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THE CANADIAN RIVER MUNICIPAL WATER AUTHORITY PROJECT

IN WEST TEXAS: A GEOGRAPHIC ANALYSIS

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This dissertation is dedicated to my wife, Helen; sons, Robert, David and Tom; and daughters, Kathleen and Karen.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF ILLUSTRATIONS

Figure		Page

Plate

Plate | Page

THE CANADIAN RIVER MUNICIPAL WATER AUTHORITY PROJECT IN WEST TEXAS: A GEOGRAPHIC ANALYSIS

CHAPTER I

INTRODUCTION

General Introduction to the Study

The recent implementation of the Canadian River Project of Texas is an attempt by citizens of the Texas Panhandle to modify the natural environment of selected cities by the diversion of water from the (South) Canadian River (Figure 1).[1] This study is an investigation of the Canadian River Project, the Canadian River Municipal Water Authority, and selected water management alternatives within the jurisdictional area of the Authority.

Ideally, geography can provide a "realistic analysis of the conditions of particular places and so aid in the clarification of the issues involved in all kinds of policy decisions."[2] Within the realm of policy decision, Gilbert F.

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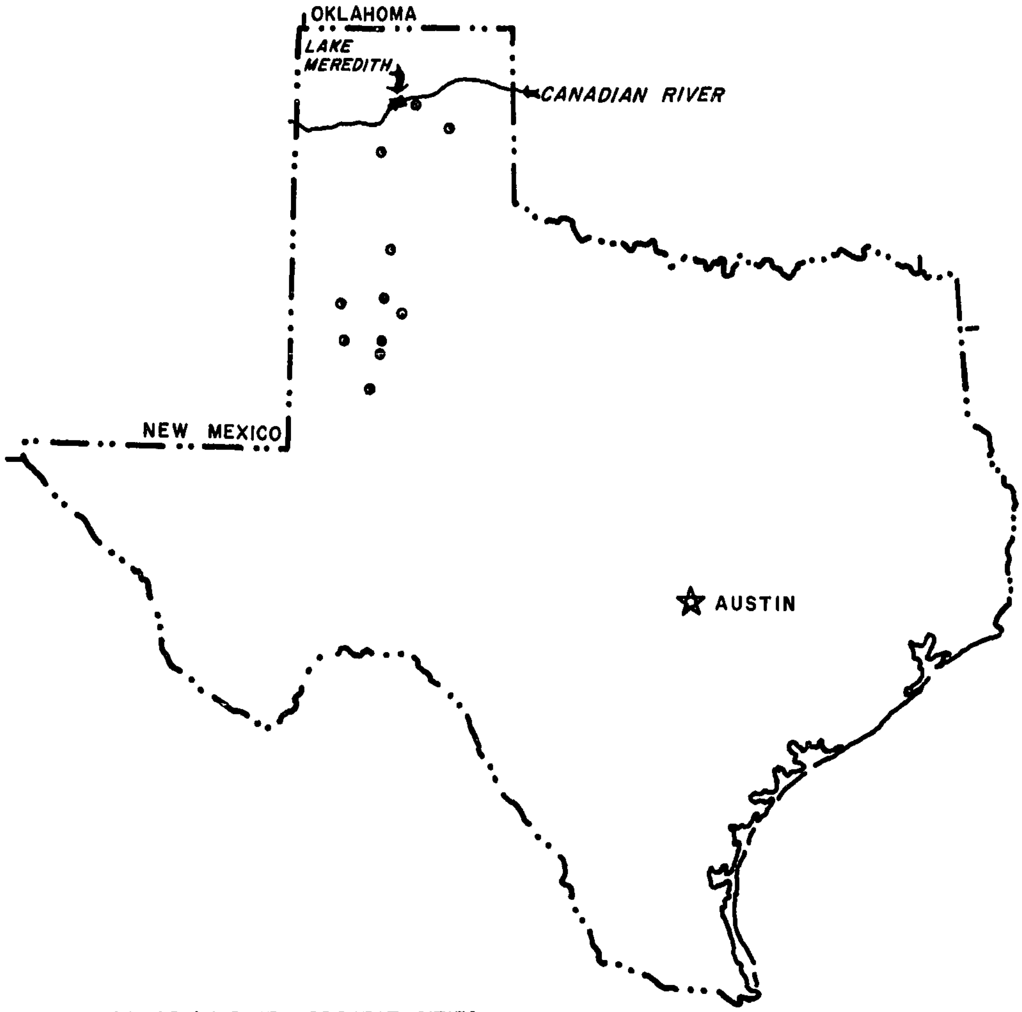
[1]The (South) Canadian River is commonly referred to as the Canadian River and is thus noted throughout this study.

[2]Preston E. James, "Geography," Encyclopaedia Britannica, 1959, X, 139.

LOCATION OF THE CANADIAN RIVER PROJECT, TEXAS



⊙ CANADIAN RIVER PROJECT CITIES

AFTER U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION MAP 662-525-1435

Fig. I

White writes that the major problem is the ". . . broadening gap between the level of scientific and technological knowledge and its sensitive application in daily management."[3] Geography, among other disciplines, should be able to contribute substantially to defining and evolving possible solutions to the problems confronting the policy decision makers and so, in some small way, help narrow the technological-application gap. In doing so, the geographer should be particularly well equipped to address himself to the question of what effect certain decisions will have on the natural environment and public welfare.[4] It is hoped that the present study makes at least a modest contribution toward the better understanding of an important regional problem.

There is a growing national awareness in the United States of the fundamental importance of water and of the need for its proper management. The mounting concern over water here and elsewhere reflects a serious worldwide shortage in the midst of plenty. Although water covers nearly three-fourths of the earth, the small usable fraction of the total supply which is fresh cannot always be found where it is needed, when it is desired, or in the amounts that are required. Compounding the problems created by the unequal distribution of fresh water on and under the land surface is the

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[3]Gilbert F. White, Strategies of American Water Management, (Ann Arbor: University of Michigan Press, 1969), p. 9.

[4]*Ibid.*, p. 14.

lack of approximate coincidence with population distribution and the general lack of adequate planning to assure a permanent supply for agricultural, municipal, and industrial users. According to Michel Batisse, the engineer heading the International Hydrological Decade, "for the first time, and forever, modern civilization will become water conscious."[5]

Some may feel that modern man's consciousness of the world's water problems may have arrived a little late. John Lear, Science Editor of the Saturday Review, in writing about the water supply problems of the past decade, has written pessimistically that

> . . . only a small fraction of the rain that falls in the United States (seven per cent) is managed with any degree of precision, and that management is done with a level of imagination that was already slanting downhill thousands of years ago.[6]

For many years there have been recurring water shortages in various parts of the United States. Very recently, five consecutive years of drought in the normally humid northeastern seaboard states brought severe adjustment problems and the urgent need for water rationing. Southern California has a perennial problem of water sufficiency for its ever-increasing economic pursuits. The Southern High Plains region between 1950 and 1956 experienced its most

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[5] "Hydrology, A Question of Birthright," Time, October 1, 1965, p. 70.

[6] John Lear, "The Crisis in Water--What Brought It On?" Saturday Review, October 23, 1965, p. 24.

severe drought on record. Many communities of the Southern High Plains suffered critical water supply shortages as the area experienced anew "dust bowl" conditions reminiscent of the early and mid-1930's. Drought is not new to the Great Plains, and it has not infrequently altered the destinies of those who have chosen to settle in the area. Fortunately, one of the world's most productive and extensive aquifers, the Ogallala formation, underlies a considerable portion of the western Great Plains of the United States (Figure 2).

Since the beginning of permanent American settlement on the Southern High Plains of Texas (Figure 3), the regional economy has been dependent upon the exploitation of the ground water resources present beneath the surface. In recent years, the availability of this supply of subsurface water has tended to offset the crucial problems that would otherwise arise from severe and extended drought.

At the present rate of pumping, between three and one-half and five million acre-feet[7] annually, it has been estimated that "the economic life of [the] water resources ranges from five to more than fifty years in individual resource use situations."[8] The bulk of present ground water use and consumption is directed toward meeting the immense

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[7]The volume of water that would cover one acre to a depth of one foot, or 325,851 gallons.

[8]William F. Hughes and Wyatte L. Harman, Projected Economic Life of Water Resources, Subdivision Number 1, High Plains Underground Water Reservoir (College Station: Texas A&M University), p. 5.

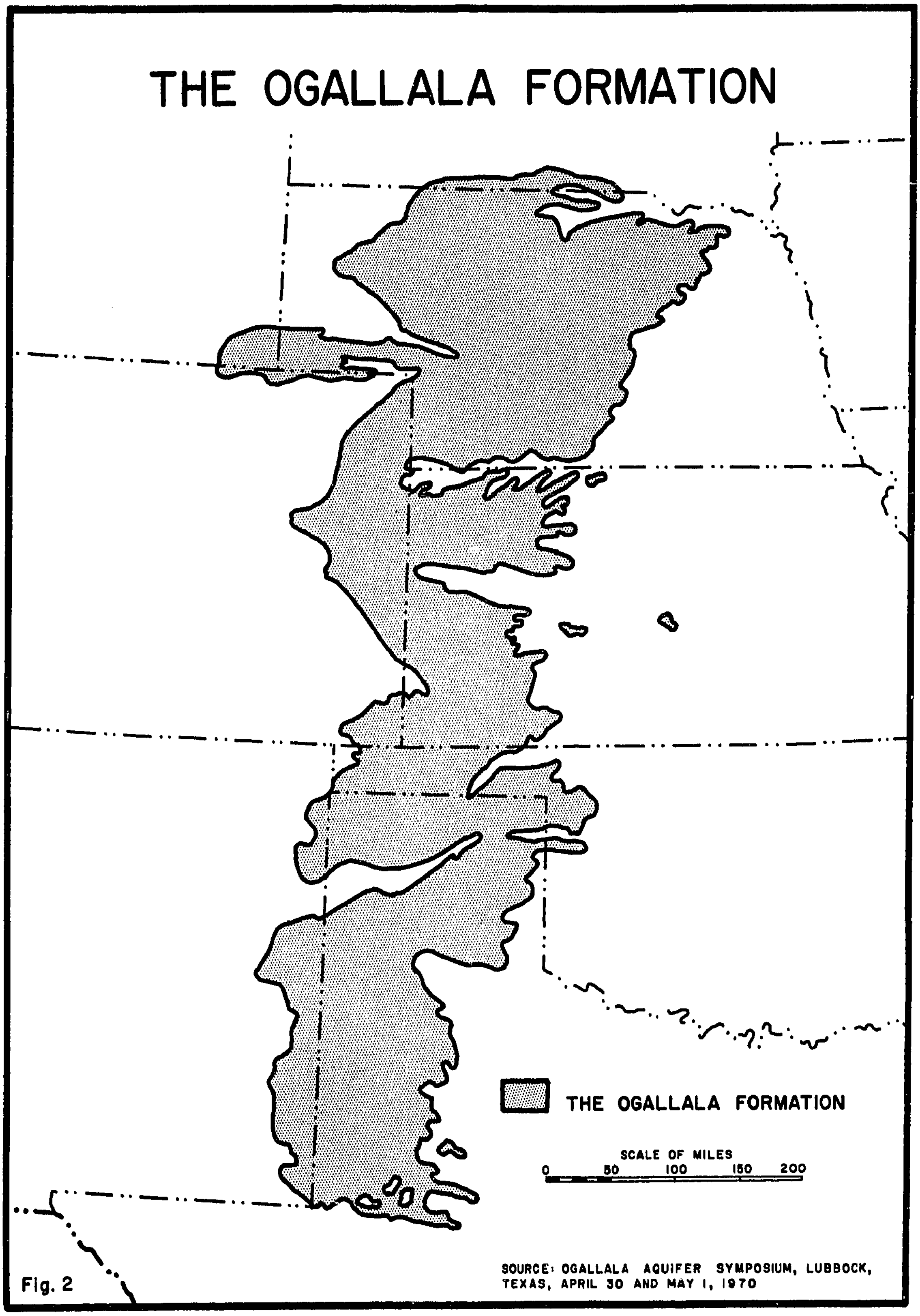
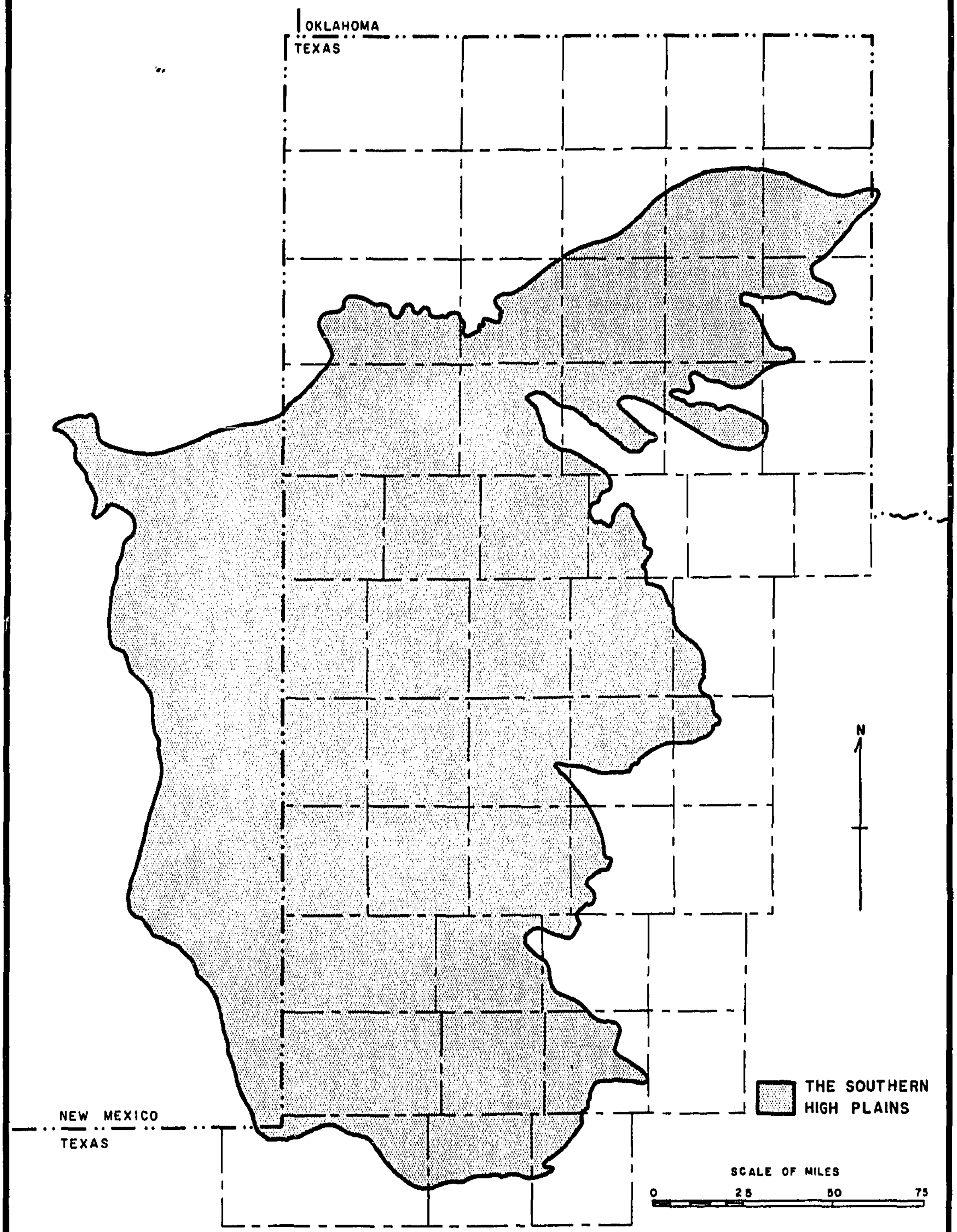

THE OGALLALA FORMATION
THE OGALLALA FORMATION
SCALE OF MILES
0 50 100 150 200
SOURCE: OGALLALA AQUIFER SYMPOSIUM, LUBBOCK, TEXAS, APRIL 30 AND MAY 1, 1970

Fig. 2

THE SOUTHERN HIGH PLAINS



SOURCE: TEXAS BOARD OF WATER ENGINEERS, BULLETIN 6107

Fig. 3

demands of one of the world's most prosperous agricultural communities. Since the rate of ground water renewal is minimal in relation to the rate of pumping, it appears that there is an imminent and evidently inescapable crisis in the future of irrigation agriculture in this region. The seriousness of the approaching crisis is dependent upon the ability of the area to secure "reasonable" supplemental supplies of water[9] and to make extensive adjustments in the cropping systems developed over the past thirty years.

It has been the feeling of many concerned citizens of west Texas that if the urban settlements of the Llano Estacado[10] are to continue to prosper during the anticipated period of agricultural adjustment, supplemental water supplies independent of underground sources must be developed. It is possible that with the establishment of a dependable municipal water supply, industrial and commercial ventures will be attracted to the area which will substantially compensate for the reduced agricultural return. The development of a supplemental surface supply could conceivably even sustain a significant amount of irrigation agriculture.

Historically, community settlement of the Texas Panhandle is a relatively recent development. Substantial

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[9]The proposed Texas Water Plan provides for substantial importation of water from the Mississippi River onto the Southern High Plains of Texas.

[10]Llano Estacado is Spanish for "staked plain." The terms "Llano Estacado" and "Southern High Plains" are used interchangeably in this study.

nucleated settlement did not begin until federal authority had been re-established in the area after the Civil War.[11] With the elimination of effective Indian resistance, county boundaries were designated in 1876, and individual counties were eligible for official organization when their population reached 150 qualified voters.[12] It was to be another twenty to twenty-five years before most of them qualified for organization. The demographic survey of 1880 showed that the ten counties in which the Canadian River Project cities are located (Figure 4) had a total population of 192 persons in an area of about 9,000 square miles.[13] At that time there were still no organized town settlements. The census of 1890 indicated that Amarillo was the first organized community with a population in that year of 482.[14] Urban growth in the Texas Panhandle began slowly, but once begun has been almost continuous and at times and places quite phenomenal. Various stimuli have resulted in marked periods of population growth. Paramount among these stimuli have been the development and improvement of means to utilize the ground water resource of the area for large scale irrigation, and the discovery of

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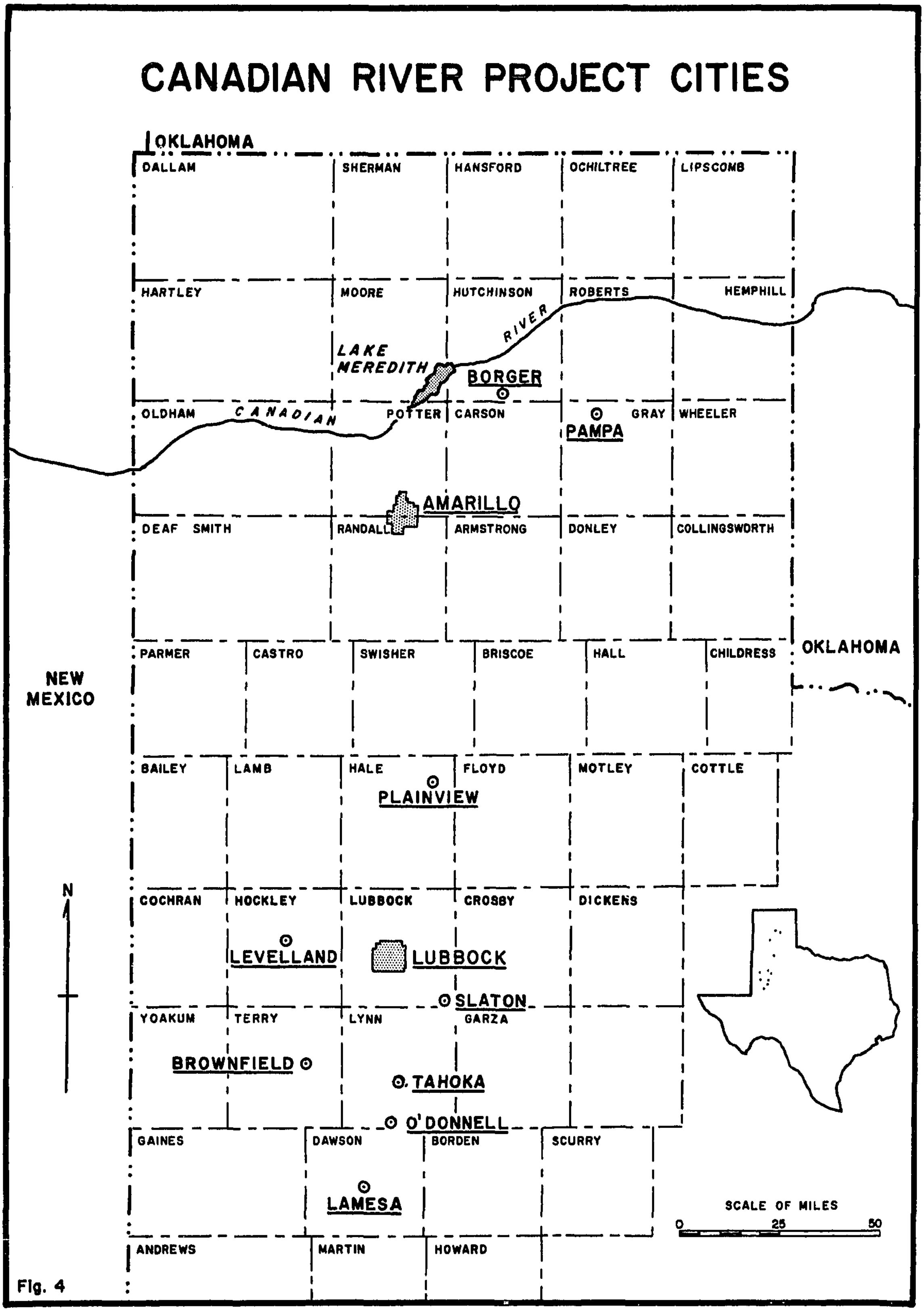
[11] J. Evetts Haley, The XIT Ranch of Texas and the Early Days of the Llano Estacado (Norman: University of Oklahoma Press, 1967), pp. 38-39.

[12] Seymore V. Connor, "The Founding of Lubbock," in A History of Lubbock, ed. by Lawrence L. Graves (Minneapolis: The Lund Press, Inc., 1962), pp. 69-70.

[13] U.S. Congress, House, Canadian River Project in Texas, H.D. 678, 81st Cong., 2d sess., 1950, p. 42.

[14] Ibid., p. 43.


CANADIAN RIVER PROJECT CITIES
OKLAHOMA
DALLAM
SHERMAN
HANSFORD
OCHILTREE
LIPSCOMB
HARTLEY
MOORE
HUTCHINSON
ROBERTS
HEMPHILL
RIVER
LAKE MEREDITH
BORGER
OLDHAM
CANADIAN
POTTER
CARSON
GRAY
WHEELER
PAMPA
AMARILLO
DEAF SMITH
RANDALL
ARMSTRONG
DONLEY
COLLINGSWORTH
PARMER
CASTRO
SWISHER
BRISCOE
HALL
CHILDRESS
OKLAHOMA
NEW MEXICO
BAILEY
LAMB
HALE
FLOYD
MOTLEY
COTTLE
PLAINVIEW
N
COCHRAN
HOCKLEY
LUBBOCK
CROSBY
DICKENS
LEVELLAND
LUBBOCK
SLATON
YOAKUM
TERRY
LYNN
GARZA
BROWNFIELD
TAHOKA
O'DONNELL
GAINES
DAWSON
BORDEN
SCURRY
LAMESA
SCALE OF MILES
0
25
50
ANDREWS
MARTIN
HOWARD
Fig. 4

major gas and oil deposits.

Irrigation first became significant in the decade from 1910 to 1920, supporting the gradual conversion of sizable areas from extensive cattle production to intensive crop production. Periodic years of drought tended to accelerate the development of irrigation facilities. The continued subdivision of the large cattle estates into farm units of much smaller dimensions provided for a steady increase in the local population. A substantial percentage of the present landowners and tenants engaged in irrigation farming on the Southern High Plains of Texas are "sidewalk" farmers who live in town, and so add to the overall concentration of population in the cities of the area.

During the decade between 1920 and 1930 there was extensive development of gas and oil deposits in western Texas. During this period the major settlements of the Canadian River Project area experienced population increases to from four to ten times the 1920 level. Borger is perhaps most representative of the oil boom towns of the decade. Borger, whose 1970 population was 13,928, was founded in 1926 and grew to more than 6,000 in less than a year. At one time during the year 1926 there were reported to be more than 50,000 persons living within the city townsite. Pampa, a small railroad town, grew from about 1,000 to slightly over 10,000 during the oil boom of the middle 1920's.[15]

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[15] Ibid., p. 43.

In a period of eighty years, from 1880 to 1960, the ten-county area of the project site grew in population from 192 persons to 478,241, in a setting that is climatically less than favorable for agriculture. In the eleven communities now participating in the Canadian River Municipal Water Authority, the population increased from 228,000 in 1950 to 375,000 in 1960. This was a decennial increase of about sixty-four per cent. As the population grew, there was obviously an increase in the total municipal and industrial water use. Although a moderate per capita increase is probably to be expected, there is reason for some concern over the disproportionate increase of water use to population growth. In 1950, 228,000 people used slightly over twenty billion gallons of water. During the decade 1950-1960, when the population increased sixty-four per cent, municipal and industrial water use increased a little over one hundred per cent.[16] The per capita use of water has evidently continued to rise during the 1960's, although preliminary data compiled unofficially from the 1970 census indicate major population adjustments downward for several of the cities, with the regional total showing little change.

Statement of Problem

This study is primarily an investigation of surface water resource development within the jurisdictional area of

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[16] John C. Thompson, "Water Resource Development," Amarillo, Texas, 1965, p. 11. (Typewritten.)

the Canadian River Municipal Water Authority in Texas. It is necessary, however, to review briefly the expansion of ground water use in the area in order to provide an understanding of the sequential pattern of water resource development that led to the implementation of the Canadian River Project. In addition to a detailed examination of the Canadian River Project, a survey of some of the future alternatives is presented.

Proceeding with the basic assumption that there is within the contributing watershed of the eleven participating cities of the Canadian River Municipal Water Authority of Texas a limited and definitive supply of water available on a sustained basis, the problem of this study is four-fold: (1) to describe the development and present status of water resource management within the area affected by the Canadian River Project, (2) to present some of the alternatives available for meeting future water requirements of the project area, (3) to present and discuss selected results of a water awareness questionnaire, and (4) to submit conclusions and recommendations for improved water resource management.

Need for the Study

Although many different scholarly studies have been conducted on water resource developments, there are none that specifically deal with the combined scope of this paper. In several respects the Canadian River Municipal Water Authority is unique. As the first project authorized for construction under the direction of the Bureau of Reclamation primarily for furnishing municipal and industrial water, it has set several precedents and provided a model for further development of municipal and industrial water supply in the semi-arid portions of the United States.[17]

Procedures Used in the Investigation

In order to accomplish the stated intent of this investigation, it has been necessary to consult a large body of descriptive and statistical literature, and to conduct extended field research in the communities directly concerned with the Canadian River Project. The bulk of the library research took place at Texas Technological University, Lubbock, Texas; West Texas State University, Canyon, Texas; and the University of Oklahoma, Norman, Oklahoma. Moderate use has been made of local libraries, newspaper files, and official city records of the urban communities which are participating members of the Canadian River Municipal Water Authority.

Collection and organization of relevant literature began in the fall of 1965 while the writer was an instructor in geography at West Texas State University, Canyon, Texas. Informal field work began at the same time. During the 1965-1966 academic year the writer travelled extensively throughout the High Plains of Texas collecting data and conducting interviews. Since that time, further field research has been done during November and December, 1969, and during the

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[17]Personal interview with John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas, March 30, 1970.

period of March through November, 1970. In the course of his research the writer spent many weeks in libraries, attended water resource conferences, devised and distributed questionnaires, and interviewed numerous city, county, and state administrators, employees of the Federal Bureau of Reclamation, water management officials and technicians, and various officials concerned with conservation. Analysis, evaluation, and organization of the material presented in this study took place mainly during the summer and fall of 1970.

CHAPTER II

LOCATION AND PHYSICAL SETTING

Location

This study deals primarily with the development of surface water resources for eleven Texas communities: Amarillo, Borger, Brownfield, Lamesa, Levelland, Lubbock, O'Donnell, Pampa, Plainview, Slaton, and Tahoka. These cities are located on the Llano Estacado in the Panhandle counties of Dawson, Gray, Hale, Hockley, Hutchinson, Lubbock, Lynn, Potter, Randall, and Terry (Figure 4). These counties are used for statistical convenience as well as a general frame of reference.

For purposes of this study, it is necessary to define the limits of the Llano Estacado. The Llano Estacado, or Staked Plains, as a physiographic unit, extends from the Canadian River in the north to an indefinite common boundary with the Edwards Plateau in the south. In the west, this section of the High Plains terminates at the Mescalero Escarpment overlooking the Pecos River Valley in New Mexico. The very irregular caprock escarpment marks the eastern boundary of the Southern High Plains of Texas. As defined, the Llano Estacado extends about 270 miles north-to-south and averages approximately 150 miles wide (Figure 5).

Physical Environment

Climate of the Llano Estacado

The Southern High Plains of Texas lie astride the transition zone between the humid subtropical (Köppen's Cfa) climate to the east and southeast and the semi-arid, mid-latitude steppelands (Köppen's BSk region) to the west. The area has a climate characterized by hot summers, usually moderate winters but with occasional sudden temperature changes, relatively high wind throughout the year, and erratic patterns of precipitation distribution both temporally and areally.

While extended periods of subfreezing temperatures are rare, the Llano Estacado does experience rather low temperatures for short periods of time nearly every winter. Average daily minimum temperatures for January at Amarillo and Lubbock[1] are 20.8°F and 25.4°F, respectively (Tables 1 and 2). Record minimum temperatures are -16°F for Amarillo and -17°F for Lubbock.[2] Characteristic of the fall, winter, and early spring seasons are the precipitous drops in

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[1] Amarillo and Lubbock are frequently used as representative of the north and south portions of the Canadian River Municipal Water Authority. Climatically, the obvious advantage is the completeness and availability of weather records.

[2] The record minimum of -17°F for Lubbock, as with several other record temperatures, is not included with the data presented in Tables 1 and 2 because these records occurred at times other than during the periods used to calculate the standard norms.

PHYSIOGRAPHY OF THE LLANO ESTACADO

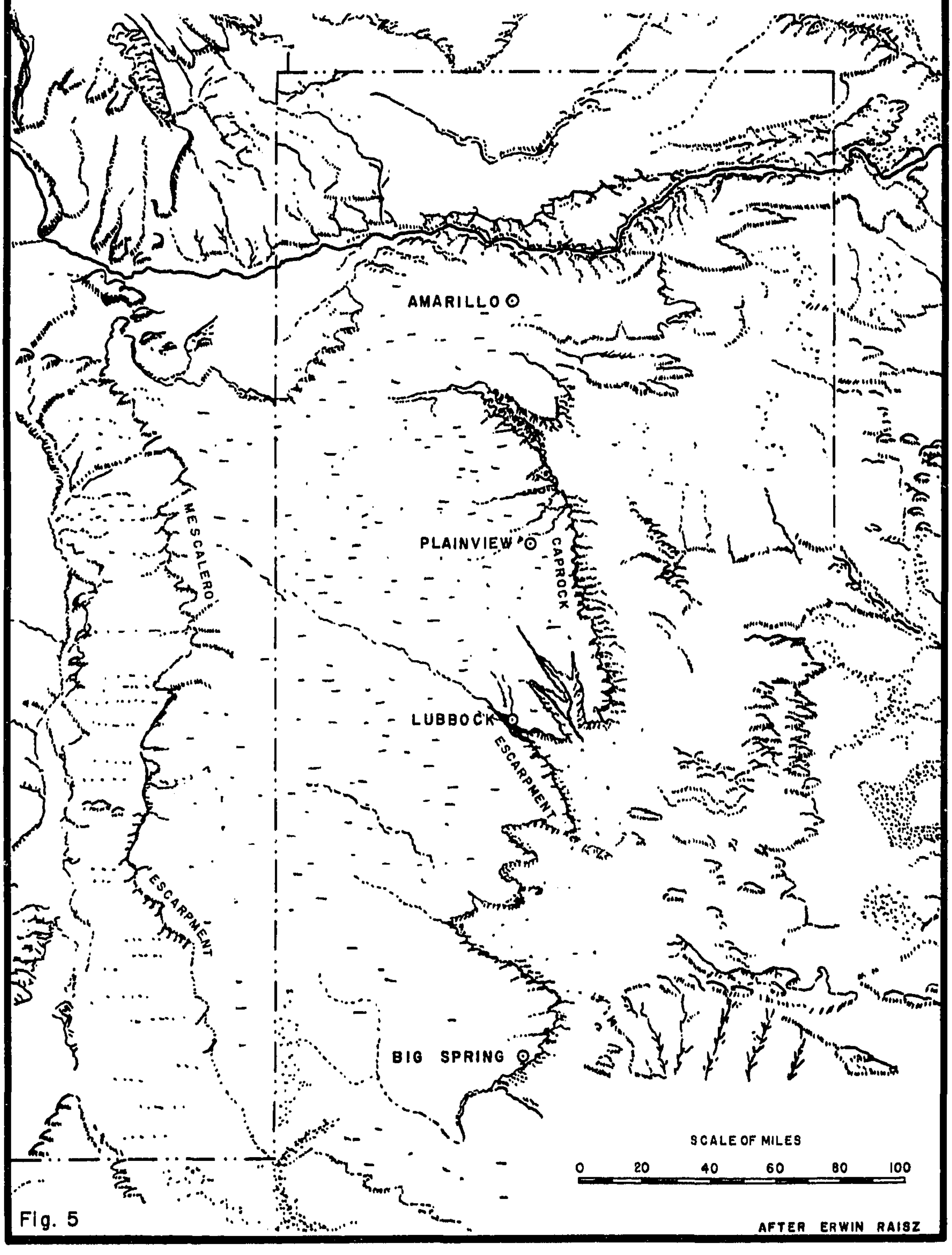

Fig. 5

AFTER ERWIN RAISZ

TABLE 1

SUMMARY OF CLIMATIC DATA FOR AMARILLO, TEXAS
1892-1968

MONTH	TEMPERATURE							PRECIPITATION			WIND	
	MEANS			EXTREMES				MEAN	EXTREMES			
	Daily Max	Daily Min	Monthly	Record High	Year	Record Low	Year	Monthly	Max Year 1923	Min Year 1956	Mean Hourly Velocity	Prevailing Direction
Jan.	45.5	20.8	33.1	83	1927	-11	1912	0.51	0.00	0.09	13.2	SW
Feb.	48.9	23.3	36.1	88	1963	-16	1899	0.51	1.71	1.10	14.3	SW
Mar.	59.0	31.6	45.3	96	1907	- 3	1948	0.71	2.97	0.03	15.5	SW
Apr.	67.3	40.4	53.8	98	1965	13	1920	1.83	3.22	0.23	15.4	SW
May	74.6	49.6	62.1	100	1925	26	1907	2.76	1.70	1.99	14.8	S
June	83.8	58.9	71.4	108	1963	38	1917	2.84	9.76	2.03	14.4	S
July	87.8	64.0	75.9	106	1940	51	1905	2.84	1.85	2.82	12.4	S
Aug.	86.6	62.6	74.6	106	1944	48	1915	3.08	1.54	0.79	11.9	S
Sep.	80.0	55.5	67.8	102	1947	32	1926	2.30	6.42	0.48	13.1	S
Oct.	68.2	43.3	55.8	95	1934	15	1917	1.66	7.34	0.38	12.9	SW
Nov.	56.3	31.2	43.8	86	1934	4	1906	0.92	2.13	T	13.1	SW
Dec.	47.1	23.9	35.5	83	1939	- 6	1924	0.80	1.11	T	13.0	SW
Year	67.1	42.1	54.6					20.99	39.75	9.94	13.7	SW

Source: U.S. Department of Commerce, Weather Bureau, Local Climatological Summary with Comparative Data, 1960, Amarillo, Texas (Washington, D.C.: Government Printing Office, 1951) and U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Local Climatological Data, Annual Summary with Comparative Data, 1968, Amarillo, Texas (Washington, D.C.: Government Printing Office, 1969).

TABLE 2

SUMMARY OF CLIMATIC DATA FOR LUBBOCK, TEXAS
(Climatological Standard Normals, 1931-1960)

MONTH	TEMPERATURE							PRECIPITATION			WIND	
	MEANS			EXTREMES				MEAN	EXTREMES			
	Daily Max	Daily Min	Monthly	Record High	Year	Record Low	Year	Monthly	Max Year 1941	Min Year 1934	Mean Hourly Velocity	Prevailing Direction
Jan.	53.0	25.4	39.2	82	1969	-16	1963	0.68	0.55	0.06	13.1	SW
Feb.	57.3	28.8	43.1	86	1962	- 8	1960	0.57	0.61	0.06	14.6	SW
Mar.	64.9	43.3	49.6	90	1963	2	1948	0.73	3.56	1.98	16.0	SW
Apr.	74.5	44.4	59.5	96	1959	22	1948	1.15	2.23	1.08	15.9	SW
May	82.1	54.3	68.2	104	1947	30	1967	3.18	12.69	1.26	15.1	S
June	91.4	63.6	77.5	107	1957	44	1947	2.53	4.13	0.28	14.9	S
July	92.4	66.5	79.5	107	1958	51	1952	2.01	3.68	0.65	12.0	S
Aug.	91.7	65.8	78.8	106	1966	52	1956	1.68	1.85	1.66	10.6	S
Sep.	84.4	58.4	71.4	103	1948	38	1963	2.36	4.47	1.86	11.2	S
Oct.	74.8	47.5	61.2	93	1965	25	1949	2.00	5.89	0.28	11.9	S
Nov.	62.4	33.3	47.9	86	1965	- 1	1957	0.54	0.17	0.55	12.4	WSW
Dec.	54.7	27.3	41.0	81	1958	1	1950	0.65	0.72	T	12.8	WSW
Year	73.6	45.8	59.7					18.08	40.55	9.72	13.4	S

Source: U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Local Climatological Data Annual Summary with Comparative Data, 1969, Lubbock, Texas (Washington, D.C.: Government Printing Office, 1970).

temperature that accompany the arrival of the continental polar (cPc) airmasses which periodically enter the region. It is not uncommon for the temperature to drop "from 50 to 60 degrees within a twelve-hour period . . . in association with these fronts, and 40 degree drops have occurred within a few minutes."[3] These cold fronts frequently pass through the Texas Panhandle at velocities of up to forty miles per hour. It is necessary to understand that while these extremely disagreeable conditions are not rare, they are not representative of the winter months. The average daily maximum temperatures for January in Amarillo[4] and Lubbock[5] are 45.5°F and 53.0°F, respectively, and the monthly average temperatures of 33.1°F and 39.2°F at the two cities are also above freezing. Winter is a low water season in the Canadian River above Lake Meredith, but the flow is never halted by freezing for any substantial period of time.

Residents of the Southern High Plains of Texas occasionally experience relatively cool summers, but more often than not, the temperatures become uncomfortably warm during

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[3]U.S., Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Local Climatological Data, Annual Summary with Comparative Data, 1968, Amarillo, Texas (Washington, D.C.: Government Printing Office, 1969), p. 1.

[4]Ibid., p. 2.

[5]U.S., Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Local Climatological Data, Annual Summary with Comparative Data, 1969, Lubbock, Texas (Washington, D.C.: Government Printing Office, 1970), p. 2.

June, July, and August. The average daily maximum temperature for July in Amarillo is 87.8°F and in Lubbock it is 92.4°F. The average July temperatures of the two cities are 75.9°F and 79.5°F, respectively. A record maximum high temperature for Amarillo of 107°F was recorded both in June and July of 1958,[6] and for Lubbock, also 107°F, in June of 1953.[7] The region averages six days each year with afternoon temperatures of 100°F or higher. High summer temperatures significantly intensify municipal demands for water supply throughout the Texas Panhandle. These demands have frequently exceeded the capability of a particular city to produce and deliver an adequate amount of water from underground sources.

Within the region, the growing season varies from an average of 219 days in the south at Lamesa to 205 days in the north at Amarillo. The length of time between spring and fall killing frosts is quite variable from year to year. Illustrative of this is Amarillo, which has experienced record minimum and maximum growing seasons of 164 and 243 days.

The higher elevations of the Southern High Plains of Texas separated from the lower plains to the east by the Caprock Escarpment, the overall remoteness of possible moisture sources, and the frequent intrusions of relatively dry polar air masses result in a relatively dry steppe climate

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[6] U.S., Department of Commerce, Climatological Data, 1968, Amarillo, p. 2.

[7] U.S., Department of Commerce, Climatological Data, 1969, Lubbock, p. 2.

throughout the entire area of the Canadian River Municipal Water Authority.[8] Frequent squall-line thunderstorm activity in late spring produces a May peak in monthly precipitation. An examination of rainfall records reveals that a very significant three-fourths of the annual precipitation normally occurs during the months of May through September. Unfortunately for the area, most of the total annual rainfall occurs in moderate to heavy convectional thunderstorms of short duration, frequently producing short periods of rapid runoff. Such storms are usually accompanied by strong wind and occasionally by damaging hail and tornadic activity. Effective use of this intermittently available surface water resource has largely eluded municipal planners of the Llano Estacado.

Winter snow is of minor importance in the overall moisture supply, with mean annual totals of 20.6 inches for Amarillo[9] and 8.9 inches for Lubbock.[10] In the northern part of the Llano Estacado, blizzards, "characterized by subfreezing temperatures, very strong winds, and considerable blowing or drifting snow,"[11] have occurred with ten inches or more of

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[8]U.S., Department of Commerce, Environmental Science Services Administration, Environmental Data Service, Climates of the States: Texas, by Robert B. Orton (Washington, D.C.: Government Printing Office, 1960), p. 2.

[9]U.S., Department of Commerce, Weather Bureau, Local Climatological Summary with Comparative Data, 1950, Amarillo, Texas (Washington, D.C.: Government Printing Office, 1951), p. 4.

[10]U.S., Department of Commerce, Climatological Data, 1969, Lubbock, p. 2.

[11]U.S., Department of Commerce, Climate: Texas, p. 5.

snow on twenty occasions in seventy-three years of record. Since 1950 there have been only two blizzards worthy of special attention. One occurred between February first and fifth in 1956, dropping thirty-three inches of snow at Hale Center, a small town thirty-four miles north of Lubbock. The other recent blizzard and the most damaging one on record, occurred between March twenty-second and twenty-fifth in 1957, dropping 11.1 inches of snow in the Amarillo area. It was accompanied by a north wind with an average sustained velocity of forty miles per hour for twenty-four hours and effectively hampered transportation in the area for several days.[12]

Annual precipitation in the area is highly erratic (Figure 6) from year to year, with annual record maxima near forty inches and record minima near nine inches (Tables 1 and 2). Trewartha describes the seasonal precipitation of the Southern High Plains as having

> . . . a striking double maximum in the warm season. Clearly the continental type of annual rainfall variation still dominates for much more rain falls in the warmer months [Figures 7 and 8], and the cold season primary minimum is particularly well developed.[13]

The precipitation pattern has

> . . . one marked maximum in May [or June] and another in September, and there is a conspicuous secondary in July and August . . . as spring advances and rapid surface heating in these subtropical latitudes takes place, the annual rainfall curve trends sharply upward, especially

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[12]U.S., Department of Commerce, Climatological Data, 1968, Amarillo, p. 1.

[13]Glenn T. Trewartha, The Earth's Problem Climates (Madison: The University of Wisconsin Press, 1966), p. 280.

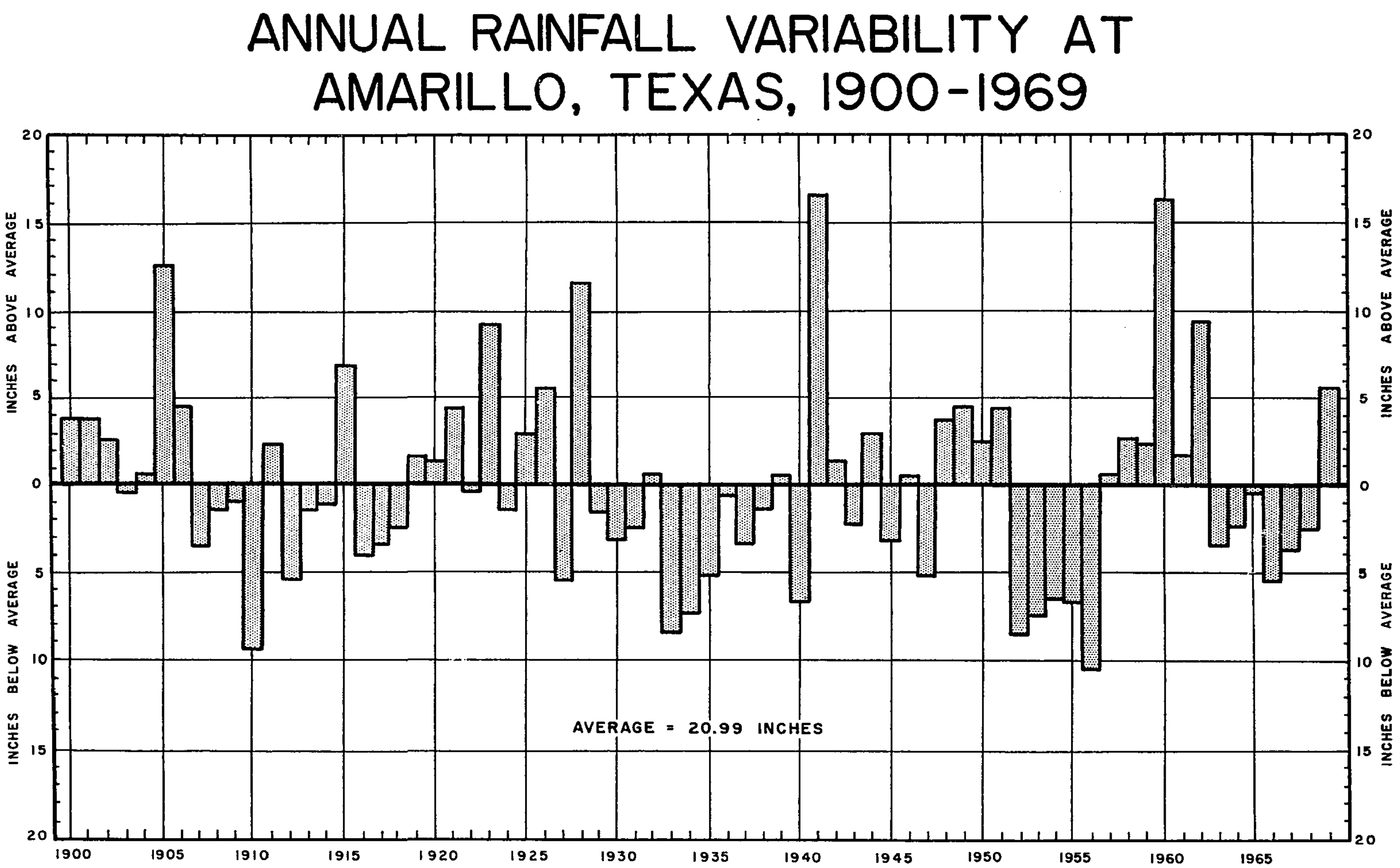

Fig. 6

SOURCE: U.S. DEPARTMENT OF AGRICULTURE, SOUTHWESTERN GREAT PLAINS RESEARCH CENTER.

RAINFALL CHARTS FOR LUBBOCK, TEXAS

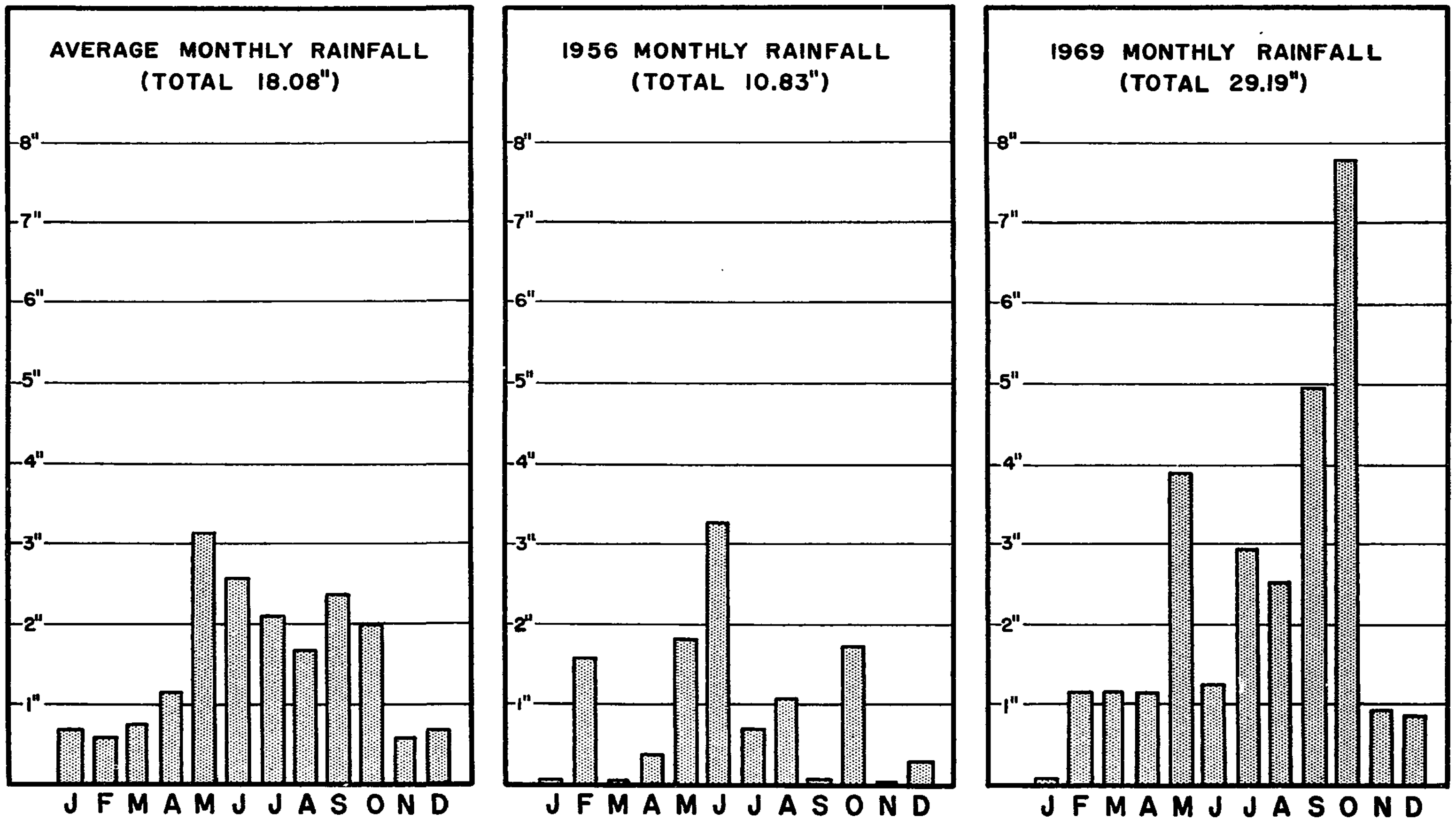

Fig. 7

SOURCE: U.S. DEPARTMENT OF COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION.

RAINFALL CHARTS FOR AMARILLO, TEXAS

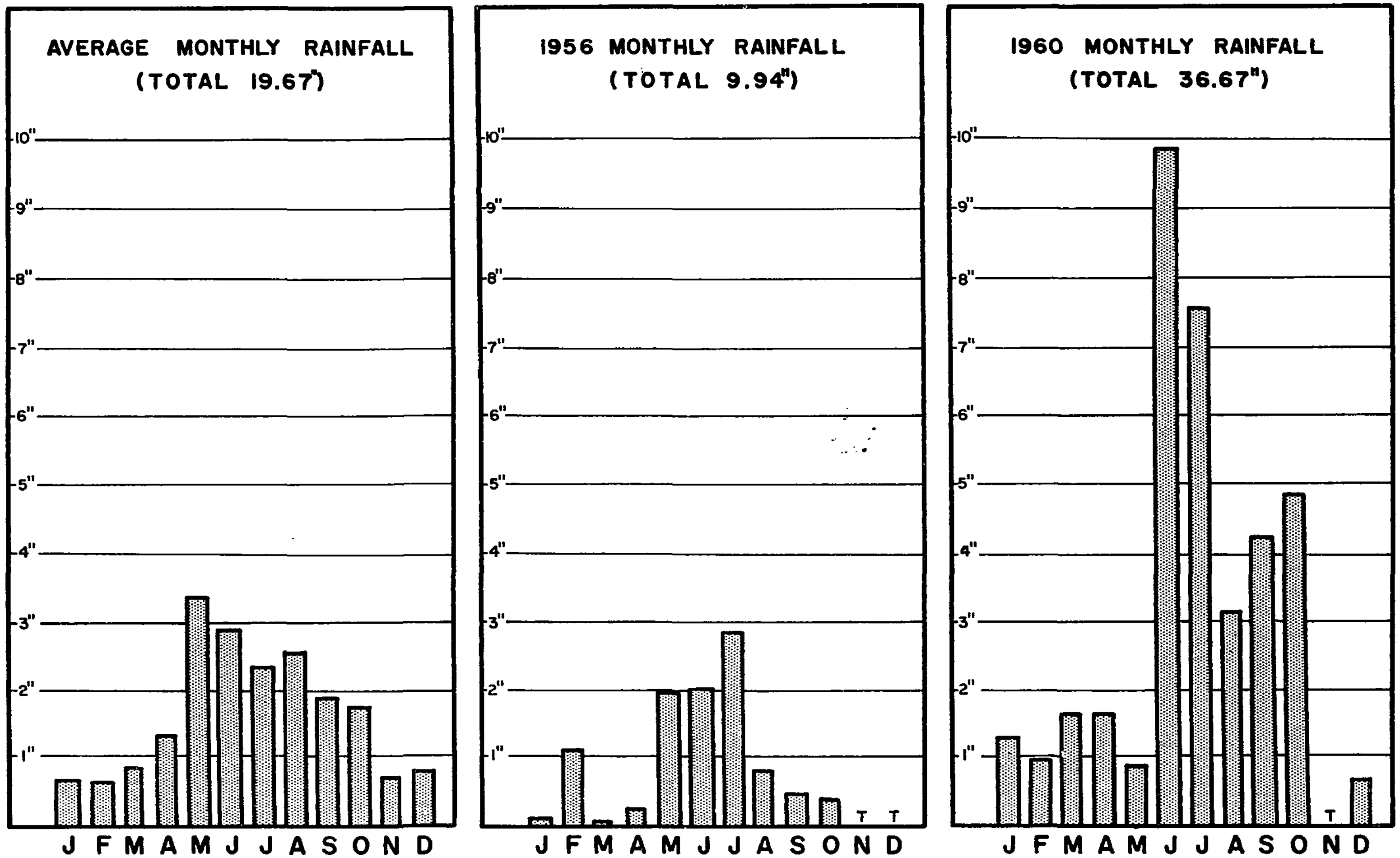

Fig. 8

SOURCE: U.S. DEPARTMENT OF COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION.

> during March and April. Surface air flow is prevailingly from the Gulf of Mexico to the heated land so that the humid maritime air experiences surface warming and increased instability. At the same time, frontal disturbances remain numerous . . . the steep ascent of rainfall . . . is abruptly checked after May and a decline sets in at the very time when surface heating is at a maximum and the inflow of surface maritime air is strong. It would appear, therefore, that the secondary minimum of summer must have its origin in dynamic process aloft.[14]

The rainfall regimes as shown in Figure 7 and 8, with the exception of the average monthly rainfall at Amarillo, illustrate and emphasize these observations graphically.[15]

Wind is an important factor in the climate of West Texas. At Amarillo the mean wind velocity is 13.7 miles per hour, and at Lubbock it is 13.4 miles per hour. At both cities it prevails from a southerly direction (Tables 1 and 2). The March wind is the strongest, prevailing from the southwest at an average monthly velocity of 15.5 miles per hour at Amarillo and of 16.0 miles per hour at Lubbock. All other months experience mean velocities of 10.6 miles per hour or more.[16]

The high average wind velocities are a significant

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[14] Ibid.

[15] The records used for Amarillo, Texas, represent monthly norms averaged over a substantially longer period of time (thirty additional years) than those used for Lubbock, Texas. Included, therefore, are a considerably larger number of convectional thunderstorms that have over a longer period of time brought the monthly averages for May through August to roughly three inches for each of these months. Figure 11, showing the precipitation for one year (1969), is more characteristic of the description given by Trewartha.

[16] U.S., Department of Commerce, Climate: Texas, pp. 30 and 35.

factor in the periodic dust storms that frequent the area of this study and in the very high evaporation loss from the surface of water bodies. According to Orton, the dust storm is the product of sparse vegetation and strong pressure gradients "such as those that accompany intense extratropical cyclones . . . during which . . . winds of 50 to 60 miles per hour and higher may persist for several days."[17] The severity of an individual dust storm is also dependent upon the kind of vegetation cover, if any, the local soil type, and the cultivation practices being employed. Greater understanding and application of soil conservation techniques have helped in recent years to minimize the occurrence of dust storms.

High wind velocity is but one of the several factors involved in the high annual rate of surface water evaporation on the High Plains of Texas. Other contributing factors of major importance are the low relative humidity and consistently high summer temperatures. Combined, these several climatic conditions account for annual average evaporation rates of 78.4 inches at Amarillo and 69.2 inches at Lubbock (Table 3). The large amount of water lost annually through evaporation is one of the region's major unsolved problems. As the area becomes increasingly dependent upon surface water sources, conserving water presently lost through evaporation could become crucial in sustaining municipal and rural water sufficiency.

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[17] Ibid., p. 7.

TABLE 3

EVAPORATION PAN DATA FOR AMARILLO AND LUBBOCK TEXAS

Station	Pan Type	Period of Record	Average Annual Pan Evaporation In Inches
Amarillo	Young Screened Pan	1961-1965	78.4
Lubbock	Young Screened Pan	1951-1965	69.2

Source: U.S., Department of the Interior, Bureau of Reclamation, Progress Report on West Texas and Eastern New Mexico Import Project Investigations (Amarillo: Bureau of Reclamation, 1968), p. 14.

Periodic drought is one of the harsher realities of The Texas High Plains, and it is an important element of the climatic pattern that residents of the area must be prepared to cope with from time to time. That drought exists is a fact, but the term itself is subject to some interpretation, dependent upon the specific context of its use. According to John T. Carr, Hydrometeorologist, Planning Division Research Program, Texas Water Commission, there are three general categories of drought: meteorological, hydrological, and agricultural.

Meteorological drought occurs over a prolonged period of time during which the moisture supply is rather consistently below what might be called normal for the area. Meteorological drought, then, is a relative condition. Hydrological drought is described by Carr as

> . . . a step further than meteorological drought . . . marked by shrinkage and drying up of streams and rivers, depletion of water stored in surface reservoirs and lakes, cessation of spring flows and decline of ground water levels . . . affecting industry as well as agriculture.[18]

From the standpoint of the economic well being of the Llano Estacado, agricultural drought is the most important type. According to Orton, agricultural drought is "a condition in which sufficient soil moisture is not available in the root zone for the plant growth and development."[19] It is important to understand that in the area of erratic precipitation on the Southern High Plains of Texas agricultural drought may occur with some frequency even though neither meteorological nor hydrological drought exists. The time that the rain falls is of prime importance if there is to be successful agricultural production. Sustained drought has occurred on three occasions during the period of record, resulting in greatly increased demands on ground water resources and substantially reducing the life expectancy of this water source. Concern over the declining ground water table, coupled with the constant threat of renewed drought, has provided a major impetus toward the development of a future surface water supply for both agricultural and municipal needs.

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[18] Texas Water Development Board, <u>Texas Droughts: Causes, Classification, and Prediction</u>, by John T. Carr, Jr., Report 30, (Austin: Texas Water Development Board, 1966), pp. 6-9.

[19] U.S., Department of Commerce, <u>Climate: Texas</u>, p. 3.

Climate of the Canadian River Basin above Sanford Dam

It is not the writer's intent to dwell at length on the climatic conditions of the contributory watershed of the Canadian River basin above the Sanford Dam (Figure 9). While important to the construction and successful operation of the Canadian River Project, climatic data are of little specific value here other than for general understanding of the regional environment. Ultimately, only one value assumes primary importance--the dependable annual average flow of the Canadian River at Sanford, Texas, as restricted by interstate compact. Incomplete streamflow records dating back to 1904 seem to indicate that the Canadian River at Sanford, Texas is capable of sustaining a firm annual yield of 103,000 acre-feet of water. Officials of both the Canadian River Municipal Water Authority and the Bureau of Reclamation readily admit that the period of record is too short to be certain that no further adjustments in average annual flow will be necessary.

The fifty-eight U.S. Weather Bureau stations located in the Canadian River Basin above Sanford Dam report an average of between sixteen and seventeen inches of annual precipitation.[20] The seasonal pattern of rainfall is almost identical to that of the Southern High Plains, with about eighty-five per cent of the total annual precipitation

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[20]U.S., Department of the Interior, Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas, (Amarillo: Bureau of Reclamation, 1960), p. 4.

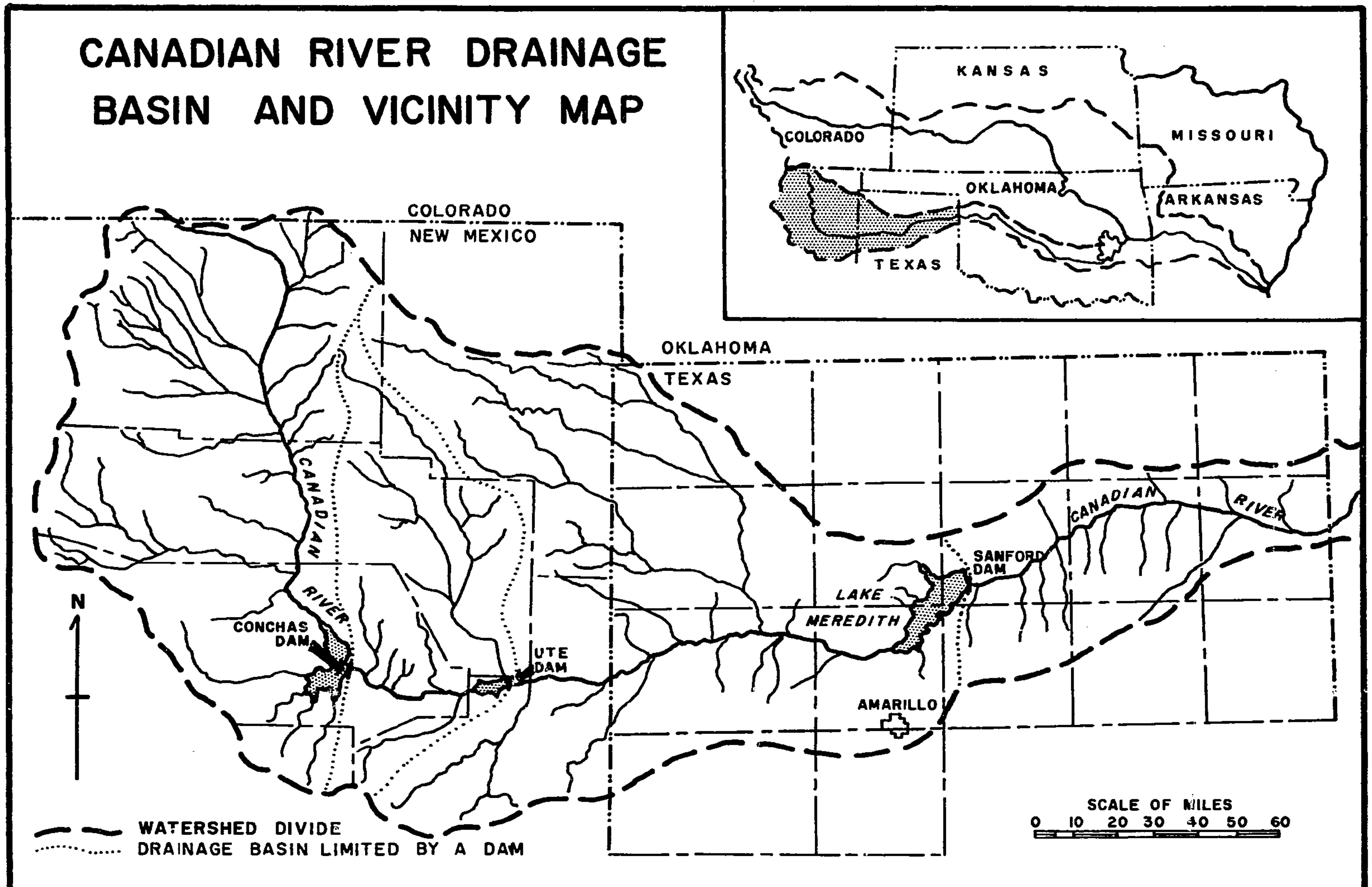

Fig. 9

SOURCE: SANFORD RESERVOIR, LOCATION AND VICINITY MAP, CORPS OF ENGINEERS.

occurring during the period of April through October. Snowfall in the basin above Sanford Dam averages about thirty-one inches annually, and in relation to total annual runoff it is not particularly significant.

The mean annual temperature within the basin is about 52°F. Variations in temperature range from a record minimum of -46°F to a record maximum of 112°F.[21] Mid-continental location and elevations that vary from 2,812 feet at the dam to higher than 8,500 feet in the Sangre de Cristo Mountains of northeastern New Mexico are contributing factors in the wide temperature range.

Geology and Ground Water

The geological units that underlie the Southern High Plains of Texas range in age from Precambrian to Holocene, but strata older than Permian have only minor significance in regard to the occurrence of known water resources suitable for general use (Table 4). For this reason no mention of earlier geological events is made.

Early in Permian time the area that is now the High Plains was a basin formed in pre-Permian rocks and covered by the sea. The pre-Permian rocks, which had been subjected to intense earlier deformation, subsided throughout the Permian period to form a geosyncline into which diverse sediments were deposited. Rocks of this period underlie all of the Texas High Plains. Although the sedimentary rocks of Permian

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[21] Ibid.

TABLE 4

STRATOGRAPHIC UNITS AND THEIR WATER-BEARING PROPERTIES, LLANO ESTACADO, TEXAS

Era	System	Estimated duration in millions of years	Series or Epoch	Formation or Group	Approximate Thickness in feet	Lithologic Description	Water Supply
Cenozoic	Quaternary	1	Holocene		0 – 15	Chiefly windblown sand and silt.	Yields no water to wells. Sandy areas form excellent facilities.
			Pleistocene		0 – 144	Sand, clay, diatomaceous earth, volcanic ash, limestone.	Mostly above water table. Does not yield large supplies.
	Tertiary		Pliocene	Ogallala Formation	0 – 500	Fine to coarse sand and gravel; clay, silt, and caliche.	Yields large supplies of water throughout the Southern High Plains.
Mesozoic	Cretaceous	72	Comanche	Washita, Fredericksburg, and Trinity Groups	0 – 200+	Fine to coarse sandstone and conglomerate; limestone, blue and yellow shale or clay.	Locally important as source of small supplies of water; Should not be considered as a major source of water for the Southern High Plains.
	Jurassic	55					
	Triassic	50		Dockum Group	150 – 1,800+	Varicolored shale and sandy shale, gray or brown cross-bedded sandstone and conglomerate.	Probably capable of yielding small to moderate amounts of water; most of the water is saline.
Paleozoic	Permiam				8,000±	Soft red sandstone, shale and clay, beds of gypsum and dolomite.	Not known to yield water to wells; water is probably saline.

Source: Texas Board of Water Engineers, A Summary of the Occurrence and Development of Ground Water in the Southern High Plains of Texas, by J. G. Cronin, Bulletin 6107 (Austin: Texas Board of Water Engineers, 1961), p. 13.

age exceed 8,000 feet in thickness in some places, water is not known to be pumped from them and is believed to be saline where it does exist.[22]

The area underwent an extended period of erosion during the early and middle parts of Triassic time. Continental sediments of the Dockum group were deposited during the late Triassic period when some subsidence may have occurred. An unconformity exists between the eroded Permian sediments and the overlying Triassic rocks over much of the Llano Estacado. In parts of Armstrong and Donley counties the Triassic rocks are absent, probably as a result of subsequent erosion rather than nondeposition.

Triassic rocks, probably fluvial in origin, exhibit a southeasterly dip averaging eight feet per mile. The formations included vary in total thickness from 150 feet to more than 1,800 feet; in some places they lie more than 500 feet below the surface, in other places they outcrop at the surface.

The quantity and quality of the water supply found in the Triassic sediments can best be characterized as uncertain, as it was by Sellards and Baker already in 1934.[23]

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[22]This section has been prepared primarily from the data presented in _A Summary of the Occurrence and Development of Ground Water in the Southern High Plains of Texas_, prepared for the Texas Board of Water Engineers by J. G. Cronin, Bulletin 6107 (Austin: Texas Board of Water Engineers, 1961), pp. 12-42.

[23]Bureau of Economic Geology, University of Texas, _Structural and Economic Geology_, Vol. II of _The Geology of_

Deep wells in Hale and Lubbock counties have generally produced salty water[24] although wells 500 feet deep in Randall county, yielding from 150 to 450 gallons per minute, produce water suitable for municipal use. Cronin rather pessimistically states that

> . . . the information currently available indicates that the yield of wells pumping from aquifers in this group [Dockum] would range from low to moderate and that the water would be rather saline, probably unsuitable in most instances for irrigation or public supply and perhaps limited to certain industrial uses.[25]

During the Jurassic period most of the Southern High Plains was subjected to either erosion or a situation of non-deposition. Non-marine sediments of this age are found at a few locations on the High Plains of New Mexico but are not known to exist in Texas.

The seas returned to cover the area once more during early Cretaceous time and to provide the last formation of marine deposits. Subsequent erosion during late Cretaceous and early Cenozoic times removed some of the Cretaceous rocks and a portion of the Triassic rocks in some places. Beginning in late Cretaceous time, and continuing through much of the Cenozoic era, considerable diastrophic and volcanic

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Texas, ed. by E. H. Sellards and C. L. Baker (Austin: University of Texas,1934), p. 396.

[24]Cronin describes a well drilled by the City of Lubbock in 1949 that had 35,000 ppm (parts per million) of dissolved solids.

[25]Texas Board of Water Engineers, Ground Water in the Southern High Plains of Texas, p. 21.

activity was occurring in the present location of the Rocky Mountains of New Mexico and Southern Colorado.

The sediments of Cretaceous age that remain "were laid down on the eroded surface of the Triassic rocks and . . . they dip to the southeast at the rate of seven to eight feet per mile."[26] In places these Cretaceous rocks form buried escarpments one hundred or more feet in height within the sub-surface. The general thickness of the Cretaceous rocks, totally absent in some places, may range to more than 200 feet in others.

Cretaceous rocks are considered to be of local importance as a source of water,[27] but should not be regarded as a major source of water for the Southern High Plains. In addition to the erratic occurrence of Cretaceous water, much of it is slightly saline. It is, therefore "believed that the aquifers in the Cretaceous rocks do not constitute an important source of water for large-scale use for irrigation, municipal, or other purposes."[28]

The evolution of the Southern High Plains during the Cenozoic era can be divided into three marked periods. The first, a period of erosion lasting through most of Tertiary

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[26] _Ibid._

[27] Cronin indicates that in Hale County, Cretaceous rocks yield up to 900 gallons per minute from fractured limestone, but that the water is probably supplied by the overlying Ogallala formation.

[28] Texas Board of Water Engineers, _Ground Water in the Southern High Plains of Texas_, p. 28.

time until nearly the beginning of the Pliocene epoch, produced a well dissected erosional surface cut into rocks of Cretaceous, Triassic, and Permian age. The principal valleys of this ancient landscape tended to trend southeastward across what is now the Panhandle area of Texas.[29]

The second period was one of stream deposition beginning in the late Miocene and lasting throughout most of the Pliocene epoch. The resulting sediments, comprising the important water-bearing Ogallala formation, had their origin in the newly uplifted Rocky Mountains to the west and northwest.[30] Because of its importance to the water supply and agricultural economy of West Texas, the Ogallala formation will be described here in some detail.

According to Frye[31] there are three somewhat distinct zones within the Ogallala formation: the Valentine, the Ash Hollow, and the Kimball. In the area of the Southern High Plains of Texas the basal Valentine zone is found only in the deeper pre-Ogallala valleys. There it is a tan-colored, largely unconsolidated deposit of silts, sands, and calcium carbonate. The reddish-brown deposits of the Ash Hollow zone

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[29]Personal interview with R. C. Redfield, Geologist, U.S. Department of the Interior, Bureau of Reclamation, Region 5, Amarillo, Texas, March 27, 1970.

[30]Texas Board of Water Engineers, <u>Ground Water in the Southern High Plains of Texas</u>, p. 16.

[31]John Frye, "The Ogallala Formation--A Review" (paper presented at the Ogallala Aquifer Symposium, Lubbock, Texas, April 30, 1970).

filled all but the deepest pre-Ogallala valleys, creating large areas of uninterrupted Ogallala surface. It was, however, during the deposition of the Kimball zone of the Ogallala formation that final and nearly complete coalescence of the deposits occurred. This portion of the Ogallala formation contains more calcium carbonate than the two deeper zones and, because of somewhat drier climate during the time of deposition, tends to be more indurated. The color of the deposits varies from tan to purple.

Thickness of the Ogallala formation varies according to the configuration of the pre-Ogallala surface. Over the deeper pre-Miocene valleys the thickness exceeds five hundred feet in several locations. Elsewhere, the Ogallala may exist only as a "knife edge where the formation wedges out against the older rocks."[32] In general, the Ogallala formation is composed of fine to course sand, with the fine to medium grades predominating. Gravel is fairly common at lower levels and may appear interbedded with sand at other levels. Silt is frequently found with the fine to medium grained sands (Plate 1).

The Ogallala formation is the principal aquifer of the Southern High Plains and, with the exception of those cities participating in the Canadian River Project, it supplies almost all water used for all purposes. The saturated

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[32] Texas Board of Water Engineers, Ground Water in the Southern High Plains of Texas, p. 35.

Plate 1--The unconsolidated sediments of the Ogallala formation approximately three miles south of Fritch, Texas, near State Highway 136.

thickness of the Ogallala varies considerably throughout the Southern High Plains of Texas because of the unevenness of the pre-Ogallala surface. At the present time it varies from zero to more than three hundred feet and is found generally under ordinary water-table conditions, although locally slight artesian pressure may be found to exist (Figure 10). The total water potentially available from storage in the Texas portion of the Southern High Plains was estimated to be about 161,544,000 acre-feet in 1958.[33]

Cronin estimates that the yearly pumpage since 1954 averaged in the neighborhood of 5,000,000 acre-feet.[34] A

[33] *Ibid.*, p. 93.

[34] *Ibid.*, p. 92.

GENERALIZED GEOLOGIC CROSS SECTIONS
SOUTHERN HIGH PLAINS OF TEXAS

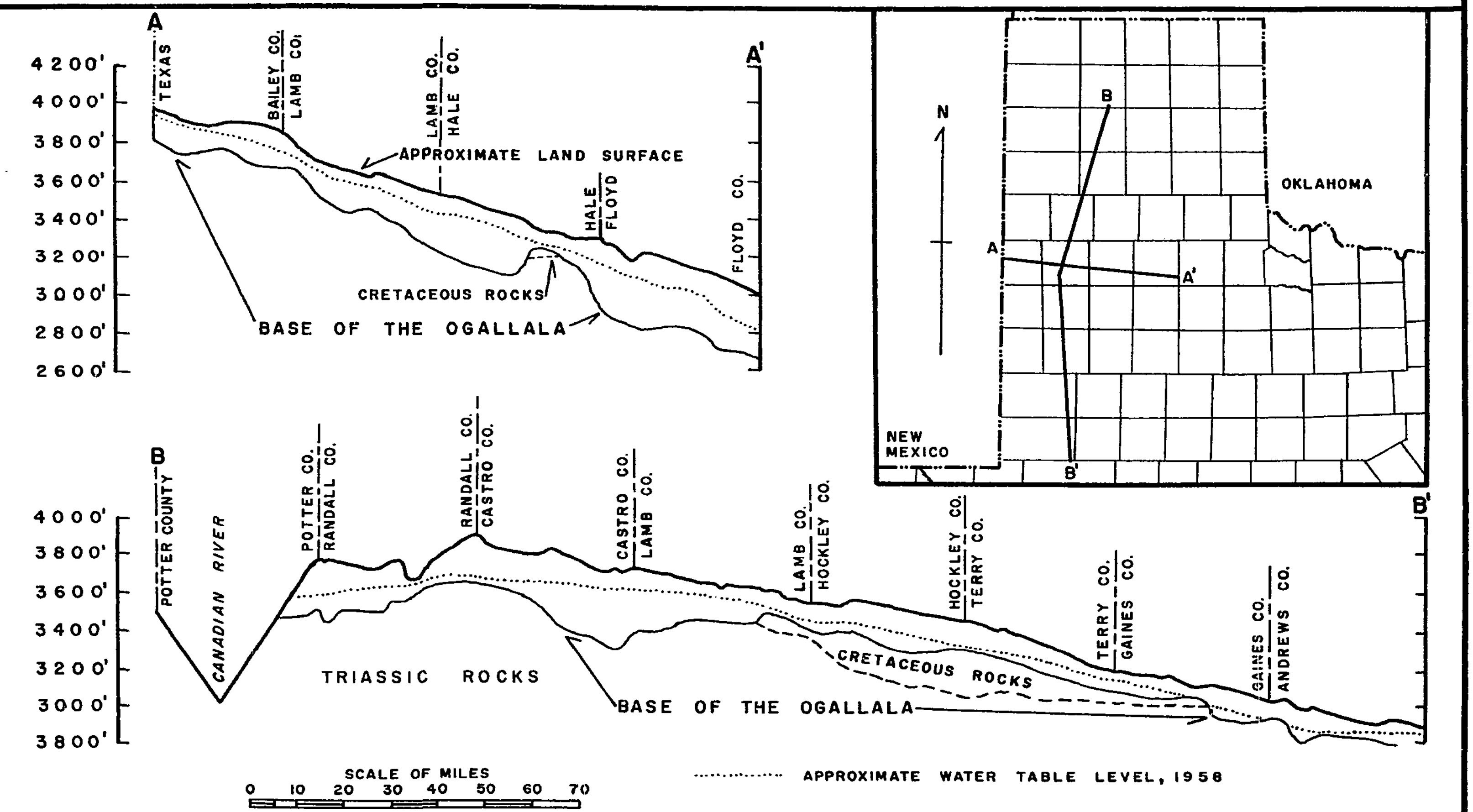

Fig. 10

SOURCE: TEXAS BOARD OF WATER ENGINEERS, BULLETIN 6107.

conservative calculation of the water available in 1970 in the Ogallala formation of the Southern High Plains of Texas reduces Cronin's estimate of 1958 by at least 54,000,000 acre-feet. These figures suggest that the available water in storage at the end of the 1970 irrigation season probably does not exceed 110,000,000 acre-feet.

Some ground water moves into Texas by underflow from New Mexico and continues east-southeastward, dropping an average of ten feet per mile toward the eastern caprock escarpment except where pre-Ogallala ridges temporarily divert it in another direction. According to Cronin,

> Ground water moves at a rate of about two inches per day in the vicinity of Plainview in Hale County. . . . It is recognized that this estimate is valid only under the geologic and hydrologic conditions assumed; however, it is believed that the estimate is of the proper magnitude for the Ogallala formation throughout the Southern High Plains.[35]

Depth to the water table ranges from less than fifty feet in several "shallow water" areas to more than three hundred feet below the land surface. The conditions that affect the depth from the surface to the water at any given location include surface configuration, proximity to areas of discharge or recharge, and position of the bedrock surface.[36]

Natural recharge in the Texas portion of the Southern High Plains is at present a partially unknown quantity. All authorities agree that water extraction greatly exceeds

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[35] *Ibid.*, p. 49.

[36] *Ibid.*, p. 61.

natural recharge, but disagree on the extent. Estimates of actual annual recharge vary from approximately 50,000 acre-feet[37] to as much as 300,000 acre-feet.[38] According to Barnes and others,

> In some localities the caliche probably prevents penetration of surface water, but more generally, throughout much of the "tightland," commonly found in Deaf Smith, Castro, Randall, Swisher, Hale and Floyd counties, downward percolation is retarded by the clayey subsoils. The principal areas in which direct infiltration can occur are the sandy zones in Bailey, Lamb, Lubbock and Hockley counties.[39]

In general, the water of the Ogallala formation is suitable for nearly all public supply, irrigation, and industrial uses. Chemical analyses of selected samples indicate that except for fluoride, the most common minerals found in solution usually do not exceed the recommended limits of the U.S. Public Health Service.[40] In industry the high silica content of the water in the Ogallala formation is generally excessive for use in boilers.

The third period of evolution began sometime during

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[37] Clyde S. Conover, "Ground Water Resources--Development and Management," (paper presented to the Ground Water Section of the Western Resources Conference, Boulder, Colorado, August 24, 1960), p. 3.

[38] Personal interview with Frank Rayner, General Manager, High Plains Underground Water Conservation District Number 1, Lubbock, Texas, April 30, 1970.

[39] Texas Board of Water Engineers, Geology and Ground Water in the Irrigated Region of the Southern High Plains of Texas, by J. R. Barnes et. al, Progress Report 7 (Austin: Texas Board of Water Engineers, 1949), p. 24.

[40] Texas Board of Water Engineers, Ground Water in the Southern High Plains of Texas, p. 96.

late Pliocene time with the cessation of stream deposition. Cronin believes that as the surface attained a state of equilibrium during this period it is likely that the caliche caprock began to form.[41] The Quaternary system brought alternating cycles of erosion and sedimentation and it seems probable that

> . . . the formation and retreat of [the] bounding escarpments, with consequent physiographic isolation of the Llano Estacado, took place mainly during the Pleistocene epoch. Deep re-entrant canyons also formed during the Pleistocene and there is evidence that canyon cutting took place mainly during intervals of accelerated erosion interrupted by long intervals of relative stability.[42]

Frye and Leonard believe that the caprock escarpment reached its present configuration during Kansan time, about midway through the Pleistocene epoch.[43] The physical separation of the Southern High Plains of Texas from the Rocky Mountains, precludes large scale natural recharge of the Ogallala formation from mountain water flow, and with the exception of the deeply entrenched Canadian River, prevents streams from crossing the region.

Pleistocene and Holocene deposits are generally above the water table and are not thought to contain significant quantities of water anywhere on the Southern High Plains of Texas, although such deposits may in some places be

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[41] _Ibid._, p. 92.

[42] G. L. Evans and G. E. Meade, _Quaternary of the Texas High Plains_ (Austin: University of Texas Press, 1945), p. 16.

[43] John C. Frye and A. B. Leonard, _Studies of Cenozoic Geology Along the Eastern Margin of the Texas High Plains_ (Austin: University of Texas Press, 1957), pp. 37-8.

responsible for the amount of recharge that takes place.

Topography and Surface Hydrology

Stretching from South Dakota through the Panhandle of Texas to South Texas is the physiographic region of the High Plains described by Fenneman as

> . . . remnants of a former great fluvite plain which stretched from the mountains on the west to the Central Lowlands. . . . The surface produced by this alluviation is as flat as any land surface in nature. . . . In the Llano Estacado or Staked Plains of Texas and New Mexico, an area of 20,000 square miles is almost untouched by erosion.[44]

The Texas portion of the High Plains has a general uniform slope to the east and southeast ranging from seven to twelve feet per mile.

The general uniformity of the surface is broken only by the sinuous channel of the Canadian River, the re-entrant canyons formed by the upper tributaries of the Red River, and the more than 30,000 playa depressions that dot the High Plains of Texas (Plate 2). These undrained depressions locally called "playas," "sinks," and "buffalo wallows" have been accurately described by Fenneman as

> . . . saucer-like depressions, nearly circular basins varying in diameter from a few rods to a mile, and in depth from a few inches to thirty or forty feet. The rim is often perfectly definite and formed by the abrupt up-curving of the well sodded bottom to meet the surrounding plain.[45]

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[44]Nevin M. Fenneman, Physiography of Western United States (New York: McGraw-Hill Book Company, Inc., 1931), pp. 11, 14.

[45]Ibid., pp. 14-5.

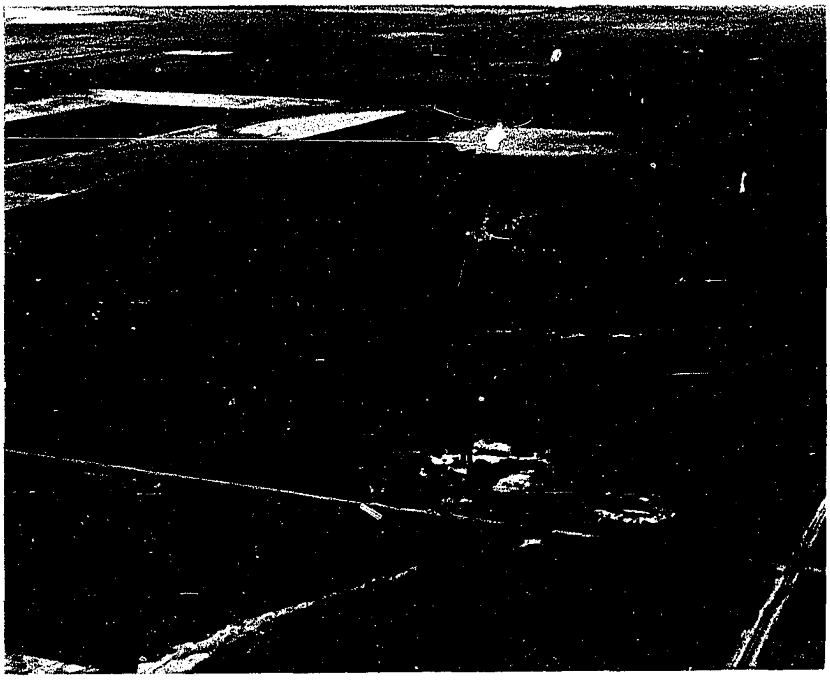

Plate 2--An aerial view of several water-filled playa basins on the nearly featureless Llano Estacado at the intersection of 34th Avenue and Eastern Street approximately three miles southeast of Amarillo, Texas. (Photograph by T. V. Jackson, courtesy of Bureau of Reclamation)

While the origin of these playas is not fully understood, and little importance has generally been attached to them, it would appear that they are gradually emerging as important units to be considered in the general program of surface water management on the High Plains of Texas (Figure 11).

In the upper part of the Ogallala formation there is an extensive area of "massive carbonate concentration."[46] This zone of carbonate caliche varies in thickness from ten

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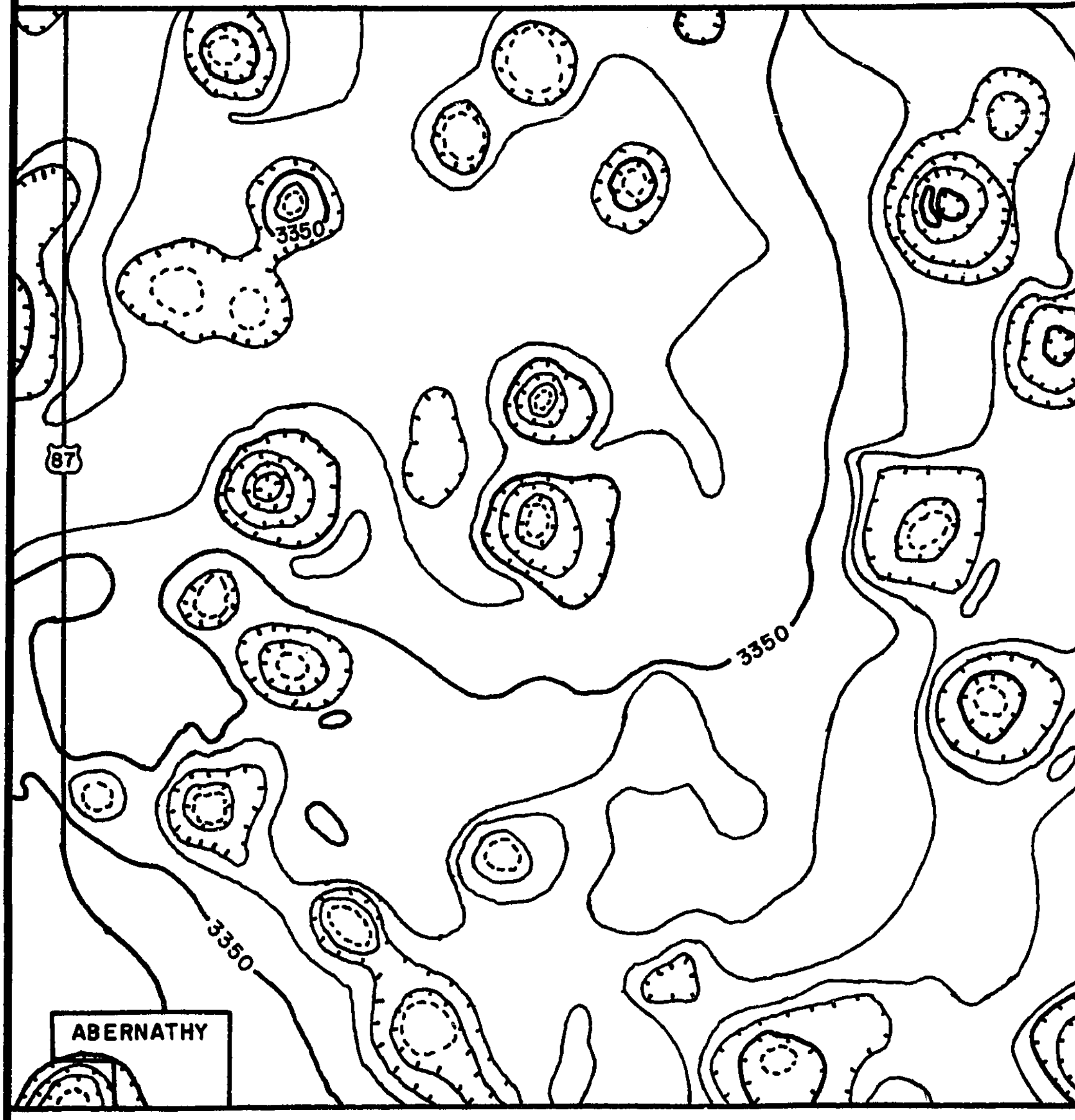
[46]William D. Thornbury, Regional Geomorphology of the United States (New York: John Wiley and Sons, Inc., 1965), p. 301.

TOPOGRAPHIC MAP OF A TYPICAL PORTION OF THE SOUTHERN HIGH PLAINS NEAR ABERNATHY, TEXAS



Scale in Miles
1 0 1 2

CONTOUR INTERVAL 10 FEET
Datum is Mean Sea Level

AFTER: ABERNATHY QUADRANGLE, TEXAS, 15 MINUTE SERIES (1:62,500), U.S.G.S., 1957

Fig. 11

to thirty feet and is very resistant to erosion. Because of its durability it has brought about the development of conspicuous escarpments on both the eastern and western fringes of the Llano Estacado. Along the eastern margin it forms the Caprock Escarpment, and along the western margin it is responsible for the Mescalero Escarpment (Plate 3).

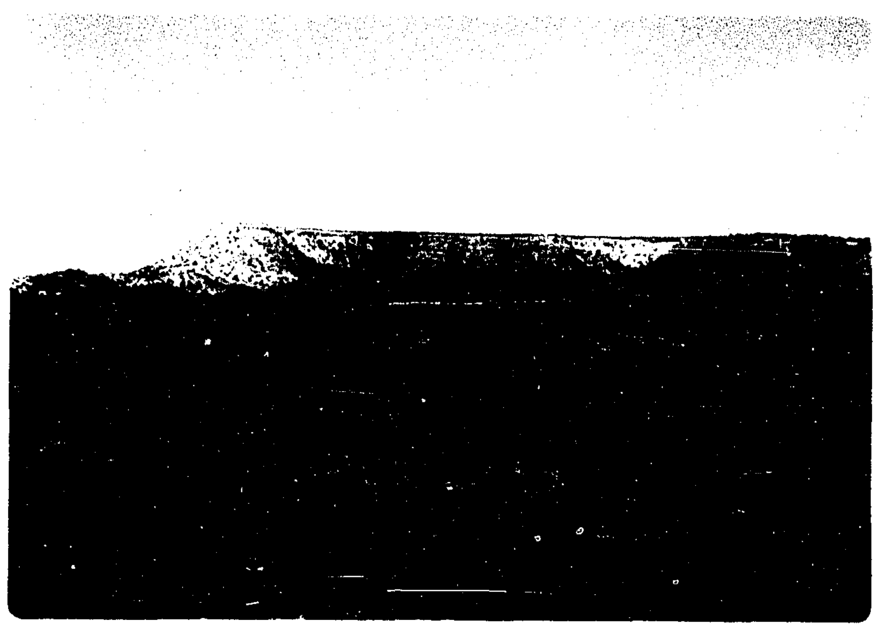


Plate 3--The Mescalero Escarpment near Elkins, New Mexico marks the western edge of the Llano Estacado.

Elias attributed the formation of the caliche in the caprock to deposition "in a number of discontinuous lacustrine basins."[47] This theory has been questioned by Bretz and

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[47]M. K. Elias, "Ogallala and post-Ogallala Sediments," Geological Society of America Bulletin 59, quoted in William D. Thornbury, Regional Geomorphology of the United States (New York: John Wiley and Sons, Inc., 1965), pp. 301-2.

Horberg who "concluded that the caliche of the caprock is a natural product of soil forming processes."[48] Swineford, Frye, and Leonard added further support to the latter point of view in 1958.[49] One important significance of the caliche caprock is that it is a rather impervious layer of rock through which possible recharge water of the Ogallala must pass. Because the caprock is very slowly permeable, it precludes rapid recharge, and thus permits substantial water loss by evaporation back into the atmosphere.

Except for the rather small percentage of surface water that is diverted into the several headwater tributaries of the Red, Brazos, and Colorado rivers of Texas, and that which is directed northward in many short tributaries of the Canadian River, the largest part of the local runoff from rainfall or melting snow flows short distances into the playa depressions from where between seventy-five and ninety per cent of it evaporates.[50] The largest volume of surface water within the physiographic limits of the Texas High Plains flows

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[48] J. H. Bretz and Leland Horberg, "Caliche in Southeastern New Mexico," Journal of Geology, LVII, quoted in William D. Thornbury, Regional Geomorphology of the United States (New York: John Wiley & Sons, Inc., 1965), p. 302.

[49] Ada Swineford, A. B. Leonard, and J. C. Frye, "Petrology of the Pliocene Pisolitic Limestone in the Great Plains" Kansas Geological Survey Bulletin 130, quoted in William D. Thornbury, Regional Geomorphology of the United States (New York: John Wiley & Sons, Inc., 1965), p. 302.

[50] Personal interview with Mr. James Valliant, Agricultural Engineer, High Plains Research Foundation, Halfway, Texas, May 29, 1970.

in the Canadian River. The Canadian rises in the Sangre de Cristo Mountains of northeastern New Mexico, flows eastward across the Texas Panhandle and crosses most of the state of Oklahoma before entering the Arkansas River. In Texas the river is entrenched from five hundred to seven hundred feet below the general level of the land surface of the High Plains. The river is flanked on both sides by the Canadian River breaks, an irregular strip of rugged land fifteen to thirty miles wide (Plate 4).

Plate 4--Rough Terrain of the Canadian River breaks approximately one mile southeast of Sanford Dam, Sanford, Texas.

Two layers of Permian dolomite of the Cloud Chief formation form a resistant rimrock that creates abrupt bluffs along both sides of the Canadian river channel (Plate 5). At

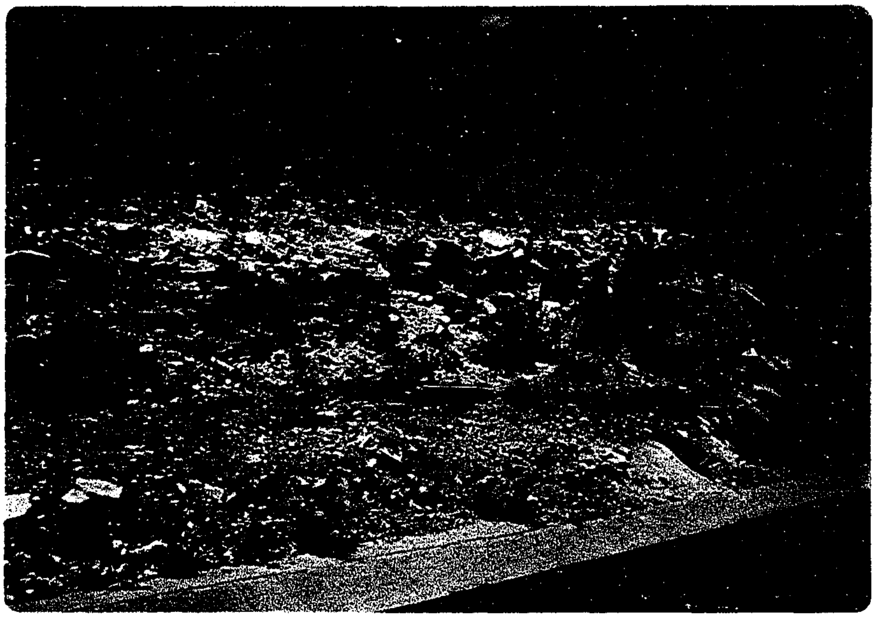

Plate 5--A road cut exposure of resistant Permian dolomite of the Cloud Chief formation near Fritch Fortress, Lake Meredith, Texas.

Sanford, Texas, the Cloud Chief formation lies at an average of 190 to 200 feet above the river bed. Away from the river this formation is overlain by 500 to 700 feet of Triassic (Dockum group) and Tertiary (Ogallala formation) sediments. Sandy outcrops of the Ogallala formation are found in many locations among the dissected lands of the Canadian River breaks. Because of its deeply dissected exposure along the flanks of the Canadian River it is generally drained of water for twenty-five to thirty-five miles back from the river.

Soils and Vegetation

In general, the soils of the Southern High Plains of Texas are of high fertility and exceptionally productive for crop growth when properly managed and enough soil moisture is present. The soils fall into two categories. The area north of a line that bows slightly northward from Lubbock, Texas to Clovis, New Mexico belongs to the "ustoll" suborder of the "mollisol" order. To the south of the line are the soils of the "ustalf" suborder of the order of "alfisol."

The "hardland" fine textured ustolls are described by the Soil Conservation Service as ". . . intermittently dry for long periods during summer . . . gently to moderately sloping . . . soils with nearly black, organic rich surface horizons and high base supply."[51] The mollisols are among the highest quality soils in the United States, with excellent agricultural potential. Mausel characterizes the mollisol as a soil that has:

> (1) Favorable structure and texture in the plow layer, promoting good soil tilth.
>
> (2) . . . a dark colored surface horizon reflecting favorable quantities of high quality organic matter.
>
> (3) A solum with high base saturation resulting in favorable soil reaction (pH 6.0-7.5).
>
> (4) A thick topsoil suitable for agriculture.
>
> (5) An absence of massive leaching of mineral matter and humus thus promoting the retention of major quantities of important selected soil nutrients in the solum.[52]

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[51] U.S., Department of Agriculture, Soil Conservation Service, Patterns of Soil Orders and Suborders of the United States, Map With Text (Hyattsville, Maryland: Soil Conservation Service, August, 1967).

[52] Paul W. Mausel, "An Introductory Approach to Soils in Geography Instruction," The Journal of Geography, LXIX (January, 1970), 33.

The Pullman-Randall association of soils covers nearly the entire extent of the northern one-half of the Llano Estacado. The pattern of uniformity that emerges in the Pullman-Randall association is in part due to the nearly uniform nature of this broad, treeless, short-grass prairie. It is an area of nearly level to gently sloping deep, fine, and moderately fine textured, very slowly permeable soils. Within the association the Pullman soils occur on the extensive and nearly smooth upland. Randall, Roscoe, Lofton, Zita, and Mansker soils are found in association with playa development, and scattered bands of Olton and Ulysses soils are present on the uplands bordering the several intermittent streams. The Pullman soils account for about three-fourths of the northern association and are characterized as "deep, dark, productive soils that have a silty clay loam surface layer and a subsoil that is very slowly permeable when it is wet."[53] This characteristic precludes any significant amount of infiltration of water to the zone of saturation in the Ogallala formation. Remaining as it does on or near the surface, most of the water is ultimately evaporated, and is of little beneficial value to those that reside in the area. Exceptions to the slow infiltration are the sandy bottoms of the several short intermittent streams that are located on

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[53]U.S., Department of Agriculture, Soil Conservation Service, Soil Survey, Armstrong County, Texas, by Louis L. Jacquot, et al., (Washington, D.C.: Government Printing Office, 1965), p. 4.

the Llano Estacado. During periods of rainfall these watercourses account for a large percentage of the ground water recharge that occurs.

The soils of the playa basins are nearly uniform in their occurrence (Figure 12). The deep, poorly drained clays of the Randall soils cover the flatter bottom portion of the depressions. This tight soil is significant in causing the ponding of water whenever runoff occurs. On the benches adjacent to the Randall clay soils are the deep, calcareous, clayey and poorly drained Roscoe soils. Adjacent to the Roscoe clays on the higher benches are the "very dark-colored, deep, clayey, very slowly permeable"[54] Lofton soils. With proper management these soils are highly productive.

The Zita, Ulysses, and/or Mansker soils are located around the rim of the basins. They vary in depth from shallow to moderately deep. They are calcareous soils which are sometimes susceptible to both wind and water erosion.

To the south of the Clovis, New Mexico-Lubbock, Texas line are the soils of the ustalf suborder of the order of alfisols. The alfisols are described by the Soil Conservation Service as soils that have "gray to brown surface horizons, medium to high base supply, and sub-surface horizons of clay accumulations in areas where the temperatures are warm and it is intermittently dry for long periods.[55] According to

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[54]*Ibid*., p. 5.

[55]U.S., Department of Agriculture, Soil Conservation Service, *Patterns of Soil, Map With Text*.

TYPICAL PLAYA SOIL ASSOCIATION

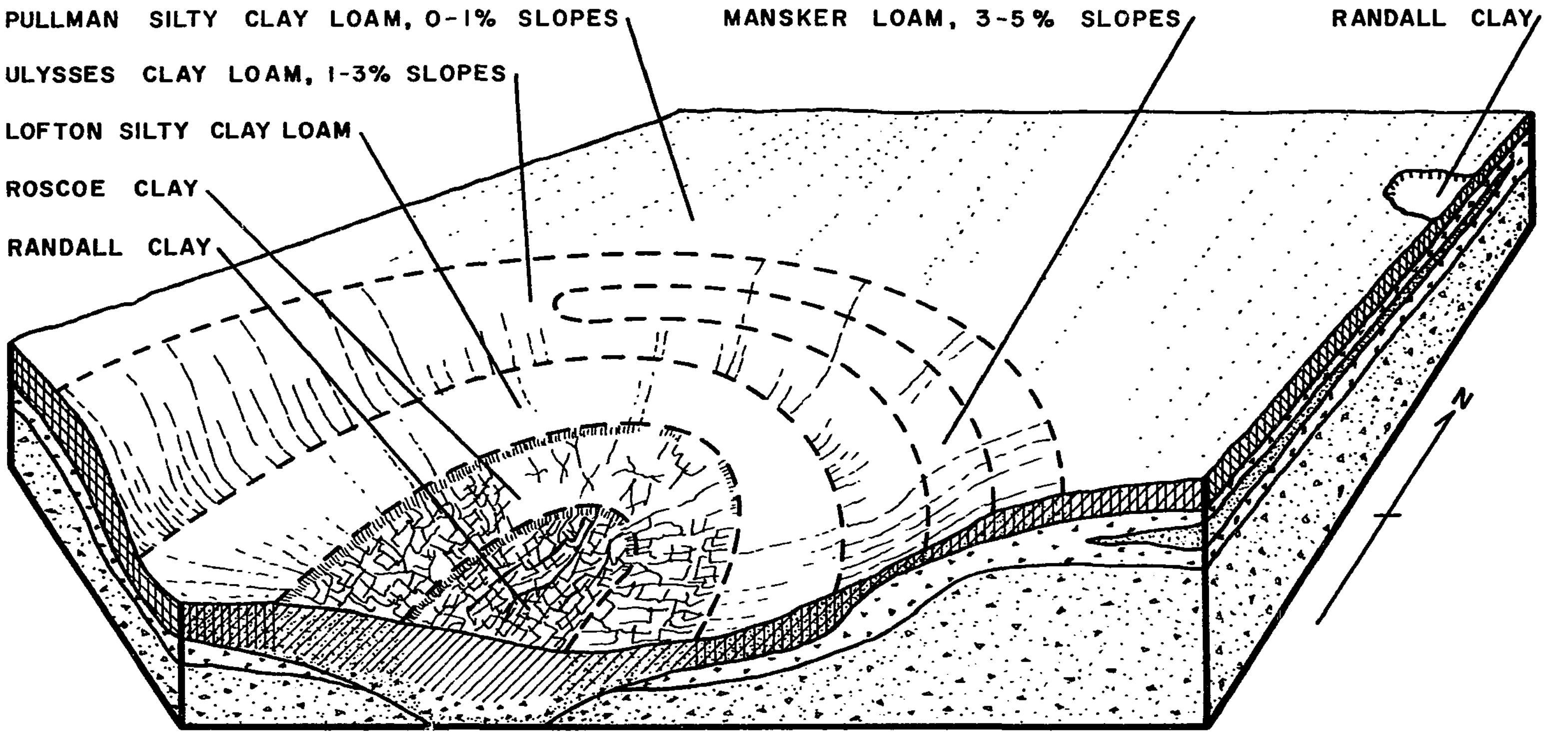

Fig. 12

SOURCE: U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE.

Mausel, the alfisol is a mineral soil that may have:

(1) Clay translocation from the surface to the subsurface resulting in somewhat fine-textured subsoils.

(2) Leaching of the mineral surface horizon resulting in translocation of mineral matter into the subsoil or beyond creating topsoils with deficiencies of nutrients formerly present in the parent material.

(3) Noticeable leaching of calcium-magnesium from the solum, in part, causing a moderately acid topsoil.

(4) Organic matter present in moderate amount only, resulting in somewhat light colored soils when well-drained.

(5) A possibility of hard horizons (pans), leached horizons and high sodium content soils that present physical and chemical difficulties when used for agricultural purposes.

(6) A variable thickness, texture, and structure of the topsoil but often favorable, resulting in good tilth.[56]

The sandy soils and deep sands of the Brownfield-Tivoli association cover approximately fifteen per cent of the Southern High Plains of Texas.[57] Nearly all of the soils of this association are found in the southwestern portion of the Llano Estacado, south of the Lubbock-Clovis line. In general, the association consists of duned and gently undulating sandy soils (Figure 13). The duned areas are the Tivoli fine sands. The dunes range in height from just a few feet to more than thirty feet and usually have short choppy slopes of as much as thirty per cent. Internal drainage of these permeable soils is very rapid, and they can be described

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[56]Paul M. Mausel, Introductory Approach to Soils, p. 34.

[57]Texas Almanac and State Industrial Guide, 1970-1971 (Dallas: A. H. Belo Corporation, 1969), p. 128.

TYPICAL BROWNFIELD - TIVOLI SOIL ASSOCIATION

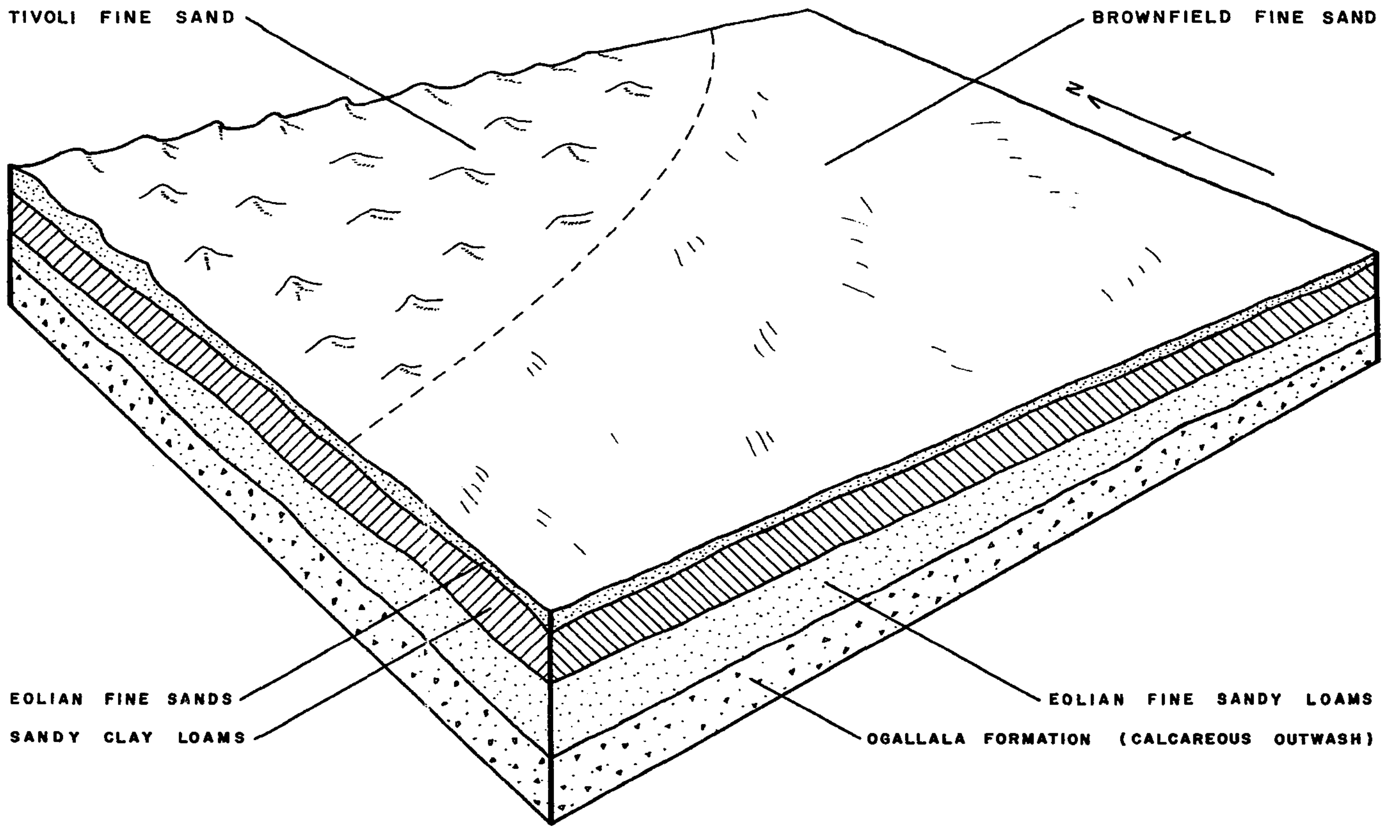

Fig. 13

SOURCE: U.S. DEPARTMENT OF AGRICULTURE,
SOIL CONSERVATION SERVICE.

as excessively drained with very low water-holding capacity. The Tivoli soils are not used for cultivated crops and demand careful range management to prevent blowouts from forming.

The Brownfield soils are deep, loose, light-colored, neutral, sandy soils with a surface layer ten to thirty inches thick occurring over broad undulating areas. Permeability is moderate to moderately high with rapid internal drainage. Runoff is very light and the water-holding capacity of Brownfield soils is low to moderate. The production of cultivated crops is hazardous and careful soil management is essential to prevent blowing dust and sand. Overhead sprinkler systems of irrigation have been the most effective means of water application.

The High Plains of Texas is an area of over twenty million treeless acres. A large part of this area is under cultivation, but native grassland remains over about one-half of it. In the northern two-thirds of the Llano Estacado blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*) dominate as the principal natural vegetation on the clay and clay loam "hardlands" soils. In addition to buffalo grass and blue grama, western wheat grass (*Agropyron smithii*) and salt grass (*Distichlis stricta*) are found associated with the Roscoe clay soils of the playas. In the southern one-third of the Texas High Plains the principal grasses found on the sandy loam soils of the Brownfield series are little bluestem (Andropogon scoparius), western wheat grass (Agropyron smithii), Indian grass (Sorghastrum nutans), switch grass (Panicum virgatum), sand reedgrass (Calamovilfa longifolia), sideoats grama (Bouteloua curtipendula), and sand bluestem (Andropogon hallii). Several of the more conspicious invading brushy plants are prickly pear (Opuntia lindheimeri), mesquite (Prosopis juliflora), three-awn (Aristida stricta), and western ragweed (Ambrosia psilostachya) in the deep hardland areas. In the southern part of the Llano Estacado sand sagebrush (Artemisia filifolia), mesquite (Prosopis juliflora), shinnery oak (Quercus mohriana Rybd), and Yucca (Yucca gloriosa) are the principal invaders.

The physical environment of the Southern High Plains of Texas has been something of a paradox for the inhabitants of the area. Few sections of the United States are so well endowed for agricultural use from the standpoint of topography, productivity of the soils, warm summer temperatures, and long growing season. Without irrigation, however, the erratic pattern of precipitation makes crop production a marginal enterprise at best. With abundant use of ground water, an agriculturally based economy has prospered throughout most of the Llano Estacado for the past thirty-five to forty years. This success, however, is based upon a diminishing resource which will be virtually exhausted before the end of the twentieth century. Providing an adequate water supply for the future looms as a formidable problem for both rural and urban residents in West Texas.

CHAPTER III

SETTLEMENT HISTORY AND THE DEVELOPMENT OF WATER RESOURCES BY THE CANADIAN RIVER PROJECT CITIES

Early History

In general, the settlement of the High Plains of Texas has been intimately dependent upon the discovery and development of water resources. There is a striking similarity in the overall pattern of growth of the eleven project cities, although they differ greatly in size.

Spanish *conquistadores* provided the first recorded glimpses of the Texas High Plains. It is the consensus of historians that Francisco Vasquez de Coronado, searching for the legendary "Seven Cities of Cibola," led the first group of Europeans to view the vast, featureless Llano Estacado. In the spring of 1541 it is recorded that Coronado's party crossed into what is now the Texas Panhandle from a winter base in New Mexico. Authorities are in disagreement over the route that the conquistadors followed across the plain before heading northward toward what is now Kansas.[1]

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[1]Lawrence L. Graves, ed., *A History of Lubbock* (Lubbock: West Texas Museum Association, 1962), p. 23.

In about 1593 Spanish explorers Bonilla and Humana crossed the Panhandle, and in 1601 Don Juan de Onate followed the Canadian River eastward into Texas in an elusive search for Gran Quivira.[2] Finding no cities of gold, official Spanish interest in the area waned for nearly two hundred years. Interest revived in the final decades of the eighteenth century when the Spanish governor of Texas commissioned Pedro Vial to scout a route from San Antonio, Texas to Santa Fe, New Mexico.[3] Vial's route took him across a portion of the Texas Panhandle along the Canadian River valley. The Spanish continued their interest in the High Plains of Texas until 1836, leaving a cultural heritage that is reflected in a pattern of colorful place-names scattered throughout the Llano Estacado.

Beginning in the early nineteenth century, the United States government began to take an exploratory interest in the Great Plains. Several expeditions were commissioned which brought citizens of the United States into or near the High Plains of Texas. In 1806 Captain Richard Spark and Lieutenant Zebulon M. Pike, in separate missions, skirted the Llano Estacado in search of the headwaters of the Red River. In 1820 Major Stephen H. Long, in search of the same goal, mistakenly followed the Canadian nearly to its source in the

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[2]J. Evetts Haley, The XIT Ranch of Texas and the Early Days of the Llano Estacado (Norman: University of Oklahoma Press, 1967), p. 7.

[3]*Ibid.*, p. 8.

southern part of the Sangre de Cristo range.

In addition to official expeditions sanctioned by the federal authorities in Washington, D.C. and/or by those of the newly independent Republic of Texas, commercial travel along the Santa Fe Trail contributed some knowledge of the Texas prairies. The southern loop of the Santa Fe Trail which passed through the Texas Panhandle was, however, seldom used because of the hostility shown by the Comanche Indians. Haley states that "except for such explorations as these, the Panhandle was the undisputed and uncoveted home of the Plains Indians, happy mortals in their nomadic life and tribal wars."[4]

The general consensus of the early explorers of the Southern High Plains of Texas was that the plains could not be inhabited by man in any great numbers. Major Long wrote that the northern Panhandle was "almost wholly unfit for cultivation, and of course uninhabitable by a people depending upon agriculture."[5] Edwin James, a companion of Long, thought the plains were

> . . . unfit residence for any but a Nomad population. The traveller who shall at any time have traversed its desolate sands will, we think, join us in the wish that this region may forever remain the unmolested haunt of the native hunter, the bison and the jackall [*sic*].[6]

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[4]*Ibid.*, p. 12.

[5]Edwin James, *Account of Stephen H. Long's Expedition*, Vol. XVI of *Early Western Travel*, ed. by R. G. Thwaites, quoted by J. Evetts Haley, *The XIT Ranch of Texas* (Norman: University of Oklahoma Press, 1967), p. 16.

[6]*Ibid.*

Captain Marcy, the first to thoroughly explore the Red River, concurred that the plains "were destined to remain the home of the savage, 'possessing as they do, so few attractions to civilized man.'"[7]

During the 1870's organized Indian resistance was broken by the United States government, and the fragmented tribes still remaining on the Southern High Plains were placed on the large reservation called Indian Territory. As soon as the plains were relatively secure from Indian attack, both Mexican-American and Anglo-American adventurers appeared on the Llano Estacado for a brief moment in history as buffalo hunters and mustangers.[8]

It is to the Spanish that Texas owes many of its colorful place names, including Los Llanos Estacados, or the Staked Plains. Of the many tales that supposedly account for the origin of the name Los Llanos Estacados, Gregg's explanation is among the most common:

> . . . there is but one route upon which this plain can be safely traversed during the dry season; and even some of the watering places on this are at intervals of fifty or eighty miles and hard to find. Hence, the Mexican traders and hunters, that they might not lose their way and perish from thirst, once staked out this route across the plain, it is said; whence it has received the name of El Llano Estacado.[9]

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[7]Haley, The XIT Ranch of Texas, p. 17.

[8]The term "mustangers" was first applied to Mexican horse hunters who would visit the Llano Estacado in search of the wild mustangs which sprang from stock that had escaped from the Spaniards two or three hundred years earlier.

[9]Josiah Gregg, Commerce of the Prairies, Vol. XX of

In the expansion of the cattle industry on the Great Plains after the Civil War, ranches were first established in eastern New Mexico. Before long, continued expansion pushed the ranchers northward into the Piedmont region of Colorado where the suitable lands rapidly became overstocked. In 1875 Charles Goodnight, one of the first ranchers to settle in Colorado, moved his herd to a location on the Canadian River in New Mexico just west of the Texas border. In November, 1876 the herd was moved to the vicinity of Palo Duro Canyon, south of present-day Amarillo, where it is reported to have flourished. Goodnight thus became the first established American rancher on the Llano Estacado.[10] Goodnight's success opened the way for Thomas S. Bugbee[11] and others intent upon utilizing the grasslands of the High Plains of Texas. Within a very short time nearly all the land had been taken over by a few large cattle companies which branded their cattle, struggled to find and protect scant water supplies, and eventually marked off their ranch holdings with barbed wire fences.

The broad plains were not without their problems. The level land provided almost no protection from the winter

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Early Western Travel, ed. by R. G. Thwaites, quoted by J. Evetts Haley, The XIT Ranch of Texas (Norman: University of Oklahoma Press, 1967), p. 35.

[10] Haley, The XIT Ranch of Texas, p. 40.

[11] Thomas S. Bugbee settled just north of the Canadian River on the creek which bears his name. The ranch site is one of the developing recreation areas around Lake Meredith.

blizzard. Grass fires were an annual threat, and surface water supplies were frequently undependable. This latter problem was largely overcome with the discovery of what seemed to be an unlimited supply of good water at fairly shallow depths over nearly all of the Southern High Plains of Texas. For a short period ranching flourished and the "windmiller" became one of the most indispensable "cowboys" of the range country. Haley reports that:

> Each division kept one or two "windmillers," whose only duty was to care for the mills. These "windmillers" lived upon a never-ending journey that carried them in a circle from one mill to another . . . They camped where night overtook them as they moved from mill to mill repairing where attention was needed. . . . About once a month they swung by headquarters, replenished their store of provisions, repaired their tools and reported to the foreman any neglect in greasing the mills on the part of the lineriders.[12]

Almost from the beginning the ranchers felt the pressure of competition from sedentary occupants as farmers came in to initiate a tenuous existence on the Llano Estacado. Even though many early attempts to farm the Llano Estacado met with failure, there were always new settlers who came in place of the ones who left.

As the plow began to cut open the prairie in the early years of this century, and as water began to flow more abundantly from the increasing number of wells in the area, land gradually became too valuable for the grazing of cattle. The huge cattle estates which were earlier either claimed by

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[12]Haley, The XIT Ranch of Texas, p. 166.

"squatters rights" or purchased for a dollar or two per acre were bringing from fifteen to twenty-five dollars per acre upon sale to prospective farmers.[13]

Water Development

During the early years of settlement on the Southern High Plains of Texas, water was occasionally obtained from the intermittent streams that traverse the area, from the ephemeral playa lakes, or from the springs fed by seeps from the water-bearing sands of the Ogallala formation. With the discovery of an abundant reservoir of ground water at moderate depth,[14] the windmill became an indispensable feature of the landscape. Continued exploration soon indicated that nearly all of the High Plains of Texas had an underlying water-bearing sand formation varying in depth from fifty to four hundred feet.[15] Technological developments in the field of pump equipment during the 1930's produced pumps that could produce water in what must have seemed to be unlimited

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[13]The same prime land under irrigation was selling for from four hundred to eight hundred dollars per acre in 1970.

[14]The first indications of the magnitude of the underground reservoir came at the turn of the century through the geologic exploration of G. M. Gould. In 1906 his study entitled The Geology and Water Resources of the Eastern Portion of the Panhandle of Texas was published as U.S. Geological Survey Water-Supply Paper 154. A year later the study was supplemented by the publication of a second part similarly titled The Geology and Water Resources of the Eastern Portion of the Panhandle of Texas, U.S. Geological Survey Water-Supply Paper 191.

[15]Harry A. Boseman, Water for Amarillo and the High Plains, Amarillo, Texas, 1970. (Mimeographed.)

quantity to those that were able to invest in a proper rig. Today the life and economy of the area depends on water.

Amarillo

The municipal water supply for Amarillo was initially developed by the predecessor of the Southwestern Public Service Company. In March of 1926 the entire system was sold to the city of Amarillo. Neither the city nor the Southwestern Public Service Company has kept operating records of the early period prior to acquisition by the city, although both have records of the units of property involved in the sale. Thus, it is recorded that in March, 1926 the public water system consisted of the following property:[16]

1. 4,738 5/8" meters
2. 52 1" meters
3. 59 2" meters
4. 1 3" meter
5. 3 4" meters
6. 358 fire hydrants
7. 28 wells averaging 250 feet deep
8. 28 20-horsepower motors
9. 1 60,000 gallon steel tank
10. 1 rectangular, concrete reservoir, 33' x 73' x 22-1/3'.

Until 1968 virtually all of Amarillo's municipal

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[16] Letter from J. D. Ballew, Manager, Nichols Station, Southwestern Public Service Company, Amarillo, Texas, May 25, 1970.

water supply was derived from the underground water resources of the Ogallala formation. Underground water is presently available to Amarillo from two developed fields in Randall and Carson counties. Further undeveloped reserves are held by the city in Hartley County (Figure 14).

The Randall County system, the sole source of water for Amarillo until the mid 1950's, consists of seventy wells located between the western city limits and the Deaf Smith County line. These wells vary in depth from 250 feet to a little over 400 feet and have an average potential production of from 300 to 700 gallons per minute. Ten of the wells are on the periphery of Palo Duro Lake, which provides some natural recharge of the aquifer by seepage.[17] With the exception of the ten Palo Duro wells, recharge is considered to be negligible. Over the years of operation there has been an average decline in the static water level of from three to four feet annually.[18] With the introduction of surface water from the Canadian River in 1968, the water table of the Randall County system has evidenced a degree of stabilization and even a slight overall rise.[19]

The future dependability of the southwest well field

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[17]Freese, Nichols and Endress, Consulting Engineers, Amarillo, Texas--Report on Long Range Water Supply, 1967, (Fort Worth: Freese, Nichols and Endress, Consulting Engineers, 1968), p. S-1.

[18]Personal interview with Harry A. Boseman, Director of Utilities, City of Amarillo, Texas, March 30, 1970.

[19]*Idem*.

UNDERGROUND WATER RESOURCES OF AMARILLO, TEXAS

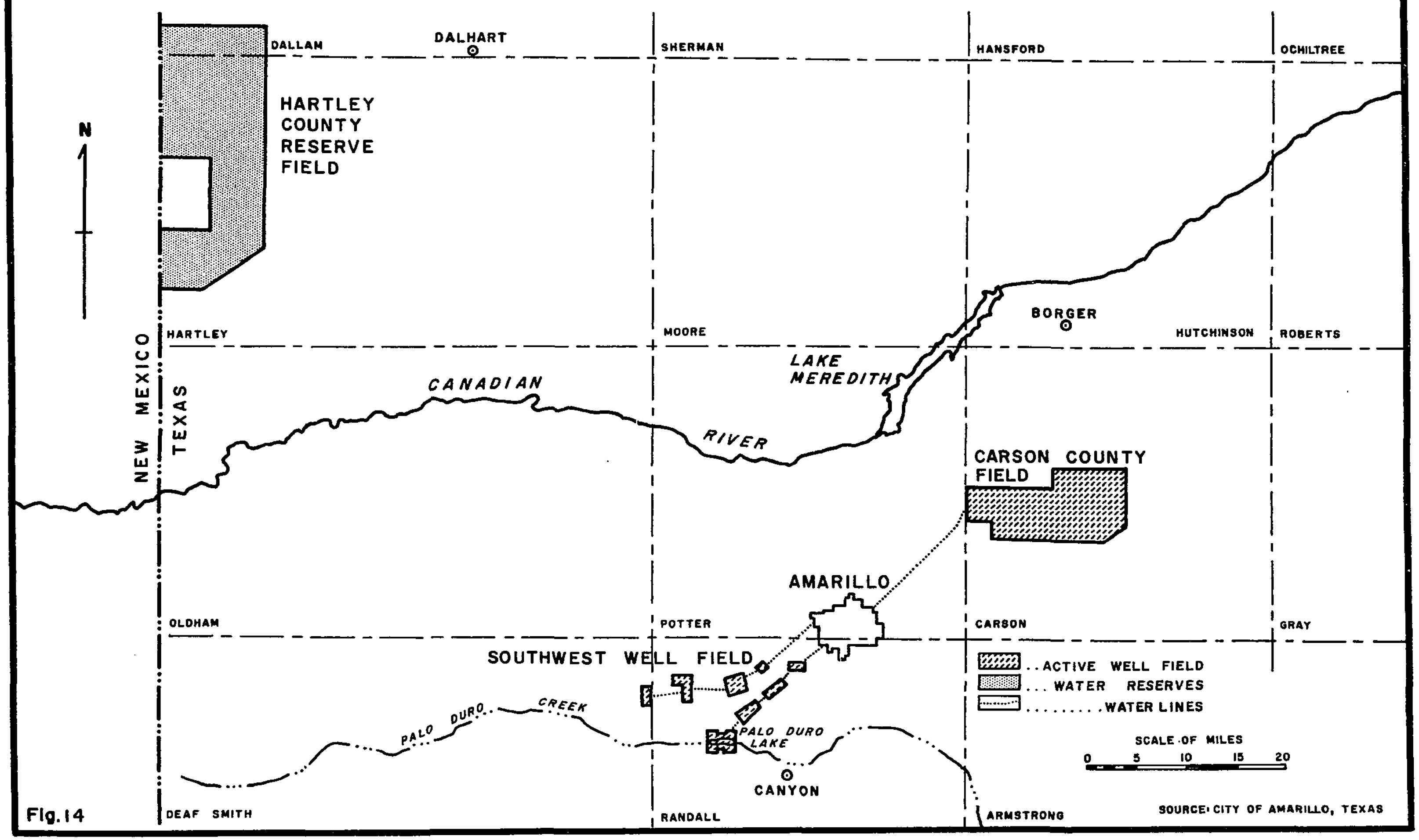

Fig. 14

involves many factors over which the city may or may not have some degree of control. The greatest single factor affecting the rate of water table decline, and one over which the city has no control, is the amount of irrigation pumping by farmers in the area. Unless city expansion to the south and west removes irrigated land from agricultural production, it may be expected that the present rate of withdrawal will continue for many years into the future.[20] Anticipating no marked improvement in the water supply to the city from the Randall County system, Amarillo has no plans to enlarge this field which presently has a daily capacity of forty-three million gallons.[21]

The Carson County system consists of 15,000 acres of water rights which were about fifty per cent developed in 1970. The existing wells include twenty-nine wells with an installed capacity of 1,050 gallons per minute each, one well with an installed capacity of 950 gallons per minute, and three wells with installed capacities of 850 gallons per minute. The combined capacity of the thirty-three deep wells in this system is presently thirty-five million gallons per day.[22]

Since it was developed the water table level in the

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[20]Freese, Nichols and Endress, Long Range Water Supply, p. S-7.

[21]Harry A. Boseman, Water for Amarillo, p. 2.

[22]These wells average 800 feet in depth.

Carson County field has shown an average decline per well of 4.88 feet per year. Although this decline conforms closely to the average throughout the area, the relatively recent development of the field has not yet markedly affected the field's capacity to yield water. The consulting firm of Freese, Nichols and Endress recommends that an additional forty wells be added by the year 2000, in order to meet the field's proposed portion of the total "maximum annual day demand."[23] By 2000 the Carson County field is projected to be capable of producing seventy million gallons per day.

The Hartley County reserves consist of 120,000 acres of exclusive water rights, with an estimated recoverable yield of 1,400,000 acre-feet of ground water in western Hartley County and southwestern Dallam County (Figure 14). These ground water reserves were acquired in 1955 after extensive exploration and investigation of the area's potential to produce water. Development of the field is not expected to begin until 1985.[24] The fully developed capacity of forty-three million gallons per day is anticipated by the year 2015.[25]

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[23]Freese, Nichols and Endress, Long Range Water Supply, p. C-4.

[24]The need to begin development by 1985 may have to be re-evaluated in light of the unexpectedly large drop in population indicated by the 1970 census. The preliminary statistics indicate that the population of Amarillo dropped nearly 15,000 between 1950 and 1970.

[25]Freese, Nichols and Endress, Long Range Water Supply, p. H-12.

Several factors make the Hartley County reserves nearly ideal. The rough, broken character of the terrain has minimized the irrigation potential of the land, thus reducing the principal competition for water. Secondly, the water rights locations in Hartley and Dallam counties are somewhat more contiguous to each other than are those in the city's other two well fields. This factor of contiguity provides for better regional control of the ground water. Finally, the sands of Punta del Aqua Creek, an intermittent tributary of the Canadian River in Hartley County, have an estimated potential for capturing through infiltration eight and one-half million gallons per day, in relation to the estimated annual recharge of at least 16.1 million gallons per day for the whole field.[26]

The overall policy of Amarillo has been to keep any water not in immediate need in reserve. It is realized that increased development of water resources for irrigation in adjoining land will ultimately reduce the reserves available to the city. It is felt, however, that the increased benefit to agriculture will, in a general sense, more than offset the loss of water through the strengthening of the area's economy.[27] In any event, it is recognized that all ground water supplies have a rather limited potential and will ultimately need to be supplemented and even supplanted by an alternative

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[26] Ibid., p. H-1.

[27] Personal interview with Harry A. Boseman.

source. Recognition of this long range anticipated deficit, in addition to other arguments, led the city of Amarillo to participate in the Canadian River Project as a means of augmenting the city's underground water supply.

In April, 1968, water deliveries from the Canadian River were initiated to Amarillo and several other cities of the Canadian River Municipal Water Authority. These deliveries provided the people of Amarillo with a very important alternative to exclusive reliance on declining ground water supplies. Under the terms of the city's contract with the Canadian River Municipal Water Authority, Amarillo is allocated 27.058 per cent of the normal water supply available from the Canadian River source.[28] Amarillo's allocation amounted to twenty million gallons per day in 1969[29] and should reach a maximum of thirty-four million gallons per day in 1989.[30]

A third source of municipal and industrial water supply, reclaimed water, has been in use since 1956. The River Road Wastewater Treatment Plant produces an effluent entirely acceptable for some industrial operations. Texaco, Inc. purchases approximately 1,400,000 gallons per day for use in its Amarillo refining plant as cooling tower makeup

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[28] U.S., Department of the Interior, Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas, (Amarillo: Bureau of Reclamation, 1960), p. 34.

[29] The year 1969 was the first full year of operation.

[30] Harry A. Boseman, Water for Amarillo, p. 3.

and boiler feed water. Because the cooling tower recirculation rate is more than forty times the makeup rate, the water is, in effect, used forty times before it is disposed of by evaporation from waste water ponds.

In addition to furnishing water to Texaco, Inc., the River Road Wastewater Treatment Plant supplies the Southwestern Public Service Company with 2,600,000 gallons per day for cooling purposes at the Nichols steam-electric generating station. The water is recycled through the cooling towers, maintaining approximately five concentrations of dissolved solids. Waste water from the Nichols station is sold to a nearby farmer for irrigation, thus making full use of the water.[31]

The Hollywood Wastewater Treatment Plant treats approximately 1,600,000 million gallons per day which is sold for irrigation. Both reclamation plants are activated sludge plants and are currently producing an average of eleven million gallons per day.[32] The surplus treated water is returned to the Canadian River upstream approximately thirty-two miles from the Canadian River Project's Sanford Dam. Sludge is contracted for by Relko, Inc., at one dollar per ton. It is then mixed with chemicals and bagged as a fertilizer for sale locally.

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[31] Personal letter from J. D. Ballew, Manager, Nichols Station, Southwestern Public Service Company, Amarillo, Texas, May 25, 1970.

[32] Personal interview with Harry A. Boseman.

The long range plans for Amarillo have always taken into account the fact that the Ogallala water basin is gradually being depleted, while recognizing that the economy of the High Plains and of Amarillo up to now has been largely based upon the irrigation of agricultural crops. With these facts ever present, civic-minded people in Amarillo have long promoted the development of the surface water resources of the Canadian River. It is hoped that securing a substantial portion of the city's municipal and industrial water supply need from the Canadian River will promote a longer life expectancy for ground water irrigation in the area. It is estimated that present water resources of all categories are adequate for Amarillo through the year 2010, even with an estimated population by then of 420,000, and could probably sustain that level of population for another fifty years.[33] Assuming, as most do, that growth is essential to a prosperous community, other sources of water would then be required to adequately supply the need. Thus, the Canadian River Project is thought of by many as a temporary measure to meet present needs until a feasible regional plan can be implemented to provide adequate "permanent" water for the area.

Lubbock

The 1890 census showed a total of thirty-three people in Lubbock County, many of whom lived in the competing towns

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[33] Harry A. Boseman, Water for Amarillo, p. 5.

of Old Lubbock[34] and Monterey, respectively on the north and south sides of Yellow House Canyon. By an act of consolidation early in 1891, the two communities were united in a mutually agreeable location under the name of Lubbock. By 1900 the population had increased to 293.

During the early years of development, a public watering trough and windmill located on the courthouse square provided the town's closest approach to a public water supply (Plate 6).

Perhaps the most striking thing about the appearance of Lubbock to a contemporary observer would "have been the small forest of windmills, all turning and pumping at the same time. Nearly every home had its own well and windmill, although a few families still hauled water from their neighbor's or the public well."[35] From the very beginning the wells were thought to tap what was generally "regarded as an inexhaustible water supply."[36] A need was apparent, however, for the development of a general and coordinated water supply for the city. In commenting on the Lubbock water situation at the time, Graves observed that "not only would a public

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[34]Old Lubbock was referred to by early inhabitants of Lubbock County as North Town.

[35]Seymour V. Connor, "The New Century," in A History of Lubbock, ed. by Lawrence L. Graves (Lubbock: West Texas Museum Association, 1962), p. 99.

[36]Lawrence L. Graves, "Health, Medicine and Sanitation," in A History of Lubbock, ed. by Lawrence L. Graves (Lubbock: West Texas Museum Association, 1962), p. 176.

Plate 6--Public watering trough and windmill located on the courthouse square, Lubbock, Texas, 1900. (Drawing courtesy of Linda Vandever of photo supplied by West Texas Museum Association.)

water supply be cheaper in the long run, but much more convenient than having to carry water in buckets into the kitchen or run a pipe into the house from a raised tank at the windmill."[37] There was also the hope that epidemics of typhoid fever and other diseases spread by contaminated water could be guarded against with a public water system.

Facilities for the first real public water works for

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[37]*Ibid*.

the city of Lubbock were constructed during 1911 and 1912 on a site purchased from J. S. Wilson for $157.00 on August 8, 1911. These works consisted of a single well about 206 feet deep and pumped with compressed air, a 150 gallon concrete ground storage tank, a 75,000 gallon kettle-shaped steel overhead water tank, a Fairbanks-Morse piston-type pump to fill the overhead tank, and thirty-five blocks of six- and eight-inch cast iron water mains.[38] Several years passed before most people shut down their private water systems and tapped into the city mains.

A city water department was created September 15, 1912, and the city gradually extended the principal water mains to serve the growing population of Lubbock. In 1914 a second well was drilled alongside the ground storage reservoir and was pumped by a sixteen-foot Eclipse windmill. This proved to be sufficient only until March, 1917 when a third well was drilled adjacent to the ground reservoir. This was the first well to be serviced with a turbine pump and an electric motor. Other wells have been added on a regular basis as they have been needed (Table 5).

Upon completion of the initial water works in 1912, a sewage system was installed serving the downtown area leading "towards the canyon [Yellow House Canyon] where a septic

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[38] Ibid. and Gordon W. Willis, "Brief History of Water Supply System for City of Lubbock," Lubbock, Texas, n.d. (Mimeographed.)

tank and filter beds were established."[39] Connection to the sewer system became mandatory by state statute in September of 1912.

TABLE 5

NUMBER OF MUNICIPAL WELLS IN SERVICE AT LUBBOCK, TEXAS, 1925-1970

Date	Number of Wells
1925	3
1930	5
1935	7
1940	13
1945	18
1950	42
1955	106
1960	131
1965	138
1970	142

Source: Gordon W. Willis, "Brief History of Water Supply System for City of Lubbock," Lubbock, Texas, n.d. (mimeographed.)

The election of 1924 brought F. R. Friend to the Office of the Mayor where he was confronted with problems of civic growth and the need to expand the city water system. According to Winifred W. Vigness:

> Friend and his commissioners faced the ever present problem of the plains, water and where to find it. The Mayor recommended that the city buy well sites for future use, since the demands on local water supply were increasing

[39]Graves, "Health, Medicine and Sanitation," p. 178.

rapidly. A new well and the repair of an old one were ordered immediately.[40]

During Mayor Friend's administration several new well sites were acquired, but the water problem continued to plague the city throughout the late 1920's and 1930's. In March, 1937, the Mayor signed "an agreement with the Texas State Board of Water Engineers for the construction of a dam ten miles southeast of Lubbock on the Double Mountain Fork of the Brazos."[41] The dam was subsequently built, creating a 5,000 acre-foot reservoir. In January, 1941, a bond election provided $175,000.00 for further improvements and additions to the water works.

During the early 1940's the water supply problem continued to worsen, compelling the City Planning Commission to recommend that Mayor Ribble request the State Board of Water Engineers and the U.S. Geological Survey to make a technical study of possible sources of future water supplies.[42] H. N. Roberts, a consulting engineer from Lubbock, also submitted an independent survey.[43] A serious water emergency arose in October, 1946, necessitating the prompt drilling of sixteen

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[40]Winifred W. Vigness, "Municipal Government of Lubbock," in A History of Lubbock, ed. by Lawrence L. Graves (Lubbock: West Texas Museum Association, 1962), p. 345.

[41]Ibid., p. 365.

[42]The Commission at the time was interested in securing access to sufficient water to meet the needs of a projected population of 125,000 people.

[43]Lubbock City Commission, Minutes of Meeting of the Lubbock City Commission, September 14, 1944. (Typewritten.)

additional wells during the remainder of 1946 and 1947.

Vigness points out that:

> The following February the city commission sent a resolution to the state legislature and copies to the legislators from the South Plains area, as well as to communities in the region, urging the adoption of an exhaustive ten-point research and study program for this indespensable resource, water. Lubbock's reaction to its resolution was the appointment in September, 1947 of a Water Resource Board.[44]

In September, 1947, the Water Resource Board went on record as having a definite interest in a regional project to secure municipal water from the Canadian River by the construction of a dam.[45]

Between 1940 and 1950 Lubbock proved to be the second fastest growing metropolitan area in the United States.[46] This led to over-optimistic population projections for the 1960 and 1970 censuses.[47] After each of these censuses local groups, upset by the facts, agitated for a recount. Lurking in the background has been the often expressed "fear that the irreplaceable water supply of the South Plains would not be sufficient to sustain such growth indefinitely into

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[44]Winfred W. Vigness, "Municipal Government," p. 383.

[45]Lubbock City Commission, Minutes of Meeting of the Lubbock City Commission, September 14, 1944. (Typewritten.)

[46]Winfred G. Steglich, "Population Trends," in A History of Lubbock, ed. by Lawrence L. Graves (Lubbock: West Texas Museum Association, 1962), p. 427.

[47]The 1960 forecast of the Chamber of Commerce was more than 30,000 higher than the actual census count of 128,691. The 1970 estimate of roughly 170,000 has missed the mark by about 24,000, according to preliminary census data.

the future."[48] It seems certain to many that the consistency of Lubbock's water problem has to some extent retarded full realization of the city's potential economic development.

In an attempt to stay abreast of increasingly greater demands upon the city's water systems, a continued program of water resource development has been undertaken. Listed below in Table 6 is a summary of water rights acquired since 1950.

TABLE 6

CITY OF LUBBOCK GROUND WATER RIGHTS
ACQUIRED SINCE 1950

Date	Acreage	Location
1953	2,000.0	Two miles northeast of Shallowater, Texas
1953-54	53,901.1	Sandhill country of Bailey County
1957	21,130.8	Sandhill country of Bailey and Lamb Counties

Source: Gordon W. Willis, "Brief History of Water Supply for City of Lubbock," Lubbock, Texas, n.d. (Mimeographed.)

As of 1960 the city of Lubbock had 1,750,000 acre-feet of water available for pumping from its water rights districts (Figure 15). It is estimated that this volume of water should be adequate to meet the city's need through the year 2000. If, however, one concludes that Lubbock's present and

[48]Steglich, "Population Trends," p. 427.

UNDERGROUND WATER RESOURCES OF LUBBOCK, TEXAS

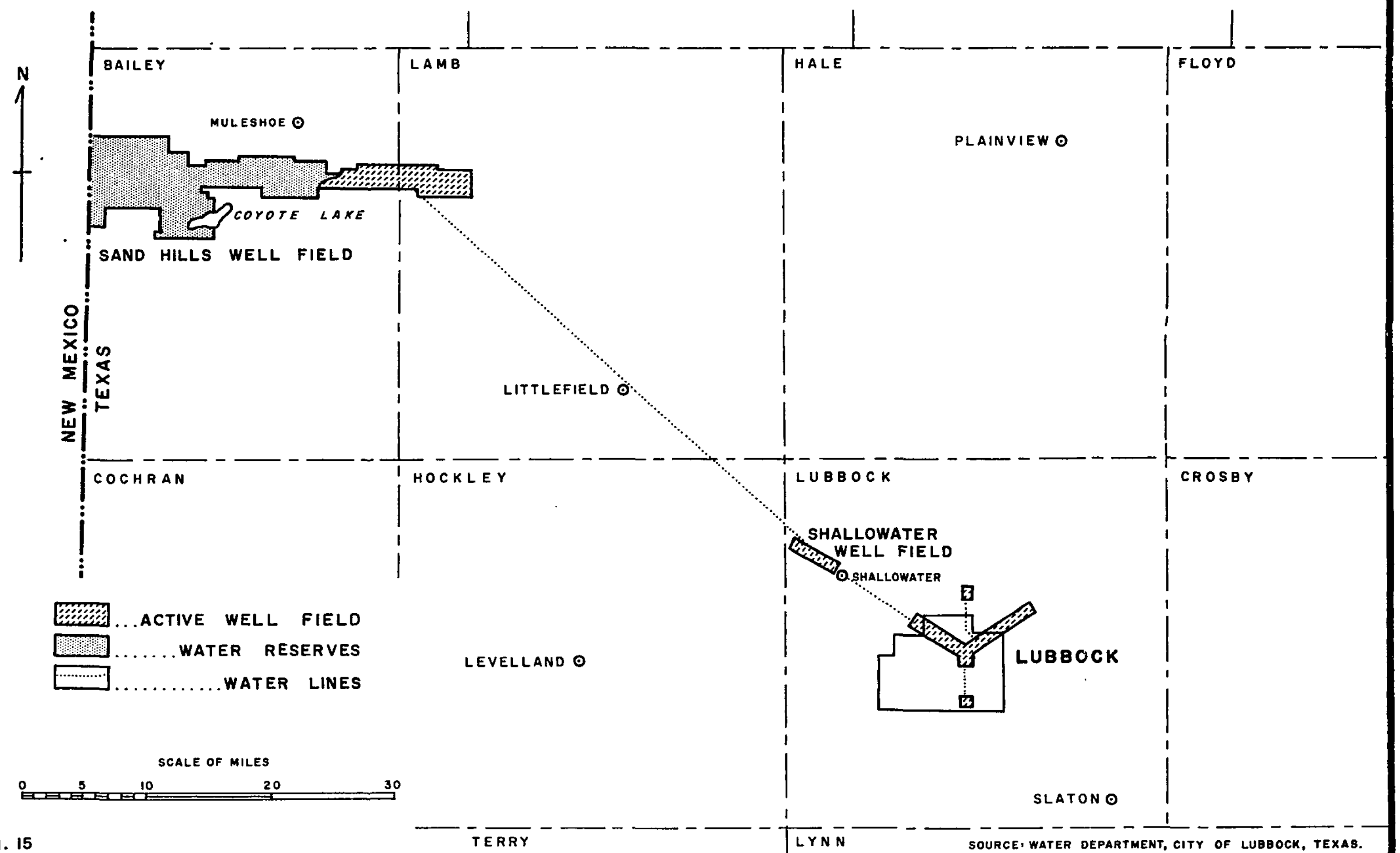

Fig. 15

SOURCE: WATER DEPARTMENT, CITY OF LUBBOCK, TEXAS.

future is tied primarily to agriculture, the average drop in the county's water table of thirty feet since 1947 is a very serious water problem not only for the irrigators but also for the city itself. With this in mind, the Canadian River Project has been of continued interest to the city as a means of supplementing ground water reserves.

The Smaller Cities

The general pattern of water development in the smaller cities has been similar to that of both Amarillo and Lubbock during the earlier period of their development. Therefore, no attempt will be made to provide equally comprehensive accounts of each community.

Borger.[49] The city of Borger was founded March 8, 1926, immediately following discovery of the Holmes-Huey gas well. Within six weeks the population climbed to an estimated 50,000 persons. Incorporation took place in 1930. During the early years of the depression the city dropped to its lowest population, around 5,000, but by the 1940 census it was showing strong growth trends. The official census for that year recorded 10,018 people as living in Borger. Mr. Spears, Borger City Manager, estimates that the city reached its peak size in 1958 when it had an estimated population of 25,000. By 1960 it had fallen to 20,911, and the preliminary

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[49]This section compiled from notes taken in a personal interview with H. S. Spears, City Manager, Borger, Texas, July 31, 1970.

census figures of 1970 show it with a population of only 13,928. Mr. Spears attributes the decline to the rather complete automation of the industrial functions of the Phillips Petroleum Corporation.

The first central water system in Borger was started in 1926 by the Panhandle Power and Light Company of Kansas City, the forerunner of the Southern Power and Light Company which now services the Panhandle region. In 1946 the distribution system was sold to the city by the utility company. Because the Southwestern Power and Light Company had purchased its water from the Phillips Petroleum Company, it became necessary for the city to contract with Phillips Petroleum for water at a rate of thirteen cents per one thousand gallons. During the 1950's the Phillips company began to have problems in furnishing all of its own needs, as well as those of Borger. The city was asked either to take over the problem of water supply or pay for new water sources at twenty-four cents per one thousand gallons. The city, feeling that the request was unreasonable, formed a committee to investigate the possibility of securing a water supply of its own.

By this time Borger was already deeply involved in promoting the Canadian River Project in addition to searching for its own ground water source. The search for available ground water rights was made more difficult by the competition of Amarillo for additional water rights in the general area. Ultimately, Borger was able to obtain water rights on 6,600 acres of land west of Stinnett, Texas. A bond election in 1961 approved an expenditure of $1,350,000 for the development of wells, and the transportation, treatment, and storage of water. Upon completion of the system, most of the people of Borger became independent of Phillips Petroleum for their water supply. A few scattered customer accounts are still supplied with water by Phillips through a private distribution system of the company.[50] These accounts are billed by the city, which in turn is billed by Phillips Petroleum.

Brownfield. Here, as elsewhere on the Great Plains, the windmill was the early unmistakable sign of life. The mill not only stood guard over the cattle, but was necessary for the survival of each shack or dugout. As with other areas of the Southern High Plains of Texas, the change from cowland to farmland took less than one generation and resulted in rapidly rising land values. The farmer, however, was under the constant threat of drought.

> Often the crop would be good until the hot July and August days came. Then the plants would begin to wither slowly until finally all would be dead. The drought drives away the weak and faint hearted . . . Even now when West Texans meet, much of their talk is on the last rain or the prospects for the next one.[51]

Early Brownfield, built on two tracts purchased from Dick Brownfield in 1903, had as its first public water supply

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[50] These areas include the residential districts of Phillips, Sanford, Buena Vista, and the Clearview Addition.

[51] Terry County Historical Survey Committee, Early Settlers of Terry, A History of Terry County, Texas (Hereford, Texas: Pioneer Book Publishers, Inc., 1968), p. 14.

a well, a windmill, and a public watering trough on the northeast corner of the courthouse square. Later a second well was drilled on the southwest corner of the block (Plate 7). Most of the early residents obtained their water supplies from these public wells until they were able to drill wells of their own.

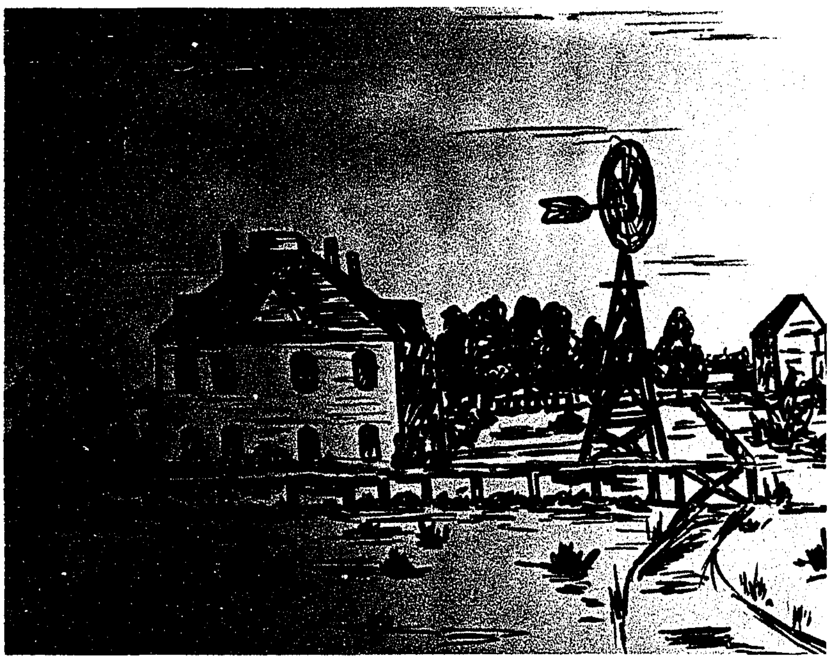

Plate 7--Terry County Courthouse and public well in 1907. (Drawing courtesy of Linda Vandever of photo supplied by Terry County Historical Survey Committee.)

Brownfield was incorporated in 1920 with a population of 1200, and six years later, the first municipal water system was installed.[52] The present water system includes eighteen working wells, which over a sixteen-year period have

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[52] *Ibid.*, p. 22.

experienced a static level drop of twenty-eight feet from the original water table reached at a depth of ninety-four feet. Brownfield has never experienced a serious water problem.[53]

Lamesa. Dawson County was devoted entirely to ranching until 1902 at which time farming began. The census of 1900 enumerated only thirty-six people in the county. Lamesa was established as the county seat on March 20, 1905. By 1970 its population had increased to 11,401.

During the early years of growth the limited ground water resources of the southern sector of the High Plains of Texas were generally adequate to meet the minimal needs of Lamesa and Dawson County. However, from the middle 1940's until the first delivery of water from the Canadian River Project in 1968, Lamesa endured a chronic insufficiency of municipal and industrial water. Water rationing became a way of life during most summer months from 1945 through 1954.

Agricultural use of ground water began in significant amounts in the Lamesa area in the post-war years of 1946-47, and peaked in 1957. Since 1957 a substantial acreage of land has been withdrawn from irrigation to be returned to either dry land farming or grazing land, resulting in a twenty-five per cent decline in the economy.[54]

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[53]Personal interview with Harold C. Jones, Water Superintendent, City of Brownfield, Texas, April 2, 1970.

[54]Personal interviews with C. A. Taylor, City Manager, City of Lamesa, Lamesa, Texas; and W. E. Sealy, Superintendent of Water and Waste Water, City of Lamesa, Lamesa, Texas, April 2, 1970.

Levelland. In 1912 Hockley City[55] in the vicinity of present-day Levelland existed only as a surveyed townsite. Eight years later in 1920, 137 citizens of the area petitioned for county organization. The first meeting of the Commissioner's Court, held on March 2, 1921, ordered the erection of a temporary frame courthouse and the drilling of a "well on the courthouse square with a fourteen-foot mill and a frame tower."[56] This well with its wooden storage tank was the principal source of public water supply for a number of years.

The Levelland area has experienced a sharp drop in the static water well levels since 1940. In that year the average depth to water was ninety feet. At present the static water level is between 130 feet and 150 feet below the surface. Prior to receiving water from the Canadian River it became necessary for several of the eight-inch wells to be converted to six-inch wells to more efficiently tap the aquifer.[57] While it is generally agreed that Levelland with its 1970 population of approximately 11,000 has no immediate problems of water supply, it is presumed that if projected city growth trends are realized, a problem of supply could

[55]In 1922 the town's name was changed to Levelland by members of the C. W. Post family, founders of the Post Food Company.

[56]O. R. Watkins, "The History of Hockley County," Levelland, Texas, n.d. (Mimeographed.)

[57]Personal interview with Cyres Humphreys, Superintendent of Water and Sewer, Levelland, Texas, April 29, 1970.

develop within twenty years.[58]

O'Donnell. During its early years, O'Donnell, like other cities in the Canadian River Project area, was largely supplied by private wells. In the 1920's a community water system was installed which gradually increased in size so as to include five wells. These are presently not used. Although O'Donnell has never had a serious problem of water sufficiency, some of the water pumped during the drought years of the early 1950's was not potable. Because of declining numbers, O'Donnell with an estimated 1969 population of 1,360 is unable to utilize all of the water presently available to it from the Canadian River Project.[59]

Pampa. The city of Pampa is located on land which was once a part of the holdings of the White Deer Land Corporation. The construction of the Santa Fe railroad through the area in 1888 determined the site of the town, which was laid out by Mr. George Tyng, Manager of the White Deer company. The townsite has been known at various times as Ontario, Sutton, and Glasgow prior to acquiring its present name. By 1910 the townsite was occupied by 500 people, all responsible for their own water supply. In 1912 the city was incorporated and a public water supply was begun.[60]

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[58] Personal interview with Jake Street, Manager, Chamber of Commerce, Levelland, Texas, April 29, 1970.

[59] Personal interview with Arlene Williams, City Secretary, O'Donnell, Texas, April 28, 1970.

[60] "Historical Development of Pampa," Pamp, Texas, 1968, (Mimeographed.)

Pampa at present, with a 1970 population of 21,239, has fourteen wells with an average static water level of 150 feet beneath the surface. These wells average 400 feet in depth. The aquifer in Gray County is apparently adequate to supply the city, although peak summer pumpage closely approaches the system's capacity. Pampa's Director of Utilities, Max Woffard, has indicated that as early as 1971 the city could experience a water shortage unless additional supplies are brought in.[61] Pampa is unique among the participants in the Canadian River Project in that an active minority of its residents has thus far effectively blocked the city's use of its allotment of water.

Plainview.[62] With the advent of the railroad in 1887, the town site of Plainview was staked out. Ranching supported the thinly populated area until about 1910 when the first irrigation well was brought in and farming begun to supplant ranching as the principal local activity. The city, incorporated in 1909, showed a population of 2,829 in the 1910 census. For the initial twenty-five years of its history the inhabitants of Plainview were responsible for supplying their own water needs.

The first municipal well was drilled in 1912, and at

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[61] Personal interview with Max Woffard, Director of Utilities, Pampa, Texas, July 30, 1970.

[62] This section is based largely on a letter from Meryl T. Walters, Supervisor, Water Production and Treatment, Plainview, Texas, January 15, 1971.

the same time the town was provided with a 50,000 gallon ground storage tank and an elevated storage tank of the same capacity. A second well was added in 1917, and a third in 1921 along with a 200,000 gallon ground storage tank. In 1935 the original well was abandoned and a three-well field was developed at Smythe and 12th Streets. This latter development included a 50,000 gallon ground storage tank and a 250,000 gallon elevated storage tank. Additional wells were added in the years from 1946 to 1968 so as to bring the current total to sixteen active and two standby wells.

Located at the center of what was once the best supplied ground water area of the Southern High Plains of Texas, Plainview has not experienced a serious water shortage. City officials, aware of the declining productivity of the Ogallala formation, felt that it was necessary to anticipate an increasing water demand in the future with supplementary supplies obtained from surface resources and became supporters of the Canadian River Project.

In February of 1969 a 4.2 million gallon per day water filtration plant was completed along with two 500,000 gallon elevated storage tanks. The city then began to use water from the Canadian River Municipal Water Authority. In 1970, with a population of 18,664, Plainview was the only Authority city to regularly mix well water and Canadian River water on a prescribed basis.

No attempt is made by the city to recycle the effluent of the sewage treatment plant. Solid waste is buried after digestion, and liquid effluent is discharged into a local draw after treatment.

Slaton. Slaton began its existence as a division headquarters town for the Santa Fe railroad on June 15, 1911. Incorporation took place the next year, on October 26, 1912. In 1970 the town numbered 6,150 inhabitants.

According to Alexander Webb, City Secretary, Slaton has never had a water shortage. The city has twenty-two wells, eighteen of which could be used if necessary. The city's treated liquid effluent is diverted to a city-owned municipal golf course and to a nearby farm. The farmer pays $1,900.00 per year for the effluent and uses it in irrigation.[63]

Tahoka. In 1883 the first permanent white settlers moved into Lynn County and leased large ranches on Texas public lands. Soon after the turn of the century these leases expired, making it possible for faster settlement of the Tahoka area. When the county was organized in 1903, Tahoka was founded as its county seat in the exact center of the county.[64]

Until the delivery of water by the Canadian River

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[63] Personal interview with Alexander Webb, City Secretary, Slaton, Texas, April 30, 1970.

[64] Personal interviews with J. M. Small, Executive Director, Chamber of Commerce, Tahoka, Texas; and Ross Smith, Federal Land Bank, Tahoka, Texas, May 1, 1970.

Municipal Water Authority in 1968, the city, which had a 1970 population of 2,860, was dependent on fifteen wells for its supply. Although the ground water supply has generally been adequate to meet the city's needs, there have been periods of low supply. During the drought years of the 1950's lawn watering restrictions were imposed--with the net result that water consumption increased.[65]

Early Efforts to Promote a Surface Water Supply

Since the 1920's there has been periodic interest in the development of surface water resources as a dependable supplement to the sparse rainfall and to the ground water resources of the Southern High Plains of Texas. At first the interest was mainly in securing additional irrigation water. Later, irrigation was eliminated from planning because the limited surface resources were considered insufficient and too costly to develop for this purpose.

Early interest in the waters of the Canadian River is recorded by Donald E. Green in his dissertation, "The Irrigation Frontier of the Texas Plains: 1910-1960." Green states that

> . . . in 1924 with the enthusiastic backing of Amarillo civic leaders, the Texas Board of Water Engineers surveyed the Canadian River for possible damsites for the purpose of flood control as well as irrigation. They [the Board] concluded that such sites did exist near Amarillo, but that no dam would be built on the Canadian

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[65] Personal interview with J. M. Uzzle, City Administrator, Tahoka, Texas, May 1, 1970.

in Texas until after the middle of the century, and even then the resulting reservoir would be used for municipal water supply and for recreation rather than for irrigation.[66]

Although interest in developing the resources of the Canadian River arose periodically, it was not until the "black dusters" of the depression and drought years of the 1930's that serious interest in exploiting surface water resources was renewed.[67] During this period irrigation agriculture became firmly established as the basis for the area's future economic prosperity (Table 7). The success of irrigation during the 1930's can be attributed to several factors. An advance in well installation technology, which reduced the average cost per well from between five and six thousand dollars to around two thousand, is considered one of the more important factors. Technology also produced pump systems that promised to be more efficient cost-wise and relatively trouble-free. In addition to the technological advances, the First National Bank in Lockney pioneered a "Turnkey" financing program which made it economically feasible for a farmer to consider irrigation as an alternative to the painful crop failures accompanying a prolonged

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[66]Donald E. Green, "The Irrigation Frontier of the Texas High Plains: 1910-1960," (Unpublished Ph.D. dissertation, University of Oklahoma, 1969), pp. 199-200.

[67]Beginning in 1931, with the exception of the years 1932 and 1939, there were nine consecutive years of below average rainfall. This has proved to be one of the most prolonged and severe droughts on the Southern High Plains of Texas.

drought.[68]

TABLE 7

NUMBER OF WELLS IN THE LLANO ESTACADO
1930-1940

Date	Approximate Number of Wells in Use	Acreage Irrigated
1930	170	-
1934	296	35,000
1936	600	80,000
1937	1,150	160,000
1940	2,180	250,000

Source: Donald E. Green, "The Irrigation Frontier on the Texas High Plains: 1910-1960," (Unpublished Ph.D. dissertation, University of Oklahoma, 1969), p. 203.

The general concern expressed by farmers over the need to develop water resources for agriculture during the depression years was fully appreciated by the majority of the farm market and service centers of the Texas High Plains. This concern was expressed in requests for surveys of the potential for water development and in the creation of conservation oriented organizations. The Panhandle Water Conservation Authority became especially active during the mid 1930's in its efforts to promote the development and conservation of the water resources of the Panhandle region of Texas. The efforts of this organization made a direct

[68]Green, "Irrigation Frontier," pp. 223-227. A "Turnkey" financing program is one in which the banker finances an installed irrigation system ready for operation.

contribution to the eventual creation of the Canadian River Municipal Water Authority.[69]

The Sanford Dam, Hutchinson County file of correspondence indicates a great deal of interest during 1939 in the initiation of a projected dam on the Canadian River at Sanford.[70] In a letter dated November 21, 1939, Mr. Carl Hinton of the Amarillo Chamber of Commerce provides one of the first concrete references to the promotion of the Sanford Dam.

> The budget of the Panhandle Water Conservation Authority is $10,000.00 for this year. This $10,000.00 budget would be sufficient for the prosecution and completion of the regular Small Lakes Program of the Panhandle Authority in 1940 . . . The reason I asked and obtained the permission of the Panhandle Authority to increase the budget from $10,000 to $15,000, was due altogether to the inclusion of the big dam at Sanford. That would be largely new work, and to guarantee any great measure of success, it would require my going to Washington the first of January, remaining there without ever returning to Amarillo until the closing days of Congress in June. . . . [it was] agreed that the burden of the Sanford Dam work should fall upon Hutchinson county and the private interests concerned in securing that dam. . . .[71]

In a letter dated December 21, 1939, reference is made to the general expectation that Congressman Marvin Jones would "introduce a bill in the early session of Congress,

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[69]Personal interview with John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas, July 31, 1970.

[70]Canadian River Municipal Water Authority, "Sanford Dam, Hutchinson County File," Sanford, Texas.

[71]Letter, Carl Hinton to Fritz Thompson, November 21, 1939, Canadian River Municipal Water Authority, Sanford Dam, Hutchinson County File, Sanford, Texas.

calling for the construction of the Childress Dam and the Sanford Dam."[72]

The concerned officials, however, felt that this act would be nothing more than authorization of the project and that funding would be very difficult, and so seemed reluctant to accept the responsibility for promoting an undertaking of such magnitude. Relationships between several of the principal promoters became strained during the latter part of December, 1939, and the early months of 1940. An additional problem arose when it was proposed that the route of State Highway 136 be changed so as to by-pass Sanford. The move was strongly opposed by the residents of the several communities in the general area because it was felt that the focus of the Rock Island railroad line and Highway 136 on Sanford as the place to cross the Canadian River was essential for the successful promotion of the proposed Sanford Dam.[73]

During this period, which was a time of great rivalry between Amarillo and Borger, the U.S. Army Corps of Engineers published a _Notice of Unfavorable Report on the Upper Sections of the South Canadian River, New Mexico, Texas and Oklahoma_.[74]

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[72]_Ibid_.

[73]Letters, Canadian River Municipal Water Authority, Sanford Dam, Hutchinson County File, Sanford, Texas

[74]U.S. War Department, Office of Division Engineer, Southwestern Division, _Notice of Unfavorable Report on the Upper Sections of the South Canadian River, New Mexico, Texas and Oklahoma_ (Little Rock: Corps of Engineers, January 26, 1940).

This report acknowledges that the study

> . . . authorized by the . . . House of Representatives of the United States adopted June 15, 1938 . . . is unfavorable to participation by the United States in the construction in any improvement for flood control for which the War Department is responsible.[75]

The unfavorable report was based on the belief that the cost of any proposed improvements for flood control alone was too great for what little benefit would be derived. The Board of Directors of the Borger Chamber of Commerce submitted a resolution on February 16, 1945, petitioning the U.S. District Engineer to re-examine the need for a dam at Sanford, Texas. Briefs prepared by the Pate Engineering Company of Tulsa, Oklahoma, in support of the construction of a dam at Sanford were submitted along with the request for further study. In an unpublished report dated September 16, 1946, it was acknowledged that there was a need for a dam and that favorable sites for such a dam did exist, but that the benefits still did not justify the expenditure.[76] In a letter dated January 8, 1949, Mayor L. R. Hagy of Amarillo requested that Governor Beauford Jester formally petition that the 1946 unfavorable report of the Corps of Engineers be withheld until a more detailed examination of the specific municipal and industrial supplies of interested cities could be made.

As part of an overall investigation of the Arkansas

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[75]*Ibid.*, p. 2.

[76]Canadian River Municipal Water Authority, "History of the Canadian River Project," a preface to Minutes of the Board of Directors Meeting, Sanford, Texas, 1954 (Typewritten.)

River drainage area, the Bureau of Reclamation began a study of the Canadian River basin in January, 1941. These investigations were suspended in 1942 because of the United States' direct involvement in World War II. In a "Statement of the Bureau of Reclamation" dated August 25, 1944, the Bureau reaffirmed that it had a "keen interest in development plans for the fullest utilization and control of water of the Canadian River for irrigation, flood control, municipal water supply, recreation and power. . . ."[77]

At the urging of representatives of Amarillo and Lubbock, the Texas delegation to Congress urged the Bureau of Reclamation to "expedite its investigation and report upon the feasibility of developing the Canadian River to provide municipal and industrial water supplies . . ."[78] The Assistant Secretary of the Interior in reply let it be known that if "local needs and interest . . . are made known"[79] the Department of the Interior would make such a survey.

On March 1, 1949 officials of Amarillo, Lubbock, and the Bureau of Reclamation met to initiate action directed toward determining the water requirements of interested cities. The Panhandle Water Conservation Authority was asked to assume the responsibility of leadership in the promotion of interest in developing the waters of the Canadian River.

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[77] _Ibid._, p. 5.

[78] _Ibid._

[79] U.S., Congress, House, _Canadian River Project in Texas_, H. Doc. 678, 81st Cong., 2d sess., 1950, p. 46.

On March 3, 1949, the Panhandle Water Conservation Authority sent letters to sixteen cities[80] requesting that they be represented at a meeting to be held at Plainview on March 7, 1949, to express public concern about the water shortage and to provide information on each city's anticipated need for municipal and industrial water. Specifically, each city was requested to:

1. State interest in the project.
2. Show annual water consumption.
3. Supply data on expected use by decades for a fifty-year period.
4. Indicate whether or not the demand would be for treated or raw water.
5. Determine whether or not the community would be totally dependent upon the resources of the proposed project for developing the waters of the Canadian River.[81]

The reports given at the Plainview meeting led to serious consideration of the feasibility of the Canadian River Project and they can be considered the earliest concrete step leading to its eventual implementation. The cities that responded provided the following assessments of

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[80] Cities included were Lamesa, Levelland, Plainview, Canyon, Tahoka, Lubbock, Kress, Panhandle, O'Donnell, Hale Center, Tulia, Borger, Brownfield, Abernathy, Pampa, and Happy.

[81] U.S., Congress, House, Canadian River Project in Texas, p. 47.

their domestic water supplies.[82]

Amarillo

Amarillo stated an interest in the project, declaring that municipal growth had been restricted because of the inadequacy of its present source of water supply. The city's representative reported that the city used 12,000 acre-feet of water in 1948 and estimated that future requirements would increase by fifty per cent each decade. It was felt that the city would be able to supply about 5,000,000 gallons per day.

Borger

Borger expressed interest in the project, providing that water could be obtained from it at rates equal to or lower than the rates being charged at that time by Phillips Petroleum Company. In 1948 the city had used about 2,500 acre-feet of water. Rather curiously, officials were predicting that the city would require between 3,000 and 3,500 acre-feet by 1950, although they were anticipating only a ten per cent increase each succeeding decade. Borger's representative expressed the intent to depend entirely on the project water. There was no interest in treated water due to the rather considerable industrial use in the city.

Dimmitt

Dimmitt's representative presented the community's

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[82] _Ibid._, pp. 48-51. The meeting was not restricted by invitation and several other interested communities sent representatives.

interest in the project. It was expected that the 1948 consumption of 200 acre-feet would double by 1958. It was pointed out that the city's wells barely met peak summer demands by pumping twenty-four hours per day.

Floydada

Floydada was expecting a ten per cent yearly increase in population and hoped to meet the increased demands for water through participation in the Canadian River Project.

Levelland

The city secretary of Levelland expressed an interest in the project. During 1948 the city used about 2,000 acre-feet of water and anticipated a need for 4,500 acre-feet in 1960, 6,000 acre-feet in 1970, and 8,000 acre-feet in 1980.

Littlefield

In addition to the oral statement of Littlefield's representative, the city expressed its official interest in this project through correspondence with the Bureau of Reclamation. In 1948 the city used about 1,000 acre-feet, and the spokesman stated that Littlefield was definitely interested in the purchase of treated Canadian River Water at a reasonable cost.

Lubbock

Approaching exhaustion of the city's local aquifer, led Lubbock's representative to express strong interest in the development of an alternate supply of water. The opinion was expressed that the city's growth was being restricted because of the inadequacy of its present source of water supply. Lubbock's anticipated municipal and industrial water requirements were expected to be:

1948, 9,000 acre-feet
1950, 12,500 acre-feet
1960, 19,500 acre-feet
1970, 27,000 acre-feet
1980, 35,000 acre-feet
1990, 46,000 acre-feet
2000, 50,000 acre-feet

O'Donnell

The representative stated that the city was very definitely interested in the project. It was pointed out that in 1948 the community used 200 acre-feet of water, but could have used an additional 100 acre-feet if it had been available. Data available showed that 200,000 gallons daily were needed but at times could not be produced. O'Donnell's strong support is evident in the statement

> . . . we are very much interested in this proposed Canadian Dam and aqueduct, and believe it is our only salvation if we are able to grow and expand as we desire as a city.[83]

It was indicated that with a sufficient supply of treated water, it could be expected that the community demand for

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[83] *Ibid.*, p. 57.

this water would increase about ten per cent yearly.

Pampa

Pampa expressed interest only if the cost of treated water was lower than the cost involved in the operation, maintenance, and expansion of the city's existent system. The city manager, Dick Pepin, explained that the city expected the existing wells to be adequate for seven more years, that is, until 1956, after which it would be necessary to rely on supplemental surface water supplies. Pampa's projected water use through the year 2000 was estimated to be:

1948, 2,000 acre-feet
1950, 2,600 acre-feet
1960, 3,700 acre-feet
1970, 4,800 acre-feet
1980, 5,900 acre-feet
1990, 7,000 acre-feet
2000, 8,200 acre-feet

Plainview

Mayor Winfield Holbrook, attending in behalf of the city of Plainview, presented the following answers to the initial inquiries of the Panhandle Water Conservation Authority. He indicated that the city during the preceding year used 2,438 acre-feet of untreated ground water, and added that future needs were uncertain. He further indicated that the city would prefer well water as long as it was available at an economical cost. By Mayor Holbrook's statement, Plainview went on record as not interested at that time in the development of surface water for municipal supply.

On March 8, 1949 five Plainview city officials transmitted a telegram of disavowal to the Bureau of Reclamation and printed it in the Lubbock Morning Avalache:

> The undersigned City Councilmen, the Board of City Development and the Chamber of Commerce (are) intensely interested in the possibilities of proposed Canadian River Dam project. Mayor Winfield Holbrook's statements at Plainview meeting March 7th misleading and without constituted authority and only his personal convictions. Please indicate when and how we shall act further in support of water conservation in the great Panhandle-South Plains region . . .[84]

Mayor Holbrook was later to become a strong supporter of the project.

Post

Post's representative explained that his community was interested in the project, but that its present supply was sufficient to furnish the city's current annual need for 800 acre-feet of water. Future needs were considered to be unpredictable at that time.

Slaton

Slaton's city commissioner expressed the city's interest in the project if delivery rates proved to be reasonable. In 1948 the city used 560 acre-feet of ground water. It was optimistically projected that use would increase ten

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[84] *Ibid.*, p. 58.

per cent yearly.

Tahoka

Tahoka's water supply was stated to be inadequate in fulfilling the city's 1948 needs of 800 acre-feet. A great deal of interest in the project was expressed.

Lamesa

Unable to send a representative, Lamesa, by a letter dated March 10, 1949, expressed strong interest in the Canadian River Project as a means of alleviating the city's chronic water shortage. In 1948 Lamesa used 1,500 acre-feet and estimated its future needs as follows:

1950, 2,000 acre-feet
1960, 2,600 acre-feet
1970, 3,200 acre-feet
1980, 3,800 acre-feet
1990, 4,400 acre-feet
2000, 5,000 acre-feet

The letter indicated an interest in a treated surface water source to supply the city's entire needs.

At mid-century the municipal and industrial water supplies of the cities interested in the Canadian River Project could be grouped together into three categories:

1. Amarillo, Lubbock, Borger, and Pampa were experiencing problems that were primarily of an economic nature. The Ogallala formation beneath

these cities is thick, and in 1950 there was still a considerable reserve of water available to be tapped. Because of the foresight and initiative of a few persons, these cities however, recognized that "complete dependence upon ground water may limit their future development or make the water thus obtained excessively costly."[85] It was realized by some that the continued heavy pumping for irrigation agriculture would produce declines in the local water tables, necessitating "periodic deepening of their wells and their eventual abandonment."[86] This local drawdown could probably be minimized by spreading wells over a large area, but such well dispersal would tend to make the costs of water supply development prohibitive. It was also recognized that heavy municipal and industrial pumpage would adversely affect the irrigation agriculture in the vicinity of the well fields, eventually bringing about a slowdown in the total economy.

The drought years of 1950 to 1956 proved that increased agricultural use would adversely affect the water supplies of the cities in the area. With the increase in the number of wells

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[85] Ibid., p. 7.

[86] Ibid.

during the decade of the nineteen-fifties, there was a significant change in the philosophy of the irrigator.[87] In the early years of irrigation development, the farmer used his ground water as a type of crop insurance at the last moment in the event that the rains did not come. During the nineteen-fifties there evolved a philosophy of maximum production every year, which seemed to require the application of large quantities of ground water almost without consideration for the contribution to crop success of the natural rainfall. One of the results of this philosophy was to heighten the concern of many urban residents for the future of the municipal and industrial water supply.

2. Plainview, Levelland, Littlefield,[88] and Slaton were also favorably situated in areas where the thickness of the Ogallala formation assures a long-lasting source of municipal water. Because of their smaller populations, these cities were not beset by a major problem of restrictive costs in maintaining an adequate supply of water. Because of some uncertainty about the

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[87]Green, "Irrigation Frontier," pp. 237-8.

[88]Littlefield's declared intent to participate in the Canadian River Project was later nullified by its electorate.

"inexhaustibility" of their ground water supplies, however, these cities also wished to be considered in any plan to divert water from the Canadian River.

3. Lamesa, Tahoka, and O'Donnell recognized that they were situated on the Llano Estacado in areas where the water-bearing Ogallala formation was quite thin and contained only limited quantities of water. These cities had virtually exhausted the water that could be "drained from the Ogallala formation"[89] and acknowledged that the current rate of withdrawal was not sufficient to meet even the present needs of these cities. They knew that they had soon to develop new sources of water supply if they were to continue in existence. These cities strongly supported the efforts to promote the Canadian River Project.

Because of the conditions just described, eleven cities of the Llano Estacado sought to develop the surplus waters of the Canadian River as an alternative to dependence upon ground water for their municipal and industrial needs. The fact that the water of the Canadian River is renewed annually and if properly managed could furnish a dependable water supply in perpetuity was not lost on early planners.

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[89] U.S., Congress, House, Canadian River Project in Texas, p. 8.

It was assumed that with a dependable source of surface water, municipal and industrial development could occur without the shadow of anticipated water shortages. The cost of water from a permanent surface water diversion also appeared likely to be more stable than the cost of water secured from well fields that periodically had to be expanded.

> Moreover, satisfaction of municipal and industrial water requirements from the Canadian River [they felt] would result in a corresponding reduction in ground-water withdrawals for those purposes, and would permit the use of an equivalent amount of ground water for irrigation.[90]

In the perspective of hindsight, it became apparent to many that election to participate in the Canadian River Project could be considered a progressive and highly desirable commitment on the part of the eleven Authority cities. The ultimate decision of cities to ask for inclusion in the project was not so much a matter of the promotional efforts of the organizers as a product of foresighted and active local individuals supported by their communities. A number of factors were involved in the election of several cities not to participate after having shown some initial interest. Among these factors were political conflict within an otherwise interested community, lack of public understanding of the full scope of the project, and plain apathy. These factors did not necessarily operate independently but were sometimes combined to produce an adverse climate within a

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[90] Ibid.

community.

Several towns that expressed little or no interest during the years of organization and construction of the Canadian River Project have since made inquiries about obtaining water from the Canadian River Municipal Water Authority. Unfortunately for those cities which are presently seeking water, the projected firm yield of 103,000 acre-feet has already been allocated among the eleven participating cities. Non-participating cities now expressing interest include Dumas (population 11,200), Hale Center (population 2,700), and Abernathy (population 3,000).[91] Dumas is presently well supplied with ground water, but there is a realization that the future of ground water pumping seems no more promising north of the Canadian River than in any other area where extensive ground water irrigation is well developed. Abernathy, on the other hand, is in an area of meager ground water supply and the present water table situation is already rather critical.

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[91] Personal interview with John C. Williams, July 31, 1970.

CHAPTER IV

THE CANADIAN RIVER PROJECT

History of Water Investigations on the Southern High Plains of Texas

Beginning about 1900, the United States Geological Survey sponsored a series of investigations concerning the water resources of the High Plains. In 1906, after extensive study, an Oklahoma geologist, Charles N. Gould, effectively refuted the theory that the Southern High Plains was an inexhaustible source of ground water, yet the notion was still widely held during the 1950's.[1] There has been less room for disagreement as to the amount of surface water available. The research program of the United States Geological Survey, Surface Water Branch, includes a collection of data on stream flow, water quality, and suspended sediments at a number of stations on the Canadian River. For some locations, these records date from 1904 (Table 8).

The United States Army Corps of Engineers, during the decade of the 1930's, began extensive investigations into flood conditions and related water problems of the Canadian

[1]Donald E. Green, "The Irrigation Frontier on the Texas High Plains: 1910-1960," (Unpublished Ph.D. dissertation, University of Oklahoma, 1969), p. 268.

TABLE 8

SUMMARY OF STREAMFLOW RECORDS OF CANADIAN RIVER AND TRIBUTARIES

Stream and Station	From	To	Supplying Agency	Accuracy of Record[d]
Conchas Reservoir	Dec. 1938	Sep. 1959	U.S.G.S.[a]	Probably good
	Sep. 1939	Dec. 1941	C. of E.[b]	Probably good
Canadian River below Conchas Dam	Apr. 1936	Dec. 1938	U.S.G.S.	Poor
	Jan. 1942	Sep. 1959	U.S.G.S.	Good
Canadian River at Logan, New Mexico	July 1904	Feb. 1905	St. Eng.[c]	Fair to poor
	Dec. 1908	Sep. 1909	St. Eng.	Fair to poor
	Dec. 1909	July 1910	St. Eng.	Fair to poor
	Jan. 1912	Apr. 1914	St. Eng.	Fair to poor
	Nov. 1922	Apr. 1923	St. Eng.	Unreliable
	June 1923	Aug. 1923	St. Eng.	Unreliable
	Jan. 1924	Dec. 1931	St. Eng.	Fair to poor
	Oct. 1930	Apr. 1934	U.S.G.S.	Fair
	Aug. 1934	Sep. 1959	U.S.G.S.	Fair to poor
Canadian River near Amarillo, Texas	Jan. 1924	Dec. 1925	U.S.G.S.	Poor
	Jan. 1938	Sep. 1959	U.S.G.S.	Poor
Ute Creek near Logan, New Mexico	Aug. 1904	June 1906	St. Eng.	Fair to poor
	May 1909	Dec. 1911	St. Eng.	Fair to poor
	Jan. 1912	May 1914	U.S.G.S.	(Gage heights only)
	Jan. 1942	Sep. 1959	U.S.G.S.	Fair to poor

Source: United States Department of the Interior, Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas (Amarillo: Bureau of Reclamation, 1960), p. 57

[a]United States Geological Survey

[b]Corps of Engineers

[c]New Mexico State Engineer

[d]Accuracy dependent upon quality and completness of record as determined by the United States Geological Survey.

River basin. In the fourth and last of a series of unpublished documents entitled "(South) Canadian River, Texas and Oklahoma" dated September 16, 1946, The Corps of Engineers reported that a flood problem did exist along the Canadian River in Texas and Western Oklahoma.[2] It was the consensus of the Corps that a large reservoir in the Texas Panhandle would provide considerable flood protection to the valley downstream. While it was acknowledged that two excellent sites existed at Tascosa, Texas, and Sanford, Texas (Figure 16), the report did not urge early development because it was felt that the "creation of a reservoir at either of these sites would not equal annual charges and recommended that the construction of neither project be undertaken by the United States at that time."[3]

Local interests submitted a technical brief asserting that the Corps of Engineers' report failed to include adequate consideration of the municipal and industrial water requirements of the Texas Panhandle and South Plains area. It was requested that submission of the report to Congress be deferred until further investigation could be undertaken.

As the agency primarily responsible for federal water conservation activity, the Bureau of Reclamation was requested early in 1949 by representatives of Amarillo and Lubbock,

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[2]U.S., Congress, House, Canadian River Project in Texas, H. Doc. 678, 81st Cong., 2d sess., 1950, p. 45.

[3]Ibid.

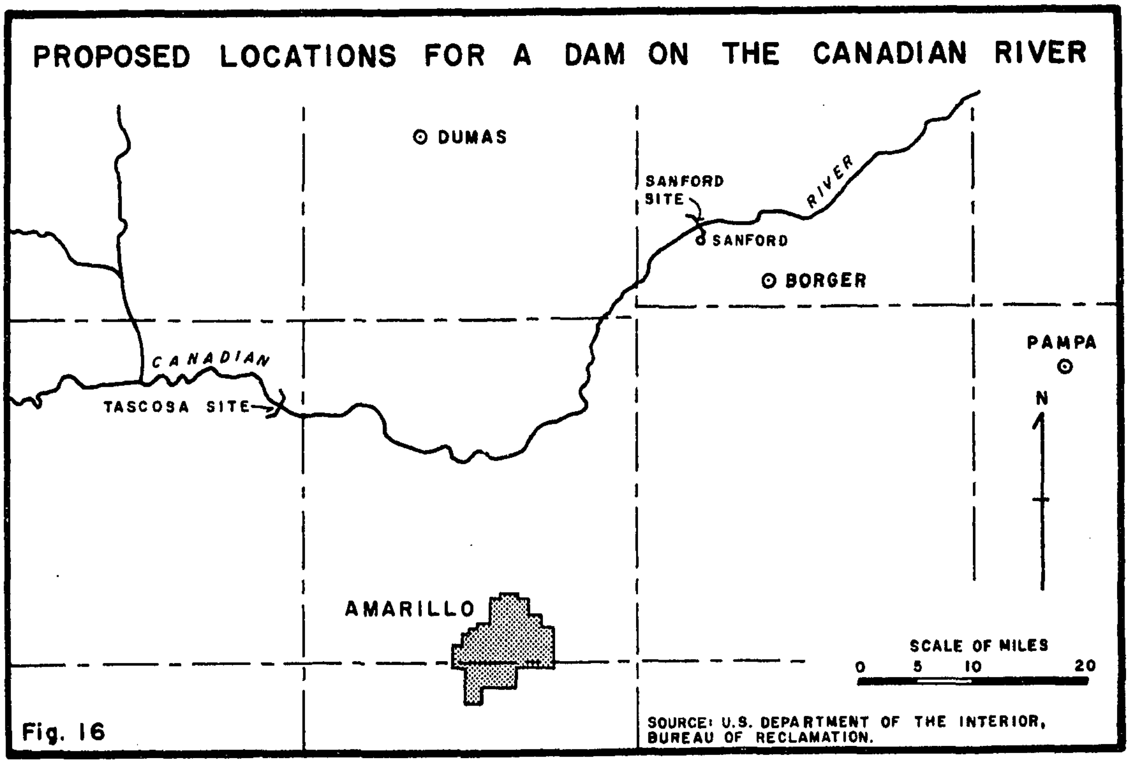

Fig. 16

acting through members of the Texas delegation to Congress, to expedite its investigation[4] of the Canadian River Basin in order to determine the feasibility of providing a surface water supply for the Panhandle-South Plains area of Texas.[5] The request was submitted in a letter, dated May 3, 1948, to Julius A. Krug, Secretary of the Interior, from Texas Congressman Eugene Worley. On May 24, 1948, Assistant Secretary of the Interior, William E. Warne replied that "the Department

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[4]Initiation of the Bureau of Reclamation investigations has been discussed earlier. These studies of the Arkansas River Basin were scheduled to be completed in July, 1951. (see *supra*, p. 102.)

[5]Canadian River Municipal Water Authority, "History of the Canadian River Project," a preface to Minutes of the Board of Directors Meeting, Sanford, Texas, 1954. (Typewritten.)

of the Interior will be glad to consider undertaking a . . . survey of the Canadian River if local needs and interests in such a survey are made known."[6]

Mayor L. R. Hagy of Amarillo then submitted a formal request to Governor Beauford Jester asking that the State of Texas request the Corps of Engineers to withhold its unfavorable report on the Canadian River until such time as it would be possible to more accurately assess the water supply requirements of the several interested cities of the Llano Estacado. Meetings were held on March 2, 7, and 21, 1949,[7] in Amarillo, Plainview, and Lubbock respectively to make community need for and interest in the Canadian River Project a matter of public record. A fourth meeting was held on March 22, 1949, this one between officials of the Bureau of Reclamation and representatives of Amarillo and Pampa, to further emphasize local interest in the project.

During March, April, May, and June of 1949, investigations necessary to complete a plan for supplying the water requirements of the interested communities were undertaken. A Project Planning Report was presented to representatives of the eleven[8] participating cities on June 17,

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[6]U.S., Congress, House, Canadian River Project, p. 46.

[7]Mention has been made earlier of these meetings designed to ascertain community interest in and need for the project. (see *supra*, p. 102.)

[8]Littlefield participated as one of the original planners, but was forced to withdraw when the city's tentative commitment failed to win the electorate's approval.

1949.[9] In addition to the establishment of an organization, The Canadian River Project Organization Committee, to promote authorization by Congress, the attendant representatives at this June meeting approved the proposal "that project water charges should be determined on a uniform basis for all the cities involved, regardless of their distance from the river."[10] This early approval of the uniform rate concept later became a major stumbling block in the way of the community cooperation needed for implementation of the Canadian River Project.

Preliminary plans were quickly assembled by the Bureau of Reclamation and compiled into House Resolution 2733.[11] Included were reports pertaining to the following aspects of water resource development:

1. Ground water potential
2. Sewage effluent available for irrigation
3. Stream flow records
4. Sanford site reservoir characteristics
5. Tascosa site reservoir characteristics
6. Problems of water rights
7. Irrigation and farm budget analyses
8. Plans and estimates for Sanford dam and reservoir

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[9]Canadian River Municipal Water Authority, "History of the Canadian River Project," p. 6.

[10]*Ibid*.

[11]U.S., Congress, House, *Canadian River Project*, pp. 58-165.

and distribution aqueduct system

9. Economic analyses
    a. National benefits
    b. Costs to the nation
    c. Allocation of construction costs
    d. Repayment alternatives
10. Statements of cooperating agencies
    a. U.S. Army Corps of Engineers (September 16, 1956)
    b. National Park Service (July, 1946, and April 13, 1949)
    c. U.S. Soil Conservation Service (April 14, 1949)
    d. U.S. Geological Survey, Ground Water Branch (May, 1949)
    e. Texas State Department of Health (May 3, 1949)
    f. U.S. Fish and Wildlife Service (May 10, 1949)

Representative Eugene Worley of Amarillo introduced House Resolution 2733 on July 8, 1949, to a sub-committee of the Committee of Public Lands which on July 21, 1949, made a favorable report to the House of Representatives.[12] On August 4, 1949, the House of Representatives approved the report whereupon, after minor modifications by the Bureau of

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[12]This section on the legislative process necessary for the project authorization is compiled from Canadian River Municipal Water Authority, "History of the Canadian River Project," pp. 5-9.

Reclamation, it was transmitted to the Secretary of the Interior for adoption on January 13, 1950. On January 19, 1950, the report was forwarded to the states of Texas, New Mexico, and Oklahoma, and to the Secretary of the Army, the Department of Commerce, the Department of Agriculture, and the Federal Power Commission.

Senate confirmation processes began on April 18, 1950, with a hearing on House Resolution 2733 before a subcommittee of the Senate Committee on Interior and Insular Affairs. After complete review by the appropriate authorities, the Commissioner of Reclamation re-submitted his formal report to the Secretary of the Interior on April 19, 1950. On May 3, 1950 the report was approved, adopted, and transmitted to President Harry S. Truman via the Bureau of the Budget. On June 19, 1950, the Bureau of the Budget advised the Secretary of the Interior that there would be no objection to legislation for authorization of the Canadian River Project providing such legislation were amended to be more specific about the process of repayment.[13] Oscar L. Chapman, Secretary of the Interior, formally transmitted the report to the Bureau of the Budget on June 23, 1950, and to the House of Representatives on June 28, 1950, with the recommendation that House Resolution 2733 as amended be enacted into law. The Project Planning Report for the Canadian River Project,

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[13] Personal interview with John C. Williams, General Manager, Canadian Municipal Water Authority, Sanford, Texas, August 1, 1970.

with attached letters of comment, was printed as House Document 678, 81st Congress, 2nd session.[14] Public Law 898 authorized the project and received the President's signature on December 29, 1950.

Public Law 898, 81st Congress, 2nd session, provided in part for:

1. Construction, operation, and maintenance of the Canadian River reclamation project including:
   a. Impounding dam and reservoir
   b. Main canals
   c. Pumping plants
   d. Distribution and drainage systems
   e. Other related work as necessary
2. The protection of water for beneficial consumptive purposes in New Mexico.
3. Defining non-reimbursable cost of the project.
4. Delaying commencement of construction until "Congress shall have consented to the Interstate Compact between the states of New Mexico, Oklahoma, and Texas. . . ."[15]
5. Delaying commencement of construction until an appropriate repayment contract be negotiated.

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[14] Canadian River Municipal Water Authority, "History of the Canadian River Project," p. 7.

[15] U.S., Congress, House, An Act to Authorize the Construction, Operation, and Maintenance by the Secretary of the Interior of the Canadian River Reclamation Project, Texas, Pub. L. 81-898, 81st Cong., 2d sess., 1950, H.R. 2733.

6. Operation and maintenance upon completion.
7. Transferal of title to pipelines and associated facilities upon payment of obligation.
8. Authorization of appropriations.

The Canadian River Compact Commission, composed of representatives of Texas, Oklahoma, New Mexico, and the United States, was organized on June 30, 1950. The compact was drafted, agreed upon, and signed by its members on December 6, 1950. Each of the three states directly involved had completed ratification by May 10, 1951. Federal ratification was provided on June 2, 1951, in Public Law 345 of the 82nd Congress, 2nd session.[16]

The central purpose of the Canadian River Compact was to promote tri-state cooperation and to provide a basis for agreement between the three states and the federal government in the development of water use and conservation on the Canadian River. The rights of each state were specifically stated to avoid future controversy. Article V of the compact gives Texas the exclusive right to impound up to 500,000 acre feet of water from the Canadian River. In the event Oklahoma should exceed 300,000 acre-feet of conservation storage downstream but west of the 97th meridian, Texas is permitted to enlarge its storage by an equal amount.[17] This

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[16] U.S. Department of the Interior. Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas (Amarillo: Bureau of Reclamation, 1960), pp. 17-23.

[17] Ibid., p. 19.

same article of the Canadian River Compact provided the legal right necessary for the impoundment of the waters of the Canadian River in Texas.

During 1952 the legal steps necessary to obtain approval by the Texas Board of Water Engineers for the formation of a Water Control and Improvement District were undertaken. The establishment of such an organization was necessary under Texas state law in order to legally contract with the United States for the construction and repayment of reimbursable project costs. Public Law 898 had empowered the Texas Board of Water Engineers to create the necessary water district, and the Board ultimately could not completely avoid taking the appropriate action. At a meeting on January 12, 1953, however, the Texas Board of Water Engineers deferred action because of the intense and eloquent opposition of an influential minority to federal funding of the proposed project.[18] The application was finally approved on March 11, 1953, at which time five temporary directors were appointed pending elections in the participating cities to ratify the water control district and to elect a permanent board of directors.

In anticipation of further delays by the Texas Board of Water Engineers, proponents of the Canadian River Project had a state senator introduce in the 53rd Texas legislature

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[18] At one of the earliest meetings of the Canadian River Project Organization Committee, the late historian and author J. Evetts Haley noted the considerable opposition to federal participation in the proposed Canadian Project and urged that all avenues of private financing be investigated.

a bill authorizing organization of a water authority.[19] Texas State Senate Bill No. 126 to establish the Canadian River Municipal Water Authority was passed by the Senate only six days after it was given the approval of the Texas Board of Water Engineers. Assent by the House of Representatives came on April 22, 1953, whereupon the legislation went to a joint conference committee on May 22, 1953. Following approval by the Texas Legislature and receipt of the Governor's signature on May 27, 1953, the Canadian River Municipal Water Authority superseded the Panhandle Water Control and Improvement District. Senate Bill No. 126 provided for:[20]

1. One director from each participating city except for two directors from each city with a population greater than 10,000.
2. Withdrawal and inclusion of additional territory within the Authority.
3. Broad authority to develop only surface water.
4. Equal and uniform water charges.
5. Authorization of the Authority to contract with the federal government, provided that "any such contract entered into as foresaid shall provide that upon the repayment of all amounts to become due thereunder, title to all facilities constructed pursuant thereto, including any dam or reservoir, shall pass to and be lodged in the District."[21]

In 1955 the State of Texas modified Senate Bill No. 126 to provide that

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[19]Personal interview with John C. Williams, July 29, 1970.

[20]U.S., Department of the Interior, _Definite Plan_, p. 24.

[21]_Ibid_.

> . . . the District shall be vested with absolute control over the release and use of waters stored in such facilities and belonging to the District . . . and . . . title to its water rights shall continue to remain in the district.[22]

This modification reconciled the principal differences between the State of Texas Law of Authorization and Public Law 898 which as passed by the federal Congress did not provide for the transfer of the title to the proposed dam upon completion of payment. In 1957 Senate Bill No. 126 was again modified to eliminate the provision that water charges would be equal and uniform throughout the district. This change in the law removed one of the greatest obstacles to the initiation of actual construction of the project.

On November 24, 1953, the twelve cities sponsoring the Canadian River Project held elections to confirm their participation in the project.[23] For the most part, opposition was light and not well organized except in Littlefield and Pampa (Table 9). The proposal to participate was defeated only in Littlefield, and that city chose to eliminate itself from the Canadian River Project.

At the first post-election meeting of the Board of Directors of the Project held at Plainview, Texas November 30, 1953, the Canadian River Municipal Water Authority came into

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[22] Ibid., p. 25.

[23] The original eleven sponsoring cities included Amarillo, Borger, Lamesa, Levelland, Littlefield, Lubbock, O'Donnell, Pampa, Plainview, Slaton, and Tahoka. On August 9, 1952, Brownfield also became an active participant in the project.

TABLE 9

RESULTS OF CANADIAN RIVER MUNICIPAL WATER AUTHORITY CONFIRMATION ELECTION, NOVEMBER 24, 1953

City	Votes for the Project	Votes against the Project
Amarillo	5,644	56
Borger	1,466	7
Brownfield	519	2
Lamesa	419	32
Levelland	194	1
Littlefield	77	178
Lubbock	1,853	71
O'Donnell	128	0
Pampa	675	423
Plainview	503	13
Slaton	192	2
Tahoka	217	8

Source: Canadian River Municipal Water Authority, Minutes of Meetings of the Board of Directors, meeting of November 30, 1953. (Typewritten.)

being as a legal political subdivision of the State of Texas. The seventeen-member Board of Directors was constituted by two members each from Amarillo, Borger, Pampa, Plainview, Lamesa, and Lubbock, and one member each from Brownfield, Levelland, O'Donnell, Slaton, and Tahoka.[24]

[24]Canadian River Municipal Water Authority, Minutes of Meetings of Board of Directors, meeting of November 30, 1953. (Typewritten.)

Period of Negotiation

Almost from the beginning, a series of problems arose to stalemate progress by the Canadian River Municipal Water Authority. Alternative methods of financing the project, and the equal and uniform rate provision, proved to be the biggest stumbling blocks.

On January 11, 1954, L. R. Hagy of Amarillo formally moved that all possibilities of private financing be explored.[25] Mayor Hagy's proposal had wide support among some of the staunchest proponents of the Canadian River Project. In the state of Texas there had long been an atmosphere of conservatism and genuine suspicion of contractual involvement with the federal government.

The assumption by some that the Authority could finance the project as a private venture led to internal dissension which for a time threatened the project's very existence. It soon became apparent to several of the participants that the interest rates, if private financing were used, would make the project impractical. It was then proposed that an attempt be made to organize the project as a joint undertaking involving both private interests and the federal government. After full consideration of the various alternatives to a total commitment to the federal government, the cities of Amarillo, Pampa, and Plainview withdrew from the

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[25] Canadian River Municipal Water Authority, Minutes of Meetings of the Board of Directors, meeting of January 11, 1954. (Typewritten.)

Authority in 1954, in protest to the obviously higher costs of private financing. It seems probable that their withdrawal was a tactical move to convince the remaining cities of the need for federal funding of project construction costs. At any rate, within a year or so it became evident that federal participation was the only practical option available, and the three cities rejoined the Authority.

Perhaps the major obstacle to be overcome by the Authority was the formulation of a mutually acceptable plan for sharing the repayment costs of the project. The provision of Senate Bill No. 126 stating that water costs must be equal and uniform[26] became completely unacceptable to the northern cities, which felt that such a plan would in fact cause them to pay part of the delivery costs to the more distant cities. After some negotiation it was agreed that the equal and uniform rate concept should be abandoned. In 1957 the basic law was amended to take note of this change.[27]

Financing the Project[28]

Once the uniform rate theory was dropped, negotiations proceeded on the basis of a scale of differentials. The main problem then became one of arriving at a graduation

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[26]<u>Supra</u>, p. 126.

[27]<u>Supra</u>, p. 127.

[28]This section was compiled from data presented in Canadian River Municipal Water Authority, "Summary of Repayment History--Canadian River Project," Sanford, Texas, n.d. (Typewritten.)

of rates that was acceptable to each of the Authority cities. A scale of actual proportionate costs made the cost of water to the southern cities unreasonably high. Meetings of the Board of Directors produced one impasse after another. Ultimately, it was urged that the city commissioners of Amarillo and Lubbock attempt to reach an agreement that would also be acceptable to the remaining nine cities.

Meetings were held periodically for two years before preliminary agreement was reached. It was the contention of the city of Lubbock during this time that Amarillo, because of its closeness to the dam, had an economic and recreational advantage for which it should be willing to pay a proportionately larger amount of the construction costs. In January, 1960, Amarillo accepted the Lubbock contention, whereupon full agreement was reached between the two cities in late May, 1960.

Under terms of the agreement, Amarillo consented to pay 162.5 per cent of its proportionate share of the cost of the dam and reservoir, and Lubbock agreed to pay 42.5 per cent of its share.[29] Both cities agreed to pay for their own pipeline and maintenance costs. Because of their proximity to the proposed reservoir, Borger and Pampa also agreed to pay a higher percentage of the cost, while Plainview agreed

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[29]A city's proportionate share of the cost of the dam and reservoir was based on each city paying the same percentage of the construction costs as the percentage of the water allotted to each city. See Table 10 for the percentage of the total firm yield allotted to each city.

to pay 100 per cent of its proportionate share. By these agreements, Amarillo, Borger, Lubbock, Pampa, and Plainview showed a willingness to pay for the entire cost of the dam and reservoir, thereby reducing the charges for the smaller cities in the more distant southern part of the Authority area to only their proportionate pipeline costs. Even with these adjustments, the representatives of Brownfield, Lamesa, and Levelland still considered the proposed cost of water too high. A final settlement was reached after a series of additional meetings during which Borger, Pampa, and Plainview consented to accept more water than their original commitment to the Authority, thereby eliminating what had been an anticipated surplus in the reservoir and increasing the expected annual revenues from the sale of water. Eventually, after still further negotiation, Lubbock, O'Donnell, Slaton, and Tahoka agreed to increases in their proposed water rates. These moves made a reduction in costs to Brownfield, Lamesa, and Levelland possible, and the adoption of repayment rates considered to be acceptable by the representatives of these cities (Table 10).

At a meeting held in Plainview in July, 1960, a table of rates per thousand gallons of water compatible with the Authority's anticipated obligation to the federal government was approved by representatives of each of the eleven cities (Table 10). Municipal elections were held November 22, 1960[30]

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[30]The city of Lamesa held its election September 5, 1961.

TABLE 10

SUMMARY OF NEGOTIATED DISTRIBUTION OF CONSTRUCTION COST AND RATES PER THOUSAND GALLONS OF WATER[a]

City	Distribution of Construction Costs: Dam and Reservoir Percentage of total	Dam and Reservoir Dollars[b]	Aqueduct Percentage or total	Aqueduct Dollars[b]	Rates Per Thousand Gallons of Water (in cents)	Use Commitment Percentage of Total Yield
Amarillo	60.216	16,972,782.84	15.132	8,569,847.80	12.79	37.06
Borger	13.146	2,705,397.29	1.792	1,014,880.21	12.79	5.55
Brownfield	0.000	—	5.573	3,156,209.48	28.50	2.19
Lamesa	0.000	—	5.913	3,348,764.87	28.50	2.18
Levelland	0.000	—	7.031	3,981,932.32	27.26	2.79
Lubbock	15.752	4,441,064.94	50.975	28,869,150.92	17.33	37.06
O'Donnell	0.000	—	.654	370,385.97	25.00	.28
Pampa	7.181	2,024,072.57	6.137	3,475,624.90	13.30	7.17
Plainview	3.705	1,044,309.83	2.700	1,529,226.38	13.95	3.69
Slaton	0.000	—	3.139	1,777,739.37	21.26	1.57
Tahoka	0.000	—	.954	540,287.78	21.76	.46
Total	100.00	18,186,000.00	100.00	56,633,940.00		100.00

[a] Calculated from: U.S., Department of the Interior, Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas (Amarillo: Bureau of Reclamation, 1960) p. 97, and Canadian River Municipal Water Authority, "Summary of Repayment History—Canadian River Project," Sanford, Texas, n.d. (Typewritten.)

[b] These values are approximate for known reimbursable costs as of June 30, 1968. Final settlement of the contract between the Canadian River Municipal Water Authority and the Bureau of Reclamation is still pending.

to determine whether or not the member cities of the Canadian River Municipal Water Authority should approve entering into contract with the Authority for a water supply (Appendix I). Results of the elections were overwhelmingly in favor of the project, and on November 28, 1960, Repayment Contract No. 14-06-500-485 between the Canadian River Municipal Water Authority and the United States was executed.[31] The basic contract

> . . . provides that the Authority's maximum repayment obligation shall be $92,960,000.00 plus interest during construction and annual interest on the unamortized balance of the cost allocated to municipal water. The term of the contract is for fifty years [and] provides for the Authority's operation and maintenance of the project at its own expense, except for reasonable cost allocable to flood control.[32]

Most foreseeable legal contingencies are covered in the contract. Supplemental and amendatory contracts have been executed to assign responsibility for public recreational work to the National Park Service and to adjust the allocation of costs accordingly.

> The contract [14-06-500-485] obligates the Authority to collect all monies to meet the obligation to the United States and to negotiate water supply contracts . . . with member cities. The contracts between the Authority

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[31]See Appendix II for the complete text of Contract No. 14-06-500-485 between the United States and the Canadian River Municipal Water Authority.

[32]Canadian River Municipal Water Authority, "Summary of Repayment History--Canadian River Project," Sanford, Texas, n.d. (Typewritten.) Based on Corps of Engineer records, $3,130,000 of the total construction costs were assigned to flood control benefits and considered non-reimbursable. (see Infra p. 171.)

and the member cities are assignable to the United States[33]

and obligate each city to pay a percentage of the reimbursable construction costs and the required operation and maintenance charges.[34]

Bureau of Reclamation Planning Resumes

In anticipation of eventual agreement on a specific plan for payment of reimbursable costs, the Authority formally requested, in September, 1957, that the Bureau of Reclamation initiate all action necessary for the construction of the Canadian River Project as a federal development to serve the Authority cities. In November, 1957, the Authority contributed $12,500.00[35] toward financing the necessary pre-construction investigations.

The Bureau's Definite Plan Report, which had been essentially complete in 1954, now underwent intensive review. Upon completion of the review and exhaustive post-authorization investigations, it was concluded that House Document No. 678 should be modified to show that:[36]

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[33] Ibid., pp. 2-3.

[34] See Appendix III for a representative contract between the Canadian River Municipal Water Authority and a member city.

[35] Bureau of Reclamation policy requires that the costs of pre-construction investigations be shared equally by the initiator and the Bureau.

[36] U.S., Department of the Interior, Definite Plan, p. 30.

1. The most serious drought on record (1950-56) had caused the projected firm yield of the project to be reduced from 134,000 acre-feet to 103,000 acre-feet annually.

2. Rising construction costs increased the cost of the project from an estimated $84,656,000.00 to $96,909,000.00.

3. The conservation capacity of Sanford Reservoir had been increased from 440,000 acre-feet to 500,000 acre-feet.

4. The aqueduct system had been extended from 275 miles to 322 miles to include Brownfield.

5. Irrigation and sewage effluent systems had been eliminated from the project plans.

6. The development of recreational facilities had been delegated to the National Park Service.

7. Fish and wildlife conservation measures were pending Presidential action as required by law.

Well and Pipeline Relocation[37]

Before construction could begin on the impoundment works at Sanford, Texas, measures had to be taken to protect the interests of eleven petroleum companies located in the vicinity of the proposed dam and reservoir. At a cost of about five million dollars, thirty-five producing gas wells and several pipelines were either protected in place or relocated. Utility services were also relocated.

Whenever possible in cases in which the wellhead was located at an elevation near the projected conservation pool

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[37]All data pertaining to well and pipeline relocations were obtained in an interview with John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas, March 30, 1970.

level of water, the head was raised and a riprap-protected dike with an access road was provided (Plate 8). In those

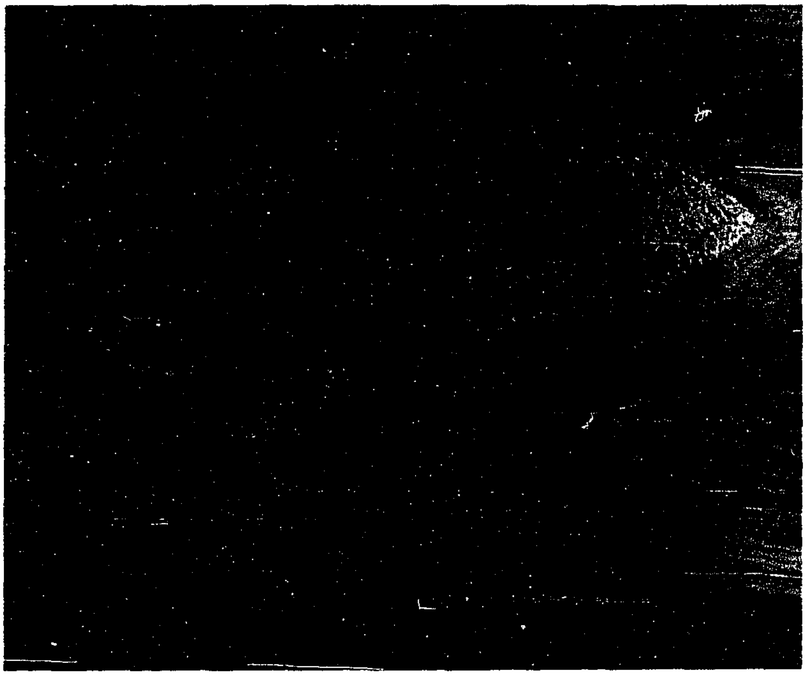

Plate 8--Gas wellhead protection dike.

cases in which the wells could be expected to be permanently covered by such deep water that protection became impossible, a replacement well of equal value was drilled for the company involved. In order that withdrawal continue in approximately the same location as with the original well, whipstock drilling was employed to direct the well from its altered surface location toward that point of earlier withdrawal beneath the surface. Because all relocated wells resulted in varying degrees of increased production, none of the petroleum companies involved have had any regrets about relocation. The drilling operations were contracted out by the Bureau of

Reclamation, and in some cases the oil companies were paid by the Authority to relocate their own wells.

Summary of the Construction Phase

Sanford Dam

The major construction contract for Sanford Dam was awarded on February 12, 1962, to the Zachary Construction Company[38] which began the first phase of the project on March 11, 1962.[39] Work on the dam proceeded for slightly over three years on the basis of two ten-hour shifts, six days a week. During the period of construction only one severe cold spell delayed the progress. In June of 1965, when construction was completed and the gates were closed, it started raining. During the months of June and July[40] an astonishing 12.27 inches of rain fell in the vicinity of the reservoir, making possible an impoundment of over 200,000 acre-feet of water during the first two months.[41] Contributing to the rather amazing collection of water in the initial months was the fact that both upstream dams on the

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[38] John C. Thompson, "Water Resource Development," Amarillo, Texas, 1962, p. 13. (Mimeographed.)

[39] Texas Water Development Board, Dams and Reservoirs in Texas, Historical and Descriptive Information by Cleo Lafoy Dowel and Seth Darnaby Breeding, (Austin: Texas Board of Water Development, 1967), p. 221.

[40] U.S., Department of Commerce, Environmental Science Services Administration, Local Climatological Data, Annual Summary with Comparative Data, 1968 (Washington, D.C.: Government Printing Office, 1969), p. 3.

[41] John C. Thompson, "Water Resource Development," p. 13.

Canadian River, at Ute and Conchas in New Mexico, were full.

Aqueduct System

The major contractor for pipe laying on the aqueduct system was the R. H. Fulton Company of Lubbock. Construction began "in early 1963 when the first of several contracts was let for 56 miles of 72-, 78-, and 96-inch concrete pipe, running from the dam to approximately 18 miles south of the city of Amarillo."[42] The contractor, by developing new equipment for trenching and laying pipe, made several substantial breakthroughs in technology that permitted a reduction in costs of more than $10,000,000.00 from earlier estimates (Plates 9, 10, and 11). Working under ideal conditions, improved equipment made it possible to install as much as 3,600 feet of 18-inch pipe and 1,600 feet of 66-inch pipe in a single day.[43] The aqueduct was finished by the fall of 1967, and by April, 1968, operational testing of the central system of the main aqueduct had been completed.[44]

The testing process demonstrated the need for minor modification of the Amarillo to Lubbock portion of the pipe structure. Several of the inverted U pipes (Plate 12) with

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[42] U.S., Department of the Interior, Bureau of Reclamation, Canadian River Project (Washington, D.C.: Government Printing Office, 1965).

[43] John C. Thompson, "Water Resource and Conservation Development," Amarillo, Texas, 1965, p. 13. (Mimeographed.)

[44] Personal letter from John C. Thompson, Acting Director, Bureau of Reclamation, Regional Office, Region 5, Amarillo, Texas, October 29, 1968.

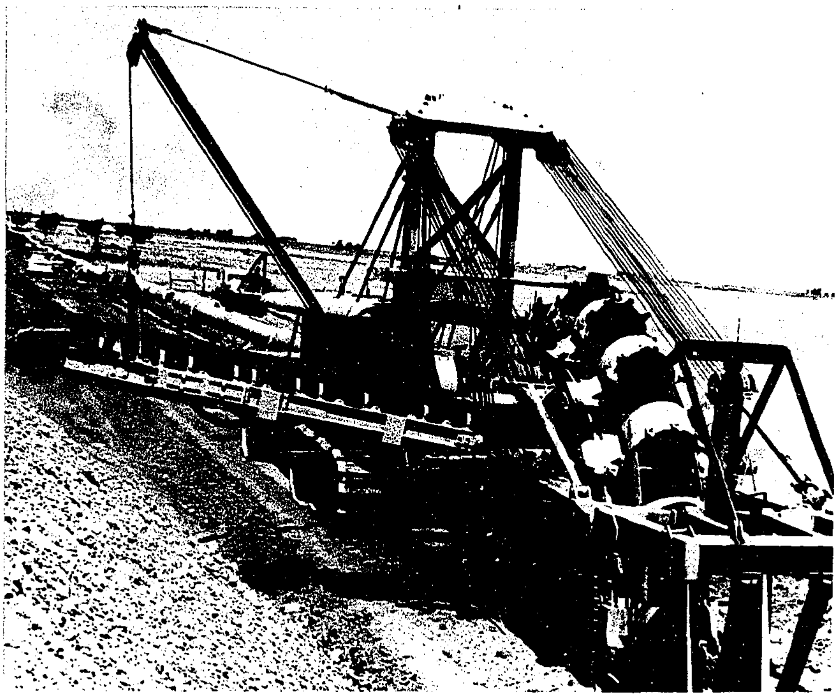

Plate 9--Wheel type trenching machine preparing a trench for eighteen-inch pipe. (Photograph courtesy of Bureau of Reclamation.)

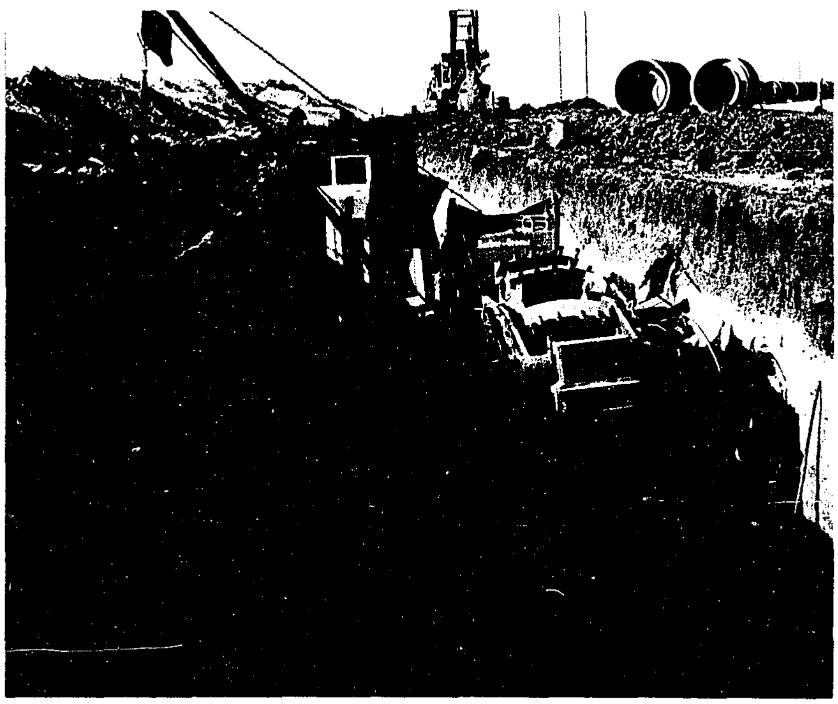

Plate 10--Excavating a deep cradle with a Barber-Greene trencher. (Photograph courtesy of Bureau of Reclamation.)

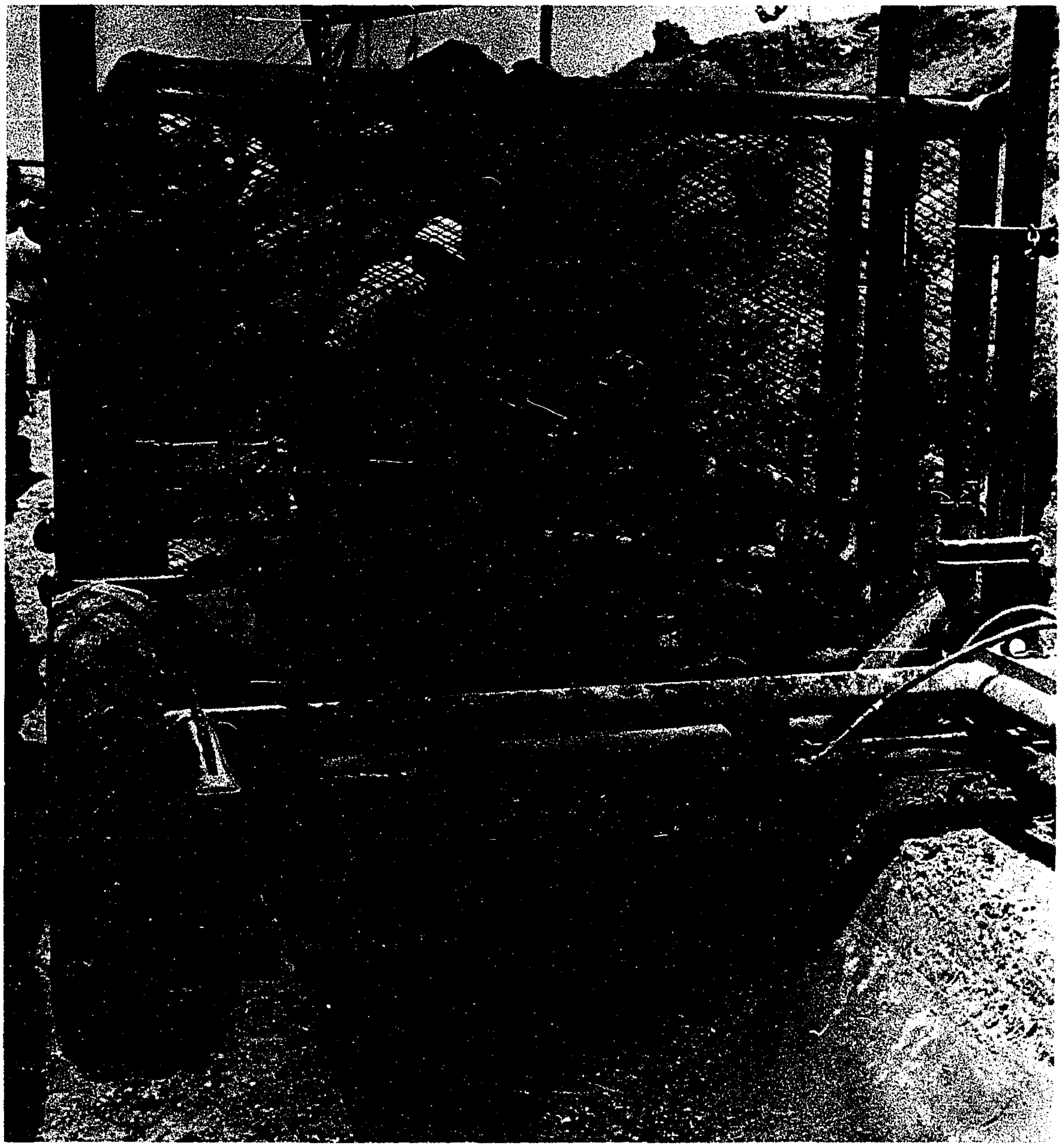

Plate 11--Machine designed to excavate for pipe bells. The machine is capable of digging a bell hole in about thirty seconds. This machine replaces five to six laborers formerly utilized for bell excavation. (Photograph courtesy of Bureau of Reclamation.)

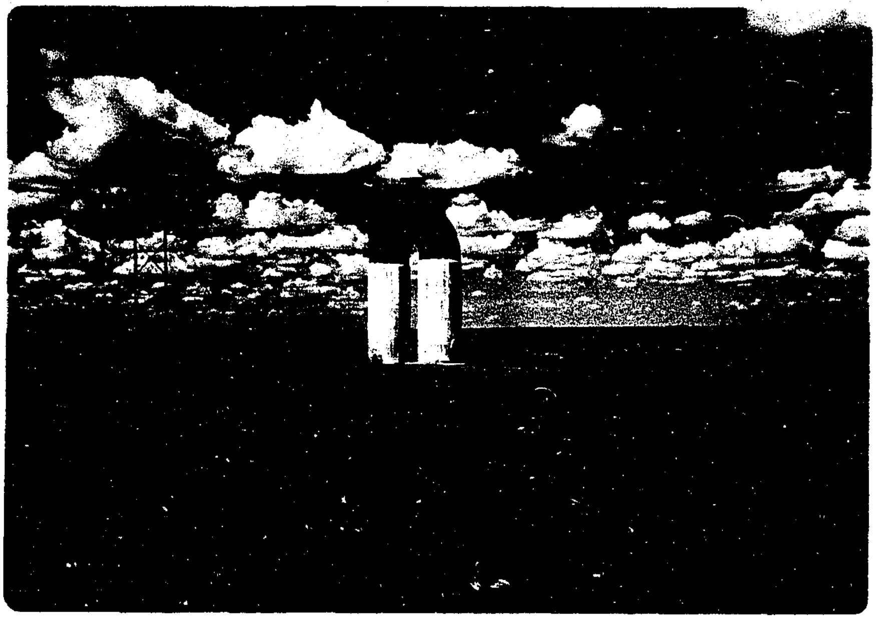

Plate 12--Inverted U Pipe with air vent on main aqueduct southeast of Amarillo, Texas.

top vents were converted into enclosed structures (Plate 13) to eliminate spray as water surged through the pipes.[45] The inverted U pipe was designed for use on the gravity-flow portion of the aqueduct to permit retention of water in the pipe throughout its length when the pumping stations were shut down.

Description of the Structural Features of the Canadian River Project

Sanford Dam

Sanford Dam, one of the two principal structures of the Canadian River Project, is a compacted earth-fill

[45]Personal interview with John C. Williams, March 30, 1970.

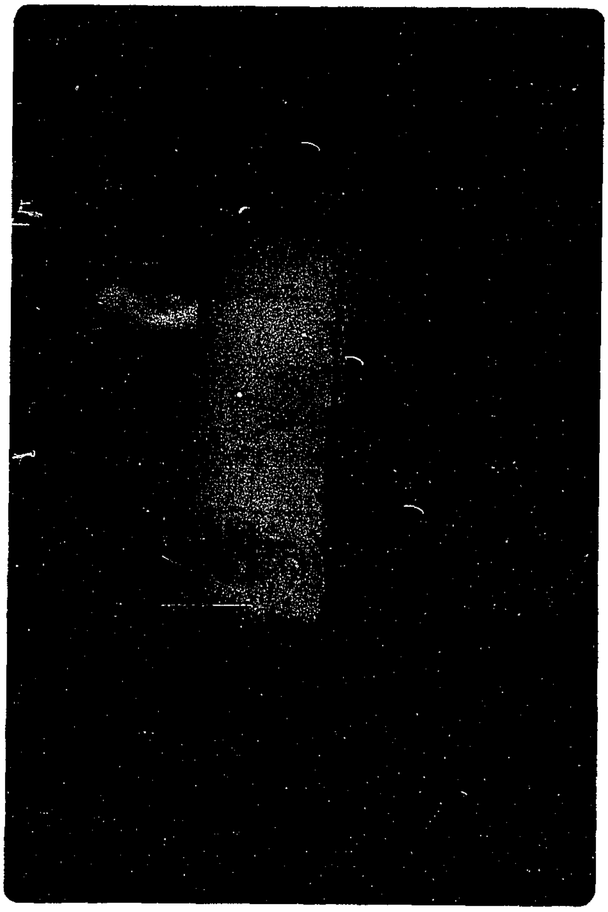

Plate 13--Covered regulator
tank on main aqueduct near Kress, Texas.

embankment located on the Canadian River about forty miles northeast of Amarillo, nine miles west of Borger, and nearly a mile northwest of Sanford, Texas (Figure 16).

Prior to construction the sandy flood plain of the Canadian River at the Sanford dam site was about 2,500 feet wide and marked by small shifting channels. Bluffs capped with dolomite rising steeply to a height of about 160 feet on both sides of the channel formed ideal abutments for the dam (Plate 14). The dam was designed with a crest length of

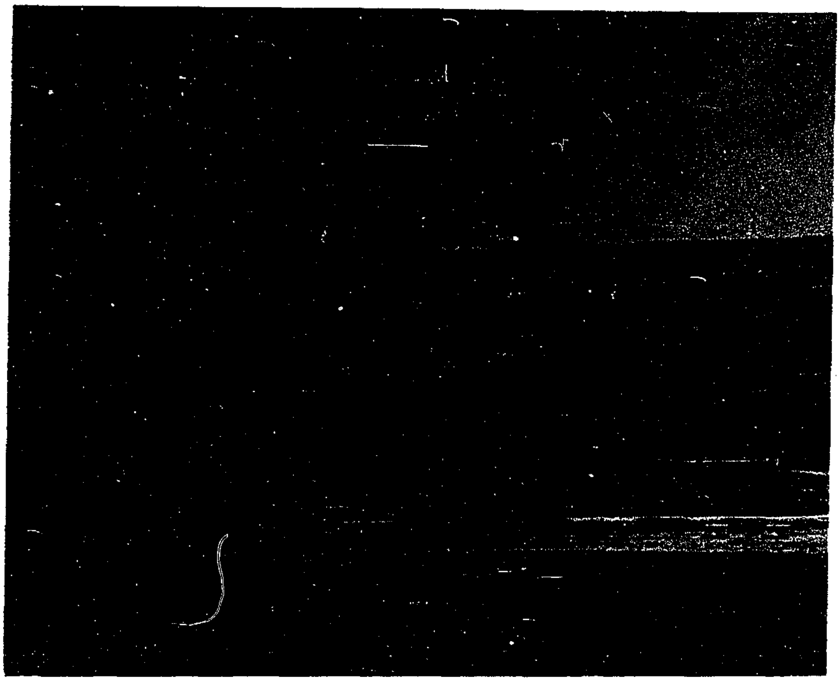

Plate 14--Steeply rising bluffs on both sides of the Canadian River channel as viewed downstream from the crest of Sanford Dam. (Photograph courtesy of Bureau of Reclamation.)

6,380 feet at 198 feet above the stream bed, and contains 15,500,00 cubic yards of earth material (Plate 15).[46] Its upstream face was protected from wave action by a four-foot layer of rock riprap quarried from the dolomite bluffs flanking the stream channel. The opposite face of the dam was "protected against erosion by a 24-inch layer of rock fill on the steeper slope and by grass cover on the flatter slope."[47] A cut-off trench was excavated in the sands of the

[46]U.S., Department of the Interior, Bureau of Reclamation, Factual Data Canadian River Project, Texas (Washington, D.C.: Government Printing Office, 1967).

[47]U.S., Department of the Interior, Definite Plan, p. 35.

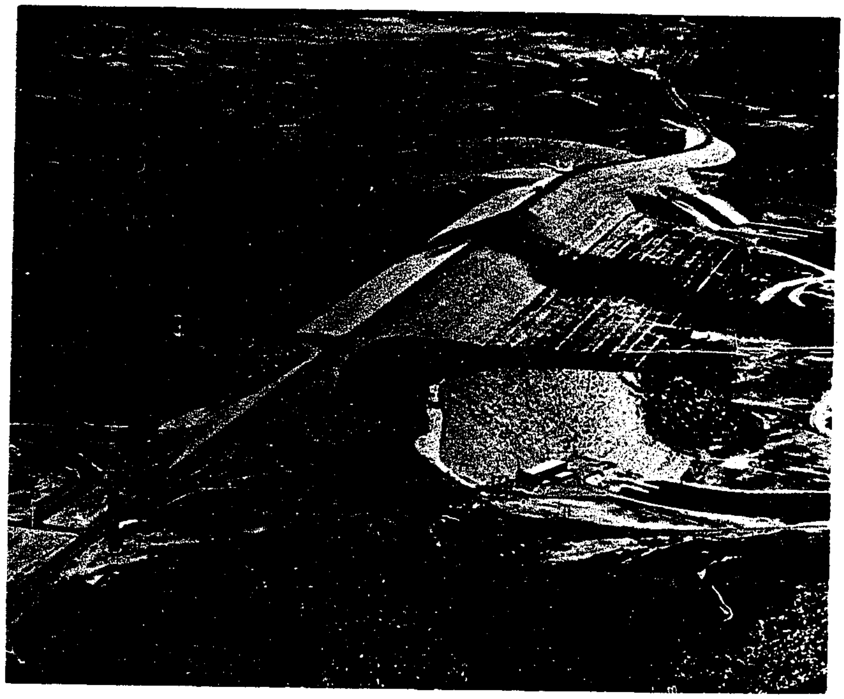

Plate 15--An aerial view of Sanford Dam (Photograph courtesy of Bureau of Reclamation.)

stream bed thirty feet deep and filled with compacted impervious earth materials to provide structural stability for the dam and to reduce downstream seepage losses through the embankment.

Structural appurtenances of the dam include a flood control outlet system, an uncontrolled spillway, and the river outlet works.[48] The flood control outlet system, located near the left abutment, consists of a vertical intake

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[48]The technical description and statistics pertaining to the dam, aqueduct, and associated engineering structures have been taken from U.S., Department of the Interior, Bureau of Reclamation, Factual Data, Canadian River Project, Texas (Washington, D.C.: Government Printing Office, 1967) and U.S., Department of the Interior, Bureau of Reclamation, Definite Plan Report, Canadian River Project, Texas (Amarillo: Bureau of Reclamation, 1960), pp. 35-42.

structure fitted with trash racks. It has a maximum discharge capacity of 26,400 cubic feet per second (Plate 16). Discharge is through a three-tubed tunnel, down a chute for 365

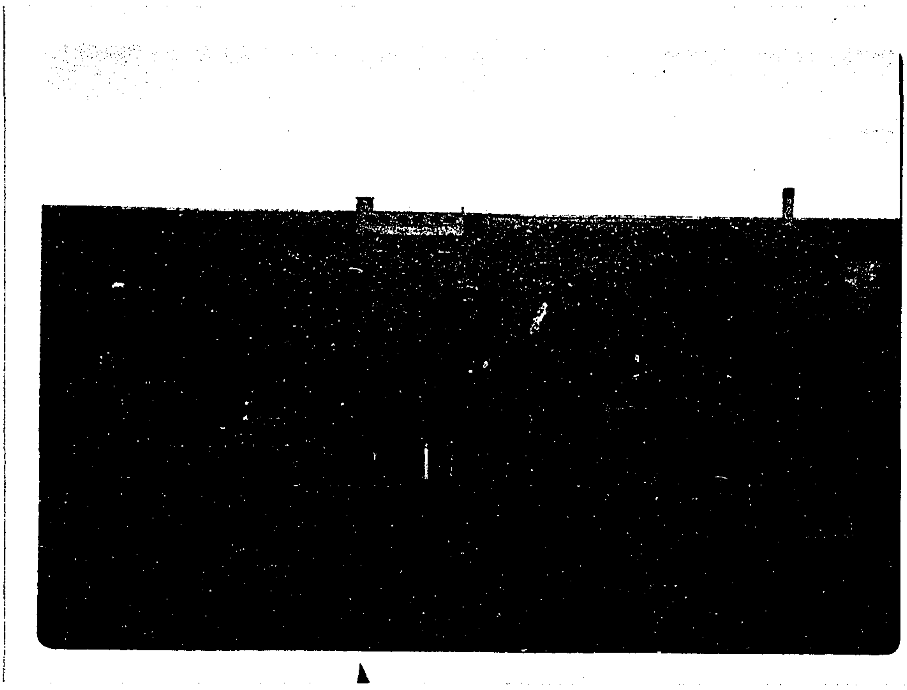

Plate 16--Vertical intake structures of the flood control system.

feet, and into a stilling basin which is 100 feet wide and 215 feet long (Plate 17). Reinforced concrete walls seventy-nine feet high channel the water from the stilling basin into the river outlet, thereby protecting the fixtures at the base of the dam. Each of the three outlet tubes can be operated independently to release water through a twelve-by-fifteen foot top seal radial service gate. An emergency set of fixed wheel gates has been mounted upstream from the service gates. Service access is gained through a control cubical which opens onto the crest of the dam. These fixed wheel gates

Plate 17--Flood control outlets, spillways, and stilling basins near left abutment of Sanford Dam.

allow for the release of water in the event of a major flood and serve to protect the dam from overflowing. They are worked periodically to check their operation. The actual release of flood water downstream is under the control of the U.S. Army Corps of Engineers through its district headquarters in Tulsa, Oklahoma.[49]

The Spillway, which is located directly adjacent to the flood control outlets, is a free-flowing morning glory drop inlet type with an intake structure having an outside diameter of sixty-one feet and a throat diameter of twenty-three feet (Plate 18). The spillway conduit has a maximum

[49]Personal interview with John C. Williams, Sanford, Texas, August 4, 1970.

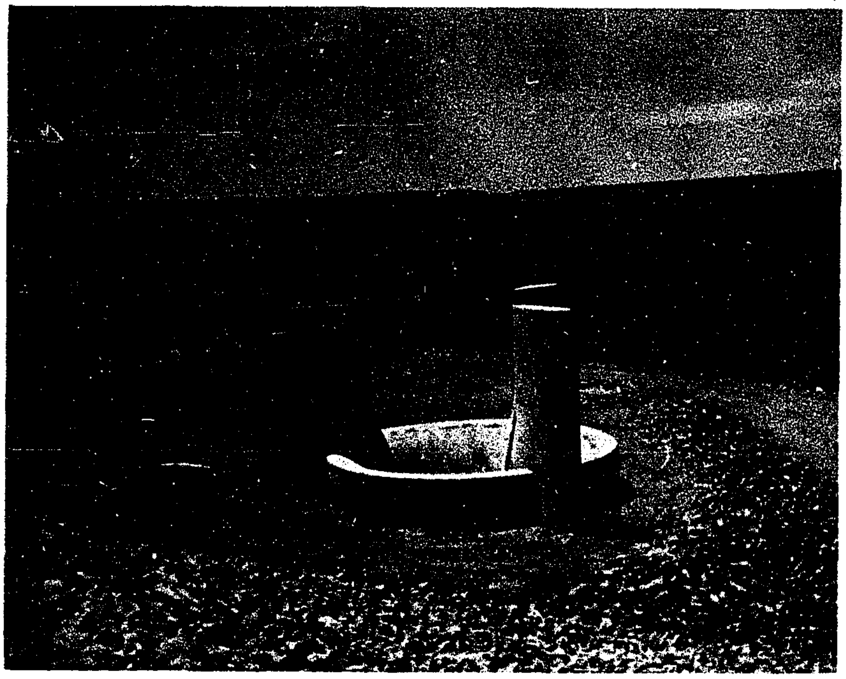

Plate 18--The uncontrolled morning glory drop inlet spillway of Sanford Dam. (Photograph courtesy of Bureau of Reclamation.)

discharge capacity of 19,300 cubic feet per second. It is so planned that the water passing through it is delivered by way of a chute to a stilling basin from where it is discharged into an outlet channel which it shares with the flood control outlets. This outlet channel

> . . . has a base width near the structures of 232 feet and a bottom elevation about 90 feet below the original ground surface. The channel widens to 600 feet and the bottom grade rises to original riverbed elevation at a distance of 1,115 feet downstream . . .[50]

Since construction, the basin has been used as a public swimming area managed by the National Park Service (Plate 19), but this use is temporary and will have to be eliminated

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[50]U.S., Department of Interior, Factual Data, p. 1.

Plate 19--Temporary recreational facilities for swimming in the outlet channel of the spillway and flood control works. (Photograph courtesy of the Bureau of Reclamation.)

as water reaches the elevation of the uncontrolled spillway. As water flows through the spillway, the current of water flow through the swimming area would make swimming hazardous.

The river outlet works serves a dual purpose, although its primary function is to divert water into the main distribution aqueduct for municipal and industrial use. It can also be used to release water downstream during flood times should this become necessary. One of the principal structures of the river outlet works is the multi-level intake tower (Plate 20). The intake tower is 198 feet high and has intake ports at five different levels thereby enabling the Authority to divert water from the optimal depth for the maintenance of quality. Water delivered to the aqueduct

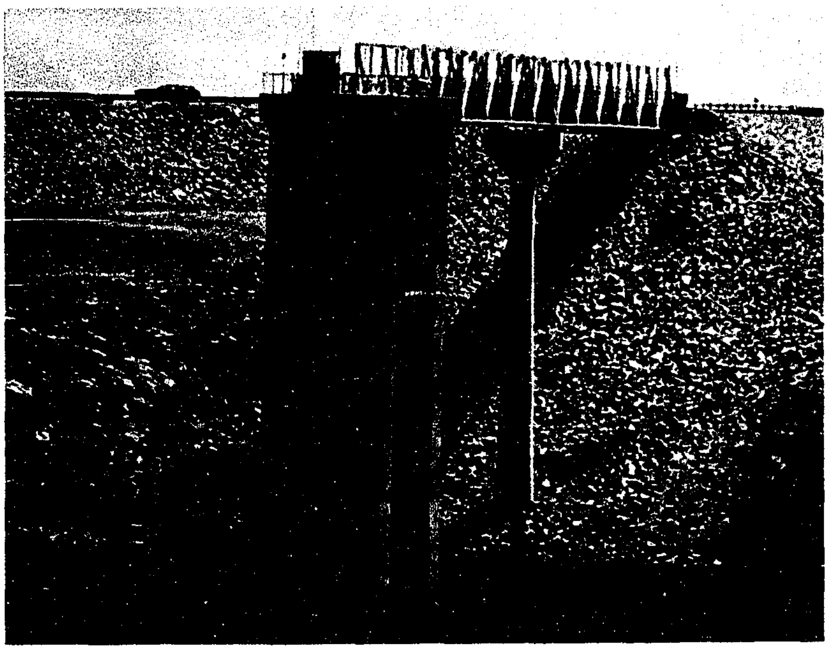


Plate 20--Multi-level intake tower of the river outlet works. (Photograph courtesy of the Bureau of Reclamation.)

system travels 480 feet through a tunnel twelve feet in diameter to the gate chamber. From the gate chamber, deliveries can be made through two gate-controlled conduits, one of 46-inch and one of 102-inch diameter. The two steel pipe conduits deliver water to the pumping plant (Plates 21 and 22) with any return flow to the river carried by the larger pipe. The two separate pipes will permit maintenance of the butterfly control valves without interrupting the flow of water to the Authority cities. The river outlet works have a total capacity of 3,400 cubic feet per second.

Aqueduct System

The aqueduct system, the second of the two principal

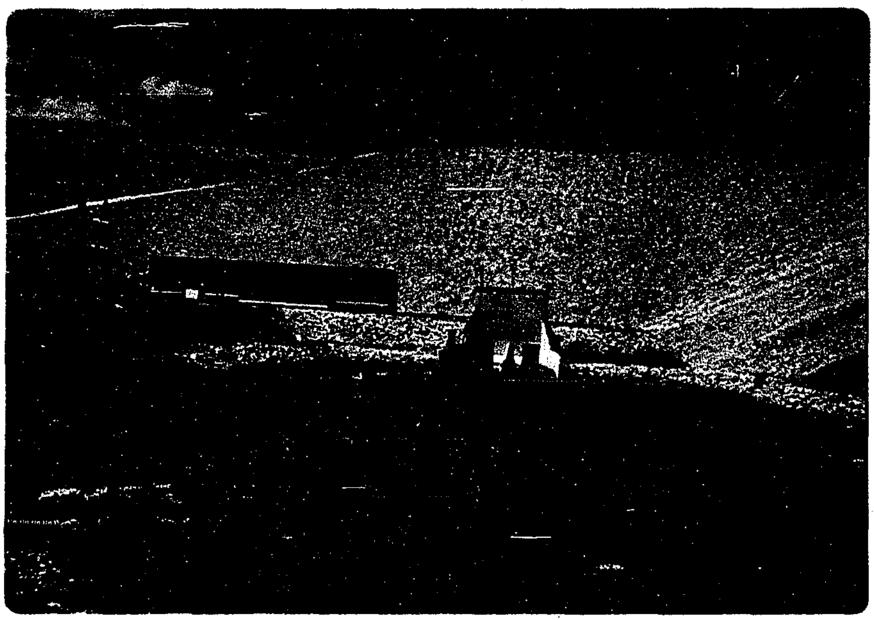
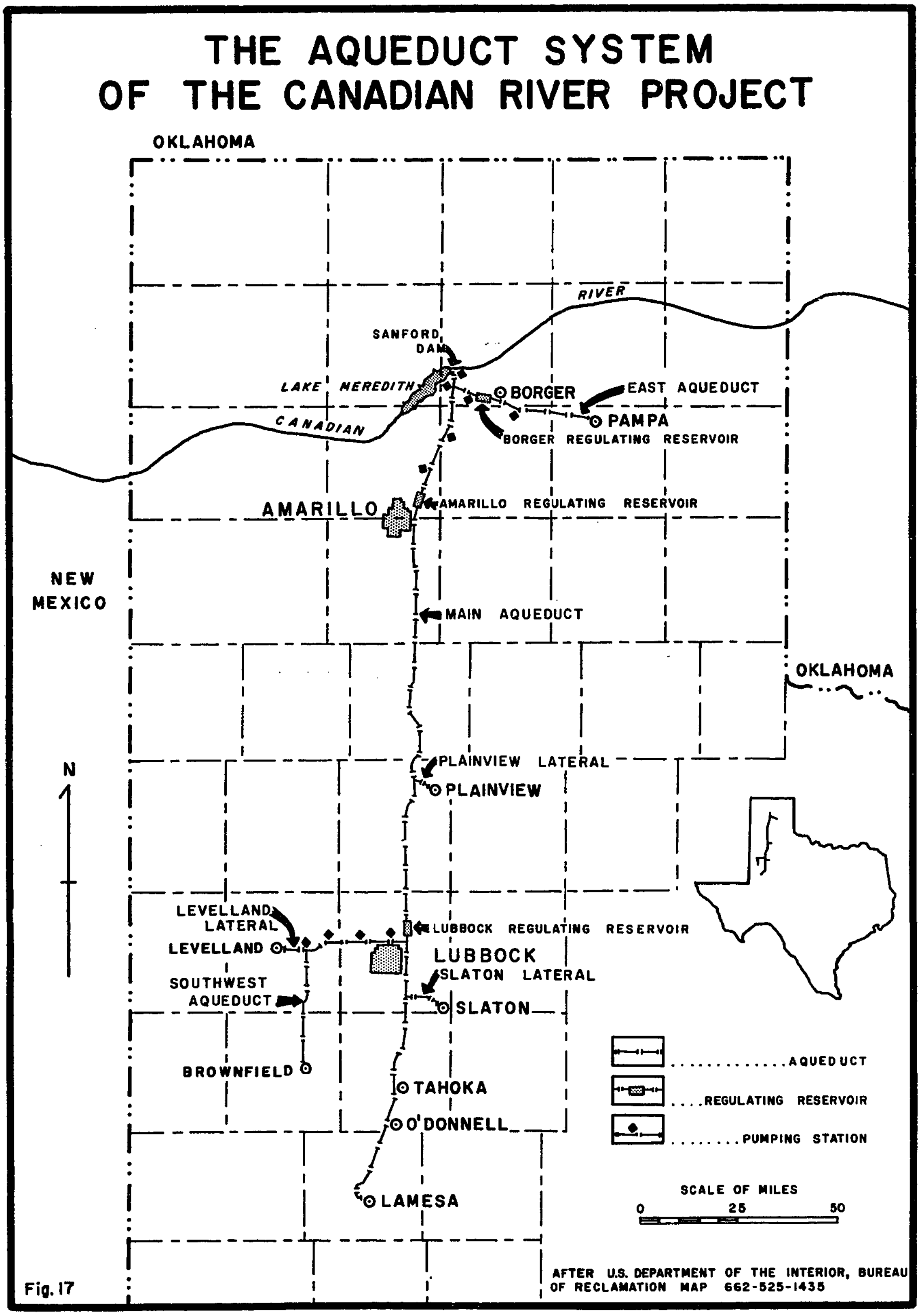


Plate 21--Water release structures opposite intake tower. The large building in the background is Pumping Plant No. 1. The smaller structure in the front of the pumping plant is a chlorination station, and the structure just to the right of center is the downriver discharge facility and stilling basin.

structures of the Canadian River Project, consists of 322.4 miles of pipeline, ten pumping stations, three regulating reservoirs, and chlorination facilities (Figure 17). Whenever possible, the system was routed so as to follow existing highways or railroads in order to facilitate access during construction. This placement was also expected to facilitate maintenance and minimize right-of-way costs. The pipeline consists of reinforced concrete sections varying in diameter from ninety-six inches near Sanford Dam to ten inches at the southern end of the line (Plate 23).

Each of the three pumping plants on the main aqueduct


THE AQUEDUCT SYSTEM
OF THE CANADIAN RIVER PROJECT
OKLAHOMA
RIVER
SANFORD DAM
LAKE MEREDITH
BORGER
EAST AQUEDUCT
CANADIAN
PAMPA
BORGER REGULATING RESERVOIR
AMARILLO
AMARILLO REGULATING RESERVOIR
NEW MEXICO
MAIN AQUEDUCT
OKLAHOMA
N
PLAINVIEW LATERAL
PLAINVIEW
LEVELLAND LATERAL
LEVELLAND
LUBBOCK REGULATING RESERVOIR
LUBBOCK
SLATON LATERAL
SOUTHWEST AQUEDUCT
SLATON
BROWNFIELD
TAHOKA
O'DONNELL
LAMESA
AQUEDUCT
REGULATING RESERVOIR
PUMPING STATION
SCALE OF MILES
0
25
50
AFTER U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION MAP 662-525-1435
Fig. 17

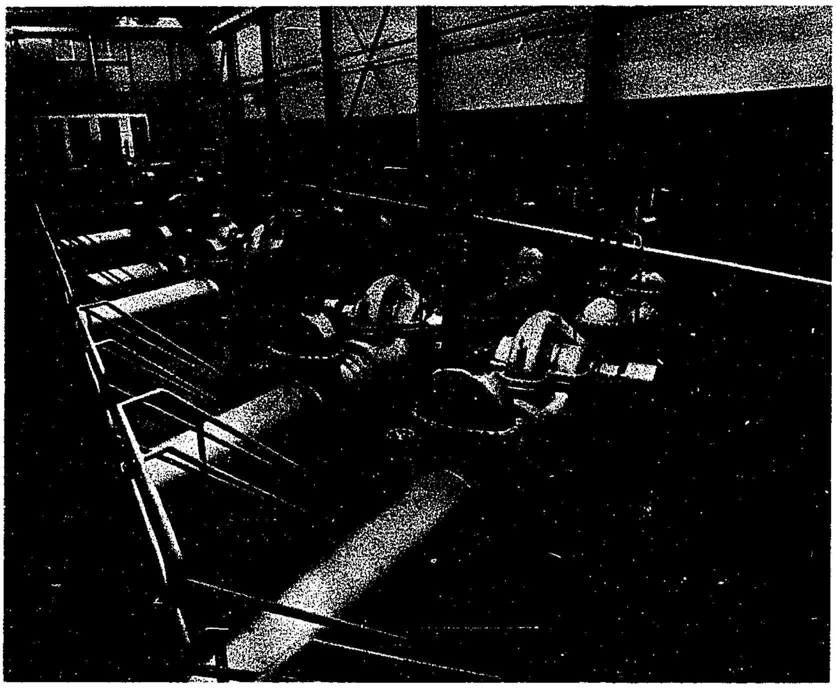


Plate 22--Interior View of Pumping Plant No. 1 near left abutment of Sanford Dam. (Photograph courtesy of the Bureau of Reclamation.)

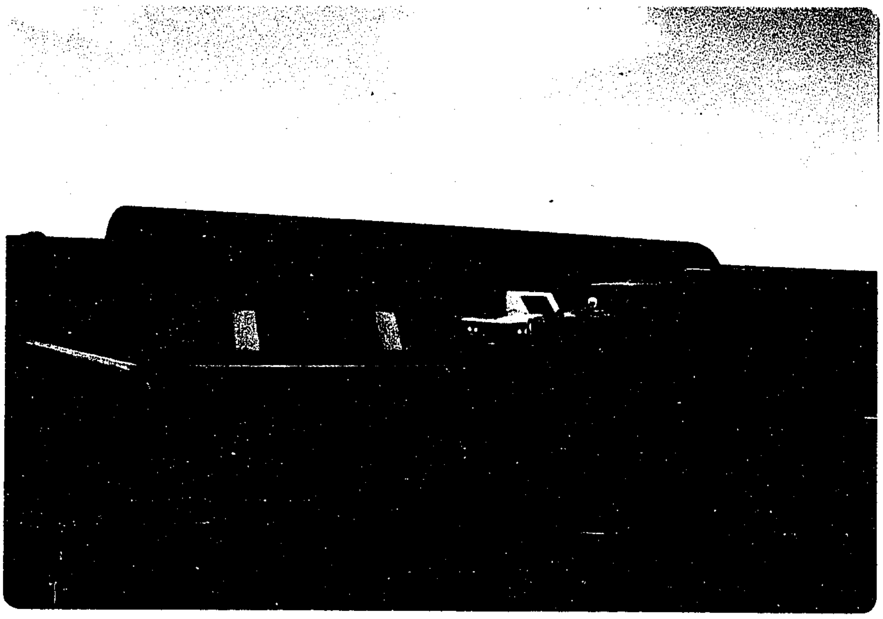


Plate 23--Two sections of reinforced concrete pipe on permanent display near Sanford Dam.

between Sanford and Amarillo has a forebay to permit free discharge from the preceding section of the system and to provide some emergency storage should there have to be a temporary shutdown of the system (Plate 24).

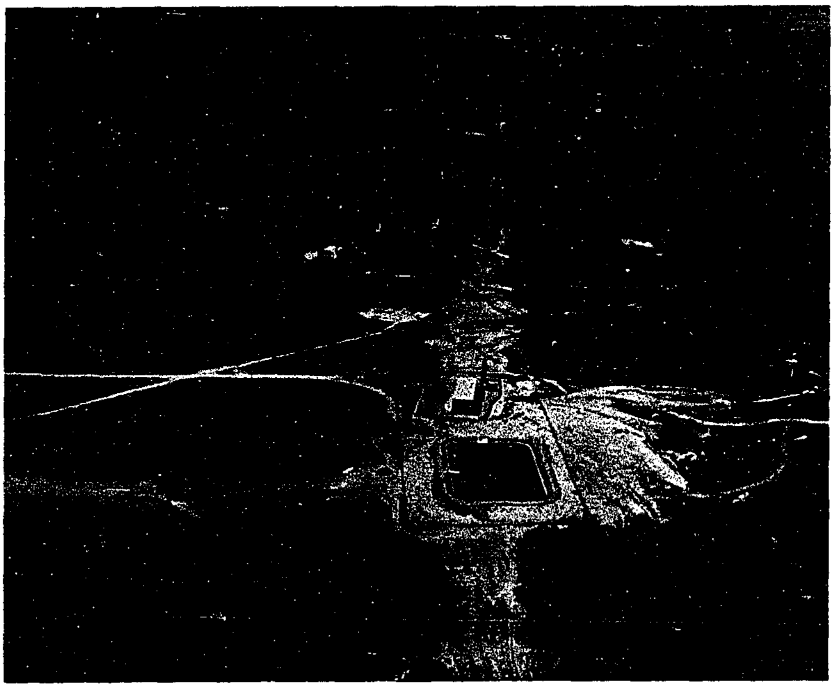


Plate 24--Aerial view of a forebay, pumping plant, and surge tank on the main aqueduct. (Photograph courtesy of Bureau of Reclamation.)

A surge tank is located within three thousand feet down-system from each pumping plant in order to absorb variations in line pressure which arise because of the changing rate of flow which results from starting and stopping the pumps (Plate 25).[51] The surge tanks vary in height from 75 feet

[51] Personal interview with John C. Williams, August 4, 1970.

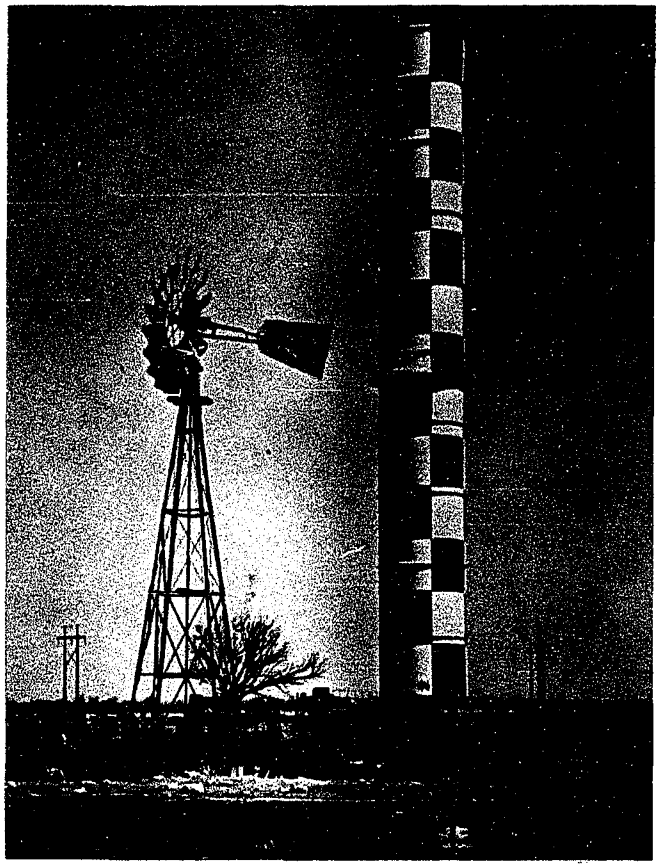


Plate 25--Surge tank and an old windmill along the main aqueduct near Fritch, Texas. This picture provides an interesting contrast between two eras of water development on the High Plains. (Photograph courtesy of the Bureau of Reclamation.)

to 192 feet and are highly evident structures of the Canadian River Project on the otherwise nearly featureless plains of west Texas.

Each of the ten smaller pumping stations is of a design similar to that at Sanford Dam (Plate 22). Each has a full-sized standby pumping unit to be used during maintenance of the regular system. The pumping stations are normally unattended except for periodic inspection and maintenance. An automatic remote control telemetering system is responsible for the routine operation of water delivery to the Authority cities.

Located near the cities of Amarillo, Borger, and Lubbock are large regulating reservoirs that serve as major balances in the operation of the water delivery system (Plate 26). Each reservoir is enclosed by a riprap-protected

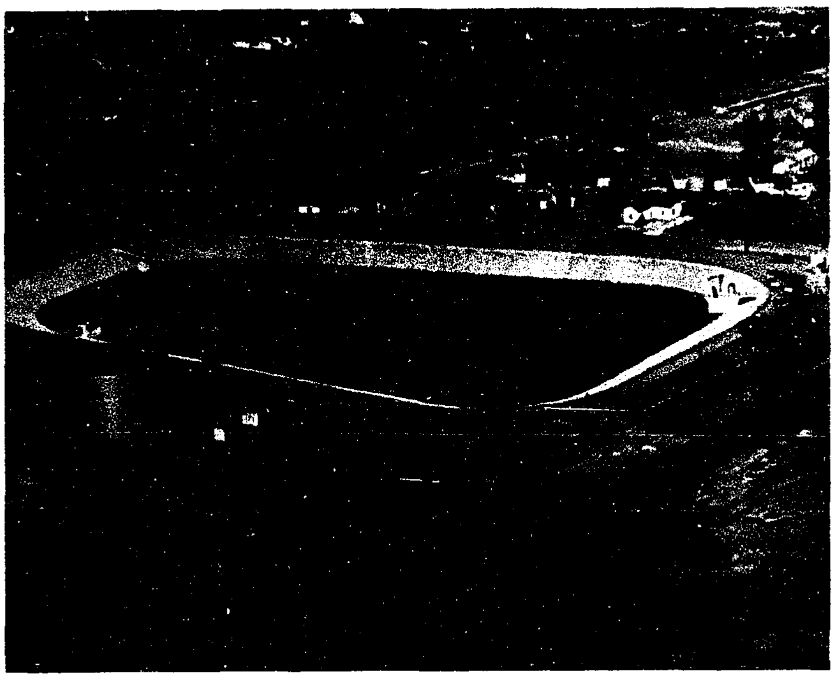


Plate 26--Borger regulating reservoir.
(Photograph courtesy of Bureau of Reclamation.)

ring dike of compacted earth and gravel (Plate 27). The bottoms of these reservoirs have been lined with compacted earth and soil cement. Each of them has a covered inflow structure and is protected against overflowing by an open uncontrolled outlet (Plate 27). Chlorination facilities have been located along the pipeline for the occasional addition

Plate 27--North portion of Amarillo regulating reservoir. The structure in the background is the receiving unit and the uncovered structure in front is the overflow outlet.

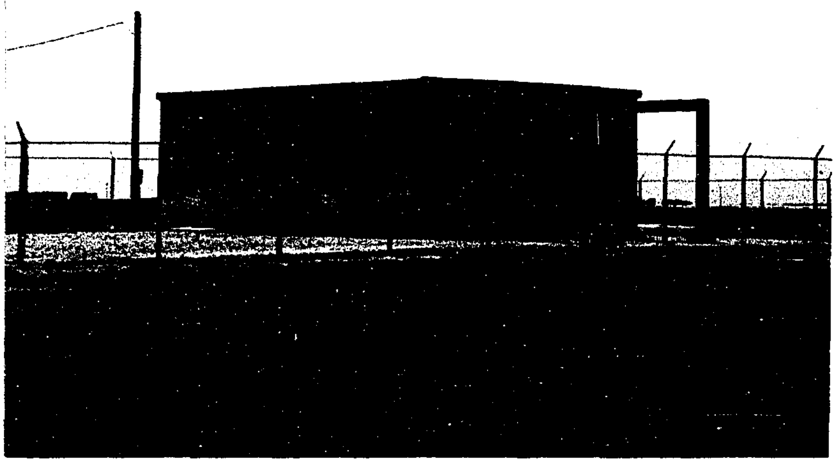


Plate 28--Main aqueduct chlorination building approximately one mile north of Kress, Texas. (Photograph courtesy of Bureau of Reclamation.)

of chemicals to the water for the prevention of algal growth within the aqueduct (Plate 28).

General Operation of the Project[52]

After successful operational testing of the aqueduct was completed, the Canadian River Municipal Water Authority assumed operation and maintenance of the entire water delivery system on July 1, 1968.[53] The Authority headquarters is in an attractive building located on the right bank overlooking the reservoir and dam (Plate 29). In addition to administrative offices, the maintenance shops, a water analysis laboratory (Plate 30), and an operational control center (Plate 31) are housed in the building at the dam site.

Water for municipal and industrial use is diverted from Lake Meredith[54] through the intake tower at whatever level under prevailing conditions insures the highest quality water. The water is transported by gravity flow to the pumping plant where shortly before entry it is divided into four separate channels. Water flow through these four pipes is

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[52]Information presented here pertaining to the operation of the project is based largely on notes taken during interviews with John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas during March, April, May, July, and August, 1970.

[53]Personal letter from John C. Thompson, October 29, 1968.

[54]A. A. Meredith, former city manager of Borger and the first secretary of the Canadian River Municipal Water Authority, was one of the strongest supporters of the project until his death.

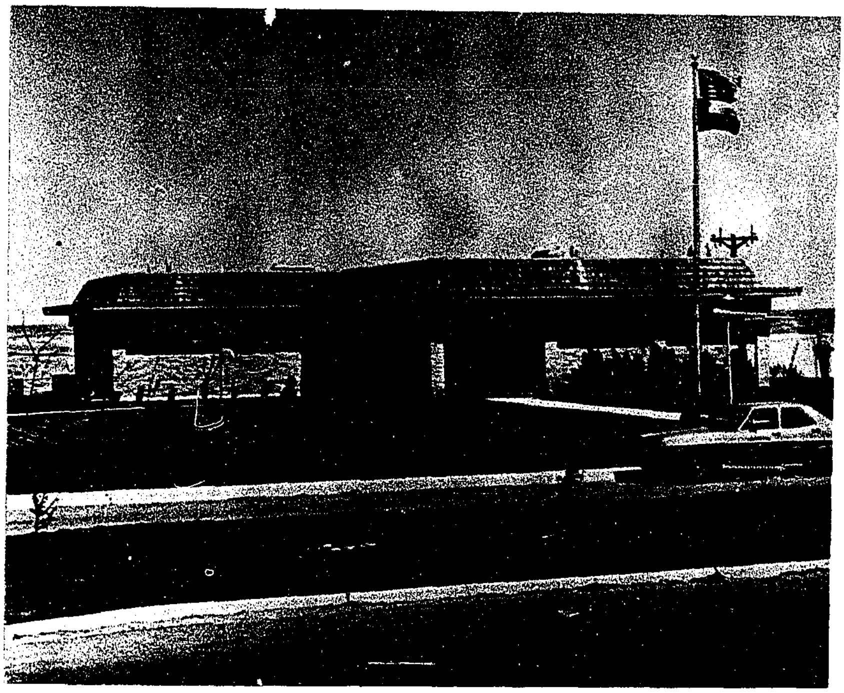

Plate 29--Headquarters building, Canadian River Municipal Water Authority located one mile northwest of Sanford, Texas.

Plate 30--Water analysis laboratory. Daily samples of water are tested to determine reservoir water quality at various depths. (Photograph courtesy of Bureau of Reclamation.)

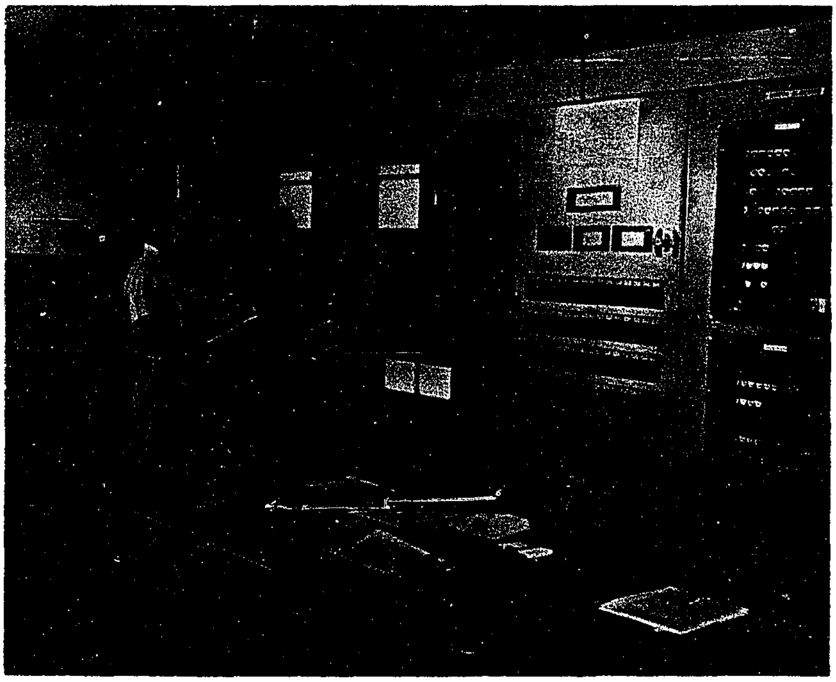

Plate 31--Interior view of Northern Control Station. This station monitors all control circuits and is attended twenty-four hours per day. (Photograph courtesy of Bureau of Reclamation.)

regulated by butterfly valves. Pumpage of water into the main aqueduct system is remotely controlled, and whenever possible the pumping is accomplished during the normal low use hours when electricity is supplied by the Southwestern Public Service Company at lower rates. Pumping during the late night and early morning hours utilizes what is generally regarded as surplus electricity, thereby reducing operational costs considerably. During the summer months when water use is highest, it is often necessary for the pumps to operate continuously.

Each of the pump units is automatically controlled by a float switch in the forebay of the next pump station down system. When the water in the forebay falls below a prescribed level, a circuit is closed thereby activating the pump to restore the water level. In case of an operational failure or malfunction, a warning signal is given and an automatic shutdown occurs.

Three regulating reservoirs serve as the major storage facilities for water moving through the system. Except during the warmer summer months, these reservoirs are capable of holding enough water to supply the needs of the Authority cities for a twenty-four hour period. This permits most of the pumping to occur between 10:30 p.m. and 9:00 a.m. each day, a time period generally long enough to refill the reservoirs throughout all but the summer months.

Along the route water is diverted to city reservoirs or holding tanks by means of a tap or a turnout and a tap.[55] A turnout is used in those cases in which the city receiving and treatment station must be reached by means of a lateral line extending from the main aqueduct (Plate 32). Each turnout consists of a wye branch. In the event that a shutdown to the city is necessitated, water can then by-pass the turnout and travel on to other Authority cities.

At the time of writing, August, 1970, there are sixty-seven installed water taps. Of these, only twenty-six are being serviced. Lubbock and Brownfield each have two taps,

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[55] A "tap" is any water distribution outlet. A "turnout" is a division of the main aqueduct pipeline into two lines with separate waterflow control valves. Major water taps are located in conjunction with all turnouts.

Plate 32--Amarillo turnout during construction. Wye branches and valves are in place. (Photograph courtesy of Bureau of Reclamation.)

an arrangement necessitated by the location of existing water treatment and distribution systems. Each of the other cities has but a single tap. Pampa is the only city included in the Authority that has not yet begun use of the project water.[56]

In addition to those put in place for Authority cities, taps have also been installed for the cities of Sanford, Tulia, Hale Center, and Abernathy although there is presently no unappropriated water available to them. Four industries along the aqueduct, Panhandle Products Company,

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[56] Pampa's delay in developing facilities for proper treatment of the raw Canadian River water has resulted in that city's selling its allotment to other cities of the Authority. A new treatment plant is now under construction.

Hill Chemical Company, Dorchester Gasoline Company, and Cities Service Oil Company, have individual taps and have either contracted with nearby Authority cities for their water or are hoping for a way in which they might be serviced. A tap west of Canyon, Texas serves the recreation development in Palo Duro Canyon. This area receives its water from the Amarillo allotment.

In addition to the aforementioned connections, there are forty-five one-inch taps for domestic use along those portions of the pipeline south and west of Lubbock (Plate 33).[57] Domestic taps were installed only for those landowners on whose properties the pipeline easement occurs. These taps were installed upon application by the owner and the payment of a $150.00 tap fee.[58] Of the ten domestic taps being serviced, the largest user has contracted for about 20,000 gallons of water per day. Such contracts must be executed with the next city down the aqueduct, and the amount withdrawn is considered a part of that city's water apportionment.

Cost Adjustments

Because of unusually favorable weather and the time saving innovations used during the construction period, costs

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[57] A single treatment plant northeast of Lubbock and owned by the city treats the water for Levelland, Brownfield, Slaton, Tahoka, O'Donnell, Lamesa, and Lubbock. Treated water is therefore available to any point beyond Lubbock.

[58] Domestic tap fees were $150.00 only if installed during the construction phase of the project. Those installed at a later date cost $225.00

Plate 33--Manhole for domestic water tap near Plainview, Texas.

were significantly lower than the $96,909.000.00 estimate of July, 1960.[59] Including accrued interest during the construction period through June 30, 1968, the estimated reimbursable cost of the Canadian River Project on July 1, 1970 was $84,820,440.00.[60] This estimated cost is not a final figure, however, and a contractual commitment for a specified amount has not yet been agreed upon between the Authority and the United States.

The final establishment of the reimbursable cost has been delayed, at least in part, by the need which developed

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[59] U.S., Department of the Interior, Definite Plan, p. 30.

[60] Personal interview with John C. Williams, August 4, 1970.

for structural modifications after construction was nearly completed and by the necessity to replace some defective parts during the initial period of operation. Those supplementary costs which are not covered by construction contractors' or manufacturers' warranties will have to be added to the total cost of the project.

A construction circumstance that for a time caused some concern was what appeared to be a seepage flow of five to ten gallons per minute from the left abutment of the dam (Plate 34).[61] Had this been occurring, major modifications at additional cost would have been necessary. Analysis of water seepage samples, however, proved conclusively that the water did not derive from Lake Meredith. It was concluded that, as the reservoir filled, the water table in the adjacent bluff had risen, and that the water emerging from the left abutment was simple ground water. The cost of the investigation, of course, had to be added to the total cost figure.

Two major claims against the Bureau of Reclamation, as of the time of writing, have still not been settled. These claims, one for $3,000,000 and one for $500,000, are the result of an aqueduct pipe subcontractor filing a claim for work considered to be outside the requirements of the

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[61]Personal interviews with R. C. Redfield, Geologist, Department of the Interior, Bureau of Reclamation, Regional Office, Amarillo, Texas, March 27, 1970; and John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas, March 28, 1970.

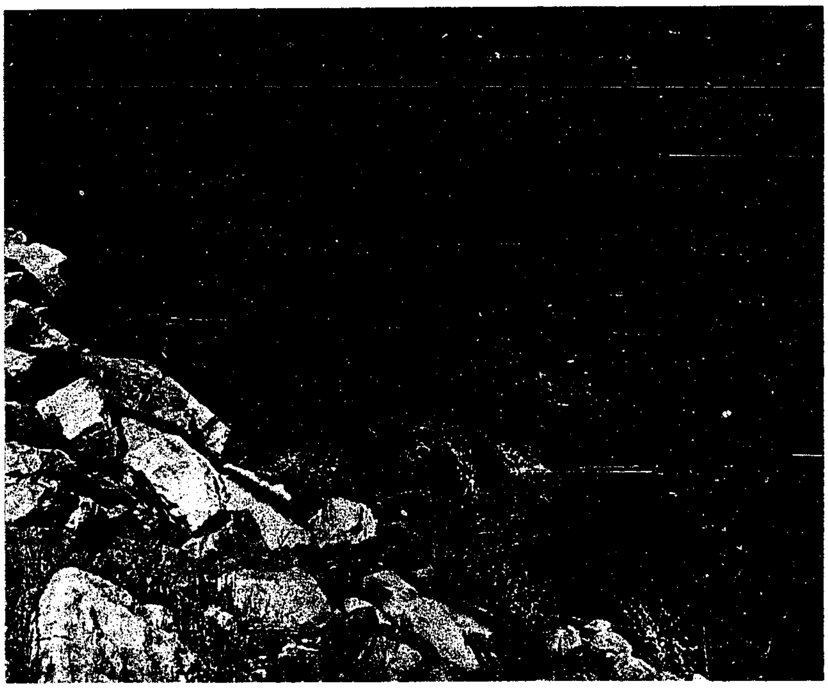

Plate 34--Area of suspected seepage. Darker streaks indicate water emerging from the left abutment of the dam. (Photograph courtesy of Bureau of Reclamation.)

basic contract. In such cases, the federal Bureau has three options: (1) accept the claim, (2) reject the claim, or (3) negotiate a settlement. In the event the federal authorities reject the claim, the contractor has the right of appeal. Negotiation is being attempted.

In the case of the larger of the two claims, the contractor contends that the unreasonable quality demands of Bureau of Reclamation inspectors cost the company an additional $3,000,000. The government's case is made on the fact that in the early stages of construction, sixty per cent of the builder's work did not meet contract specifications. After warnings proved futile, the Bureau felt obliged to supervise production techniques more closely until aqueduct pipe rejects dropped to between two and three per cent.[62] Officials of both the Authority and the Bureau in the summer of 1970 expected it would be another two years before all claims were settled and the final obligation of the Canadian River Municipal Water Authority to the United States determined.

Problems of Water Conservation

As in all parts of the Texas Panhandle, one of the most serious conservation problems is the evaporation loss from the surface of the reservoir. During the calendar year 1969 the evaporation loss from Lake Meredith was estimated at 53,000 acre-feet.[63] The total potential evaporation when the lake is full has been calculated to average 75,000 acre-feet annually. This is nearly three-fourths of the proposed firm yield of 103,000 acre-feet. Obviously any success in evaporation control, either directly or indirectly, would greatly enhance the total value of the Canadian River Project.

Water quality control in the reservoir is a problem

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[62]Mr. Williams believes that the interposition of the government inspectors may have saved the contractor from bankruptcy and that eventually a compromise will be worked out in which part of the contractor's claim will be paid.

[63]This loss estimate is only 3,275 acre-feet less than the total amount of water delivered to the Authority cities during 1969. During 1969 the Authority delivered approximately 55,000 acre-feet of water to the participating cities. The deliveries will increase by about 2,400 acre-feet per year until the projected annual delivery of 103,000 acre-feet is reached in 1989.

which will have to be dealt with, although it has not yet been necessary because of the relative newness of the project. In time, the process of eutrophication[64] may become serious enough to warrant attention. Perhaps the most immediate threat of eutrophication comes from Amarillo's sewage effluent which is returned to the Canadian River thirty-two miles upstream from Sanford Dam. This effluent is considered to be of excellent quality, but it does add an unusually high concentration of nitrates and phosphates which is known to accelerate the process of "aging" the lake, thereby reducing its general utility. Lake Meredith is certainly not yet critically anaerobic and there is not expected to be any problem of taste or odor for at least several years, although in time it may be necessary to prohibit the dumping of sewage effluent into the river above the lake.

Some contamination through recreational use no doubt does occur (Plate 35), but this evidently does not yet pose a serious threat to the water quality. Both the Authority and National Park Service personnel readily agree that the pollution problem will grow in the future, and they have little hope that it will be controlled. A commitment from the National Park Service to supply adequate personnel for policing the recreational areas around the lake is apparently

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[64]In the process of eutrophication a lake becomes rich in dissolved nutrients, mainly phosphates and nitrates, which increase the growth and accumulation of organisms, thereby causing a kind of "aging" of the lake. Eutrophication generally produces seasonal oxygen deficiency.

Plate 35--Abandoned picnic litter near water's edge, Lake Meredith.

not forthcoming.

Multi-purpose Features of the Canadian River Project

The Canadian River Project was designed as a multi-purpose water resource development. As such, along with municipal and industrial water, it was designed to provide flood control, a wide range of water-associated recreational facilities, and fish and wild life development. These purposes are often not easy to reconcile with each other, and they may at times be in direct conflict. The multi-purpose concept has been a popular one, however, for it affords easier economic "justification" for large-scale river development projects.

Flood Control

The U.S. Army Corps of Engineers has the primary responsibility for the administration of flood control functions at Sanford Dam. The Corps will operate the flood control gates of Sanford Dam as a part of its total plan for flood control on the Canadian River. In regard to this function, the reservoir is operated in conjunction with the Conchas and Ute reservoirs in New Mexico. The designed capacity of Lake Meredith provides for 462,100 acre-feet of storage specifically for flood control.[65] It has been stated that

> . . . with the proposed flood control storage, Sanford Reservoir would have prevented all flooding immediately below the damsite and would provide a high degree of protection downstream as far as Taloga, Oklahoma, and minor benefits would be obtained to the head of Eufaula Reservoir.[66]

Prior to construction of Sanford Dam, the Corps of Engineers estimated that average annual flood control benefits would amount to $136,000 (Table 11). This calculation is based on experienced flood losses which could have been prevented and estimated future value realized from intensified land utilization.

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[65]U.S., Department of the Interior, Bureau of Reclamation, Canadian River Project (Washington, D.C.: Government Printing Office, 1966), p. 1.

[66]U.S., War Department, Army Engineer District, Tulsa Corps of Engineers, Evaluation of Flood Control Operation, Sanford Reservoir, Canadian River Project, Texas, Report to Bureau of Reclamation, Department of the Interior, Amarillo, Texas (Tulsa: Office of U.S. Army Engineers, 1959), p. 13.

TABLE 11

SUMMARY OF ANNUAL FLOOD CONTROL BENEFITS

Item		Amount
Experienced Flood Losses Prevented		
Crops		$ 3,700
Structures		87,300
Increased Land Utilization		45,000
	Total	$136,000

Source: U.S., War Department, Army Engineer District, Tulsa Corps of Engineers, Evaluation of Flood Control Operation, Sanford Reservoir, Canadian River Project, Texas, Report to Bureau of Reclamation, Department of the Interior, Amarillo, Texas (Tulsa: Office of U.S. Army Engineers, 1959), p. 18.

Recreation

At a meeting on March 27, 1953, in Amarillo, Texas, officials of the Bureau of Reclamation officially requested that the National Park Service prepare a project report on the recreation potentialities of the reservoir project.[67] The primary purpose of this report was to produce recommendations on: (1) suitable sites, (2) types of developments, (3) an appropriate general recreation plan, and (4) cost estimates.[68] The initial report was emphatic in pointing

[67]The Park, Parkway and Recreational Area Study Act of June, 1936 authorized the National Park Service to cooperate with other federal and state agencies.

[68]U.S., Department of the Interior, National Park Service, Project Report, Recreation Use and Development, Sanford Reservoir, (Santa Fe: Region Three Office, National Park Service, 1953), p. 3.

out that without the reservoir the sites suggested had no particular value for recreation.

Although niggardly budget appropriations have severely limited development of the recreation potential of Lake Meredith, the area has become the chief water recreation site for the people of the region, drawing regular visitors from adjacent areas of Oklahoma, Kansas, Colorado, and New Mexico as well as from all of West Texas. The National Park Service arrived on the scene at Lake Meredith in May, 1965, with the establishment of the Sanford Recreation Area and began keeping visitation figures on July 1, 1965 (Tables 12 and 13). In the five-year period from July 1, 1965, to June 30, 1970, there were recorded 5,696,718 visitor-use days.[69]

On January 1, 1971, the recreation facilities administered by the National Park Service consisted of eight permanent public-use sites in addition to a temporary swimming area located in the river channel outlet of the flood control works (Figure 18). All water-edge features have been developed in recognition of the anticipated fluctuations of the water surface. The eight public-use sites around the reservoir are designated as follows: Sanford-Yake, Fritch Fortress, Alibates, McBride Canyon, Plum Creek, Blue West, Blue East, and Bugbee Canyon.

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[69]Figure computed from data supplied by Ronald J. Ice, Archeologist, National Park Service, Sanford, Texas, March 30, 1970 and August 3, 1970.

TABLE 12

VISITOR-USE DAYS, SANFORD RECREATION AREA
July 1, 1965 to June 30, 1970[a]

Month	Year					
	1965	1966	1967	1968	1969	1970
Jan.		20,809	37,104	34,052	36,551	36,018
Feb.		25,482	36,347	46,603	32,632	58,996
Mar.		66,016	82,148	80,323	53,758	59,428
Apr.		85,120	107,191	236,216	155,822	120,177
May		148,729	126,694	213,101	218,191	288,851
June		112,524	128,682	195,623	224,295	192,136
July	91,522	116,820	221,962	163,244	183,407	
Aug.	59,508	106,107	134,414	96,982	85,420	
Sep.	41,273	118,321	83,839	85,470	150,327	
Oct.	42,907	67,032	38,096	63,289	51,821	
Nov.	21,897	67,574	49,743	38,189	46,191	
Dec.	19,558	56,849	28,952	28,718	27,758	
Total	276,665	1,041,383	1,075,172	1,281,719	1,266,173	755,606
Cumulative Total		1,318,048	2,343,220	3,674,939	4,941,112	5,696,718

[a]Source: National Park Service, Sanford, Texas.

PUBLIC USE SITES

SANFORD RECREATION AREA, LAKE MEREDITH, TEXAS

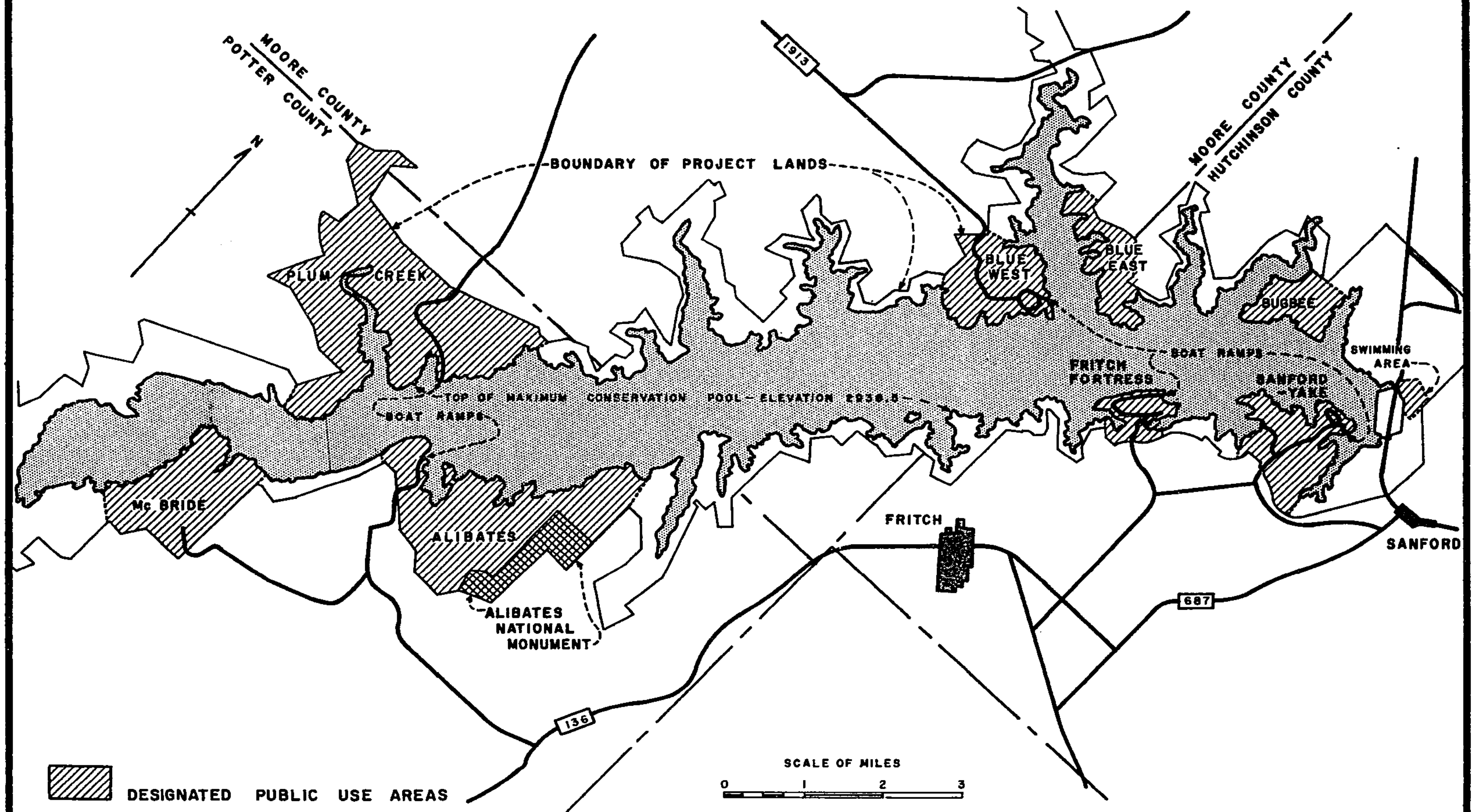

Fig. 18

SOURCE: U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, MAP 662-525-1436.

TABLE 13

VISITOR-USE DAYS, SANFORD RECREATION AREA
1969

Use	Visitor Days
Sightseeing	588,237
Picnicking	48,946
Camping	49,561
Swimming	79,611
Water Skiing	3,702
Boating	168,941
Fishing	32,530
Hunting	22,304
Other	272,341
Total	1,266,173

Source: National Park Service, Sanford, Texas.

Sanford-Yake. The Sanford-Yake, Cedar Canyon public-use site is the principal recreation development of the National Park Service at Lake Meredith (Plate 36). The only marina and concession headquarters is located on a floating platform adjacent to the Sanford-Yake deep-water launching ramp (Plate 37). This site also has a well developed picnic area with shelters, modern rest rooms, tables, and fireplaces (Plate 38). Camping, while not encouraged, is permitted throughout the picnic area. A second deep-water boat ramp with adjoining unimproved camping facilities is located in the southwest portion of the Sanford-Yake recreation area known as Cedar Canyon (Plate 39). Other than a portable van

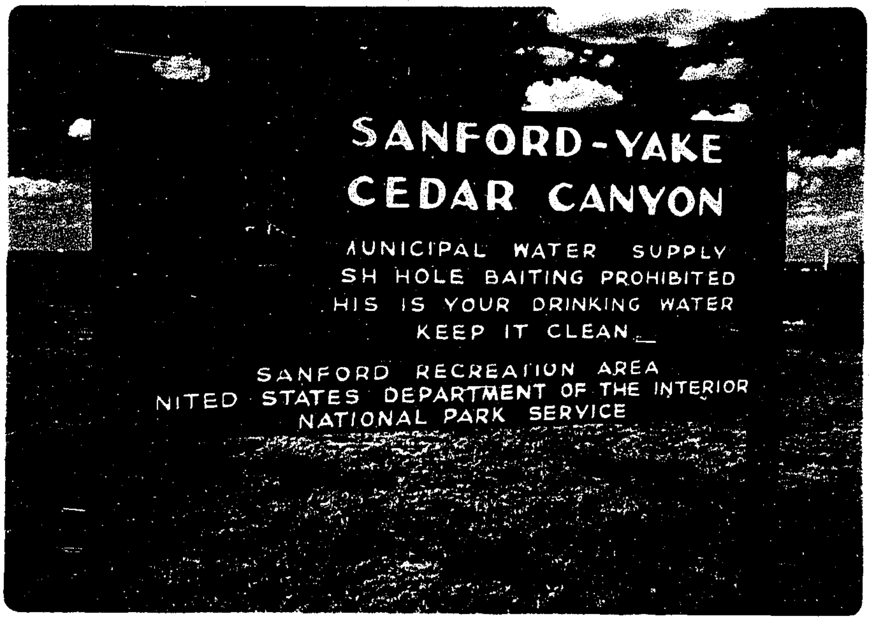

Plate 36--National Park Service sign at entrance to Sanford-Yake, Cedar Canyon Recreation development.

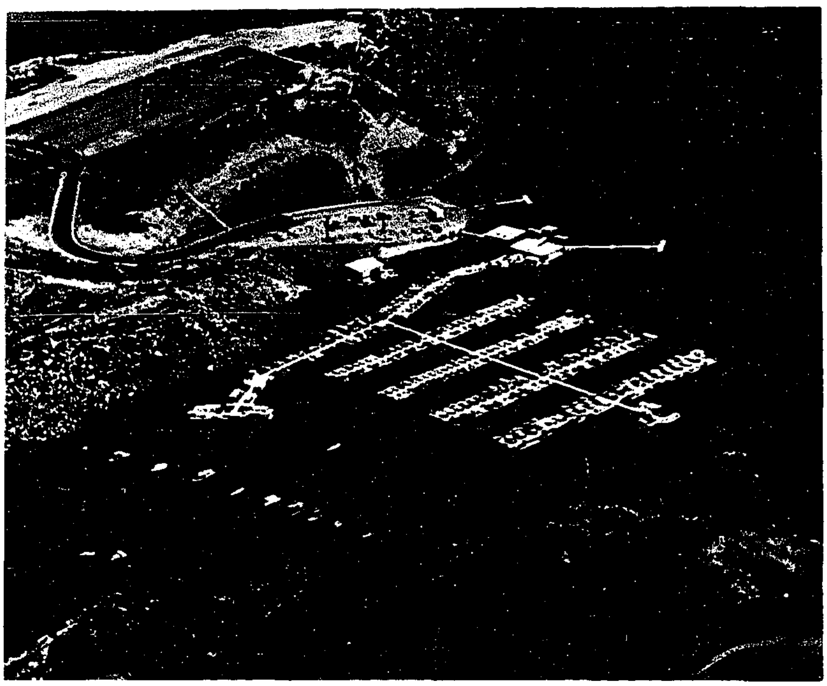

Plate 37--An aerial view of the Sanford-Yake launching ramp, marina, concession stand, and parking lot. (Photograph courtesy of Bureau of Reclamation.)

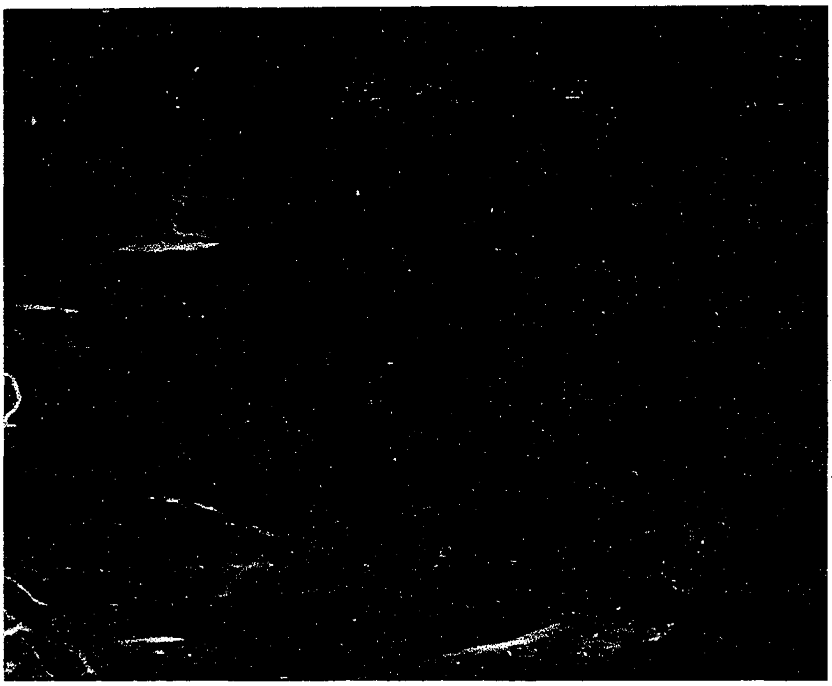

Plate 38--Aerial view of Sanford-Yake Picnic Area. The boat ramps at Fritch Fortress (upper left) and Blue West (upper right are visible. (Photograph courtesy of Bureau of Reclamation.)

Plate 39--Cedar Canyon Camp Area.

with "monomatic" recirculating toilets, there are no improvements. The area now used for camping will eventually be inundated, leaving only the deep-water boat launching ramp. Parking space is available on the bluff above the ramp for vehicles and trailers.

Fritch Fortress. Fritch Fortress was the site chosen in the original plan for the development of the marina, but it was not used when it became apparent that it lacked the natural protection from waves that was considered necessary for docking facilities.[70] Fritch Fortress is nonetheless the second best developed recreation area. Facilities here include a deep-water launching ramp, a courtesy dock, a parking area, and a picnic spot with shelters, tables, fireplaces, potable water, and rest rooms.

Alibates. Alibates, although of little present importance, has considerable potential for future development. Here there is sufficient relatively level ground adjacent to the projected mean water level of the lake. Unfortunately, the area has a somewhat barren and unattractive appearance not conducive to attracting large numbers of visitors (Plate 40). The National Park Service describes the facilities at the Alibates Recreation Area as having a "shallow-water launching ramp, parking area, semi-improved picnic and

[70] U.S., Department of the Interior, National Park Service, Project Report, pp. 22-3.

Plate 40—A view of a portion of the Alibates Recreation Area.

camping area, and chemical toilets.[71] In the summer of 1970 this semi-improved picnic and camping area consisted of a number of small fireplace grates along barely passable vehicle trails adjacent to the water's edge. A further potential attraction of the Alibates Recreation Area is the projected development of the Alibates National Monument (Figure 18). The Alibates Ruins complex has been determined to be the "actual remains of pre-historic man's habitat."[72] The nearby Alibates flint quarries, it seems, provided prehistoric man a source of material for tools over a period of

[71]U.S., Department of the Interior, National Park Service Sanford Recreation Area, Texas (Washington, D.C.: Government Printing Office, 1969), n.p.

[72]U.S., Department of the Interior, National Park Service, Project Report, p. 22.

many thousands of years.

McBride Canyon. McBride Canyon has the best potential for the development of camping and picnicking sites of any of the designated public recreation areas. Apparently as the result of seepage, a zone of large trees extends about a mile into the canyon from the conservation pool shore. As of January 1, 1971, the collection of water in Lake Meredith had not yet reached the mouth of McBride Canyon, which means that access to the lake shore is out of reach of all except those who possess four-wheel drive vehicles. Fluctuations in the lake level will cause the water to recede periodically even after the conservation pool water level has been reached. Access to a satisfactory depth of water can perhaps be obtained by extending a road around the base of the bluff a short distance to the east. The National Park Service report states that "the merits of the canyon site are considered great enough to warrant it as a choice for camping by many reservoir visitors even under . . . occasional adverse shore situations."[73] At present the facilities at McBride Canyon consist of fireplace grates and chemical toilets.

Blue West. The best developed facility on the north shore of Lake Meredith is located at Blue West. These facilities consist of a deep water launching ramp, parking area, chemical toilets, and a picnic area with shelters, tables,

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[73] Ibid.

and fireplace grates. This development is of easiest access to communities north of the Canadian River.

Plum Creek. Plum Creek, like Alibates, has shallow water facilities and semi-improved picnic and camping areas. An access truck trail for hunters crosses the Plum Creek Recreation Area to provide entry into the upper reservoir wildlife areas.

Bugbee Canyon. Bugbee Canyon has no boating facilities and is very difficult of access. Fireplace grates and chemical toilets are the only improvements found at this site.

Blue East. There is neither land access nor development at Blue East. Prospects for future use are bleak.

Other Areas. Other potential recreation areas do exist, but so far insufficient public land acreage has been set aside for development. These might include such sites as North Busby Canyon, Morton's Canyon, and Evans Canyon. Improvements are not expected here for some time.[74]

Because all the member cities of the Canadian River Municipal Water Authority are located south of the Dam and reservoir, an agreement was reached between the Authority and the National Park Service which insures that the south shore

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[74]Personal interview with John C. Williams, General Manager, Canadian River Municipal Water Authority, Sanford, Texas, August 4, 1970.

potential will be developed first and to the greatest extent, especially those sites which are most readily accessible from Borger, Pampa, and Amarillo.[75] This arrangement has caused some discontent among people in the northern part of the Panhandle, and there has been some talk of municipal development of certain sites.

The recreational advantages associated with the Canadian River Project are so far the most readily apparent benefits of it. While many residents of the Southern High Plains of Texas recognize the necessity of developing surface water resources for municipal and industrial use, the most obvious and overt interest, from the inception of the project, has been in water associated recreation.

Fish and Wildlife

The Fish and Wildlife Service of the U.S. Department of the Interior, in a report dated May, 1954, estimated that the average annual benefits which would accrue to fish and wildlife from the Canadian River Project would be $839,400 (Table 14).[76] Without Sanford Dam, no measurable value could be attributed to the fish that may have occasionally existed in the Canadian River in the vicinity of the project. Stream flow in the Canadian River valley was usually too low to

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[75] Ibid.

[76] U.S., Department of the Interior, Fish and Wildlife Service, A Detailed Report on the Fish and Wildlife Resources, Sanford Reservoir, Canadian River Project, Texas (Albuquerque: Fish and Wildlife Service, 1954), pp. 14,17.

maintain a reliable habitat for fish life. With the construction of the dam and reservoir, the Fish and Wildlife Service estimated that eventually the reservoir would "permanently inundate twenty-one valueless miles of the Canadian River."[77] The river was stocked shortly after the impounding of water began in 1965. The variety of fish species in the reservoir at the present time makes it one of the most popular fishing lakes on the High Plains. Many new businesses have opened to cater to the fishing trade.

TABLE 14

SUMMARY OF ESTIMATED ANNUAL FISH AND WILDLIFE VALUES[a] LAKE MEREDITH, TEXAS

Group	Without the Project	With the Project	Difference
Fish	$ 0	$780,000	$780,000
Big Game	300	11,000	10,700
Upland Game	800	4,600	3,800
Fur Animals	0	1,000	1,000
Water Fowl	100	44,000	43,900
Total	$1,200	$840,600	$839,400

Source: U.S., Department of the Interior, Fish and Wildlife Service, A Detailed Report on the Fish and Wildlife Resources, Sanford Reservoir, Canadian River Project, Texas (Albuquerque: Fish and Wildlife Service, 1954), pp. 14, 17.

[a]1954 values.

Wildlife benefits were anticipated to be small. Some habitat area was destroyed as water in the reservoir

[77]*Ibid*., p. 13.

rose, but the more permanent supply of water has attracted waterfowl to the upper reaches of the lake. Benefits are summarized in Table 14. The Texas Game and Fish Commission working with the U.S. Fish and Wildlife Service, is responsible for the management of wildlife development.

The Canadian River Project typifies prevalent attitudes toward multi-purpose water resource development in the United States. Water resource developments have usually met with strong regional opposition by organizations with conflicting philosophies of water conservation. Multi-purpose development takes into consideration more direct personal benefits to the greatest number of people of divergent points of view within the area.

The multi-purpose concept also provides a means of allocating the large cost of adequate water management to several segments of the economy that directly benefit by the construction of any such project. The Canadian River Project had as its primary purpose the supply of a firm yield of municipal and industrial water to the Authority cities. The total cost of the project, however, becomes somewhat more acceptable to all concerned if a portion of the expenditures can be attributed to several acceptable areas of benefit rather than a single purpose. The multi-purpose concept of development, in which there is an allocating of costs to a number of benefit categories, and to the provision of a wide variety of services, has often been necessary for political acceptance of large scale water development.

CHAPTER V

WATER SUPPLY ALTERNATIVES FOR THE SOUTHERN HIGH PLAINS OF TEXAS

The adequacy of the water supply available to meet the long-range needs of the urban and rural residents in the region under study is a matter of serious concern. The inevitable conclusion of many knowledgeable students of the water supply problem is that the further economic recovery of underground water over most of the High Plains of Texas will be difficult, if not impossible, at some indeterminable date within a relatively short time. Federal and local water resource authorities familiar with the Llano Estacado are in agreement that the Canadian River Project supplies and can supply but a scant portion of the total water needs of the area. While it does provide a sizable and reasonably dependable supply of industrial and municipal water, it can at best be considered only a minor and temporary factor in the conservation of ground water for agriculture. It must, therefore, be assumed that if the prosperous agricultural community of the High Plains of Texas is to be maintained, alternate sources of irrigation water must be developed. Chapter V is a survey of possible options available to inhabitants of the area.

Possibilities for Surface Diversion to West Texas[1]

On October 15, 1966, Public Law 89-689 was approved by Congress, giving the Bureau of Reclamation authority and funds to provide a "preliminary appraisal of any possible means of augmenting the natural [water] supply of water-deficient areas of west Texas and eastern New Mexico."[2] Although the final report of the Bureau is not scheduled for completion until 1972, the preliminary report provides tentative conclusions on the several possibilities.

The Columbia River Basin

The quantity and quality of water discharging from the mouth of the Columbia is sufficient to meet the needs of the semi-arid Southern High Plains area, and it is technically possible to divert the water to the area. The Bureau of Reclamation report concludes, however, that the opportunity for use in areas closer to the Columbia River is so great that no surplus for export diversion to the High Plains is likely to be available.

The Colorado River Basin

The potential users of Colorado River water in and

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[1]This section is based on U.S., Department of the Interior, Bureau of Reclamation, Progress Report on West Texas and Eastern New Mexico, Import Project Investigation (Amarillo: Bureau of Reclamation, 1968).

[2]Ibid., p. 1.

near the basin far exceed the available supply. There is no possibility for any diversion to the Southern High Plains from the Colorado River Basin.

The Missouri River Basin

A change in navigation provisions from a free-water system to a slack-water system along the Missouri River would make available for other purposes a substantial part of the twelve million acre-feet presently allocated to navigation in that basin.[3] It appears, however, that the cost of conversion to a slack-water navigation system would be too costly to be justified. It also must be noted that opportunity for making beneficial use of any surplus water in Kansas and Nebraska would make the export to either Texas or New Mexico unlikely. The Bureau of Reclamation report concludes that there is no water available to the Southern High Plains area from the Missouri River Basin.

The Arkansas River Basin

The preliminary investigation of the Bureau indicates that "substantial quantities of water could be diverted from the Arkansas River at times of high flow."[4] Problems of

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[3]A free-water navigation system is one in which the channel depth of natural water flow is sufficient for intended shipping. A slack-water system is one artificially created by the impoundment of water in a series of reservoirs designed to provide adequate water depth for navigation.

[4]U.S., Department of the Interior, Bureau of Reclamation, Progress Report on West Texas and Eastern New Mexico, Import Project Investigation (Amarillo: Bureau of Reclamation, 1938), p. 55.

quantity and quality could be expected to arise during periods of low flow, thereby necessitating a connection with a Mississippi River source for maintenance of volume and quality. The total amount available is unknown at the present and the subject of further study.

The Red River Basin

Some surplus water is considered to be available in the Red River basin, but it is not necessarily available for diversion. New Mexico, Texas, Oklahoma, and Arkansas are engaged in interstate compact negotiations to determine each state's right to water from the basin. Both the Texas Water Plan and the Oklahoma Basins Project are depending upon fairly substantial use of water from the Red River Basin.[5] It appears that the water available to Texas will be small and of variable quality.

Texas Gulf Stream Basins

Diversion of surplus discharge now entering the Gulf of Mexico through Texas streams is a part of the Texas Water Plan. Most of this water is scheduled for use elsewhere or is to be maintained within the basin of origin as a reserve to support additional municipal and industrial growth. The total amount available for potential diversion to west Texas is considered minor.

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[5]*Infra*, pp. 191-198.

Rio Grande Basin

The projected need in the Rio Grande basin is much greater than the supply available. This basin must expect to import water from elsewhere if its projected potential is to be realized. There is therefore no water available for export from it to the High Plains.

Lower Mississippi River System

The lower Mississippi River, consisting of the main river and the Atchafalaya River, is the largest source of surface fresh water in North America, and it is the source under serious consideration for supplying requirements under the Texas Water Plan.[6] The implications of this plan for West Texas are discussed later in the chapter.

Canadian Sources

Although Canada is not at this time officially promoting the export of its vast supply of surplus water, many areas of the United States, including Texas, are looking toward Canada as a possible future source of water supply. Many Canadians recognize that their country has a marketable commodity here, and have conducted studies of the engineering and economic feasibility of delivering surplus water to the international border for purchase by public or private authorities within the United States.[7]

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[6] *Infra*, pp. 191-198.

[7] Arleigh H. Laycock and George A. Whetstone, "Canadian

Several different plans have been proposed to divert water from Canada into the United States, and it does not seem necessary to elaborate upon all of them here. One of the proposals, that of the North America Water and Power Alliance, based on a survey by the Ralph M. Parsons Company, met with strong opposition among the Canadian people. Other proposals have been able to avoid most of the major Canadian objections to the export of water to the United States.

Canadian diversion proposals under consideration include: (1) Great Replenishment and Northern Development, (2) the Canadian Water Export Plan, (3) the Mangum Canal Concept, and (4) the Central North American Water Plan.[8] Dr. Arleigh H. Laycock[9] believes that the last of these plans, proposed by Dr. E. Roy Tinney,[10] or one similar to it will eventually be implemented.

The Tinney plan was devised after extensive reevaluation of the earlier proposal, the North American Water and Power Alliance (NAWAPA). It is believed by supporters that the Tinney plan corrects most of the shortcomings of

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View for Water Export," (paper presented at Water Resources and Irrigation Symposium, Lubbock, Texas, March 31, 1970).

[8]U.S., Department of the Interior, Progress Report, p. 51. and Lewis Gordy Smith, "Toward a National Water Plan," Irrigation Age, April, 1969, pp. 13-17.

[9]Dr. Arleigh H. Laycock is Vice-President of the American Water Resources Association and Professor of Geography at the University of Alberta, Edmonton, Canada.

[10]Dr. E. Roy Tinney is Director of Planning, Engineering, Mines, and Resources Department, Ottawa, Ontario, Canada.

the NAWAPA scheme. The principal features of the plan include:[11] (1) the utilization of existing lakes rather than the creation of huge land-inundating reservoirs, (2) the ability of the proposed collection basins to provide over 150 million acre-feet of surplus water, (3) the complete absence of mountains in the path of the proposed linking canals, (4) the reclamation of low marshy land for the expansion of waterways for navigation, and (5) the development of enough hydroelectric power at the three major drops to offset the pumpage requirements of the system. A particular selling point of the Tinney plan is that it is an all-Canadian scheme which simply proposes to sell surplus water as an export commodity.

Most long-range water resources experts consider it a certainty that Canadian water will eventually reach the High Plains of Texas. The question seems to be not whether the water will come to the area but when it will come.

The Texas Water Plan[12]

Foremost among plans for a temporary solution to the water supply problem of West Texas is the Texas Water Plan, which includes a provision for importing substantial quantities of water first from East Texas and later from the

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[11]Laycock and Whetstone, "Canadian View for Water Export."

[12]Texas Water Development Board, The Texas Water Plan (Austin: Texas Water Development Board, 1968.)

Mississippi River system into the Llano Estacado.

History

Under the title "Texas Basin Projects," the Bureau of Reclamation has studied the Texas water supply problem for nearly twenty years.[13] In a brochure[14] released in January, 1957, the results of preliminary study were made public. This, the first of several related publications, was an inventory of problems and potential approaches to them. Six years later, "A Water Plan for Texas" was published in a second brochure in a series, this one entitled The Texas Water Problem, Its Solution and Economic Impact.[15] This publication proposed for the first time a state-wide water plan. Contending that "water supply was controlling to economic growth,"[16] it suggested that there was enough water within the state boundaries to meet the needs throughout the state, "but that it must be captured and redistributed to points of need."[17] The plan called for the construction of eighty-three

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[13] U.S., Department of the Interior, Bureau of Reclamation, The Texas Water Problem, Its Solution and Economic Impact (Washington, D.C.: Government Printing Office, 1963), p. 1.

[14] U.S., Department of the Interior, Bureau of Reclamation, Elements of the Texas Water Problem, The Background and Basis of a Solution to the Problem of Water Supply (Washington, D.C.: Government Printing Office, 1957).

[15] U.S., Department of the Interior, Texas Water Problem.

[16] Ibid., p. 13.

[17] Ibid.

new dams to guarantee a firm supply of seventeen million acre-feet of water to meet projected needs for "the next five decades."[18]

One of the most striking features of this original Texas Water Plan is that it was unrealistically modest in planning for the anticipated needs of west Texas. An article in the Engineering News Record reporting on the plan stated in part:

> The Texas Water Development Board last week unveiled a $2.7 billion plan to redistribute water from the state's water-rich regions to its perennially drought stricken areas. . . .
>
> The plan, however, excludes specific recommendations for the state's sparsely populated western regions. . . . There is not enough surplus water available in east Texas to supply the entire state and . . . it is not economically feasible to transport water from east to west Texas.
>
> The report says that the Trans-Pecos, High Plains, and El Paso areas will have to import future supplies of water from such sources as the Missouri, Mississippi or Columbia river basins.[19]

Many residents of west Texas were dismayed at the plan in view of the current pessimistic predictions concerning the reliability of ground water supplies.[20] Groups were organized

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[18] Ibid.

[19] "Texas Plans," Engineering New-Record, June 9, 1966, p. 18.

[20] According to Jean O. Williams and Paul T. Gillett of the Texas Water Development Board, it is expected that ground water use will peak in 1985 with nearly six million acres under irrigation. By 2020 farmland under ground water irrigation will have declined to only about 2.19 million acres. Yet, there will be an estimated need in the year 2020 for 8.57 million acres of irrigated farmland requiring 12.7 million acre-feet of water.

to promote re-evaluation of the future water needs of west Texas. Water, Incorporated, foremost among these organizations, was created in May, 1967, to promote a water-import program for bringing additional supplies of water to west Texas, eastern New Mexico, and western Oklahoma.[21] Initial efforts were successful, as in December, 1968, the Texas Water Development Board unveiled the "Texas Water Plan." In January, 1969, the state legislature called for a vote of the people to provide monies for the implementation of the plan. In August of the same year, the essential constitutional amendment was defeated by approximately 6,000 votes. Apathy is considered to have been responsible for the defeat rather than organized opposition. The negative vote, however, was only on the method of financing the Texas share of the cost and not on the need for the Water Plan.[22] West Texas state representative Bill Clayton optimistically suggests that the proposal will come before the electorate a second time before the end of 1972.[23]

Some Features of the Texas Water Plan

The current version of the Texas Water Plan, dated

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[21]Water, Incorporated, Action Today for Water Tomorrow (Lubbock: Water, Incorporated, n.d.).

[22]Bill Clayton, "The Texas Water Plan--What is Being Done About It." (paper presented at the Water Resources and Irrigation Symposium, Lubbock, Texas, March 31, 1970), p. 2.

[23]Personal interview with Bill Clayton, Executive Director, Water Incorporated, Lubbock, Texas, April 1, 1970.

November, 1968, lists twenty-seven specific objectives to guide the plan's implementation.[24] Appendix IV catalogs these goals. Several of them are broad in scope and are applicable throughout the state. Specifically pertinent to west Texas are these goals of the Plan: (1) to provide for the importation of twelve to thirteen million acre-feet of water per year from out-of-state sources, and (2) to deliver about seven and one-half million acre-feet of supplemental water annually for irrigation to north central Texas, the High Plains, and the Trans-Pecos area.[25] To accomplish the importation of significant quantities of water into the High Plains, it will be necessary to construct the Trans-Texas Diversion Canal. As proposed, this canal will extend from northeast Texas and transport water to the Dallas area, north central Texas, the High Plains, the Trans-Pecos and El Paso areas, and on to the state line for importation into New Mexico (Figure 19).

> Of the 10 million acre-feet of water the Trans-Texas Canal will move, 7.6 million acre-feet will be available for agriculture (6.5 million acre-feet for the High Plains, 933,000 for the Trans-Pecos, and 171,000 for north central Texas), and another 1.5 million acre-feet will go to New Mexico.[26]

The proposal to divert twelve to thirteen million

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[24]Texas Development Board, The Texas Water Plan, pp. I-8, I-9.

[25]*Ibid*., p. I-8.

[26]"The Texas Water Plan," The Progressive Farmer, February, 1969, p. 26.

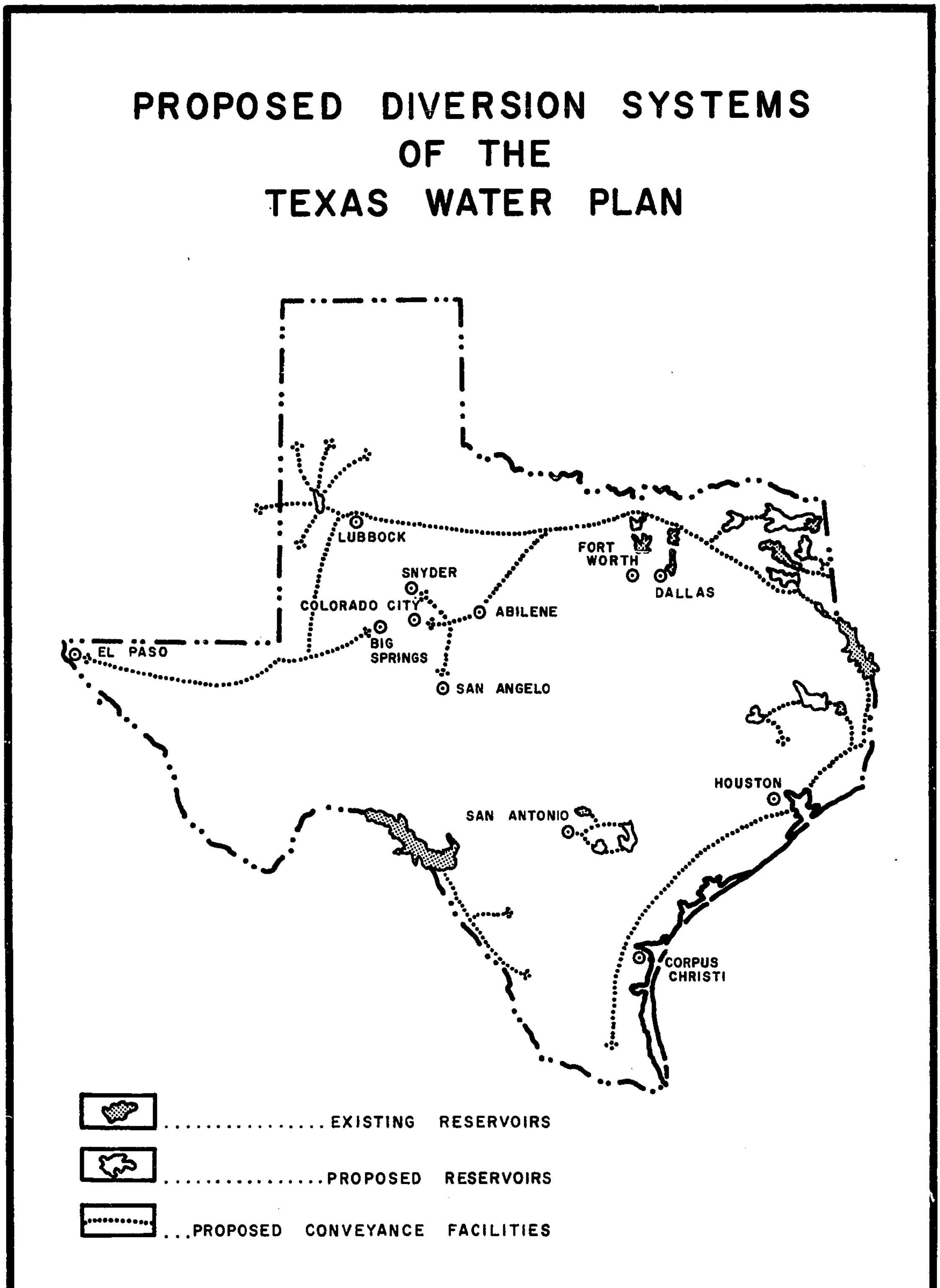

Fig. 19

SOURCE: TEXAS WATER DEVELOPMENT BOARD, THE TEXAS WATER PLAN.

acre-feet of water from the most probable source, the Lower Mississippi River near New Orleans, is "highly controversial and stands little chance of realization unless engineering studies can convince states along the Mississippi that they will not be harmed by water loss."[27] The appropriate federal agencies are now making a survey to determine the feasibility of Mississippi water transfer.

Backed by the powerful House Appropriations Committee Chairman, George H. Mahon,[28] the Texas Water Plan has a better than average chance of receiving congressional approval. Approval does not, however, insure the construction of the plan, nor does it seem likely that any water can be diverted to west Texas in sufficient time to prevent the entire High Plains economy from being pushed into a serious decline.[29] Numerous problems must be worked out before even serious planning can begin. There seems to be no doubt that there is surplus water in the Mississippi River which can be transferred to west Texas and New Mexico. Problems of national priority will undoubtedly be the major obstacle that proponents of the Texas Water Plan will have to overcome. The

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[27]Joseph Mastrangelo, "Texas Board Reveals Plans for $10 Billion Water Project," The Washington Post, December 18, 1968.

[28]Mr. Mahon's 16th Congressional District is centered in the heart of the irrigated farmland of the Texas High Plains.

[29]Burt Schoor, "Fetching a Water Plan, Texas-Style," The Wall Street Journal, September 23, 1968.

project will probably cost more than fifteen billion dollars,[30] a figure which according to one critical commentator is equal to more than one-half

> . . . of the $26 billion Uncle Sam has poured from his pork barrel for all types of waterway construction since 1824. . . . Indeed, because of its enormity, the west Texas proposal likely will lumber head-on into an issue more [sic] smaller Federal water projects have side-stepped: Can Uncle Sam continue to provide ever-larger amounts of water for thinly populated rural regions at a time when the nation's densely packed cities also are pressing for vast infusions of financial aid from Washington?[31]

To informed expansion-minded residents of west Texas, there seems to be little doubt as to the urgent need for the Texas Water Plan. To many others, it seems improbable that the implementation of the Texas Water Plan at any time in the near future is in the best interests of the United States.

Finally, it appears that the Texas Water Plan is in itself only a partial remedy for the expected water deficiencies of west Texas. Ultimately, the Plan must be integrated into a national water plan that will look to Canadian surplus water to supply a substantial portion of the projected needs of the United States.[32]

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[30]Estimates of costs for the Texas Water Plan range from eight and a half to twenty billion dollars.

[31]Burt Schorr, "Fetching a Water Plan."

[32]Personal interviews with Duncan Ellison, Assistant Director for Public Relations, Water Incorporated, and Gerald Ivey, Associate Director and General Counsel, Water Incorporated, Lubbock, Texas, May 1, 1970.

Miscellaneous Plans for Augmenting the Water Supply

The Texas Water Development Board has encouraged research in many diverse areas of water resource development. In addition, private foundations, other state agencies, and federal organizations have addressed their efforts toward the water problems of the arid and semi-arid southwest of the United States. A summary of several of the plans that have been proposed follows.

Desalinization

An economically competitive desalinization process would be a boon to the dry lands of the world adjacent to saline water bodies. To the Southern High Plains of Texas the value of lower cost desalinization would be severely restricted by the great distance between abundant sources of saline water and the plains. Proponents of desalinization, however, point out that the distances involved are no greater than those proposed in the diversion of water from the Mississippi River through the systems of the Texas Water Plan. Nevertheless, the cost of long-distance water transfer, in addition to the cost of desalinization, seems to prohibit the extensive use of desalted water. The moderate supplies of saline water found in the Permian and Triassic deposits[33]

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[33]Texas Board of Water Engineers, A Summary of the Occurrence and Development of Ground Water in the Southern High Plains of Texas, by J. G. Cronin, Bulletin 6107 (Austin: Texas Board of Water Engineers, 1961), p. 13.

underlying the High Plains, as for instance under the Pecos River valley, may one day be a limited source of water for desalinization, but they could never be sufficient to sustain the present water demand of the area.[34] The costs associated with deep pumping and desalinization apparently exclude agricultural use of such water except perhaps along the Canadian River breaks where highly mineralized water may have local value.

Geothermal Water[35]

The detonation of nuclear charges at depths of one thousand feet or greater may provide a means for the recovery of deep brackish water. The explosions would produce steam under great pressure, thereby expelling it to the surface where it would be condensed as a fresh water supply. For the Texas High Plains such recovery seems most impractical and improbable for several hundred years.

Playa Water Recovery

One of the most obvious ways to augment somewhat the water resources now available on the High Plains of Texas is to utilize the water that collects in the Playa depressions of the area. There are over 19,000 playa lakes on the Texas High Plains which annually collect between 2.5 and 3.0 million

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[34]Personal interview with R. C. Redfield, Geologist, U.S. Department of the Interior, Bureau of Reclamation, Regional Office, Amarillo, Texas, March 30, 1970.

[35]*Idem*.

acre-feet of water from local rainfall and irrigation runoff.[36] The 1969 High Plains Irrigation Survey shows that only 2,955 playa basins are being pumped for recovery of water, and far fewer, only 166, have multiple-purpose wells in operation.[37] The conclusion is that only a very small amount of water is presently salvaged from these lakes. The playa bottoms are usually of Randall clay (Figure 12), a very slowly permeable soil that restricts practical amounts of natural recharge.[38] [39] Valliant estimates that recharge amounts to no more than "one to one and one-half million acre-feet per year with a portion of this coming from water pumped on the land for irrigation."[40] The very high evaporation rate throughout the Texas High Plains results in the loss back into the atmosphere of between 85 and 90 per cent of all water collected in the playas.[41]

The most practical possibility for the conservation

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[36] Personal letter from Mr. James C. Valliant, Soil Scientist, High Plains Research Foundation, Halfway, Texas, April 20, 1970.

[37] Texas Agricultural and Mechanical University, Agricultural Extension Service, 1969 High Plains Irrigation Survey, compiled by Leon New (College Station: Texas A&M University, 1969).

[38] Letter from Arland Schneider, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas, April 17, 1970.

[39] Supra., pp. 46-50.

[40] Personal letter from Arland Schneider, April 17, 1970.

[41] Ibid.

of the playa water involves the modification of the playa basin so as to effectively encourage infiltration into the underlying rock. Such surface water harvesting for storage as ground water is achieved by soil management techniques which insure a maximum water catch that is then diverted to a properly modified playa bottom. Several different designs for modifying playa basins appear to offer some promise for significant savings in water. All such designs involve the reshaping of the playa bottom into a deep pit-type detention reservoir that will permit the temporary storage and subsequent infiltration of the greatest amount of water with the least surface exposure (Figure 20).

A study of Grubb and Parks shows "that it would be economically feasible to modify approximately 35 per cent of the playas of the Texas High Plains on the basis of water, lake-bed land, and health benefits."[42] These writers indicate that up to 180 thousand acre-feet of water could be conserved in the region, thus providing economic benefits of an estimated $31,000,000 over a twenty-year period.[43] Hauser believes that the most efficient method for conserving runoff water impounded in playas is the combination of dentention

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[42]International Center for Arid and Semi-Arid Land Studies, Multipurpose Benefits and Costs of Modifying Playa Lakes of the Texas High Plains, by Herbert W. Grubb and Don L. Parks, Special Report No. 6. (Lubbock: International Center for Arid and Semi-Arid Land Studies, 1968), p. 9.

[43]Ibid.

RECTANGULAR PIT MODIFICATION PLAN FOR PLAYAS

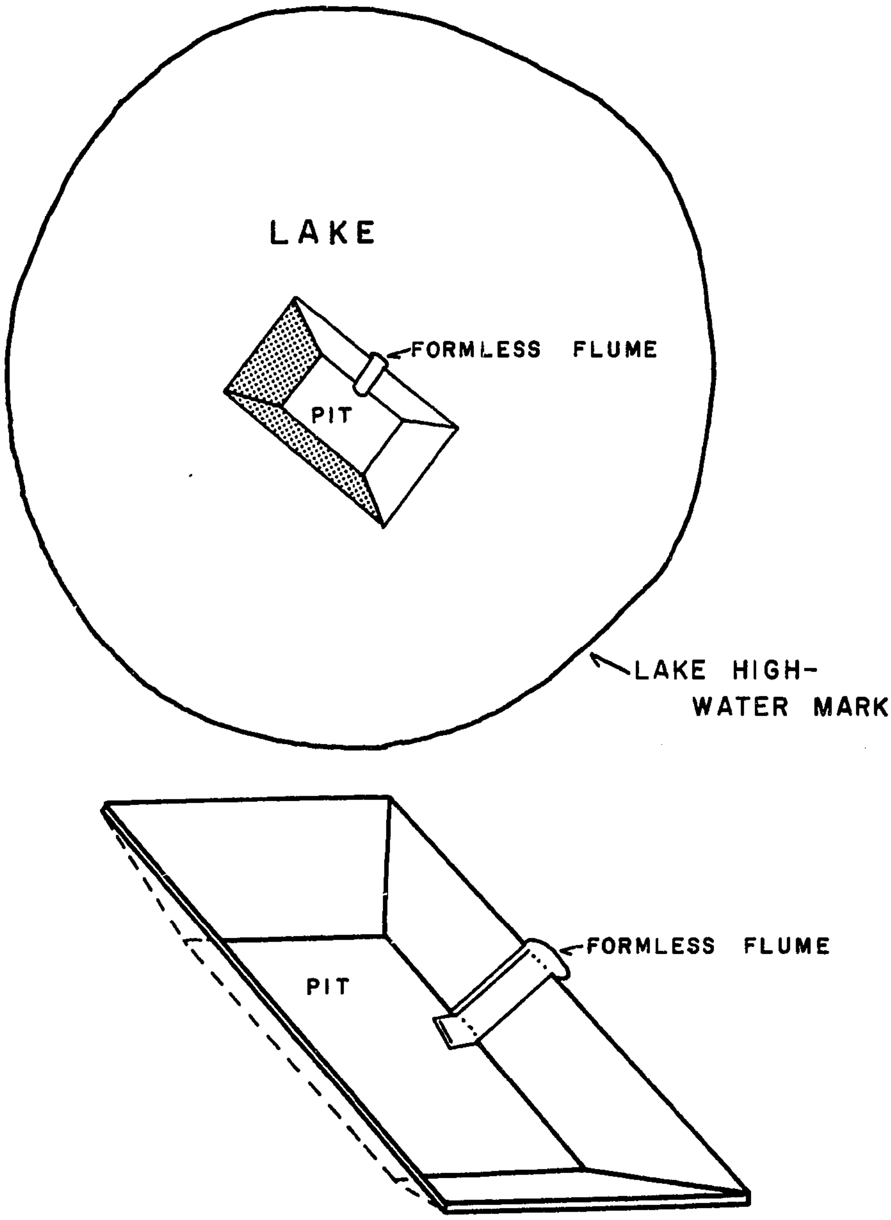

Fig. 20

SOURCE: INTERNATIONAL CENTER FOR ARID AND SEMI-ARID STUDIES, SPECIAL REPORT NUMBER. 6.

reservoir with ground water recharge.[44]

In addition to the loss of a valuable resource, the unmanaged playa represents a serious health hazard.[45] Huddleston and Riggs report that "more than 70 per cent of the mosquitoes in the High Plains are produced from these playas."[46] In addition to the pest variety, encephalitis carrying varieties have been responsible for 180 reported cases of the disease in the High Plains of Texas during the years of 1957 through 1964.[47]

Ground Water Recharge

Ground water recharge is obviously one of the best ways to conserve and store harvested water. Rayner[48] states that there is an estimated air-filled void of 254,453,000 acre-feet within the dry matrix of the Ogallala formation, which exists as an ideal reservoir for the storage of water. A little more than half of this void, 134,336,200 acre-feet,

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[44]U.S., Department of Agriculture, Agricultural Research Service, Hydrology, Conservation, and Management of Runoff Water in Playas on the Southern High Plains, by Victor L. Hauser, Conservation Research Report No. 8. (Washington, D.C.: Government Printing Office, 1966), p. 3.

[45]Texas Water Development Board, "Public Health Aspects of High Plains Water," by Ellis W. Huddleston and Virginia C. Riggs in Studies of Playa Lakes in the High Plains of Texas, Report No. 10, (Austin: Texas Water Development Board, 1965), p. 9.

[46]U.S., Department of Agriculture, Hydrology, Conservation and Management, p. 23.

[47]Ibid., p. 10.

[48]Frank A. Rayner is the Manager of the High Plains Underground Water Conservation District No. 1, Lubbock, Texas.

is considered to be the safe storage potential of the formation.[49] Unfortunately, endeavors at ground water recharge have been disappointing when attempted on a truly meaningful scale.

Several techniques exist for ground water recharge. The least expensive one involves a conveyance system using large unlined canals. Although recharge canals are readily accessible for maintenance and are easy to operate, the canal system has a number of drawbacks. There is a considerable loss of water by direct evaporation and from transpiration through undesirable vegetative growth along the canals.[50] The canal system's effectiveness is largely limited to those areas where sandy soils provide relatively rapid infiltration.

A second technique of ground water recharge is through the use of recharge wells. Research on ground water recharge through wells was begun by the U.S. Geological Survey in 1953.[51] Theoretically, an aquifer's ability to produce water should be a direct indication of its ability to accept

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[49]Frank A. Rayner, "Potential for Storage of Water in Southern High Plains of Texas," The Cross Section, May, 1967, p. 2.

[50]Personal interview with Frank A. Rayner, April 28, 1970.

[51]Victor L. Hauser and Donald C. Signor, Water Conservation and Ground Water Recharge Research, Texas High Plains, Prepared for the Texas Agricultural Experiment Station (College Station: Texas A&M University, 1967), p. 5.

water.[52] Research has only partially solved the problems associated with the use of recharge wells, and much more must be learned about their design and maintenance if they are to become an acceptable means of ground water replenishment. More than anything else, "successful ground water recharge systems, capable of being applied over wide areas in sand aquifers, require clean water."[53] The turbidity of the available playa water in the High Plains makes water clarification a necessity for successful recharge by the use of wells.

Recharge shafts offer still another means for ground water recharge. A shaft is a well-like opening terminating above the water table and normally backfilled with gravel. The purpose of the shaft is to permit infiltrating water to bypass the less permeable layers between the aquifer and the surface. Signor, Hauser, and Jones believe that the "shafts have the following advantages over wells: (a) less biological pollution hazard to the aquifer, (b) less chance of aquifer damage by sediments and (c) less costly."[54]

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[52] Frank A. Rayner, "Potential for Storage of Water in Southern High Plains of Texas," The Cross Section, May, 1967, p. 4.

[53] Hauser and Signor, Water Conservation, p. 2.

[54] D. C. Signor, V. L. Hauser, and O. R. Jones, "Ground Water Recharge Through Modified Shafts," Transactions of the American Society of Agricultural Engineers, XII, No. 4, (St. Joseph, Michigan: American Society of Agricultural Engineers, 1969), p. 486.

Conservation and Management

The best of conservation and land management practices will not provide a perfect and final solution to the problems of water sufficiency in the Texas Panhandle. There is no doubt, however, that better use of the water now available will permit the limited resources on hand or readily procurable to meet the area's need for a much longer period of time. The concept that there is an inexhaustible sheet of water under the Southern High Plains, deriving from some unknown source, had its origin at the beginning of the century and remained a prevalent attitude during the 1950's.[55] Recommendations for any type of water conservation enforcement have always been met by vehement rhetoric from a great many individualistic inhabitants of west Texas. Many farmers in the region still envision a real economic threat in any attempt to regulate the use of ground water supplies.

It is the writer's conclusion that prompt implementation of the strictest of conservation measures is necessary to minimize the seriousness and length of the economic decline that seems inevitable during the period between the beginning of serious decline in ground water irrigation and the first arrival of imported water in significant quantities from outside the region. Such conservation measures should include:

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[55]Donald E. Green, "The Irrigation Frontier on the Texas High Plains: 1910-1960," (unpublished Ph.D. dissertation, University of Oklahoma, 1969), p. 268.

1. Optimal application of irrigation water. Unfortunately, the regional attitude during the 1950's and 1960's has been to produce the maximum crop yield each year, even at the expense of excessive water consumption. Experimental studies in computer-controlled irrigation water application seem to indicate that it is possible, through optimal application of irrigation water, to increase the production per acre of most crops with the use of less water.[56]
2. Efficient recycling of tailwater.[57] One of the writer's earliest and most vivid impressions of the southern High Plains of Texas was that of endless "streams" of water in the bar ditches on either side of the highways crossing the area (Plate 41). Tailwater has been described as "one of the biggest problems that confront the southern High Plains irrigator."[58] In 1969, although there were 1,985 recirculation systems in operation on

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[56]U.S., Department of the Interior, Bureau of Reclamation, "Irrigation Water Management--The Key to Efficient Use," by Larry Swarner and David Robb. McCook, Nebraska, n.d. (Mimeographed); and Dick Wilson, "Can Computer Scheduled Irrigation Stretch Water Supplies?" Irrigation Age, V, April, 1970, p. 10.

[57]Tailwater is that irrigation water which flows off an irrigated acreage and is generally of no beneficial value.

[58]High Plains Underground Water Conservation District No. 1. Irrigation "Tailwater" and Lake Pump Installations (Lubbock: High Plains Underground Water Conservation District No. 1., n.d.), p. 1.

Plate 41--Tailwater in bar ditch alongside U.S. Highway 87 near Plainview, Texas.

the approximately 5,442,196 acres of the Texas High Plains providing a partial return on tailwater, it was and still is apparent that there is room for much improvement in the recovery of this water.[59] Progressive farmers who have installed tailwater return systems inevitably find that the investment "pays for itself" many times over, in addition to providing a measure of water conservation (Plate 42).

3. Gradual change in the crop pattern. Gradual conversion to crops that require less water, and the

[59]Texas Agricultural and Mechanical University, Irrigation Survey, p. 1.

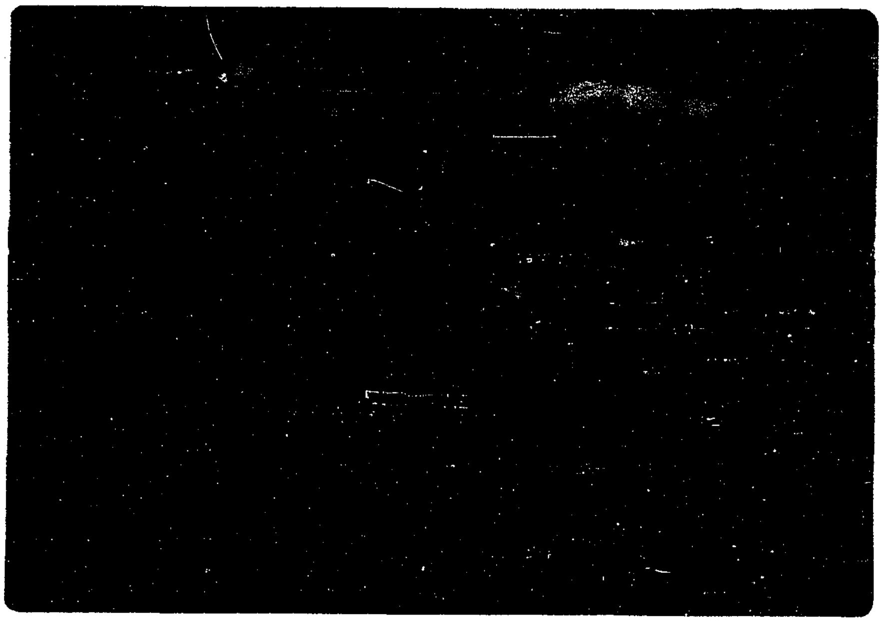

Plate 42--Tailwater recirculation pit near Plainview, Texas. Note the electric pump to the right near the highway.

elimination of those crops now under irrigation which might better be produced elsewhere, would aid in the conservation of the available water. Many people question the wisdom of producing cotton throughout the Texas High Plains when much of that cotton is in surplus or of such inferior quality that the government is forced to buy it and either store it for lack of market or sell it at substantial loss.[60] Improved varieties of grain sorghum have opened the way to a new agricultural revolution in the northern part of the

[60]Burt Schorr, "Fetching Water," p. 37.

Llano Estacado during the past ten years, making it possible to produce vastly increased yields of that crop with little or no supplementary irrigation. This enlargement of the animal feed base in turn has promoted the expansion of cattle feed lot operations. Several of the city officials interviewed during the course of the writer's field work indicated a belief that there would be gradual conversion of prime irrigation land from wheat and cotton to a much smaller acreage of high value truck garden crops.

4. <u>Innovative use of seasonal rainfall</u>. Experiments are being conducted with the direction of some of the natural precipitation falling on an area onto an adjoining area of intensive cropping. Near Brownfield, Texas, for example, a temporary sealant has been applied to alternate strips of cropland so as to minimize infiltration. The runoff was directed to an adjacent unsealed area of planted cropland. Initial results indicated that the total application of water to the adjacent land was nearly double the measured rainfall.[61]

5. <u>Municipal re-use of liquid effluent</u>. At the present time only minimal use is made of municipal

[61] Personal Interview, R. J. Purtell, President Tri-matic Inc., Brownfield, Texas, April 29, 1970.

sewage effluent. Harvey and Contrell, after a study of effluent use, concluded that "a resource of great economic value is not being used."[62] Dr. George A. Whetstone[63] believes that within fifty years the re-use of water through many cycles will be routine in relation to irrigation, recreation, industry, ground water recharge, and even potable water requirements.[64]

There are many reasons to believe that the communities served by the Canadian River Municipal Water Authority face a bleak economic future unless maintenance of the region's agricultural activity is assured. Without new water supplies this appears impossible. A Texas Water Development Board study, projecting total benefits to irrigation through the year 2020, indicates that peak economic activity will be reached between 1980 and 1985. At that time, estimated annual benefits from agriculture in the area will average more than 500 million dollars. As irrigated acreage reaches its peak and begins to decline after 1985, economic benefits will start

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[62] Texas Water Development Board, Use of Sewage Effluent for Production of Agricultural Crops, by Clark Harvey and Ronald Contrell, Report No. 9, (Austin: Texas Water Development Board, 1965), p. 7.

[63] Dr. George A. Whetstone, Professor of Civil Engineering at Texas Technological College, is well known throughout the western United States as a water resources expert.

[64] Texas Water Development Board, Re-Use of Effluent in the Future, with an Annotated Bibliography, by George A. Whetstone, Report No. 8 (Austin: Texas Water Development Board, 1965), pp. 1-5.

dropping. By 2020 these benefits are expected to have declined to about 195 million dollars annually (Table 15).[65]

If water should become available in the quantities projected by the Texas Water Plan, irrigation benefits would continue to rise gradually over a period of several decades until finally a point of stability would be reached. The writer, however, does not believe that water in such quantities will be supplied to the Texas HIgh Plains in time to avoid a serious adjustment in agricultural land use. The history of reclamation projects already completed in the American West suggests that inhabitants of the Llano Estacado are in a race with time which they are certain to lose, at least on a temporary basis.

A continuous research program is needed to improve water use efficiency, proper allocation of water among competitive users, and the development of long range alternative plans and policies pertaining to water use. In addition, there should be a continuous program of conservation education in the local area directed toward making present supplies last longer. The Canadian River Municipal Water Plan was designed to meet only one phase of the area's total water needs. If the irrigated acreage declines and land utilization in the area becomes less intensive, the eleven Authority cities may

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[65] Texas Water Development Board, Importance of Irrigation Water to the Economy of the High Plains, by Herbert W. Grubb, Report No. 11, (Austin: Texas Water Development Board, 1966), p. 21.

TABLE 15

PROJECTED TOTAL BENEFITS TO IRRIGATION, TEXAS HIGH PLAINS, 1970-2020[a]

	1970	1980	1990	2000	2010	2020
Projected Irrigated Acreage	5,695,000	5,816,000	4,475,000	3,584,000	2,931,000	2,191,000
Primary Benefits[b]	$106,000,000	$116,000,000	$ 90,000,000	$ 72,000,000	$ 59,000,000	$ 44,000,000
Secondary Benefits[c]	97,000,000	107,000,000	82,000,000	66,000,000	54,000,000	40,000,000
Agricultural-Inputs Tertiary Benefits[d]	89,000,000	98,000,000	76,000,000	60,000,000	49,000,000	37,000,000
Consumer - Items Tertiary Benefits[d]	178,000,000	196,000,000	151,000,000	121,000,000	99,000,000	74,000,000
Total Benefits	$470,000,000	$517,000,000	$349,000,000	$319,000,000	$261,000,000	$195,000,000

[a]Source: Texas Water Development Board, Importance of Irrigated Water to the Economy of the High Plains, by Herbert W. Grubb, Report No. 11, (Austin: Texas Water Development Board, 1966), pp. 12-21.

[b]Primary benefits are dollar values obtained directly from irrigation output.

[c]Secondary benefits are dollar values added by the marketing sector of the economy.

[d]Benefits that accrue to agricultural input suppliers and to consumer items retailers, due to High Plains irrigation, are classified as tertiary benefits in order to distinguish these from other benefits.

not need all the water for which they have contracted, for in that case there would be a significant general economic contraction and a diminished population throughout the Texas High Plains.

CHAPTER VI

WATER AWARENESS SURVEY OF THE TEXAS HIGH PLAINS

The purpose of conducting a water awareness survey was to identify significant attitudes toward the water resources of the Texas High Plains and to measure and compare the attitudes of respondents by sex, location of residence, and vocational status. The survey was carried out during the 1970 calendar year.

Population

The subjects participating in the survey were seventy-six responding residents from nine of the eleven cities included in the Canadian River Municipal Water Authority.[1] Names of 615 residents of the eleven cities were randomly selected from current telephone directories for the eleven cities. Amarillo and Lubbock were each sent 150 questionnaires; the nine remaining communities were each sent thirty-five questionnaires.[2] The selection of individuals to receive

[1]Usable replies were received in the following numbers--from Amarillo 25, Borger 4, Lamesa 4, Lubbock 24, O'Donnell 4, Pampa 3, Plainview 3, Slaton 3, and Tahoka 6.

[2]Questionnaires were mailed in April, 1970.

questionnaires was determined by drawing numbers from two separate boxes representing line and column directory listings, these numbers indicating a particular entry for each page. If the entry chosen appeared to be business listing, the selector moved down the column to the next private residence listed. After each selection, the line and column numbers were returned to the boxes and mixed with the other numbers before the next selection was determined. The response to the mailing was poor, and the respondents included in the study represent only about 12 per cent of those who were mailed questionnaires.

Development of the Questionnaire

The questionnaire was developed in response to the writer's interest as to whether or not attitudes toward water resources varied from place to place within the territorial area of the Canadian River Municipal Water Authority, and curiosity as to what residents believed about selected aspects of water management. An initial list of statements was prepared by the investigator. These were then modified by Dr. Ralph E. Olson, Professor of Geography, University of Oklahoma; Mr. Bill Clayton, Director, Water Incorporated; Mr. Gerald Ivey, Associate Director and General Counsel, Water Incorporated; Mr. Duncan Ellison, Assistant Director for Public Relations, Water Incorporated; and Mr. John C. Williams, General Manager, Canadian River Municipal Water Authority.

In final form, the questionnaire included a section requesting information as to the respondent's age, sex, education, occupation, family size, length of residence, ownership of water using appliances, and estimated daily water use, along with a question as to what each respondent considered to be the area's most pressing problem. The second section of the questionnaire included forty-four statements, each to be rated on a five-point scale by the respondent indicating his degree of agreement of disagreement with it (Appendix V).

Preliminary analysis of the results indicates that several of the statements were of only minor importance to the overall problem and are not discussed in this report. Thirteen of the statements were chosen by the writer for consideration. The answers to them indicate a positive attitude toward the water resource problems of the southern High Plains. The following is a list of the thirteen statements selected for inclusion in the study and the rating scale employed with them.

	Strongly Agree	Tend to Agree	Undecided	Tend to Disagree	Strongly Disagree
1. Periodic drought is not one of the major water problems of West Texas.					
2. Purified sewage water is safe for home use.					
3. I would be willing to be taxed to a greater extent than at today's rates to support a strong irrigation agricultural economy in this area.					
4. The lack of water could cause a general decline in the population of West Texas.					
5. There is no practical solution to the water problems of West Texas.					
6. There will be an economic decline in my community if the surrounding area should revert to dryland farming.					
7. Underground water conservation districts should exert greater control over underground water use for irrigation.					
8. "Water Incorporated" is a positive step toward the solution of the water problems of Texas.					
9. Underground water depletion is one of the main water problems of West Texas.					

	Strongly Agree	Tend to Agree	Undecided	Tend to Disagree	Strongly Disagree
10. The lack of adequate recovery of local rain water supplies is one of the main water problems of the High Plains.					
11. Properly treated liquid sewage should be recycled through the cities water supply.					
12. The concern of some over water in West Texas is generally given too much attention.					
13. Underground water depletion would not seriously affect either me or this area.					

A positive attitude for statements 2, 3, 4, 6, 7, 8, 9, 10, and 11, it was determined, would be agreement, and for statements 1, 5, 12, and 13 a positive attitude would be disagreement. The questionnaire provided a great amount of data, that is not directly essential to the stated purpose of this study. The responses used do provide some insight into these two general questions: (1) Is the local attitude positive or negative toward the water resources of the area? (2) Do attitudes vary significantly between different segments of the population, considering them on the basis of sex, location of residence, and occupation.

Hypotheses

Three hypotheses were formulated to test whether or not significant differences existed between segments of the population according to sex, location of residence, or occupation.

Ho_1: There is no significant difference in water awareness between male and female respondents to the questionnaire.

Ho_2: There is no significant difference in water awareness between responding residents of the northern and the southern cities of the Canadian River Municipal Water Authority.

Ho_3: There is no significant difference in water awareness between business and professional respondents and respondents with other vocations.

Statistical Treatment of the Data

The statistical method used to determine if there was a significant difference between paired groups at the 0.05 level of confidence was the chi-square test. Siegal states that the chi-square test may be used to determine significant differences between two independent variables involving nominal scaling.[3]

The rating scale was weighted by value for each

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[3]Sidney Siegal, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, Inc., 1956), p. 104.

category, with the most positive attitude rated five, the least positive rated one, and a neutral value represented by three. The values assigned to each of the thirteen statements by the respondents were summed, and for each of these statements a mean was determined to see whether the total response to it was positive or negative. Respondents with positive means (3.0001 or more) were tallied and classified, and those with negative means (2.9999 or less) were likewise tallied and classified. Seven responses yielded the neutral value of three and were assigned to an unclassified category (Table 16).

TABLE 16

TALLY OF TOTAL RESPONSE VALUES TO THE WATER AWARENESS QUESTIONNAIRE

	Positive	Negative	Unclassified
Male	29	27	4
Female	6	7	3
North	14	18	3
South	21	16	4
Professional and business	13	8	3
Other	22	26	4

Results of the Chi-Square Test[4]

The chi-square test was applied to each of the three

[4]Chi-Square Test--

$$x^2 = \sum_{i=1}^{r} \sum_{j=1}^{k} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

sets of variables to determine whether or not a significant attitude toward water awareness existed. In testing the three null hypotheses the following results were revealed.

1. There was no statistically significant difference in water awareness between male and female respondents.
2. There was no statistically significant difference in water awareness between responding residents of the northern and southern cities of the Canadian River Municipal Water Authority.
3. There was no statistically significant difference in water awareness between business and professional respondents, and respondents with other vocations.

Conclusions

The surveyed population, as previously described, consisted of seventy-six respondents to a questionnaire randomly distributed in each of the eleven cities of the Canadian River Municipal Water Authority. Conclusions drawn from the study are applicable only to that population, and extrapolations to other situations are not appropriate.

The following conclusions are based on the evaluation of data obtained in the investigation:

1. There are no evident differences in water awareness between male and female respondents.
2. There are no evident differences in water

awareness between responding residents of the northern and southern cities of the Canadian River Municipal Water Authority.

3. There are no evident differences in water awareness between business and professional respondents and respondents with other vocations.

4. Sex, location of residence, and vocation are not significant variables in relation to awareness of the water resource problems of the eleven cities of the Canadian River Municipal Water Authority.

Recommendations Based on the Questionnaire

Since there were no significant differences between the tested segments of the population, it can be concluded that methods of informing the public about the water resource problems within the Canadian River Municipal Water Authority area have been equally effective or ineffective in reaching the male and female population, the southern and northern cities of the Authority, and the various business, professional, and other vocational groups.

Further investigation using either a larger sample or a different approach to questioning might reveal regional or structural variables of some sort, but the results indicated by the writer's limited study were essentially negative.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The settlement history of the Southern High Plains of Texas has been closely and consistently tied to the struggle to provide water in adequate quantity and of sufficiently good quality to sustain man in his economic activities. Throughout the period of Spanish and American occupation, the residents of the area have been reluctant to accept the climatic limitations of the natural environment as being a final deterrent to continued development.

The first permanent white settlers of the Llano Estacado staked out huge cattle estates which were limited in their grazing capacity not so much by availability of forage as by access to suitable water supplies. Most of the first ranch headquarters were located below the caprock where springs issuing from the Ogallala formation provided dependable water for people and livestock. With the development of the windmill and the installation of water tanks in the mid 1880's, the cattlemen began to push westward onto the High Plains. Success was short-lived, for the commercial cattle industry was soon dealt two telling blows that signaled the need for a new pattern of agricultural land use. The first of several severe droughts descended on the Llano Estacado in the summer of 1886 to dry up the water holes and to scorch the grasslands. Intensifying the problems created by the summer drought, the following winter produced such a severe blizzard that large herds of cattle froze to death. Although summer droughts and winter blizzards were fierce natural enemies on the Southern High Plains, so many additional settlers came in that there was never a lack of people willing to challenge the elements.

As memories of the first great drought faded, the cattle ranches were gradually subdivided into farm units and crops began to replace cattle as the primary economic foundation of the region. With the conversion of the cattle estates to farm land, organized communities began to spring up throughout the plains. Developing a water system was always one of the most immediate problems of these new communities. Fortunately, during their early years of development most of them had little difficulty in securing enough ground water to meet their municipal needs.

During the 1930's, a complex of favorable events, including a policy of federal crop price support, expanding overseas markets, technological advances in irrigation systems, and liberal financing terms, made ground water irrigation a reality in many parts of the Southern High Plains. As irrigation farming developed, the rural population increased and the towns of the area grew and prospered. Nurtured by the myth of an inexhaustible ground water supply, the readily available resources were recklessly exploited with little regard for the future. Gradually a few farsighted individuals began to take cognizance of the geologic fact that the ground water supply was indeed limited and eventually could be effectively exhausted throughout the region. To them it seemed inevitable that the Canadian River, fed by melting snow on the eastern slopes of the Sangre de Cristo Mountains should be tapped as a surface source to supplement the declining supply of ground water.

Studies of stream flow records made it apparent that the water of the Canadian River was not sufficient to significantly augment irrigation supplies. The river did, however, carry enough water to make a valuable contribution to the municipal and industrial needs of the area. It was expected that developing the water of the Canadian River for local municipal and industrial use would contribute somewhat to prolonging the effective availability of the ground water in the Ogallala aquifer.

The extended drought of the 1950's convinced many concerned citizens of the Southern High Plains of the necessity to begin an earnest search for supplemental water sources to replace the declining ground water supply. It seems apparent that this drought was one of the factors which provided the necessary impetus for the construction of the Canadian River Project.

The water needs of most of the cities of the Canadian River Municipal Water Authority were not yet critical at the time of project completion, and numerous area residents saw its immediate worth more in the recreational opportunities it afforded than in the water supply provided. Water-related recreational developments of the Texas Panhandle have never been adequate to meet the potential demands of the area. Lake Meredith, as a consequence, has become a very popular recreational attraction to an area that lacks large natural water bodies.

Officials responsible for planning urban development and economic growth in the Texas High Plains seem to agree that:

1. The dominant economic foundation of the urban communities is the agricultural productivity of the surrounding irrigated farmland.
2. The irrigated acreage will peak sometime before 1985, and the result will be a decline in farm productivity and a diminution in the total economy.
3. The stability of the cities is dependent upon (a) increasing industry to take up the slack left by a declining agriculture, (b) obtaining alternate supplies of water, (c) a radical

alteration of the cropping pattern, or (d) possibly some combination of the above three.

4. The diversion of water from the Canadian River is only a stop-gap measure intended to delay the impending crisis in regional water supply.
5. There is a need to actively promote the development of alternative sources of water for the High Plains.

Alternative sources of water, albeit from a considerable distance away, seem to be available to west Texas if in the final analysis the appropriate authorities determine that the benefits to the region, the state of Texas, and the United States are sufficient to warrant the enormous expenditure of public funds that would be required. Paramount among the schemes now under discussion is the Texas Water Plan, which would not only sustain the present level of irrigation on the Southern High Plains of Texas, but would eventually permit substantial expansion. The principal source of water which would supply the needs of the Texas Water Plan would at first be the lower Mississippi River, although it is generally agreed that at some point water taken from the Mississippi River would have to be replaced by the importation of water from Canada. Other river basin sources are under consideration but none of these seem to promise more than token amounts of water that would probably be insufficient to warrant the costs of diversion.

Research has been initiated by private foundations and government agencies to explore some of the other possibilities which offer promise of meeting part of the water deficit in the drier portions of the country. These include soil and water conservation measures to utilize a greater percentage of the natural precipitation of the area as well as measures to recover water from totally new sources. Among the more promising of these are soil mulching, surface sealing, playa water recovery, ground water recharge, and reclamation of saline and brackish water.

Analysis of the results of a questionnaire distributed to residents of the eleven cities of the Canadian River Municipal Water Authority reveals that statistically there is no significant difference in water awareness between men and women, between residents of the northern cities and residents of the southern cities, or between professional and business people and those with other vocations. Nine per cent of the responses were statistically neutral, and among the others, the balance was nearly evenly divided between positive and negative attitudes. Coupled with the meager response, it is necessary to conclude that a substantial segment of the population in the Llano Estacado is indifferent or negatively oriented to the problems of water insufficiency that threaten the future of the Southern High Plains of Texas.

Conclusions and Recommendations

The future prosperity of the eleven communities of the Canadian River Municipal Authority will to a large extent be determined by how well the municipal, county, and regional authorities succeed in solving the regional problems of water supply. It is necessary to understand that the well being of the communities, as they presently function, is inseparably tied to the irrigation agriculture of the Llano Estacado. Were the urban communities the only consumers of Ogallala formation ground water, there would seem to be no problem of sufficiency for the foreseeable future. The total municipal use is less than 125,000 acre-feet, while agricultural use exceeds 5,000,000 acre-feet annually. Yet, without irrigation agriculture to help support the rather impressive level of urban business activity, it seems very improbable that municipal and industrial use of water would be significant. The communities exist as prosperous trade centers because of the highly productive irrigated farm land which surrounds them. The cities, therefore, to a large extent exist because of the irrigated farms, while these same farms are creating one of the major problems confronting the cities. Economists at Texas A&M University periodically evaluate irrigation agriculture's contribution to the total economy of the Texas High Plains. Estimates of this contribution vary from forty per cent to more than sixty per cent for the region. Any efforts directed toward prolonging the effective use of irrigation within the Southern High Plains of Texas is of direct significance to the communities of the area.

In order to prolong the economic life of the ground water of the Ogallala formation, the writer recommends that:

1. Research be continued on the development of plant hybrids to produce crop varieties that require less water than those presently in use.
2. A serious re-evaluation be undertaken by the appropriate agencies to determine whether or not each irrigated crop produced on the Southern High Plains of Texas is in the overall best interest of the region.
3. All irrigation farmers who live within underground water conservation districts be required to operate under appropriate new legislation providing for more effective regulation of ground water used in irrigation.
4. Research be undertaken to increase the efficiency of natural rainfall in crop production by such means as water harvesting.
5. Area irrigators be encouraged to (a) line open irrigation ditches, (b) recover tailwater, (c) modify playas for maximum water recovery, and (d) plan for minimum reliance on ground water.
6. Research be continued to discover an economic and effective means of ground water recharge.

The writer has concluded that there will be no way for supplemental surface water to reach the High Plains of Texas before a serious decline in irrigation occurs. Such a decline will inevitably force major readjustments in the economic orientation of the urban communities. Application of the aforementioned measures to irrigation agriculture will aid in reducing the length of time of the anticipated water insufficiency to a minimum.

In addition to those water conservation measures which should be undertaken by the crop growers of the Southern High Plains of Texas, city dwellers can likewise take a more active part in planning for the future of the region. A healthy economy in the west Texas setting must be the result of farmers and city dwellers understanding that success lies in cooperation to meet the regional needs. To fulfill this goal, the writer recommends that responsible citizens:

1. Promote a far reaching program of water awareness education aimed at reaching all segments of society with a positive, yet realistic plan for the future which includes (a) an honest appraisal of the life expectancy of the local ground water resources, (b) an awareness of the need for economic adjustments as a result of the declining water supply in the Ogallala aquifer, and (c) a comprehensive water conservation program.
2. Actively support water-oriented organizations

intent on preserving and augmenting the region's water supplies.

3. Realistically consider any alternatives to an irrigation based economy that show some promise of providing economic stability for the region.
4. Financially support water-oriented research specifically directed at solving the problems of (a) effective water harvesting, (b) ground water recharge, and (c) water reclamation and re-use.

The writer applauds those segments of the population which are uniting to promote the redistribution of the water surpluses of North America by supporting state, regional, and national water plans. He feels that in this "era of the environment" population dispersion into smaller pre-planned cities of optimum size, built new, is one possibility for alleviating the economic and social ills of excessive urbanism. Tyler asserts that

> . . . we cannot juggle the 70 per cent of the American people around on 1 per cent of the land to solve the urban mess. We are compelled to think in terms of new towns and new cities planned . . . by public action with public funds.[1]

Given dependable water supplies of the magnitude proposed by the Texas Water Plan, the Southern High Plains of Texas would

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[1]Lewis G. Smith, "Regional Water Management, Key to Improving the Nation's Quality of Environment." (paper presented at Water Resources and Irrigation Symposium, Lubbock, Texas, April 1, 1971.)

provide large tracts of land suitable for new cities, surrounded by farmland compatible with "the new emerging concept of rural-urban symbiosis."[2]

The residents of the eleven cities of the Canadian River Municipal Water Authority for the most part have been privileged to enjoy the benefits of a highly prosperous regional economy. If they are to maintain their present high standard of living, they must begin making adjustments now in order to prepare for the inevitable decline in agricultural productivity which will accompany the draining of the Ogallala formation. Decisions which are made at all levels of concern during the next decade are critical to the communities of the High Plains of Texas. Sincere, concentrated efforts by the citizens of the region, the state of Texas, and the United States can assure that this highly productive farmland will continue to produce the crops necessary to the maintenance of continued prosperity. Imaginative development of the land to support larger numbers of people in model cities could contribute in a small way to solving some of America's urban crises. A reliable national water supply, a concern to which this study is directed, is an auxiliary challenge of urgent importance.

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[2] Ibid., p. 5.

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APPENDIX I

SAMPLE INFORMATION LEAFLET DESCRIBING THE CANADIAN RIVER PROJECT

QUESTION: WHAT IS WATER WORTH WHEN YOU DON'T HAVE IT?
ANSWER: WHATEVER YOU HAVE TO PAY TO GET IT!

X On November 22, citizens of Lubbock will have an opportunity to vote for a permanent supply of water.

LUBBOCK WATER RESOURCES BOARD

The Proposal

On November 22nd citizens of the eleven towns making up the Canadian River Authority will vote on the execution of two contracts to provide a permanent water supply for these cities, as follows:

a. A contract between the Canadian River Municipal Water Authority and the United States Government for the construction of the Canadian River dam and distribution system. The vote on this contract is to be taken in each of the eleven member cities and requires approval by a majority of the total votes cast in the eleven member cities:

b. A contract between the Canadian River Municipal Water Authority and the City of Lubbock for a water supply. The execution of this contract requires approval by a majority of the total votes cast in the city of Lubbock.

The Canadian River Municipal Water Authority is composed of Lubbock and the following ten other cities: Pampa, Borger, Amarillo, Plainview, Slaton, Tahoka, O'Donnell, Lamesa, Levelland, and Brownfield.

Actually, the Authority is an agency created by an act of the Texas Legislature in 1953 to do a special job of developing surface water supply under the management of a Board of

Directors, each of whom has equal authority and is appointed by the member cities.

QUESTIONS

Section I--Financing

1. Will the project be financed through ad valorem or property tax?

A. NO!

2. Will the project be financed through bonded indebtedness?

A. NO!

3. How will it be financed?

A. By revenue from water sales.

4. Who is eligible to vote in this election?

A. All presently qualified voters in the city of Lubbock.

Section II--Necessity of The Project

1. Do we need the Canadian River project?

A. Yes. The Canadian River is the only known source of a permanent water supply for Lubbock.

2. Why can't we continue to rely on the underground water?

A. The underground supply is being constantly depleted, resulting in a higher and higher unit cost, whereas the Canadian River water supply will result in lower and lower unit costs. The water cost after 50 years will be only the amount necessary to deliver the water to the city.

3. What is the estimated cost of the project?

A. $92,960,000. Of this amount, Lubbock's part of the cost is $37,548,000 payable over a 50-year period. The interest rate figured for the entire period is 2.632. (In addition to the $92,960,000 refundable cost, there is an additional cost of $3,130,000 which will be paid by the Federal Government for flood control).

4. How much water will the reservoir hold?

A. The reservoir will hold 1,331,500 acre feet at the crest of the spillway, assigned as follows:
   a. Municipal Supply. . . . . . 500,000 acre feet
   b. Silt Storage. . . . . 405,000 acre feet
   c. Dead Storage. . . . . 1,500 acre feet
   d. Flood Control . . . . 425,000 acre feet

5. What will be the quality of the water? Will it be "gyppy"?

A. Reports of the U. S. Corps of Engineers--the Bureau of Reclamation--and a nationally recognized private firm of engineers, Parsons, Brinkerhoff, Hall, and McDonald of New York--indicate that the quality of the water will be equal to or better than that now obtained from underground sources.

6. Will the water be treated?

A. Yes. It has not as yet been determined whether the water will be treated at the reservoir or by each city. The cost of treating the water is not included in the figures used herein.

7. Is the flow of the Canadian River sufficient to maintain the project planned?

A. After checking records over a long period of time, the above named engineers have certified that even in severe drought periods a minimum dependable yield in excess of 103,000 acre feet (92 million gallons per day), the amount contracted for by member cities, can be expected from the Sanford Reservoir drainage area of 12,655 square miles.

8. What will the effect of silt deposits in the reservoir be?

A. A 50-year silt storage capacity is being provided and after 50 years of silting there will still be 500,000 acre feet of water storage for use by the cities.

9. Will the lake provide fishing and recreational advantages?

A. Yes. There will be boat docks and sheds, repair shops, cabin site areas and good roads to make them accessable to the general public, all to be later provided by the Authority.

10. When will water be available to Lubbock?

A. Present est~~imate is that water~~ will be delivered to Lubbock by July 1, 1967.

Section III--Project Effect on Member Cities

1. Will the price of Canadian River water be the same to all cities?

A. No.

2. Why is there a difference in rates?

A. Because it costs a lot more to build the pipelines to the southernmost cities and to deliver water to them. Because the southernmost cities cannot enjoy any substantial recreational advantages, they are paying a disproportionately small portion or no portion of the cost of the dam. On the other hand, much longer pipelines have to be built to these cities than to those in the north, and the cost of transporting water to these cities is greater than to the cities in the north. Because of these various differences, costs have been worked out which are considered equitable.

3. Can the average water user in Lubbock expect an increase in water rates?

A. Yes. With or without the Canadian River project, water rates will have to be increased in Lubbock over the years.

Without the Canadian River water, our costs will go up anyway. If we do not secure the Canadian River water, another pipeline to Bailey County will have to be constructed by 1970 and many more wells drilled. Without the Canadian River water, as additional pipelines and wells are required, our water rates will have to be increased from time to time.

In the last five years the water rates in Lubbock have been increased approximately 27 percent. Rates for Canadian River water will increase to Lubbock users about 34 percent. This is about what water rates would have to be increased in ten years without the Canadian River water.

This is our only chance to get Canadian River water, and without Canadian River water we are eventually going to be out of water.

4. When do we start paying?

A. When we start getting the water.

5. How much water will Lubbock get?

A. Lubbock will get 37.058 percent of all municipal water in the reservoir--the same amount as Amarillo. This is 34,077,000 gallons per day.

6. What will the water rates per thousand gallons be for the various cities?

A.

Pampa	13.52c
Borger	12.88c
Amarillo	12.90c
Plainview	14.13c
Lubbock	17.66c
Slaton	21.70c
Tahoka	22.85c
O'Donnell	25.43c
Lamesa	29.16c
Levelland	27.85c
Brownfield	29.13c

7. What will happen if the project costs are different than the present estimates?

A. If less, then the Authority and member cities would get the benefit of the decrease. If more, the increase would be subject to further negotiations with the Government. However, the U. S. Bureau of Reclamation has assured the Authority that the estimates are plenty high. The estimates have been increased 25 percent over what they were five years ago.

8. Who is going to build the dam?

A. The Bureau of Reclamation will let contracts on a bid basis to private contractors.

9. What happens if we fail to approve these contracts?

A. We give up all rights to Canadian River water. Then we will have to rely solely upon underground water which is being depleted annually.

Added Information

The Lubbock Water Resources Board and the Campaign Executive Committee, with City officials, have spent hours and hours studying all the facts in connection with the Canadian River project. The information and the answers to the questions herein have been carefully compiled and unanimously approved by this Committee. Every effort has been made to give all the information possible--to answer questions that have been asked over a period of time--and, in the judgment of the Committee, all information is accurate.

The Canadian River project in some form or other has been in existence some 15 or 20 years. On June 15, 1949, the Federal Bureau of Reclamation made a detailed report on the Canadian River project to the 81st Congress. The report said that the project was feasible to supply the average daily requirements of the project cities with water. On December 29, 1950, the President signed the bill, Public Law No. 898, authorizing construction of the project when and if funds were appropriated. The Canadian River Municipal Water Authority was created by an act of the Texas Legislature in 1953.

Since 1950 there have been at least three elections held in connection with the project, and many, many changes have been made in various phases throughout the entire period.

At various times various citizens have questioned the wisdom of the project in the form it was at that particular time. We believe the project is as near perfect at this time as it is possible to make it. Some argue that the cost of the water should be the same to all cities. In the first place, that is not equitable because of the increased cost of delivering water to the southernmost cities. But the complete answer is that Amarillo and the northernmost cities will not go along on a uniform rate. We have got to take the present rates if we are to get Canadian River water for Lubbock.

In fact, anyone that will take all the facts which were considered in arriving at the present rates will have to admit--to our way of thinking--that the rates are equitable.

APPENDIX II

CONTRACT

Between

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

and the

CANADIAN RIVER MUNICIPAL WATER AUTHORITY, TEXAS

THIS CONTRACT, made this 28th day of November, 1960, between the UNITED STATES OF AMERICA, hereinafter called the United States, acting through the Secretary of the Interior, and pursuant to the Federal Reclamation Laws, and the CANADIAN RIVER MUNICIPAL WATER AUTHORITY, organized and existing pursuant to the laws of the State of Texas, with its principal place of business and office at Plainview, Texas.

WITNESSETH THAT:

WHEREAS, the Act of Congress effective December 29, 1950, (64 Stat. 1124) authorized the construction, operation, and maintenance of the Canadian River Project, Texas, and

WHEREAS, the Authority desires to contract with the United States for payment of the reimbursable costs of the construction, operation, and maintenance of the project in accordance with Reclamation Law, and

WHEREAS, the Authority is empowered to contract with the United States for payment of the reimbursable costs of construction, operation, and maintenance of project works, and is vested with all necessary powers for accomplishment of the purposes of this contract;

NOW, THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is agreed between the parties hereto as follows:

GENERAL DEFINITIONS

1. Where used in this contract,

a. Contracting Officer - shall mean the Secretary of the United States Department of the Interior or his duly authorized representative.

b. Federal Reclamation Laws - shall mean the Act of June 17, 1902 (32 Stat. 388) and all acts amendatory thereof or supplementary thereto.

c. Authority - shall mean the Canadian River Municipal Water Authority, an authority duly created and existing under the laws of the State of Texas, acting through its Board of Directors.

d. Member City - shall mean a city, town, or municipality which is a member of the Authority and is contracting for project water.

e. Dam and Reservoir - shall refer to the Sanford Dam and Reservoir on the Canadian River used for storing and regulating project water, including all lands and rights of way.

f. Project - shall mean the Canadian River Project, Texas, as authorized by the Act of Congress dated December 29, 1950 (64 Stat. 1124).

g. Project Works - shall mean all works or facilities constructed including the dam, reservoir, and aqueduct, together with land and rights of way for such works.

h. Project Water - shall mean water available for use through the project works for municipal and industrial purposes.

i. Project Water User - shall refer to all member cities and other contractors, their successors and assigns, which have contracted with the Authority to receive a portion of the project water supply.

j. Project Cost - shall mean sums expended by the United States on planning and constructing the project, within the limits of funds made available by the Congress.

k. Directors - shall mean the Board of Directors of the Authority, represented by quorum as required in its authorizing legislation.

l. Construction Charge Obligation - shall mean that portion of the project cost payable by the Authority as finally allocated to municipal and other water supply purposes, as provided for in the Act of December 29, 1950 (64 Stat. 1124).

m. Aqueduct - shall mean the project system for transporting stored water to the points of delivery established for the project, and includes all pipelines, conduits, pumping facilities, and related works, and the land and rights of way for such works and facilities.

n. Year - shall mean the period January 1 through the next following December 31.

PROJECT PLAN

2. The proposed plan of construction for the project is to construct Sanford Dam and Reservoir and an aqueduct for transporting untreated water to the member cities.

ALLOCATION OF COSTS

3. The construction cost of the project has been estimated as of July 1960 prices to total $96,090,000 distributed as follows:

Sanford Dam and Reservoir		$31,060,000
Aqueduct		$65,030,000
	Total	$96,090,000

Allocation of estimated construction cost is as follows:

Sanford Dam and Reservoir	
a. Reimbursable by Authority	$27,930,000
b. Nonreimbursable - Flood Control	$ 3,130,000
Aqueduct - Reimbursable by Authority	$65,030,000
Total	$96,090,000

Subject to the terms and conditions of this contract, the United States will spend on the construction of the project not to exceed $96,090,000 plus such amounts, if any, as may be justified by reason of ordinary fluctuations in construction costs, or so much thereof as in the opinion of the Contracting Officer is necessary, within the limit of funds made available by the Congress. The Authority's maximum construction charge obligation under this article of the contract is $92,960,000, plus interest during construction and annual interest on the unamortized balance of the cost allocated to municipal water. Interest during construction shall not accrue during any extended period in which construction is deferred or postponed by the United States as the result of a National emergency. Interest during construction shall be calculated as follows: Simple interest during construction shall be charged on one-half of each fiscal year's expenditures allocated to municipal water at 2.632 percent annually together with interest at the same rate annually on the full amount of such expenditures during previous fiscal years. The total amount of all interest thus accumulated through the construction period prior to the date of actual completion of the project, as established by announcement of the Contracting Officer, shall be added to the construction cost of the project allocated to the municipal water supply component of the project. The Authority shall also pay interest at 2.632 percent each year of the repayment period on the unamortized balance of the project cost. Should the final cost of constructing the project works be less than is estimated in this contract, as determined and announced by the Contracting Officer, then all allocations of project costs shall be reduced proportionately to the original allocations, and such lesser amount allocated for reimbursement by the Authority shall become its obligation. If the Contracting Officer finds at any time that the works required to carry out the objectives of this contract cannot be completed within the estimate above, he shall consult with the Authority Board of Directors, and appropriations therefor then being available and authorized, may make continuation of construction contingent upon the execution and confirmation of a valid contract by the Authority increasing its maximum repayment obligation to cover the increased reimbursable costs. If the parties hereto are unable to agree upon the terms of such an amendatory contract for repayment of the additional cost, the Contracting Officer may issue the requisite notice for commencing repayment in the manner contemplated in Article 4.

CONSTRUCTION CHARGE OBLIGATION

4. a. The Authority shall pay to the United States on account of construction of the works and facilities contemplated herein all reimbursable project costs as itemized in Article 3, which is herein referred to as the construction charge obligation, as determined and announced by the Contracting Officer, but not to exceed amounts calculated as set forth in said Article 3. Such construction charge obligation shall be paid in 50 successive annual installments as follows, based upon a reimbursable cost of $92,960,000 plus interest during construction, and interest on the unamortized balance thereof at the rate of 2.632 percent.

Annual Installment Number	Annual Installment Payment	Annual Installment Number	Annual Installment Payment
1	$ 2,379,000	26	$ 4,083,000
2	2,473,000	27	4,083,000
3	2,569,000	28	4,083,000
4	2,664,000	29	4,083,000
5	2,759,000	30	4,083,000
6	2,854,000	31	4,083,000
7	2,950,000	32	4,083,000
8	3,045,000	33	4,083,000
9	3,140,000	34	4,083,000
10	3,235,000	35	4,083,000
11	3,330,000	36	4,083,000
12	3,425,000	37	4,084,000
13	3,520,000	38	4,084,000
14	3,616,000	39	4,084,000
15	3,710,000	40	4,084,000
16	3,806,000	41	4,084,000
17	3,886,000	42	4,084,000
18	3,964,000	43	4,084,000
19	4,044,000	44	4,085,000
20	4,083,000	45	4,085,000
21	4,083,000	46	4,085,000
22	4,083,000	47	4,085,000
23	4,083,000	48	4,086,000
24	4,083,000	49	4,086,000
25	4,083,000	50	4,086,000

Each annual installment shall become due and payable on or before October 1 of each year commencing with the year immediately following that in which a notice is given stating that the project is sufficiently complete to permit the initiation of water deliveries and water is available to serve member cities if such notice is given prior to October 1, otherwise to commence in the second calendar year after such notice is given. Payments shall be made on the basis of the above table until all project costs are, in the opinion of the Contracting officer, finally determined, at which time a revised schedule of payment shall be prepared based upon substantially the same ratio of annual repayment as the above table; payments thereafter shall conform with that table. If construction of the project works shall have been commenced, but is terminated prior to completion by reason of lack of funds or failure to secure the necessary amendatory contracts, then the Authority shall pay to the United States its proportionate share of the total amount theretofore incurred or obligated at such time and in such manner as the Contracting Officer may then prescribe.

b. The costs of constructing works in accordance with a plan approved by the President of the United

States for the preservation and propagation of fish and wildlife, including any allocation of dam and reservoir construction costs, shall be nonreimbursable.

OPERATION AND MAINTENANCE BY THE AUTHORITY

5. a. The Authority shall care for, operate and maintain the project works upon sufficient completion of the project to permit the delivery of water, as announced by the Contracting Officer, without cost or expense to the United States and in full compliance with applicable Federal laws, the terms of this contract, and in such a manner that the project works shall remain in good and efficient operating condition. No substantial change shall be made by the Authority in any of the project works without first obtaining the written consent of the Contracting Officer.

b. The Authority shall make promptly any and all repairs to the project works which the Contracting Officer may determine are reasonably necessary. If the Contracting Officer determines that any part of the project works is for any cause unfit for service, or being operated contrary to the terms of this contract, he may order the water shut off until in his opinion such part of the project works is put in proper condition for service and properly operated. In case of neglect or failure of the Authority to make such repairs, the Contracting Officer may cause the repairs to be made and the cost thereof, as determined by the Contracting Officer, shall be paid by the Authority to the United States as provided in Article 8. Failure to pay and/or failure to shut off water when ordered shall constitute a breach of contract.

c. During all periods of project operation by the Authority, the reasonable annual cost of operation and maintenance of Sanford Dam and Reservoir allocated to flood control and fish and wildlife as determined by the Contracting Officer, shall be credited against payments due the United States.

d. The Contracting Officer may from time to time cause an appropriate inspection of the project works to be made to ascertain whether the requirements of this contract are being satisfactorily performed by the Authority. Such inspections may include physical inspection of all properties of the Authority. Any such inspection shall, except in a case of emergency, be made after written notice to the Authority and the actual expense thereof shall be paid by the Authority to the United States in the manner provided in Article 8 hereof.

e. The Authority shall hold the United States, its officers, agents and employees, harmless as to any and all damages which may in any manner grow out of the care, operation and maintenance of any of the project works by the Authority.

OPERATION AND MAINTENANCE BY THE UNITED STATES

6. In the event the Authority is at any time in default on any of its obligations to the United States under this contract, or is found by the Contracting Officer to be operating the project works or any part thereof in violation of this contract and the Authority refuses after due notice to correct such violation, then at the election of the Contracting Officer, the United States may take over from the Authority the care, operation and maintenance of all or any part of the project works by giving written notice to the Authority of such election, the effective date thereof, and the funds required to be advanced by the Authority to the United States. Thereafter, during the period of Government operation, the Authority shall pay to the United States annually in advance of the use of such project works the reasonable cost of operation and maintenance of such works, as fixed in notices from the Contracting Officer to the Authority. Such works may be retransferred to the Authority upon proper notice. The Authority shall surrender possession and accept the retransfer on being given the notice provided for herein. Nothing herein contained shall be construed as denying to the Authority the right to resume operation of the project works at such time as the Authority corrects any default in payment by paying all amounts owing to date, or corrects the violation of contract which caused the United States to take over operation, and the United States agrees to return operation of said facilities to the Authority upon the correction of such default or violation.

CONSTRUCTION, OPERATION AND MAINTENANCE OF RECREATIONAL AND FISH AND WILDLIFE FACILITIES

7. The Authority may construct, operate and maintain without cost to the United States, such recreational facilities as are desired by it. Construction of such facilities and any operation thereof shall be subject to advance approval of the plan by the Contracting Officer. No recreational use shall be permitted which is inconsistent with the laws of the State of Texas and the United States. The Authority shall also operate and maintain such facilities as are constructed by the United States for the protection, preservation and propagation of fish and wildlife. The United States may contract with proper agencies of the State of Texas for the construction, operation and maintenance at their expense of all or any part of these facilities approved by the

Contracting Officer upon his determination that performance of work or transfer of responsibility to the State of Texas is in the best public interest.

ADDITIONAL COSTS TO BE PAID BY THE AUTHORITY

8. In addition to all other payments the Authority shall pay to the United States on or before October 1 of the year following that in which they have been incurred, the following costs:

a. The cost of inspection and repairs to project works incurred by the United States.

b. Such items for administration, supervision, and general expenses as are properly and equitably chargeable to the Authority.

RESERVE FUND

9. a. Commencing with a deposit on August 1 of the fifth calendar year after the first installment is payable on the construction charge obligation, and continuing until the sums of money becoming due under this contract shall have been paid to the United States, the Authority shall accumulate and maintain a reserve fund to be available for the purposes and in the circumstances herein mentioned.

b. Such reserve shall be accumulated by the Authority through the deposit of annual amounts of not less than $30,000 until the aggregate reserve fund accumulated shall total not less than $300,000. Said sum shall be maintained at all times thereafter, and when depleted by expenditures as contemplated herein, it shall be restored to the original total by annual deposits on each August 1st in amounts of not less than $30,000, or such lesser amount as shall be necessary to re-establish a total of $300,000.

c. The reserve fund shall be available to meet the extraordinary and unforeseen costs of operation and maintenance, repair and betterment of the project works, and may be used for capital or major improvement or replacement with the approval of the Contracting Officer.

d. The reserve fund shall be deposited and maintained apart from other funds of the Authority in a depository satisfactory to the Contracting Officer.

e. During such times as the project works constructed hereunder shall be operated and maintained by the United States in accordance with the provisions of Article 6 hereof, the reserve fund shall be available for use by the

United States for the purposes specified in this article.

f. At the option of the Authority, the reserve fund may be invested in short term securities of or guaranteed by the United States and maturing in not to exceed five years from the date of purchase.

TITLE TO PROJECT WORKS

10. Title to the dam and reservoir shall remain in the United States until otherwise provided by the Congress, notwithstanding transfer of the operation and maintenance of said works to the Authority. Title to the aqueduct shall pass to the Authority or its designee or designees upon payment to the United States of all the Authority's obligations arising under this contract.

RIGHTS OF WAY

11. a. The Authority shall, if and when requested by the Contracting Officer, and to the extent of its authority, acquire by condemnation or otherwise, and convey to the United States all lands or interests in lands required for the construction, operation and maintenance of the project works.

b. Title to all lands or interests in lands and improvements acquired through negotiation by the Authority shall be taken in the name of the United States at prices not exceeding the appraised value as supported by the appraisal reports approved by the Contracting Officer. In acquiring said title, the Authority shall use such forms of contracts, deeds, and other necessary papers as may be required by the United States. After title has been found satisfactory to the United States, payment for rights acquired through such negotiation shall be made directly by the United States to the seller. Payments of more than the appraised value will be made only upon the approval of the Contracting Officer.

c. Where the Authority acquires lands by condemnation, upon approval by the Contracting Officer of the title to be acquired and of the amount of the condemnation award, the United States will pay into the appropriate state court for and on behalf of the Authority the amount of such condemnation award plus all proper court costs and the Authority simultaneously therewith will deliver to the United States a properly executed warranty deed conveying to the United States the title or interests in lands being acquired in such condemnation proceedings. The Authority will defend against any landowner's appeal from a condemnation award or judgment and, at the request of the Contracting Officer, will prosecute to the fullest extent of its remedies an appeal from any unfavorable award or judgment. The United States will pay into the appropriate court for and on behalf of the Authority the amount required to satisfy the award as finally determined plus appropriate court costs. Should the amount of the award be reduced, the Authority will make appropriate refunds to the United States.

d. To the extent approved by the Contracting Officer, expenses (other than normal overhead, general, and continuing expenses) incurred by the Authority in connection with the acquisitions above provided for shall be paid to the Authority. Statements of such expenses shall be submitted by the Authority to the United States at the close of any calendar month, and to the extent that such expenses are paid by the United States, they shall be treated as construction costs.

AUTHORITY REVENUE

12. The Authority shall cause to be collected all moneys to meet the obligation of the Authority to make in full all payments to be made pursuant to this contract on or before the date such payments become due and to meet its other obligations under this contract. Payments due the United States under this contract shall be a first obligation upon all revenues of the Authority, except as specifically provided in Article 18b. (3).

INTEREST ON DELINQUENT INSTALLMENTS

13. Every installment or charge required to be paid to the United States under this contract which shall remain unpaid after its due date shall bear interest at the rate of 6 percent per annum from the date of delinquency. Provided, that no penalty shall be charged to or be paid by the Authority unless such delinquency continues for more than thirty (30) days.

DEFAULTS

14. a. No water shall be available to or delivered to the Authority or to the member cities or other water contractors or by the Authority through project works for the use of said member cities or contractors during any period in which the Authority may be:

(1) More than 12 months in arrears in the payment to the United States or any construction charges accrued under this contract.

(2) In arrears in the advance payment to the United States of the operation and maintenance charges fixed under Article 6 of this contract.

b. No Water shall be delivered by the Authority through project works to any member city or water contractor when such user is in arrears in the payment to the Authority of any charges fixed by the Authority for the purpose of raising revenues to meet the payment by the Authority to the United States of any of the Authority's obligations under this contract, and furthermore, the Authority will utilize the rights and remedies available to it for effecting collection of funds for paying its obligations under this contract.

c. All rights of action for breach of this contract are reserved to the United States as provided in Section 3737 of the Revised Statutes of the United States, as amended (41 U.S.C. 15). Nothing contained in this contract shall be construed as abridging, limiting, or depriving the United States or the Authority of any means of enforcing any remedy either at law or in equity for the breach of any provisions hereof which either party would otherwise have. The waiver of a breach of any of the provisions of this contract shall not be deemed to be a waiver of any provisions hereof, or of any other or subsequent breach of any provision hereof.

WATER RIGHTS

15. a. In no event shall the United States be obligated to commence any of the work contemplated by this contract or perform any other act in pursuance of this contract until and unless water rights satisfactory to the Contracting Officer are obtained and made available for project purposes. The Authority shall have a first right to the project's available water supply for use by its member cities and approved contract water users during the repayment period, and a permanent right to such share or quantity of water thereafter, all subject to payment on a current basis of such charges as are provided for in this contract.

b. The parties hereto do not abandon nor relinquish any of the seepage or return flow water attributable to the use of the project water supply.

WATER SHORTAGES

16. a. On account of drought or other causes, there may occur at times during any year a shortage in the quantity of water available to the Authority pursuant to this contract. In no event shall any liability accrue against the United States or any of its officers or employees for any damage, direct or indirect, arising out of any such shortage.

b. The United States assumes no responsibility for the quality of water made available under this contract.

USE, ALLOTMENT AND PROTECTION OF PROJECT WATER

17. a. Use of Water During Construction - During construction of the project works, any project water which may become available and usable may be distributed by the United States at such rental rates as the Contracting Officer may determine and establish. Payment for water so used shall be made in advance and the places of measurement and delivery shall be established by the Contracting Officer after consultation with the Authority directors.

b. Authority to Control Releases - After completion of construction, the Authority shall have absolute control over the release and use of all project water so long as it shall remain current in the payment of such amounts as are due the United States under this contract; Provided, however, that such control shall not affect the right of the United States to exercise dominion thereover for flood control and fish and wildlife purposes, consistent with the authorized project and the nonreimbursable allocation of funds therefor.

c. Water Supply Contracts - The Authority shall make allotments and contracts for the disposal of project water for municipal and industrial uses in accordance with the applicable Federal and state laws. All such water allotments and disposal contracts shall be upon terms satisfactory to the Contracting Officer and the Authority, and shall be approved in advance, and shall not be amended without mutual written consent.

d. Use of Project Water - Beneficial use shall be the basis, the measure and the limit of the right to the use of project water. Such water shall be used by the Authority, its member cities and miscellaneous users who contract with the Authority.

e. Protection of Project Water Supply - In case a dispute arises as to the character, extent, priority or validity of water rights claimed for the project, the Authority shall promptly bring and diligently prosecute or defend judicial proceedings for the determination of such dispute and shall take all other measures necessary toward the defense and protection of the water supply.

AUTHORITY FACILITIES - ISSUANCE OF BONDS

18. a. In addition to the project works specified in Article 2 hereof, the Authority may require other facilities for delivering treated or untreated project water to project water users. The Authority may find it necessary to finance the acquisition of such facilities by the issuance

of bonds and other securities pursuant to the laws of the State of Texas.

b. Nothing in this contract shall be construed to deny:

(1) The right of the Authority to construct, lease, purchase or otherwise acquire additional facilities for handling project water, or the right of the Authority to issue bonds or other evidence of indebtedness to finance the acquisition of such facilities;

(2) The right of the Authority to operate and maintain such additional facilities which are not directly integrated with project works free of all supervision or control by the United States;

(3) The right of the Authority to impose separate charges or to levy separate assessments for water treatment or distribution facilities for delivery of project water to project water users, in addition to those charges required to meet the obligations of the Authority to the United States under this contract. The proceeds of such additional charges or assessments may be used by the Authority for the payment of principal or the interest on the aforementioned bonds or other securities, free of any claim thereto by the United States.

The United States has a prior claim to that part of the Authority's income from its contracts with member cities designated for the purchase and sale of the project water supply, as may be necessary in each year to assure the prompt payment of the amount due the United States hereunder in such year, and such prior claim is hereby expressly recognized by the Authority.

WATER SUPPLY CONTRACTS NECESSARY PREREQUISITES TO CONSTRUCTION

19. The United States shall be under no obligation to commence, or having commenced, to continue construction of the project works until the Authority shall have negotiated and confirmed contracts acceptable to the Contracting Officer with the member cities or others, requiring said contractors to purchase a portion of the project water supply at rates adequate to repay that portion of the construction charge obligation allocated for repayment by the Authority. Such contracts shall provide for assignment to the United States upon the request of the Contracting Officer and shall provide for approval in advance of the effective date by the Contracting Officer. They shall not be amended or terminated without his written consent. The obligation of each member

city shall constitute an operating expense of its water system.

COMPUTATION OF COSTS

20. The costs which shall be the basis of determining the Authority's construction charge obligation as well as the various charges to be paid by the Authority to the United States under this contract shall embrace expenditures of whatsoever kind in connection with, growing out of, or pursuing from the work or operation described, including but without limitation by means of this enumeration, the cost of labor, material, equipment, engineering and legal work, superintendence, administration and overhead, general expenses, rights of way, inspections, special services, property damages of all kinds. The determination of what costs are properly chargeable hereunder and the amount thereof shall be determined by the Contracting Officer on the basis of costs actually incurred in construction and completion of the project.

AUTHORITY RECORDS AND REPORTS

21. The Authority shall establish and maintain a modern set of books of account and records, and furnish reports as the Contracting Officer shall request pertaining to:

a. Accounts and financial transactions of the Authority.

b. Water supply and the disposition thereof.

ACCESS TO BOOKS AND RECORDS

22. Duly authorized representatives of each party shall have the right, during office hours, to inspect and to make copies of the other party's books and official records relating to matters covered by this contract.

RULES AND REGULATIONS

23. a. There is reserved to the Contracting Officer the right, so far as the purport thereof may be consistent with the provisions of this contract, to make reasonable rules and regulations and to add to and modify them as may be deemed proper and necessary to carry out this contract, and to supply necessary details of its administration, and the Authority agrees to observe such rules and regulations.

b. A portion of the cost of constructing the project has been allocated on a nonreturnable basis to controlling floods, and may be allocated to the preservation and propagation of fish and wildlife. To insure securing the benefits for which participation by the United States has been included in the cost of constructing the project, operation of project works shall be in accordance with rules and regulations prescribed by the Secretary of the Interior and the Secretary of Defense.

CONTINGENT UPON APPROPRIATION OR ALLOTMENT OF FUNDS

24. The expenditure of any money or the performance of any work by the United States herein provided for, which may require appropriations of money by Congress or the allotment of funds, shall be contingent upon such appropriation or allotments being made. The failure of Congress to appropriate funds or the failure of any allotment of funds shall not, however, relieve the Authority from any obligations theretofore accrued under this contract, nor give the Authority the right to terminate this contract as to any of its executory features. No liability shall accrue against the United States in case of such funds not being appropriated or allotted.

DETERMINATIONS

25. Where the terms of this contract provide for action to be based upon the opinion or determination of either party to this contract, whether or not stated to be conclusive, said terms shall not be construed as permitting such action to be predicated upon arbitrary, capricious, or unreasonable opinions or determinations.

ASSURANCES RELATING TO VALIDITY OF CONTRACT

26. This contract shall not be binding upon the United States until the proceedings on the part of the Authority for the authorization of the execution of this contract shall have been confirmed by decree of a court of competent jurisdiction or pending appellate action if ground for appeal be laid. Upon the execution of this contract, the Authority diligently shall process to final conclusion such confirmation proceedings. The Authority at its cost shall furnish to the United States two certified copies of the decree of confirmation and all pertinent supporting records.

CHANGES IN AUTHORITY ORGANIZATION

27. While this contract is in effect, no change shall be made in the Authority by proceedings to dissolve, consolidate, merge, or other wise except upon the Contracting Officer's written consent thereto.

NOTICES

28. Any notice authorized or required to be given to

the United States shall be delivered or mailed, postage prepaid, to the Regional Director, Bureau of Reclamation, Amarillo, Texas. Any notice authorized or required to be given to the Authority shall be delivered or mailed, postage prepaid, to the Canadian River Municipal Water Authority, Plainview, Texas. The designation of the addressees or the addresses given above may be changed by notice given in the same manner as provided in this article for other notices.

ASSIGNMENT LIMITED- SUCCESSORS AND ASSIGNS OBLIGATED

29. The provisions of this contract shall apply to and bind the successors and assigns of the parties hereto, but no assignment or transfer of this contract or any part or interest therein shall be valid until approved by the Contracting Officer.

NONDISCRIMINATION IN EMPLOYMENT

30. a. In connection with the performance of work under this contract, the Authority agrees not to discriminate against any employee or applicant for employment because of race, religion, color or national origin. The aforesaid provision shall include, but not be limited to, the following: Employment, upgrading, demotion, or transfer; recruitment or recruitment advertising, layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. The Authority agrees to post hereafter in conspicuous places, available for employees and applicants for employment, notices to be provided by the Contracting Officer setting forth the provisions of the nondiscrimination clause.

b. The Authority further agrees to insert the foregoing provision in all subcontracts hereunder, except subcontracts for standard commercial supplies or raw materials.

OFFICIALS NOT TO BENEFIT

31. No member of or Delegate to Congress or Resident Commissioner shall be admitted to any share or part of this contract or to any benefit that may arise herefrom, but this restriction shall not be construed to extend to this contract if made with a corporation or company for its general benefit.

IN WITNESS WHEREOF, the parties hereto have signed their names the day and year first above written.

THE UNITED STATES OF AMERICA

By /s/ Leon W. Hill

Title Regional Director
[Bureau of Reclamation]

CANADIAN RIVER MUNICIPAL WATER AUTHORITY

By /s/ C. T. Johnson

Title President

(Seal)

ATTEST:

/s/ A. A. Meredith
Secretary

Supplement No. 1

SUPPLEMENTAL CONTRACT

Between

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

and the

CANADIAN RIVER MUNICIPAL WATER AUTHORITY, TEXAS

THIS SUPPLEMENTAL CONTRACT, made this ________ day of ____________________ 19___, between the UNITED STATES OF AMERICA, hereinafter called the "United States," acting through the Secretary of the Interior and through the Bureau of Reclamation, hereinafter referred to as the "Bureau," pursuant to the Federal Reclamation Laws, and the CANADIAN RIVER MUNICIPAL WATER AUTHORITY, hereinafter called the "Authority," organized and existing pursuant to the laws of the State of Texas, with its principal place of business and office at Plainview, Texas.

WITNESSETH THAT:

WHEREAS, the United States and the Authority entered into a contract dated November 28, 1960, as amended and supplemented, hereinafter referred to as the "basic contract," covering the construction, operation, and maintenance of the Canadian River Project, Texas; and

WHEREAS, under the terms of the basic contract, the Authority is responsible to care for, operate, and maintain the project works which consist of all works or facilities constructed, including the dam, reservoir, and aqueduct, together with land and rights-of-way for such works; and

WHEREAS, the Authority is authorized to construct, operate, and maintain recreational facilities desired by it and obligated to operate and maintain facilities constructed by the United States for the protection, preservation, and propagation of fish and wildlife; and

WHEREAS, the Authority has reviewed plans for recreational development proposed by the National Park Service, hereinafter referred to as "Park Service," and has concluded that such plans, to the extent authorized for completion, would constitute the most desirable development for permitting maximum public use of project lands and the water area for recreation.

NOW, THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is agreed between the parties hereto as follows:

1. The Authority is relieved of responsibility assumed under the basic contract to care for, operate, and maintain project works designated for public recreational use. The project works specifically excepted from the basic obligation of the Authority hereinunder will include those land and water areas and recreational facilities constructed at Sanford Reservoir for public recreation use. The Authority is also relieved of responsibility to operate and maintain facilities constructed by the United States for the protection, preservation, and propagation of fish and wildlife.

2. The Bureau will negotiate a memorandum of agreement with the National Park Service under the terms of which the Park Service will assume responsibility for administration and development of designated areas of the Sanford Reservoir and contiguous lands for public recreation use.

3. This contract shall be effective only following execution of a memorandum of agreement acceptable to the Authority, for the purposes described in the preceding article, between the Bureau and the National Park Service.

4. All terms and conditions of the basic contract shall remain in full force and effect and shall be applicable to this supplemental agreement to the same extent as though herein specifically incorporated.

IN WITNESS WHEREOF, the parties have executed this memorandum of agreement as of the day and year first hereinabove written.

THE UNITED STATES OF AMERICA

By__________________________

Title Regional Director
[Bureau of Reclamation]

(SEAL)

ATTEST:

____
Secretary

CANADIAN RIVER MUNICIPAL
WATER AUTHORITY

By__________________________

Title President

CANADIAN RIVER RECLAMATION PROJECT, TEXAS
Contract No. 14-06-500-1471

A M E N D A T O R Y   C O N T R A C T

Between

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

and the

CANADIAN RIVER MUNICIPAL WATER AUTHORITY, TEXAS

THIS AMENDATORY CONTRACT, made this ______ day of ______________ 1967, between the UNITED STATES OF AMERICA, hereinafter called the United States, acting through the Secretary of the Interior, and pursuant to the Federal reclamation laws, and the CANADIAN RIVER MUNICIPAL WATER AUTHORITY, hereinafter called the Authority, organized and existing pursuant to the laws of the State of Texas, with its principal place of business and office at Plainview, Texas.

WITNESSETH THAT:

WHEREAS, by contract dated November 28, 1960, as amended and supplemented, hereinafter referred to as the basic contract, the Authority contracted with the United States for payment of the reimbursable costs of construction, operation, and maintenance of the Canadian River project in accordance with reclamation law; and

WHEREAS, the parties hereto desire to provide for waiving certain interest charges as authorized by the Water Supply Act of 1958, as amended and supplemented (Act of Congress approved July 3, 1958, amended by the Act of July 20, 1961; 43 U.S.C.A. 390 (b)); and

WHEREAS, the parties hereto propose to conform the allocation of costs and construction charge obligation estimates set forth in the basic contract to more accurately reflect the present estimate of construction costs.

NOW, THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is agreed between the parties hereto as follows:

1. Article 3 of the basic contract is deleted and superseded by the following:

ALLOCATION OF COSTS

3. The construction cost of the project has been estimated as of June 1967 to total $84,605,000 distributed as follows:

Sanford Dam and Reservoir	$ 29,906,000
Aqueduct System	$ 52,745,000
Specific Recreation and Fish and Wildlife Facilities	$ 1,954,000
Total	$ 84,605,000

Allocation of estimated construction cost is as follows:

Sanford Dam and Reservoir	
a. Reimbursable by Authority	$ 24,994,000
b. Nonreimbursable - Flood Control	$ 2,828,000
c. Nonreimbursable - Fish and Wildlife	$ 2,084,000
Aqueduct - Reimbursable by Authority	$ 52,745,000
Specific Recreation and Fish and Wildlife Facilities - Nonreimbursable	$ 1,954,000
Total	$ 84,605,000

Subject to the terms and conditions of this contract, the United States will spend on the construction of the project not to exceed $84,605,000 plus such amounts, if any, as may be justified by reason of ordinary fluctuations in construction costs, or so much thereof as in the opinion of the Contracting Officer is necessary, within the limit of funds made available by the Congress. The Authority's maximum estimated construction charge obligation under this article of the contract is $77,739,000, plus 5 percent of such amount for contingencies resulting from fluctuations in project construction costs including the settlement of claims, plus interest during construction and annual interest on the unamortized balance of the cost allocated to municipal water, but excepting any portion of the annual interest waived under authority of the Water Supply Act of 1958 and detailed in the next succeeding paragraph of this article. Interest during construction shall not accrue during any extended period in which construction is deferred or postponed by the United States as the result of a National emergency. Interest during construction shall be calculated as follows: Simple interest during construction shall be charged on one-half of each fiscal year's expenditures allocated to municipal water at 2.632 percent annually together with interest at the same rate annually on the full amount of such expenditures during previous fiscal years. The total amount of all interest thus accumulated through the construction period prior to the date of actual completion of the project, as established by announcement of the Contracting Officer, shall be added to the construction cost of the project allocated to the municipal water supply component of the project. The Authority shall also pay interest at 2.632 percent each year of the repayment period on the unamortized balance of the project cost, except as modified by the next succeeding paragraph of this article. Should the final cost of constructing the project works be less than is estimated in this contract, as determined and announced by the Contracting Officer, then all allocation of project costs shall be reduced proportionately to the original allocations, and such lesser amount allocated for reimbursement by the Authority shall become its obligation. If the Contracting Officer finds at any time that the works required to carry out the objectives of this contract cannot be completed within the estimate above, he shall consult with the Authority's Board of Directors, and appropriations therefor then being available and authorized, may make continuation of construction contingent upon the execution and confirmation of a valid contract by the Authority increasing its maximum repayment obligation to cover the increased reimbursable costs. If the parties hereto are unable to agree upon the terms of such an amendatory contract for repayment of the additional cost, the Contracting Officer may issue the requisite notice for commencing repayment in the manner contemplated in article 4.

Project storage is designed to yield 103,000 acre-feet of water annually for municipal and industrial use. That portion of the firm annual yield provided for anticipated future water demand is 30,900 acre-feet. Costs allocated to anticipated future water demand shall be either 30 percent of total estimated project costs or the amount of construction costs of the dam and reservoir, including interest during construction, allocated to water supply, which may be deferred to future water demand, whichever is the lesser amount. No interest payment is required to be made on such amount during a 10-year period of the repayment term unless all or a portion of said annual yield reserved for anticipated future water demand is used in any year in said 10-year period. In the event of such use of a portion of the storage allocated to anticipated future water demand, all payments required to be made in subsequent years shall be adjusted to reflect interest payments on that portion of the reserve storage then placed in use. Such adjustments will be determined by multiplying the percentage of the yield allocated to future water demand which is withdrawn in such year for municipal and industrial use by the cost allocated to future water demand.

2. Article 4 of the basic contract is deleted and superseded by the following:

CONSTRUCTION CHARGE OBLIGATION

4. The Authority shall pay to the United States on account of construction of the works and facilities contemplated herein all reimbursable project costs as itemized in article 3, which is herein referred to as the construction charge obligation, as determined and announced by the Contracting Officer. Such construction charge obligation shall be paid in 50 successive annual installments. Based upon an estimated reimbursable cost of $77,739,000 plus interest during construction, interest on the unamortized balance thereof at the rate of 2,632 percent, but excepting that portion of the interest waived under authority of the Water Supply Act of 1958 and detailed in the closing paragraph of article 3 of this contract, the annual installments would be as follows:

Annual Installment Number	Annual Installment Payment	Annual Installment Number	Annual Installment Payment
1	$ 2,014,060	26	$ 3,457,120
2	2,094,450	27	3,457,120
3	2,175,050	28	3,457,120
4	2,255,550	29	3,457,120
5	2,336,350	30	3,457,120
6	2,416,700	31	3,457,120
7	2,429,910	32	3,457,120
8	2,440,240	33	3,457,120
9	2,450,440	34	3,457,120
10	2,530,190	35	3,457,120
11	2,819,650	36	3,457,120
12	2,900,180	37	3,457,120
13	2,980,750	38	3,457,120
14	3,061,280	39	3,457,120
15	3,141,770	40	3,457,120
16	3,222,500	41	3,457,120
17	3,289,520	42	3,457,120
18	3,356,610	43	3,457,120
19	3,423,670	44	3,457,120
20	3,457,120	45	3,457,120
21	3,457,120	46	3,457,120
22	3,457,120	47	3,457,120
23	3,457,120	48	3,457,120
24	3,457,120	49	3,457,120
25	3,457,120	50	3,456,810

Each annual installment shall become due and payable on or before October 1 of each year commencing with the year immediately following that in which a notice is given stating that the project is sufficiently complete to permit the initiation of water deliveries and water is available to serve member cities if such notice is given prior to October 1, otherwise to commence in the second calendar year after such notice is given. Payments shall be made on the basis of the above table until all project costs are, in the opinion of the Contracting Officer, finally determined, at which time a revised schedule of remaining payments shall be prepared based upon substantially the same ratio of annual repayment as the above table; payments thereafter shall conform with that table. If construction of the project works shall have been commenced but is terminated prior to completion by reason of lack of funds or failure to secure the necessary amendatory contracts, then the Authority shall pay to the United States its proportionate share of the total amount theretofore incurred or obligated at such time and in such manner as the Contracting Officer may then prescribe.

3. Article 30 of the basic contract is hereby replaced with the following:

EQUAL EMPLOYMENT OPPORTUNITY

30. During the performance of this contract, the Authority, hereinafter in this article referred to as the contractor, agrees as follows:

(1) The Contractor will not discriminate against any employee or applicant for employment because of race, creed, color, or national origin. The contractor will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, creed, color, or national origin. Such action shall include, but not be limited to, the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. The contractor agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the contracting officer setting forth the provisions of this nondiscrimination clause.

(2) The contractor will, in all solicitations or advertisements for employees placed by or on behalf of the contractor, state that all qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

(3) The contractor will send to each labor union or representative of workers with which he has a collective bargaining agreement or other contract or understanding, a notice, to be provided by the agency contracting officer, advising the labor union or workers' representative of the contractor's commitments under Section 202 of Executive Order No. 11246 of September 24, 1965, and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

(4) The contractor will comply with all provisions of Executive Order No. 11246 of September 24, 1965, and of the rules, regulations, and relevant orders of the Secretary of Labor.

(5) The contractor will furnish all information and reports required by Executive Order No. 11246 of September 24, 1965, and by the rules, regulations, and orders of the Secretary of Labor, or pursuant thereto,

and will permit access to his books, records, and accounts by the contracting agency and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

(6) In the event of the contractor's noncompliance with the nondiscrimination clauses of this contract or with any of such rules, regulations, or orders, this contract may be cancelled, terminated, or suspended in whole or in part and the contractor may be declared ineligible for further Government contracts in accordance with procedures authorized in Executive Order No. 11246 of September 24, 1965, and such other sanctions may be imposed and remedies invoked as provided in Executive Order No. 11246 of September 24, 1965, or by rule, regulation, or order of the Secretary of Labor, or as otherwise provided by law.

(7) The contractor will include the provisions of paragraphs (1) through (7) in every subcontract or purchase order unless exempted by rules, regulations, or order of the Secretary of Labor issued pursuant to Section 204 of Executive Order No. 11246 of September 24, 1965, so that such provisions will be binding upon each subcontractor or vendor. The contractor will take such action with respect to any subcontract or purchase order as the contracting agency may direct as a means of enforcing such provisions including sanctions for noncompliance: Provided, however, That in the event the contractor becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction by the contracting agency, the contractor may request the United States to enter into such litigation to protect the interests of the United States.

4. The following article 32 is added to the basic contract.

WATER POLLUTION CONTROL

32. The Authority agrees that it will comply fully with all applicable Federal laws, orders, and regulations and the laws of the State of Texas, all as administered by appropriate authorities, concerning the pollution of streams, reservoirs, groundwater, or water courses with respect to thermal pollution or the discharge of refuse, garbage, sewage effluent, industrial waste, oil, mine tailings, mineral salts, or other pollutants. The Authority further agrees that any contract it may enter into with a third party for the furnishing of project water will contain a similar water pollution

control article.

5. The following article 33 is added to the basic contract:

QUALITY OF WATER

33. The operation and maintenance of project facilities and the construction of new project facilities for the provision of project water under this contract shall be performed in such manner as is practicable to maintain the quality of raw water to be furnished hereunder. The United States is under no obligation to construct or furnish water treatment facilities to maintain or to better the quality of water except to the extent such facilities are expressly referred to elsewhere in this contract as part of the project facilities to be constructed by the United States pursuant to reclamation law or as otherwise required by law. Further, the United States does not warrant the quality of water to be furnished pursuant to this contract.

6. The following article 34 is added to the basic contract:

CIVIL RIGHTS ACT OF 1964

34. The Authority (hereinafter called "Applicant-Recipient") HEREBY AGREES THAT IT will comply with Title VI of the Civil Rights Act of 1964 (Public Law 88-352) and all requirements imposed by or pursuant to the Department of the Interior Regulation (43 CFR 17) issued pursuant to that title, to the end that, in accordance with Title VI of that Act and the Regulation, no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives financial assistance from the U.S. Bureau of Reclamation and Hereby Gives Assurance That It will immediately take any measures to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the U.S. Bureau of Reclamation, this assurance obligates the Applicant-Recipient or, in the case of any transfer of such property, any transferee for the period during which the real property or structure is used for a purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance obligates the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the U.S. Bureau of Reclamation.

This assurance is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts, or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the bureau or office, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall reserve the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, or assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

7. All the terms and conditions of the basic contract shall remain in full force and effect save to the extent they are specifically modified by this contract.

8. No Member of or Delegate to Congress or Resident Commissioner shall be admitted to any share or part of this contract or to any benefit that may arise herefrom, but this restriction shall not be construed to extend to this contract if made with a corporation or company for its general benefit.

IN WITNESS WHEREOF, the parties here signed their names the day and year first above written.

THE UNITED STATES OF AMERICA

By ______________________________

Title ______________________________

(SEAL)

CANADIAN RIVER MUNICIPAL WATER AUTHORITY

ATTEST:

By ______________________________

____
Secretary

Title ______________________________

APPENDIX III

CONTRACT

between the

CANADIAN RIVER MUNICIPAL WATER AUTHORITY

and the

CITY OF PLAINVIEW, TEXAS

for providing a

MUNICIPAL WATER SUPPLY

THIS CONTRACT, made this 9th day of January, between the CANADIAN RIVER MUNICIPAL WATER AUTHORITY, an authority duly created and existing under the laws of the State of Texas, and the CITY OF PLAINVIEW, a municipal corporation in the State of Texas acting by virtue of authority of general law.

WITNESSETH THAT:

WHEREAS, the Authority has contracted or is negotiating with the United States for payment of the reimbursable costs of construction, operation, and maintenance of the project works of the Canadian River Project, Texas, which project is designed to provide a municipal water supply for member cities of the Authority, and

WHEREAS, the City desires to secure a municipal water supply from the Authority, and

WHEREAS, construction of the project depends upon the negotiation of a sufficient number of contracts for a municipal water supply from the project, and a number of water users within the boundaries of the Authority, and possibly others outside the Authority, must execute contracts to receive a share of the project water supply;

NOW, THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is mutually agreed between the parties hereto as follows:

GENERAL DEFINITIONS

1. Where used in this contract,

a. United States - Shall mean the United States of America, acting through the Secretary of the Interior, or his duly authorized representative.

b. Authority - Shall mean the Canadian River Municipal Water Authority, an authority duly created and existing under the laws of the State of Texas, acting through its Board of Directors.

c. City - Shall mean the City of Plainview, Texas.

d. Member City - Shall mean a city, town, or municipality which is a member of the Authority and is contracting for project water.

e. Dam and Reservoir - Shall refer to the Sanford Dam and Reservoir on the Canadian River used for storing and regulating project water, including all lands and rights of way.

f. Project - Shall mean the Canadian River Project, Texas, as authorized by the Act of Congress dated December 29, 1950 (64 Stat. 1124).

g. Project Water - Shall mean water available for use through the project works for municipal and industrial purposes.

h. Project Water User - Shall refer to all member cities and other contractors, their successors and assigns, which have contracted with the Authority to receive a portion of the project water supply.

i. Aqueduct - Shall mean the project system for transporting stored water to the points of delivery established for the project, and includes all pipelines, conduits, pumping facilities and related works, and the land and rights of way for such works and facilities.

j. Repayment Contract - Shall mean the contract, or contracts, between the Canadian River Municipal Water Authority and the United States of America for construction of the project.

k. Normal Water Supply - Shall mean the amount of water which studies indicate will normally be available from the project for delivery each calendar year. Allocations of water are based upon an estimate of 103,000 acre-feet (33,563 million gallons) to normally be available for release from the reservoir each year.

l. Year - Shall mean the period January 1 through the next following December 31.

PLAN

2. This contract between the City, which owns and operates its water distribution system, and the Authority is for requiring the Authority to make available for delivery to and use by the City, all or part of the municipal water supply to be used in or for the distribution system of such City. This contract provides for payment solely out of the water system revenues of such City and all moneys herein required to be paid by the City shall constitute an operating expense of the City's water system, and the City shall fix and maintain rates and charges for services rendered by such water system as will be sufficient to pay the expenses thereof, including those contemplated by Articles 1109e, 1109g and 1113, Vernon's Texas Civil Statutes.

CONSTRUCTION REPAYMENT OBLIGATION

3. In consideration of the allocation to it of 3.691 percent of the normal water supply from the project, or a like percentage of any lesser available supply, the City shall pay to the Authority 3.701 percent of the actual reimbursable cost of constructing the dam and reservoir, and 2.700 percent of the actual cost of constructing the aqueduct, all as determined by the United States. Such construction charge obligation shall be paid in fifty (50) successive annual installments as follows, based upon a total construction obligation allocation to the City of $2,791,000, plus interest during construction and interest on the unamortized balance thereof at the rate of 2.632 percent.

FULL CALENDAR YEAR AFTER COMMENCEMENT OF SERVICE	ANNUAL CONSTRUCTION SERVICE CHARGE
1	71,700
2	74,400
3	77,400
4	80,200
5	83,100
6	86,000
7	88,800
8	91,800
9	94,700
10	97,400
11	100,300
12	103,200
13	105,900
14	108,900

FULL CALENDAR YEAR AFTER COMMENCEMENT OF SERVICE	ANNUAL CONSTRUCTION SERVICE CHARGE	FULL CALENDAR YEAR AFTER COMMENCEMENT OF SERVICE	ANNUAL CONSTRUCTION SERVICE CHARGE
15	111,800	33	123,000
16	114,500	34	
17	117,100	35	
18	119,400	36	
19	121,900	37	
20	123,000	38	
21		39	
22		40	
23		41	
24		42	
25		43	
26		44	
27		45	
28		46	
29		47	123,000
30		48	123,100
31		49	123,100
32		50	123,100

Should construction costs payable by the Authority to the United States vary from $92,960,000, the amount upon which annual installments are established for repayment by the Authority, the amounts designated in the preceding table shall be adjusted, but not increased unless the City has executed an amendatory contract or contracts by which it agrees to pay an increased amount. The City may make additional payments on the construction repayment obligation at any time, whereupon appropriate adjustments in the schedule of future payments will be made. Under the terms of the contract between the Authority and the United States, each annual installment due the United States shall become due and payable on or before October 1 of each year commencing with the year immediately following that in which a notice is given by the United States stating that the project is sufficiently complete to permit the initiation of water deliveries and water is available to serve member cities, if such notice is given prior to October 1, otherwise to commence in the second calendar year after such notice is given. The first annual construction repayment obligation payment by the City to the Authority shall become due and payable on or before September 1 of the same year in which the first installment is due and payable by the Authority to the United States. Subsequent installments shall become due consecutively on September 1 of each succeeding year. Payments shall be made on the basis of the above table until all project costs are finally determined by the United States and reported to the Authority at which time a revised schedule of payment shall be prepared based upon the same ratio of annual repayment as was used in preparing the above table. Payments thereafter shall conform with that table. If construction of the project works shall have been commenced, but is terminated prior to completion by reason of lack of funds or failure to secure the necessary amendatory contracts, then the City shall pay to the Authority its percentage share of the total amount theretofore incurred or obligated by the Authority at such time and in such manner as will permit the Authority to meet its obligation to the United States.

OPERATION AND MAINTENANCE CHARGES

4. a. At an appropriate meeting in each calendar year, in no event, however, to be later than November 1, the Board of Directors of the Authority shall determine the total charges estimated to be required during the next year for operation and maintenance of the project including accumulating the necessary reserve funds. A detailed budget shall be made available to the City at least two weeks prior to the Board meeting for review and comment.

b. The City shall pay its share of the total operation and maintenance charges required to deliver water to the City, on the basis of the advance estimates prepared by the Authority. At the end of each year an adjustment will be made in the operation and maintenance charges to reconcile the charges with actual costs, reserve fund requirements, and water uses.

c. Payment of all operation and maintenance charges due from the City shall be made by the City to the Authority on such dates and in such amounts as are designated by the Authority to provide it with funds when needed, as determined by the Authority, provided that no installment shall be due and payable before the day upon which the project is sufficiently complete to permit diversion by the City of the supply of water allocated to it in this contract, or when the project works shall be deemed to have been completed within the meaning of the contract between the United States and the Authority for constructing and financing the project, all as set forth in a prior written notice by the Authority to the City. Whenever collections from all sources are insufficient to defray Authority operation and maintenance expenses and payments, proportionate additional payments may be required through supplemental notice to the City at least sixty (60) days in advance of the effective date. Such notice shall set forth the justification for the increase in full detail.

WATER SUPPLY

5. a. Quantity - For and in consideration of the payments required to be made under this contract, the Authority agrees to make 1,238 million gallons of untreated project water available to the City for municipal and industrial use during each year of normal supply, which is the City's pro rata share of the project normal water supply.

b. Allocations - Nothing in this contract shall be construed as restricting the right of the Authority to enter into firm contracts for delivery of the entire estimated normal water supply of the project, provided, however, that all such contracts shall recognize the right and responsibility of project water users to share in the normal water supply in the ratio of their contract rights. During periods of scarcity when rationing is in the opinion of the Authority required, the allocation of a lesser volume than listed in Article 5a shall not affect the continuing obligation of the City to make the payments provided in this contract.

c. Quality of Water - Water delivered to the City under this contract shall be as received from storage in the Sanford Reservoir.

d. Unit of Measurement - The unit of measurements for water delivered hereunder shall be 1,000 gallons of water, U. S. Standard liquid measure.

e. Allocated Water not Used - If the City does not use the total amount of water to which it is entitled in any particular year, it shall not retain any carryover rights into succeeding years.

f. Other Uses - It is understood that the Project is authorized for the purpose of irrigating land, delivering water for industrial and municipal use, controlling floods, providing recreation and fish and wildlife benefits, and controlling and catching silt. The supply to be available for City use and the price it pays for water may reflect apportionment among these purposes or regulation of releases to coordinate all listed benefits.

g. Surplus Water - All project water available for use in excess of the normal water supply, as determined by the Authority, is hereby defined as surplus water. Surplus water may be disposed of by the Authority for municipal and industrial purposes on such terms or at such rates as are established by it.

WATER SHORTAGES

6. On account of drought or other causes beyond the reasonable control of the Authority, there may occur at times during any year a shortage in the quantity of water available for transmission to the City by the Authority pursuant to this contract. In no event shall any liability accrue against the Authority, the United States, or any of their officers or employees for any damage, direct or indirect, arising out of any such shortages.

CONTROL OF WATER

7. Right and responsibility for the control of all waters of the project to the point or points of delivery shall remain in the Authority of the United States. Upon passing through the Authority's meter installed at the point or points of delivery, right and responsibility for the control of water shall pass to the City.

POINT OF DELIVERY

8. Deliveries of water to the City shall be made at one point on the aqueduct system, which point shall be designated by the City in advance of construction. A location map or plat showing the proposed location of the aqueduct will be available for use by the City in selecting its point of delivery. Thereafter, the City may request that all or any part of its share of the project water supply be delivered at the dam and reservoir, or may request deliveries at additional points on the aqueduct where the City has reserved aqueduct capacity. Upon approval of such request for a change in the point of delivery or for additional points of delivery, the cost of new connections as determined by the Authority shall be advanced by the City as provided in Article 14.

ALLOCATION OF AQUEDUCT CAPACITY

9. In the event the combined demand of all water users at a given time for the delivery of water shall exceed the carrying capacity of the aqueduct to the proposed point of diversion, deliveries to project water users will be made equitably on the basis that the maximum rate of delivery to project water user will be in proportion to its share of the designed capacity of the aqueduct. When the carrying capacity of the aqueduct is taxed to its limit, the rate of delivery available for serving the City shall be at least 4.15 million gallons daily (6.42 cubic feet per second). The rate of delivery will be increased when possible without infringing upon the rights of others, giving consideration to the demands made by all project water users and the relative rights of each which remain unused for the year. The

determination of availability of water from time to time, and quantity, shall be made by the Authority, whose determination shall be final.

OBLIGATION TO COMPLETE PROJECT

10. The obligation of the Authority to contract for payment of the reimbursable costs of construction, operation, and maintenance of the project shall be conditioned upon the execution of contracts with sufficient water users to produce revenues which, in the judgment of the Authority and the United States, will repay the costs of constructing and operating the project water supply and distribution system. If contracts are not secured whereby such estimated costs of the Authority can be met, the Authority shall notify the City, whereupon this contract will be voided.

PLEDGE OF CONTRACT

11. This contract, or the repayment obligations assumed by the City under it, may be pledged or assigned by the Authority to the United States as security for repayment of the Authority obligation for construction, operation, and maintenance of the project, but only together with other like contracts with all project water users covering the disposition of the major portion of the project normal water supply.

PROJECT ALTERATIONS AND REPAIRS

12. It is expressly recognized by the City that the Authority may be compelled to make necessary alterations, repairs, and installations of new or additional equipment from time to time during the life of this contract, and any suspension of delivery to the City due to such work shall not be cause for claim of damage on the part of the City. However, every reasonable effort shall be made by the Authority to provide the City with water in accordance with this contract. In cases of necessary suspension, the Authority shall give the City as much advance notice as is practicable, in no event to be less than fifteen (15) days, and set forth the estimated duration thereof. In the event any project facility instrumental in the delivery of water to the City is destroyed or damaged as the result of any cause, whether by force majeure or otherwise, so as to make deliveries of water requirements as herein specified impossible, the Authority shall, to the extent of available resources, immediately proceed to restore said project facilities. Each City assumes the responsibility for maintenance of its distribution system from the point of connection with the aqueduct and agrees that its system shall be constructed and maintained to result in a minimum of waste. Should the Authority determine that any part of the City system is causing

unreasonable waste, it shall notify the City, and upon failure of the City to remedy the situation, at its option the Authority may discontinue or limit deliveries until the condition complained of has been corrected.

LIMITATION ON FINANCIAL LIABILITY OF CITY

13. The City is obligated under this contract to pay its share of the costs of construction, operation, and maintenance of the project. Nothing herein shall be construed as prohibiting the Authority from making reasonable rate increases to cover expenses authorized by this contract.

WATER MEASUREMENT

14. a. Water shall be metered at the point or points of delivery. The Authority shall furnish, install, operate and maintain at its own expense at said delivery point a master meter of standard type for measuring properly the quantity of water delivered under this contract. Meters for more than one point of delivery requested by the City shall be furnished, installed, operated, and maintained by the Authority, with the cost of the meter and its installation to be paid by the City. The City may, at its option and expense, install, operate and maintain at said delivery points, a check meter or meters of standard type. The City shall have access to all such metering equipment at all reasonable times, but the reading, calibration, and adjustment of the Authority's master meter shall be done only by employees or agents of the Authority. The Authority shall keep a true record of all meter readings as transcribed from the reports of the Authority's employees or agents with respect thereto. Upon written request of the City, the Authority will give it such information as it may request from the Authority's journals or record books or permit the City to have access to the same in the office of the Authority during business hours.

b. The Authority shall calibrate its metering equipment as often as it considers necessary and at such times as the City may show reasonable evidence of error. If upon any test, the percentage of any inaccuracy thereof is found to be in excess of 2 percent, registration thereof shall be corrected for a period extending back to the time when such inaccuracy began if such time is ascertainable, and if not, then for a period extending back one-half of the time elapsed since the last date of calibration, but in no event further back than a period of six months. In the event the City has provided no check meter with reference thereto and if for any reason any master meter is out of service or out of repair so that the amount of water delivered cannot be ascertained or computed from the reading thereof, the water delivered during the period such meter is out of service or out of repair shall be agreed upon by the parties thereto, by correcting the error if the percentage of the error is ascertainable by calibration tests or mathematical calculations, or by estimating the quantity of delivery by the deliveries made during preceding periods under similar conditions when the meter was registering accurately.

CONTRACT CONTINGENT UPON CONSTRUCTION OF PROJECT

15. This contract shall not be valid and binding unless the repayment contract between the Authority and the United States is confirmed. The Authority agrees to proceed promptly and to the best of its ability for securing construction of the facilities necessary for the performance of its obligations hereunder and to negotiate all contracts necessary to finance the construction of such facilities. It is understood that at this time the Authority is not in a position to guarantee the undertaking of the construction of the facilities or the date upon which it will be able to make the first delivery of water to the City. The Authority shall not be liable to the City for any damages occasioned by any delay in the commencement of such service to the City.

EASEMENTS

16. The Authority is hereby granted the right to use any easements, right-of-way, or property held by the City for the purpose of making connections to the point or points of delivery and the placing of necessary equipment to carry out the Authority's obligation to deliver water to the City, including related operation and maintenance.

CERTIFICATION

17. The City certifies and recites that the execution of this contract is duly authorized by law and by a majority of the resident qualified electors owning taxable property in said City and who have duly rendered the same for taxation, voting at an election held for that purpose within said City; that all acts, conditions, and things required to exist precedent to this contract, to render the same lawful and valid, have been properly done, and happened, and have been performed in regular and due time, form and manner as required by the consitution [sic] and laws of the State of Texas, and that this contract does not exceed any constitutional or statutory limitations, and that provision will be made for all payments due hereunder by irrevocably pledging to the payment hereof sufficient revenues of the waterworks system of the City. The City warrants and guarantees that it has not obligated itself, and is not now bound by the issuance of prior bonds or otherwise in such a manner that

prohibits or makes inoperative any of the terms, conditions, or obligations herein provided.

BENEFITS CONDITIONED UPON PAYMENT

18. Should any charges or payments required by the terms of this contract and levied against any water user be judicially determined to be irregular or void, or the City or its officers be enjoined or restrained from making or collecting any charges as provided for herein, such user shall have no right to any of the benefits of this contract and no water shall be made available from the project for such user. If it is judicially determined that the City is not authorized to accomplish collections necessary for the sale or distribution of water to meet its obligations under the contract, the Authority is hereby authorized to sell water direct to those using the City supply and apply net revenues therefrom to the credit of the City's account.

TERM OF CONTRACT

19. This contract shall be effective on execution and shall continue until the construction repayment obligation is paid in full. Upon the expiration of said term the City shall have a vested right to renew said contract indefinitely at appropriate annual service charges so long as a water supply may be available and the City is current on its payments for water service. After the construction repayment obligation is paid, succeeding payments shall be the estimated amounts which will be required to meet the City's proper share of the Authority's obligations.

RATES AND CHARGES BY THE CITY

20. a. City shall fix and collect such rates and charges for water and services to be supplied by its waterworks system as will make possible the prompt payment of all expenses of operating and maintaining its waterworks system, the making of all payments contracted hereunder, and the prompt payment of the principal and interest on all of its obligations payable from the revenues of its waterworks system. The City may in its discretion, as permitted under laws at the time effective, appropriate money from any sources for the purpose of relieving the necessity of increasing the said rates and charges for water service.

b. The Authority shall never have the right to demand payment by the City of any obligation assumed or imposed on it under and by virtue of this contract from funds raised or to be raised by taxation. The City's obligations under this contract shall never be construed to be a debt of the City of such kind as to require it under the Constitution and laws of the State of Texas to levy and collect a tax to discharge such obligation, it being expressly understood by the parties hereto that all payments due by the City hereunder are to be made from water revenues received by the City.

c. The City represents and covenants that all payments to be made hereunder by it shall constitute Operating Expenses of its waterworks system as defined in Article 1113, Vernon's Texas Civil Statutes.

d. Should the City fail to collect charges due from any water user, or should the City be prevented from collecting such charges by any judicial proceeding, or otherwise fail to collect them, no such water user shall receive water available under this contract. The Authority reserves the right without liability to refuse delivery of water to the City in the event the City fails to pay charges at the time and in the manner and amounts provided for in this contract.

CITY OBLIGATION NOT SEPARABLE

21. The City as a whole is obligated to pay to the Authority the charges becoming due as provided in this contract, notwithstanding the default in the payment to the City by individual water users of charges fixed by the City.

ACCESS TO BOOKS AND RECORDS

22. Each party shall have the right, during office hours, to inspect and to make copies of the other party's books and official records relating to matters covered by this contract.

DETERMINATIONS

23. Where the terms of this contract provide for action to be based upon the opinion or determination of either party to this contract, whether or not stated to be conclusive, said terms shall not be construed as permitting such action to be predicated upon arbitrary, capricious, or unreasonable opinions or determinations.

PENALTY FOR DELINQUENT PAYMENTS

24. Every installment or charge required to be paid to the Authority under this contract which remains unpaid after it has become due and payable, shall be subject to a penalty of one-half of one percent per month from the date of delinquency.

DEFAULT

25. In the event the City shall fail to pay all or any part of its obligations incurred under this contract, and such delinquency shall have continued for a period of not less than two years, the Authority may, at its option, in addition to all other rights provided in this contract, exercise all or any of the following rights and remedies.

a. The Authority may stipulate water rates to be charged by the City and the City shall conform its rates accordingly.

b. The Authority may withhold all or any part of the normal water supply allocated to the City by this contract and may sell or dispose of such part without obligation, responsibility, or liability for damages to the City and shall apply the net revenue from said sales as a credit upon the obligation of the City to the Authority.

c. The Authority may terminate this contract whereupon all rights thereunder accruing to the City shall cease and determine. Such termination, however, shall not relieve the City from its obligation to pay all costs, charges, or installments due and payable under this contract prior to the effective date of such termination.

All rights of action for breach of this contract are reserved to the Authority or the United States. Nothing contained in this contract shall be construed as abridging, limiting, or depriving the United States or the Authority of any means of enforcing any remedy either at law or in equity for the breach of any provisions hereof which either party would otherwise have. The waiver of a breach of any of the provisions of this contract shall not be deemed to be a waiver of any provisions hereof, or of any other or subsequent breach of any provision hereof.

NOTICES

26. Any notice authorized or required by this contract shall be deemed properly given, except where otherwise herein specifically provided, if mailed postage prepaid to the office of the General Manager, Canadian River Municipal Water Authority, on behalf of the Authority, and to the Mayor of the City of Plainview, at Plainview, Texas, on behalf of the City. The designation of the person to be notified, or the address of such person, may be changed at any time by similar notice.

SUBJECT TO UNITED STATES AND AUTHORITY CONTRACT

27. This contract shall be subject to the terms, conditions, and provisions of the repayment contract between the Authority and the United States for constructing and financing the project, as amended or modified. This contract cannot be amended or supplemented without the advance written approval of a duly authorized representative of the United States. The Authority may assign all or any part of its rights or authority under this contract to the United States.

ASSIGNMENTS BY CITY

28. The City may sell or assign this contract or any portion of its allocation of the right to receive project water only with the approval of the Authority and the United States. Under any assignment, it must be established to the Authority's satisfaction that the water right may be transferred under Texas Law and the laws of the United States for diversion as proposed. The alternate user must enter a contract or contracts satisfactory to the Authority and the United States.

NONDISCRIMINATION IN EMPLOYMENT

29. a. In connection with the performance of work under this contract, the City agrees not to discriminate against any employee or applicant for employment because of race, religion, color or national origin. The aforesaid provision shall include, but not be limited to, the following: Employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. The City agrees to post hereafter in conspicuous places, available for employees and applicants for employment, notices to be provided by the United States setting forth the provisions of the nondiscrimination clause.

b. The City further agrees to insert the foregoing provision in all subcontracts hereunder, except subcontracts for standard commercial supplies or raw materials.

IN WITNESS WHEREOF, the parties hereto acting under authority of their respective governing bodies have caused this contract to be duly executed in several counterparts, each of which shall constitute an original, all as of the day and year first above written.

CANADIAN RIVER MUNICIPAL WATER AUTHORITY

By /s/ C. T. Johnson
President

CITY OF PLAINVIEW, TEXAS

By /s/ M. B. Hood

Title Mayor

ATTEST:

/s/ A. A. Meredith
Secretary

(SEAL)

ATTEST:

/s/ P. H. Bryan
City Clerk

Approved as to Form:

/s/ Joe Sharp
City Attorney

APPENDIX IV

THE OBJECTIVES OF THE TEXAS WATER PLAN

(1) Satisfy vested water rights with proper modes and procedures to be followed for the equitable adjustment of any water rights that might be affected by the program, including continuance of vested riparian rights now supplied by direct diversion from streams.

(2) Provide the projected 2020 municipal and industrial water requirements throughout the State.

(3) Provide for the importation of an estimated 12 to 13 million acre-feet per year from out-of-State sources by 2020 to meet Texas' water needs, and deliver 1.5 million acre-feet to New Mexico through joint use of the facilities.

(4) Deliver about 7.5 million acre-feet of supplemental water annually for irrigation in North Central Texas, the High Plains, and the Trans-Pecos area. Planning will continue as to possible import of water to supply additional economically justified water needs throughout the State, as those needs arise.

(5) Deliver 727 thousand acre-feet of water annually for irrigation in the Coastal Bend area and 700 thousand to the Lower Rio Grande Valley through the Coastal Canal; and make available 200 thousand acre-feet annually for irrigation in the Winter Garden area and 190 thousand acre-feet annually for irrigation in Webb and Maverick Counties by releases from Amistad Reservoir, with water supplied to the Lower Rio Grande Valley through the Coastal Canal in replacement for these releases.

(6) Based on best available estimates of need, provide regulated fresh water inflows to the bays and estuaries, and participate as justified in other measures such as structural modifications to obtain better tidal circulation, with the objective of maintaining suitable quality conditions for fish and shellfish.

(7) Supply projected water requirements for wildlife

management areas and refuges.

(8) Meet projected water requirements for secondary oil recovery programs.

(9) Recognize interstate compact commitments.

(10) Use return flows and reclaimable waste waters to the maximum feasible extent.

(11) Through conjunctive use of surface and ground water and other measures, make possible a decrease in ground water extractions from aquifers to the safe yield, thus minimizing subsidence and other adverse effects of overdraft.

(12) Decrease loss of the State's water resources through control of phreatophytes and salvage of phreatic non-beneficial consumptive uses.

(13) Provide flood control through storage in proposed reservoirs, and by channel improvements and levees where necessary.

(14) Coordinate hurricane protection projects along the Gulf Coast with other actions in order to minimize the adverse effects of those projects.

(15) Support projects to provide drainage where feasible for land reclamation and where necessary for maintenance of agricultural productivity.

(16) Alleviate degradation of the State's fresh water resources from sources of naturally poor quality water, such as saline springs.

(17) Develop means to provide regional systems for the collection, treatment, and disposal of municipal sewage and industrial wastes that will be necessary to maintain the quality of the State's waters at requisite levels.

(18) Develop other necessary means for quality protection and management.

(19) Preserve and protect river reaches and springs of great scenic beauty or scientific value.

(20) Perserve and protect site and natural phenomena of historic and archeological importance.

(21) Provide additional water-associated recreational opportunities.

(22) Integrate feasible navigation projects on Texas streams with other water development objectives, and provide necessary water requirements for navigation purposes.

(23) Provide for expanded upstream watershed programs for erosion control and land treatment, and additional floodwater retarding structures and channel improvements.

(24) Generate electrical energy for pumping to the extent that energy cannot be made available from other sources at requisite prices.

(25) Develop hydroelectric power where feasible.

(26) Protect and enhance fish and wildlife resources to the maximum feasible extent.

(27) Provide increased financial assistance to qualified local agencies for necessary water facilities.

APPENDIX V

COVER LETTER AND RESEARCH QUESTIONNAIRE

Dear

The enclosed questionnaire has been designed to provide basic information to be used in a student research project in Geography. Won't you please take a few minutes to fill out the information form and return it in the enclosed self-addressed, stamped envelope?

Your name has been randomly selected from the telephone directory of your community and can in no way be connected to your individual response if you choose to remain anonymous.

Thank you for your co-operation,

Charles R. Kelly

RESEARCH QUESTIONNAIRE

Part I - Personal Information

1. Check your age group:

Under 18	( )	18 - 25	( )
26 - 35	( )	36 - 55	( )
56 - 65	( )	over 65	( )

2. Male ( ) Female ( )

3. Indicate the last year in school completed by circling that number:

   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

   If a college graduate, please check the highest degree earned:

   Bachelor ( )
   Master ( )
   Doctorate ( )

4. What is your occupation? ______________________________

5. Number of persons in your house hold:
   Adults __________
   Children under 16 ______

6. Check the number of years that you have been a resident of your community:
   less than 3 years ( )
   3 - 5 years ( )
   6 - 8 years ( )
   9 - 11 years ( )
   12 or more years ( )

7. Check the number of years that you have been a resident of the High Plains of Texas:
   less than 3 years ( )
   3 - 5 years ( )
   6 - 8 years ( )
   9 - 11 years ( )
   12 or more years ( )

8. Check the following that you have or expect to have within five years:

	Have Now	Expect to Have
a. automatic dishwasher	( )	( )
b. automatic kitchen garbage disposal	( )	( )
c. automatic clothes washer	( )	( )
d. evaporative air cooler	( )	( )

9. Estimate your household's daily use of water. (Please do not check your water bill, and do not include water used on gardens and lawns)
   a. 0 - 50 gallons per day ( )
   b. 51 - 100 gallons per day ( )
   c. 101 - 150 gallons per day ( )
   d. 151 - 200 gallons per day ( )
   e. 201 - 250 gallons per day ( )
   f. 251 - 300 gallons per day ( )
   g. 301 - 350 gallons per day ( )
   h. 351 - 400 gallons per day ( )
   i. 401 or more gallons per day ( )

I think that the most pressing problem of my area is

____

____

____

If you would be willing to co-operate in a follow-up interview, please give your name and address. Please understand that there is no obligation to do this, and you may remain anonymous.

Thank you for your co-operation

Part II. The following is a scale in which you are to mark with a check mark ( ) the one of the five choices that most closely indicates your feeling toward the statement in the left column. Please make only one check for each statement.

	Strongly Agree	Tend To Agree	Undecided	Tend To Disagree	Strongly Disagree
1. A city must grow in population to maintain a prosperous economy.					
2. Periodic drought is not one of the major water problems of West Texas.					
3. I would readily leave West Texas for some other area if the water supply of my community became critically short.					
4. The Canadian River Municapal Water Authority has solved my communities water problems for the next 30 years.					
5. My community will experience rapid economic growth over the next 30 years.					
6. Purified sewage water is safe for home use.					
7. Industry will keep the local economy strong and prosperous even if agricultural productivity should decline in the future.					
8. I would be willing to be taxed to a greater extent than at today's rates to support a strong irrigation agricultural economy in this area.					
9. My city has no water problem at the present time.					
10. The lack of water could cause a general decline in the population of West Texas.					

	Strongly Agree	Tend To Agree	Undecided	Tend To Disagree	Strongly Disagree
11. My community will soon reach a point of economic stability with little or no change within the next 30 years:					
12. I would not be willing to make a conscious effort to conserve water over an extended period of time.					
13. All well equipped kitchens should have automatic garbage disposals.					
14. I would probable continue to use the same volume of water as I now do even if my water bill were doubled.					
15. There is no practical solution to the water p problems of West Texas.					
16. There will be an economic decline in my community if the surrounding area should revert to dryland farming.					
17. Underground water conservation districts should exert greater control over underground water use for irrigation:					
18. Texas should develop water supplies not dependent upon the import of water supplies from outside the state boundaries.					
19. My job would be threatened if there were a serious decline in agricultural productivity of the Texas High Plains.					
20. My community will experience a rather rapid economic decline over the next 30 years.					

	Strongly Agree	Tend To Agree	Undecided	Tend To Disagree	Strongly Disagree
21. "Water Incorporated" is a positive step toward the solution of the water problems of Texas.					
22. I would probably continue to use the same volume of water as I now do even if my water bill were to be tripled.					
23. Regular summer watering of lawns is desirable in an attractive community.					
24. I do not believe my income would be affected if there were to be a serious economic decline.					
25. The Texas Water Plan will meet the water needs of Texas for the next 50 years.					
26. Underground water depletion is one of the main water problems of West Texas.					
27. Texas should develop a water system to import water from the Mississippi River.					
28. It is not necessary that a city (or region) experience steady population increase in order to have a prosperous economy					
29. I am satisfied with the quality of my cities water supply.					
30. Texas should begin making plans to import water from Canada to meet future needs.					
31. My community will experience a slow down in economic growth until a state of economic stability exists over the next 30 years.					

	Strongly Agree	Tend To Agree	Undecided	Tend To Disagree	Strongly Disagree
32. The Southern High Plains of Texas must keep a strong irrigation agricultural economy.	:	:	:	:	:
33. The agricultural cropping system of my region will not change radically within the next 30 years.	:	:	:	:	:
34. Regularly summer watering of lawns is essential in an attractive community.	:	:	:	:	:
35. I would be willing to make a conscious effort to conserve water over a long period of time.	:	:	:	:	:
36. Irrigation agriculture is an unnecessary waste of the limited water resources of the Texas High Plains.	:	:	:	:	:
37. My community will experience slow, continuous growth over the next 30 years.	:	:	:	:	:
38. All well equipped kitchens should have electric automatic dishwashers.	:	:	:	:	:
39. The lack of adequate recovery of local rain water supplies is one of the main water problems of the High Plains.	:	:	:	:	:
40. Properly treated liquid sewage should be recycled through the cities water supply.	:	:	:	:	:
41. I would like to live the rest of my life in West Texas.	:	:	:	:	:
42. People generally do not bathe often enough.	:	:	:	:	:
43. The concern of some, over water in West Texas, is generally given too much attention.	:	:	:	:	:

	Strongly Agree	Tend To Agree	Undecided	Tend To Disagree	Strongly Disagree
44. Unde. ground water depletion would not <u>seriously</u> affect either me nor this area.					