SALT CONTAMINATION OF THE BRAZOS RIVER FROM THE DOVE CREEK AND CROTON CREEK AREAS, TEXAS

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Leslie Glen McMillion

1957

SALT CONTAMINATI

IN THE DOVE CREEK A

Leslie G

Submitted to th
Michigan State U
Applied Science
the require

MA

Department

SALT CONTAMINATION OF THE BRAZOS RIVER FROM THE DOVE CREEK AND CROTON CREEK AREAS, TEXAS

By

Leslie Glen McMillion

A THESIS

Submitted to the College of Agriculture
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Resource Development

1957

Approved C. R. Humphrys

CONTENTS

Page

Introduction - 1

Previous work done on the salt problem 9

Scope of this investigation 10

Acknowledgements 11

General description of detailed area - - - - - - - - - 13

Climate and soils - - - - - - - - - - - - - - - - - - 15

Stratigraphy - 17

Permian deposition 17

Correlation 19

Permian system 20

Guadalupe series

El Reno (Pease River) group 23

Whitehorse group 24

Ochoa series 26

Quaternary deposits 26

Salt producing areas - - - - - - - - - - - - - - - - - 28

Dove Creek area 28

Croton Creek area 35

Geomorphology 37

Origin of Dove Creek Flat 39

Origin of Salt Flats of Hayrick Creek 43

Salt Producing
Origin of S
Geologic se
Hydrology - -
Topography
Source of sa
Source of sa
Structure
Artesian
Suggested metho
water - - - -
Reduction of
Reduction of
Suggestions fo
Eastern ext
Bibliography

CONTENTS

	Page
Salt Producing areas - continued	
Origin of Short Croton and Hot Springs Flats	44
Geologic sections in the salt producing areas	52
Hydrology -	58
Topography and the water table	58
Source of salt water in Croton Creek area	60
Source of salt water in Dove Creek area	65
Structure	68
Artesian system of the Childress gypsum	72
Suggested methods for decreasing amount of salt water -	82
Reduction of salt in Dove Creek area	82
Reduction of salt in Croton Creek area	89
Suggestions for future studies - - - - - - - - - -	93
Eastern extent of salt beds in Permian deposits	95
Bibliography	99

I L L U S T R A T I O N S

		Page
Figure 1.	Average annual rainfall for Texas as of January 1, 1956 - - - - - - - - - - - -	3
2.	Net reservoir evaporation loss in the Brazos River watershed and in Texas - -	4
3.	Brazos River watershed with average annual run-off in inches for 30-year period, 1924-1953, inclusive - - - - - -	5
4.	Brazos River watershed with average annual run-off in inches for 4-year period, 1950-53, inclusive - - - - - - -	6
5.	Index map showing location of detailed area in Texas - - - - - - - - - - - - - - - -	12
6.	Outcrop map of rocks from Permian through Cretaceous - - - - - - - - - - - - - - - - -	18
7.	Correlation of Permian rocks of detailed area with standard reference sections - -	21
8.	Western part of Abilene Geological Society cross section, Scurry Co. to Parker Co., Texas, 1949 - - - - - - - - - - - - - - - - -	22
9.	View of Dove Creek area taken from a point one mile south of Dove Creek Flat - - - -	30
10.	Steep bluff on Hayrick Creek showing El Reno clay below the Childress gypsum- - -	30
11.	Detail of the clay shown in figure 10 - -	31
12.	Same clay, as in figure 11, exposed near mouth of Dove Creek Flat - - - - - - - -	31
13.	Low bluffs or scarp around upper part of Dove Creek Flat - - - - - - - - - - - - - -	42
14.	Detail of Childress gypsum shown in figure 13 - - - - - - - - - - - - - - - - - - -	42
15.	Talus of small dry wash entering the Lower Salt Flat of Hayrick Creek - - - -	45

ILLUSTRATIONS

		Page
Figure 16.	One of several knolls in Lower Salt Flat of Hayrick Creek - - - - - - - - - -	45
17.	View of Croton Creek area taken from a point about 3/4 mile southwest of Short Croton Flat - - - - - - - - - - - -	48
18.	Closer view of canyon at left side of figure 17 - - - - - - - - - - - - - - - - - -	48
19.	110-foot bluff on southwest side of Short Croton Flat - - - - - - - - - - - - - - -	49
20.	Detail of salt crust in figure 19 - - -	49
21	Hard, resistant, 6 to 8-inch clayey layer formed by ground water in the floor of the southwest corner of Short Croton Flat - - - - - - - - - - - - - - -	50
22.	Salt water "spring" about 12 feet from hole shown in figure 21 - - - - -	50
23.	Rough, salt-gypsum crust as is typical in Short Croton and Hot Springs Flats -	51
24.	Small cone-shaped pits occur between main drainage courses in Short Croton Flat - - - - - - - - - - - - - - - - - -	51
25.	Vertical section showing the ground-water hydrology of the Croton Creek area - - - - - - - - - - - - - - - - - -	63
26.	Determination of the eastern extent of salt deposits in Permian rocks - - - -	71
27.	Generalized diagram showing the way that an artesian system could develop up the dip in the Childress anhydrite-gypsum - - - - - - - - - - - - - - - - -	78
28.	Cavern about ten feet high in the Childress gypsum at a place several yards upstream from the proposed dam site on Dove Creek Flat - - - - - - - - - - - -	84

ILLUSTRATIONS

Page

Figure 29. Salt crust forming in Dove Creek Flat - - - - - - - - - - - - - - - - - - 84

30. Map showing location of oil-test holes drilled with cable-tool equipment in and near the detailed area - - 96

Plate 1. Land map of parts of Stonewall, Kent, Dickens, and King Counties, Texas showing locations of water wells, deep oil tests, exploration holes, measured geologic sections, and outcrop of base of Childress gypsum.

Plate 2. Reconnaissance topographic map of parts of Stonewall, Kent, Dickens, and King Counties, Texas.

Plate 3. Reconnaissance map of the water table in parts of Stonewall, Kent, Dickens, and King Counties, Texas.

Plate 4. Structure map on the top of the Childress gypsum in parts of Stonewall, Kent, Dickens, and King Counties, Texas.

Plate 5. Structure map on the top of the Upper Eskota gypsum in parts of Stonewall, Kent, Dickens, and King Counties, Texas.

(All plates inside pocket of back cover)

Page

Table 1. Records of wells in parts of Stonewall, Kent, Dickens, and King Counties, Texas - 104

ILLUSTRATIONS

Page

Table 2. Partial record of oil-test holes drilled with cable-tool equipment in and near the detailed area - - - - - - - 113

3. Record of exploration holes showing elevations of surface and tops of marker beds used in report - - - - - - - - 115

4. Drillers' logs of cable-tool holes numbers 88, 93, and 98 - - - - - - - - - - - 131

ABSTRACT

SALT CONTAMINATION OF THE BRAZOS RIVER

FROM THE DOVE CREEK AND CROTON CREEK AREAS, TEXAS

By Leslie Glen McMillion

An area of about 345 square miles in northwest Texas contributes unusually large quantities of salt to the Brazos River. The salt damages crops which are irrigated with water from the river and limits the uses of the water by industries and municipalities. The users greatly desire to reduce the quantity of salt contributed by this area, and the Brazos River Authority plans to spend $7,500,000 for this purpose.

The writer studied the area for four months to determine the source or sources of salt water and thus be able to suggest methods for alleviating the situation and to suggest future plans of study.

The detailed area is conveniently divided into the Croton Creek area, western part, and the Dove Creek area, eastern part. Spectacular salt flats occur in each of these areas. The rocks cropping out are of Permian age and dip regularly west 25 feet per mile. The Childress gypsum is the most prominent marker bed; below its base lies clay of El Reno group and above it is sand of Whitehorse group. A thick salt section belonging to the Seven Rivers formation, Whitehorse group, occurs in the shallow subsurface. In the Croton Creek area, unconfined ground water moves downward through some of these salt beds and issues at the surface as widespread salt-water seepage. The situation is intensified by land conservation practices which cause increased recharge to the water table of the nearby plain, thus increasing the amount of salt water discharged. Recently irrigation by ground water has been started in this area and the local interest in favor of such irrigation is strong. An intensive irrigation program here would lower the water table and could possibly stop all discharge of salt water into the Croton Creek drainage system.

Artesian salt water occurs in the Dove Creek area. By an elimination process, the artesian pressure is inferred to be developed in a cavernous system up the dip in the Childress gypsum, which is anhydrite in subsurface. The pressure is produced by a distal water table much higher in elevation than the elevation of the salt water discharge in Dove Creek. The salt water is forced out of the Childress is the shallow subsurface where anhydrite is changing to gypsum, moves into the underlying El Reno clay, and seeps to the surface. Five methods of disposal were suggested, however, much more detailed research is needed to decide which one is most appropriate. A coring program to determine the characteristics and pressure heads of the Childress artesian system is strongly urged. The program for measuring the amount of salt carried by streams of the Brazos River should be expanded to determine if any other areas are large producers of salt, and if so found, studies of these areas should be made.

INTRODUCTION

The Brazos River watershed is the largest watershed within the State of Texas. Its extension is from eastern New Mexico across Texas in a southeasterly direction to the Gulf of Mexico. Overall length of the watershed is 640 miles and the maximum width is 120 miles; its total area is about 44,670 square miles - 2,673 square miles in New Mexico and the remainder in Texas. The distance along the river channel from eastern New Mexico to the Gulf of Mexico is 1,210 miles.

This watershed is in three physiographic provinces of the United States (Finneman, 1931). These provinces are the Great Plains, Central Lowlands and Coastal Plain. The Great Plains province, being divided by an extension of the Central Lowlands, occupies two separate areas in the watershed. The first of these areas is the High Plains. The other is the Central Great Plains area which is bounded on the northwest by low escarpments extending across the watershed near Mineral Wells, Texas, and on the southeast by a series of small escarpments near Waco, Texas. The Central Lowlands province of the watershed is the area between the two Great Plains areas. The Coastal Plain occupies the part of the watershed between the Central Great Plains area and the Gulf of Mexico.

The High Plains area of the watershed has little relief. It declines gently to the southeast with land elevations ranging from about 4,500 feet along the northwestern

THE

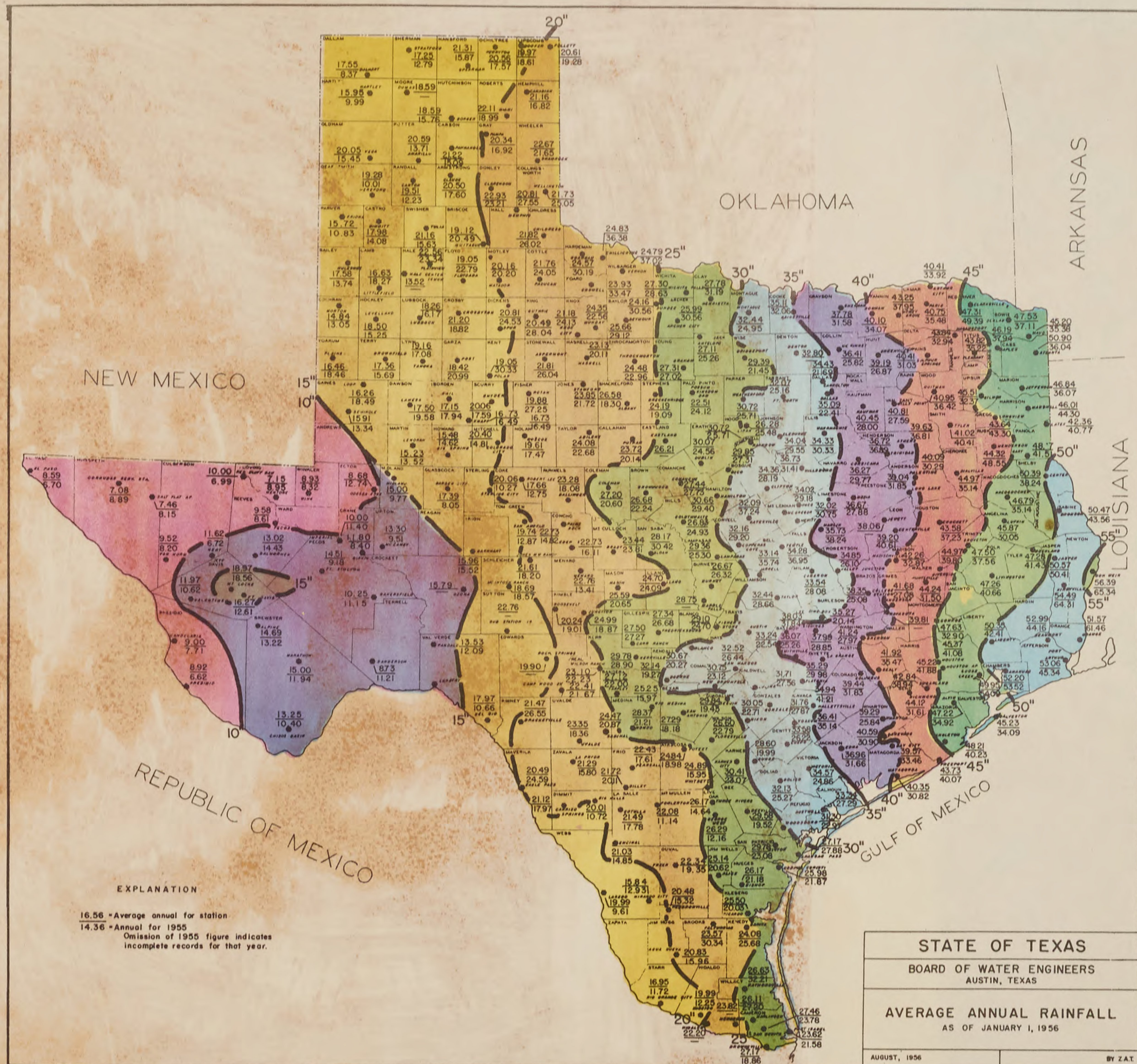


Figure 1. Average annual rainfall for Texas as of January 1, 1956.

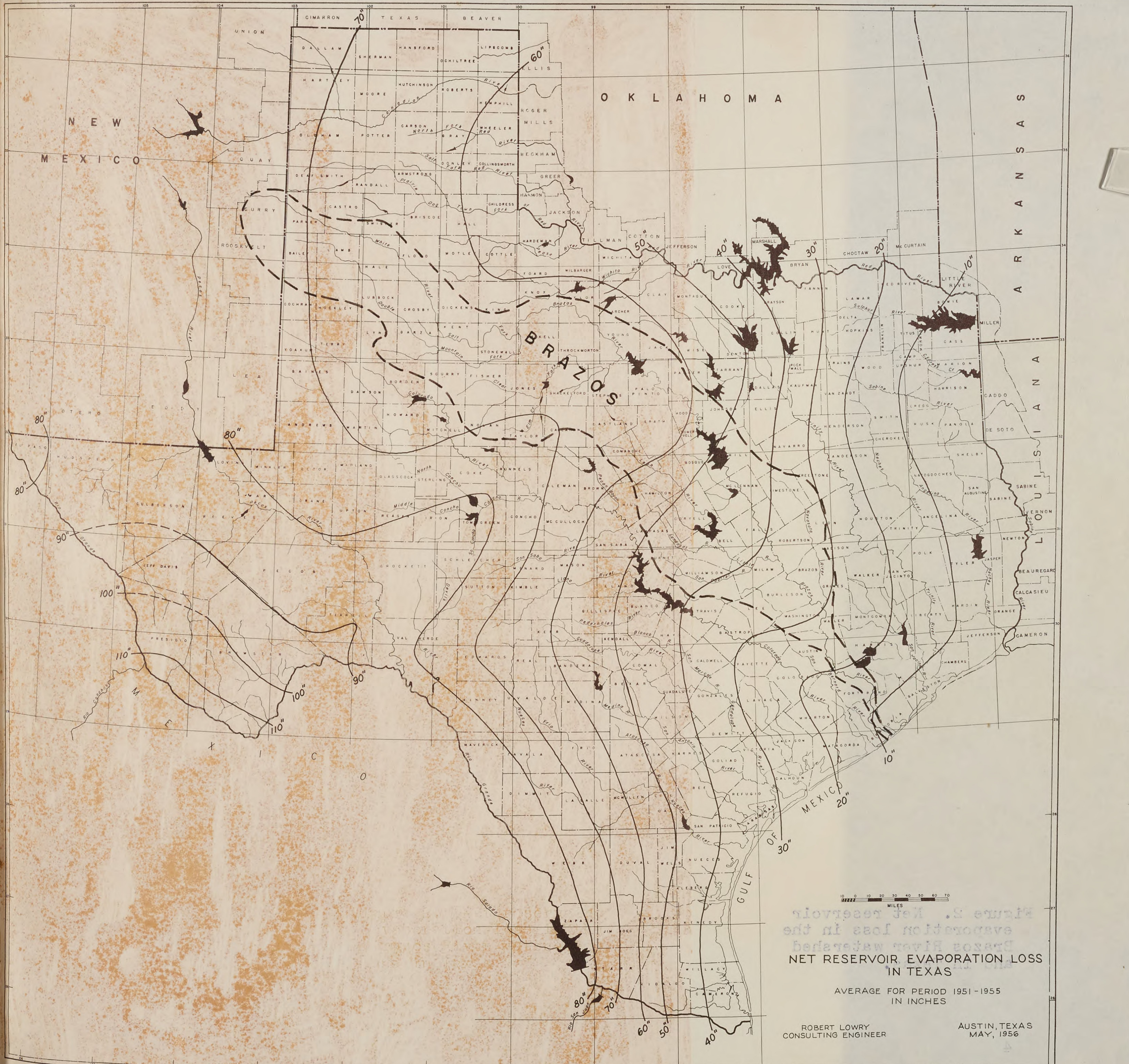

NET RESERVOIR EVAPORATION LOSS IN TEXAS
AVERAGE FOR PERIOD 1951-1955 IN INCHES
ROBERT LOWRY
CONSULTING ENGINEER
AUSTIN, TEXAS
MAY, 1956
MILES
BRAZOS
OKLAHOMA
NEW MEXICO
ARKANSAS
LOUISIANA
MEXICO
GULF OF MEXICO

Figure 7

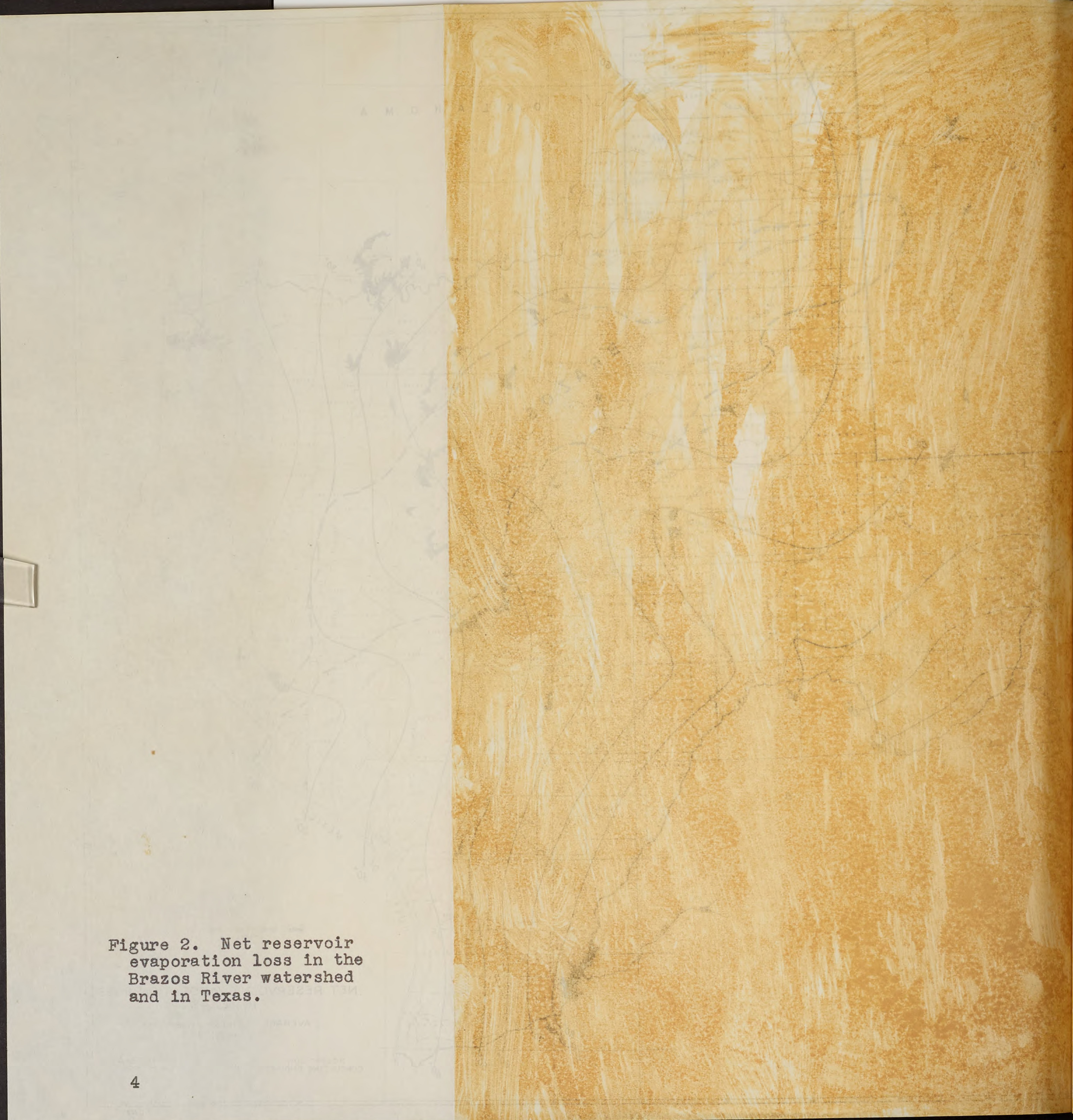


Figure 2. Net reservoir evaporation loss in the Brazos River watershed and in Texas.

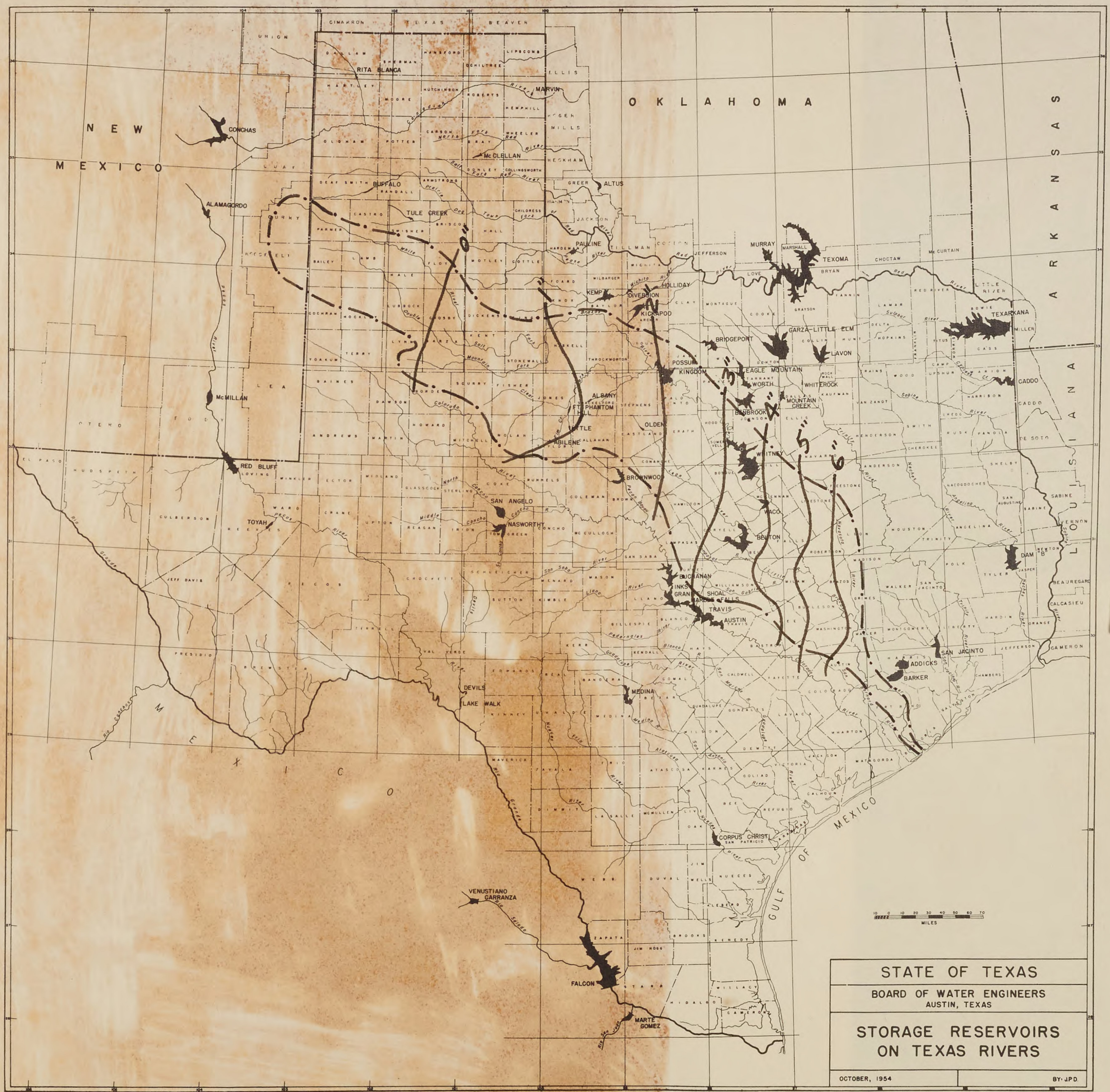


Figure 3. Brazos River watershed with average annual run-off in inches for 30-year period, 1924-1953, inclusive.

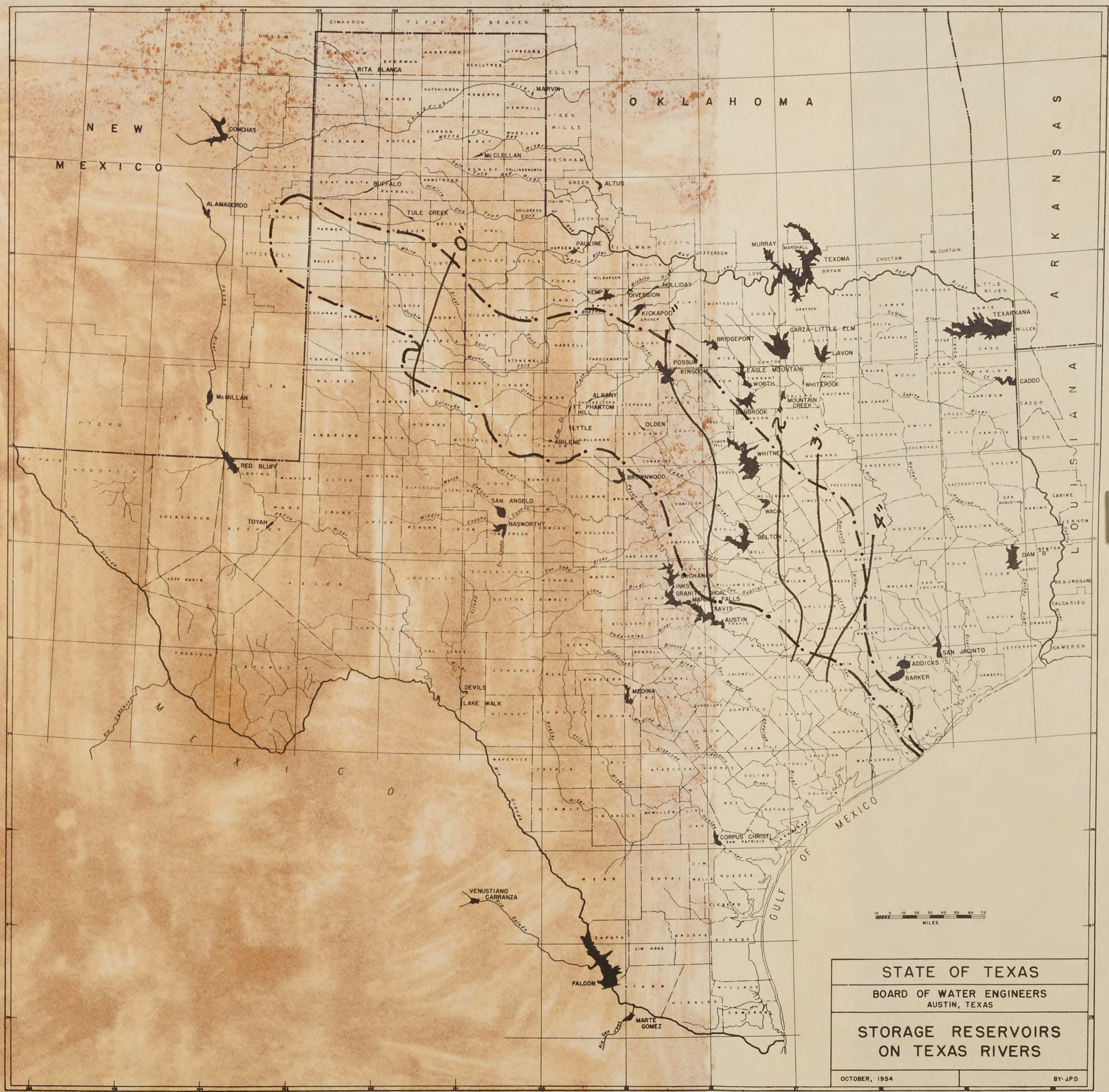


Figure 4. Brazos River watershed with average annual run-off in inches for 4-year period, 1950-1953, inclusive.

above normal rainfall and consequently, the dam soon filled with water.

The Brazos River Authority has long realized that the water of the headwater streams of the Brazos River is high in mineral content, especially in sodium chloride (NaCl) and in calcium sulfate ($CaSo_4$). When run-off is large, as in 1941, the minerals are so diluted that the large quantity present is not easily noticed. However, with small run-off and with reduction of bodies of water in reservoirs by evaporation, the mineral content or dissolved solids increases in parts per unit of water and the uses of the water are controlled by the concentration of the mineral content. Sodium chloride or common salt is extremely injurious to vegetation. The Brazos River watershed and much of the Southwestern United States endured one of the worst droughts in recorded history during the period 1950 through 1956. The dissolved solids in the Brazos River at the Possum Kingdom Dam increased from a few hundred parts per million in 1941 to an average of 1,200 parts per million in the water year October, 1953 to September, 1954. During 1941 to 1952, the Possum Kingdom water contained chloride in quantities less than 100 parts per million; however, since 1952 the water has contained chloride as high as 700 or 800 parts per million. Records of chemical analyses of the river at the Possum Kingdom Dam are available for the period from January, 1942 to September, 1954. On the next page is a partial record of these chemical

BRAZOS RIVER AT POSSUM KINGDOM DAM NEAR GRAFORD, TEXAS

Location.--Immediately below dam on Brazos River, 2.6 miles upstream from Loving Creek, 11.3 miles southwest of Graford, Palo Pinto County, and 20 miles upstream from gaging station near Palo Pinto.

Drainage Area.--22,550 square miles, approximately, of which 9,240 square miles is probably non-contributing.

Partial record of chemical analyses, in parts per million, water year October 1953 to September 1954

Date of collection	Mean Discharge (cfs)	Sodium (Na) Potassium (K)	Sulfate (SO_4)	Chloride (Cl)	Total Dissolved Solids	Specific Conductance (Micromhos at 25°C)
Oct. 1-31, 1953-	850	320	260	535	1,350	2,390
Nov. 1-30-------	899	285	261	458	1,210	2,090
Dec. 1-31-------	368	282	249	445	1,180	2,030
Jan. 1-31, 1954-	233	314	268	500	1,300	2,220
Feb. 1-5, 20-28-	325	357	281	578	1,450	2,530
Feb. 6-19-------	39.6	463	324	750	1,790	3,170
Mar. 1-31-------	234	316	251	510	1,300	2,300
Apr. 1-30-------	663	294	241	470	1,210	2,090
May 1-31--------	5,431	291	235	460	1,190	2,090
June 1-30-------	1,669	271	230	438	1,140	1,990
July 1-31-------	985	259	250	410	1,120	1,960
Aug. 1-31-------	826	283	272	438	1,200	2,080
Sept. 1-30------	171	298	297	458	1,270	2,150
Weighted average	1,052	289	245	460	1,200	2,100

JHI

analyses from October, 1952, to September, 1954.

Conservation programs on the farm and range lands and increased water useage in the drainage areas have also reduced the amount of run-off. Some of the practices under the conservation programs are as follows:

Contour farming
Cover cropping
Crop residue management
Stubble mulching
Terracing
Pond construction

Irrigation with ground water is extensive in several counties between the salt contributing area and the Possum Kingdom Reservoir. This ground water used in irrigation must be replaced by surface recharge before discharge to streams takes place; thus, run-off is reduced. If the rainfall returns to normal in this area, the run-off will only be about 57 per cent of the run-off before these conservation practices and water uses were begun (Lowry, 1955). Therefore, it is paramount that a program be developed to reduce the salt content of the headwaters of the Brazos River.

Previous work done on the Salt Problem

A program was begun in 1954 to study the sources of salt water entering the upper reaches of the river. H. R. Blank supervised a field survey in the summer of that year to determine the areas producing salt water. A report titled "Sources of Salt Water Entering the Upper Brazos River", Project 99, Texas A and M Research Foundation, resulted.

All the tributaries in the upper reaches of the Brazos are intermittent except one or two which flow from sources of artesian salt water. Practically all the stream channels were dry in the summer of 1954. Samples of water for Project 99 were obtained from bodies of standing water and from shallow subsurface water, assumed to be underflow, in sand bars and channel fills of stream beds.

Dr. Blank concluded that the Dove Creek Salt Flat in northwestern Stonewall County contributed about 40 per cent of the Brazos River salt and that two salt flats in northeastern Kent County were large contributors of salt.

The Ambursen Engineering Corporation, Houston, Texas, did core drilling in the Dove Creek Salt Flat in 1955 and proposed a dam for a salt evaporating reservoir.

The U. S. Geological Survey, Surface Water Branch, constructed weirs and a gaging station in the Dove Creek area of Stonewall and King Counties in 1956. Samples for chemical analysis are taken and water flow is measured at two-week intervals. A continuous flow record is obtained from the gaging station. The results are not yet (April, 1957) calculated and released by the U. S. Geological Survey.

Scope of this Investigation

Upon the basis of conclusions of Project 99, A and M Research Foundation, the Texas Board of Water Engineers proposed a geology and ground-water study of the four-county area to determine the source and movement of the salt water.

The area covers about 345 square miles of Dickens, Kent, King and Stonewall Counties, Texas, and is approximately 100 miles northwest of Abilene (figure 5, p. 12.).

Acknowledgments

Grateful acknowledgment is due numerous individuals for valuable assistance rendered. Dr. D. C. Van Siclen and Mr. G. C. Frazer, III supplied useful geologic information. Messrs. Jack Brown, R. T. Peyton and Otis Richards, geologists of Continental Oil Company, provided much helpful data and many sound ideas. The area ranchers, especially Messrs. G. W. Springer, W. A. Springer, Sr., W. A. Springer, Jr. and E. M. Jones, cooperated and assisted the writer in field activities on their ranches. The writer is indebted to his wife, Barbara E. McMillion, for her help and encouragement.

Much appreciation is due Mr. R. T. Littleton, Chief of Ground Water Branch, Texas Board of Water Engineers, for his patient and careful supervision. The writer deeply thanks his major professor, Dr. C. R. Humphrys, for guidance and proofing of this report.

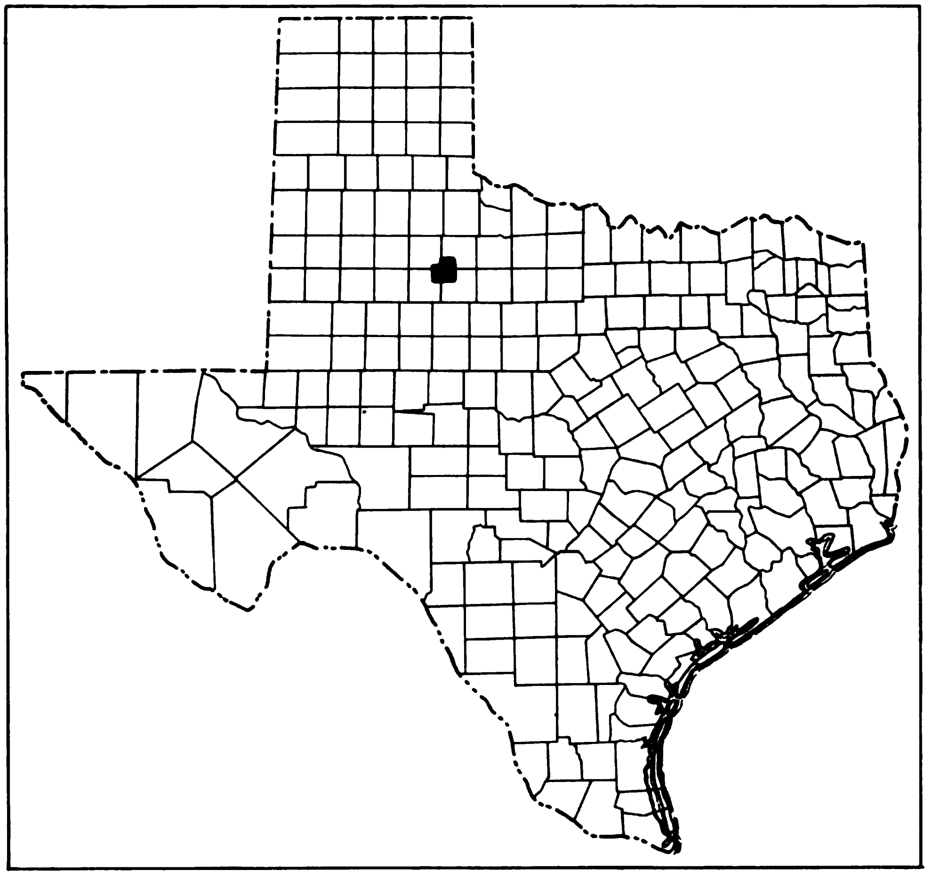


Figure 5. Index map showing location of detailed area in Texas.

JHE

GENERAL DESCRIPTION OF DETAILED AREA

The detailed area lies in the Osage Plains section of the Central Lowlands province. Topography varies from featureless through gently rolling and scarped plains to intricately dissected terrain. Altitudes range from 1665 feet along the Salt Fork of the Brazos River at the eastern edge of the area, to 2180 feet on the level plains at its northwestern corner. The surface has an average eastward slope of about 20 feet per mile. Local relief is comparatively large with about 330 feet as a maximum. Bedrock exposures are plentiful where local relief is appreciable but rare on the featureless plains.

Geomorphic features of the area are results of deposition and erosion of sediments, with little or no effects from diastrophic movements. These features are prominent scarps trending in a north-south direction; hills and valleys; isolated buttes; meandering river channels to deep, almost vertically-walled canyons; and spectacular flats covered with white salt and gypsum deposits.

The activities of this report are centered around three salt flats of this area. The Dove Creek Flat is in Stonewall County near the King County line and four miles east of the Kent County line. The Short Croton Flat and Hot Springs Flat are in Kent County about two and one-half miles west of the Stonewall County line and six and one-half miles and four miles, respectively, south of the Dickens County line. These two flats are about nine miles

JHE

west-southwest of Dove Creek Flat. The flats are in large ranches, and access to them is difficult since these parts of the ranches are seldom used by the ranchers.

THE

CLIMATE AND SOILS

The climate of the detailed area is classified as semi-arid. The average annual precipitation is about 21 inches (figure 1). The annual rainfall varies from year to year, and in some years there are extended periods of dry weather. The lightest precipitation is usually during the winter. Local thunderstorms or "cloudbursts" are the usual form of rain during warm weather.

Winters are mild except for several short and severe cold spells due to north winds, known as "northers". Summers are long and comparatively hot. Evaporation rates are high because a very large percent of the days year-round are clear, humidity is low, and wind velocities are usually high.

The soils in this area are mainly residual soils with characteristics very similar to the underlying parent material. The Childress gypsum outcrop (figure 6, p. 18) is the dividing line between clayey soils to the east and fine sandy soils to the west. Irregular-shaped bodies of wind-blown sand, called "shinnery sand", occur scattered over the area.

The fine sandy soils extending west of the Childress gypsum outcrop are of principal concern in this report. They are described by the Soil Conservation Service as deep, medium-textured soils with moderate to high permeability. The texture range is from fine sand to silt loam. At least 75 per cent of these soils are loamy sand and silt.

JHE

The soils are dominantly red in color due to the red color of the parent material, Whitehorse sand of Permian age. They are generally high in mineral content necessary for plant growth. These soils are easily eroded by both sheet and gully erosion. Conservation practices are the rule on land under cultivation.

Less than one-tenth of the detailed area is under cultivation. Principal crops grown are cotton, winter wheat, oats and maize. The other nine-tenths of the land is rough and often deeply dissected by erosion. This rough land is sparsely covered by such plants as mesquite, juniper, cacti and short grasses, and is used to pasture cattle. Farming and ranching are the principal sources of income for the area.

THE

STRATIGRAPHY

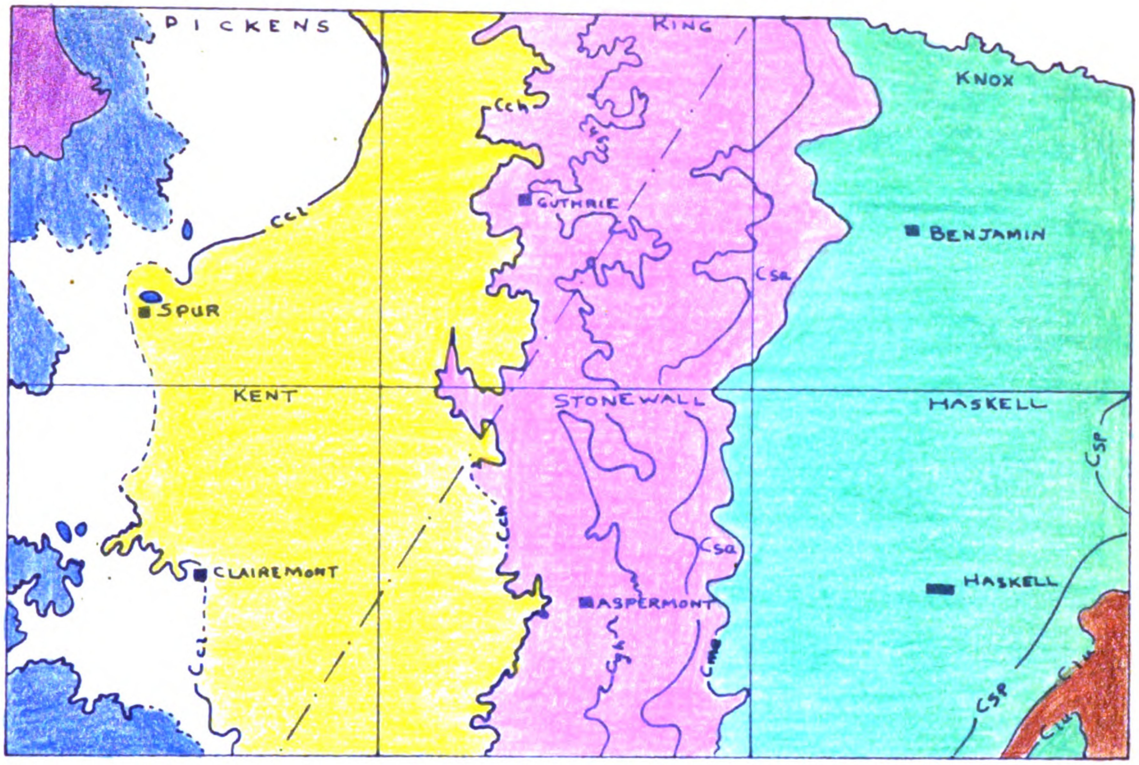
Permian Deposition

Figure 6 on page 18 shows the outcrop of the groups of series, Permian age, in the problem or detailed area and surrounding region. Triassic and Cretaceous also crop out in the region. None of the Triassic and Cretaceous rocks extends into the detailed area and thus they will not be considered further. The Permian rocks of this region were deposited in the province of the Permian sea referred to as the Eastern Shelf area. It is also called the Eastern Platform of the Midland basin.

The Permian sea covered a large part of Texas. It reached northeastward into Oklahoma and Kansas and northwestward into New Mexico and Arizona. At many places in Texas, Oklahoma and Kansas, no pronounced break occurs between Pennsylvanian and Permian sediments; thus indicating that the Permian sea was an inheritance from Pennsylvanian time (Sellards, 1932).

6000 to 6500 feet of Permian sediments underlie the surface of the detailed area. In Wolfcamp, earliest Permian, extensive limestone deposits were formed. In Leonard, the limestone was gradually replaced by dolomite, which was displaced westward by evaporites and red shale from the east. Red shale, red and some gray sandstone, evaporites, and occasional dolomite beds continued to accumulate more or less continuously during Guadalupe. Deposition of red-beds and evaporites continued intermittently in Ochoa.

JH



EXPLANATION

(Scale: 1 inch = 15 miles)

Cretaceous

Cret. Undivided

Triassic

Dockum Group

Permian

Ochoa Series

Ochoa Series Undivided

Guadalupe Series

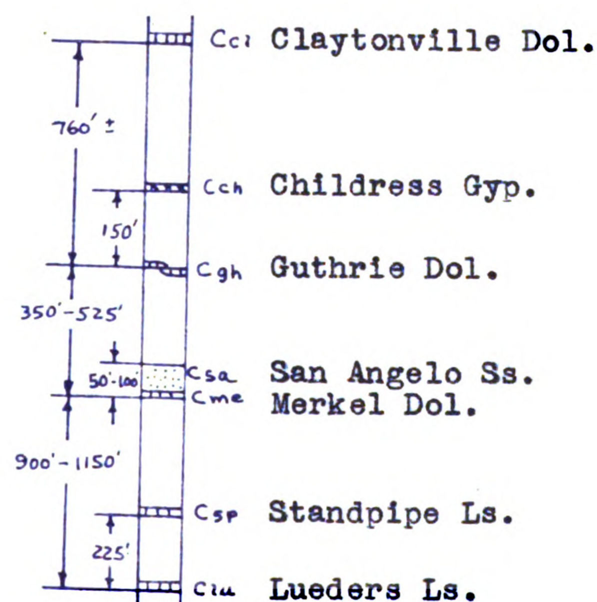
Whitehorse Group

El Reno Group

Leonard Series

Clear Fork Group

Wichita Group



—·— Probable eastern extent of salt beds in Permian sediments.

Figure 6. Outcrop map of rocks from Permian through Cretaceous in problem area and surrounding region.

JH

The beds with surface exposures in the detailed area have a regional due west dip of 25 feet per mile which is locally modified by gentle anticlines with flank dips not exceeding 60 feet per mile. (Plates 4 and 5, pocket). Lithologic changes are more common basinward rather than along the strike. Surface erosion since uplift has developed a topographic slope to the southeast which exposes the Permian beds, oldest to youngest, from east to west.

Correlation

Correlation of the rocks at the surface in the detailed area to those described in standard reference areas and in subsurface is very important. For example, salt beds seldom, if ever, are exposed at the surface because they dissolve very easily in circulating water. If salt beds are present in the subsurface of a formation, their presence may be detected or suspected by a knowledge of the formation as described elsewhere.

L. T. Patton classified these rocks in 1930 in his brief report, The Geology of Stonewall County, Texas, The University of Texas Bulletin No. 3027. In 1932, E. H. Sellards, W. S. Adkins, and F. B. Plummer relied heavily upon Patton's publication for stratigraphy of this area in their publication, The Geology of Texas, Vol. 1 Stratigraphy, The University of Texas Bulletin No. 3232. Since then, no publication describing the stratigraphy of these rocks has been widely distributed. The stratigraphic system of Patton and Sellards is still prevalent in many geologic circles,

JHE

despite the fact that for this area it is incomplete and out-dated. However, much detailed and accurate work has been done since 1932 by persons interested in oil exploration and many of these studies have been printed in the "Bulletin of the American Association of Petroleum Geologists" and the "Bulletin of the Geological Society of America".

Correlations used in this report are based on the Abilene Geological Society cross-section, "Scurry County to Parker County", prepared by committees of the Study Group on Stratigraphy in 1949 and modified slightly by D. C. Van Siclen in 1951 (figure 8, p. 22). This cross-section represents the best opinion of the most interested geologists active in the region. Series and systemic divisions are those defined by M. G. Cheney in 1940, with subsequent slight modifications (1945, 1947).

Permian System

The Correlation Chart (figure 7) on page 21 shows the systemic classification of the Permian rocks in this area. The lowest Permian rocks at the surface in the detailed area belong to the upper El Reno group (Dog Creek formation). The other Permian outcrops are all in the Whitehorse group. Thus, this section on Permian rocks will discuss basal El Reno through the Ochoa series. The Ochoa is included since it is stratigraphically above the rocks cropping out in the detailed area and may influence the area hydrologically.

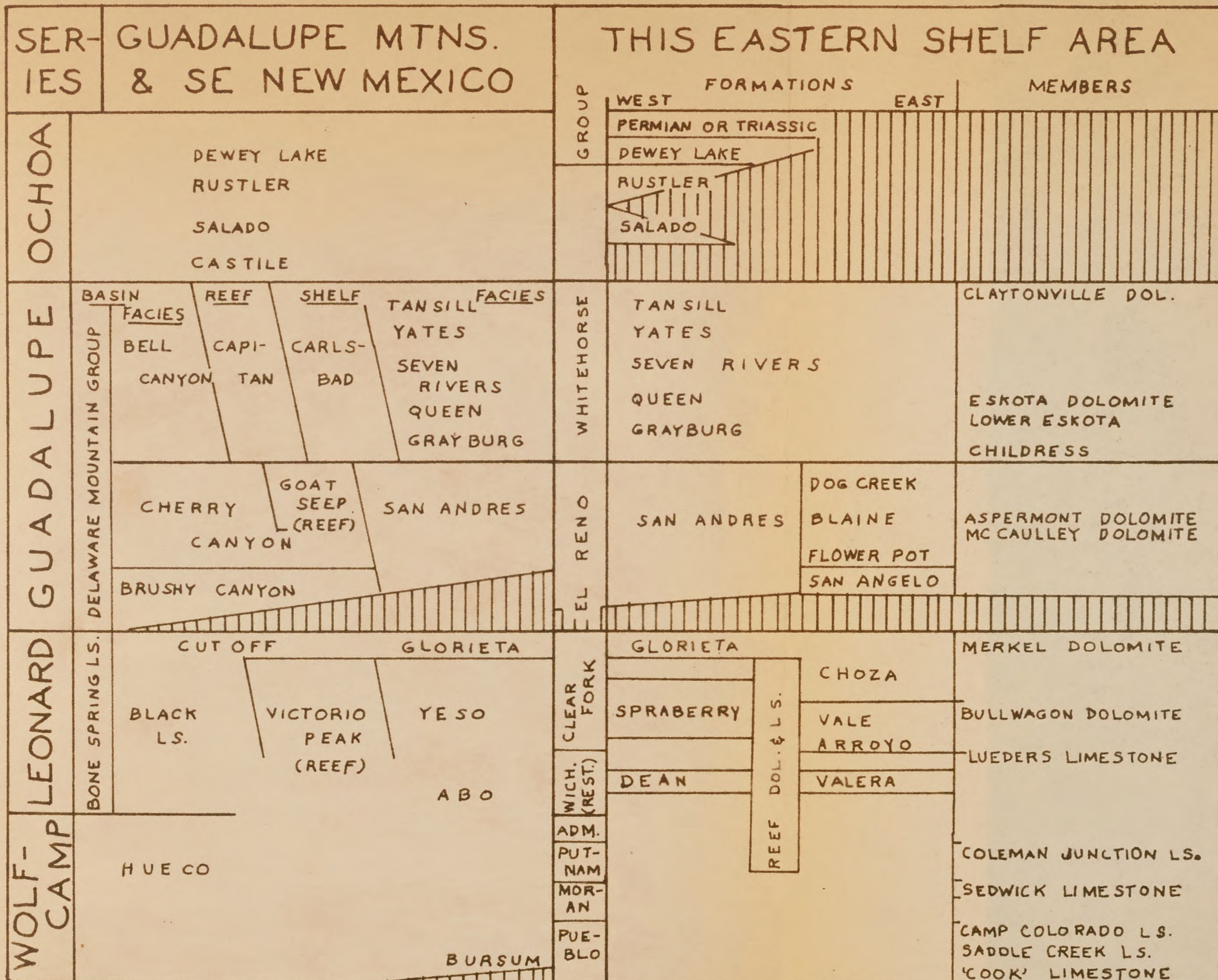


Figure 7. Correlation of Permian rocks of detailed area with standard reference sections. (P. B. King, 1942 and D. C. Van Siclin, 1951).

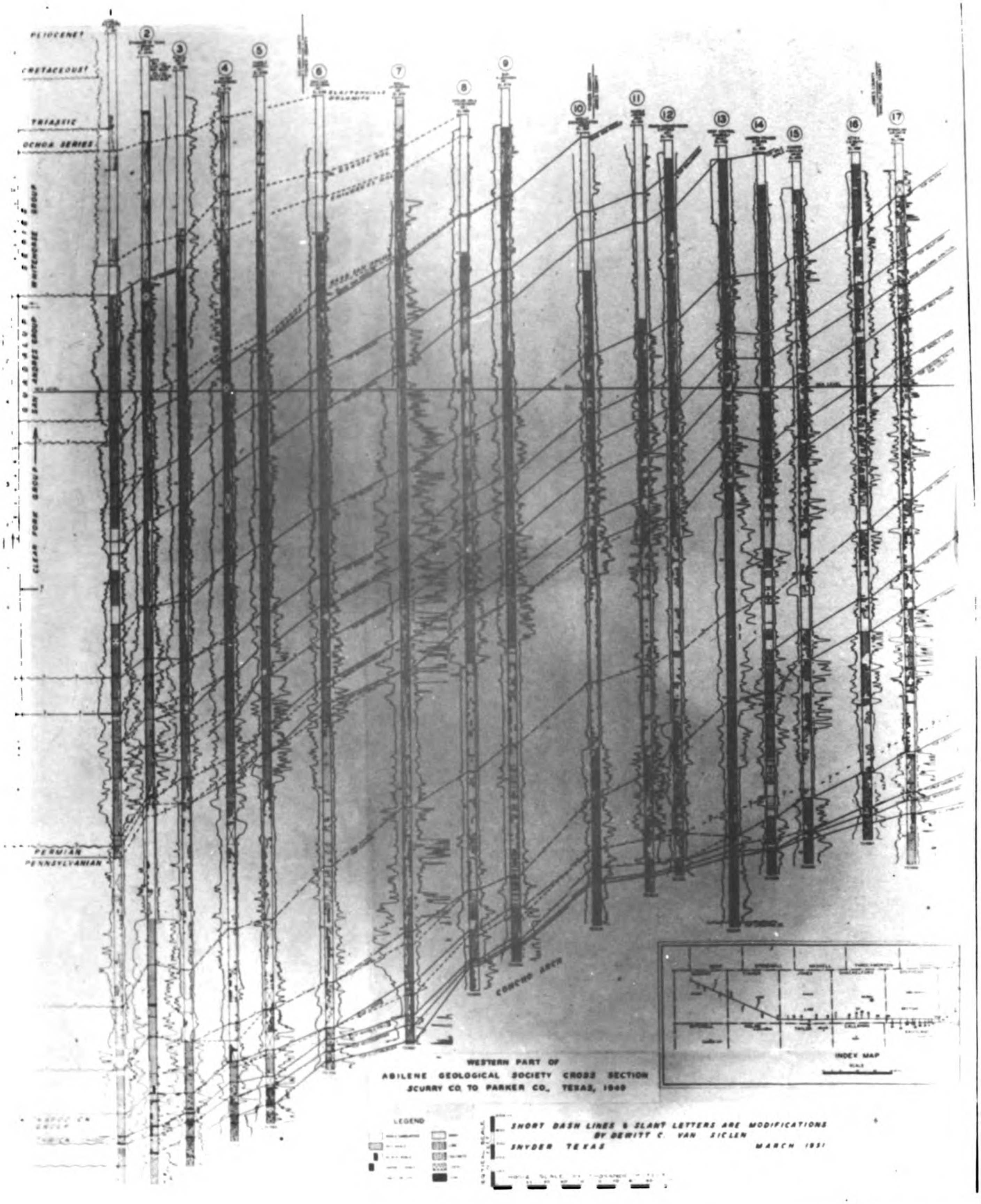


Figure 8. Western part of Abilene Geological Society cross section, Scurry Co. to Parker Co., Texas, 1949.

Guadalupe Series
El Reno (Pease River) group

The El Reno group was defined in Oklahoma to include beds from the top of the Hennessey shale up to the base of the sandstones at the base of the Whitehorse group (Becker 1930, pp. 37-56). In Stonewall County, Texas this includes beds from the base of the San Angelo sandstone to the base of the Childress gypsum and dolomite. The entire group crops out in a north-south belt crossing Stonewall County. The basal San Angelo, about twenty-five to one hundred feet of massive sandstone and conglomerate of chert and quartz pebbles at the outcrop, thins westward and practically disappears in subsurface of the eastern part of the detailed area. Detailed sample log on exploration hole no. 189 shows only a small amount of sand at interval 920 feet to 950 feet; this interval is the position of the San Angelo with reference to the Merkel dolomite which is at 990 to 1000 feet depth. Perhaps farther west it does disappear.

The San Angelo sandstone is overlain by the Flower Pot, Blaine and Dog Creek formations. These formation names are of Oklahoma type sections and thus far have not been applied to the Stonewall County area. However, the term "Blaine" is used in Texas (Sellards 1932, pp. 178-9) to include all three of the formations above San Angelo. This is not an appropriate use of the term since it includes more than does its type section.

The formations of the El Reno group are not specifically described and mapped in this report since only about one hundred feet of the upper part crop out here. In general, the Flower Pot, Blaine and Dog Creek formations consist principally of red and some green shales with a few persistent dolomite beds and some sandstone. Lenticular, massive gypsum beds occur in the upper part (Dog Creek). These gypsum beds are usually less than four feet in thickness.

Series affiliation of this group has long been disputed (Lewis, 1941, pp. 73-103). Some have placed it in Leonard series with top of series at the base of the Childress gypsum and dolomite. Others (Skinner, 1946, pp. 1857-74; Lloyd, 1949, pp. 19-20) place it in lower Guadalupe with top of Leonard at base of San Angelo. There is a definite unconformity at the base of the San Angelo. An unconformity at the base of the Childress is doubtful; many geologists in the Abilene area contend that the Childress rests conformably on the El Reno group. On this basis, the El Reno is assigned to the Guadalupe series.

Guadalupe Series

Whitehorse group

Lloyd and Thompson in 1929 (pp. 945-56) first recognized in this part of Texas strata equivalent to the Whitehorse group of Oklahoma. The term is used in this report to include the beds between the base of the Childress gypsum and the top of the Claytonville (formerly Sweetwater) dolomite; although, the writers cited excluded the Childress and may have included another 100 feet of section above the Claytonville.

J1

The Whitehorse crops out in most of the detailed area. Fine red sand is predominate in sharp contrast to the shales of the underlying El Reno group. Several thick, white gypsum beds reach the outcrop; these are anhydrite in the subsurface. Also, light gray to red dolomite beds crop out, and a thick salt section present in subsurface fails to reach the outcrop because of its solubility. Five lithologic formations into which the Whitehorse has been divided in West Texas and southeastern New Mexico have been traced into the general region of the detailed area in publications by Dickey (1940, pp. 37-51) and Page and Adams (1940, pp. 52-64). All five formations appear to be present and reach the outcrop. About ten feet of outcrop Childress gypsum changes westward into thirty feet of dolomite which forms the basal part of the Grayburg formation (Dickey, 1940, p. 46; Van Siclen, 1951, p. 30). This is followed by 300 to 450 feet of clastics with much red shale and salt in the lower 150 feet, and more red sand and anhydrite above. The lower clastics perhaps belong with the Grayburg and their top at the outcrop seems to be the top of the Lower Eskota gypsum. The upper clastics, at the outcrop extends from the top of the Lower Eskota to 140 feet above it or to 100 feet above the top of the Upper Eskota gypsum (sometimes called just "Eskota" without "Upper"), correlate with the Queen formation. Above the Queen in subsurface is 400 feet of salt and interbedded sand which passes upward into several hundred

HC

feet of sand and anhydrite, with the upper part having been traced into the outcrop of the Claytonville dolomite. Perhaps, the salt section represents substantially all of the Seven Rivers (salt) formation. The Yates formation is described by Van Siclen (1951, p. 31) as overlying this salt section and represented in a Fisher County outcrop as a sandstone with large frosted quartz grains. He also states that this sandstone is 75 feet below the Claytonville dolomite. The Transill formation consists of the Claytonville and associated strata. Several disconformities occur within the Whitehorse group, and a disconformity at its top is indicated by the absence of the lowest Ochoa series, the Castile formation.

Ochoa Series

The Permian Ochoa series consists of strata from the top of the Guadalupe series to the base of the Triassic system. In this general area it is the section from the top of the Claytonville dolomite to the base of the Triassic conglomerate which outcrops in western Kent County. The Ochoa is composed of red silt and sandstone. The outcrop section is from 100 to 200 feet thick. The writer has not attempted to divide the Ochoa into groups and formations.

Quaternary Deposits

Wind-blown sand deposits related to development of present topography and thinly scattered "upland" gravels are classified as the Quaternary of the area. The wind-blown sand, known locally as "shinnery sand", covers fairly large areas. A rather large but thin layer of this sand is near Girard, a small town west of Short Croton and Hot Springs Flats. Other large areas are along the Salt Fork of the Brazos River. None is found along Croton and Dove Creeks. This loose sand has high infiltration rates and probably influences the salt problem by rapid recharge to the water table.

Scattered cobbles and gravel were observed on a few knolls and ridges in the detailed area. These are related to erosion (pediment) surfaces. The cobbles and gravel are cherty and quartziferous. They exert no influence on the present problem.

SALT PRODUCING AREAS

Dove Creek Area

About nine square miles or 5,760 acres (figure 9, p. 30) in the Dove Creek area of King and Stonewall Counties contribute much of the salt of the Brazos River. This salt-producing area lies in sections 196-198, 183-185, 175-178, inclusive, Block F, H. & T.C. R.R. Survey. The salt water rises from clay in the beds of Dove Creek and its tributaries, especially Dove Creek Flat and Hayrick Creek. The table of average discharge and average load in tons per day of chloride and sulfate at sampling points in the Brazos River Basin during the period 1949-1951, (p.32) was prepared from records of the U. S. Geological Survey. Croton Creek and Dove Creek are the only streams of appreciable size that empty into the Salt Fork of the Brazos River between Peacock (No. 1) and Aspermont (No. 2) gaging stations; Aspermont (No. 2) station is downstream from the Peacock station. No measurement was made at the Peacock station in 1949. In 1950 the mean daily discharge between these two stations increased 32 cubic feet per second or 24 per cent, while the average daily chloride load increased 579 tons or 138 per cent. The average daily load of 579 tons represents about 52 per cent of the average daily chloride load of 1,103 tons in the Brazos River at the Possum Kingdom station (No. 5).

In 1951 the mean daily discharge between the Peacock and Aspermont stations increased 33 cubic feet per second or 107 per cent; the average daily chloride load increased 469 tons or 310 per cent. This average daily chloride load of 469 tons from these two creeks was 59 per cent of the average daily chloride load of 798 tons at the Possum Kingdom Dam.

The Dove Creek area flows salt water continuously from an artesian source; however, this is not the situation in the rest of the detailed area. As a result of the artesian water of the Dove Creek area, the percentage of increase in run-off and in daily chloride load between the Peacock and Aspermont stations is much greater for dry years than for rainy years, as can be seen by comparing 1950 run-off to that of 1951.

The Childress gypsum is the most prominent bed in the Dove Creek area (figure 10, p. 30). In most of the area it forms the cap for pronounced scarps, but where vegetation is well established and chemical erosion is active, the Childress gypsum, with associated strata, forms rounded and low gradient slopes. Salt water rises from clay which is stratigraphically below this gypsum bed. Fresh water is obtained in the vicinity of Dove Creek Flat from sand which directly overlies the Childress. The base of the Childress is mapped on figure 6 (p. 18) and will be used as a reference bed in this report.

The clay that produces artesian salt water is in the upper El Reno group, Permian system. It is described in the geologic sections 1, 2 and 3 on pages 52 and 52. For

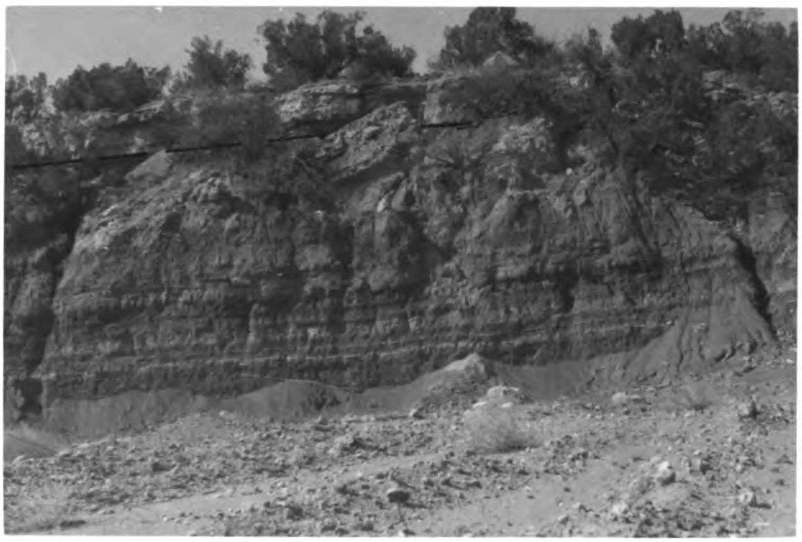


Figure 9. (Top) View of Dove Creek area taken from a point one mile south of Dove Creek Flat. Notice the relatively low relief.

Figure 10. (Bottom) Steep bluff on Hayrick Creek showing El Reno clay below the Childress gypsum. Dashed line is base of Childress. The banding in the clay is alternating red and green layers.

Figure 11. (Top) Detail of the clay shown in figure 10. Crumbly, conchoidal fracture results in this clay when dry. Compare with photo below.

Figure 12. (Bottom) Same clay, as above, exposed near mouth of Dove Creek Flat. Due to the effect of being saturated with salt water, the clay is tough, hard, and resistant, forming cascades and waterfalls.

AVERAGE DISCHARGE AND AVERAGE LOAD IN TONS PER DAY OF CHLORIDE AND SULFATE AT SAMPLING POINTS IN THE BRAZOS RIVER BASIN DURING THE PERIOD 1949-1951

Station No.	Name	Mean Daily Discharge Sec. Ft.	Average Daily Load in Tons Chloride	Average Daily Load in Tons Sulfate
1949				
2	Salt Fork Aspermont	157	771	301
4	Double Mountain Fork Aspermont	139	56.3	143
5	Brazos Possum Kingdom	769	1,103	779
6	Brazos Whitney	1,566	1,023	727
7	Brazos Richmond	4,645	1,292	953
8	Clear Fork Nugent	58.1	9.9	22.7
1950				
1	Salt Fork Peacock	134	420	149
2	Salt Fork Aspermont	166	999	352
3	Double Mountain Fork Rotan	146	65.4	120
4	Double Mountain Fork Aspermont	171	68.3	212
5	Brazos Possum Kingdom	898	1,093	679
6	Brazos Whitney	1,520	1,001	644
7	Brazos Richmond	5,783	1,358	906
8	Clear Fork Nugent	64.6	10.3	22.8
9	Clear Fork Fort Griffin	131	23.7	24.1
1951				
1	Salt Fork Peacock	31.2	151	46.3
2	Salt Fork Aspermont	64.5	620	178
3	Double Mountain Fork Rotan	32.6	23.8	46.2
4	Double Mountain Fork Aspermont	63.0	34.5	119
5	Brazos Possum Kingdom	603	798	474
6	Brazos Whitney	840	991	590
7	Brazos Richmond	1,418	819	513
8	Clear Fork Nugent	43.8	11.4	23.3
9	Clear Fork Fort Griffin	88.7	16.0	24.2

the most part the clay is laminated, jointed (figure 12, p. 31), usually friable and exhibits a conchoidal fracture (figure 11, p. 31). The conchoidal fracture is due to flocculation of the clay particles. Clay particles in fresh water possess like electrical charges but when contact is made with certain substances such as sodium chloride in solution, these charges are neutralized and the particles collect much as does butter in a churn. The flocculation of the clay of this area perhaps occurred when the sediments were deposited in the Permian sea. The sea at that time was very salty, since evaporites were being deposited. Flocculation structure may or may not mean that the clay is associated with salt beds.

The clay is predominantly red but much green and gray clays are present. The red color of the clay, and also of the overlying sand, is a result of oxidation of detrital magnetite and ilmenite during time of deposition. The green and gray colors probably resulted when conditions of deposition induced reduction rather than oxidation of these minerals (Miller and Folk, 1955). It has been suggested that the salt water caused the green color; however, the above explanation seems more logical, and also salt water moves to the surface through much red clay as well as green.

The clay yields salt water almost entirely by slow seepage. This water collects in small rivulets and then moves downgrade to form larger streams of flow. The clay in Dove Creek and Dove Creek Flat produces salt water from

its surface exposures at the contact with the farthest westward outcrop of the Childress base to about one and one-half miles east of this contact. East of the 178-183 section line only a small amount of salt water seepage in Dove Creek occurs. Hayrick Creek is the only other producer of salt water. Here seepage is about 30 feet below the base of the Childress. The creek flows south-southeast then turns and flows about one-fourth mile due east to its mouth at Dove Creek. The farthest downstream seepage is where the stream turns to the east.

Directly overlying the salt-producing clay is the Childress gypsum, a ten to thirteen foot thick gypsum bed in the outcrop; some salt water seeps from it in Dove Creek and Dove Creek Flat. The salt water seeps up through hydration fractures reworked by solution processes.

Overlying the Childress is four to five feet of red and green laminated clay which is followed by red, loose, fine sand. This fine sand yields good quality stock water in the Dove Creek locality. Above the sand is a four foot gypsum bed which locally forms the cap for low ridges and scarps (geologic sections 4 and 5, p. 54). Geologic section 5 was measured on a 143-foot bluff at the south side of Dove Creek near the center of land section 197. This is the steepest and highest bluff in this locality. Beds from top of Childress gypsum to top of Lower Eskota gypsum are exposed here. The 103-foot interval between the four-foot gypsum bed described above and the base of the Lower Eskota gypsum consists of fine-grained, red, unconsolidated sand with a medial six inch gray dolomite. The Lower Eskota gypsum is ten feet thick, massive, white, and contains many solution cavities.

Another 143 feet of Whitehorse group outcrop occurs at the head of Hayrick Creek and geologic section 6 was made there. Measurements started with the Lower Eskota gypsum and continued to the top of Hayrick Mountain, a small butte rather than a mountain as the name suggests. Thirteen feet-two inches of fine, red sand separates the Lower Eskota from a one foot-two inch brownish red dolomite which is followed upward by nineteen feet of fine, red sand to the base of the Upper Eskota gypsum. The Upper Eskota has physical characteristics similar to the Lower Eskota except that a one foot dolomitic layer occurs at its base. Alternating strata of fine, red, loose sand and thin massive, white gypsum occur in the one hundred foot interval between the top of the Upper Eskota and the top of Hayrick Mountain.

Croton Creek Area

The Croton Creek area of this report is in the northeastern part of Kent County. Salt water seeps to the surface from red silt and fine sand of the beds and banks of the main creek, tributary creeks, Short Croton Flat and Hot Springs Flat (figure 17, p. 48). The salt water seepage occurs over many square miles and is not restricted to definite boundaries, as is the situation in the Dove Creek area. Most of the salt water evaporates, leaving a thick salt-gypsum crust. Little or no run-off of salt water occurs except during and for a few days after periods of precipitation. The thick, widespread salt crust is readily dissolved and carried downstream during these periods of precipitation and run-off. All of the streams of this area are classified either as ephemeral or intermittent. Ephemeral streams flow only in direct response to precipitation and intermittent streams flow for protracted periods when water is received from surface or underground sources.

A stream cannot erode below the gradient necessary to permit transportation of sediment load across it. Neither can a stream erode below its base level. Croton Creek has reached the low limit for both of these regulations. Its gradient is in equilibrium with its base level, its mouth at the Salt Fork of the Brazos River, and with the detritus which it must transport. Thus, stream down-cutting for it is negligible and it has developed a wide-channeled, meandering course. Parts of the area in the lower reaches of Croton Creek and northeast of it for about three miles have been lowered from a high flat plateau to low rolling hills and valleys; however, north and west of these parts a deep-canyoned, badlands-type of topography has developed (figure 18, p. 48).

The geologic strata cropping out in this area consist almost entirely of red, unconsolidated, practically homogeneous, very fine sand and silt, with only a few beds of white, massive gypsum. Geologic sections 7 through 11 were made in this area. Above 27 feet 6 inches of fine, red sand in section 7 is a three-foot gypsum bed which probably is the same as the 3-foot 6-inch gypsum at the top of Hayrick Mountain (section 6) in King County. Overlying the three-foot gypsum is 108 feet 6 inches of very fine, red sand, followed by a 3-foot 4-inch white, massive gypsum bed (section 8). Above this bed is another thick stratum (121 feet) of this homogeneously textured, red, very fine sand; and again it is followed by a gypsum bed, this one 1 foot 2 inches thick. 36 feet 6 inches more of this very fine sand occurs above the 1 foot 2 inch gypsum. Overlying this latter sand stratum is a prominent, twelve-foot gypsum layer which is pure massive gypsum throughout. It is commercially mined in this area. Overlying this thick gypsum bed upward is 33 feet of red silt with a few round cherty cobbles on its surface. From the bed of Short Croton Flat to the top of the high plateau south of the flat, the combined geologic section totals 346 feet - 326½ feet of very fine red sand and 19½ feet of gypsum.

The fine, silty sand of this area often stands as vertical or nearly vertical walls as high as 200 feet. In places where a cap of gypsum occurs, the underlying silt produces angles as large as 120 degrees or 30 degrees overhanging from vertical. These features are picturesque, but make access to and travel in the area most difficult and dangerous.

Geomorphology

The salt flats and other physical features of this area developed as a result of erosional agencies acting upon the rocks present and the original land forms. Such a discussion is classed under geomorphology. In a narrow view, the valleys and hills appear to be just like those seen everywhere else. However, careful examination will reveal definite conditions which caused their individual characteristics.

In a regional sense, the present land surface consists of a series of gently sloping plains intersecting each other or separated by faint to cliffed scarps. In the detailed area they are often dissected into hilly terrain and badlands by ephemeral and intermittent streams. Plains and scarps are broad features and more readily observed and understood than valley sides and hilltops.

Plain is here defined as a circumscribed area of even surface and gentle slope. The plains are underlain by nonresistant rocks covered by little or no alluvium except locally by scattered gravel. They are distinguished from dip slopes by not being developed in a single resistant bed, although some do dip westward with the dip of the bedrock. Plains have developed at various levels and often one occurs above another separated by steeper slopes or scarps, like a series of broad stair treads separated by gentle risers.

The scarps range to several hundred feet high and may be continuous for tens of miles. The larger and more prominent are protected at the top by an erosion-resistant bed but this is not necessarily true of the smaller local scarps. There are no thick accumulations of talus. The scarps are cut back by local gullies which first attack their base and then gradually work their way to the top of the scarp. These gullies possess a characteristic steep-walled, box canyon head. The scarps are not forced back by lateral planation of streams. Most scarps have a fairly sharp change of slope at the top and the steeper scarps undergoing active erosion ordinarily have one at the base which separates the scarp from the slope at its foot. In some cases the plain below the front of a less active scarp rises continuously with gradually increasing inclination until at the top the slope abruptly decreases.

The erosion cycle of more active scarps resembles that for desert conditions - the source of detritus lying on the lower plain is the scarp which rises abruptly above it. "Sheetwash" is the leading erosional agent and the scarps are not covered with vegetation, thus they are exposed to rapid erosion during each rain. Most of the precipitation falls as high-intensity rain and hail storms of short duration.

The retreating scarps leave local areas of terrain dissected by deep gullies and canyons. Vegetation becomes established on these areas and simultaneously they are worn down to form rounded hills and valleys, which now are part of the plain at the foot of the scarp.

Origin of Dove Creek Flat

Dove Creek Flat covers about 400 acres in sections 183, 184, 197 and 198, Block F, H. & T.C. R.R. Survey, Stonewall County. Its main body is circular with elongated-upstream extensions at places where streams enter. Dove Creek flows in a semi-circular course to the north around it. The drainage area of the creeks entering the flat is circular, with the center of the circle coinciding closely with the center of the flat. Its floor or bed is practically flat and slopes gently downstream to the east. The lower one-half to one-third of the floor is an exposure of red and green clay which is saturated with salt water. The upstream part of the floor is the surface of the outcropping Childress gypsum. Both the clay and the Childress gypsum are in places covered by silt deposits and salt crust. The flat is surrounded by a 30-foot high bluff. The strata of the bluff are a basal five-foot clay layer, a medial fine-grained, loose, red sand, and a four-foot gypsum bed.

Clay saturated with salt water is sticky, tough, and resistant to both physical and chemical erosion. Figure 12 on page 31 shows the characteristics of the clay which forms the lower part of this salt flat. The water from Dove Creek Flat flows into Dove Creek; between the flat and this lower level the salt-saturated clay has developed cascades and small waterfalls instead of wearing down smoothly (figure 12, p.31). Cascades and waterfalls are usually characteristic of hard resistant rocks. These features have developed along a right-angle joint system in the clay.

The drainage area, except areas of flowing-artesian salt water, has run-off only at periods of precipitation. Rainwash is the principal agent of erosion because of the common violence of the storms, the deficiency or absence of vegetation, and the loose, sandy nature of the local regolith. Thus, the rapid run-off carries heavy loads of silt and sand. The Childress gypsum has developed a hard smooth surface where exposed as the floor of the flat, making it rather resistant to the abrasive action of sand-loaded run-off.

The bluff surrounding the flat is also the scarp of a small local plain. The twenty feet of loose sand, its main stratum, is not resistant to rainwash. With each rain much of the sand is washed away. The bluff, being capped by the more resistant four-foot gypsum bed, maintains a high angle of inclination. Since the drainage area is circular and small, the scarp moves radially away from the center of the flat. Also, the wind is usually of high velocity and probably removes much of the loose sand without eroding the floor of the flat appreciably.

The Childress gypsum is more easily eroded than the underlying clay (figure 14, p. 42); therefore, more and more of the clay which yields salt water by seepage is being exposed and the amount of salt water seepage should increase as a result.

From the above study, conditions necessary for development of these salt flats are established as follows:

1. A confluence of several streams at a place with a local base level which restricts downward erosion.

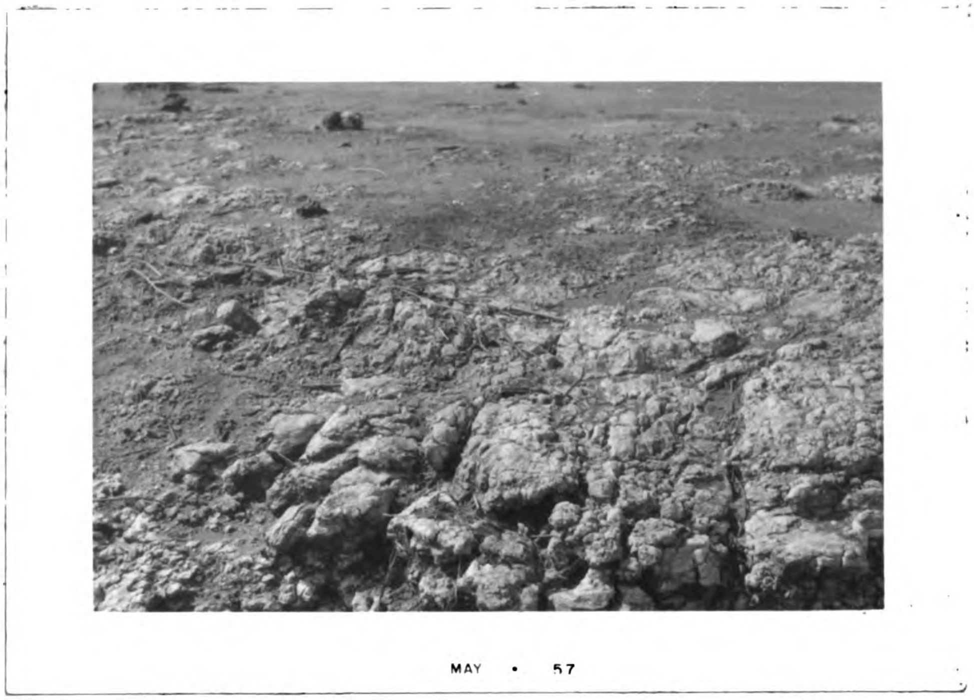


Figure 13. (Top) Low bluffs or scarp around upper part of Dove Creek Flat. The fine sand below the gypsum bed near the top erodes readily by rainwash and uncovers the more resistant Childress as the floor of the flat.

Figure 14. (Bottom) Detail of Childress gypsum shown in above picture. Solution is enlarging fractures caused by hydration; nevertheless this bed is still more resistant than the bluffs.

2. A rather high bluff or scarp composed of sediments which erode easily by rainwash and which maintain a high angle of inclination due to properties of the sediments or to a cap formed by a more resistant bed.
3. An arid type climate typified by violent storms and land sparsely covered by vegetation.

Origin of Salt Flats of Hayrick Creek

Three small areas, present on the west side of Hayrick Creek in King County, were described by Blank (pp. 9 and 10, 1955) as the Lower, Middle and Upper Salt Flats of Hayrick Creek. He attributes their origin, as well as the origin of all the other salt flats in the detailed area, to "sapping" by salt water seepage.

Only a small amount of salt water is produced in these areas, since most of the salt water-yielding clay is covered by thick alluvial-fan deposits of silt and gypsum talus. At the heads of these flats where the "sapping" is supposed to occur, little or no salt water seepage is present.

The conditions for development of salt flats, as established in the above section, can well be applied here. For the first condition, several small, ephemeral streams join at each flat and the local base level is established by proximity to the major stream, Hayrick Creek. A tributary stream does not degrade below the level of the larger stream into which it flows. For the second condition, about 30-37 feet of crumbly, nodular clay, capped by the Childress gypsum, forms a high angle slope. The clay, being dry and crumbly (figure 11, p. 31), is readily carried away by the driving force of rain. Of course the climate remains fairly constant over the whole area, satisfying the third condition. Actually, these three local flats are much like valley fans. The upper parts of these areas are covered with large gypsum talus (figure 15, p. 45) and the fragment size of the deposits decreases downstream. These flats have a higher slope of floor than is found in the other flats of the detailed area. The drainage courses of the surface run-off have developed around certain places in these flats, leaving many small isolated knolls (figure 16, p. 45).

The opposite or east side of Hayrick Creek has no prominent bluffs or scarps for creation of flats. The surface slopes gradually to the creek bed and vegetation is well established. Gypsum beds, elsewhere prominent in the area, form part of the surface slope. Since the surface is broad and gently sloping, this area is supplied with much subsurface moisture for plant growth and solution of the gypsum beds.

Origin of Short Croton and Hot Springs Flats

Short Croton and Hot Springs Flats are flat, salt-covered areas spectacularly surrounded by high red silt bluffs about 110 feet high. Several small dry washes enter each of the flats. Both are tributaries of Croton Creek. The lowest gradient possible has been developed between these flats and Croton Creek, thus the base level of the first

Figure 15. (Top) Talus of small dry wash entering the Lower Salt Flat of Hayrick Creek. Such talus is typical of valley fans.

Figure 16. (Bottom) One of several knolls in Lower Salt Flat of Hayrick Creek. The knoll was isolated by surface run-off developing its drainage course around it. These flats were formed by rainwash.

condition is present. There is a 110-foot section of easily eroded fine sand and silt from the base of each flat to the first gypsum bed, answering the qualifications for the second condition. The origin of these flats is essentially the same as that for flats on Hayrick Creek except that here the silt and very fine sand can maintain a high angle of inclination without a cap rock at the top.

In the Short Croton Flat, there is a salt water "spring" which yields about 25 gallons per minute. It is located 38 feet from the base of the nearest bluff. Realizing that elsewhere in this Croton Creek area salt water rises only as slow seepage, the writer made a thorough investigation of it. The highly mineralized water has created a very tough, gypsiferous, silty clay layer over about 200 square feet of the southwest corner of the flat. The layer averages about six inches thick and in a cavity below it is eight inches of standing water. Below this water is several feet of soft, water-filled silt. The salt water seeps up through the silt, collects under the six-inch layer, and then finds its way out by the opening called the "spring". The picture (figure 21, p. 50) shows a hole in this six-inch layer. The hole was originally made by a cow which stepped through it and broke a leg. The above situation is odd, but illustrates that strong, tough deposits are formed by salty, gypsiferous water.

Also evident in the Short Croton Flat is a swirling action of the run-off water over its floor during and after a hard rain. This has formed several cone-shaped holes, two to four feet in diameter, which occur between main drainage courses on the flat. This action aids in distributing the sediments evenly and, thus, keeps an almost level surface (figure 24, p. 51).

Salt plays its part in the formation of these flats by preventing the growth of vegetation. Thus, the sediments are always bare and ready to be shifted or washed away by the force of running water.

Figure 17. (Top) View of Croton Creek area taken from a point about 3/4 mile southwest of Short Croton Flat (white area in background). Note the high relief and barren canyons. Compare with figure 9.

Figure 18. (Bottom) Closer view of canyon at left side of upper picture. The gypsum bed at the top of canyon wall is about 300 feet higher than floor of Short Croton Flat.

Figure 19. (Top) 110-foot bluff on southwest side of Short Croton Flat. The bluff consists entirely of red silt and very fine sand except for a thin wavy layer of secondary gypsum. The white area near the base is salt crust formed by seeping ground water.

Figure 20. (Bottom) Detail of salt crust in upper picture. The salt has been scraped off a vertical strip just left of the shovel.

Figure 21. (Top) Hard, resistant, 6 to 8-inch clayey layer formed by ground water in the floor of the southwest corner of Short Croton Flat. Salt water from seepage collects under the layer and was about 8 inches deep when visited by the writer.

Figure 22. (Bottom) Salt water "spring" about 12 feet from above hole. The water which collects under the layer comes to surface here.

Figure 23. (Top) Rough, salt-gypsum crust as is typical in Short Croton and Hot Springs Flats. The salt of this crust will be flushed downstream by run-off from precipitation.

Figure 24. (Bottom) Small (2 to 4 feet in diameter) cone-shaped pits occur between main drainage courses in Short Croton Flat. These were formed by the swirling action of run-off during a heavy rain.

Geologic Sections in the Salt Producing Areas

Section 1. North side of Dove Creek at gaging station in NE corner, section 177, Block F, H. & T.C. R.R. Survey, Stonewall County.

	Feet	Inches
Childress gypsum, massive, white, fractured and weathered	9	0
Clay, nodular, green	0	9
Clay, nodular and conchoidal fracture due to flocculation, red	26	6
Gypsum, Gray, platy	0	2
Clay, nodular, red, silty	2	0
Gypsum, greenish-gray	0	1
Clay, nodular and conchoidal fracture, red	8	0
Gypsum, white, crumbly	0	3
Clay, nodular, red	8	0
Gypsum, green to gray, strongly laminated	5	0
Clay, exhibits flocculation structure (nodular and conchoidal fracture), red and green	4	6
Clay, exhibits flocculation structure, red, crumbly when dry	3	6
Clay, exhibits flocculation structure (nodules about ¼ inch to 1½ inches in diameter), green to gray	1	6
Clay, exhibits flocculation structure, red, shaly	3	6
Bed of Dove Creek		
Total of section	72	9

Section 2. High bluff west of Hayrick Creek where road crosses creek in SE $\frac{1}{4}$, SW $\frac{1}{4}$, section 176, Block F, H. & T.C. R.R. Survey, King County.

	Feet	Inches
Childress gypsum, massive, white, many solution cavities filled with red silt and powdered gypsum	10	0
Clay, green, nodular, dense and hard	1	0
Clay, red, scattered green reduction blotches	10	0
Clay, red, gypsiferous	0	5
Clay, red, with green circular blotches about one inch in diameter	6	6
Clay, green, nodular, red streaks	0	8
Clay, red, nodular, a few horizontal layers of green clay	10	0
Gypsum, gray, interbedded with red clay	0	6
Clay, red, nodular, friable	5	0
Gypsum, white, crumbly, platy	0	2
Total of section	44	3

Section 3. North side where Dove Creek Flat joins Dove Creek, SW $\frac{1}{4}$, SE $\frac{1}{4}$, section 197, Block F, H. & T.C. R.R. Survey, Stonewall County.

	Feet	Inches
Childress gypsum, white, massive, fractured by hydration and weathering	9	6
Clay, green, gypsiferous, dense and hard	1	6
Clay, red, contains green reduction specks and then green layers, dense and hard	5	0
Total of section	16	0

Section 4. Bluff at west side of Dove Creek Salt Flat, section 197, Block F, H & TC RR Survey, Stonewall County.

	Feet	Inches
Gypsum, white, massive, a few dolomitic lenses	4	0
Sand, fine, red, loose	20	0
Clay, laminated, red and green, horizontal bedding planes	5	0
Top of Childress gypsum		
Total of section	29	0

Section 5. 140' bluff on south side of Dove Creek, near center of section 197, Block F, H & TC RR Survey, Stonewall Co.

	Feet	Inches
Soil, thin, sandy, gypsiferous	2	0
Lower Eskota gypsum, massive, white, some residual dolomitic layers	10	0
Sand, very fine, red, unconsolidated	42	0
Dolomite, dense, gray	0	6
Sand, very fine, red, unconsolidated	60	6
Gypsum, anhydritic and dolomitic, white	4	0
Sand, fine, red, unconsolidated	20	0
Clay, red and green, gypsiferous, hard	3	6
Top of Childress gypsum in creek bed		
Total of Section	142	6

Section 6. In canyon at head of Hayrick Creek to top of Hayrick Mountain in SE corner, section 193, Block F, H & TC RR Survey, King County.

	Feet	Inches
Gypsum, massive, white	3	6
Sand, very fine, red, unconsolidated	22	0
Gypsum, massive, gray	0	4

Section 6, continued	Feet	Inches
Sand, very fine, red, loose	5	6
Gypsum, massive, white	3	0
Sand, fine, red, loose	8	2
Gypsum, white to gray, platy	2	0
Sand, fine, red, unconsolidated	55	0
Upper Eskota gypsum, massive, white, near base is 1'0" of red, silty dolomite	10	0
Sand, fine, silty, red	19	0
Dolomite, brownish red, silty, breaks into thin sheets and flagstones when exposed at surface-	1	2
Sand, fine, silty, red	13	2
Lower Eskota gypsum, massive, white, many solution cavities	10	0
Total of section	152	10

Section 7. Measured on bluff of north side of Short Croton Creek about one mile east of extreme western end of Short Croton Flat, section 1, Block OK, H & TC RR Survey, Kent Co.

	Feet	Inches
Sand, very fine, and silt, red, unconsolidated	15	6
Gypsum, massive, white	0	8
Sand, very fine, and silt, red, loose	3	10
Gypsum, massive, white, (probably same bed as 3'6" gypsum of section 6)	3	0
Sand, fine, loose, lower 4'0" saturated with salt water and thus more compact and harder	27	6
Bed of Short Croton Creek		
Total of section	50	11

Section 8. Measurements made on steep bluff at west end of Short Croton Flat and directly south of fence (north line of James Castleberry Survey, Kent County).

	Feet	Inches
Sand, very fine, red, loose, on surface covered with powdery, gypsum crust	22	0
Sandstone, fine-grained, highly gypsiferous, red with gray blotches	0	3
Sand, fine, red, unconsolidated	3	6
Gypsum, massive and granular, white	3	4
Sand, very fine, red, unconsolidated	108	6
Base of Short Croton Flat		
Total of Section	137	7

Section 9. Measurement made on east side of steep canyon which is tributary to Short Croton Flat from the south in James Castleberry Survey, Kent County.

	Feet	Inches
Silt, red, scattered cherty, round cobbles	33	0
Gypsum, massive, white, pure	12	0
Sand, very fine to silty, red, unconsolidated	36	6
Gypsum, massive, white, forms small ledge	1	2
Sand, very fine, silty, red, loose, has high angle of inclination	121	0
Gypsum, massive, white (is same bed as 3'4" gypsum of section 8)	3	4
Total of section	207	0

Section 10. Bluff at north side of Hot Springs Flat, one-fourth mile upstream from its mouth at Croton Creek in center of Chas. Hardwick Survey, Kent County.

	Feet	Inches
Silt to fine sand, red, loose	20	6
Gypsum, massive, white (same bed as 3'0" gypsum of section 7 and perhaps is same as 3'6" of section 6).	3	0

Section 10, continued	Feet	Inches
Silt, red and green, gypsiferous	0	6
Gypsum, nodular, white	0	4
Sand, very fine, silty, red, forms high angle of inclination	22	6
Gypsum, platy, gray, wavy	0	5
Silt, red, salt crust on lower three feet	11	6
Silt, deposited by creek of Hot Springs Flat, saturated with salt water	3	6
Creek bed		
Total of section	62	3

Section 11. A steep bluff at the southwest end of Hot Springs Flat in SE ¼, NE ¼, section 1, Block H, H & TC RR Survey, Kent County.

	Feet	Inches
Gypsum, massive, white, (same as 3'4" gypsum of sections 8 and 9)	3	4
Sand, very fine, silty, red with grayish-green reduction spots	107	0
Floor of Hot Springs Flat and top of 3'0" gypsum bed		
Total of section	110	4

HYDROLOGY

Topography and the Water Table

A topographic map is essential for a study of this nature; however, no topographic coverage is available for any part of this area. The only established elevations are a line of U. S. Coast and Geodetic bench marks along the Wichita Valley Railroad between Jayton and Girard in Kent County.

Plate 2 is a generalized topographic map drawn on a contour interval of 100 feet. Elevations of 219 exploration holes, oil wells, and water wells, as well as a personal knowledge of the general surface features from field work and from use of aerial photographs, were used to draw the map. It shows most of the main topographic features needed for this study; however, many of the smaller features are lost because of the limited number of control points and the 100-foot contour interval.

The map showing contours on the water table (plate 3 in pocket) was prepared from water levels of elevation-controlled water wells. A 50-foot contour interval is used to show as much detail as possible while sufficient control is available. Table 1 is a record of these wells. All of the water wells in the Dove Creek vicinity were scheduled and measured, unless obstructions prevented measurement. All the wells that could be measured in northeast Kent County, south and west of the salt flats there, were scheduled and measured; however, some of the wells in this vicinity were scheduled even though measurement of them was not possible. No attempt was made to schedule water wells in Stonewall County south and east of the wells shown on Plate 3. Elevations of the wells were taken by barometric method. One altimeter was kept stationary near a known elevation and readings on 15-minute intervals were made by the writer's wife. Another altimeter was taken to each well and the altimeter reading and time of reading were noted. Later, the readings for the wells were corrected for changes in barometric pressure which occurred between the time of departure from the known elevation and the time of the reading at the well. The Coast and Geodetic bench marks were used as control points in eastern Kent County. In King and Stonewall Counties, the ground elevations of exploration holes and deep oil well tests were used for elevation control. These elevations were determined by oil companies in the years 1949-1952.

The water table or the uppermost surface of the unconfined ground water generally conforms to the surface topography. The water table elevations decrease sharply near high bluffs and scarps and deep canyons. Likewise, it increases rapidly from these features to highly elevated, broad plains. Two localities in this detailed area illustrate these statements. One is at the head of Hayrick Creek in King County and the other is in northeast Kent County. Hayrick Creek Canyon cuts abruptly into a broad rolling plain. The plain near the head of Hayrick Creek

has a few prominent buttes but then gradually increases from about 1980 feet to almost 2100 feet in a northwest direction. Southeast of the plain, elevations drop rapidly to about 1720 feet in Hayrick Creek Canyon. The water table reflects these rapid surface changes, as can be seen on Plate 3; a drop from 1900 feet to less than 1750 feet occurs in only a few miles. The water-table gradient at this place is about 100 feet per mile. The water table meets the surface at several places in the canyon, producing fresh water seeps and springs.

The other area having these similar topographic and water table conditions lies in northeast Kent County; there a large, rather flat plain is sharply reduced in elevation by tributary canyons of Croton Creek. Salt water seeps and springs are produced at the contact of the water table with the surface. This discussion is continued under the following section, "Source of salt water in Croton Creek area".

Source of Salt Water in Croton Creek Area

The broad plain mentioned above covers most of the western part of the detailed area and extends twenty miles farther west where it is intercepted by the scarp of the High Plains. In the detailed area it is flat to rolling, except where deep gullies and canyons have cut into its edges. It slopes gradually from 2176-foot elevation in the northwest part of this area to 2008 feet at Jayton in the southeast part. Soils of this plain have moderate to high infiltration rates. The water table is commonly 25 to 45 feet below the surface, but much deeper depths occur near deep canyons and high scarps. The northeast part of this plain is deeply incised by canyons tributary to Short Croton Flat, Hot Springs Flat and Croton Creek itself. These canyons have vertical boxed-heads, many as deep as 100 feet. The predominent fine sand and silt have a low coefficient of transmissibility, and thus the water table follows closely the steep gradient of these deeply eroded surfaces. The water table makes contact with the surface in the lower parts of the canyons, and in the salt flats and creek beds. Salt seepage results at this contact.

Figure 25 on page 63 is a vertical section that typically illustrates the ground-water hydrology of this area. This section is along a line which extends from the southwest corner of Short Croton Flat to a point about three miles southwest of this corner. The surface configuration was plotted from elevations of wells and from data of hand-leveled, geologic sections. Measurements of water wells were used to draw the position of the water table. The distance of the well locations on this illustration are not actual; the distance of individual wells from prominent canyons or scarps was calculated and this distance was used in preparing the vertical section. An "ocean of salt water" was reported at depth 253 feet (elevation 1797 feet) in well 74 by its driller. No other reports of depths to salt water were obtained since water wells are not usually drilled much deeper than the water table and records are not generally kept by local drillers. The elevation of Short Croton Flat is approximately correct. Horizontal distances were measured from aerial photographs.

The surface gradient from the flat to the top of the plain, as shown in the vertical section, is about 150 feet per mile; whereas, the corresponding hydraulic gradient of the water table is about 131 feet per mile. The hydraulic system is judged "unconfined" since no impermeable or thick soluble beds are present to form an artesian system, and since the salt water seepage is widespread and not restricted except by elevation and proximity to places of high local relief. A 285-300-foot thickness of this unconfined, saturated sand is present between the highest water-table elevation and the elevation of salt water seeps. The water moves from points of high to points of low potential -- in other words, from points at which the water table is high to points at which it is low. Water at point "C" of figure 25 is of higher potential than that at "B" due to difference of elevation; however, all along a vertical line intersecting "A" and "C" potentials higher than that at "B" exist because of pressures exerted by the overlying column of water with high static level. Thus, threads of water move from points throughout this unconfined body toward the place of discharge at "B". Movement is slow and frictional losses in lateral movement are large due to resistance offered by the low permeability of the fine sand. For continuation of this movement over long

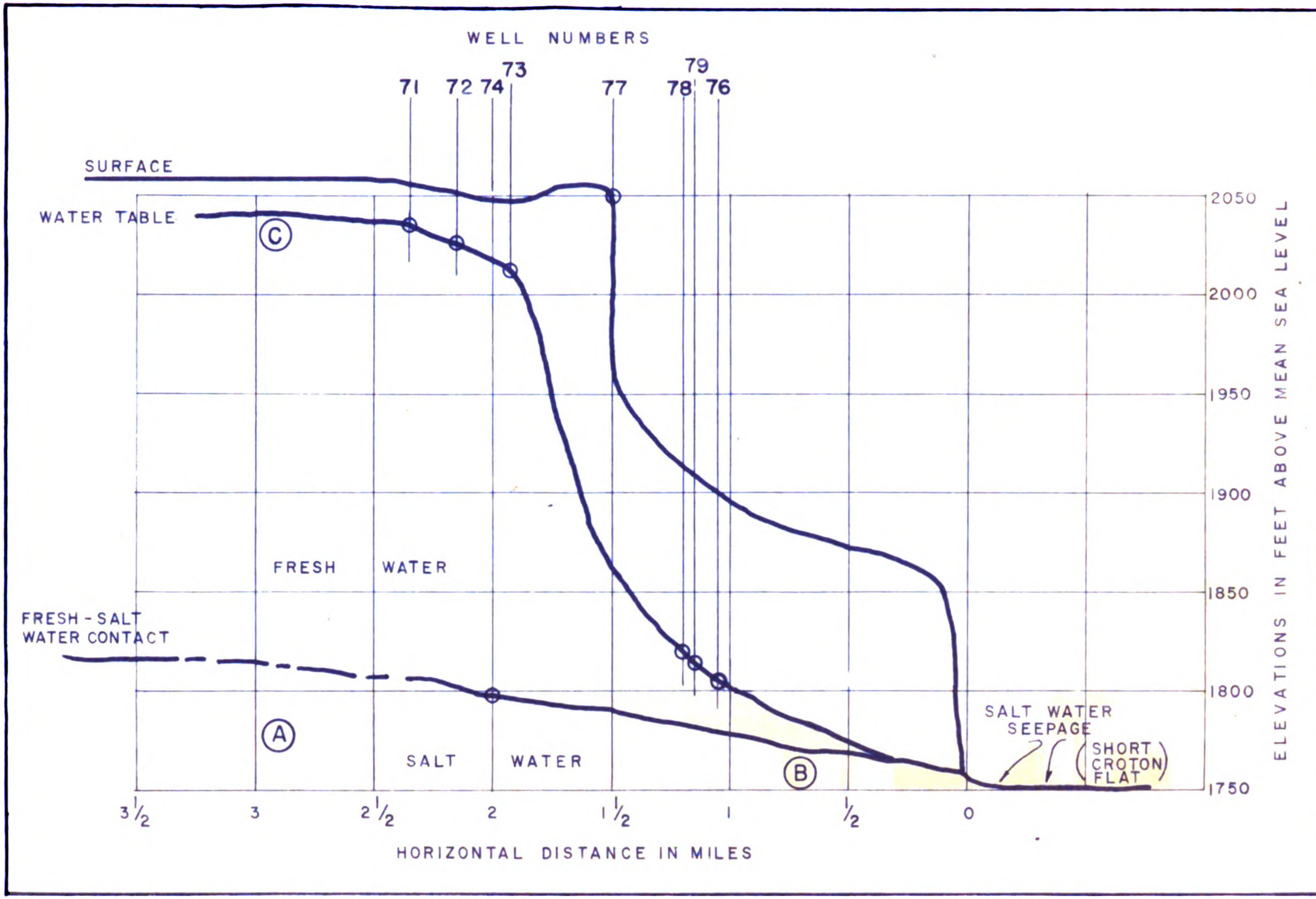
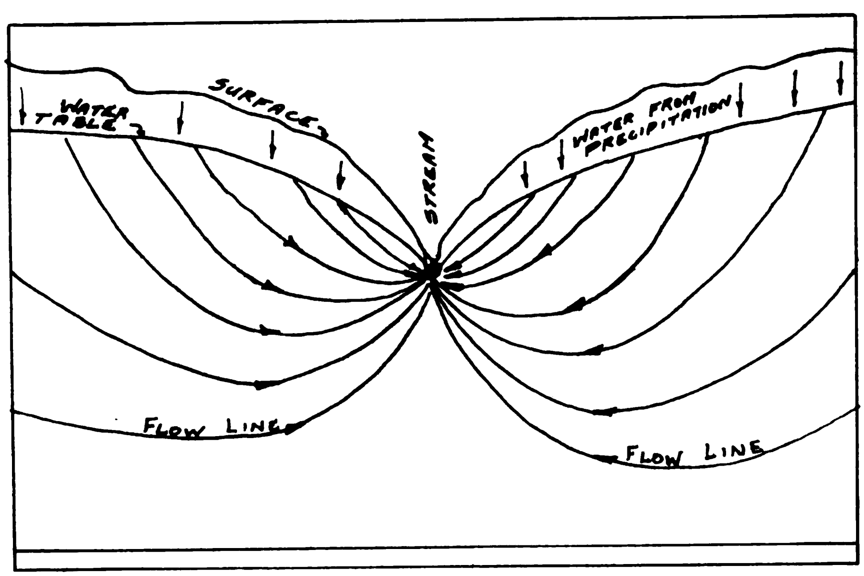


Figure 25. Vertical section showing the ground-water hydrology of the Croton Creek area. The section is along a line which runs southwest from Short Croton Flat. See text for further explanation.

periods of time, recharge by infiltration of water from precipitation is necessary. The movement is schematically shown below as theoretical flow lines extending from the recharge area, then throughout the body to the place of discharge (Bennett, 1952, p. 104). This type of movement applied to figure 25 reveals that much of the water moves downward, laterally, and upward through sediments containing crystalline salt (halite) and issues at the surface as salt water.



Schematic cross section showing the general pattern of ground-water flow into a stream (after Bennett).

The salt water is a product of solution of salt beds by circulating ground water. Perhaps all of the salt beds of this locality belong to the Seven Rivers "salt" formation.

Circulating water readily dissolves salt and becomes very salty after only a short period of contact with the salt. The salt water seeps to the surface in the flats and other places in the drainage system. A salt-gypsum crust is formed due to the extremely high evaporation rate of the area. Gypsum is the dominant constituent of this crust (figure 23, p. 51) since it does not dissolve as easily as the salt when surface run-off occurs at periods of precipitation.

On the broad plain above and southwest of Croton Creek, conservation practices are applied on practically every cultivated field. These practices increase recharge to the water table. Increased recharge develops increases in the water-table elevation and also increases the amount of ground water discharge. This is the only locality in the detailed area which has a report of a rising water table; however, no actual figures of this rise are available since this study is the pioneer work in the area.

Source of Salt Water in Dove Creek Area

In 1955, the Ambursen Engineering Corporation, Houston, Texas, discovered the salt water of the Dove Creek area to be under artesian pressure. They drilled several core holes in the vicinity of Dove Creek Flat. One core hole (Ambursen Engineering No. C-4) was still open and flowing about 20-25 gallons per minute of salt water in February, 1957. This hole is located near the mouth of the main flat where it joins with a rather large stream which enters it from the south. The drilling of this hole started in red and green clay which yielded all of the artesian salt water encountered. The lowest salt water noted was 50 feet below the surface. The water rose five feet above the surface or to about elevation 1705 in a stand pipe. The table on the next page shows the partial chemical analyses of water from this hole and of other places in the Dove Creek area. These analyses were made in 1955 by Texas A and M College under Project 99. Water from the above-mentioned core hole is high in both chloride (146,850 ppm) and sulfate (2,173 ppm). Water from a pool (sample no. 2-B-2) that had endured some evaporation had an extremely high content of chloride (175,800 ppm) and a low content of sulfate (202 ppm) since sulfate crystallizes from solution before chloride.

The Ambursen Engineering Corporation, under their dual program to determine the source of salt water and to plan an evaporation-type dam which is intended to hold the salt within the Dove Creek Flat, believed that the source of salt water was a local ground water situation. They asserted that water of precipitation infiltrates the surface, percolates down to the clay where it dissolves lenses of salt contained in the clay and simultaneously produces low artesian pressures. However, Blank in 1955 (pp. 15 and 16) stated that this does not seem to be the situation but he offers little explanation for its source.

In 1949, when Continental Oil Company drilled exploration hole No. 153 of table 3, p.120, they struck artesian

Sample No.	Date Coll.	Source and Location	Specific Conduct. (m.mhos. 25° C)	Sp. Gr.
2-2	10-10-55	Outlet stream of Dove Creek Flat	220,500	1.160
2B-2	10-10-55	Spring pool, depositing gypsum and salt, Dove Creek Flat	230,550-	1.185
2C-1	10-10-55	Boring C-4, flowing at Dove Creek Flat	225,040	1.169
2D-1	10-10-55	Stream flow in flat above Boring C-4, Dove Creek Flat	88,550	1.046
2E-1	10-10-55	Stream flow above outlet of main flat, Dove Creek Flat	217,460	1.153
1-1	8-19-54	Brine spring at Short Croton Flat	123,500	1.065

at (°C)	Diss. Solids	Cl	SO_4	Ca	Mg	Alk. $CaCO_3$	P_H
	Constituents Determined (parts per million)						
26.3	216,900	140,520	1,908	4,215	2,318	36	7.4
26.5	247,100	175,800	202	7,578	2,227	32	6.9
26.3	225,600	146,850	2,173	6,971	1,787	31	7.0
25.7	63,193	49,703	1,720	n.d	n.d	n.d	n.d
25.8	204,830	143,970	1,394	2,948	841	43	7.8
31.5	98,700	52,580	1,726	610	1,031	47	7.6

salt water at a shallow depth. This salt water flowed steadily above their 43-foot drilling rig for about 48 hours before the drilling crew was able to case it off. This hole is located about 1-1/3 miles west of the Ambursen Engineering core hole C-4 (of above discussion). It has a surface elevation of 1726; thus the top of the rig was elevation 1769 or about 64 feet higher than the hydrostatic head of the salt water in hole C-4. Had the water pressure been measured by a stand pipe, it would have risen somewhat higher than the top of the drilling rig.

The conditions present in this area are summarized as follows:

1. Outcropping clay, stratigraphically below the 10-foot Childress gypsum, contains artesian salt water to a shallow depth of less than 50 feet below the surface.
2. A fine sand contains fresh (non-salty) water from the top of the Childress upward.
3. The surface has a local and regional slope to the southeast.
4. The bedrock has a regular dip of 25 feet per mile westward.
5. The ground water does not produce springs in this area except along Hayrick Canyon, and these are fresh-water springs.

Structure

An artesian system generally consists of a confined

aquifer dipping away from a recharge area with artesian pressures being produced by the weight of water contained in this aquifer and with flowing water being produced at places with elevations lower than the recharge area. However, the conditions in the Dove Creek area are just the opposite of this. The artesian pressures are produced in strata that dip away from the discharge area rather than the recharge area. The surface slopes in a direction opposite the dip of the aquifer. Movement of the artesian water is up the dip rather than down the dip.

In the planning of this present program, it was strongly suggested by capable geologists that this salt water possibly rises from deep formations to the surface by way of faults or major fractures. Thus, an initial step was the examination of geologic structure for faulting and/or fracturing. Several dip and strike measurements were made on the outcrop of the Childress gypsum. There was a small variation between these measurements; however, a variation should be expected since it is difficult to obtain accurate strike-dip measurements on gently-dipping beds and since the gypsum has expanded as much as 33 per cent in changing from anhydrite. No prominent fractures or faults were observed in the field or on aerial photographs.

It was soon learned that oil companies and consulting geologists do not map the outcrops of this area for determination of structure because they believe that differential settling of shallow strata in places of solution of salt beds has caused psuedo-structures. Thus, they drill through these strata and map on deeper beds, such as the Guthrie dolomite (about 150 feet below the Childress) and Merkel dolomite (about 500-600 feet below the Childress). The information used in preparing figure 26, (p. 71) was obtained from George C. Frazer, III. The Claytonville dolomite dips regularly and smoothly westward until suddenly its dip becomes erratic. The erratic character of the dip is attributed to slumping at places where salt beds have dissolved and been removed by circulating ground water.

One hundred forty-five logs of exploration holes were used to draw contours on top of the Childress and Upper Eskota gypsum beds (plates 4 and 5, in pocket). The logs consist of one resistivity curve and a self-potential curve. The companies donating this data did not desire that their names be published since this type of information is usually kept confidential. These maps rather accurately show the structure of the shallow strata. No indications of faults are present on them. The type of structure on both of these marker beds suggests a stable area without disruptions by diastrophic movements. Not even any predominant structural differences exist between the two maps.

According to petroleum engineers, specialists in the field of brine disposal, the deep formations of the detailed area are under low pressures and gravity-disposal of oil-well brines is commonly practiced here.

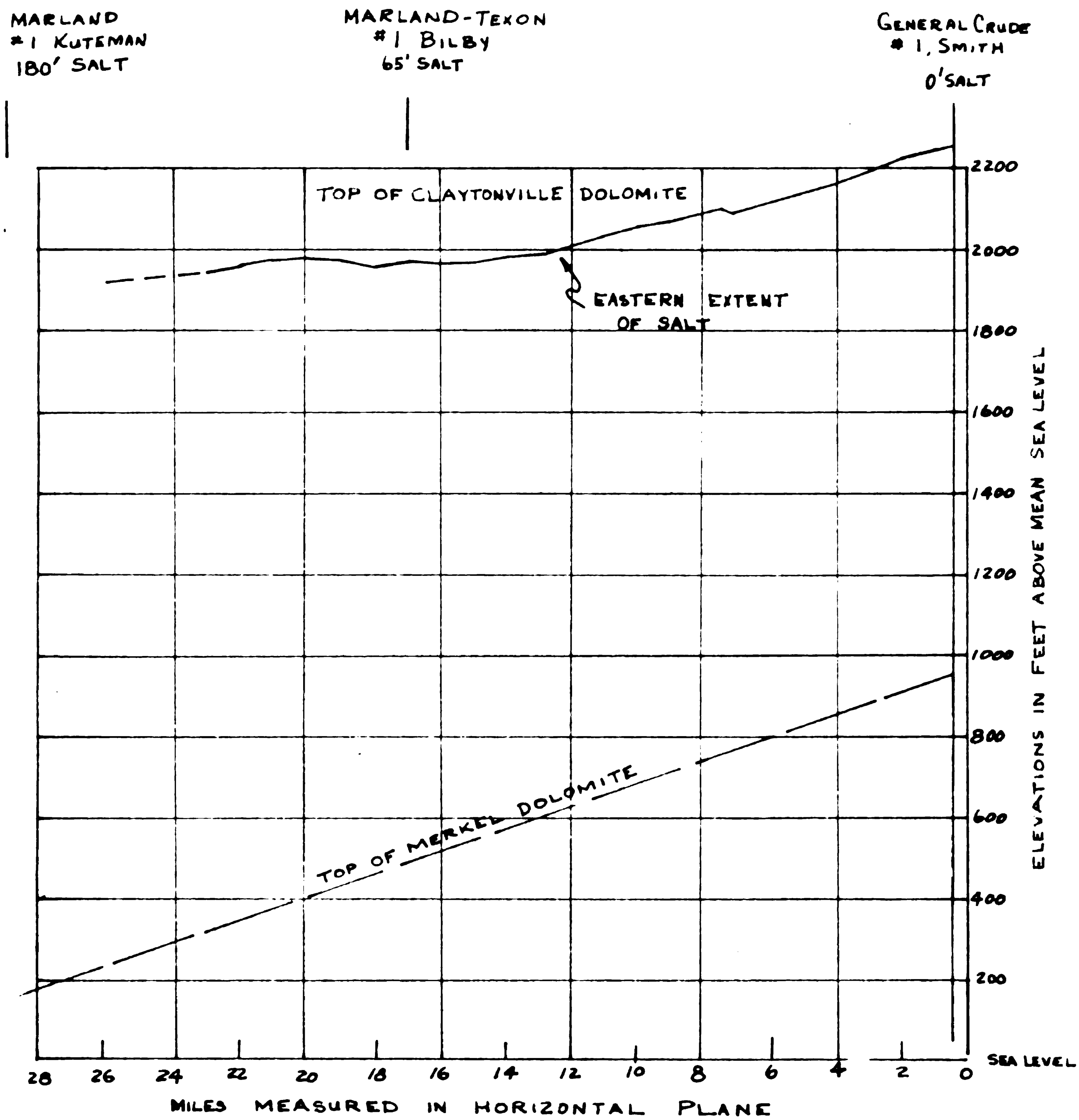


Figure 26. Determination of the eastern extent of salt deposits in Permian rocks by noting the erratic changes of the otherwise regular westward dip of the Claytonville dolomite. (G. C. Frazer, III mapped the Claytonville along the Double Mountain Fork of Brazos River, Kent County. Top of Merkel was obtained from electric logs of wells near the mapped area.)

Artesian System of the Childress Gypsum

Either one of two situations can account for the unusual way in which this artesian system has developed, since a recharge area does not lie east or up the dip from a discharge area and since the water does not move to the surface from deep formations.

The first of these is formation pressures in the clay underlying the Childress gypsum. Formation pressures are here defined as pressures due to overburden which tends to squeeze water from a stratum in much the same manner as water is squeezed from a sponge by force exerted upon it. The other situation is one in which the artesian pressure at the discharge area is produced by a very permeable aquifer transferring the large head of a distal unconfined ground water body.

Consultation concerning formation pressures was held with Dr. King Hubbert and Dr. DeWitt C. Van Siclen, both of whom are authorities in the field of ground water movement and reservoir characteristics. They presented information of proof that formation pressures do not develop unless the overburden is at least 5,500 to 7,000 feet thick with the variation depending upon the specific gravity and interstitial water of the overburden. Maximum surface elevation increases of this region are due west. Fifty miles in this direction from Dove Creek Flat to Crosbyton, elevations increase from 1,700 feet to 3,017 feet, but west of Crosbyton the surface increases slightly in elevation. The Childress

gypsum dips about 750 feet in this fifty miles. Thus a total of only 2,067 feet of overburden of the clay is present. This is less than one-half of the required minimum for development of formation pressures.

Before the second situation can develop, there must be a locality with a water table much higher than 1,700 feet, with a very permeable aquifer connecting it to the Dove Creek area, and with an abundant source of salt. The plain of northeast Kent County (as discussed under "Source of salt water in the Croton Creek area") lies about ten miles west of Dove Creek Flat and has a water table as high as 2,089 feet in elevation. This is 389 feet higher than the 1,700-foot elevation at the Flat. Thick beds of salt of the Seven Rivers formation, Whitehorse group, are present in the shallow subsurface of this locality. Salt beds are not logged when drilling is performed by a rotary method since the salt is dissolved by the large amount of water used for drilling. Rotary equipment is used almost exclusively by the oil industry today. Before about 1935, cable tool drilling was predominant. Logs of holes drilled with this equipment show salt beds. A few such logs are available for the region of the detailed area. The cable-tool holes closest to northeast Kent County are one at Spur (Udden, 1926) and another, Moutray Oil Company - Jones No. 1, in Sec. 311, Blk. 1, H. and G.N. R.R. Survey. Both of these holes are in Dickens County and about twelve miles northwest of Girard. Log of the Spur well records 152 feet of salt and the log of the Moutray Oil Company well shows 167 feet of salt. Most of this salt consists of beds ranging from 4 to 75 feet in thickness and individual beds are separated by red silt and anhydrite (table 4, p. 131). These salt beds can be projected into the Girard area of northeast Kent County by making corrections for differences of land elevations and for bedrock dip. In the Girard area these beds would occur in the upper 28 to 728 feet of strata, forming a very large source of salt for solution by unconfined ground water. The contact between fresh water and salt water is about 250 feet below surface. Solution by ground water has evidently removed much of the salt.

Exploration hole 153, which is 1-1/3 miles west of Dove Creek Flat, flowed enormous quantities of salt water at a steady rate for about two days. It was the only exploration hole of several drilled in this locality that produced flowing salt water.1/ The producing aquifer is very permeable since only very permeable aquifers, such as coarse sand and gravel and cavities in soluble beds, produce such phenomenal flows. The aquifer is also very

1/ Exploration hole 102 located 6½ miles north of hole 153 flowed salt water from a zone about 150 feet above the Childress gypsum, whereas hole 153 produced water from near the base of the Childress. The artesian systems are not the same but may have similar characteristics, since both zones are near thick anhydrite beds. The flow of 102 is not considered further in this report since it does not directly affect the problem at Dove Creek and since only a very small amount of information is available on the area near it.

narrow in width in the Dove Creek area since only one hole of the several drilled struck it. Only very fine sand, silt, clay, anhydrite, thin dolomite, and possibly some salt are present in the shallow strata of this area. Exploration hole 153 produced salt water from a cavernous-type aquifer, since no coarse clastics occur in the subsurface and since it is characteristic of only cavernous aquifers to be of narrow width in this area of the Permian sediments. (This statement does not apply outside this local area.)

Anhydrite is present and salt beds or lenses of salt may be present here for development of the cavity-type aquifer. There are no indications or reports of such salt deposits in the clay below the Childress gypsum. It is also difficult to infer that these heretofore unknown beds or lenses of salt are extensive enough to form a continuous aquifer for several miles. Ordinarily we would not expect to find extensive salt beds below such a thick gypsum-anhydrite bed as the Childress, since calcium sulfate crystallizes from solution before sodium chloride. The presence or absence of salt lenses in the clay beneath the Childress cannot be known except by intensive core drilling.

The Childress gypsum is evidently the bed in which solution cavities have developed to produce the artesian system. The Childress extends persistently over the entire region as a bed 10 to 13 feet thick. It is underlain by thick, rather impervious clay which forms a lower confining layer. In surface exposures there is a five-foot, dense clay layer above it. In the subsurface, the Childress is 100 per cent anhydrite. This anhydrite bed is the most competent bed in this shallow subsurface, and undoubtedly contains many fractures which act as avenues through which ground water can move and enlarge by solution. Anhydrite is only slightly soluble in pure water but if sodium chloride is present in the water, its solubility is much greater (Sellards and Baker, 1934, p. 623). Thus the subsurface Childress is vulnerable to the dissolving action of this area's salty ground water.

It should be carefully noticed that the cavernous artesian system does not extend to the surface, but that the salt rises at the surface as slow seepage through a rather impermeable clay. Stand pipe measurements in the clay produced only small artesian heads. Maximum was about 60 feet lower in elevation than the top of the 43-foot drilling rig at exploration hole 153. The explanation of this unusual situation throws much light upon this study and much weight in favor of the Childress gypsum-anhydrite being the highly permeable aquifer of this artesian system. In order to accomplish solution by ground water, the ground water must be able to maintain a continuous circulation through or in contact with the soluble rock. The circulation is through original permeability in the soluble rock or through permeability of rocks in contact with it. Anhydrite is $CaSO_4$, but when exposed in shallow subsurface and at the surface it chemically combines with water, a process known as hydration, and becomes gypsum, $CaSO_4 \cdot 2H_2O$. The hydration of

anhydrite to gypsum increases the volume of the bed by 33 per cent (Sellards and Baker, 1934, p. 623) and large pressures are generated. Where the bed is exposed in the outcrop, the pressures produce in the resulting gypsum many fractures, known as hydration fractures (figure 14, p. 42). But if room for expansion is restricted by overburden, these pressures close the fractures of the changing anhydrite, thus producing a water-tight bed through which no ground-water movement is permitted. As was pointed out previously, hydration of an anhydrite bed extends into the subsurface and a transition zone exists where some gypsum and some anhydrite occur together with hydration being accomplished when weathering conditions are proper and expansion is possible. For the Childress gypsum, the transition zone seems to extend along Dove Creek for about 1½ miles west of Dove Creek Flat.

Figure 27 on the next page is a generalized diagram showing this artesian system. The unconfined body of ground water in the vicinity of Girard, northeast Kent County, is here shown to be the source of the water and salt. The water moves into and up the dip in the Childress anhydrite at first through original fractures, but later through cavities developed by solution, toward the place of discharge - the Dove Creek area. Perhaps most of the movement is in the lower part of the anhydrite bed since downward movement is restricted by the relative impermeability of the underlying clay. When the water reaches the transition

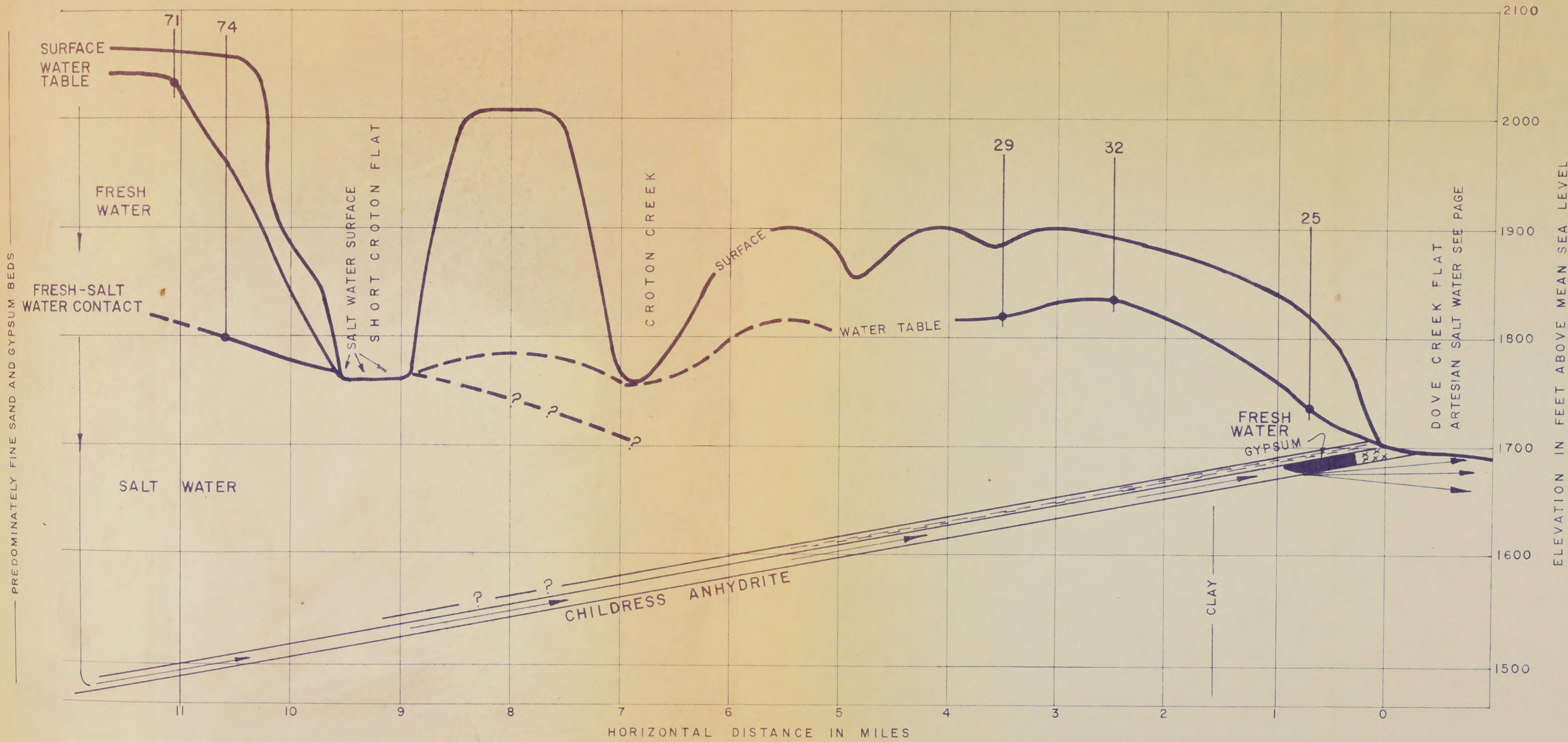


Figure 27. Generalized diagram showing the way that an artesian system could develop up the dip in the Childress anhydrite-gypsum. The high water table near Girard, Kent County, is conveniently shown as the source of recharge and pressure but does not necessarily have to be. The salty circulating ground water develops a cavity system in the Childress but when the anhydrite-gypsum transition zone is reached the water moves out of the Childress into the underlying clays and emerges at the surface in Dove Creek area.

zone of hydration, it can move no longer in the Childress since the fractures have been closed by expansion. Also, the contact between this bed and the underlying clay permits no movement of water in it because of this same expansion. Thus, the water moves from the Childress and comes to the surface by the way requiring the least pressure. Perhaps the fine sand above the Childress is more permeable than the clay below the Childress, but this artesian water moves more easily through the clay since it has some permeability and since it is about fifteen feet stratigraphically below the sand. The water does not follow a smooth regular course through the clay but works its way through the often irregular fractures and more permeable parts of the clay until a point of egress is found. Its lowest movement is to 50 feet below the surface of the main flat or about elevation 1650 feet.

Water under pressure of the large head of a ground water body with high-elevation water table is transmitted to the cavernous system of the Childress anhydrite-gypsum. The water confined within this cavernous anhydrite develops an artesian system. This confined water transmits pressures almost as well as an open body of water due to the relatively large cavities in which it is contained, however, there is a gradual loss of pressure due to resistance in movement along the walls and floor of the cavity system. At the place near Dove Creek Flat where the water moves into the low-permeability clay, a rapid drop of pressure occurs.

The chloride content of the water from boring C-4 in Dove Creek Flat is almost three times as high as that of the water from the brine spring in Short Croton Flat and the sulfate content is almost twice as high (table on p.67). As shown in figure 27 (p. 78), the water to the Dove Creek area moves through an additional 300-foot interval of strata with much salt and gypsum and then moves through the soluble Childress. Thus the water becomes much more mineralized than that of the Croton Creek area.

The Dove Creek area is the only known place along the outcrop of the Childress gypsum in the Central Texas region that produces artesian salt water. There is a very definite and important reason for artesian salt water coming to the surface here. A careful examination of figure 6 (p. 18) reveals that the base of the Childress crops out in the Dove Creek area about two miles farther west than at any other point along it.2/ This means that the base of the Childress is about 50 feet lower here than at any other place in the region, since the bedrock dips west 25 feet per mile. As stated before in this report, a stream does not develop a gradient less than that required to transport its sediment load and here, Dove Creek and Salt Fork of the Brazos River have both reached this low gradient. In this area the course of Dove Creek is east-west and the course

2/ The reader should note that the Geologic Map of Texas (Sellards, 1933) shows the outcrop of the top of Childress gypsum with about five-mile east-west inaccuracies of the outcrop in this region.

of Salt Fork is northeast-southwest. At a point ten miles upstream from their junction, Dove Creek has cut deeper into the north-striking strata than has Salt Fork. Hence the tributary, Dove Creek, has cut deeper into the Childress gypsum and moved its outcrop farther west. At some time during this downcutting, a critical elevation was reached in the Dove Creek area and salt water was able to move from the Childress to the surface. The flow at first was very small, but as solution cavities developed in this bed, pressures increased and produced more discharge.

SUGGESTED METHODS FOR DECREASING AMOUNT OF SALT WATER

In the introduction of this report it was pointed out that different land uses, particularly conservation measures, have reduced the future run-off by about 43 per cent of the run-off before these practices were begun. Under "Source of salt water in Croton Creek area" it was explained that conservation practices on cultivated land, especially in northeast Kent County, increases recharge to the water table and this in turn increases the amount of ground water discharged which here is mainly salt water.

The Brazos River Authority plans to spend $7,500,000 to reduce the amount of salt entering the Brazos River from this area. Every possible method of reducing the quantity of this salt should be carefully considered and evaluated.

Reduction of Salt in Dove Creek Area

Several methods for reducing the amount of salt from the Dove Creek area have already been suggested by Ambursen Engineering Corporation and H. R. Blank. These suggested methods and other possible methods should be considered in light of this present study. These are:

1. A dam at the mouth of Dove Creek Flat.

This idea has been most strongly pushed by the Brazos River Authority and Ambursen Engineering Corporation. It features a salt-water evaporation reservoir in the salt flat. The height of the water in the dam is hoped to stop the issuance of salt water by a stand pipe effect. However, evaporation is very high in the area and water removed by evaporation will be replaced by more salty ground water during extended dry periods and crystallization from solution will produce a large body of salt. At periods of run-off its tributary streams will add large amounts of silt and fine sand to the salt being crystallized (a study of this sediment load should be made). The reservoir will in time be filled with salt and clastics and will remain as part of the integrated drainage system of the Brazos River, always subject to overflow, leakage and destruction by flood. The water in the reservoir will be subject to much leakage through the thick Childress gypsum above the salt-water-saturated clay and the fine sand above the Childress. A cavern about ten feet high and five to six feet wide (figure 28, p. 84) is in the bluff on the south side of the flat and upstream several yards from the proposed dam site. Local reports are that the cavern extends underground for about one mile and then comes to surface again downstream on Dove Creek. Some persons say they have crawled through it. This cavern is only one of many solution cavities in the Childress gypsum which crops out all around the lower part of the Dove Creek Flat. Nearby water wells produce good stock water from the sand which overlies the Childress and which forms the bluff around the upper part of the flat. Leakage to this sand would contaminate the water of these wells, therefore, if a dam is built a carefully-planned dike system around the flat should be considered.

The reservoir will have to be large enough to hold not

Figure 28. (Top) Cavern about ten feet high in the Childress gypsum at a place several yards upstream from the proposed dam site on Dove Creek Flat.

Figure 29. (Bottom) Salt crust forming in Dove Creek Flat. The picture was made two days after a hard rain. The crust may become several inches thick before another rain.

just the run-off from the largest single rain that may occur, but the largest series of rains that occur during a period of low evaporation plus the amount of water already in it. A diversion system for the surface run-off could be devised.

2. The above dam modified by grouting the exposures of clay

It was very well reasoned that grouting the clay with an impermeable substance would stop the emergence of the salt water. Uncovering of the clay, the reverse of grouting, at this elevation is the process that has made possible the development of this artesian system. It should not be forgotten that the solution cavities in the Childress, as postulated in previous discussions, have enlarged greatly since the beginning of this development and as a result larger pressures are transmitted to the Dove Creek area since less is lost enroute by resistance. There is a possibility that this water under the increased pressures, when confined by a grouting of the clay through which it now gains relief by movement to the surface, will break out elsewhere and possibly upward into the sand above the Childress. Therefore, the writer strongly suggests that the artesian pressure in the Childress be measured and the possibility of the water finding other means of egress should be studied.

An associated dam would have the same disadvantage as pointed out above.

3. An evaporation basin away from the immediate

drainage system.

A large basin could be constructed in tight clay or silty clay away from any permanent drainage courses and the salt water pumped from the Dove Creek area to it where evaporation would remove the water, leaving salt deposits. This method is used quite successfully near Carlsbad, New Mexico, where a similar salt-water problem occurs in the Pecos River.

This method has several advantages. It is away from the river system and thus chances of the salt getting back into the river are lessened. There is less possibility of contamination of fresh water sources, since it would be constructed in an impermeable stratum or strata. It could be located in a much smaller watershed of lower local relief than that of Dove Creek Flat and thus would receive less sediments from run-off. Its chances of destruction and overflow by floods would be little or none. The initial cost should be less than that of the dam.

Several disadvantages of this method can be enumerated. Since the immediate area has no suitable locations, the salt water would have to be pumped for a considerable distance eastward where many clayey soils and subsurface occur. The pumping of salt water requires special equipment of high cost due to the corrosive action of salt. However, a fiber hose works better than metal ones since the salt water seeps through the fiber, evaporates, and leaves a sturdy impermeable layer of crystalline salt around the hose. Maintenance and operation of this pumping equipment would be fairly expensive. The salt water rises over a large surface by slow seepage and during hot, dry weather much of the seepage is immediately evaporated, forming a widespread, thick salt crust which is flushed by flash floods common in this area. Thus, means to catch this salt for transference will be difficult and expensive to devise and operate. (Figure 29, p. 84)

4. Disposal into deep subsurface

Disposal of oil-well brines is usually by reinjection into the subsurface. Often the brines are injected into strata other than those from which they came. Such disposal of the Dove Creek salt water is possible and has the big advantage of being completely away from the surface and zones of usable ground water. The deep subsurface here is under low pressures and disposal by gravity may be possible.

Anaerobic bacteria rapidly grow in water which has surface exposure. When this water is injected into a permeable stratum the anaerobic bacteria cause chemical reactions, especially with sulfates, which form solid substances that plug the interstices of the stratum. This plugging is more effective in sandstones and conglomerates than in limestones, and limey reef structures. The Ellenburger is a 100-foot thick, extensive limestone at depth from surface of about 6,700 to 6,800 feet. The great expense of drilling this deep practically rules it out; however, a dry oil-test hole could be used if this deep and close enough to this locality. The Coleman Junction limestone, also about 100 feet thick, lies about 3,100 to 3,200 feet below the surface. It is permeable and under low pressure, thus, it is a bed that should be studied if deep-well disposal is sought.

Disadvantages are essentially the same as for suggested method 3. Expense of drilling deep holes must be added to it. The water will not have to be pumped as far as in method 3.

5. Commercial salt industry

Today most commercial salt is produced inexpensively by mining from pure or almost pure rock salt. But only a few years ago the salt brine industry was a chief industry in many regions, particularly in the Appalachians. The salt water (brine) was pumped from the ground and evaporated in huge vats over fires.

To the writer's knowledge, no consideration has been given the idea of a subsidized salt industry in the Dove Creek area. Most persons to whom this plan was mentioned seemed to think that such an industry could not compete on a commercial scale, and therefore considered the plan worthless. However, this salt industry would not be one of pure competition, but one of competition with considerable subsidization by funds allocated for the disposal of this salt water.

An estimated 450 to 500 tons of chloride flow from this area daily. Thousands of kilowatt hours of solar energy are being wasted in this sun-baked semi-arid region. $7,500,000 will be spent to lower the salt content of the water of this area. Perhaps some interested salt-producing company can develop an inexpensive system of producing this salt by the sun's energy. (A simple system of open vats could be used.) Such a works at first should be heavily subsidized but later might become self-sufficient.

The remoteness of the area is probably the biggest factor against this suggestion since transportation costs are high on cheap, bulky products such as salt. Better roads would have to be built for local access than would be needed for the other suggestions. Impurities in the water may be expensive to remove, but on the other hand, valuable substances may be present. Solving the problem of the wide-spread salt crust, described in method 3, could also be a disadvantage of this proposal.

This method of disposal completely removes the salt from the area. It has an added advantage of promoting local economy.

This suggested method should not be overlooked.

Reduction of Salt in Croton Creek Area

The conditions under which salt occurs in Croton Creek are briefly summarized as an unconfined ground-water body with a very steep water-table gradient causing movement of fresh water downward through salt beds and then laterally to emerge at the surface as highly mineralized water. It emerges as seepage in a large part of the Croton Creek drainage system; the seepage quickly evaporates leaving crystalline salt and gypsum, and producing little run-off.

The five methods suggested for reducing salt in the Dove Creek area could not be applied as effectively in this area. However, earthen dams across the mouths of Short Croton and Hot Springs Flats were suggested by Ambursen Engineering Corporation. The sites are suitable for only low dams, less than 30 or 40 feet high. The drainage areas of both of these flats consist of steep, barren, silty badland. Heavy storms cause immediate run-off which rushes down barren canyons and bluffs into the flats with tremendous velocities and unusually large sediment loads.

If these little dams withstand the storms, they will soon be filled by the large amount of silt carried in run-off. Thus, a new flat would be formed at this higher level. The higher level would have the effect of temporarily lowering the gradient of the water table. A lower gradient would produce less discharge at this particular place, however, discharge approximately equals recharge and increased discharge would be produced elsewhere in the Croton Creek drainage system. Very little benefit can be gained by the construction and operation of these dams.

The hydraulic gradient to the discharge area can be lowered, thus reducing the rate of discharge by lowering the water table on the plain in northeast Kent County. This can be accomplished by development of intensive irrigation from wells. Above the salt-fresh water contact there is at least 225 feet of fine sand saturated with fresh water. Most of the soils of this area are under cultivation and are productive when sufficient water is available. There are six to eight irrigation wells in this area at the present time. The local farmers seem to be very much interested in development of irrigation on their farms, but they need technical aid and encouragement. The average farmer cannot afford such technical help.

Research needs to be done on the development of wells which will produce large quantities of water from this fine sand and silt. This ground water contains much gypsum and the effect of this gypsum on the soils needs to be studied. Also, the possibility of salt-water intrusion into irrigation wells should be studied.

This research will have to be done by state and/or federal agencies since such a program cannot be supported by the local economy. If the results of the studies are favorable, the farmers should be informed and encouraged to make use of this water. Thus, intensive irrigation would be established in the area.

The water table will be lowered many feet and will possibly drop beneath the elevation of salt water discharge in Croton Creek. The salt content would be reduced in this whole area of Croton Creek rather than just in the two flats. Not only will the salt seepage be reduced or completely stopped in the creek, but also a large irrigation program will be developed which will improve the local economy greatly. The expense to those concerned with reduction of this salt would be much less than that of any other suggested method.

If the ground water of this area is connected with the Dove Creek area as illustrated in figure 27 (p. 78), the lowering of the water table here will lower pressures and flow of salt water in the Dove Creek area.

SUGGESTIONS FOR FUTURE STUDIES

The amount of salt carried by a stream cannot be determined by just analyzing samples of the flowing water - the stream discharge must also be measured and the two calculated together. This must be performed over a rather long period of time to derive an average. H. R. Blank, in one summer and part of another, made samples of low stream flows, standing water, and assumed underflow of the upper watershed of the Brazos River. Stream flows were not measured, thus the samples of these flows are practically meaningless since they do not give the quantity of salt being carried. Standing bodies of water are not representative of a stream since the salinity of such water increases rapidly as evaporation takes place. It is not likely that underflow is of the same chemical quality as the flow of a stream. First of all, the chemical quality of these streams are not consistent. During long dry periods, thick salt crusts accumulate in parts of these streams and this salt is flushed by run-off from precipitation. The first part of the run-off dissolves the salt and thus, run-off afterwards will be much fresher. It is more logical to assume that the channel fills and sand bars will be recharged by the last part of the run-off from a single period of rainfall. This is evident in the situation of Croton Creek area. In parts of this creek a thick salt crust is formed during dry periods and no run-off occurs during these periods. A little farther downstream the channel fills contain water suitable for watering stock. In prior years, ranchers in this area would scoop out basins in the bed of the creek and their cattle would drink the water which seeped into it (E. E. York, personal conversation).

From the table on page 32, observe that in 1950 the Salt Fork of the Brazos River contained 420 tons of chloride daily at the Peacock Station (No. 1). This station is upstream on the Salt Fork from Dove Creek and Croton Creek. The 420 tons is about 40 per cent of the average daily chloride load of the River at Possum Kingdom Dam (station No. 5) in that year and it is 73 per cent of the 579 tons of chloride entering the river from Dove and Croton Creeks (difference between the Salt Fork at Aspermont and at Peacock). In 1951, the percentage of these comparisons are only about one-half as high. The large percentage difference is accounted for by a large difference in rainfall in these two years. The salt entering the Salt Fork above the Peacock station is assumed to be of unconfined ground water origin and not of an artesian source as that of the Dove Creek area; thus more salt was flushed out of this upstream area in 1950, wetter year, than in 1951, the drier year. The salt load at Peacock is apparently a large part of the salt in the Brazos River. Undoubtedly there are localities upstream from the Peacock station that are large producers of salt. Some of these localities may have situations that can be alleviated by such a simple, inexpensive method as the writer's main suggestion for the Croton Creek area. This salt problem of the Brazos is large enough to justify a rather intensive program of stream gaging with chemical analyses made simultaneously, such as is now being done in the Dove Creek area. Such a program would give conclusive results and will serve as a yardstick of future chemical quality of the River.

Eastern Extent of Salt-beds in Permian Deposits

Figure 30 (p. 96) shows the locations of thirteen cable-tool holes in and near the detailed area. Drillers' logs of seven of these holes show thick sections of salt, most of which is correlative with the Seven Rivers formation, Whitehorse group3/. However, in a regional sense the Permian salt beds have an eastern extent which runs from northeast to southwest, as shown in figure 6 (p. 18). Salt-forming conditions are present in a sea of deposition when evaporation equals or exceeds the rate of inflowing water and the sea becomes so saline that crystalline salt is deposited. The Permian sea of the Eastern Shelf Area progressively retreated from north to south. During this retreat salt-forming conditions were present along the northern margin of the sea, so that salt beds occur in older formations northward to younger formations southward

3/ A partial record of these thirteen holes is in Table 2. Table 4 contains the drillers' logs of numbers 88, 93, and 98. These logs typically show the salt sections of this area.

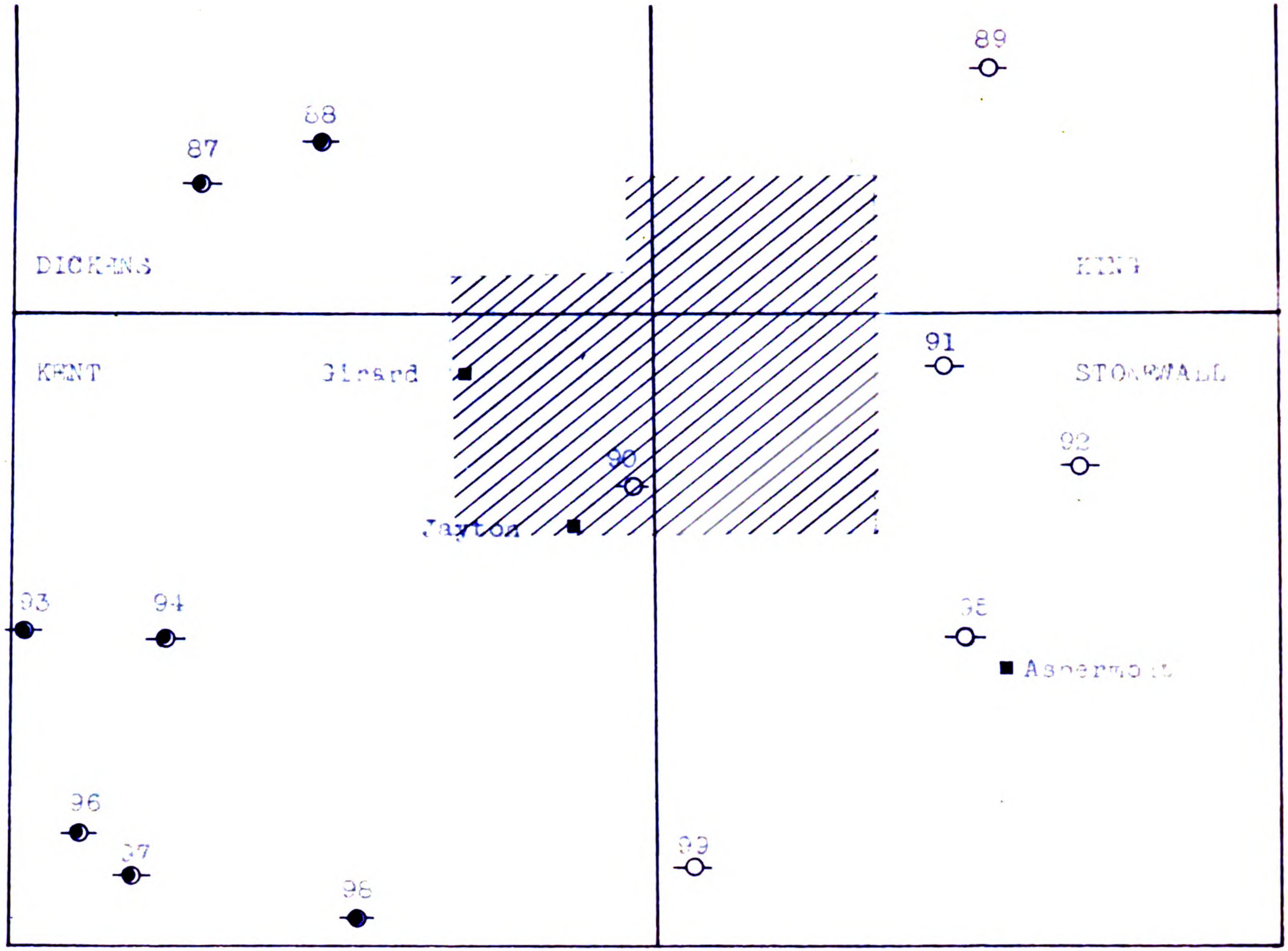


Figure 30. Map showing location of oil-test holes drilled with cable-tool equipment in and near the detailed area (shaded area on map).

-○- No salt reported in log.

-●- Salt reported in log.

(Sellards, 1932, pp. 185-186; King, 1942, pp. 730-731). Erosion since deposition and uplift have developed a surface slope to the southeast which exposes the Permian rock oldest in the east to youngest in the west. Combining these two conditions of salt-bed deposition and surface erosion, salt beds are found in the shallow subsurface in a band from northeast to southwest. The band is irregular due to irregularities in the sea of deposition and in the present drainage system.

To the writer's knowledge, no economic importance has been attributed to a map which would show the position of these salt beds in the shallow subsurface. However, this present study has revealed several reasons this information is valuable. People living in areas adjacent to localities where salt beds are known to occur are afraid to risk drilling very deeply for ground water since they believe that all of the local subsurface contains salt. But if their locality is east of the eastern extent of the salt-forming conditions for that area, their beliefs are unfounded and useable ground water may occur there. Thus, ground water development in many areas of the state could be improved by a correct knowledge of the location of these salt beds. Surface reservoirs for towns in areas near shallow salt beds could more easily and efficiently be located if knowledge of salt beds were available. Petroleum geologists are interested in the locations of salt beds which are being removed by circulating ground water since slumping after solution causes pseudo-structures and the outcrops cannot be used for geologic mapping (figure 26, p. 71). A compilation of data from those interested in oil exploration and from those interested in development of water resources would be a suitable beginning toward this end. Other information could be added as future work is performed.

BIBLIOGRAPHY

Abilene Geological Society, Geological contributions 1950, 95 pp., Abilene, Texas.

Adams, J. E., et al, 1939, Standard Permian section of North America: Bull. Amer. Assoc. Pet. Geol., vol. 23, pp. 1673-81.

Adams, J. E., 1929, Triassic of West Texas: Bull. Amer. Assoc. Pet. Geol., vol. 13, pp. 1045-55.

Adams, J. E., 1935, Upper Permian stratigraphy of West Texas Permian basin: Bull. Amer. Assoc. Pet. Geol., vol. 19, pp. 1015-17.

Adams, T. C., 1938, Recent depositions of salt from Great Salt Lake: Jour. Geol., vol. 46, pp. 637-46.

Adams, T. C., 1932, Some hydrologic features of Great Salt Lake: Utah Engr., vol. 6, no. 5, pp. 1-3 and 5.

Baker, C. L., 1929, Depositional history of the red beds and saline residues of the Texas Permian: Univ. Texas Bull. 2901.

Barton, J. M., 1945, Pre-Permian axes of maximum deposition in West Texas: Bull. Amer. Assoc. Pet. Geol., vol. 29, pp. 1336-48.

Becker, Clyde M., 1930, Structure and stratigraphy of Southwestern Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 14, no. 1, pp. 37-56.

Beede, J. W., and Christner, D. D., 1926, The San Angelo Formation: Univ. Texas Bull. 2607.

Bennett, Robert R., and Meyer, Rex R., 1952, Geology and ground-water resources of the Baltimore area: State of Maryland Department of Geology, Mines and Water Resources Bull. 4, pp. 98-111.

Blank, H. R., 1955, Sources of salt water entering the Upper Brazos River: Texas A & M Research Foundation, Project 99.

Bloodgood, D. W., Patterson, R. E., and Smith, R. L. Jr., 1954, Water Evaporation studies in Texas: U. S. Dept. of Agriculture Bull. 787.

Branson, E. B., 1915, Origin of thick gypsum and salt deposits: Bull. Geol. Soc. Amer., vol. 26, pp. 231-42.

Carter, W. T. Jr., and others, 1922, Reconnoissance soil survey of northwest Texas.

Cheney, M. G., et al, 1945, Classification of Mississippian and Pennsylvanian rocks of North America: Bull. Amer. Assoc. Pet. Geol., vol. 29, pp. 125-169.

Cheney, M. G., 1940, Geology of North-Central Texas: Bull. Amer. Assoc. Pet. Geol., vol. 24, pp. 65-118.

Cheney, M. G., 1947, Pennsylvanian classification and correlation problems in North-Central Texas: Jour. Geol., vol. 40, pp. 202-219.

Cheney, M. G., 1929, Stratigraphic and structural studies in North-Central Texas: Univ. Texas Bull. 2913, p. 29.

Darton, N. H., 1921, Permian salt deposits of the South-Central United States: U. S. Geol. Soc. Bull. 715.

Eardley, A. J., 1938, Sediments of Great Salt Lake: Bull. Amer. Assoc. Pet. Geol., vol. 22, no. 10, pp. 1305-1411.

Finneman, N. M., 1931, Physiography of western United States, New York, McGraw-Hill.

Halbouty, Michel T., and Hardin, George C. Jr., 1956, Genesis of salt domes of Gulf Coastal Plain: Bull. Amer. Assoc. Pet. Geol., vol. 40, no. 4, pp. 737-746.

Heaton, R. L., 1950, Late Paleozoic and Mesozoic history of Colorado and adjacent areas: Bull. Amer. Assoc. Pet. Geol., vol. 34, pp. 1659-98.

Hills, J. M., 1942, Rhythm of Permian seas - a paleogeographic study: Bull. Amer. Assoc. Pet. Geol., vol 26, pp. 217-55.

Hoats, H. W., 1926, Geology of a part of Western Texas and Southeastern New Mexico with special reference to salt and potash: U. S. Geol. Sur. Bull. 780.

Ireland, Burge, 1956, Chemical composition of Texas surface waters in 1954: U. S. Geol. Sur. and Texas Bd. of Water Engrs., Austin, Texas.

King, P. B., 1942, Permian of West Texas and Southeastern New Mexico: Bull. Amer. Assoc. Pet. Geol., vol. 26, pp. 535-763.

King, Ralph, 1947, Sedimentation in Permian Castile sea: Bull. Amer. Assoc. Pet. Geol., vol. 31, pp. 471-477.

Lewis, F. E., 1941, Position of San Andres group, West Texas and New Mexico: Bull. Amer. Assoc. Pet. Geol., vol. 25, pp. 73-103.

Lloyd, A. M., and Thompson, W. C., 1929, Correlation of Permian outcrops on eastern side of the West Texas basin: Bull. Amer. Assoc. Pet. Geol., vol. 13, pp. 945-56.

Lloyd, E. R., 1949, Pre-San Andres stratigraphy and oil-producing zones in southeastern New Mexico - a progress report: New Mexico Bur. Mines and Mineral Resources Bull. no. 29, pp. 19-20.

Lowry, Robert L., 1946, An inventory of the surface water resources of Texas: Texas Bd. of Water Engrs., Austin, Texas.

Lowry, Robert L., 1955, Run-off in the Brazos and Colorado River Basins: Prepared for the Texas Electric Service Company, Austin, Texas.

Meinzer, O. E., 1923, Outline of ground-water hydrology: U. S. Geol. Sur. Water-supply Paper 494.

Miller, D. N. Jr., and Folk, Robert L., 1955, Occurrence of detrital magnetite and ilmenite in red sediments - New approach to significance of red beds: Bull. Amer. Assoc. Pet. Geol., vol. 39.

Page, L. R., and Adams, J. E., 1940, Stratigraphy, eastern Midland Basin, Texas: Bull. Amer. Assoc. Pet. Geol., vol. 24, pp. 52-64.

Patton, L. T., 1930, the geology of Stonewall County, Texas: Univ. Texas Bull. no. 3027, p. 76.

Pettijohn, F. J., 1949, Sedimentary rocks, 526 pp., New York, Harper and Brothers.

Rich, J. L., 1950, Flow markings, groovings, and intra-stratal crumplings as criteria for recognition of slope deposits, with illustrations from Silurian rocks of Wales: Bull. Amer. Assoc. Pet. Geol., vol. 34, pp. 717-40.

Rich, J. L., 1934, Origin and evolution of rock fans and pediments: Bull. Geol. Soc. Amer., vol. 46, pp. 999-1024.

Rich, J. L., 1951, Three critical environments of deposition and criteria for recognition of rocks deposited in each of them: Bull. Geol. Soc. Amer., vol. 62, pp. 1-20.

Roth, Robert, 1937, Custer formation of Texas: Bull. Amer. Assoc. Pet. Geol., vol. 26, pp. 452-54.

Roth, Robert, 1945, Permian Pease River group of Texas: Bull. Geol. Soc. Amer., vol. 56, pp. 893-908

Roth, Robert, 1942, West Texas barred basin: Bull. Geol. Soc. Amer., vol. 53, pp. 1659-1674.

Sellards, E. H., and others, 1933, Geologic map of Texas.

Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The geology of Texas: Univ. Texas Bull. 3232.

Sellards, E. H., and Baker, C. L., 1934, Geology of Texas, vol. II, Structural and economic geology of Texas: Univ. Texas Bull. 3401.

Skinner, J. W., 1946, Correlation of Permian of West Texas and Southeast New Mexico: Bull. Amer. Assoc. Pet. Geol., vol. 30, pp. 1857-74

Tomlinson, C. W., et al, 1940, Classification of Permian rocks: Bull. Amer. Assoc. Pet. Geol., vol. 24, pp. 337-58.

Udden, J. A., 1926, The deep boring at Spur: Univ. Texas Bull. 363.

Van Siclen, D. C., 1957, Cenozoic strata on the southwestern Osage plains of Texas.

Van Siclen, D. C., 1951, Ancient organic reefs of a West Texas area.

West Texas Geological Society, 1949, Stratigraphic problems committee, L. S. Jones, Chairman, East-west cross section through southern Permian Basin of West Texas (Fisher County through El Paso County with text), Midland, Texas.

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas.

All wells are drilled unless otherwise noted in remarks column.

Method of lift: E, electric; G, gasoline; W, windmill.
Use of water: D, domestic; N, not used; S, stock

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
1	Bar U Ranch	--	--	55	6	1946	51.7	1-14-57
2	Bar S Ranch	Dick Shirley	1944	80	6	1880	--	--
3	do	--	--	--	6	1891	39.8	2-12-57
4	do	Clyde Spray	1951	--	6	1884	33.4	do
5	Bar U Ranch	--	--	105	7	1986	--	--
6	Bar S Ranch	Obie Wright	1953	75	7	1963	59.1	1-14-57
7	do	Russel	1939	75	7	1922	50.0	do
8	do	do	--	135	7	1976	126.3	do
9	Bar U Ranch	--	old	95	7	1987	81.9	do
10	Bar S Ranch	Obie Wright	1953	180	7	1950	172.0	do

Well	Method of lift	Use of Water	Remarks
1	W	S	--
2	W	S	--
3	W	S	--
4	W	S	Driller went thru Childress (12') into salt-bearing clay. Fresh water sand overlies 3' clay which lies on the Childress.
5	W	S	--
6	W	S	--
7	W	S	Reported good enough for drinking
8	W	S	do
9	W	S	--
10	W	S	--

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
11	Mary Martin	Continental Oil Company	1950	7100	-	1973	--	--
12	Bar S Ranch	Russel	1939	175	7	1958	149.0	2-12-57
13	do	--	--	80	5	1801	66.4	do
14	Mary Martin	Continental Oil Company	1951	6345	-	1949	--	--
15	do	do	1950	7173	-	1831	--	--
16	G. W. Springer	Obie Wright	1950	150	7	1875	136.8	2-13-57
17	do	--	old	113	12	1854	104.3	do
18	Mary Martin	Desoto Oil Co.	1946	4905	-	1880	--	--
19	Bar S Ranch	Russel	1939	135	7	1957	118.6	1-14-57
20	Mary Martin	Continental Oil Company	1952-	4650	-	1710	--	--

Well	Method of lift	Use of water	Remarks
11	--	N	Oil test, plugged and abandoned.
12	W	S	--
13	W	S	Top of casing is 33' (hand-leveled) above top of 13' thick Childress.
14	--	N	Oil test, plugged and abandoned.
15	--	N	do
16	W	S	--
17	W	S	--
18	--	N	Oil test, plugged and abandoned.
19	W	S	--
20	--	N	Oil test, plugged and abandoned

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas, Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
21	Mary Martin	Continental Oil Company	1952	4877	--	1822	--	--
22	G. W. Springer	Byars Oil Co.	1954	5511	--	1883	--	--
23	G. C. Carothers	Sid Katz	1953	6435	--	1835	--	--
24	W. A. Springer, Jr.	Continental Oil Company	1952	4872	--	1785	--	--
25	G. W. Springer	Obie Wright	1949	150	$6\frac{1}{4}$	1876	138.6	2-13-57
26	Carl Springer Estate	Continental Oil Company	1952	4840	--	1874	--	--
27	G. W. Springer	--	--	30	5	1734	26.4	2-15-57
28	G. C. Carothers	Continental Oil Company	1950	6686	--	1675	--	--
29	G. W. Springer	Obie Wright	1950	--	$6\frac{1}{4}$	1924	105.5	2-19-57
30	G. W. Springer	Dick Shirley	--	112	6	1875	95.2	2-13-57

Well	Method of lift	Use of water	Remarks
21	--	N	Oil test, plugged and abandoned.
22	--	N	do
23	--	N	do
24	--	N	do
25	W	S	--
26	--	N	Oil test, plugged and abandoned.
27	W	S	--
28	--	N	Oil test, plugged and abandoned.
29	W	S	"Gyppy" water perched at 90' in same well.
30	W	S	Pumping rods pulled. 120' well and 30' lower elevation is old caved-in well reported depth 75'.

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
31	Carl Springer Estate	Continental Oil Company	1951	6948	-	1905	--	--
32	G. W. Springer	do	1949	--	7	1889	55.2	2-13-57
33	do	Houston Ward	--	--	6	1858	40.5	do
34	do	do	1930	--	3½	1872	38.6	do
35	do	Dick Shirley	1945	68	6	1874	57.2	do
36	T. H. Ward	Continental Oil Company	1952	5307	-	1872	--	--
37	Ben Roach	Ben Roach	1952	30	48	1858	20.5	4-17-57
38	do	do	1936	100	-	1876	70.2	1-10-57
39	Ned Ward	--	1923	175	5	--	--	--
40	T. H. Ward	Ashland Oil	1955	6948	-	1914	--	--

Well	Method of lift	Use of water	Remarks
31	--	N	Oil test, plugged and abandoned.
32	--	N	Not developed for use as water well. Exploration hole cased for water well.
33	W	S	--
34	W	S	--
35	W	S	--
36	--	N	Oil test, plugged and abandoned.
37	W	S	Dug well
38	W	S	Gypsiferous dolomite at depth 90-100'; salty sandy clay below 100'. Not enough water here to make well water salty so not plugged off.
39	W	S	--
40	--	N	Oil test, plugged and abandoned.

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altutude of land surface (ft.	Water level: Below land surface datum (ft.)	Water level: Date of measurement
41	M. S. Sandell	Tex. Pac. Coal and Oil Co.	1946	6837	-	1913	--	--
42	J. D. Patterson, Jr.	U.S. Smelting & Ref. Company	1951	5345	-	2115 (?)	--	--
43	J. D. Patterson, Jr.	Shell Oil Co.	1940	6760	-	1862	--	--
44	M. L. Patterson	do	1941	6827	-	1839	--	--
45	A. R. Daniels	Desoto Oil Co.	1952	6812	-	1871	--	--
46	Doc Burleson	Norsworthy Oil Company	1950	7510	9-5/8	2017	--	--
47	Charles Dunlap	--	1917	120	-	2138	105.2	3-26-57
48	W. P. Peak	--	old	--	5	2112	50.9	do
49	Gewel Cooper	--	old	150	-	2177	133.6	4-3-57
50	Luther Bowen	Skelly Oil Co.	1951	343	6	2167	127.2	do

Well	Method of lift	Use of water	Remarks
41	--	N	Oil test, plugged and abandoned.
42	--	N	do
43	--	N	do
44	--	N	do
45	--	N	do
46	--	N	do
47	W	D, S	--
48	W	N	--
49	W	S	--
50	--	N	Exploration hole.

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
51	Henry Stiles	--	1930	45	-	2092	38.3	4-3-57
52	do	Rogers	1941	65	-	2107	42.6	do
53	Ted Dardin	--	--	--	6	2107	43.1	3-26-57
54	W. B. Francis	--	--	80	8	2107	41.0	do
55	J. R. Carr	--	1947	82	8	2109	58.2	4-3-57
56	Girard Garage	--	--	90	-	2119	62.1	3-26-57
57	T. B. Page	T. B. Page	1947	--	-	2107	58.8	4-3-57
58	Lum Davidson	--	1925	120-	-	2140	107.9	3-26-57
59	Red Cooper	--	1925	90	-	2119	71.0	do
60	Hamlin Standlind	--	--	75	6	2143	53.8	4-3-57
61	J. G. Page	--	old	175	-	2132	98.6	do

Well	Method of lift	Use of water	Remarks
51	W	S	--
52	--	D, S	--
53	--	N	--
54	--	N	--
55	W	S	Irrigating a house garden.
56	W	S	--
57	W	S	--
58	W	S	--
59	W	N	--
60	W	S	--
61	W	S	--

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
62	Occie Borrows	--	1951	120	6-5/8	2135	51.3	3-26-57
63	Hastings Estate	--	--	220	6	2159	148.5	4-4-57
64	Lamore Page	--	--	120	6	--	--	--
65	C. C. York	--	--	40	6	--	27.4	4-11-57
66	Charles Branch	Ryan, Hays and Burke	1951	6695	-	1947	--	--
67	Mrs. B.F.Spradling	B. F. Spradling	1909	53	48	2102	33.3	4-4-57
68	C. C. York	--	old	90	-	2098	60.4	do
69	do	--	--	--	36	--	5.4	do
70	E. W. Clark	--	--	140	6	2105	86.7	4-2-57
71	C. C. York	--	--	42	48	2059	28.0	4-11-57
72	W. L. Buckelew	--	--	45	36	2053	30.2	4-2-57

Well	Method of lift	Use of water	Remarks
62	W	S	--
63	W	S	--
64	W	S	Hit obstruction at 111' before reaching water.
65	--	N	10' from this hole is another well with a windmill.
66	--	N	Oil test, plugged and abandoned.
67	W	S	Dug well.
68	W	S	New well 25' west of this one.
69	W	S	Dug well.
70	W	S	--
71	--	N	Dug well.
72	W	S	Dug well.

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.)	Water level: Below land surface datum (ft.)	Water level: Date of measurement
73	E. M. Jones	Black and Jay	1941	36	48	2044	30.0	4-4-57
74	do	do	1940	202	-	2050	--	--
75	do	Merle Jay	1943	14	48	--	8.2	3-25-57
76	do	Webb	--	110	-	1902	94.0	do
77	Marvin Fuller	Floyd Fuller	1947	170	5	2008	146.2	4-5-57
78	E. M. Jones	Shortie Leach	--	250	7	2053	236.5	3-25-57
79	do	do	1950	290	7	2088	272.0	do
80	E. E. York	--	--	--	6-5/8	--	--	--
81	W. D. Hall	Floyd Wilhoit	1942	--	5	2009	162.0	4-5-57
82	E. E. York	--	--	--	6-5/8	2037	171.9	do
83	do	--	--	265	6-5/8	2088	228.3	do

Well	Method of lift	Use of water	Remarks
73	E	S	Dug 48" hole, curbed it with 2" x 4" wood, then put in 6" pipe and filled hole with gravel.
74	E	S	Could not get tape in hole. Drilled to 254' and hit ocean of salt water (about 253') which rose up 30-40' in hole. Not artesian pressure, just more permeable stratum. Plugged back to 202'.
75	W	S	Dug well.
76	W	D	--
77	W	S	--
78	G	S	--
79	W	S	--
80	W	D, S	--
81	W	D, S	Can be used for drinking. Water level is reported 145' from surface. Well pumped 3 days before measuring.
82	W	S	--
83	W	S	--

Table 1. Records of wells in parts of Stonewall, Kent, Dickens and King Counties, Texas--Continued

Well	Owner	Driller	Date completed	Depth of well (ft.)	Diameter of well (in.)	Altitude of land surface (ft.	Water level: Below land surface datum (ft.)	Water level: Date of measurement
84	C. D. McCurry	--	--	120	6-5/8	1988	48.7	4-4-57
85	O. C. Lowrance	Webb	--	180	5-5/8	2013	135.1	do
86	Walton Davis	--	1930	--	-	2013	120.4	3-24-57

Well	Method of lift	Use of water	Remarks
84	W	S	--
85	W	S	--
86	W	D	--

Table 2. Partial record of oil-test holes drilled with cable tool equipment in and near the detailed area.

No.	Location	Driller	Year Drilled	Ground Elevation Feet above Msl
*87	At Spur in Sec. 244, Blk. 1, H & GN RR Co. Survey, Dickens Co.	Swenson Land Co.	1913	2335
*88	SE Cor. NW ¼, 300' from E line and 300' from S line, Sec. 311 H & GN RR Co. Survey, Blk. 1, Dickens Co.	Moutray Oil Co.	1927	2271
89	1320' from N line and from E line, Sec. 102 Blk. A, John B. Rector Survey, King County	Midwest Exploration Co.	1927	1706
90	330' from N line and from E line, Sec. 429 Blk. D, H & TC RR Co. Survey, Kent County	Phillips Petroleum Co.	1926	--
91	300' from S line and 960' from W line, Sec. 120, Blk. F., H & TC RR Co. Survey, Stonewall County	Arkansas Fuel Oil Co.	1926	1732
92	Center of NE ¼ of NE¼ Sec. 105, Blk. D, H & TC RR Co. Survey, Stonewall County	Peer Oil Corp.	1927	1740
*93	1320' from W line and from N line, Sec. 57, Blk. 7, H & GN RR Co. Survey, Kent County	Douglas Oil Co.	1927	2398
*94	200' from N line and 200' from W line, Sec. 131, Blk. G., W & NW Survey, Kent County	The Texas Company	1926	--

Table 2. Partial record of oil-test holes drilled with cable tool equipment in and near the detailed area--cont'd.

No.	Location	Driller	Year Drilled	Ground Elevation Feet above Msl
95	In center of the SW ¼, Sec. 153, Blk. D, H & TC RR Co. Survey, Stonewall Co.	F. P. Zoch	1927	--
*96	330' from S line and from W line, Sec. 60, Blk. G., W & N RR Survey, Kent County	Atlantic Oil Prod. Company	1930	2256
*97	1980' from N line and 660' from W line, Sec. 11, Blk. 4, H & GN RR Co. Survey, Kent Co.	Marland Oil Co. of Texas	1925	--
*98	In SW Corner of Blk. K, Sec. 49, T. A. Thomson Survey, Kent County	Marland Oil Co. & Texon Oil Co.	1928	--
99	330' from S line and from E line, Sec. 371 Blk. 2, H & TC RR Co. Survey, Stonewall Co.	General Crude Oil	1938	--

* Salt reported in log

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report.

NOTE: p means projected and np means not present.

Hole No.	Location	Elevation above mean sea level (ft.): Ground Surface	Top of: Childress	Top of: Lower Eskota	Top of: Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, King County					
100	35' from N line and 40' from W line, Sec. 211	2075	1677p	1827	1871	
101	1525' E and 110' N of SW Cor., Sec. 210	1990	1695	1845	1885	
102	On E line and 670' S of NE Cor., Sec. 210	1956	1731	1891p	1931p	(102) Flowed salt water above 43' drlg. rig from zone of L.Eskota or U.Eskota. 7" csg. set to 158'.
103	On N line and 150' W of NE Cor., Sec. 191	1940	1740	1890	1930p	
104	120' E and 735' N of SW Cor., Sec. 190	1997	1732	1877	1917	
105	300' W and 880' S of NE Cor., Sec. 190	1941	1746	1896	1936p	
106	2550' S and 2775' W of NE Cor., Sec. 171	1898	1773	np	np	
107	225' S and 575' W of NE Cor., Sec. 171	1882	1777	np	np	(103) Base of fresh water elevation 1748
108	On E line and 95' N of SE Cor., Sec. 171	1961	1766	1916	1956p	
109	200' E and 100' N of SW Cor., Sec. 209	2089	1684	1834	1874	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, King County, Continued					
110	900' W and 190' N of SE Cor., Sec. 209	2046	1696	1846	1886	
111	300' E and 50' S of NW Cor., Sec. 172	1937	1752	1897	1937p	(111) Base of fresh water at elevation 1748
112	855' E and 570' N of SW Cor., Sec. 172	1979	1759	1904	1944	
113	2300' S and 2825' W of NE Cor., Sec. 172	1951	1746	1896p	1936p	
114	1000' E and 900' N of SW Cor., Sec. 169	1963	1758-	1908	1948p	
115	25' E and 25' S of NW Cor., Sec. 152	1982	1797	1947	1987p	
116	1250' E and 1425' N of SW Cor., Sec. 152	1955	1785	1935p	np	
117	20' from N line and 300' from E line, Sec. 228	2087	1687	1845	1887	
118	200' S and 50' E of NW Cor., Sec. 188	1941	1731	1881	1921p	
119	550' W and 40' N of SE Cor., Sec. 188	1921	1747	1897	np	
120	1300' W and 140' N of SE Cor., Sec. 173	1956	1786	1931	np	
121	2650' W and 2650' S of NE Cor., Sec. 168	1931	1766	1916p	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (Ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, King County, Continued					
122	500' N and 200' W of SE Cor., Sec. 168	1856	1771	np	np	
123	1600' S and 500' W of NE Cor., Sec. 153	1926	1791	np	np	
124	100' S and 100' W of NE Cor., Sec. 148	1963	1818	np	np	
125	200' N and 1650' W of SE Cor., Sec. 133	1861	1821p	np	np	
126	220' from S line; 120' from E line, Sec. 234	1871	1636	1789	1833	
127	270' W and 70' N of SE Cor., Sec. 214	1916	1691	1841	1881	
128	1700' E and 710' S of NW Cor., Sec. 207	1998	1683	1833	1873	
129	1150' W and 150' N of SE Cor., Sec. 207	1942	1717	1872	1912	
130	170' E and 1980' S of NW Cor., Sec. 187	1943	1735	1888	1928p	
131	175' E and 600' N of SW Cor., Sec. 187	1911	1736	1886p	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (Ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, King County, Continued					
132	180' E and 250' N of SW Cor., Sec. 174	1792	1762	np	np	
133	1800' E and 1400' S of NW Cor., Sec. 167	1854	1789	np	np	
134	1050' N and 2300' E of SW Cor., Sec. 167	1859	1779	np	np	
135	2350' N and 100' E of SW Cor., Sec. 154	1894	1774	np	np	
136	2300' E and 240' N of SW Cor., Sec. 154	1848	1778	np	np	
137	1950' S and 2700' E of NW Cor., Sec. 154	1872	1782	np	np	
138	200' E and 300' S of NW Cor., Sec. 147	1890	1795	np	np	
139	330' W and 100' N of SE Cor., Sec. 147	1823	1813p	np	np	
140	1620' E and 1140' N of SW Cor., Sec. 127	1868	1843	np	np	
141	660' from S line; 350' from E line, Sec. 235	1868	1634	1784	1825	
142	50' N and 625' E of SW Cor., Sec. 215	1860	1655	1810	1850p	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, King County, Continued					
143	1060' E and 310' N of SW Cor., Sec. 206	1886	1681	1836	1876p	
144	2050' W and 2030' N of SE Cor., Sec. 186	1919	1744	1894	np	
145	450' W and 1800' S of NE Cor., Sec. 175	1849	1774	np	np	
146	110' from S line and 480' from E line, Sec. 225	1950	1625	1780	1825	
147	100' E and 900' N of SW Cor., Sec. 205	1847	1672	1822p	np	
148	950' E and 1710' S of NW Cor., Sec. 196	1873	1718p	1868p	np	
149	325' N and 700' E of SW Cor., Sec. 185	1741	1736p	np	np	
150	2350' W and 1600' S of NE Cor., Sec. 185	1847	1752	np	np	
151	380' E and 920' N of SW Cor., Sec. 176	1756	1741p	np	np	
152	1750' N and 300' W of SE Cor., Sec. 176	1797	1762	np	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, Stonewall County					
153	1200' W and 980' N of SE Cor., Sec. 204	1726	1701p	np	np	(153) Salt water from aquifer near base of Childress flowed above 43' drlg. rig. 7" csg. set to 173'.
154	825' N and 350' W of SE Cor., Sec. 184	1775	1740	np	np	
155	175' S and 300' E of NW Cor., Sec. 124	1744	np	np	np	
156	1975' E and 50' N of SW Cor., Sec. 124	1698	np	np	np	
157	2400' E and 150' S of NW Cor., Sec. 117	1757	np	np	np	
158	1290' E and 160' N of SW Cor., Sec. 117	1722	np	np	np	(163) Base of fresh water at depth 90'.
159	760' E and 740' N of SW Cor., Sec. 104	1721	np	np	np	
160	60' W and 200' S of NE Cor., Sec. 104	1773	np	np	np	
161	550' E and 100' S of NW Cor., Sec. 218	1885	1640	1785	1830	
162	100' S and 300' E of NW Cor., Sec. 163	1810	1755	np	np	
163	100' E and 380' N of SW Cor., Sec. 163	1826	1741	np	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, Stonewall County, Continued					
164	700' S and 180' W of NE Cor., Sec. 163	1706	np	np	np	
165	700' W and 1450' N of SE Cor., Sec. 158	1710	np	np	np	
166	220' W and 200' S of NE Cor., Sec. 143	1808	1793	np	np	
167	100' W and 200' S of NE Cor., Sec. 239	1991	1606	1756	1796	
168	800' W and 400' S of NE Cor., Sec. 219	1822	1632	1782p	1822p	
169	On W line and 500' S of NW Cor., Sec. 182	1775	1690	np	np	
170	1720' W and 550' N of SE Cor., Sec. 182	1866	1711	1861p	np	
171	250' S and 100' W of NE Cor., Sec. 142	1716	np	np	np	
172	2000' E and 300' S of NW Cor., Sec. 122	1677	np	np	np	
173	2100' E and 150' N of SW Cor., Sec. 122	1675	np	np	np	
174	25' W and 0' N of SE Cor., Sec. 122	1731	np	np	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block F, H & TC RR Co. Survey, Stonewall County, Continued					
175	100' W and 400' S of NE Cor., Sec. 119	1667	np	np	np	
176	100' E and 350' N of SW Cor., Sec. 221	1928	1623	1768	1808	
177	1450' S and 25' E of NW Cor., Sec. 220	1952	1642	1792	1832	
178	75' W and 325' S of NE Cor., Sec. 220	1863	1663	1808	1848p	
179	1300' N and 2200' E of SW Cor., Sec. 201	1903	1678	1828p	1868p	
180	1125' S and 1675' W of NE Cor., Sec. 201	1889	1674	1824	1864p	
181	1840' W and 300' N of SE Cor., Sec. 180	1868	1698	1848p	np	
182	2250' E and 1770' S of NW Cor., Sec. 160	1780	1750	np	np	
183	130' W and 200' N of SE Cor., Sec. 160	1807	1772	np	np	
184	190' W and 1280' S of NE Cor., Sec. 141	1683	np	np	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block D, H & TC RR Co. Survey, Stonewall County					
185	220' W and 600' N of SE Cor., Sec. 397	1855	1640p	1790p	1830p	(185) 7" csg. set to 296'. Assume artesian salt water gave drillers trouble.
186	130' S and 185' W of NE Cor., Sec. 396	1885	1670	1815	1855	
187	60' N and 170' E of SW Cor., Sec. 360	1840	1635	1785	1825p	
188	170' S and 260' W of NE Cor., Sec. 360	1879	1669	1819	1859p	
189	54' N and 65' W of SE Cor., Sec. 325	1878	1688	1838	1878p	
190	735' W and 680' N of SE Cor., Sec. 289	1896	1731	1871p	np	
191	2470' W and 2400' N of SE Cor., Sec. 253	1798	1773	np	np	
192	1080' S and 410' E of NW Cor., Sec. 217	1692	np	np	np	
193	0' N and 600' E of SW Cor., Sec. 216	1747	np	np	np	
194	35' E and 1100' N of SW Cor., Sec. 398	1823	1618	1768p	1808p	
195	250' N and 700' W of SE Cor., Sec. 395	1737	1637	np	np	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block D, H & TC RR Co. Survey, Stonewall County, Continued					
196	46' N and 30' W of SE Cor., Sec. 359	1878	1673	1828	1868p	
197	100' E and 100' N of SW Cor., Sec. 323	1900	1685	1835	1875p	
198	900' N and 700' W of SE Cor., Sec. 251	1670	np	np	np	
199	700' E and 600' N of SW Cor., Sec. 358	1722	1647	np	np	
200	1000' E and 2650' S of NW Cor., Sec. 327	1868	1683	1833	1873p	
201	880' W and 1200' S of NE Cor., Sec. 322	1887	1707	1862p	np	
202	On S line and 1100' E of SW Cor., Sec. 286	1713	np	np	np	
203	650' S and 520' W of NE Cor., Sec. 286	1805	1760	np	np	
204	75' W and 200' N of SE Cor., Sec. 429	1949	1636	1782	1832	
205	1000' W and 200' S of NE Cor., Sec. 328	1836	1666	1806p	np	
206	400' S and 250' W of NE Cor., Sec. 426	1918	1593	1746	1783	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block 1, H & GN RR Co. Survey, Dickens County					
207	100' from S line and 45' from W line, Sec. 162	2176	1386	1536	1586	
208	50' N and 100' W of SE Cor., Sec. 158	2147	1327	1542	1587	
	Block F, H & TC RR Co. Survey, Kent County					
209	50' from S line and 330' from W line, Sec. 237	2052	1582p	1732	1777	
	Block 1, H & GN RR Co. Survey, Kent County					
210	600' W and 50' S of NE Cor., Sec. 120	2095	1355	1515	1555	
211	300' from N line and 30' from E line, Sec. 121	2134	1404	1559	1602	
212	260' from S line and 35' from W line, Sec. 123	2176	1421	1571	1616	
213	50' W and 50' N of SE Cor., Sec. 87	2169	1409	1564	1614	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block H, HT & B RR Co. Survey, Kent County					
214	220' from N line and 1000' from E line, Sec. 3	2112	1490p	1640	1680	
215	550' from N line and 1230' from E line, Sec. 2	1951	1521	1671	1716	
	Block 1, H & GN RR Co. Survey, Kent County					
216	25' E and 100' S of NW Cor., Sec. 83	2102	1347	1497	1547	
217	400' S and 50' E of NW Cor., Sec. 84	2109	1389	1549	1599	
218	80' N and 120' E of SE Cor., Sec. 85	2153	1428p	1588	1633	
	Block L, H & TC RR Co. Survey, Kent County					
219	480' from N line and 2635' from W line, Sec. 57	2101	1451p	1604	1646	
220	50' N and 550' W of SE Cor., Sec. 57	2153	1506	1636	1680	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block L, H & TC RR Co. Survey, Kent County, Continued					
221	1500' S and 900' W of NE Cor., Sec. 58	2059	1486	1636	1676	
	Block L, Chas. S. Hardwick Hrs. Survey, Kent County					
222	50' E and 100' N of SW Cor.	1951	1491	1641	1683	
	Block OK, H & TC RR Co. Survey, Kent County					
223	750' N and 950' W of SE Cor., Sec. 1	2091	1541	1671	1711	
	Block L, H & TC RR Co. Survey, Kent County					
224	1775' N and 300' W of SE Cor., Sec. 4	1883	1523	1673	1718	
	Block D, H & TC RR Co. Survey, Kent County					
225	180' S and 100' W of NE Cor., Sec. 434	1882	1577	1727	1772	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.): Ground Surface	Top of: Childress	Top of: Lower Eskota	Top of: Upper Eskota	Remarks
	Block L, H & TC RR Co. Survey Kent County					
226	100' N and 150' W of SE Cor., Sec. 2	1871	1561	1706	1746	
227	20' S and 800' E of NW Cor., Sec. 18	2119	1439	1574	1619	
228	50' S and 100' W of NE Cor., Sec. 13	2062	1481	1613	1657	
	Block OK, H & TC RR Co. Survey, Kent County					
229	200' N and 2800' W of SE Cor., Jas. Castleberry Section	2089	1499	1629	1669	
	Block L, H & TC RR Co. Survey, Kent County					
230	1425' W and 50' N of SE Cor., Sec. 6	1920	1540	1683	1727	
	Block D, H & TC RR Co. Survey, Kent County					
231	1000' N and 800' W of SE Cor., Sec. 435	1791	1581	1731	1771	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block L, H & TC RR Co. Survey, Kent County					
232	40' S and 45' E of NW Cor., Sec. 12	2054	1429	1587	1631	
233	100' W and 100' N of SE Cor., Sec. 12	2006	1481	1616	1664	
234	E. Barefoot Survey, Kent Co. On NW Cor. of Survey	2015	1515	1665	1715	
	Block L, H & TC RR Co. Survey, Kent County					
235	350' S and 100' E of NW Cor., Sec. 20	2065	1430	1565	1610	
236	85' E and 45' N of SW Cor., Sec. 11	2015	1450	1590	1630	
237	50' E and 400' N of SW Cor., Sec. 8	2010	1503	1640	1683	
	H. H. Sandell Survey, Kent Co.					
238	1000' N and 1050' E of SW Cor. of Survey	1929	1539	1692	1734	

Table 3. Record of exploration holes showing elevations of surface and tops of marker beds used in report--continued.

Hole No.	Location	Elevation above mean sea level (ft.) Ground Surface	Top of Childress	Top of Lower Eskota	Top of Upper Eskota	Remarks
	Block D, H & TC RR Co. Survey, Kent County					
239	800' S and 200' W of NE Cor., Sec. 437	1834	1585	1737	1782	
240	280' W and 100' N of SE Cor., Sec. 437	1975	1595	1746	1788	
	Block L, H & TC RR Co. Survey, Kent County					
241	2900' S and 100' E of NW Cor., Sec. 26	2007	1422	1562	1612	
	P. A. Harris Survey, Kent Co.					
242	100' W and 65' N of SE Cor. of Survey	1974	1464	1604	1644	
	Block 98, H & TC RR Co. Survey, Kent County					
243	75' S and 600' W of NE Cor., Sec. 89	2013	1536p	1686	1723	
	Block F, H & TC RR Co. Survey, Kent County					
244	800' W and 600' N of SW Cor., Sec. 438	1992	1575	1727	1767	

Table 4. Drillers' logs of cable-tool holes numbers 88, 93, and 98 which show typical salt sections in and near the detailed area.

WELL NO. 88

CASING RECORD:

$12\frac{1}{2}$"	320'
10	1290
$8\frac{1}{4}$	2155'5"

Cellar	0-8
Red sandrock	19
red rock	70
red sandrock	85
red bed	95
red sand	103
red bed	120
red bed & gyp strks	135
red rock	145
hard sand rock	150
red rock	165
red rock & gyp strks	175
red rock	185
gyp rock & gravel	203
salt water at 200	
red rock	220
lime	240
red rock	253
red quick sand	264
hd gyp rock	280
red bed	317
lime shell	320
red bed	335
red rock	340
gyp water	345
gyp & gravel	360
350-359 lime	
salt	435
red bed	465
salt	475
lime	490
salt	512
lime	525
salt	530
lime	540
red bed	575
red rock	620
salt	645
red bed	650
hd lime	665
red sand	675
red rock	680
red sand	685
lime	715
red rock	730
lime	740
Salt	750
red rock & shells	785
sdy shale	860
red rock	895
lime	925
sdy shale	955
red rock	970
lime	980
sand	985
no report	992
sand	1002
red shale	1065
gop lime by correlation w/ Blackwell is at 1097	
red rock	1097
grey lime	1114
salt & gyp rock	1130
lime shells	1150
blue shale	1165
red rock	1180
no report	1195
lime	1200
grey sand $1\frac{1}{2}$ bbl W	1205
red rock	1211
salt	1215
grey lime	1228
blue shale	1233
hd grey lime	1270
blue shale show gas	1233-70
light grey lime	1288
dark grey lime	1321
blue shale	1328
grey lime	1336
pink shale & light grey ls	1345
hd light grey lime	1368
hd grey lime (lt.)	1513
hd grey lime	1700
blue shale	1708
bkn lime shells	1722

Table 4. Drillers' logs of cable-tool holes - continued.

WELL NO. 88 Cont'd.

less than $\frac{1}{2}$ bbl. water 1740-50	
grey lime	1758
sdy 3 bbls. per hr. Rainbow at 1728-32	
hd dk grey lime	1790
light grey lime	1896
red rock	1962
grey lime	1985
red beds	2055
hd grey lime	2110
blue shale	2116
red rock	2141
lime	2143
gray lime	2445
brken lime	2480
brown shale by samples est.by Wichita Albany 2605	
brkn lime	2545
blue shale	2575
brkn lime	2620
grey lime	2880
blue shale	2895
lime shells	3065
grey lime	3085
brkn lime	3105
grey lime	3165
black lime	3184
grey lime	3315
brkn lime	3346
black lime	3369
brkn lime	3391
lime	3430
brkn lime	3515
SLM 3528	
brkn lime	3575
dk grey lime	3595
bkn lime & shale	3610
dk grey lime	3620
blk slate grey lime shells	3635
grey lime	3645
slate & lime shells	3660
light grey lime	3705
grey lime	3760
dk grey lime sdy	3770
salt water $\frac{1}{2}$ bbl. per hr.	
gray lime	3802
dk gritty lime	3815
grey lime	3850
light grey lime	3865
salt water 3855 $\frac{1}{2}$ bbl. per hr.	
dk grey lime	3865-3870
grey lime	3930
gritty lime almost white	3943
HFW 10% sand	

TOTAL DEPTH: 3943'

WELL NO. 93

CASING RECORD:

20	19'4"
$15\frac{1}{2}$	342
$12\frac{1}{2}$	1050
10	1542
$8\frac{1}{4}$	2625

red rock	0-300
brkn lime	320
gravel HFW	330
red rock	362
salt	447
red sand	457
red rock & salt	540
white lime	550
anhy & red rock	550
red sand	560
red rock & salt	600
red rock	650
hd lime	700
salt	725
lime	755
soft salt	775
red rock	800
red rock & salt	860
brkn lime	875
red rock	900
salt	920
anhydrite	940

Table 4. Drillers' logs of cable-tool holes - continued.

WELL NO. 93 Cont'd.

salt	965	anhydrite	2480
anhydrite	970	shale & red rock	2490
red rock cave	985	blue shale	2575
salt	995	lime hd	2590
red rock	1035	anhydrite	2595
red sand	1050	lime	2605
salt	1070	red rock anhy	2620
red sand	1080	lime soft hd	2640
red rock salt	1475	anhy & red rock	2680
lime shells		lime hd	2695
sdy hard	1490	blue shale & anhy	2700
red rock	1505	lime hd dark	2730
anhydrite	1515	shale soft	2745
white sand HFW	1532	lime brkn	2750
lime coarse	1538	lime black	2755
lime fine	1545	blue shle & anhy	2785
slate	1575	lime grey	3060
lime white hd	1610	lime brkn	3065
lime & slate	1670	lime hd	3075
lime & slate	1670	blue shale	3085
salt	1675	anhy & shale	3110
lime	1700	lime brkn	3120
shale	1705	lime black	3493
lime	1715	dark shale	3500
lime brkn slate	1835	lime	3925
lime hd	2055	lime brkn	3935
anhydrite	2070	lime black	4130
lime hd	2090	lime brkn	4145
brkn lime soft	2100	lime	4150
lime hd	2180	anhy & shale	4165
lime dark	2195	lime	4190
sand white	2200	lime brkn & shale	4205
lime	2315	lime	4475
sand HFW	2335	sand HFW	4508
lime brkn dk	2393		
sdy lime grey	2398		
lime dark	2470	TOTAL DEPTH 4508'	

WELL NO. 98

CASING RECORD:		surface red sdy	0-110
20"	275'	anhydrite, white	125
$15\frac{1}{2}$"	445'	red bed	170
$8\frac{1}{4}$"	2646'	lime white	182
6-5/8	2801'	red sdy	250

Table 4. Drillers' logs of cable-tool holes - continued.

WELL NO. 98 Cont'd.

sand quick	275	shale sdy grey	1590
lime white	285	lime brkn grey	1630
red sdy	300	shale blue	1640
water 300' 320		sdy shale	1800
sand quick sand	310	shale red	1830
gravel	320	lime	1840
red sdy	375	shale red	1920
red quick sand	385	lime white	1925
red sdy	400	shale blue	1935
gravel red	410	lime grey	1980
red sdy	415	shale blue	2080
red rock W 420-455	420	lime white	2100
gravel sand	455	shale blue	2150
clay red	460	lime white	2160
red rock	465	shale blue	2190
anhy	585	lime white	2340
red sdy	610	shale red	2380
salt white hd	675	brkn lime grey	2455
water 675' 750'		lime grey	2700
sand red sharp	750	slate sdy blue	2800
sand red	800	shale blue cavy	2805
lime white	845	lime grey hard	3025
sand red	1010	shale blue	3050
lime grey	1055	black lime	3160
shale brown	1070	lime grey	3576
lime grey	1105		
lime white brkn	1140		
red rock	1160		
lime white	1165		
red rock	1190		
lime white	1200		
shale blue	1240		
lime white	1470		
shale blue	1480		
lime grey	1495	TOTAL DEPTH: 3576'	
lime	1540	in hard lime.	

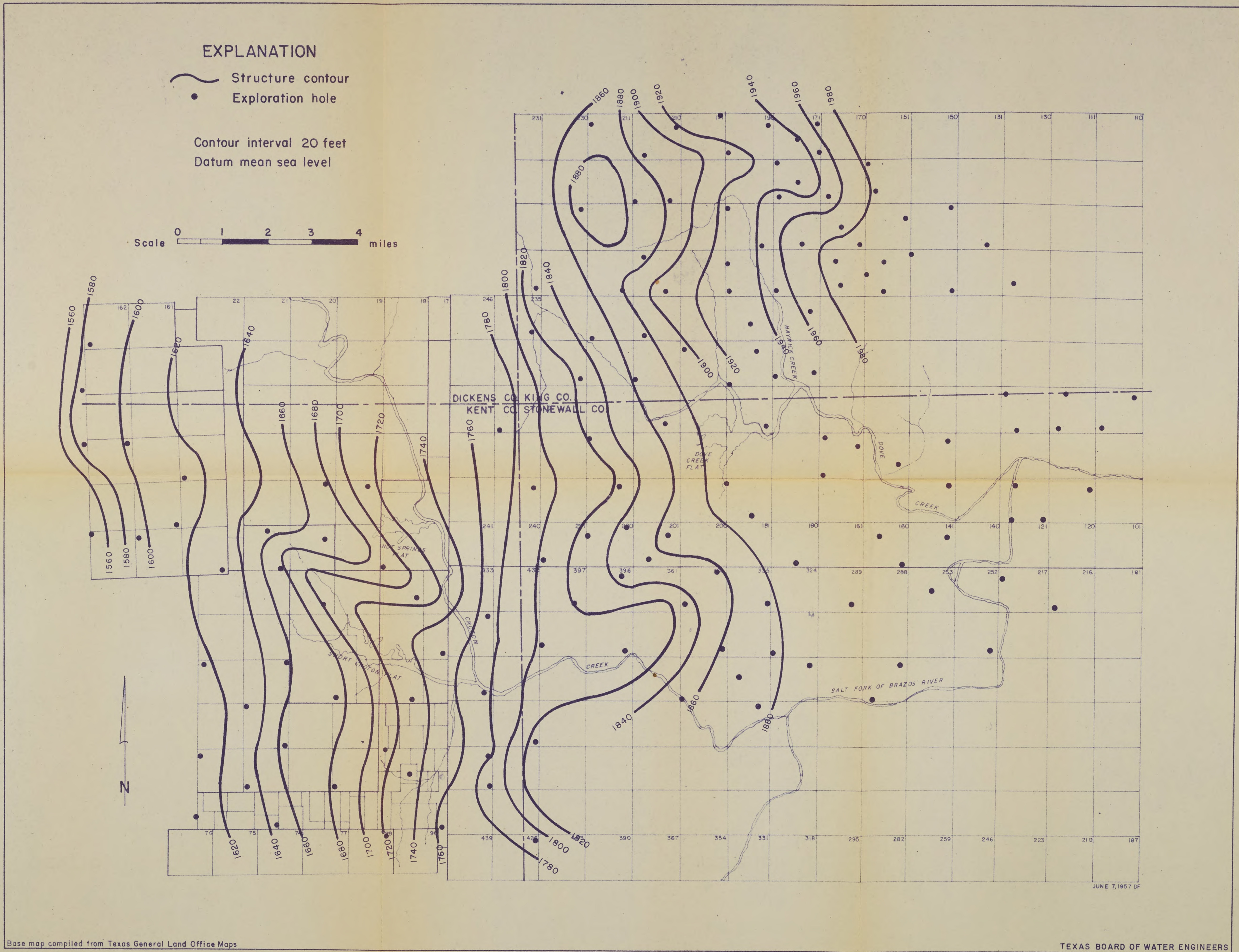


PLATE 5 – STRUCTURE MAP ON THE TOP OF THE UPPER ESKOTA GYPSUM IN PARTS OF STONEWALL, KENT, DICKENS, AND KING COUNTIES, TEXAS

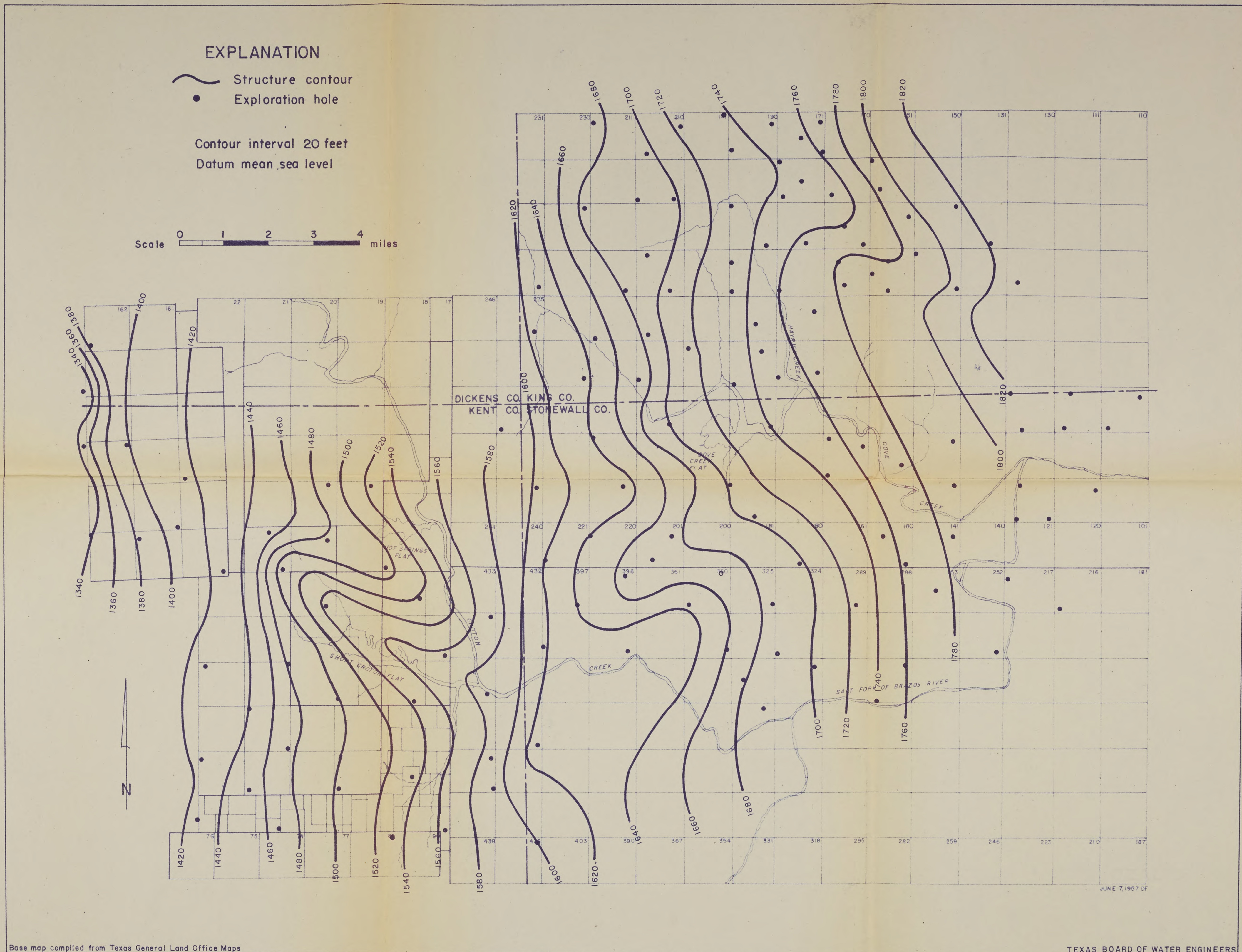


PLATE 4 — STRUCTURE MAP ON THE TOP OF THE CHILDRESS GYPSUM IN PARTS OF STONEWALL, KENT, DICKENS, AND KING COUNTIES, TEXAS

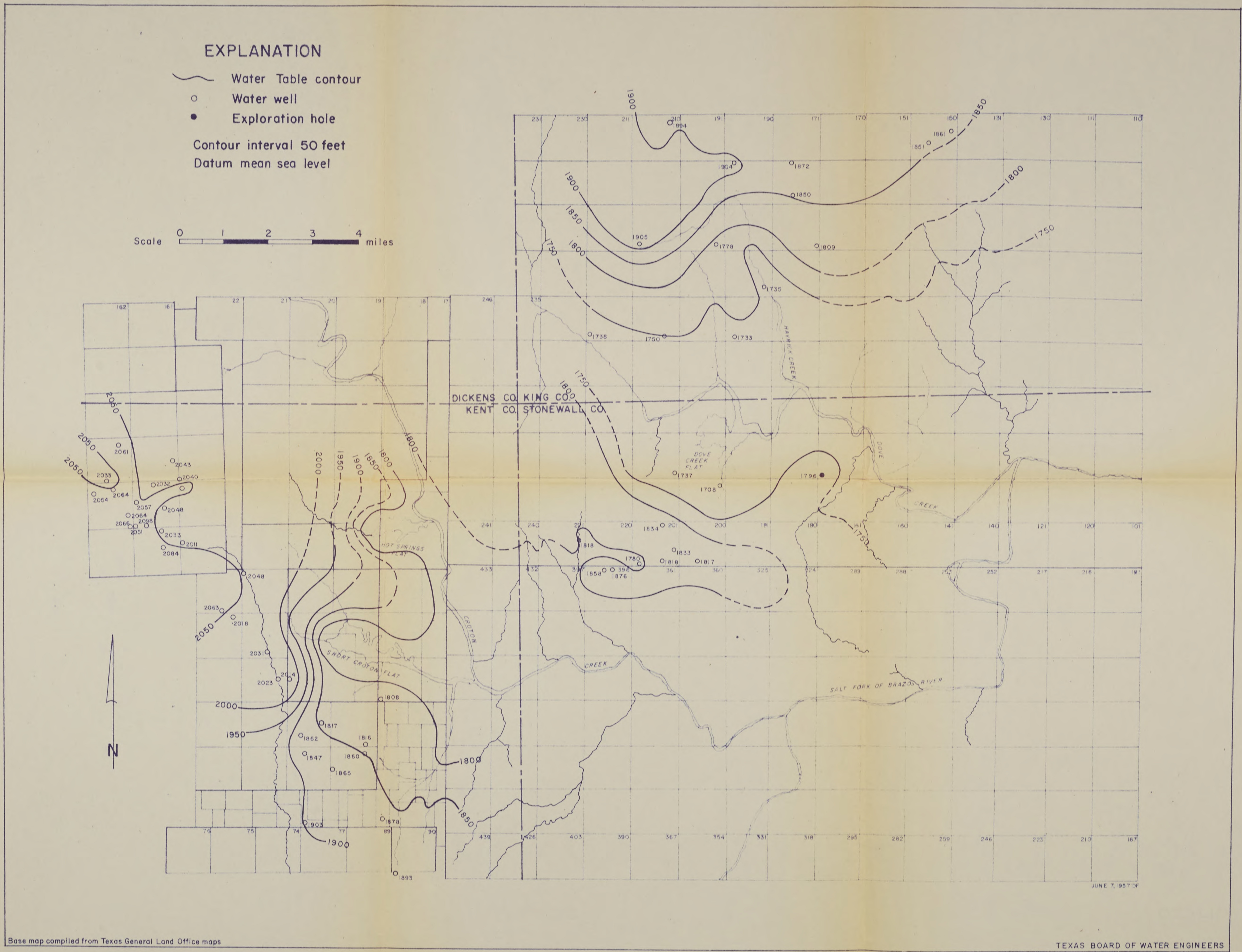


PLATE 3 - RECONNAISSANCE MAP OF THE WATER TABLE IN PARTS OF STONEWALL, KENT, DICKENS, AND KING COUNTIES, TEXAS

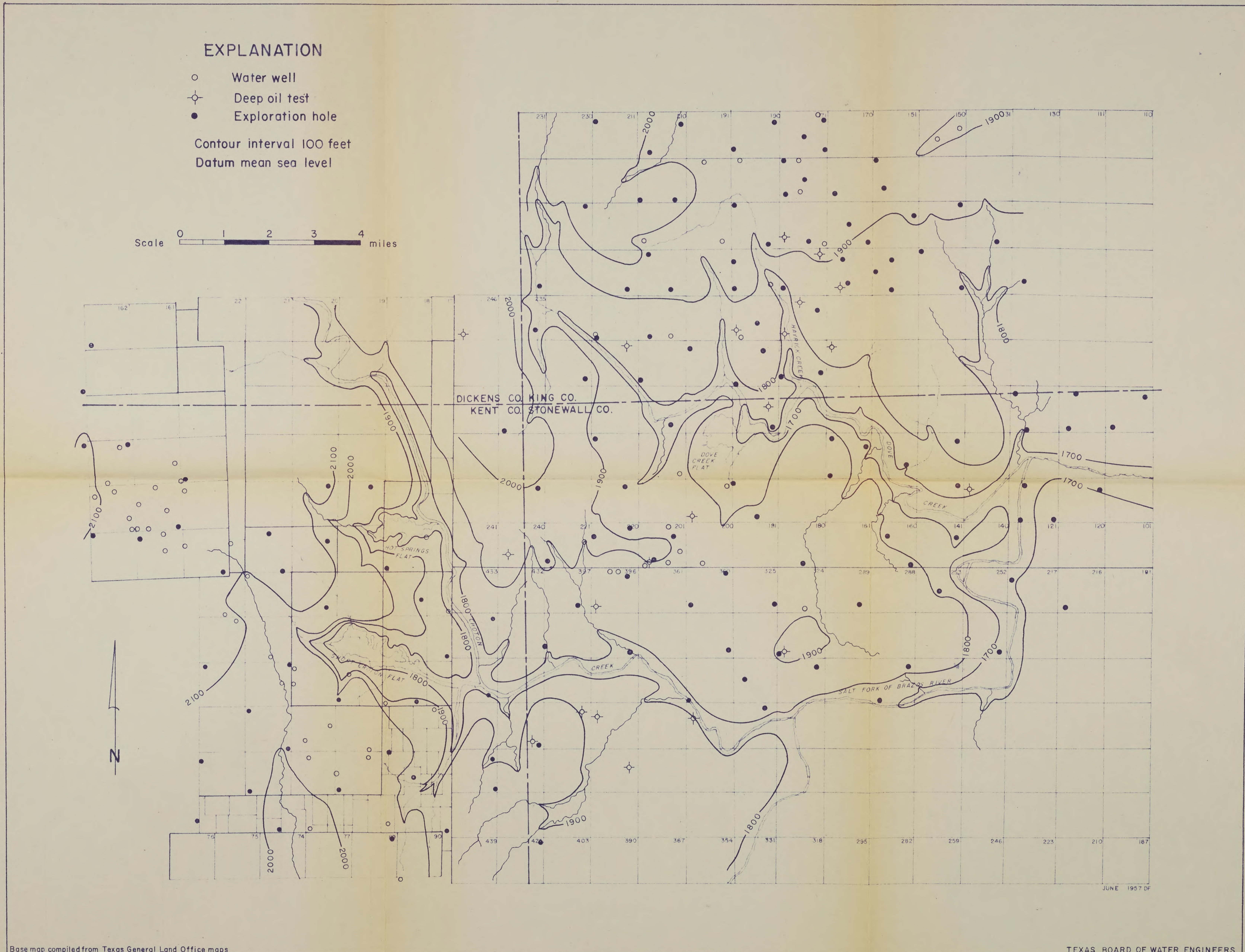


PLATE 2 - RECONNAISSANCE TOPOGRAPHIC MAP OF PARTS OF STONEWALL, KENT, DICKENS, AND KING COUNTIES, TEXAS

Pocket has: 5 Plates

[redacted]

Date Due

[illegible]			
	[redacted]		

Demco-293