there was a loss in discharge of 13.6 cfs. Because of the possibility that the maximum flow of water released from Red Bluff Reservoir had not reached site 21 at the time of measurement, the actual loss in the reach is uncertain. A discharge of 60.6 cfs at State Highway 18 near Grandfalls was the lowest discharge measured on the Pecos River during the water-delivery study.

At State Highway 18, which is below all diversions for irrigation from the Pecos River in this area, the total measured loss between Red Bluff Reservoir and this site was 68.4 cfs, or 53 percent of the amount released. There was some ground-water inflow to the river between Pecos and State Highway 18 as shown by the investigation in May 1965; therefore, the loss of water released from Red Bluff Reservoir may have been greater than indicated by measurements made in March 1964.

Low-Flow Study

During the investigation of May 10-12, 1965, the flow increased from zero at Pecos River at Pecos (site 11, mile 71.8) to 3.18 cfs 0.1 mile downstream from Toyah Creek (site 13, mile 86.4), which was not flowing, and then decreased to 1.99 cfs below Grandfalls-Big Valley Diversion Dam (site 16, mile 93.6). The chloride concentration was 7,020 ppm at site 13 and increased to 7,910 ppm at site 16.

The flow decreased from 1.99 cfs to zero in the reach of river from site 16 to site 18 (mile 93.6 to mile 105.8) on May 11, 1965, with no diversion to Pecos County W.I.D. No. 2 (upper diversion) canal (site 17, mile 105.6). There was some seepage (0.1 gallon per minute) between pools in the river below the upper diversion dam.

On May 11, 1965, the flow increased from zero just below Pecos County W.I.D. No. 2 (upper diversion) dam (site 18, mile 105.8) to 0.99 cfs at the bridge on Farm Road 1776 near Grandfalls (site 20, mile 114.3), and increased to 1.59 cfs at the bridge on State Highway 18 near Grandfalls (site 21, mile 127.4). The inflow between these latter two sites was highly saline, as evidenced by the chloride concentration of 7,910 ppm at site 20 and 16,300 ppm at site 21. The inflow of 0.6 cfs between these two sites had to have an average chloride concentration of 30,150 ppm to account for this increase. The source of the very saline inflow in this reach is unknown but may be associated with oil production in the area (see oil well in channel, Figure 2).

Reach From State Highway 18 Near Grandfalls (Mile 127.4) To Girvin (Mile 188.4)

Water-Delivery Study

During March 1964 the flow of the Pecos River was 66.2 cfs at the former gaging station, Pecos River below Grandfalls (site 22, mile 141.4), and 68.5 cfs at the Farm Road 1053 bridge near Imperial (site 23, mile 150.2), and apparent gain of 2.3 cfs. No major ground-water irrigation occurs along this reach of the river, and the ground-water table slopes toward and intersects the channel. Ground-water studies by Armstrong and McMillion (1961) in 1958 showed

that the ground-water gradient was toward the river between State Highway 18 and Farm Road 1053. The elevation of the ground-water table where it intersects the river is higher than the elevation of the river channel, and water would flow from the aquifer into the river.

The discharge at the stream-gaging station, Pecos River near Girvin (site 26, mile 188.4) was measured on March 5, 1964. This discharge measurement and those made at all sites below site 18 (mile 105.8) were made after the flood wave created by water released from Red Bluff Reservoir reached these sites, but before the actual water released from the reservoir arrived. The water measured in this reach of the channel was in reality water displaced from channel pools. Chemical analyses indicate that water released from Red Bluff Reservoir did not reach Girvin until March 9, 1964, and the mixture of releases and seepage flows did not reach equilibrium until about March 13, 1964 (Figures 5 and 6). The flow of the Pecos River near Girvin reached a maximum of 75 cfs on March 11, 1964, and continued at this rate until March 15, 1964.

The amount of water lost between Red Bluff Reservoir and Girvin was computed for the water-delivery study by using the salt-dilution method. The water discharges and chloride concentrations are related as follows:

(1) $q_1 + q_2 = q_3$

(2) $q_1c_1 + q_2c_2 = q_3c_3$

(3) $q_5c_1 + q_4c_4 + q_2c_2 - Lc_1 - 0c_1 = q_3c_3$

Where: q_1 = discharge in cfs of water from Red Bluff Reservoir that reached Girvin station

c_1 = concentration of chloride in water released from Red Bluff Reservoir (2,950 ppm)

q_2 = discharge in cfs of inflow between Red Bluff and Girvin

c_2 = concentration of chloride in inflow water as determined at Girvin station before water from Red Bluff Reservoir reached that station (7,500 ppm)

q_3 = maximum water discharge at Girvin (75 cfs)

c_3 = concentration of chloride in water at Girvin after released water and seepage inflow reached equilibrium about March 13 (4,120 ppm)

q_4 = discharge of Salt (Screwbean) Draw (0.17 cfs)

c_4 = concentration of chloride in q_4 (6,430 ppm)

q_5 = discharge from Red Bluff Reservoir, including seepage (129 cfs)

L = reduction in peak rate of flow due to losses, cfs

0 = measured outflow (diversions) of released water (2.3 cfs)

Solving equations (1) and (2) simultaneously we get:

$$(2)\quad q_1\ (2{,}950\ \text{ppm}) + q_2\ (7{,}500\ \text{ppm}) = 75\ \text{cfs}\ (4{,}120\ \text{ppm})$$

$$(1)\quad \underline{q_1\ (2{,}950\ \text{ppm}) + q_2\ (2{,}950\ \text{ppm}) = 75\ \text{cfs}\ (2{,}950\ \text{ppm})}$$

$$q_2\ (4{,}550\ \text{ppm}) = 75\ \text{cfs}\ (1{,}170\ \text{ppm})$$

$$q_2 = 19.3\ \text{cfs inflow.}$$

Then using the above value of q_2 in equation (3):

$$129\ (2{,}950) + 0.17\ (6{,}430) + 19.3\ (7{,}500) - L\ (2{,}950) - 2.3\ (2{,}950)$$

$$= 75\ (4{,}120)$$

$$L = 71.4\ \text{cfs}$$

Therefore, the constant discharge of 129 cfs released from Red Bluff Reservoir in February and March 1964 was reduced to 57.6 cfs at the Girvin Station, or a reduction of 55 percent.

After the gates were closed on Red Bluff Reservoir on March 9, 1964, and before the released water passed the lower end of the study reach near Girvin, some surface runoff occurred at the lower end of the reach as a result of rain showers on March 18-19, 1964. There was no effect on the flow hydrograph for Pecos River near Orla, but surface runoff had to be eliminated from the flow at Pecos River near Girvin to obtain the total released flow passing the Girvin gaging station. (See Figure 5.) The released water continued to drain out of the river until about March 29, 1964, when the flow at Girvin was back to 24 cfs, which was the base flow at this station before the study began. The reduction of the base flow from 24 cfs to the computed inflow of 19.3 cfs during the study is attributed to a damming or backwater effect on the effluent ground water.

Low-Flow Study

The gain in flow in the reach between State Highway 18 (site 21, mile 127.4) and Farm Road 1053 (site 23, mile 150.2) that was indicated by measurements made during the water-delivery study in March 1964 was verified by the measurements made in May 1965. The flow increased from 1.59 cfs at the bridge on State Highway 18 near Grandfalls to 4.90 cfs at the former gaging station, Pecos River below Grandfalls (site 22, mile 141.4), with a further increase to 5.44 cfs at the bridge on Farm Road 1053 near Imperial.

Between State Highway 18 (site 21) and Pecos River below Grandfalls (site 22), the chloride concentration of the water decreased from 16,300 to 7,220 ppm, indicating that about 3.31 cfs of better quality water (about 2,860 ppm chloride) entered the river. The chloride concentration of the water increased to 8,680 ppm at Farm Road 1053 near Imperial (site 23), indicating that the inflow between sites 22 and 23 contained a higher concentration of chloride than the inflow between sites 21 and 22.

During the investigation in May 1965 the flow increased from 5.44 cfs at the bridge on Farm Road 1053 near Imperial (site 23, mile 150.2) to 5.75 cfs at the former stream-gaging station, Pecos River near Buenavista (site 24, mile 158.2). The largest increase in flow occured between this point and the Pecos River at Horsehead Crossing near Girvin (site 25, mile 173.2) where the flow was 11.2 cfs. The flow was apparently stable (11.2 to 11.5 cfs) from Horsehead Crossing to the lower end of the reach at Pecos River near Girvin (site 26, mile 188.4). No surface runoff occurred in the area during May 10-12, 1965, and the increase in flow in the reach is attributed to effluent ground water.

Between Farm Road 1053 (site 23) and Horsehead Crossing (site 25) the flow increased from 5.44 to 11.2 cfs, a gain in 5.76 cfs. In the same reach the chloride concentration decreased from 8,680 ppm to 8,290 ppm. The inflow of 5.76 cfs thus had an average chloride concentration of 7,920 ppm. Between Horsehead Crossing and the station at Girvin the concentration remained constant.

WATER QUALITY AND USE

General

Extreme drouth conditions have prevailed in the Pecos valley since 1960. Inflow to Red Bluff Reservoir through 1965 consisted mainly of low flows with high salt concentrations. Therefore, the salt concentrations recorded during these investigations were not representative of average runoff conditions that would include flood inflow with a diluting effect causing the reservoir water to be usable for irrigation. Salinity alleviation projects proposed by the Bureau of Reclamation are estimated to reduce the average annual concentration of dissolved solids in diverted water by 10 percent or more. The character of the water is predominantly calcium-sulfate and has been proven satisfactory for irrigation of free-draining soils.

Domestic

Drinking water used on common carriers in interstate traffic should not exceed limits of concentrations of dissolved constituents listed by the U.S. Public Health Service (1962). These standards are usually accepted as the basis for determining the suitability of waters for municipal and domestic use. The recommended limits for chloride and sulfate concentrations are 250 ppm, and the total dissolved solids should not exceed 500 ppm.

The saline water in Red Bluff Reservoir at the time of these investigations greatly exceeded these limits and was unsatisfactory for domestic use. The concentrations of Red Bluff water in February 1964 and May 1965 were as follows:

	February 1964	May 1965
Chloride	2,950 ppm	6,050 ppm
Sulfate	2,020 ppm	2,860 ppm
Dissolved solids	7,640 ppm	13,900 ppm

Water with more than 180 ppm hardness (as calcium carbonate) is considered very hard. The hardness of the Red Bluff water was 2,260 ppm in February 1964 and 3,270 ppm in May 1965.

The concentration of dissolved constituents of base flow of the Pecos River at Girvin in February 1964 was about double the concentration of the Red Bluff water.

Industrial

Saline waters, similar to the Red Bluff Reservoir water at the time of this investigation, are highly corrosive, and when these waters are heated or evaporated, scale will form rapidly in pipes or other containers. Because of these two characteristics, saline water is unsatisfactory for most industrial uses.

Irrigation

The U.S. Salinity Laboratory Staff (1954, p. 69) lists the total concentration of soluble salts and the relative proportion of sodium to the other cations as the two most important characteristics in determining water quality for irrigation. Based on standards of the Salinity Laboratory Staff, the Red Bluff Reservoir water would be classified as having a very high sodium hazard. The salinity hazard of the water would be classified as very high; therefore, the Red Bluff Reservoir water at the time of this investigation was undesirable for irrigation. However, the reservoir content has been held at low levels for the last few years so that any probable flood inflow could be retained. During years of above-average runoff the quality of water is better than when these studies were made.

SUMMARY AND CONCLUSIONS

During the period February 21 to March 9, 1964, the rate of release from Red Bluff Reservoir, including the seepage, was 129 cfs as measured about 1,500 feet downstream from the dam. The chloride concentration of the water at this site was 2,950 ppm. In the 188.4 miles of river studied, there was only 2.27 cfs of surface outflow (leakage into diversion canals). No other diversions from the river are known. During this period 4,370 acre-feet of water passed the stream-gaging station, Pecos River near Orla (mile 14.3), which is near the upper end of the reach. This included 0.17 cfs of saline water (6,430 ppm chloride) from Salt (Screwbean) Draw near Orla (mile 2.9) and seepage flow (0.15 cfs) from Red Bluff Reservoir measured at mile 0.05.

The released water, minus losses and plus base flow and surface runoff, passed the stream-gaging station, Pecos River near Girvin (mile 188.4), at the lower end of the reach during the period March 2-29, 1964. A total of 3,000 acre-feet of water passed the gaging station during this period. This included the base flow (chloride concentration 7,500 ppm) and surface runoff of March 17-21, 1964. Subtracting the base flow (1,165 acre-feet), which was computed from streamflow and quality-of-water records for Pecos River near Girvin, and the surface runoff (75 acre-feet) between Pecos and Girvin, from the water measured at the Girvin gaging station leaves 1,760 acre-feet. This remainder is the quantity of released water that passed the lower end of the reach.

The total diversions during this investigation were 2.27 cfs. The diversion rate was constant during the period March 2-29, 1964, and a total of 130 acre-feet was diverted from the river.

In summation, of the 4,370 acre-feet of water passing the stream-gaging station Pecos River near Orla (mile 14.3), 130 acre-feet was diverted from the river, and 1,760 acre-feet passed the stream-gaging station Pecos River near Girvin (mile 188.4). The difference, 2,480 acre-feet, is 57 percent of the water measured at Pecos River near Orla. The water was lost to ground-water aquifers, evaporated, or transpired in the 174.1 miles between the stations near Orla and near Girvin. Because the weather was cool and phreatophytes were relatively dormant in February and March, most of the loss was to ground-water aquifers.

During the low-flow study of May 10-12, 1965, the flow in the Pecos River 1,500 feet downstream from Red Bluff Reservoir was 2.58 cfs, which was seepage from the reservoir and leakage through the central gates at the dam. The chloride concentration was 5,970 ppm. There was no inflow from Salt (Screwbean) Draw (mile 2.9). The flow in the river decreased to 0.39 cfs and the chloride concentration increased to 7,710 ppm at the gaging station Pecos River near Orla (mile 14.3). The river was completely dry at the Reeves County W.I.D. No. 2 dam (mile 43.3) and at the former gaging station Pecos River at Pecos (mile 71.8). Between the Pecos station and Toyah Creek (mile 86.3) the river began to flow again and had a flow of 3.18 cfs with a chloride concentration of 7,020 ppm 0.1 mile downstream from Toyah Creek, which was not flowing. At Pecos County W.I.D. No. 2 (upper diversion) dam (mile 105.8) the river was dry. Below this site the flow began again and increased to 11.5 cfs at the gaging station Pecos River near Girvin (mile 188.4). In this same reach the chloride concentration decreased from 16,300 ppm (concentration at site 21, probably due to upstream oil-field pollution) to 8,290 ppm.

The water in Red Bluff Reservoir in March 1964 was of poor quality (2,950 ppm chloride), and most of the ground-water inflow to the river was of poorer quality (7,500 ppm chloride). The reservoir water at this time was unsatisfactory for domestic use, unsatisfactory for most industrial uses, and undesirable for irrigation. In May 1965 the water in Red Bluff Reservoir was even poorer in quality (6,050 ppm chloride). However, because of the prolonged dry period preceding these investigations, the quality of the water in Red Bluff Reservoir in March 1964 and May 1965 is not indicative of the quality to be expected during years of average or above-average runoff.

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Table 1.--Summary of water discharge measurements and chloride concentrations, Pecos River water-delivery study, March 1964

Site No.	Date	Stream	Location	River mile[1]	Water temp. (°F)	Discharge in cfs			Chloride (ppm)	Specific conductance (micromhos at 25°C)	Remarks
						Main stream	Tributary	Diversion			
	1964 Mar.										
1	3	Bank seepage	Lat 31°54'05", long 103°54'30"	0.05	--		a0.15		--	--	Seepage along left river bank, which is composed of alluvium.
2	3	Pecos River	Lat 31°53'58", long 103°54'18", about 1,500 feet downstream from Red Bluff Dam.	.35	47	129			2,950	10,900	Channel has bed of small gravel, with salt cedars on both banks and short grass on right bank.
3	3	Salt (Screwbean) Draw	Lat 31°52'33", long 103°53'04", about 500 feet upstream from mouth.	2.9	48		a.17		6,430	20,100	Channel has bed of sand and gravel, with heavy growth of salt cedars along each bank.
4	3	Pecos River	Lat 31°48'14", long 103°48'26", 600 feet downstream from stream-gaging station, Pecos River near Orla.	14.3	52	124			2,990	11,000	Channel has bed of gravel, with heavy growth of salt cedars in channel and along each bank. Sandstone outcrops at the gaging station.
5	3	Reeves Co. WID No. 2 Canal	Lat 31°37'57", long 103°34'30", 175 feet downstream from Headgates.	43.3	--			a.15	--	--	Channel is composed of gravel and silt and has heavy growth of salt cedars along each bank.
6	3	Pecos River	Lat 31°37'57", long 103°34'22", 800 feet downstream from Reeves Co. WID No. 2 channel dam.	43.4	52	110			2,980	11,100	Channel is composed of gravel and silt and has grass and salt cedars along each bank.
7	3	Ward Co. WID No. 3 Canal	Lat 31°36'03", long 103°30'14", at headgates of canal.	52.6	--			b0	--	--	Seepage through headgates.
8	3	Pecos River	Lat 31°35'58", long 103°30'16", 1,000 feet downstream from Ward Co. WID No. 3 dam.	52.8	51	102			2,990	11,100	Channel has bed of gravel, with salt cedars along each bank.
9	3	Ward Co. Irr. Dist. No. 1 Canal	Lat 31°31'26", long 103°29'44", at headgates of canal.	61.0	--			a.3	--	--	Leakage through gates. There is a sandstone outcrop at channel dam.
11	3	Pecos River	Lat 31°26'11", long 103°28'00", 300 feet downstream from former stream-gaging station, Pecos River at Pecos.	71.8	50	77.6			3,180	11,200	Channel has bed of sand and gravel. Steep banks have heavy growth of salt cedars.
12	4	Toyah Creek	Lat 31°24'46", long 103°19'36", at mouth.	86.3	--			0	--	--	Streambed is sandy loam.
13	3	Sulphur Well (known locally as The River Well)	Lat 31°25'40", long 103°15'24", at abandoned oil well about 1,000 feet from river.	93.0	73		a.08		6,820	20,500	Flow follows a small draw leading to river. No surface flow into river.
15	4	Grandfalls-Big Valley Canal	Lat 31°25'21", long 103°15'21", at headgates of canal.	93.2	--			0	--	--	Channel has bed of sandy loam, with salt cedars along each bank.
16	4	Pecos River	Lat 31°25'02", long 103°15'28", about ½ mile downstream from Grandfalls-Big Valley diversion dam.	93.6	46	80.2			--	--	Channel has bed of silt, with salt cedars along each bank.
17	4	Pecos Co. WID No. 2 Canal (upper diversion)	Lat 31°21'54", long 103°06'06", at headgates of canal.	105.6	51			1.82	--	--	Channel has bed of sandy clay.
18	4	Pecos River	Lat 31°21'54", long 103°06'00", 800 feet downstream from Pecos Co. WID No. 2 (upper diversion) dam.	105.8	54	74.2			3,280	11,400	Channel has bed of sand and gravel, with grass and salt cedars on both low banks. High banks of sandy loam are covered with salt cedars.
19	4	Ward Co. WID No. 2 Canal	Lat 31°22'10", long 103°00'22", at headgates of canal.	111.5	--			0	--	--	Channel is covered with salt cedars.
21	4	Pecos River	Lat 31°18'20", long 102°52'30", at bridge on State Highway 18 near Grandfalls.	127.4	50	60.6			--	--	Right bank is steep with a few salt cedars. Left Bank is low with salt cedars. Two oil wells located in river, one upstream and one downstream from highway bridge.
22	4	Pecos River	Lat 31°17'10", long 102°44'30", about ½ mile downstream from former stream-gaging station, Pecos River below Grandfalls.	141.4	52	66.2			--	--	Channel has bed of sandy loam and gravel. Banks are covered with salt cedars.
23	5	Pecos River	Lat 31°18'50", long 102°39'20", 300 feet upstream from Farm Road 1053 bridge near Imperial.	150.2	50	68.5			--	--	Channel bed is sandy loam. Banks are low with very few trees. Salt cedars are dense on the flood plain.
24	5	Pecos River	Lat 31°16'00", long 102°35'50", at site of former stream-gaging station, Pecos River near Buenavista.	158.2	53	62.7			--	--	Channel has bed of sand and gravel, and has steep banks. Salt cedars cover each bank.
26	5	Pecos River	Lat 31°06'40", long 102°25'00", in flume at stream-gaging station, Pecos River near Girvin (regular gage).	188.4	53	66.2			c4,120	14,400	Channel has bed of sandy loam, with salt cedars along each bank. Concrete control on rock outcrop 60 feet below gage.

1 Downstream from Red Bluff Dam. a Estimated. b Less than 1 gpm. c Sample collected March 13.

Table 2.--Summary of water discharge measurements and chloride concentrations, Pecos River low-flow study, May 1965

Site No.	Date	Stream	Location	River mile[1]	Water temp. (°F)	Discharge in cfs			Chloride (ppm)	Specific conductance (micromhos at 25°c)	Remarks
						Main stream	Tributary	Diversion			
1	1965 May 10	Bank seepage	Lat 31°54'05", long 103°54'30", about 250 feet downstream from Red Bluff Dam.	0.05	--		0.06		6,050	--	Seepage along left river bank, which is composed of alluvium.
2	10	Pecos River	Lat 31°53'58", long 103°54'18", about 1,500 feet downstream from Red Bluff Dam.	.35	69	2.58			5,970	21,000	Channel has bed of small gravel, with salt cedars on both banks and short grass on right bank.
3	10	Salt (Screwbean) Draw	Lat 31°52'33", long 103°53'04", about 500 feet upstream from mouth.	2.9	78		0		--	--	Channel has bed of sand and gravel, with heavy growth of salt cedars along each bank.
4	10	Pecos River	Lat 31°48'14", long 103°48'26", 600 feet downstream from stream-gaging station, Pecos River near Orla.	14.3	81	.39			7,710	26,200	Channel has bed of gravel, with heavy growth of salt cedars in channel and along each bank. Sandstone outcrops at the gaging station.
5	10	Reeves Co. WID No. 2 Canal	Lat 31°37'57", long 103°34'30", 175 feet downstream from Headgates.	43.3	--			0	--	--	Channel is composed of gravel and silt and has heavy growth of salt cedars along each bank.
6	10	Pecos River	Lat 31°37'57", long 103°34'22", 800 feet downstream from Reeves Co. WID No. 2 channel dam.	43.4	--	0			--	--	Channel is composed of gravel and silt and has grass and salt cedars along each bank.
7	10	Ward Co. WID No. 3 Canal	Lat 31°36'03", long 103°30'14", at headgates of canal.	52.6	--			0	--	--	
8	10	Pecos River	Lat 31°35'58", long 103°30'16", 1,000 feet downstream from Ward Co. WID No. 3 dam.	52.8	--	0			--	--	Channel has bed of gravel, with salt cedars along each bank.
9	10	Ward Co. Irr. Dist. No. 1 Canal.	Lat 31°31'26", long 103°29'44", at headgates of canal.	61.0	--			0	--	--	There is a sandstone outcrop at channel dam.
10	10	Pecos River	Lat 31°31'27", long 103°29'44", at Ward Co. Irr. Dist. No. 1 Canal dam.	61.0	--	0			--	--	Channel is sandstone.
11	10	Pecos River	Lat 31°26'11", long 103°28'00", 300 feet downstream from former stream-gaging station, Pecos River at Pecos.	71.8	--	0			--	--	Channel has bed of sand and gravel. Steep banks have heavy growth of salt cedars.
12	11	Toyah Creek	Lat 31°24'46", long 103°19'30", at mouth.	86.3	--			0	--	--	Streambed is sandy loam.
13	11	Pecos River	Lat 31°24'46", long 103°19'30", 0.1 mile downstream from Toyah Creek.	86.4	68	3.18			7,020	23,700	Channel is sandy loam.
14	11	Sulphur Well (known locally as The River Well)	Lat 31°25'40", long 103°15'24", at abandoned oil well about 1,000 feet from river.	93.0	--			0	--	--	Flow follows a small draw leading to river. No surface flow into river.
15	11	Grandfalls-Big Valley Canal	Lat 31°25'21", long 103°15'21", at headgates of canal.	93.2	--			0	--	--	Channel has bed of sandy loam, with salt cedars along each bank.
16	11	Pecos River	Lat 31°25'02", long 103°15'28", about ½ mile downstream from Grandfalls-Big Valley diversion dam.	93.6	70	1.99			7,910	26 200	Channel has bed of silt, with salt cedars along each bank.
17	11	Pecos Co. WID No. 2 Canal (upper diversion)	Lat 31°21'51", long 103°06'06", at headgates of canal.	105.6	--			0	--	--	Channel has bed of sandy clay.
18	11	Pecos River	Lat 31°21'54", long 103°06'00", 800 feet downstream from Pecos Co. WID No. 2 (upper diversion) dam.	105.8	--			0	--	--	Channel has bed of sand and gravel, with grass and salt cedars on both low banks. High banks of sandy loam are covered with salt cedars.
19	11	Ward Co. WID No. 2 canal	Lat 31°22'10", long 103°00'22", at headgates of canal.	111.5	--			0	--	--	Channel is covered with salt cedars.
20	11	Pecos River	Lat 31°22'00", long 103°00'15", at bridge on Farm Road 1776 near Grandfalls.	114.3	74	.99			7,910	26,400	Channel is sandy loam.
21	11	Pecos River	Lat 31°18'20", long 102°52'30", at bridge on State Highway 18 near Grandfalls.	127.4	72	1.59			16,300	45,400	Right bank is steep with a few salt cedars. Left bank is low with salt cedars. Two oil wells located in river, one upstream and one downstream from highway bridge.
22	11	Pecos River	Lat 31°17'10", long 102°44'30", about ½ mile downstream from former stream-gaging station, Pecos River below Grandfalls.	141.4	74	4.90			7,220	24,100	Channel has bed of sandy loam and gravel. Banks are covered with salt cedars.
23	11	Pecos River	Lat 31°18'50", long 102°39'20", 300 feet upstream from Farm Road 1053 bridge near Imperial.	150.2	72	5.44			8,680	25,000	Channel bed is sandy loam. Banks are low with very few trees. Salt cedars are dense on the flood plain.
24	11	Pecos River	Lat 31°16'00", long 102°35'50", at site of former stream-gaging station, Pecos River near Buenavista.	158.2	74	5.75			8,490	28,200	Channel has bed of sand and gravel, and has steep banks. Salt cedars cover each bank.
25	12	Pecos River	Lat 31°12'20", long 102°27'35", at Horsehead Crossing near Girvin.	173.2	69	11.2			8,290	27,100	Channel is sandy loam.
26	12	Pecos River	Lat 31°06'40", long 102°25'00", in flume at stream-gaging station, Pecos River near Girvin (regular gage).	188.4	74	11.5			8,290	27,600	Channel has bed of sandy loam, with salt cedars along each bank. Concrete control on rock outcrop 60 feet below gage.

1 Downstream from Red Bluff Dam.

Table 3.--Summary of chemical analyses of water from selected sites, Pecos River watershed below Red Bluff Reservoir, March 3-5, 1964, and May 10-12, 1965

[Analytical results in parts per million except as indicated]

Site No.	Date	Discharge (cfs)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids (calculated)			Hardness as $CaCO_3$		Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Density
											Parts per million	Tons per acre-foot	Tons per day	Calcium, Magnesium	Noncarbonate				
Water-Delivery Study, March 3-5, 1964																			
	March																		
2	3	129	2.5	565	212	1,830	56	114	2,030	a2,950	b7,700	10.5	2,680	2,280	2,190	17	10,900	7.6	--
3	3	.17	--	--	--	--		168	--	6,430	--	--	--	4,150	4,010	--	20,100	7.8	1.011
4	3	124	--	--	--	--		112	--	2,990	--	--	--	2,310	2,220	--	11,000	7.6	1.004
6	3	110	--	--	--	--		105	--	2,980	--	--	--	2,350	2,260	--	11,100	7.6	1.006
8	3	102	--	--	--	--		106	--	2,990	--	--	--	2,350	2,260	--	11,100	7.6	1.005
11	3	77.6	--	--	--	--		104	--	3,180	--	--	--	2,470	2,380	--	11,200	7.5	1.005
12	4	--	--	--	--	--		107	--	3,180	--	--	--	2,430	2,340	--	11,300	7.6	1.006
14	5	.08	--	--	--	--		87	--	6,820	--	--	--	4,250	4,180	--	20,500	6.9	1.011
16	4	80.2	--	--	--	--		109	--	3,080	--	--	--	2,430	2,340	--	11,400	7.6	1.005
18	4	74.2	.3	606	223	2,080		103	2,160	c3,280	8,400	11.5	1,680	2,430	2,340	18	11,400	7.4	1.006
Low-Flow Study, May 10-12, 1965																			
	May																		
2	10	2.58	--	--	--	--		--	--	5,970	--	--	--	--	--	--	21,000	--	1.009
4	10	.39	--	--	--	--		--	--	7,710	--	--	--	--	--	--	26,200	--	1.010
13	11	3.18	14	801	435	4,510		171	3,480	7,020	16,400	22.5	141	3,860	3,720	--	23,700	7.2	1.011
16	11	1.99	--	--	--	--		--	--	7,910	--	--	--	--	--	--	26,200	--	1.012
20	11	.99	--	--	--	--		--	--	7,910	--	--	--	--	--	--	26,400	--	1.012
21	11	1.59	15	1,030	744	9,620		250	3,210	16,300	31,000	43.1	133	5,630	5,420	--	45,400	7.3	1.022
22	11	4.90	3.7	890	542	4,300		119	3,420	7,220	d16,400	22.5	217	4,450	4,400	--	24,100	6.9	1.011
23	11	5.44	--	--	--	--		--	--	8,680	--	--	--	--	--	--	25,000	--	1.014
24	11	5.75	1.4	948	648	5,160		116	4,010	8,490	19,300	26.6	300	5,030	4,940	--	28,200	7.4	1.013
25	12	11.2	1.2	928	684	5,070		172	4,140	8,290	19,200	26.5	581	5,130	4,990	--	27,100	7.4	1.013
26	12	11.5	--	--	--	--		--	--	8,290	--	--	--	--	--	--	27,600	--	1.013

a Includes 1.4 ppm bromide (Br) and 0.7 ppm iodide (I).
b Includes 0.6 ppm boron (B).
c Includes 1.5 ppm bromide (Br) and 0.7 ppm iodide (I).
d Includes 1.0 ppm nitrate (NO_4).

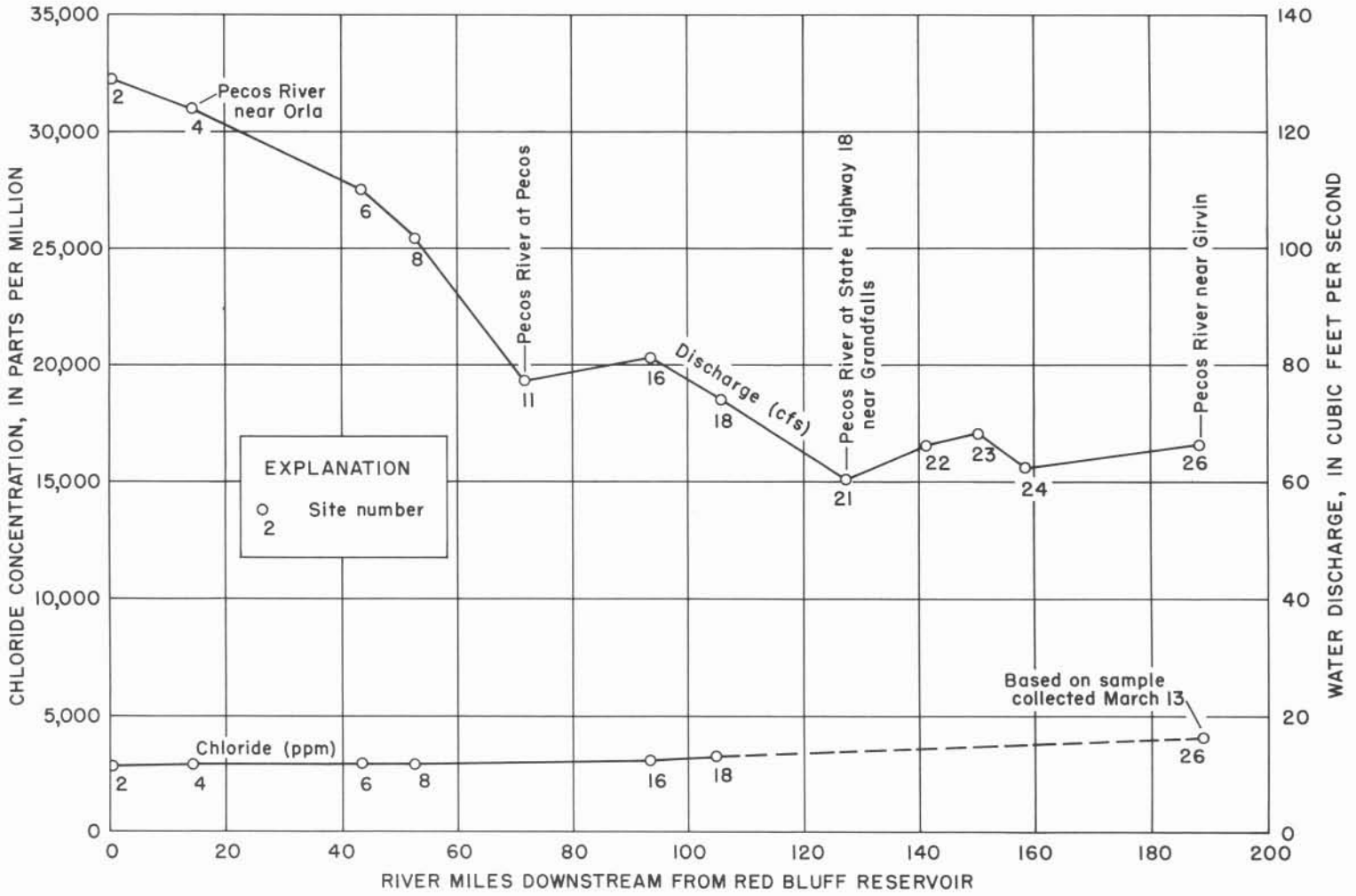

Figure 3

Chloride Concentration and Water Discharge, Pecos River, March 3-5, 1964

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District

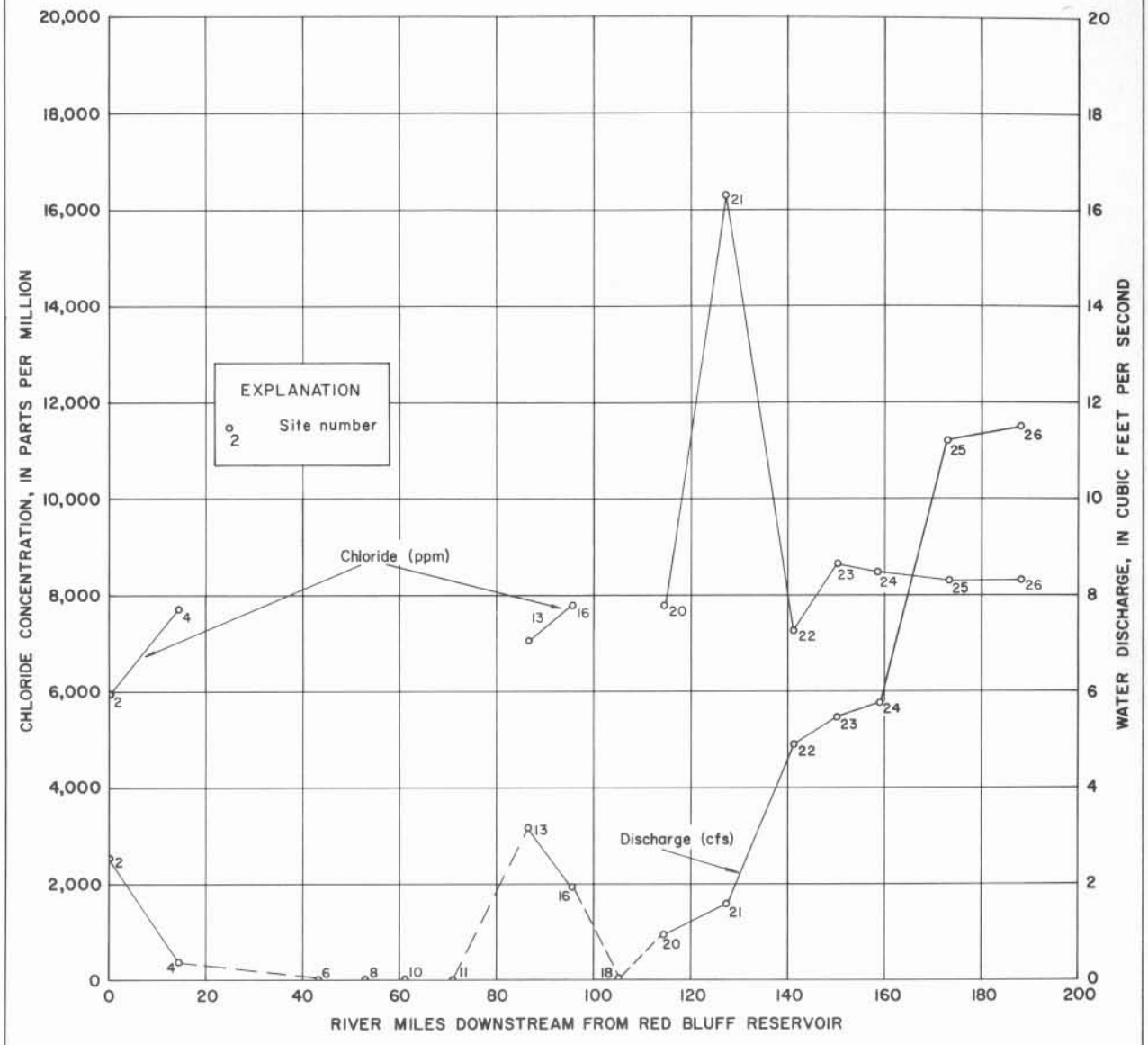

Figure 4

Chloride Concentration and Water Discharge,

Pecos River, May 10-12, 1965

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District

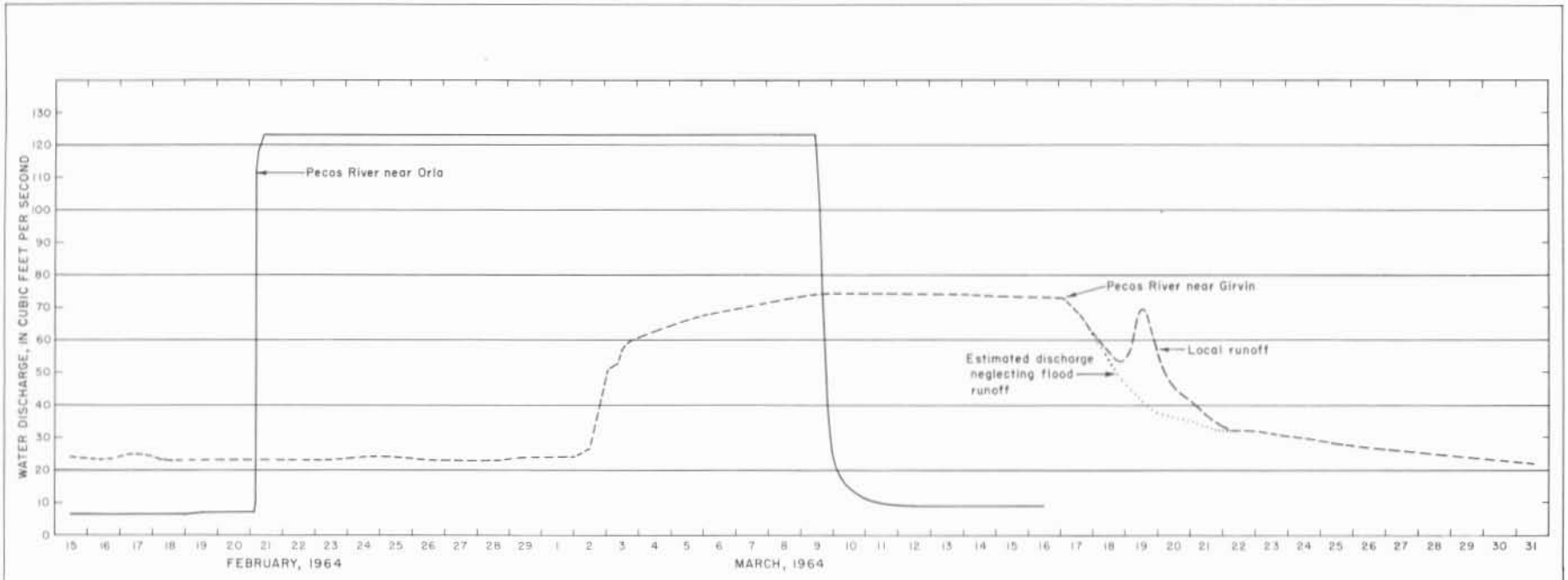

Figure 5

Hydrograph of Flow, Pecos River Near Orla and Pecos River Near Girvin, February 15 to March 31, 1964

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District

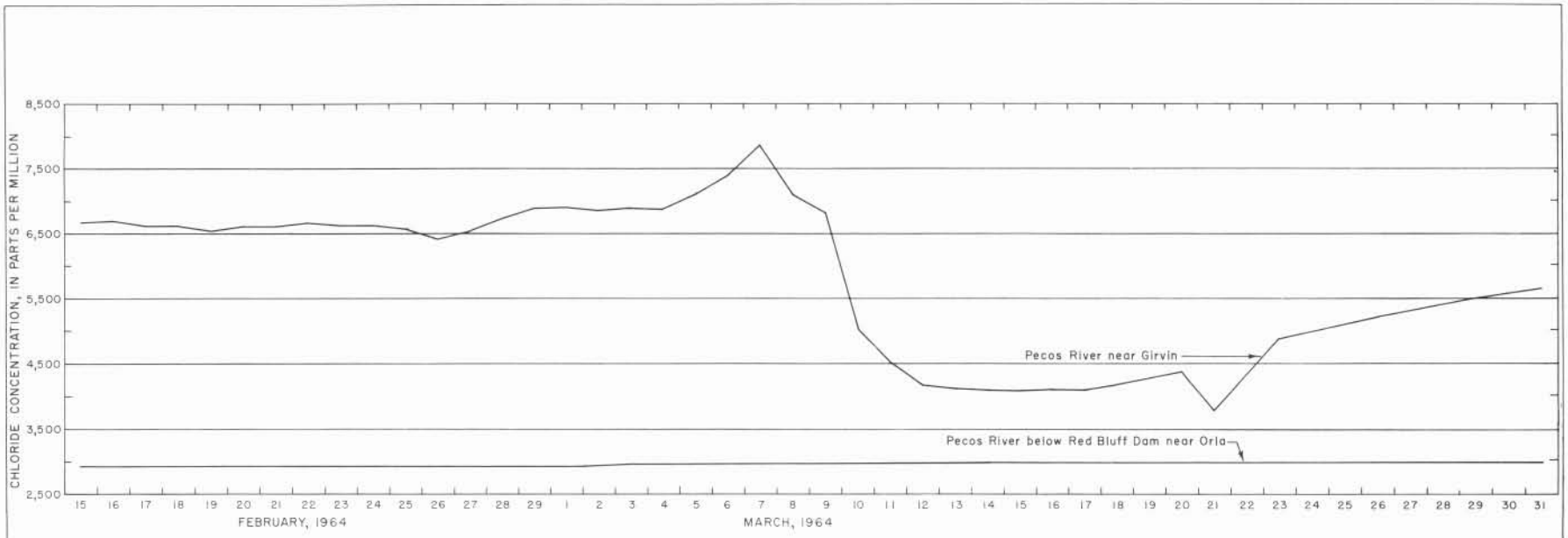

Figure 6

Daily Chloride Concentrations, Pecos River Below Red Bluff Dam Near Orla and Pecos River Near Girvin, February 15 to March 31, 1964

U.S. Geological Survey in cooperation with the Texas Water Development Board and the Red Bluff Water Power Control District