TEXAS WATER COMMISSION

Memorandum Report No. 62-02

RECONNAISSANCE SURVEY OF SALT WATER DISPOSAL IN THE MEXIA, NEGRO CREEK, AND CEDAR CREEK OIL FIELDS LIMESTONE COUNTY, TEXAS

By

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FOREWORD

Daily records of stream discharge and chemical quality of the Navasota River near Bryan, Texas, which are available for the period October 1958 through September 1961, indicate non-natural chloride concentrations occurred in that stream at the gaging site at the U. S. Highway 190 bridge in Brazos County. Studies by the staff of the Texas Water Commission, utilizing these data, show that during possible critical drought periods, the chemical quality of water that could be obtained from a proposed major reservoir on the Navasota River may have undesirable concentrations of chlorides because of apparent contributions from non-natural sources.

Information available to the Commission indicated that large quantities of oil field brines were being disposed into tributaries of the Navasota River. Therefore, the Ground Water Division of the Commission was instructed to determine the source or the sources of possible non-natural chloride contributions indicated in the chemical load of the Navasota River in order that the Texas Water Commission would have information to evaluate the water quality problem in the proposed reservoir.

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INTRODUCTION

Purpose and Scope

This report contains the results of a preliminary investigation undertaken by the Ground Water Division to obtain data regarding the mineral contamination of ground and surface waters resulting from disposal of oil-field brines in the Navasota River watershed. The fieldwork included the locating of all oil and gas fields and brine disposal pits and a determination of the approximate amount of brine being disposed of in the watershed of the Navasota River. Oil and gas fields which are located within the watershed of the Navasota River include the Mt. Calm field in Hill County; Mexia, Negro Creek, Cedar Creek, Groesbeck, Oletha, Pokey, Arnett, South Fallon, Christmas Creek, and Coit fields in Limestone County; Bi-Stone and Freestone fields in Freestone County; McBee and Normangee-Flynn fields in Leon County; and Millican and East Millican fields in Brazos County. The Coit, South Fallon, Bi-Stone, Freestone, McBee, and Normangee-Flynn fields produce little or no brine. The Mt. Calm, Arnett, Christmas Creek, Groesbeck, and East Millican fields no longer produce oil or gas and are abandoned. This investigation indicated that approximately 95 percent of the brine currently being disposed of in the watershed of the Navasota River is produced in the Mexia, Negro Creek, and Cedar Creek oil fields; this report, therefore, deals particularly with these three fields.

A brief reconnaissance was made of the Navasota River watershed from the Negro Creek oil field to the headwaters of the river northeast of Mt. Calm in southeastern Hill County in order to determine whether oil-field brines were entering the river upstream from the Mexia, Negro Creek, and Cedar Creek fields. The reconnaissance failed to locate any producing oil or gas fields contributing brine to this upper portion of the Navasota River watershed. Two abandoned oil tests were located in the area of the headwaters northeast of Mt. Calm. Further study would be required to determine the condition of these wells and of any other wells in the area, and to determine whether such wells are contributing salt water to the river by subsurface seepage.

This report discusses the surface and shallow subsurface geology of the Mexia, Negro Creek, and Cedar Creek oil-field areas and the method of disposal of brines. Also included are tabulations of the amount of brine produced in these oil fields, and the amount of brine currently being produced on the various leases in the fields (Table 3), a compilation of chemical analyses of water collected from stream-sampling points during the period 1957-1961 (Table 1), a geologic map showing chloride concentrations in streams and location of water samples obtained during the current field investigation (Plate 1), and two generalized geologic cross sections showing shallow subsurface geology and stratigraphic relationships in this area (Plate 2).

Location and Extent

This investigation covered an area of approximately 55 square miles in Limestone County, in northeast Texas. The county is bounded on the north by Navarro and Hill Counties, on the east by Freestone County, on the south by Robertson County, and on the west by Falls and McLennan Counties.

There are three oil fields in the area of study: (1) Mexia, (2) Negro Creek, and (3) Cedar Creek. The Mexia field covers approximately 3,800 acres and extends west of State Highway 14 from approximately 3-1/2 miles south of Mexia to 1 mile north of Mexia (Figure 1). The Negro Creek field is approximately 6 miles west of the city of Mexia along U. S. Highway 84 and covers approximately 171 acres. The Cedar Creek field, which is sometimes referred to as the Honest Ridge field, covers approximately 120 acres and is 8 miles southwest of the city of Mexia.

GEOGRAPHY

Topography and Drainage

The topography of the area of investigation is level to gently rolling with a range in elevation from 400 to 550 feet.

The area is drained by Plummers Creek, Rocky Creek, Jacks Creek, Negro Creek, and Cedar Creek, all of which are tributary to the Navasota River.

Economy

The economy of the area is based primarily upon oil production, agriculture, and to some extent upon manufacturing. Industries include a textile mill, cotton compress, furniture factory, and clothing manufacture.

MEXIA MUNICIPAL WATER SUPPLY

Prior to 1960, the municipal water supply for Mexia was obtained from a well field located about 3 miles west of the city. The city wells, ranging in depth between 300 and 400 feet, obtained water primarily from the Tehuacana member of the Kincaid formation with lesser amounts from the Pisgah member. The well field lies in a large graben formed by the Mexia and Tehuacana fault zones (Bryan, 1951). Steadily declining water levels in these wells prompted the city to construct a surface reservoir on the Navasota River. This reservoir, known as Lake Mexia, was put into use in 1960, and it presently constitutes the source of municipal water for Mexia, with the water wells maintained on a standby basis. Also available on a standby basis is water from a spring at the old Springfield townsite south of Mexia (See Plate 1). The area around the spring has been excavated and cemented, forming a small holding basin. A pump station has been maintained at the spring for many years and has furnished some water for the city in the past.

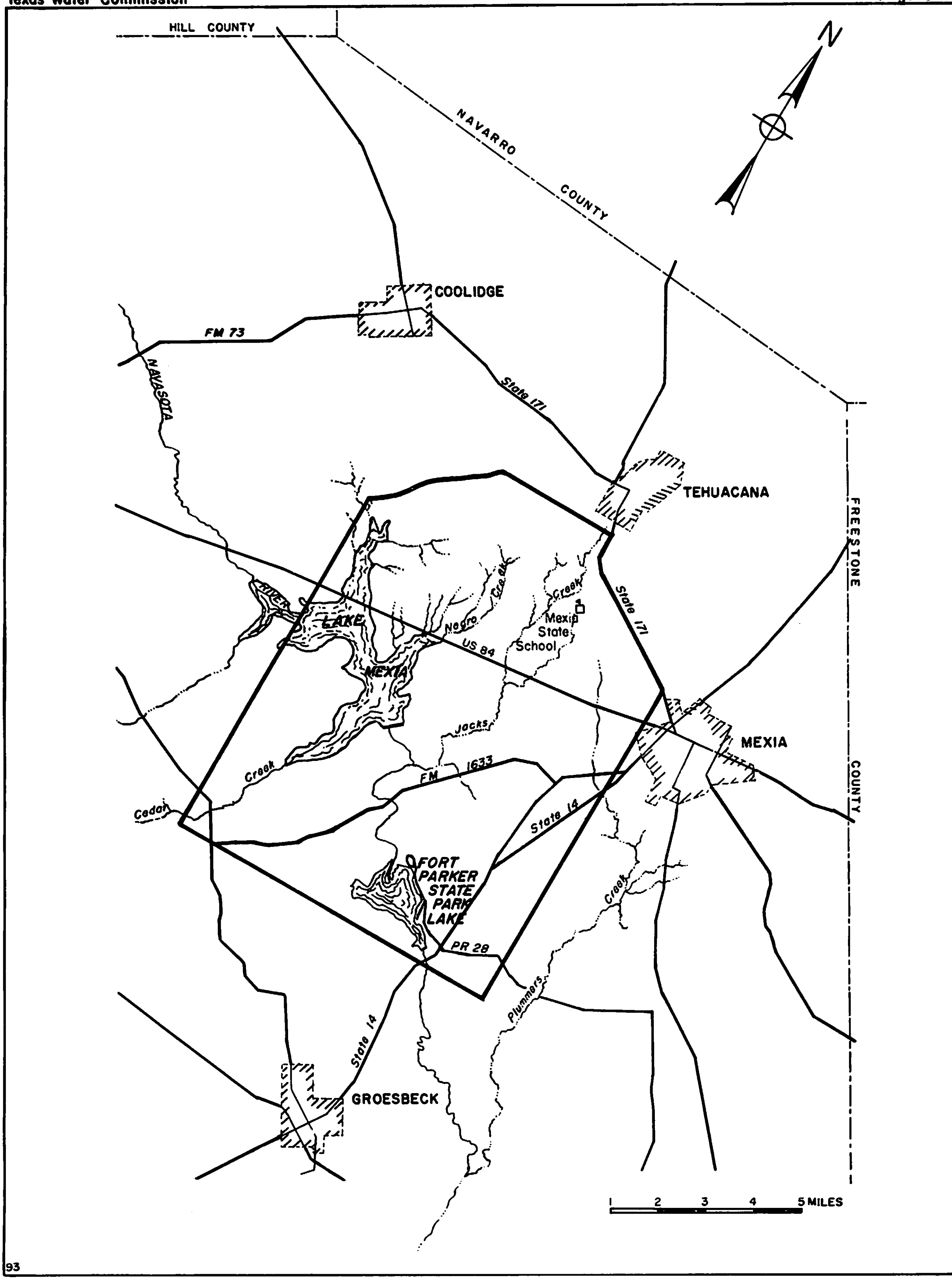

FIGURE 1.- Index map of part of Limestone County showing area of study

PREVIOUS WORK

An investigation was made by the Railroad Commission of Texas in 1956 of complaints of salt water pollution of the Navasota River from the Mexia oil field. Similar surveys were made in 1958 and 1959 by the Texas State Department of Health, and in 1962 the firm of Freese, Nichols, and Endress prepared a report on the Millican reservoir site, which included a section on quality of water in the Navasota River.

In January 1956, the Railroad Commission conducted an investigation in the Mexia field which included a study of the disposition of the produced brine, the approximate amount of brine produced, and the size of pits used for storage of the water. Mr. M. P. Edmondson, Deputy Supervisor, Railroad Commission District 5, determined that approximately 5-1/2 million barrels of salt water were produced during the year 1955. The water was disposed of into surface pits and was reportedly released from the pits only during periods of high rainfall.

As a result of the report by Mr. Edmondson, a hearing was held by the Railroad Commission on February 27, 1956, to consider the salt water disposal problem in the Mexia field. It was concluded at the hearing that continuing observation of the quality of water in the Navasota River would be maintained by taking periodic water samples of the river and Plummers Creek during periods of salt water flow. Results of analyses of these samples, which were to be taken by oil operators in the area and by the Game and Fish Commission, were to be made available to the Game and Fish Commission and to the Railroad Commission. The samples were taken from 1957 through 1961 by Mr. E. G. Hall, representing the operators, and Mr. Gene Schuh of the Game and Fish Commission (Table 1 and Figure 2).

In September 1958, the State Department of Health conducted a preliminary water-quality survey of surface streams in Freestone, Limestone, and Navarro Counties. This report, entitled "Oil Field Survey, Mexia-Corsicana, October-1958," included a general survey of the Mexia oil field showing the surface drainage pattern and chemical quality of water in the streams. The report stated that a sample taken for chemical analysis from Plummers Creek, one-half mile above its confluence with the Navasota River, had a chloride content of 5,680 parts per million.

In September 1959, an investigation of the chloride content of Plummers Creek was begun by the State Department of Health. The report of this investigation, entitled "Plummers Creek Chloride Investigation, Limestone County," included a survey of brine pits, brine production, number of wells, and water quality. Data included in the report indicated the chloride content of the water in Plummers Creek below the Mexia oil field ranged as high as 5,800 ppm during the period of study. The report indicated also that no major source or sources of high chloride concentrations were discovered other than from brine pits in the Mexia oil field. It was concluded by the author, Mr. Bruce R. McGee, that brine releases from the Mexia oil field were responsible for the high chloride content found in Plummers Creek.

In March 1962, Freese, Nichols, and Endress, consulting engineers, prepared a report on the proposed Millican reservoir site for potential water users in the reservoir area. The report includes a section on the chemical quality of the Navasota River and it utilizes stream discharge and chemical quality data obtained by the U. S. Geological Survey for the Navasota River at the U. S. Highway 190 crossing on the Madison-Leon County line.

Table 1.--Chloride concentration (in parts per million) of the Navasota River and Plummers Creek for the period 1957-61

Location of sampling points (See Figure 2)

(1) Navasota River - 100 yards above confluence with Plummers Creek
(2) Navasota River - 200 yards below confluence with Plummers Creek
(3) Plummers Creek - 100 yards north of confluence with Navasota River
(4) Navasota River at bridge of State Highway 164

1957

Date		Chloride concentration (in ppm.) at sample location no.				Samples taken by
		1	2	3	4	
July	1	75	590	--	--	Game and Fish Commission 1/
	9	78	200	1,120	980	Do.
	16	80	185	1,340	--	Do.
	22	344	112	--	1,304	Do.
	30	160	1,960	2,500	--	Do.
Aug.	7	520	2,110	2,780	--	Do.
	13	825	2,240	2,640	--	Do.
Sept.	9	1,440	--	--	--	E. G. Hall
Oct.	15	--	1,950	--	3,015	Do.
	30	--	360	--	360	Do. 2/
Nov.	30	--	350	--	270	Do.
Dec.	30	--	350	--	1,240	Do.

1958

Jan.	6	--	--	--	1,060	E. G. Hall
Mar.	3	--	700	--	--	Do.
Apr.	1	--	700	--	1,750	Do.
	30	--	--	--	350	Do. 2/
June	1	--	300	--	350	Do.
July	1	--	700	--	700	Do.
Aug.	1	--	1,240	--	1,050	Do.
	23	--	--	--	1,950	Do.
Sept.	29	--	350	--	350	Do. 2/
Oct.	30	--	530	--	530	Do.
Nov.	29	--	700	--	1,000	Do.

1959

Jan.	29	--	700	--	2,000	E. G. Hall
June	3	--	400	--	1,000	Do.
	30	--	175	--	200	Do. 2/
Aug.	1	--	400	--	700	Do.
Sept.	5	--	1,250	--	1,400	Do.
	30	--	900	--	1,200	Do.
Oct.	30	--	900	--	1,350	Do.

See footnotes at end of table.

Table 1.--Chloride concentration (in parts per million) of the Navasota River and Plummers Creek for the period 1957-61--Continued

1960

Date		Chloride concentration (in ppm.) at sample location no.				Samples taken by
		1	2	3	4	
Jan.	2	--	--	--	270	E. G. Hall
	11	--	300	--	300	Do.
Feb.	29	--	360	--	440	Do.
Mar.	31	--	440	--	900	Do.
June	4	--	1,080	--	1,150	Do.
July	4	--	700	--	880	Do.
Aug.	2	--	1,530	--	1,620	Do.
Sept.	2	--	1,800	--	1,890	Do.
Oct.	4	--	800	--	800	Do. 3/
Nov.	2	--	700	--	900	Do.
Dec.	5	--	900	--	900	Do.

1961

Jan.	3	--	450	--	450	E. G. Hall 2/
Feb.	3	--	450	--	540	Do.
Apr.	9	--	450	--	450	Do.
May	1	--	360	--	360	Do.
July	3	--	270	--	270	Do. 2/
Aug.	8	--	540	--	630	Do.
Sept.	1	--	810	--	810	Do.
Oct.	3	--	720	--	800	Do.
Nov.	3	--	540	--	630	Do.
Dec.	4	--	990	--	990	Do.

1962

Jan.	1	--	900	--	810	E. G. Hall
Feb.	1	--	630	--	630	Do.
Mar.	1	--	720	--	720	Do.

1/ Samples taken by Game and Fish Commission were analyzed by the State Department of Health.
2/ Transmittal letter indicates heavy rains since previous sample taken.
3/ Fort Parker State Park Lake level lowered.

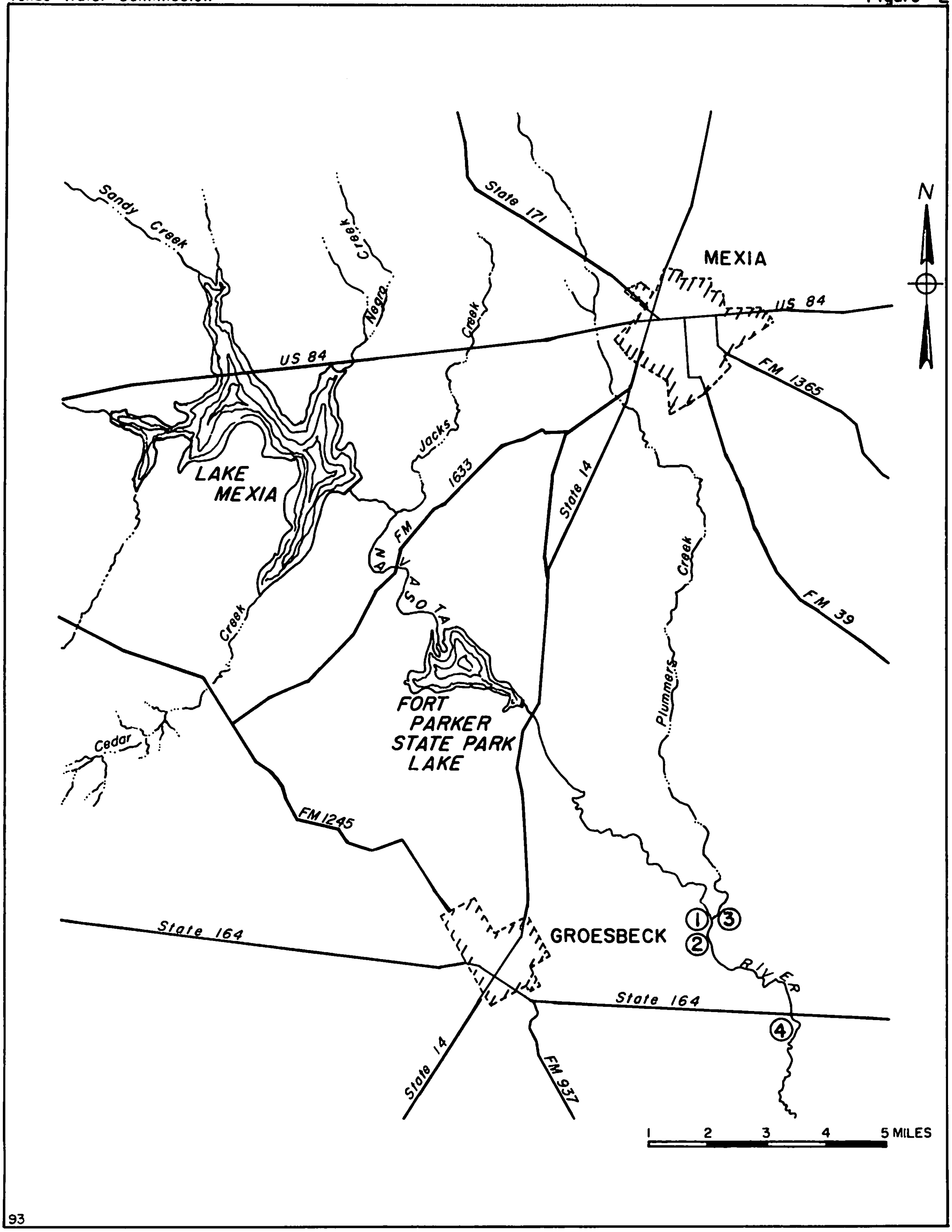

FIGURE 2.—Map showing locations of sampling stations for sampling program during the period 1957-1961

Stratigraphy

No detailed surface geologic mapping was done in the area during this investigation. However, the major shallow formations and their members were mapped in the subsurface by interpreting electric logs of oil and gas wells, and by study of available geologic data.

Rocks which crop out at the surface or occur in the shallow subsurface in the general area of study are of sedimentary origin and belong to the Midway group of early Eocene age (Table 2). The soft, generally fine-grained, marine sediments of the Midway group, which includes all strata between the upper Cretaceous (Navarro group) and the basal sandstone of the Wilcox group, have been divided into two formations. These formations, the Kincaid formation and the overlying Wills Point formation, are differentiated on the basis of fauna and general lithology.

Kincaid Formation

The Kincaid formation consists of glauconitic sandstones, soft gypsiferous clays, and hard indurated limestones in the following proportions: limestone, 10%, clay and silty clay, 50%, and sand, 40% (Sellards, Adkins, and Plummer, 1932).

The formation is composed of three distinct, rather easily recognizable members. These are, from bottom to top, the Littig sandstone member, the Pisgah member, which consists predominantly of fine-grained sandstone, siltstone, and clay, and the Tehuacana limestone member. In many places, the outcrop of the formation is characterized by prominent cuestas where indurated ledges mark the upper contact. The Tehuacana "limestone" typically caps the tops of these ridges, and the sands and clays form the slopes. The total thickness of the Kincaid formation ranges to more than 250 feet in the Mexia oil field area; however, the average thickness is reported to be about 150 feet (Sellards, Adkins, and Plummer, 1932).

Littig Member

The Littig member consists of glauconitic sandstone, reportedly 1 to 3 feet thick in the Mexia area, which rests unconformably upon the uppermost clays of the Navarro group.

Pisgah Member

The Pisgah member is made up of clays, glauconitic clays, and fine-grained, glauconitic, quartz sandstones and commonly contains thin limestone lenses. In the Mexia area, this member varies in thickness from 100 to 150 feet.

Tehuacana Member

The Tehuacana member ranges to 50 feet in thickness in the area, the average thickness being approximately 40 feet. It is composed predominantly of highly fossiliferous, clastic limestone and subordinate amounts of fine-grained sandstone. In many places, the Tehuacana reportedly consists predominantly of quartz

Table 2.--Geologic formations in the Mexia area

System	Group	Formation and member		Thickness (feet)	Lithology	Water-bearing characteristics
Quaternary		Alluvium		0. 5	Sand, gravel, clay and silt.	Does not yield potable water in area.
Tertiary	Midway group	Wills Point formation	Kerens member	0- ?	Dark gray, silty to sandy claystone. Grades upward into siltstone and poorly sorted, fine-grained, micaceous, thinly bedded, silty sandstone. Weathers to produce dark gray or grayish-brown, noncalcareous, Crockett sandy loam soil.	Do.
			Wortham member	0- 1	Impure, concretionary limestone consisting predominantly of aragonite crystals arranged in rosettes.	Do.
			Mexia member	0-75	Dark-colored, thinly laminated or compact, fossiliferous claystone. Contains clayey siltstone lenses locally. Thin, glauconitic sandstone bed commonly occurs at base of the member. Weathers to produce dark grayish-brown, Wilson clay loam top soil 4 to 10 in. thick.	Basal sandstone probably yields potable water where it occurs at or near the surface.
			unconformity			
		Kincaid formation	Tehuacana member	30-40±	Grayish white, glauconitic, sandy limestone, locally highly fossiliferous. In places essentially a highly fossiliferous quartz sandstone strongly cemented by calcite.	Yields moderate to large quantities of potable water in area. Formerly principal aquifer for Mexia municipal water supply.
			Pisgah member	100-200	Alternating glauconitic sand, sandy claystone, and claystone. Contains thin limestone lentils in places.	Yields moderate amounts of potable water to wells in area. Formerly source of water for Mexia municipal water supply.
			Littig member	0- 8	Fine-grained, gray, fossiliferous, glauconitic sandstone containing phosphatic nodules, reworked Navarro shale boulders and commonly spherical, calcareous concretions.	Probably yields potable water in structurally high areas.
unconformity						

(Continued on next page)

Table 2.--Geologic formations in the Mexia area--Continued

System	Group	Formation and member	Thickness (feet)	Lithology	Water-bearing characteristics
Cretaceous	Navarro group	Upper-including the Kemp clay and the Corsicana marl undivided	275+	Shale, light gray, silty, calcareous, locally containing lignite seams.	Does not yield potable water in Limestone County.
		Nacatoch formation	200	Fine to very fine-grained, subangular, cherty, phosphatic, glauconitic sandstone interbedded with thick beds of light gray shale.	Do.
		Neylandville marl	140	Dark gray and greenish-gray calcareous clay, locally sandy, glauconitic, and fossiliferous.	Do.
		Upper: Marlbrook formation	0-580	Tan, fossiliferous, calcareous marl, containing irregular beds of gray silty shale and fine-grained, glauconitic sandstone.	Do.
		Upper: Pecan Gap chalk	0-100	Highly fossiliferous, white chalk.	Do.
	Taylor group	Lower: Taylor formation: Wolfe City member	200+	Fine-grained, glauconitic sandstone.	Do.
		Lower: Taylor formation: Undifferentiated	0-450	Light gray, silty shale interbedded with a fine-grained glauconitic sandstone.	Do.
		Austin chalk	300-480	Soft, gray, fossiliferous chalk, with 30-foot thick weathered zone at top. Contains several thin gray shale breaks. The lower part is composed of matted brown and white shaly chalk.	Do.
		Eagle Ford shale	320-480	Dark gray to black, thinly laminated shale containing thin beds of impure limestone.	Do.
		Woodbine formation	270-650	Fine- to medium-grained sandstone, containing chlorite crystals along the upper contact. Contains thin lignitic shale lenses throughout.	Yields large amounts of brine with oil in Limestone County.
unconformity					

sand grains and fossil fragments solidly cemented with sparry calcite. Where the Tehuacana is exposed at the surface, the calcareous cement is commonly leached out, leaving a loose, unconsolidated sandstone as a residue.

The clays of the Kincaid formation contain much silica, aluminum, and calcium. The amount of iron varies considerably (Sellards, Adkins, and Plummer, 1932). The glauconitic quartz sandstones commonly contain gypsum.

Wills Point Formation

The Wills Point formation consists of glauconitic sandstone, siltstone, and claystone at the base, above which is a compact, fossilferous clay (Mexia member) that grades upward into slightly fossiliferous layers of silty clay (Kerens member) at the top (Sellards, Adkins, and Plummer, 1932). The total thickness of the Wills Point formation in the Mexia area is not known, since the complete section is nowhere exposed in the report area.

Mexia Member

The Mexia member makes up the lower 50-75 feet of the Wills Point formation. It is composed of 1-10 feet of glauconitic sandstone overlain by dark-blue, thinly laminated, fossiliferous, concretionary claystone. Thin layers of fine, micaceous to quartzose silt are present but not common.

Wortham Aragonite Member

The Wortham member is an impure, concretionary limestone bed, 8 to 10 inches in thickness, which consists primarily of aragonite crystals arranged in rosettes.

Kerens Member

The Kerens member is made up predominantly of dark gray, silty to sandy claystone. The amount of silt and sand increases upward; the upper 100 feet of the formation contains more than 10 percent quartz silt and in some places as much as 25 percent. The upper silty beds commonly contain large boulder-like concretions 3-4 feet in diameter. The upper part of the Kerens member is probably not present in the Mexia oil field area.

The Wills Point clay contains a higher percentage of silica and aluminum, and less calcium than the clays of the underlying Kincaid formation.

Structure

Regional Structure

The sedimentary rocks in this region strike northeast with a regional dip to the east-southeast of approximately 100 feet per mile. The strata are displaced by the Luling-Mexia-Talco fault zone which trends northeast in the area of investigation. The Mexia fault zone consists of a group of subparallel normal faults, which strike generally northeast and dip at a relatively low angle toward the west. They are predominantly downthrown on the west with total displacement of the major faults ranging from 250 to more than 600 feet. A series of asymmetrical anticlinal folds commonly flank the major faults. Local drag along these faults has accentuated the folding in the upthrown beds, thus forming a trap for the accumulation of oil, gas, and brine.

Local Structure

The Mexia oil field is located on the Mexia anticline, which is the largest producing structure in the Mexia fault zone. The total surface area of production is approximately 36,000 feet long, and has a maximum width of 7,000 feet. The western edge of the field occurs where the Woodbine formation is displaced by the major fault. Total displacement along this fault ranges from 550 feet in the Austin chalk to between 260 and 300 feet in the Midway strata at the highest part of the structure; this suggests that the faulting, which produced a throw of 250 to 300 feet in pre-Midway and post-Navarro time, probably was renewed with further vertical movement of from 260 to 300 feet after Midway time. The fault plane dips to the west at an angle of approximately 37 degrees to the top of the Austin chalk, below which it steepens markedly. The structure at the south end of the oil field is extremely complex, with indications that additional faulting may be present which has not been mapped.

The Negro Creek and Cedar Creek fields are situated on structures developed within the Tehuacana fault zone, a zone of faulting similar to the Mexia zone but downthrown to the east and lying 3-1/2 to 4-1/2 miles west of the Mexia zone. The structure in the areas of the Negro Creek and Cedar Creek fields is similar to that in the Mexia field, in that the controlling fault has a throw of 200 feet in Midway strata and 500 feet in the Austin chalk. These two major zones of faulting have produced a large graben within the central part of the area of study (Plate 2).

Numerous smaller faults transect the major zones of displacement in the areas of the oil fields.

HYDROLOGY

The most important aquifer in the Mexia area is the Tehuacana member of the Kincaid formation. A well developed fracture system, together with the cavernous and vugular nature of the clastic limestone beds, have resulted in good permeability. Interlayered fine-to-medium grained quartz sandstone layers within the member also contain potable water, which increases the capacity of the aquifer. The fine-grained sand and siltstone of the underlying Pisgah member also contains potable water. However, the small effective grain size, calcareous cementation, and impervious nature of the interlayered clay deposits have resulted in lower permeability than that of the Tehuacana. On the upthrown side of the main Mexia fault, and also in the southern part of the area, the Tehuacana member has been removed by erosion and the Pisgah member is exposed at the surface (Plate 2). Relatively large quantities of potable water can generally be obtained from the Pisgah member in those areas where a sufficient thickness of sand is present.

Bryan, in his report titled "Ground Water Resources in Mexia, Texas" which was completed in 1951, defined two major ground water reservoirs in the area, a "closed" reservoir, so described because of its relatively isolated position with respect to recharge and discharge, and an "open" reservoir.

The "closed" reservoir, in which the Tehuacana and Pisgah members constitute the aquifer, is terminated on the east by the main Mexia fault and on the west by the Tehuacana fault. The southern extremity is fixed by the Kincaid outcrop, and the northern boundary by a gradual pinching out of the formation in the vicinity of the Limestone-Navarro County line. This reservoir is overlain by the relatively impermeable Wills Point formation in almost all of the area. There is apparently no area of major recharge, although small amounts of rainfall apparently enter by slow infiltration through the overlying Wills Point formation.

The city of Mexia has maintained a well field in the "closed" reservoir since 1933. The water level declined from 125 feet below the land surface in 1933 to about 245 feet below the surface in 1952, with a corresponding decrease in yields of the wells from 360 gpm in 1933 to 75-185 gpm in 1952. The continued decline of the water levels and decrease in yield of the wells resulted in abandonment of the well field as a municipal water supply in 1960. The quality of water from these wells has remained consistently good, with a general chloride concentration of between 110 and 140 ppm. Bryan (1951) reported contaminated water elsewhere in the reservoir beneath the Mexia oil field.

The "open" ground-water reservoir is formed where the Kincaid formation crops out at the surface on the upthrown side of the Mexia fault. The western edge of this reservoir is terminated by the Mexia fault where the Kincaid formation is adjacent to the Wills Point clay. The south and southwest limits occur where the formation is exposed and eroded at the surface (in the vicinity of Fort Parker Lake), and to the east the Kincaid reportedly pinches out beneath the Wilcox group.

The large surface brine disposal pits in the eastern edge of the Mexia oil field are constructed on the Pisgah outcrop at the northern end of the "open" reservoir. This "open" reservoir is continually recharged by rainfall on the outcrop, which readily percolates through the loose, sandy soil characteristic of the Pisgah member.

For many years, the city of Mexia has maintained a pump station at a large spring near the southeast end of Fort Parker State Park Lake at the old Springfield townsite. Movement of ground water in the aquifer is toward the south where it is discharged into Fort Parker Lake and the Navasota River. The water pumped from the Springfield holding basin has reportedly always been of good quality.

No appreciable amounts of subsurface water are known to occur in the Wills Point formation.

HISTORY OF OIL AND GAS PRODUCTION

Oil and gas has been produced in the Mexia field for 50 years. Gas was discovered in the Nacatoch formation in 1912. This zone was essentially depleted by 1920, although about 8 wells were still producing in 1950. At present, there is no known production from the Nacatoch in this area. Oil was discovered in 1920 in the Mexia field in the upper part of the Woodbine formation at a depth of 3,065 to 3,117 feet below the surface. Production reached its peak in 1922 when 417 wells produced 33,937,513 barrels of oil. During these early years, there was no regard for well spacing or flow rates; thus oil production decreased sharply and has steadily declined while brine production has rapidly increased. Currently, in the Mexia field there are 115 wells producing a total of approximately 800 barrels of oil per day, predominantly from the Woodbine formation.

Prior to 1955, several stratigraphic horizons below the Woodbine were penetrated during drilling activities; however, no wells produced commercial amounts of oil or gas from any zone below the Woodbine. In 1955, the Humble Oil and Refining Company completed two deep wells, one an oil well and the other a gas distillate well, in the Smackover formation of Jurassic age at a depth of approximately 8,600 feet. This renewed interest in the area has reportedly led many operators to continue pumping some essentially non-commercial Woodbine wells in order to retain their lease holdings.

Discovery of Woodbine oil in the Negro Creek field in 1926 resulted in a total of 72 well completions by January 1, 1927. During the first two years of operation 2,690,000 barrels of oil were produced. Because of constant pumping and lack of proper well spacing, the field had to be abandoned as fully depleted in 1931. During the years 1938 to 1941, the field was again listed as a producer with one well pumping. In 1950, the J. C. Bertrand et al. No. 1 C. R. Yelverton was completed, initially pumping 22 barrels of oil and 86 barrels of water per day. At present, there are 3 wells producing approximately 40 barrels of Woodbine oil per day.

Oil was first produced in the Cedar Creek field in 1927. By 1930, when the Woodbine was depleted, total production amounted to 330,600 barrels of oil. In 1946, the J. V. Fleming No. 1 Ward was completed in what is sometimes designated as the Honest Ridge field. A peak production of 3,660 barrels of oil was reached in 1947. Currently, three wells are producing approximately 12 barrels of oil per day from the Woodbine formation in the field.

BRINE PRODUCTION

Since the discovery of the Mexia Woodbine field, most of the wells have had a high brine-oil production ratio. The Woodbine reservoir has moderately good permeability in which a relatively strong natural water drive is maintained. Oil production declined sharply after 1923; since that time, steady brine encroachment has resulted in an extremely unfavorable oil-brine ratio and the production of enormous amounts of brine.

No data were available to this study concerning brine production prior to 1955. As a result of an investigation of the oil field by Mr. M. P. Edmondson of the Railroad Commission in January 1956, it was learned that salt water constituted approximately 95 percent of gross production. The field produced 291,413 barrels of oil in 1955 from 125 wells, and the total salt-water production for the year was estimated to be 5-1/2 million barrels. An inventory, by the Railroad Commission, of salt-water production in the Mexia field during the year 1956 indicated a total daily production of 20,412 barrels being disposed of into open surface pits.

The current (February, 1962) estimated daily brine production from the three oil fields is approximately 17,493 barrels from 121 wells. This figure is based upon field investigation and verbal reports of the oil operators. Table 3 shows the current estimated daily brine production for each lease in the fields.

Of the total estimated daily brine production, the Mexia field produces approximately 91.0 percent or 15,918 barrels of brine daily from 115 wells, all but 2 of which are completed in the Woodbine formation. Two wells yield about six barrels of brine per day from the Smackover formation.

The Negro Creek field produces an estimated 975 barrels per day from three wells. This represents approximately 5.6 percent of the total brine production of the area. A fourth well in this field is currently shut down and, in addition, a deep Smackover test is presently under way.

Brine is pumped at the rate of about 600 barrels per day from three wells in the Cedar Creek (Honest Ridge) field; this is 3.4 percent of the total areal Woodbine production.

Based on the current production data and using an average of 341 producing days per year, the total calculated yearly brine production for each oil field would be as follows:

Mexia field	5,428,038 barrels
Negro Creek field	332,475 barrels
Cedar Creek field	204,600 barrels
	5,965,113 barrels per year

Nine wells in the northern end of the Mexia field produce approximately 745,085 barrels of the total each year which are disposed of on the watershed of the Trinity River. The remaining 5,220,028 barrels of brine are disposed of on the surface within the watershed of the Navasota River.

DISPOSAL OF BRINE

Mexia Field

Most of the estimated 15,918 barrels of brine produced daily in the Mexia field is pumped into open, unlined surface pits of varying sizes. There is no subsurface injection of brine in this area. Most of the surface pits are reportedly drained to surface tributaries only during periods of heavy rainfall. Approximately 2,185 barrels of brine from nine wells are discharged daily into eight pits in the extreme northern part of the field (north of State Highway 171). These pits are situated in the watershed of Salt Creek, which drains into the Trinity River, and they are therefore not pertinent to this investigation.

Except for water lost by evaporation and seepage into the subsurface, all of the remaining salt water eventually enters the Navasota River. Most of the brine entering the subsurface by seepage also drains, or will probably eventually drain, into the Navasota River.

Forty-nine wells discharge about 6,300 barrels of brine daily into 18 surface pits situated within the drainage area of Plummers Creek. These pits range in size from 1/3 to 40 acres. The largest of these pits, which covers approximately 40 acres and is reportedly 15 feet deep at the deepest point, is located in the Stubenrauch lease at the headwaters of a tributary to Plummers Creek. Although pits in this area are located on the outcrop of the clayey Mexia member of the Wills Point formation, there is considerable seepage from the pits and capillary movement of brine in the subsurface. The pits are reportedly drained only during heavy rains, yet Plummers Creek and its tributaries which are intermittent, effluent streams, were constantly flowing brine during the period of investigation. Two large pits, with a total surface area of about 50 acres, located on the east Berthelson lease in the central part of the field, are constructed on the sandy Pisgah member of the Kincaid formation. Seepage loss was observed in this area, and brine was noted to be flowing in road ditches some distance from the pits. Brine is periodically drained from these pits into Plummers Creek. Much of the brine which percolates into the subsurface in this area probably also ultimately discharges into Plummers Creek.

There are 14 surface pits receiving about 6,100 barrels of brine daily within the watershed of Rocky Creek above its confluence with Jacks Creek. These pits range in size from approximately 1/2 to 10 acres, and they are constructed on the Wills Point formation. No pits were seen being drained during the investigation, although brine was noted to be flowing in Rocky Creek at several points.

Eight surface pits ranging in size from 1/2 to 2 acres lie within the watershed of Jacks Creek and its tributaries. These pits receive approximately 1,228 barrels of brine daily. No discharge was observed from any of these pits during the current investigation. Since brine was flowing in several streams in this area, loss from the pits through seepage is apparently occurring to a considerable extent. Most of these pits are constructed on the sandy Pisgah member of the Kincaid formation.

Negro Creek Field

Nine hundred and seventy-five (975) barrels of brine produced daily in the Negro Creek field are disposed of into 4 surface pits, the largest of which covers approximately 10 acres. These pits are within the Negro Creek watershed and are located approximately 500 feet upstream from the confluence of Negro Creek with Lake Mexia. All are constructed on the Tehuacana member of the Kincaid formation. At the request of the Bi-Stone Municipal Water District, the largest pit is drained only during periods of flood when the lake level rises at least 2 feet above the top of the dam. Although none of the pits were being drained during the period of field investigation, small amounts of brine were flowing at several localities in Negro Creek, indicating seepage of brine from these pits and saturation of the shallow subsurface.

Cedar Creek Field

The total daily brine production of 600 barrels produced in the Cedar Creek (Honest Ridge) field is disposed of into three surface pits situated within the watershed of Cedar Creek. The thin, basal sandstone of the Wills Point formation crops out as isolated outliers in this area; however, the disposal pits are excavated down into the Tehuacana member of the Kincaid formation. Considerable seepage of brine from these pits was observed.

QUALITY OF PRODUCED BRINE

During the early years of production in the Mexia field, some variation was observed in the mineral concentration of the brine produced. In general, the mineral content of the produced brine was similar, although there has been areal variation in the relative concentration of dissolved solids. Brine produced along the eastern edge of the Mexia field had an average content of approximately 31,000 ppm (parts per million) of total dissolved solids. Brine produced from the middle and western edge of the field generally had a range of 35,000 to 39,000 ppm of total dissolved solids, while that produced from the extreme south end of the field had an average total dissolved-solids content of only 17,000 ppm. Mineral concentration was considerably higher near the fault than in the central and east-central parts of the field. Locally, in brines produced near the faults, a minor increase in sulfate, carbonate, and bicarbonate was noted.

Removal of the oil with resulting encroachment and upward movement of the brine has resulted in abandonment of approximately three-fourths of the wells originally drilled in the field. Almost all of the wells currently pumping large amounts of brine are located on the crest of the structure near the fault. Although brine samples were not taken directly from gun barrels during the current study, the surface pit sample analyses in Table 4 are comparable to available data on analyses of brine samples from the Woodbine formation.

Data in Table 4 suggest that brine produced in the south-central part of the present Mexia field may be higher in total solids and total alkalinity than that produced in the north-central parts of the field; however, additional sampling would be needed to substantiate this. Brine produced from the Smackover formation is apparently extremely high in chloride concentration; however, it is reported that not more than six barrels of brine are produced daily from the two wells completed in this formation.

Brine produced in the Negro Creek field is lower in total dissolved solids and chloride content than that produced in the Mexia field. This has apparently been consistently true throughout the history of the fields.

QUALITY AND QUANTITY OF BRINE ENTERING WATERSHED

Determination of the average quality and quantity of brine entering the Navasota River during any given time interval would be speculative because of the large variation in rates of release of stored brine to surface drainage. Average total dissolved-solid and chloride concentrations of stored brines, based on current and past sample analyses, are 33,600 and 19,500 ppm respectively in the Mexia field. At the current reported daily disposal rate of 13,733 barrels, approximately 81 tons of total dissolved solids and 48 tons of chlorides are being contributed daily to the Navasota River watershed from the Mexia field. With an average brine concentration of 28,200 ppm of total dissolved solids and 16,300 ppm of chlorides, and with an average daily brine production of 975 barrels from the Negro Creek field, the daily average increment from this field is calculated to be 4.8 tons of total dissolved solids and 2.5 tons of chlorides. Added to approximately 3.2 tons of total dissolved solids and 2 tons of chlorides contributed daily from the Cedar Creek (Honest Ridge) field, these figures indicate that a total of 89 tons of total dissolved solids and 52.5 tons of chlorides are being disposed of daily on the Navasota River watershed. During an estimated 341 producing days per year, approximately 30,349 tons of total dissolved solids and 17,902 tons of chlorides are currently being contributed to the watershed by the three oil fields. In recent years the tonnages of total dissolved solids and chlorides contributed to the watershed by the three oil fields probably approached the current amounts, as indicated by the Railroad Commission's investigation of the Mexia field in 1956.

Minerals contained in the brine do not enter surface drainage at the same rate that they are produced. Conventionally, it is assumed that all minerals disposed of into surface pits eventually will be released to surface drainage either by direct loss from the pit or by movement through the subsurface to points of discharge to surface drainage ways. However, due to the extensive faulting in this area, with resulting complex hydrologic factors, it cannot be accurately predicted that all brine entering the subsurface by seepage will reach areas of surface discharge.

Much of the brine that is seeping from pits constructed on the Wills Point formation appears to be moving horizontally into effluent stream channels. It would be difficult to estimate the amount of brine that is infiltrating into the underlying Tehuacana aquifer of the "closed" reservoir without an extensive coring and sampling program in the area. The brine that does enter the aquifer will eventually move downdip and in a southerly direction; however, without a coring and sampling program, the current degree of contamination and the period of time required for the water of altered quality to reach areas of discharge cannot be determined.

The several large disposal pits constructed on the "open" reservoir on the east side of the Mexia fault, at a surface elevation of approximately 550 feet, appear to be contributing substantial amounts of brine to the subsurface. Much of this brine is entering Plummers Creek as base flow at an elevation of approximately 500 feet. Seepage into a road ditch south of the pits in this area indicates that the salt water is also moving in a southerly direction, paralleling the slope of the land, toward the Mexia fault. Bryan (1951) indicated that brine contamination of ground water in this area had extended to approximately 2 miles north of Forest Glade (see Plate 1). However, the basic data on which this conclusion was based are not available to permit review of this observation.

Surface seepage is occurring from the pits in Cedar Creek field. The pit walls consist of excavated material from the underlying Tehuacana limestone and they are highly permeable. Most of the brine which is seeping through the pit walls contributes to surface runoff. The degree of contamination of ground water in the underlying Tehuacana member is not known.

ABANDONED OIL AND GAS WELLS AS A POSSIBLE SOURCE OF BRINE

Currently, there are an estimated 600 or more abandoned oil and gas wells in the general area of the Mexia, Negro Creek, and Cedar Creek fields. The casing and plugging records of these wells, if available, were not obtained during this study. It is reported that many, if not most, of these holes are not properly plugged. Considerable study would be necessary to determine whether there is any leakage of brine from these holes. Abandoned wells were inundated beneath Lake Mexia when the dam was completed in 1960, and there are several abandoned wells in Fort Parker State Park Lake which are known to be leaking gas.

Salt water in the Woodbine sands is under relatively low hydrostatic head and is reported to rise in wells only to depths from 2,400 to 2,500 feet below the land surface. The brine levels vary throughout the fields because of structural influences and changes in porosity and permeability of the reservoir. No data is available concerning fluid levels in the abandoned Nacatoch wells.

One abandoned well was located on the Carter lease during the field study. It had apparently been excavated during construction of a surface disposal pit. No plug was present at the top of the surface casing, and the brine level in the casing stood approximately 2 feet below the land surface. No sample was obtained from this well.

SUMMARY

1. A preliminary study of oil and gas fields within the drainage area of the Navasota River, and north of the proposed Millican dam site, indicated that

more than 95 percent of the salt water being disposed of on the surface was originating in the Mexia, Negro Creek, and Cedar Creek oil fields of northeast Limestone County.

2. The current estimated daily brine production in the Mexia, Negro Creek, and Cedar Creek oil fields is 17,493 barrels per day from 121 wells. Of this total, nine wells in the northern part of the Mexia field produce approximately 2,185 barrels of brine per day which are disposed of on the watershed of the Trinity River. The remaining 15,308 barrels of brine produced daily are disposed of into open, unlined surface pits on the watershed of the Navasota River. Based on an average of 341 producing days per year, these three fields are producing approximately 5,220,028 barrels of brine each year which is disposed of into open surface pits in the Navasota River watershed. Based on an average brine quality from these three fields, it is calculated that 30,349 tons of total dissolved solids and 17,902 tons of chlorides are disposed of into surface pits each year in this area.

3. Despite efforts by the oil-field operators to contain this salt water by construction of large surface pits, a chemical quality sampling program of surface drainage from the oil-field areas since 1957 indicates brine has continually entered the Navasota River by direct surface drainage from the fields. At the present time, the surface pits are reportedly drained only during periods of high rainfall.

4. Most of the brine produced in these fields probably enters surface drainage by direct runoff. Presence of flowing brine in road ditches and intermittent streams indicates loss of brine from the surface pits by seepage. Gross seepage is occurring from surface pits constructed on the outcrop of the Kincaid formation in the Negro Creek field, Cedar Creek field, and parts of the Mexia field, whereas small to moderate amounts of brine are lost by seepage from pits constructed on the outcrop of the Wills Point formation in the Mexia field. Much of the brine lost by seepage into the subsurface moves into Plummers, Jacks, Negro, Rocky, and Cedar Creeks and their tributaries.

5. Extensive faulting of the geologic formations has resulted in complex ground-water conditions in the area. A "closed" ground-water reservoir in the Kincaid formation, the chief aquifer in the area, was defined within the Mexia-Tehuacana fault graben in an earlier investigation (Bryan, 1951). There is apparently a minimum of recharge and movement of ground water in this relatively isolated reservoir. The lower part of the Kincaid formation occurs as an "open", constantly recharged aquifer where it is exposed at the surface in the area east of the main Mexia fault. Movement of ground water toward areas of natural discharge to the south is probably more rapid in this reservoir than in the "closed" reservoir.

6. Available data indicate areas where the chemical quality of the native ground water directly beneath the Mexia and Negro Creek oil fields has been altered. The time required for movement of this ground water toward areas of discharge will vary because of the complex structural characteristics of the area. It is possible that an extremely long period of time may be required for movement and subsequent discharge of contaminated ground water in the "closed" aquifer. Areas of salt water contamination within the "open" reservoir will probably be removed within a shorter period of time. In addition, the large brine load of Plummers Creek has probably resulted in some contamination of the fresh water-bearing strata of the Wilcox group which outcrop south-southeast of the oil fields. Further investigation, including a detailed sampling and coring program, would be necessary to determine the overall degree of ground-water contamination in the area.

7. The average natural chloride content of the Navasota River was not determined or studied by the Ground Water Division in this investigation. Geologic formations such as the Wolf City sandstone and Pecan Gap chalk members of the Taylor group, and the Nacatoch formation of the Navarro group, which crop out at the surface in the upper watershed, are known to contain generally poor quality water in the subsurface. A detailed study of the upper watershed of the river, including analyses of surface and ground water, would be helpful in determining the quality of water entering the Navasota River watershed in this area.

8. Subsurface injection of brine as a possible means of disposal should be studied thoroughly. It is generally thought that injection of brine back into the Woodbine formation in the field area would probably result in channeling of this water with resulting harmful effects to producing wells. It is possible that the brine could be injected into the Woodbine on the downthrown, unproductive side of the Mexia fault. The Nacatoch formation constitutes another possible injection zone; however, it is not known if it could accommodate such large amounts of brine.

9. The presence of more than 600 abandoned oil and gas wells, many of which may be inadequately plugged, could constitute a hazard to fresh water strata and surface drainage in the area if subsurface disposal of brines is initiated without prior remedial action.

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* Name of agency changed to Texas Water Commission January 30, 1962.

Table 3.--Records of brine production and disposal facilities in the Mexia, Negro Creek and Cedar Creek oil fields as of February 1962

Remarks: NRD, no evidence of recent release to drainage
ERD, evidence of recent release to drainage
* located within watershed of Trinity River
GS, gross seepage of brine from pits
MS, moderate seepage of brine from pits
VS, very little seepage of brine from pits

Operator	Lease	No. of wells	Producing horizon	Brine production (bbls/day)	Method of brine disposal and remarks	Watershed
			Mexia Field			
Brown Estate	Nussbaum	1	Woodbine	200	Pit	Rocky Creek
Do.	Smith	1	do	175	Pits, VS, trench into Rocky Creek	Do.
Do.	Thompson "A"	4	do	20	Pits, allowed to overflow through trench into Plummers Creek, MS	Plummers Creek
Do.	Thompson "B"	5	do	770	Do.	Do.
Do.	Thompson "C"	1	do	100	--	--
Do.	Abner	2	do	200	Pit, VS	Rocky Creek
Davis, J. O.	Reid	2	do	650	Pits, MS	Salt Creek*
Fisher (Flo-Jac)	Freeman	2	do	500	Pits, MS	Do.
Do.	Thompson	1	do	250	Pits, VS	Plummers Creek
Glover, Homer	Mills	1	do	300	Pit	Do.
Hall, E. G.	Adamson	2	do	8	Pit	Do.
Do.	Baker	1	do	1	--	--
Do.	Berthelson (east)	8	do	14	Pit, GS	Plummers Creek
Do.	Berthelson (west)	8	do	1,280	Pit, GS, ERD	Do.
Do.	Dancer	5	do	850	Pit, trench into Rocky Creek	Rocky Creek
Hall, E. G.	Ellis	6	do	1,575	Pit	Do.
Do.	Gamble	4	do	400	Pits	Jacks Creek
Do.	Hayter	3	do	800	Pit	Rocky Creek
Do.	Henry	8	do	7	Pit, new, very sandy	Jacks Creek
Do.	Kendrick	6	do	700	Pits	Rocky Creek
Do.	Kennedy, C. A.	1	do	2	Pit	Jacks Creek
Do.	Kennedy, Joe	2	do	2	Pit	Do.
Do.	Kembell	1	do	8	?	Do.
Do.	Manning	2	do	2	?	?
Do.	Mills, T. W.	2	do	12	Pit, MS, trench into Plummers Creek	Plummers Creek
Do.	Nussbaum	2	do	3	Pit, MS, trench into Plummers Creek	Do.
Do.	Rogers	5	do	600	Thought to be pumped into east Berthelson pit, GS	Do.
Do.	Ross, H.	1	do	2	Pit	Rocky Creek

(Continued on next page)

Table 3.--Records of brine production and disposal facilities in the Mexia, Negro Creek and Cedar Creek oil fields as of February 1962--Continued

Operator	Lease	No. of wells	Producing horizon	Brine production (bbls/day)	Method of brine disposal and remarks	Watershed
Hall, E. G.	Ross, J.	1	Woodbine	300	Pit, MS	Rocky Creek
Do.	Speer	3	do	12	Pumped into east Berthelson pit	Plummers Creek
Do.	Thomas	1	do	1	Pit, MS	Jacks Creek
Do.	Wilson	1	do	1	?	--
Do.	Winn	1	do	0	--	--
Hitt & McHargue	Gamble	2	do	480	Pits, MS to GS	Jacks Creek
Do.	Ross	1	do	325	Pits, MS to GS	Do.
Humble	Mexia Gas Unit	1	Smackover	3	Pit, NRD	Do.
Do.	Ross Heirs	1	do	3	Pit, NRD	Rocky Creek
Kelton, D.	Herod	1	Woodbine	300	Pit	Salt Creek*
Lytle, F. K.	Thompson	1	do	400	Pit, MS	Plummers Creek
Lytle-Holloway-Phillips	Atlantic	1	do	175	Brine pumped into pit on Roller lease	Do.
Lytle-Phillips	Mills, T. B.	2	do	800	Pit, MS	Do.
Do.	Roller	2	do	800	Pit, MS	Do.
Do.	Blake-Smith-Thompson	1	do	400	Pits, MS	Do.
Olson Brothers	Harris (16-1/2 acre)	1	do	400	Pumped into pit on lease, then into large pit on Berthelson lease	Rocky Creek and Plummers Creek
Do.	Harris (14-1/2 acre)	1	do	450	Do.	Do.
Do.	Slaughter	1	do	900	Pit, MS, overflows into Rocky Creek	Rocky Creek
Texas Alberta	Barham	2	do	435	Pits	Salt Creek*
Walker & Brookshire	Desenberg	2	do	300	Pits	Do.
Wiggins, Ben	Brotherton	1	do	2	?	--
	Totals	115		15,918 barrels per day		

Negro Creek Field

Operator	Lease	No. of wells	Producing horizon	Brine production (bbls/day)	Method of brine disposal and remarks	Watershed
Fisher	Yelverton	2	Woodbine	700	Pit, ERD; seepage from pits currently discharging	Negro Creek
Texas Alberta	Atkins	1	do	275	Pit, ERD; into Lake Mexia via Negro Creek	Do.
	Totals	3		975 barrels per day		

Cedar Creek Field

Operator	Lease	No. of wells	Producing horizon	Brine production (bbls/day)	Method of brine disposal and remarks	Watershed
Fisher	Reed	1	Woodbine	0	Not pumping at present; to be abandoned	--
Smackover Prod.	Ward	2	do	600	Pits, GS	Cedar Creek
	Totals	3		600 barrels per day		

Table 4.--Analyses of water samples in the area of the Mexia, Negro Creek and Cedar Creek oil fields

(Analyses given are in parts per million except specific conductance and pH)

Location No.	Source	Depth of Well (ft.)	Date of Collection	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Carbonate (CO_3)	Nitrate (NO_3)	Dissolved solids	Total Hardness as $CaCO_3$	Total Alkalinity	Specific Conductance (Micromhos at 25° C.)	pH
1	Plummers Creek	--	2-12-62	330	159	5,100	166	62	8,900	0	<0.4	16,000	1,480	136	34,250	8.0
2	Surface pit	--	do	420	207	11,500	290	0	19,300	0	<0.4	31,700	1,900	238	67,500	7.7
3	Surface pit	--	do	560	225	11,400	224	2	18,900	0	<0.4	32,900	2,325	184	70,000	7.8
4	Surface pit	--	do	510	231	11,800	415	3	19,800	0	<0.4	35,000	2,225	340	75,000	7.3
5	Jacks Creek	--	do	114	26	345	220	36	680	12	<0.4	1,564	390	200	2,300	8.6
6	Surface pit	--	do	420	164	9,800	305	1	16,300	0	<0.4	28,200	1,725	250	60,000	7.8
7	Lake Mexia	--	do	48	4	28	137	22	40	0	<0.4	316	135	112	465	7.8
8	Navasota River	--	2-13-62	182	29	175	488	310	160	0	<0.4	1,270	575	400	1,900	7.8
9	Surface pit	--	do	450	210	12,000	390	4	19,600	0	<0.4	32,600	1,990	320	70,000	7.8
10	Creek	--	do	570	219	11,400	329	10	18,800	0	<0.4	32,600	2,325	270	70,000	7.7
11	Navasota River	--	do	64	7	123	168	20	200	0	<0.4	640	190	138	1,055	8.0
12	Surface pit	--	3- 7-62	21,800	2,904	40,500	20	86	110,000	0	<0.1	178,000	66,600	16	380,000	5.7
13	Surface pit	--	do	560	204	12,200	405	3	21,000	0	<0.1	33,600	2,250	332	71,500	7.7
14	Ingram water well	30	do	1,160	192	2,350	547	1,730	4,800	0	<0.1	10,700	3,700	448	22,800	6.8
15	Surface pit	--	3- 8-62	540	180	10,600	400	7	18,500	0	<0.1	29,850	2,100	328	63,500	6.9
16	Spring	--	do	112	6	8	334	14	18	0	0.8	497	305	274	675	7.0
17	Little water well	25	do	1,400	252	1,860	361	1,300	5,200	0	<0.1	10,530	4,550	296	22,400	7.2
18	Martin water well	30	3- 9-62	80	11	36	293	18	34	0	<0.1	495	245	240	675	7.3
19	Spring	--	do	176	10	62	481	15	150	0	<0.1	920	480	394	1,370	6.8
20	Neal water well	--	do	152	7	17	407	14	42	0	3.5	507	410	334	845	7.5
21	McHargue water well	--	3-15-62	34	11	292	439	6	295	0	< .4	1,080	130	360	1,800	8.0

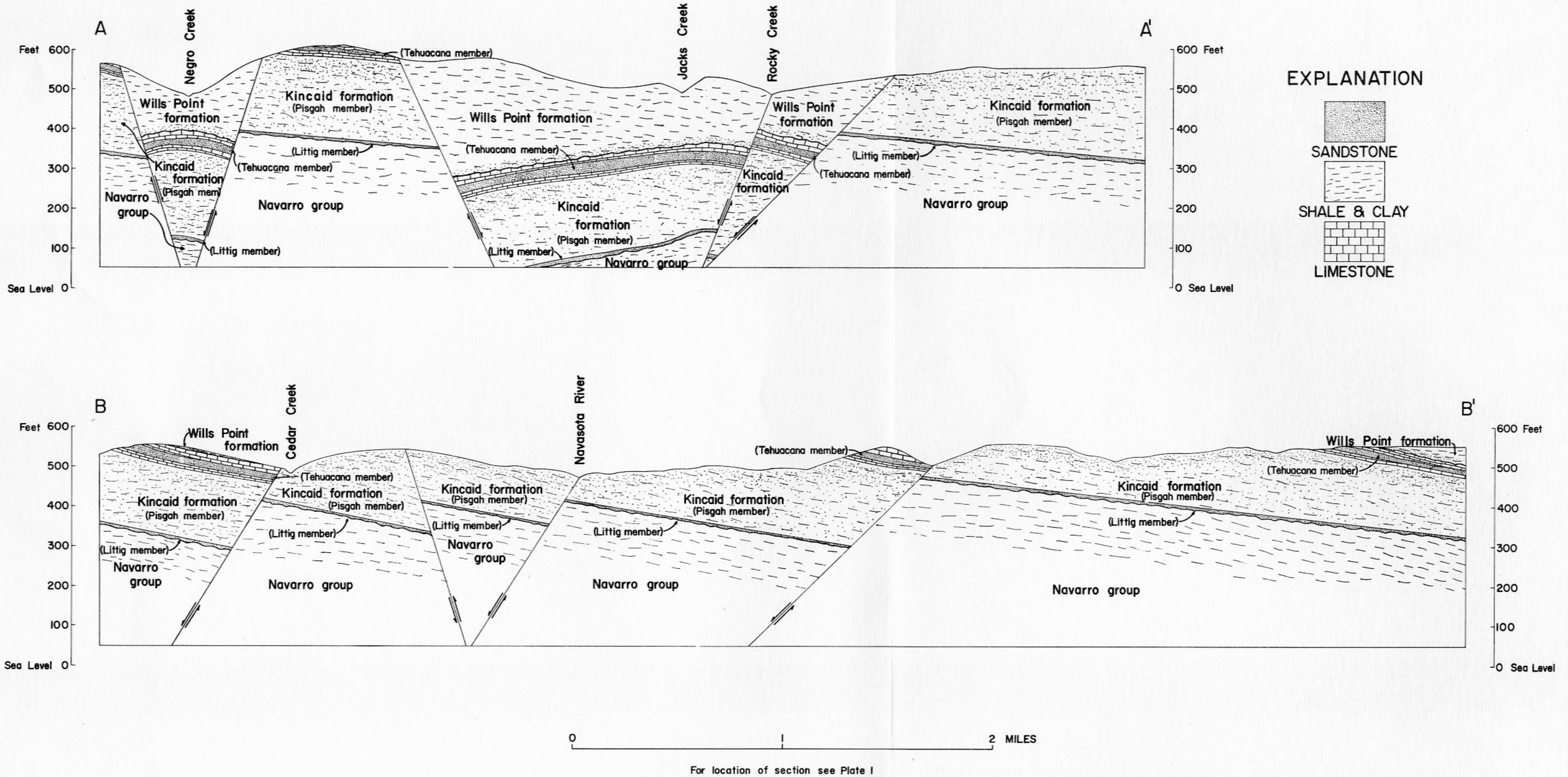
Table 5.--Measured geologic sections

Section of the Kincaid formation at its type locality at the town of Tehuacana (Sellards, Adkins and Plummer, 1932):

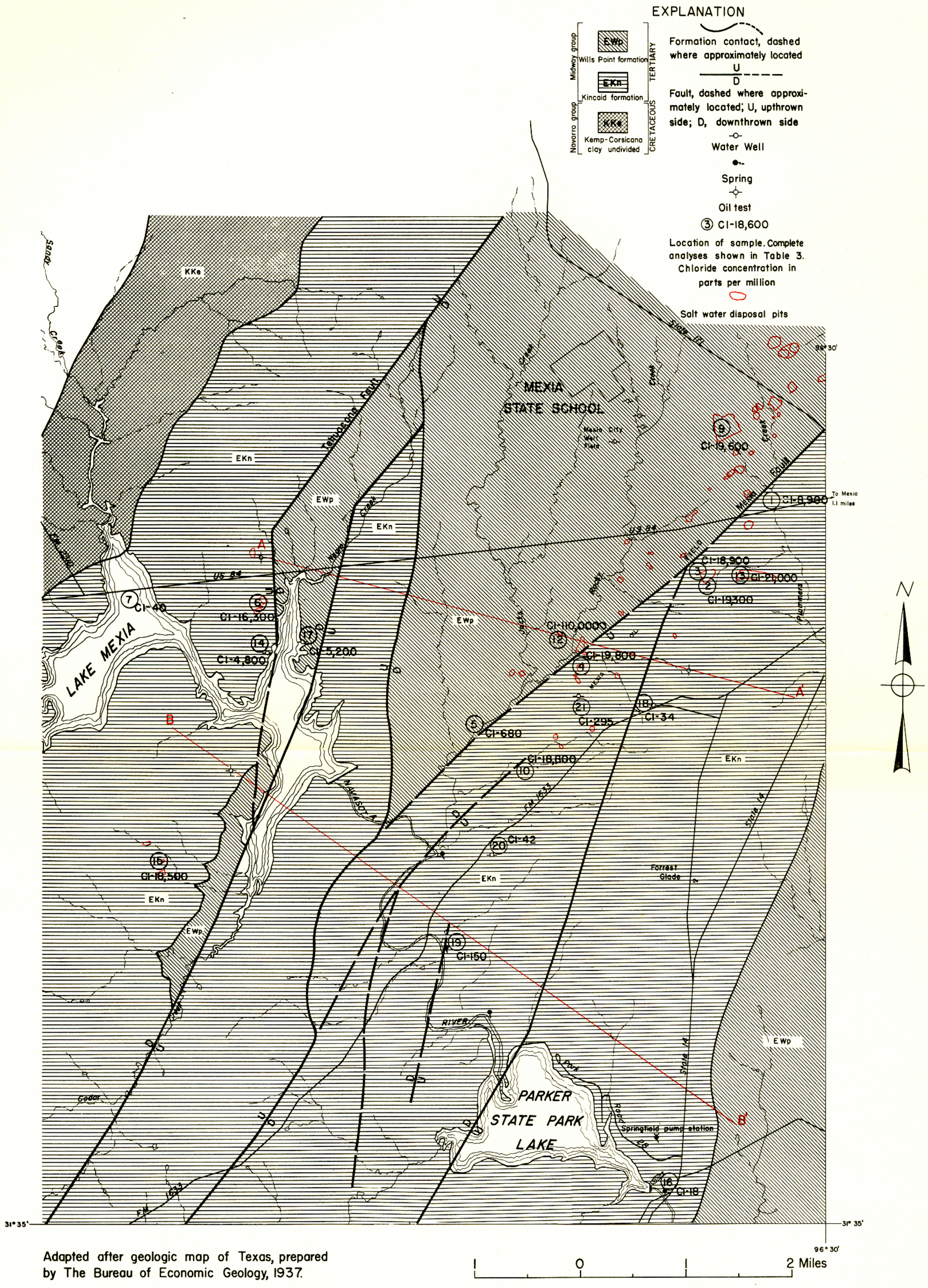
Bed	Description	Thickness (feet)
Pisgah member		
6	Tehuacana limestone lentil -	
	c. Limestone, grayish white, in places stained yellow and in other spots brown by water saturated by ferruginous matter. The rock is composed of a great mass of small and highly fragmental shell material cemented by calcite to form a coquina. Many of the shells are microscopic, so that the rock viewed from a distance of a few feet has the appearance of a rather solid and nonfossiliferous ledge. Viewed under the hand lens the small fragments comprise a mixture of finely broken shells, small ostracods, minute pelecypods, foraminifera, and other material. In places the ledge is much jointed, the joint lines running N. 55° E. and N. 35°W. and the planes being nearly vertical----------	20
	b. Sand, greenish yellow, fine grained, not well exposed------	20
	a. Limestone, light yellowish gray, fossiliferous, the lower ledge containing many large specimens of Ostrea crenulimarginata Gabb--	10
5	Sand, grayish yellow, glauconitic, meduim grained, fossiliferous. Contains large spherical concretions and in places lenticular ledges of consolidated sand-----------------	28
4	Clay, blue gray to black, weathering yellowish gray, very silty, in places sandy and fossiliferous, especially rich in microscopic forms--	30
3	Clay, bluish gray to black, weathering yellow, contains less silt than overlying strata and breaks with conchoidal fracture. Contains seams and numerous nodules of white, soft, amorphous gypsum. Contains many fragments of fossils and a rich foraminiferal faunule (Univ. Texas Bull. 2644, pp. 53, 54, fig. 11, Sta. 40)--------------------------	25
2	Clay, bluish gray, very soft, in some layers very thinly laminated, in others massively bedded. Very fossiliferous, contains both large and microscopic fossils. The larger shells are exceedingly fragile------------------------	25
Littig member		
1	Sand, yellowish gray, very fine, glauconitic in places, contains a few pebbles and black phosphatic nodules.	
	Total thickness measured	158

Measured section of part of the Wills Point formation formally exposed in a clay pit in Mexia (Sellards, Adkins & Plummer, 1932):

Bed	Description	Thickness (feet)
Wills Point formation		
5	Sand, light grayish yellow, silty, thinly and uniformly bedded, soft, micaceous, breaks readily along bedding planes to form small, thin, smooth plates of sand. Exposed in a ditch near the town of Cotton Gin------------------------	18
4	Silt or silty clay, grayish black, weathering to yellowish gray, poorly laminated, containing large, rounded, rough-surfaced concretions, and a few poorly preserved large fossils: the nautiloid Herocoglossa vaughani (Gardner), the ornamented gastropod Volutocoribs texana Gardner n. sp. (MS), a smooth naticoid, other very thin fragments of shell and formainifera. The silty clay grades upward into fine and more evenly bedded sand. Exposed along creek near New Hope near eastern line of Limestone County--------------------	15
3	Clay, light gray, stiff, breaks with an uneven and conchoidal fracture, poorly bedded. The partings along the bedding planes show thin streaks of fine micaceous silt. The silt runs through the clay in uneven wavy bedding lines. The clay weathers to form light sandy soils. Exposed in ditch 1-1/2 miles east of Mexia---------------------------------------	15
2	Clay, dark bluish gray, compact, breaks with conchoidal fracture and contains numerous small egg-shaped limonitic concretions and a layer of rock about a foot thick, made up of a large number of botryoidal bunches of impure aragonite crystals. Exposed in ditch on Mexia-Wortham road--------	?
1	Clay, dark bluish gray, breaks with conchoidal fracture and contains poorly preserved shells and shell fragments and a few hard oval-shaped concretions from 8 to 11 inches in thickness. The concretions are greenish yellow, extremely hard, and break with conchoidal fracture. The freshly broken surfaces show fine dendritic patches of black manganese. Thickness in Mexia clay pit-----------------	25
	(The total thickness of the section that includes these described exposures is estimated to be about 500 feet.)	
	Clay, not exposed.	



GENERALIZED GEOLOGIC SECTIONS OF THE MEXIA AREA



Adapted after geologic map of Texas, prepared by The Bureau of Economic Geology, 1937.

GEOLOGIC MAP SHOWING LOCATIONS OF BRINE DISPOSAL PITS AND CHLORIDE CONCENTRATION OF WATER SAMPLES IN THE MEXIA AREA