GROUND WATER IN LASALLE AND McMULLEN COUNTIES, TEXAS.

By Alexander Deussen and R. B. Dole.

INTRODUCTION.

Lasalle and McMullen counties lie near the center of the area commonly referred to as southwestern Texas, which includes that

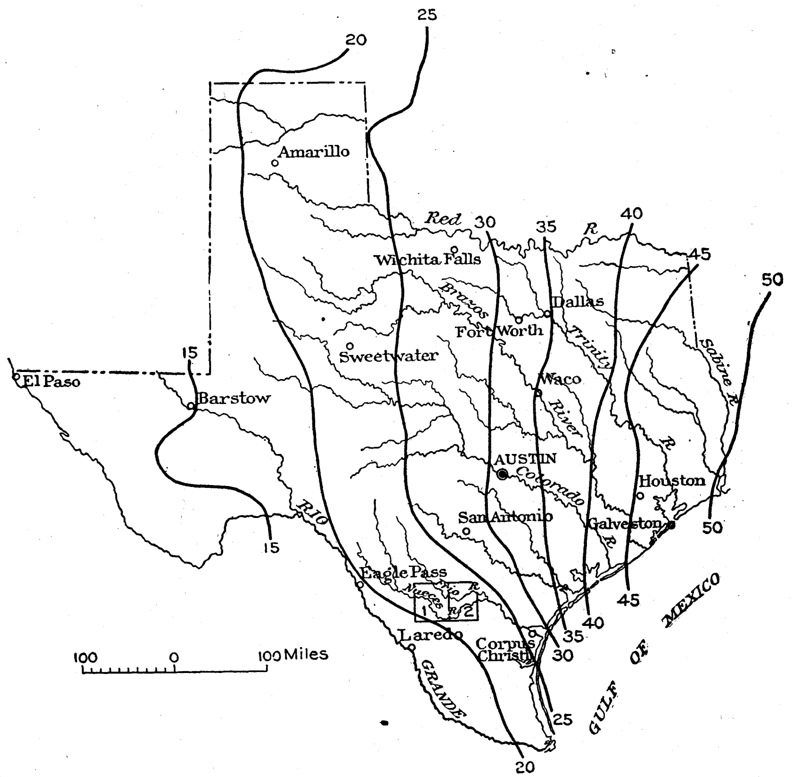


FIGURE 31.—Map of Texas showing location of Lasalle and McMullen counties and mean annual precipitation for the 20-year period 1895 to 1914, inclusive (prepared by the United States Weather Bureau). 1, Lasalle County; 2, McMullen County.

portion of Texas between Guadalupe River and the Rio Grande south of the Galveston, Harrisburg & San Antonio Railway. (See fig. 31.) The area of McMullen County is 1,180 square miles and that of

Lasalle County is 1,707 square miles; the combined area of the two counties is more than twice that of the State of Rhode Island. The two counties are drained by Nueces and Frio rivers and their tributaries. None of these are permanent streams, but all carry much water after heavy rains.

The average annual precipitation in the area is about 22 inches, irregularly distributed. (See fig. 31.) At Fort McIntosh, 64 miles south of Cotulla, according to records kept since 1871, the annual rainfall has ranged between 4.31 and 36.38 inches, and there have been periods of four months in which there was only a trace of rain; but in one month (August, 1879) 12.59 inches fell. In the years of greatly deficient rainfall unirrigated crops fail. During 34 years for which there is a complete record at Fort McIntosh there were 4 years in which the rainfall was less than 10 inches and 7 years in which it was less than 15 inches, but 24 years in which it was more than 18 inches.

This area is therefore in a semiarid belt, in which dry farming is to a certain extent practicable, although attended by many discouragements, but in which irrigation supplies are valuable where the water is of satisfactory quality. A small part of the arable land can be irrigated by sinking wells and by impounding storm waters, but most of the land if cultivated at all must be reclaimed by the intelligent application of dry-farming methods. An attempt to capitalize these lands at the same value per acre as the lands of the humid regions of the United States or to practice the same kind of agriculture will eventually fail. Until this fact is frankly recognized there can be no permanent agricultural development in the region.

In McMullen County there has thus far been very little irrigation. The best statistics obtainable indicate that in 1913 the total irrigated area in Lasalle County was 5,000 acres, the water being obtained from storage reservoirs on Nueces and Frio rivers and from flowing and nonflowing wells. Garden truck is chiefly grown, Bermuda onions taking first place.

Although the trucking industry has made considerable headway in Lasalle County during the last decade, it is at present languishing, the causes being (1) lack of cooperation among the producers, which prevents satisfactory marketing; (2) excessive land values, in consequence of which some of the irrigation plants are capitalized so high that even with skillful management and low operating expense it is impossible to realize reasonable interest on the investment; (3) poorly designed irrigation systems with consequent excessive operating expenses; (4) lack of experience by those who have attempted this kind of farming; and (5) use of ground water that is too heavily mineralized.

With the development of irrigation in Lasalle County, considerable interest has been aroused in the ground-water resources of the region, and inquiries are constantly being received by the United States Geological Survey concerning these resources. To meet this demand an investigation of the ground water of these two counties was made and an extensive report on the subject was prepared by the writers. The following brief paper is issued in advance of the complete report. The field work was done by Mr. Deussen, who also wrote the parts of the report dealing with physiography, geology, water-bearing formations, and irrigation with ground water. The analyses and assays of water were made by Mr. W. T. Read in the laboratory of the University of Texas. The part of the paper dealing with the chemical character of the water was written by Mr. Dole.

PHYSIOGRAPHY.

GENERAL RELIEF.

Lasalle and McMullen counties range in altitude from approximately 100 feet in the channel of the Nueces, on the east line of McMullen County to 630 feet on the west line of Lasalle County, north of the San Antonio, Uvalde & Gulf Railroad. They are a part of that great geographic province of North America known as the Atlantic and Gulf Coastal Plain. This broad plain slopes gently from an interior highland toward the sea and is characterized by low relief and wide river valleys. Near the coast it is nearly level, but in the interior it has been broadly though gently dissected and presents an undulating aspect. Lasalle and McMullen counties are in that part of the Coastal Plain west of Guadalupe River known as the Rio Grande Plain,[1] which in vegetal and climatic conditions is distinct from the area east of the Guadalupe.

Physiographically these two counties consist of uplands and valleys. The uplands may be divided into several parallel belts trending northeast, namely, Oakville Plain, Frio Plain, Wellborn Plain, Yegua Prairie, and Cook Mountain Plain. The valley lands include two groups of terraces in addition to the flood plains. On the uplands are remnants of a late Pliocene plain now nearly destroyed by erosion.

UPLANDS.

Uvalde Plain.—In the northwestern portion of McMullen County and to a less extent in the southeastern portion of Lasalle County there are extensive upland flats characterized by a sublevel topography and a

[1] Hill, R. T., and Vaughan, T. W., Geology of portions of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with special reference to the occurrence of artesian and other underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 202-203, 1898.

soil consisting of coarse brown flint gravel in a matrix of black clay loam. These areas may be designated as the Uvalde Plain. They are coextensive with the gravels mapped as the Uvalde formation. (See Pl. VIII.) The vegetation consists of scrubby chaparral and prickly pear.

Oakville Plain.—The Oakville Plain occupies the southeastern portion of McMullen County and is coextensive with the area marked as the outcrop of the Oakville sandstone on the geologic map (Pl. VIII). This plain is not peculiar to McMullen County, but is one of several parallel belts of country making up the Rio Grande Plain.

In form the Oakville Plain is a cuesta, which may be defined as a low ridge with a very gentle slope on one side and a steep slope or scarp on the other, the shape having been developed by erosion of a series of gently inclined alternating hard and soft strata. The southeastern part is sublevel to rolling; the northwestern part is dissected and therefore rugged and hilly.

The more level portions of this plain are characterized by residual dark-gray or dark-brown loam soils that carry a high percentage of organic matter. These soils in most places support a heavy growth of mesquite, chaparral, cactus, guajillo, and other native brush. Where the topography is more broken the soil is sparse, but the familiar, thickly set brush, collectively designated by the name chaparral, including black chaparral or "black brush," white chaparral or "white brush," cat's claw, guallacón (locally pronounced wy-can'), and guajillo, is everywhere present.

The dissected western margin of the plain is a scarp, which trends northeastward across the county, and the hills so conspicuous in the topography of the southeastern portion of McMullen County are part of this scarp. Among them may be mentioned Lomo Alto, near the Duval County line, Los Tiendos, and Chusas Hills. (See Pl. VIII.)

Frio Plain.—The Frio Plain adjoins the Oakville Plain on the northwest. It lies mostly south of Nueces River in McMullen County, though in the eastern part of the county it extends north of the river. It is coextensive with the area marked as the outcrop of the Frio clay on the geologic map (Pl. VIII).

The Frio Plain is a sublevel to rolling area, not greatly dissected or broken. Its soils are fertile residual dark-gray to dark-brown loams containing a high percentage of organic matter. A black clay-loam soil also occurs. The gray and brown loam soils support a thick growth of chaparral, but on the black clay loam chaparral is absent and open prairie prevails.

Wellborn Plain.—The Wellborn Plain lies northwest of the Frio Plain and parallel to it, forming a belt about 7 miles wide that extends diagonally across McMullen County from the southwest to the northeast corner. It is coextensive with the area marked as the outcrop of the Fayette sandstone on Plate VIII. The Wellborn and Frio plains together form a cuesta that has a gently sloping surface on the southeast side and a pronounced scarp on the northwest side.

The southeastern part of the Wellborn Plain is a rolling area, not very greatly dissected. The soils here are prevailingly dark-gray and dark-brown loams that carry large quantities of organic matter. The vegetation is characteristically chaparral, mesquite, and cactus.

The northwestern part of the plain is rough, broken country, constituting a range of hills that includes Opossum Hill, in the vicinity of Crowther, the hills in the vicinity of Tilden, the hills 7 miles southwest of Tilden, and the Busky Hills, about 14 miles southwest of Tilden. In the places protected from erosion the soils are dark loams, but in many localities there is practically no soil, the country rock being exposed at the surface. The chaparral, however, pervades the barren spots as well as the more fertile areas.

Yegua Prairie.—The Yegua Prairie, which is coextensive with the outcrop of the Yegua formation (Pl. VIII), borders the Wellborn Plain on the northwest and occupies the southeastern part of Lasalle County and much of the northwestern part of McMullen County. In some places it is gently rolling and in others almost flat. The prevalent soil is a fertile black clay loam containing a large amount of organic matter. This belt is mostly treeless, but is covered with grass and presents a pleasing contrast to the chaparral-covered plains so common in southwestern Texas. Owing to the lack of transportation facilities these lands are at present almost entirely devoted to ranching.

Cook Mountain Plain.—The Cook Mountain Plain lies northwest of the Yegua Prairie and occupies the northwestern half of Lasalle County. It is coextensive with the outcrop of the Cook Mountain formation. (See Pl. VIII.) Its surface is sublevel to rolling. The prevalent type of soil is a red or brownish-red fine sandy loam, underlain by a bright-red sandy clay subsoil of rather compact structure. The soil is well suited for the growing of garden truck and cotton. The native vegetation consists of a heavy growth of mesquite, chaparral, prickly pear, tasajillo, guajillo, cat's claw, etc., in places so thick that passage through it, except by cutting the way with an ax, is impossible. Another type of soil which occurs on this plain but which is much less widely distributed, is a black loam on a red clay subsoil. This soil is not so thickly set with the native brush as the sandy loam. The black-loam type of soil prevails in the immediate vicinity of Gardendale, north of the Nueces, and of Atlee, south of the Nueces.

VALLEY LANDS.

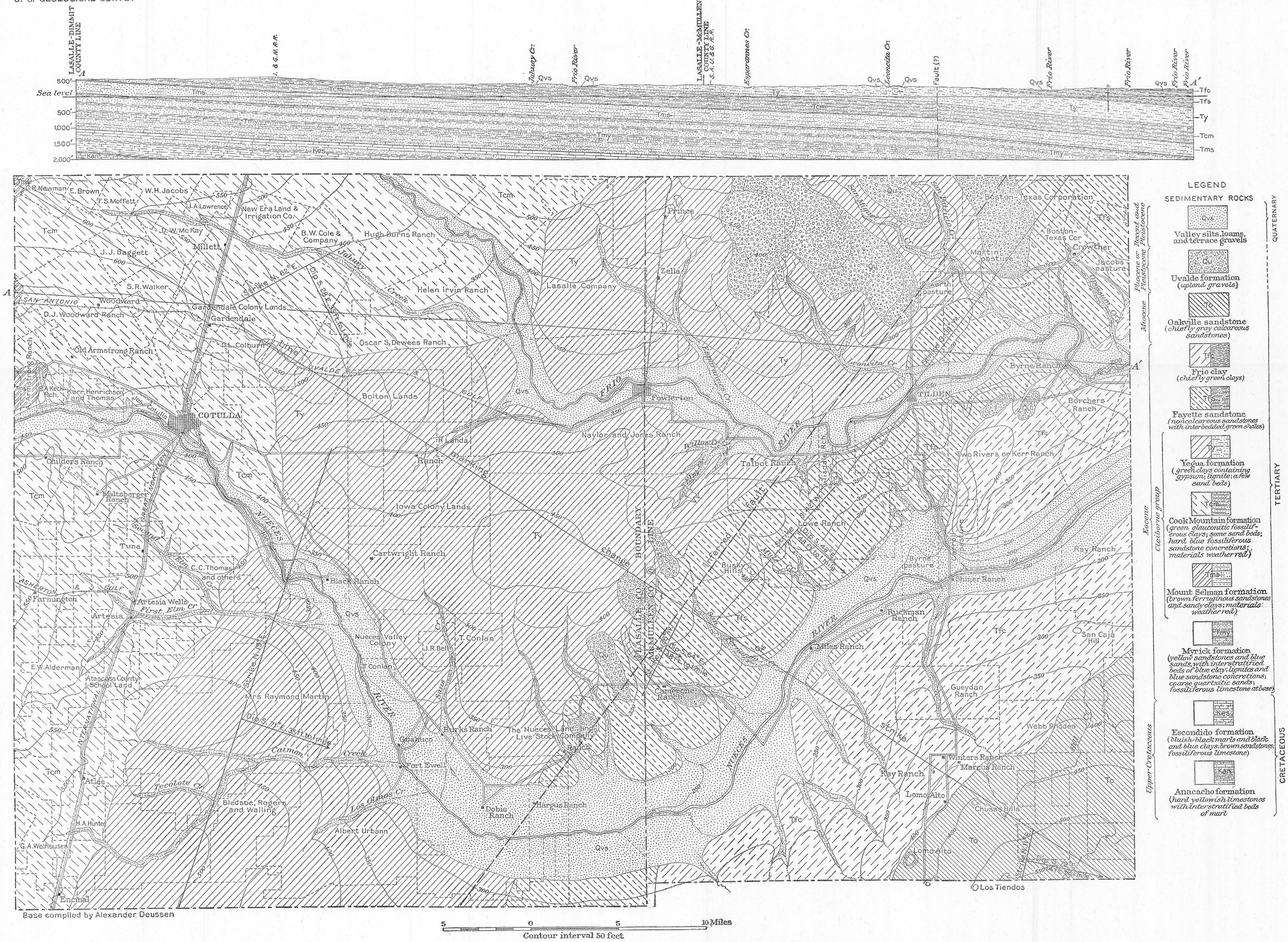
The valleys of Nueces and Frio rivers cut the upland plains, generally at right angles, the trend of the upland plains usually being northeast and the course of the valleys northwest. However, the valley of the Nueces in McMullen County and that of the Frio in the eastern part of McMullen County parallel the trend of the plains.

The uplands as a whole have a gradual and more or less uniform slope to the southeast, or in the direction of the Gulf. The profile of the valleys shows in general a similar slope, but the grade is not quite so steep. However, the valleys are 50 to 200 feet below the general level of the uplands. They have been partly filled with alluvium deposited by the streams. The valley lands are separable into three groups, differing in geologic age, in soil and vegetal conditions, and in their level with respect to the present stream channels.

Middle Pleistocene terrace.—What may be called the middle Pleistocene terrace stands at a level about 40 to 60 feet above the present stream bed in the Nueces and Frio valleys, in Lasalle and McMullen counties. This terrace occupies a comparatively small area, appearing at irregular intervals on both sides of the streams. The characteristic feature is the heavy coat of gravel, consisting largely of flint and forming the surface of the flat. The vegetation consists of chaparral, guajillo, cat's claw, prickly pear, etc.

Lowest Pleistocene terrace.—The lowest Pleistocene terrace is much more extensive than the terrace just described, constituting the main portion of the valleys of the two streams in the counties under consideration. It lies at a level 20 to 40 feet below that of the middle Pleistocene terrace. The lands of this terrace are nearly level and have been subject to very little erosion. The prevalent type of soil is a grayish-brown loam, rather high in silt and in places containing a large quantity of fine sand. The soil has a grayish and sometimes yellow appearance on the surface but appears much darker immediately below. An especially characteristic feature of these soils is the great number of Recent land shells scattered through them, causing the land to be locally known as "shell land." Nearly all the irrigation farms in the Nueces Valley in Lasalle County utilize these terrace soils for growing truck crops. A heavy growth of mesquite and prickly pear occupies these lands in their native state.

Overflow terrace or bottom.—The lowest terrace in these stream valleys lies at a level 10 to 20 feet below that of the lowest Pleistocene terrace, or about 10 to 15 feet above the present stream beds. This terrace is subject to overflow during periods of flood. The surface is level to gently undulating, but in places it is cut by so-called "bayous," representing abandoned channels of the streams or of tributaries discharging into them. A common soil of this terrace is a grayish-



GEOLOGIC MAP AND SECTION OF LASALLE AND McMULLEN COUNTIES, TEX.

brown to dark-brown silty clay loam underlain by a gray to slightly yellowish-gray or yellowish-brown silty clay loam, usually more compact than the soil. This soil supports a vigorous growth of mesquite, prickly pear, guajillo, tasajillo, several species of native grasses, and in places along the streams considerable live oak, pecan, hackberry, and sycamore. Another soil of this terrace is a dark-gray heavy plastic clay loam, varying somewhat in color according to the moisture content. On account of the high lime and humus content the soil when dry is loose and granular. When wet the color varies from dark drab to nearly black; when dry, from dark gray to slightly lighter shades. This soil in most places supports mesquite, prickly pear, and native grasses, but in the Nueces Valley from old Fort Ewell, in Lasalle County, to the Miles ranch, in McMullen County, it supports a heavy growth of sacahuiste grass, a tall, rank, coarse species. This portion of the Nueces Valley is locally known as the Sacahuiste Flats. The presence of the grass indicates the existence of salt in the soil.

GEOLOGIC OUTLINE.

General stratigraphy and structure.—The sediments exposed in Lasalle and McMullen counties comprise several formations belonging to two systems, the Tertiary and the Quaternary. (See Pl. VIII.) Deep wells also encounter formations belonging to the underlying Cretaceous system. The beds older than the Quaternary were originally almost horizontal but have been gradually elevated and tilted toward the Gulf. Since their elevation above the sea they have been subjected to erosion, those having the highest altitude and the longest period of exposure having suffered the most. The oldest and lowest formation exposed in these counties is therefore found along the west line of Lasalle County, at the greatest distance from the coast, and the youngest and uppermost formation, except the upland gravels and the valley deposits, is found in the southeast corner of McMullen County, at the least distance from the coast. The upland gravels and valley deposits were laid down after some tilting and erosion had taken place. In traveling from the southeast corner of McMullen County to the northwest corner of Lasalle County the geologist may inspect the entire series just as he could by descending a shaft sunk to the bottom of the series in the southeast corner of McMullen County. By thus determining the geologic section he can predict the sequence and character of the materials that would be encountered in sinking such a shaft or well. (See geologic section, Pl. VIII.)

An important feature in the geology of the area is a difference in the direction in which the formations dip on the opposite sides of a line extending from the northwest corner of Lasalle County to a point a short distance north of the southeast corner of McMullen

County, as suggested by the underground contours in Plate IX. North of this line in Lasalle County the older Tertiary formations (Yegua and older—see table below) dip S. 28° E., whereas south of it they dip S. 71° E. On both sides the rate of dip is about 35 feet to the mile. In central McMullen County the Frio, Fayette, and Yegua formations (see table below) dip S. 48° E. at a rate of 48 feet to the mile; in northeastern McMullen County the same formations dip S. 51° E. at a rate of 68 feet to the mile; in southeastern McMullen County the Oakville sandstone (see table, p. 149) dips S. 79° E. at a rate of apparently only 14 feet to the mile.

Faults.—A normal fault having a vertical displacement of probably 40 feet or less, downthrow on the east side, and a trend of N. 30° E., is believed to exist in northwestern McMullen County. This fault is believed to enter McMullen County approximately 8 miles north of the southwest corner and to leave it approximately 10 miles west of the northeast corner. (See geologic map, Pl. VIII.) No exposures were found which show the fault, but its existence is inferred on the evidence of well sections and the quality of the water. Along this line and in most of McMullen County east of it nearly all the ground water, both deep and shallow, is very salty. As the chemical composition of the strata from which the water comes is not such as would account for this condition and as water derived from the same formation elsewhere is not salty, it would seem that faulting along the line indicated has afforded opportunity for the ascent of salt water from much lower levels.

A second fault cuts across the southeastern portion of McMullen County in a direction N. 40° E. (See Pl. VIII.) It is exposed at Los Picachos Hill, in Duval County; its trend toward the northeast in Live Oak County is inferred.

Geologic section.—The formations that are exposed or have been reached in drilling are shown in the following table and are described briefly under the heading "Water-bearing formations" (p. 150).

Geologic formations of Lasalle and McMullen counties, Tex.

System.	Series.	Formation.	Thickness.	Lithology and characteristic fossils.
Quaternary.	Recent.		*Feet.* 0–20	Fluviatile deposits of black silt or loam composing low overflow terrace of Nueces and Frio rivers; also present flood-plain materials, sand and gravel bars.
	Pleistocene.	Lowest Pleistocene terrace.	1–30	Yellow to gray silt, containing great numbers of Recent land shells; on a foundation of limestone and flint gravel in places.
		Middle Pleistocene terrace.	1–30	Flint cobbles and pebbles, with some limestone and sandstone cobbles and pebbles.
		Highest Pleistocene terrace.	1–30	Flint cobbles, embedded in a lime matrix in some places, loose in others.
		Unconformity		
Tertiary or Quaternary.	Pliocene or Pleistocene.	Uvalde formation.	1–50	Upland gravels, waterworn brown flint pebbles, embedded in a lime matrix.
		Unconformity		
Tertiary.	Miocene.	Oakville sandstone.	150±	Gray sandstones, soft and highly calcareous in some places, hard and noncalcareous in others; some clay beds. Fossils: *Protohippus medius* Cope, *Protohippus perditus* Leidy, and *Protohippus placidus* Leidy.
		Unconformity		
	Eocene.	Frio clay.	660±	Green and pinkish-red compact jointed clay, with small lime nodules; concretions of siliceous limestone 4 to 12 inches in diameter stained with manganese; in lower part beds of brown marl with *Ostrea georgiana* Conrad. Of Jackson age.
		Fayette sandstone.	460±	Gray to yellow noncalcareous sandstones; flaggy sandstones near the center with *Tellina eburniopsis* and other fossils; brown and green compact shale; silicified wood very common. Of Jackson age.
		Claiborne group. Yegua formation.	600±	Green and brown shales, the latter with plant remains; beds of lignite; in places sand and sandstone; in the lower portion oyster beds with *Ostrea alabamiensis* Lea and green shales with masses of selenite.
		Claiborne group. Cook Mountain formation.	540±	Fossiliferous glauconitic marl with interbedded ferruginous glauconitic sands and sandstones; large concretions of fossiliferous sandy limestone; materials weather into red soils. Fossils: *Phos texanus* Gabb, *Turritella nasuta* Gabb, *Dentalium minutistriatum* Gabb, *Corbula smithvillensis* Harris, and *C. gregorioi* Cossman.
		Claiborne group. Mount Selman formation.	325–473	Ferruginous sands and sandstones or altered glauconite, with many rounded calcareous sandstone concretions, fossiliferous in places; beds of clay and shale. Fossils: *Cornulina armigera* Conrad.
		Myrick formation.	1,142±	At the top, yellow noncalcareous sandstones and blue sands, with interbedded blue shale; in the middle, yellow and blue shales, with beds of lignite, brown sandstone, and hard blue sandstone concretions, underlain by coarsely crystalline noncalcareous quartzitic white to yellow sands, which overlie yellow and brown sandstones with beds of lignite and sandy shale; these lower beds carry fossil leaves; at the base, fossiliferous limestone, clay, and sandstone with *Turritella mortoni* Conrad, *Ostrea pulaskensis*, *Ostrea crenulimarginata* Gabb, and *Venericardia perantiqua* Conrad.
		Unconformity		
Cretaceous.	Gulf.	Escondido formation.	700±	Bluish-black calcareous marls with interbedded black and blue clays, yellow-brown and brown sandstones, limestones, and oyster bed,. Fossils: *Exogyra costata* Say, *Ostrea cortex* Conrad, *Sphenodiscus pleurisepta* Conrad.

WATER-BEARING FORMATIONS.

Among the geologic formations underlying Lasalle and McMullen counties there are several extensive sandy beds separated by beds of impervious material, such as clay or shale. These sandy beds are in general saturated with water which enters at their outcrops and which supplies the artesian wells of these counties. A description of these artesian reservoirs follows.

ESCONDIDO FORMATION.

The Escondido formation, of Upper Cretaceous age, which underlies these counties but crops out farther northeast, rests on older Upper Cretaceous impervious clays and is covered by more or less impervious material at the base of the Eocene Myrick formation. It is on the whole a sandy formation in which water is stored. A well driven to the bottom of this formation will at various levels pass through sands that will supply water.

The catchment or outcrop area of this formation is in eastern Maverick and southern Uvalde counties. East and south of the catchment area the formation dips beneath the surface. At Carrizo Springs the top is 650 feet and the base 1,350 feet below the surface. At Cotulla the top is 1,830 feet and the base 2,530 feet below the surface.

The wells at Crystal City, in Zavalla County, are supplied by the Escondido formation. Sands belonging to this formation supply the Hidy well, 2 miles northwest of Crystal City, at a depth of 1,000 feet, and are found at a depth of 1,000 feet in a well 1 mile west of Brundage; at 1,000 feet in the well at Brundage; at 1,320 and 1,520 feet in the well half a mile west of Big Wells; at 1,510 and 1,660 feet in the Allen & Thomson well, 3½ miles southeast of Las Vegas; and between 1,919 and 2,414 feet in the well of Joe Cotulla, sr., 1 mile west of Cotulla.

At Cotulla water from the Escondido formation rises 460 feet above sea level, and at Crystal City about 600 feet. Flowing wells from these sands can be had over a considerable portion of Dimmit County, chiefly in the lowlands flanking the valley of the Nueces and in much of Lasalle County west of the International & Great Northern Railroad. The area of flowing wells is slightly larger in Dimmit and western Lasalle counties than the area indicated for the Myrick formation on Plate IX.

A number of wells have been driven to this formation and are drawing water from it in Dimmit and Zavalla counties, but so far the only well in Lasalle County deriving its supply from this source is the well of Joe Cotulla, sr., 1 mile west of Cotulla.

Detailed studies on the quality of the water from this reservoir have not been completed because the reservoir has not been exploited in Lasalle County, but preliminary studies indicate that these sands supply a calcium carbonate water of moderate mineral content suitable for boilers, domestic use, and irrigation. It is much better than the water obtained from other formations in Lasalle and McMullen counties.

Two samples of water were collected from the well of Joe Cotulla, sr., during the process of drilling one from the sands between 1,200 and 1,965 feet, and the other from the sands between 1,600 and 2,414 feet. The analyses (see analyses 39 and 40, p. 176) indicate that the lower water contains much less mineral matter than the upper. Both samples represent a mixture of water from the basal sands of the Myrick formation with that of water from the Escondido reservoir, and the water represented by the first analysis, owing to the method of casing, has had opportunity to mingle with the water represented by the second. If the lower sands in this well were completely segregated from the sands in the lower part of the Myrick and the upper sands of the Escondido, the well would probably yield much better water, which would compare favorably with that from these sands in portions of Dimmit and Zavalla counties.

As no ground water better adapted for irrigation can be obtained within the limits of Lasalle County, that from many wells being unsuited not only for irrigation but also for domestic and boiler use, it would be well worth while to make additional experiments in that portion of the county lying west of the International & Great Northern Railroad, with the view to determining definitely the extent of these sands and the quality of water in them. The chances are favorable for procuring from them in this portion of the county a supply of water that can be depended on for irrigation and other uses. It can not be too strongly emphasized, however, that in undertakings of this kind it is necessary to exclude completely from the well by proper casing all waters except those from beds near the base of the Escondido formation. Unless this is done success can not be expected.

East of the International & Great Northern Railroad these sands lie too deep to make their exploitation profitable, even if water of good quality could be obtained from them.

MYRICK FORMATION.

The Myrick formation is the artesian reservoir chiefly exploited in Lasalle County. The white, coarsely crystalline quartzitic sands lying between more or less impervious materials at the bottom and impervious clays in the middle of the Myrick formation constitute the water-bearing member. They will supply water to wells anywhere in Dimmit, Lasalle, and McMullen counties, but in eastern McMullen County the water is unfit for use.

The intake area is in eastern Maverick County and western and northern Zavalla County. (See Pl. IX.) East and south of this area the sand bed passes beneath the surface with a dip of about 35 feet to the mile. At Carrizo Springs these sands lie between depths of 230 and 530 feet, at Big Wells between 783 and 1,083 feet, at Cotulla between 1,480 and 1,780 feet, and at Fowlerton between 1,900 and 2,200 feet. The position of the base of this reservoir in Dimmit and Lasalle counties and northwestern McMullen County is indicated by means of contours on Plate IX.

Water-bearing sands are reported at a depth of 1,500 feet 1½ miles southeast of Woodward (well 100); 1,465 feet 1 mile east of Millett (well 96); 1,700 feet, more or less, at Gardendale; 1,600 feet 1 mile west of Cotulla (well 39); 1,560 feet, more or less, 1 mile northwest of Artesia (well 22); between 1,900 and 2,053 feet at Fowlerton (well 72); between 2,050 and 2,105 feet at Zella, 6½ miles north of Fowlerton (well 131); and between 2,986 and 3,002 feet 6¼ miles southeast of Tilden (well 128). All these sands belong to the Myrick formation.

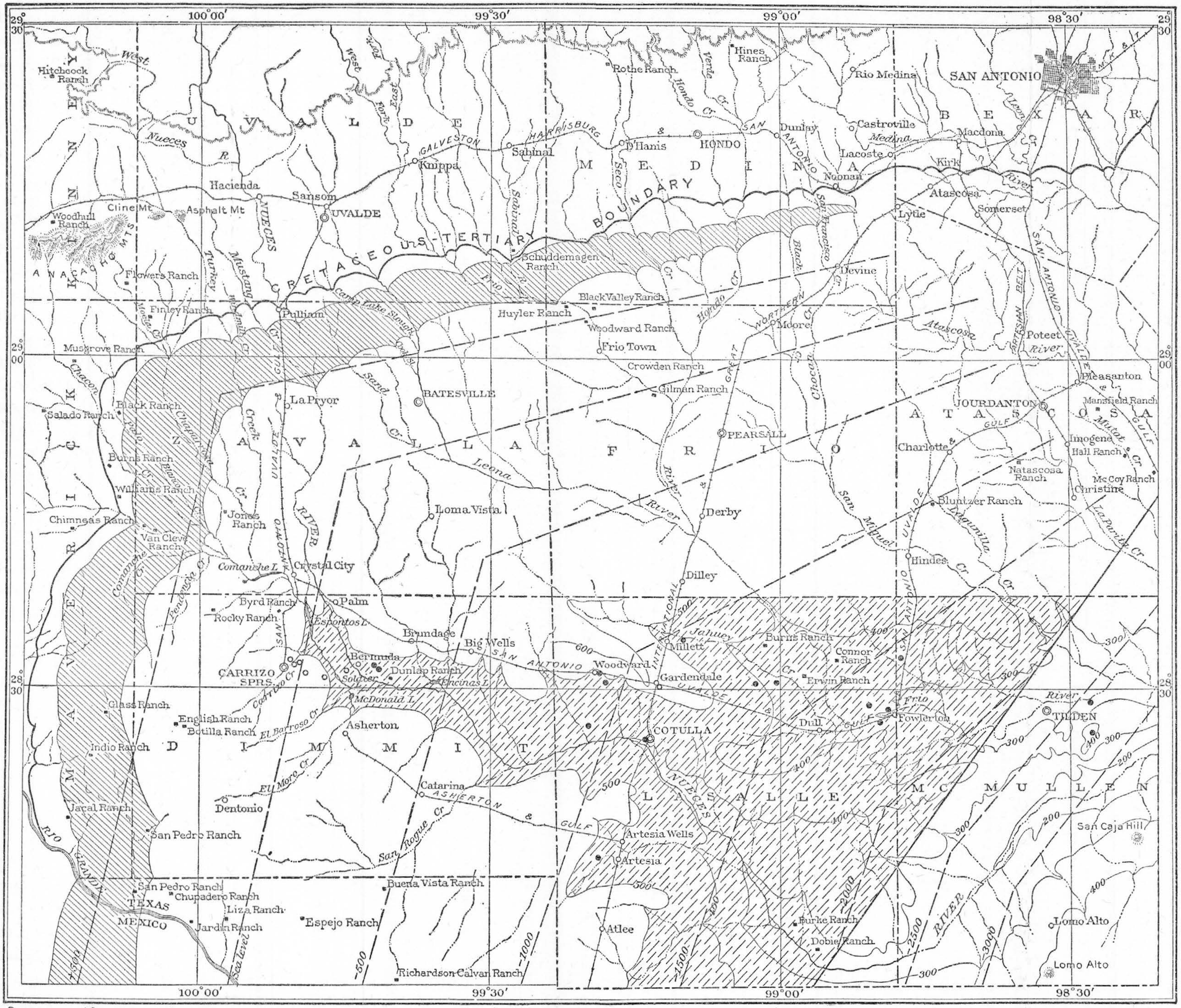
Flowing wells are obtained by tapping the sands of the Myrick formation over an area in Dimmit County that has roughly the shape of a triangle whose vertex appears on the Nueces near the Zavalla County line and whose base coincides with the east line of Dimmit County where the Nueces crosses the line, being on this boundary approximately 10 miles wide. Flowing wells may be obtained by drilling to these sands in nearly all of Lasalle County east of the International & Great Northern Railroad and in the northwestern half of McMullen County. (See Pl. IX.) Most of the deeper and larger wells of Lasalle County, such as the wells at Woodward, Gardendale, and Fowlerton, draw their supplies from these sands.

In the eastern half of Dimmit County and in all of Lasalle County the water from the Myrick formation is suitable for domestic use, but it is bad for boilers because of its tendency to foam. It is not adapted for irrigation without taking special precautions to prevent damage from alkali. In the greater part of McMullen County (all the territory east of the fault line shown on Pl. IX) the water is too salty for use.

MOUNT SELMAN AND COOK MOUNTAIN FORMATIONS.

The Mount Selman and Cook Mountain formations consist largely of porous sand, charged with water, confined between the impervious clays at the base of the Mount Selman and the clays of the Yegua formation. The formations constitute an artesian reservoir which supplies wells in Lasalle and McMullen counties, though in McMullen County the water is so highly mineralized that it can not be used.

The intake area of these two formations is coextensive with their outcrop in the western half of Lasalle County. (See Pl. VIII.) In



LEGEND

Intake area or outcrop of the lower part of the Myrick formation

Contour showing the position of the bottom of the Myrick formation. (Datum is mean sea level.) To find the depth necessary to penetrate these sands at any point in the area of availability, add the elevation of the ground to the number of the contour; the sum will be the required depth. Surface elevations can be ascertained from the contour map, Plate VIII

Fault line (inferred)

Area west of the fault line where flowing wells may be obtained by drilling to the Myrick formation in McMullen, Lasalle, and Dimmit counties, Tex.

Nonflowing wells supplied by the Myrick formation

Flowing wells supplied by the Myrick formation

In all the area west of the fault line water suitable for drinking and stock can be procured from these sands, if care is taken to case off the more highly mineralized water of overlying sands. This water is, however, not suitable for irrigation or for use in boilers. East of the fault line the water from these sands is salty and is not suitable for drinking, irrigation, or boiler use

Base prepared from a reconnaissance survey of south west Texas by Bureau of Soils U.S. Department of Agriculture 1911

10 0 10 20 30 Miles

MAP SHOWING THE MYRICK ARTESIAN RESERVOIR IN SOUTHWEST TEXAS.

the southeastern half of Lasalle County and in McMullen County they are covered by younger beds. At Cotulla these sands extend downward from the surface to a depth of 670 feet; at Fowlerton they are found between depths of 250 and 1,140 feet; and 6¼ miles southeast of Tilden they are encountered between 1,250 and 2,150 feet.

Water-bearing sands of these formations occur at a depth of 182 feet 3 miles west of Woodward (well 97); between 160 and 164 feet, 195 and 201 feet, and 260 and 290 feet 1½ miles north of Gardendale; at 60, 110, 330, and 650 feet in the vicinity of Cotulla; at 80, 140, 185, 200, 400, and 500 feet in the vicinity of Artesia Wells; at 36, 125, 270, 400, and 670 feet in the vicinity of Artesia; between 116 and 146 feet and at 200, 348, and 450 feet in the vicinity of Encinal; between 342 and 373, 495 and 523, 1,050 and 1,142 feet, 1½ miles west-northwest of Fowlerton (well 80); between 1,040 and 1,080 and between 1,391 and 1,476 feet 4½ miles east of Tilden (well 127); and at 1,155 feet at Crowther.

Flowing wells are obtained by tapping these formations on low ground along the line of the International & Great Northern Railroad, in the vicinity of Artesia and Artesia Wells, and in the Nueces Valley at Cotulla. They are not obtained at Encinal and Gardendale, owing to the higher elevation of these places. East of the railroad in the eastern half of Lasalle County and in McMullen County flows are usually obtained wherever these sands are penetrated, but in these districts the water is generally so highly mineralized that it can not be used.

These sands are developed for water chiefly along the line of the International & Great Northern Railroad, where the depths do not usually exceed 600 feet, where the pressure is good, in places being sufficient to produce flows, and where the water is usually of such a quality that it can be used for drinking and cooking. In eastern Lasalle County and in McMullen County no wells are finished in these sands because of the very poor quality of the water.

In western Lasalle County water from these sands is commonly of the sulphate or chloride type and is, as a rule, suitable for domestic use, as at Encinal, Artesia, Artesia Wells, and Gardendale, and the deeper water at Cotulla, but it is poor for boiler use and irrigation. In eastern Lasalle County and in McMullen County water from these sands is usually a highly mineralized sodium chloride water unfit for domestic use, boilers, or irrigation.

YEGUA FORMATION.

The Yegua formation includes a number of sandy strata which will yield water. The formation supplies wells in the southeastern half of Lasalle County and in McMullen County, but the water in nearly all these wells is so salty that it is nearly valueless. Cattle will drink the water from a few wells tapping this reservoir.

The outcrop area is in southeastern Lasalle County and in the northwestern half of McMullen County (see Pl. VIII), but the formation is covered by later beds in the southeastern half of McMullen County. At Fowlerton the Yegua formation extends from the surface to a depth of 250 feet; 6¼ miles east of Tilden it is found between depths of 625 and 1,140 feet. Water-bearing sands are found at various levels between these depths.

Water-bearing sands belonging to this formation occur also 1½ miles west-northwest of Fowlerton at a depth of 124 to 134 feet; at Zella, 6½ miles north of Fowlerton, between 110 and 115 feet; 5½ miles south-southwest of Fowlerton between 204 and 218 feet; 8 miles east-northeast of Tilden (well 125) between 563 and 620 feet; on the Byrne ranch, 8 miles east-northeast of Tilden (well 119), between 694 and 734 feet; and 1¼ miles south of Crowther (well 111) between 640 and 680 and between 820 and 840 feet.

The deeper sands on low ground usually produce flows. There are flowing wells supplied by these sands 4¾ miles southeast of Fowlerton, at Crowther, 5 miles southeast of Tilden (well 120), 8 miles east-northeast of Tilden (well 125), and on the Byrne ranch, 8 miles east of Tilden (well 119). All these wells are, however, without economic value because the quality of the water is such as to make it worthless for ordinary purposes.

FAYETTE SANDSTONE.

The name Fayette was first applied in Texas by Penrose in 1890 to deposits which are now subdivided into a number of formations. Dumble,[1] in 1892, separated the lower part of Penrose's Fayette and applied to it the name Yegua division, and in 1903[2] he made further discriminations. Kennedy,[3] in 1903, adopted the restricted definition for Fayette as proposed by Dumble. With the exception of Kennedy's 1893 report, in which the name Wellborn was used, all the reports dealing with this region since 1892 apply the name Fayette to the beds lying between the Yegua formation and the Frio clay.

Deussen[4] in 1914 made the following statements:

> The fossiliferous Vicksburg limestone, as developed east of Louisiana, does not outcrop in Texas, nor has it been found in wells so far as known. The investigations of G. C. Matson[5] have shown that the Vicksburg limestone of Alabama grades into sandstone toward the west. Sandstone replaces the upper part of the Vicksburg in western Alabama, more of it in Mississippi, and still more in eastern Louisiana, and in

[1] Dumble, E. T., Report on the brown coal and lignite of Texas: Texas Geol. Survey, pp. 124, 148, 154, 1892.

[2] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, p. 922, 1903.

[3] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, p. 21, 1903.

[4] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 69, 70, 1914.

[5] Unpublished notes.

western Louisiana it replaces the whole Vicksburg, and even some beds of Jackson age are lithologically similar and apparently can not be separated.

As here interpreted, the Catahoula sandstone is a lithologic and stratigraphic unit which transgresses several biologic zones. Stated differently, it is conceived to be of different ages and to have been laid down at different epochs in the respective regions of its occurrence. In central Texas, in the region of the Brazos, it is largely of Jackson age. In eastern Texas it is largely of Vicksburg age. According to Matson the vertical transgression continues across Louisiana into Mississippi, where the formation lies above the Vicksburg limestone.[1]

The term Fayette is used in the present paper in the restricted sense in which it was applied by Dumble and Kennedy, and the deposits so called are the stratigraphic equivalents of the beds that were designated Wellborn by Kennedy in 1893. They are of Jackson age, occupying a part at least of the time interval of the fossiliferous marls and clays of the typical Jackson formation to the east.

The Fayette sandstone is a water-charged reservoir confined between the impervious clays of the Yegua at the base and the Frio clay at the top. This formation supplies wells in the southeastern half of McMullen County, but the water is in most places so highly mineralized that it can not be used.

The intake area is a northeastward-trending belt extending through the center of McMullen County. (See geologic map, Pl. VIII.) The formation dips underground beneath later formations in the southeastern half of this county. At Tilden it extends from the surface to a depth of 102 feet; at the Byrne ranch, 8 miles east of Tilden, it is encountered between depths of 25 and 410 feet.

Water-bearing beds of this formation occur at a depth of 100 feet 1 mile northeast of Crowther; between 280 and 300 feet 9½ miles east of Tilden; at 135 feet 12 miles east of Tilden; between 110 and 175 feet and between 330 and 360 feet 8 miles east-northeast of Tilden (well 119); and at about 350 feet 5 miles N. 20° E. from Lomo Alto.

Flows have been obtained from the deeper sands on low ground 9½ miles east of Tilden; 12 miles east of Tilden; and on the Byrne ranch, 8 miles east of Tilden (well 119).

Owing to the poor quality of the water from the deeper wells in this formation very little use is made of such wells, but some of the shallower wells are used for domestic purposes.

The water supplied by the sands of this formation is in most places (particularly in the district north of Frio River) so salty as to be unfit for drinking, for boilers, or for irrigation. Two shallow wells in the district south of Tilden (see analyses 115 and 116, p. 177) yield carbonate waters of moderate mineral content, good for domestic use, poor to fair for boilers, and poor or fair for irrigation.

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[1] Studies made by the author since this report was written seem to indicate that the Catahoula sandstone as here described is not a stratigraphic unit but comprises two formations of similar lithologic character, the one at the base being of Jackson age, whereas the upper sandstone is of Oligocene age. The name Wellborn was applied by Kennedy to the lower of these two sandstones.

FRIO CLAY.

The Frio clay contains some sand beds that would supply wells, but the water is probably too highly mineralized for use. So far as known there are no wells in McMullen County supplied from this source at present. The deposits are, like the Fayette sandstone, of Jackson age.

OAKVILLE SANDSTONE.

The Oakville sandstone crops out in the extreme southeastern part of McMullen County (see Pl. VIII), but as a source of water it is unimportant in this section. Where it is of considerable thickness, as near the corner of the county, it doubtless contains sufficient water to supply wells, but apparently no wells have been driven to it in McMullen County, and little is known concerning the quality of its water. So far as geologic data and some preliminary studies on the water supply of Live Oak and Duval counties indicate, the water from these sands is potable, though it is not well suited for boilers or for irrigation.

LATE PLEISTOCENE GRAVELS.

The gravels at the base of the lowest Pleistocene terrace on the streams in some places supply water permanently or intermittently to such shallow wells as penetrate them. Wells driven to them do not exceed 50 feet in depth, and their supplies are local and not dependable. In most places the water is very poor, owing to the high evaporation and consequent concentration of the salts, but in some places it is of fair quality.

At Shiner's ranch house, 10¾ miles S. 10° E. from Tilden, there is a well 22 feet deep supplied by these gravels with potable water, and a quarter of a mile east of Tilden there is a well 31 feet deep (well 113) supplied by these gravels with water that is potable but poor for boiler use and irrigation.

CHEMICAL CHARACTER OF THE WATER.

GENERAL CHARACTER.

The analyses in the table on pages 175–177 indicate that strongly mineralized alkali waters abound in Lasalle and McMullen counties. Almost all the waters tested exceed 500 parts per million in total mineral content, and nearly two-thirds of them exceed 2,000 parts. Sulphate and chloride waters predominate. Though only about one-quarter of the supplies are classed as sodium carbonate, more than half contain notable amounts of black alkali. Because of this generally excessive mineral content a large proportion of the waters are poor supplies, many being unfit for use. Drinkable waters have been found in many places, and a few are only moderately high in mineral content. In general, however, the region affords supplies carrying excessive contents of alkali. The waters must be called poor for use in boilers, because they would cause excessive foaming, though they would probably not be corrosive nor would they form much scale. The content of alkali of most of them is too great to render it advisable to irrigate with them, and many are unfit for such use.

QUALITY IN RELATION TO GEOLOGIC STRATA.

The superior quality of water from the Myrick formation in Dimmit County, west of Lasalle County, indicates that that formation might afford the best supplies throughout Lasalle County. This indication is supported somewhat by the relatively low mineral content of water from the Myrick at Zella and one or two other places; but as several deep wells believed to be supplied chiefly from the Myrick yield strongly mineralized water, it would seem uncertain whether the deep strata can be depended upon to furnish supplies uniformly better than those in the upper strata. Possibly poor waters from the upper strata, not being entirely shut out from the casings of the deep wells, mix with the better deeper waters; on the other hand, the deep strata may contain supplies of different concentration from place to place. The available information indicates that the waters of the Myrick increase in mineral content toward the east and that those in that formation in eastern McMullen County are strong salt waters unfit for use.

QUALITY IN RELATION TO GEOGRAPHIC POSITION.

The waters that were tested around Encinal, in the southwestern part of Lasalle County, come from the Cook Mountain formation at depths of 120 to 500 feet. They are highly mineralized sodium sulphate waters, generally poor for domestic and boiler use and for irrigation. They are fairly but not excessively hard, though they are high in alkali. The best waters tested in this vicinity are from a 300-foot well 1½ miles west of Encinal (analysis 47) and from a 284-foot well 7 miles northwest of Encinal (analysis 53). Though both are rather hard, they are of fairly good quality for domestic and industrial use, and neither contains an excessive quantity of alkali.

The numerous waters from the Cook Mountain formation and around Artesia and Artesia Wells are sodium sulphate in character, but they are not so highly mineralized as those around Encinal. They are generally better for domestic use but poor for irrigation and for boiler feed, chiefly because of their high content of alkali. Two of the waters from the Mount Selman formation in the same locality are somewhat similar in quality to those from the Cook Mountain formation, though one well supposed to tap the Mount Selman formation (analysis 21) yields a very hard calcium sulphate water that is bad for domestic use and unfit for boilers. The only water tested from the deeper part of the Myrick in this vicinity (analysis 22) is salty and unfit for use.

Wells at Cotulla, 100 to 300 feet deep, drawing chiefly from the Cook Mountain formation, yield sodium sulphate and sodium chloride waters that differ widely in quality. Some are fair for domestic use, but most are poor for irrigation and bad for use in boilers. Some wells, 1,800 to 2,500 feet deep, drawing from the Myrick formation yield less strongly mineralized waters, which are nevertheless poor for general use. A 2,424-foot well 1 mile west of Cotulla (analysis 40) yields, however, a soft water that is exceptionally low in mineral content and good for domestic use but poor for irrigation.

Shallow wells around Gardendale, drawing from the Cook Mountain formation, yield alkali waters ranging in mineral content from 900 to 2,600 parts per million. The supplies are generally fair or poor for domestic use, poor for irrigation, and poor for use in boilers. One water (analysis 95) from the Myrick, containing only 1,146 parts per million of total solids, is a fair domestic supply, though it is poor for irrigation.

At Fowlerton, on the Lasalle-McMullen county line, farther east than the places already mentioned, waters from the Cook Mountain formation are much more strongly mineralized. Those tested range in mineral content from 4,600 to 8,500 parts per million and are salty alkali waters unfit for use. The waters tested from the Mount Selman formation in the same neighborhood are somewhat better, ranging in mineral content from 1,200 to 6,000 parts per million. Most of them are, however, too strongly mineralized to be useful and must be classed as unfit for irrigation. The waters tested from deep wells entering the Myrick formation near Fowlerton are generally the lowest in mineral content. With two exceptions they contain about 2,000 parts per million of mineral matter and are not good supplies because of their carbonate character. One well tapping the Myrick southwest of Fowlerton (analyses 85 and 86) yields water unfit for use, as it contains more than 4,000 parts per million of solids. Another well recently drilled to the Myrick at Zella (analysis 131) yields distinctly better water that is good for domestic use, though poor for boiler use and for irrigation. These marked differences in the quality of water from wells supposed to draw from the same horizon in a relatively small area indicate either that water from upper strata finds access to the supplies or that the basal sands are not homogeneous.

The waters tested from deep wells near Tilden are distinctly bad. That from a well (analysis 126) entering the Cook Mountain formation (?) is salty and unfit for use. Two from wells tapping the Yegua formation (analyses 119 and 122) also are too strongly saline to be usable. A deep well entering the Myrick formation near Tilden yields similar water. Two shallow wells drawing from the Fayette sandstone south of Tilden afford waters of exceptionally low mineral content (analyses 115 and 116).

The composition of the few waters tested near Crowther indicates that deep wells drawing from the Yegua formation will yield salt waters unfit for use. The best water tested from this locality comes from a well about 100 feet deep (analysis 104) in the Fayette sandstone. The water is highly mineralized and of bad quality. The general indications are that deep wells in McMullen County will yield poorer waters than deep wells in Lasalle County. Though no analyses of water from the Myrick formation in eastern McMullen County are available, the water of one well entering that formation on the Kerr ranch, southeast of Tilden, is salty. It is probable that the Myrick contains salt water throughout eastern McMullen County.

QUALITY FOR DOMESTIC USE.

Waters that do not exceed 200 parts per million in total hardness and do not contain enough mineral matter to have a disagreeable taste are acceptable for drinking and cooking, though some of them might not answer all requirements of a good municipal supply. Hardness greater than 1,500 parts renders water undesirable for cooking, and water much softer than that consumes excessive quantities of soap in washing. Approximately 250 parts per million of chloride makes a water taste slightly salty. Somewhat less of the carbonate and somewhat more of the sulphate are detectable by taste. Yet though the lower a water is in mineral content the more acceptable it is as a source of domestic supply, the amount of dissolved substances that can be tolerated is much greater than is ordinarily believed. Alkaline carbonates apparently are most injurious, alkaline sulphates are least injurious, and alkaline chlorides occupy an intermediate position. Drinking water containing more than 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate is unhealthful to most people. On these bases a sodium chloride water showing more than about 3,000 parts per million of mineral matter or a sulphate water showing more than 3,500 parts of mineral matter is reasonably classed as unfit for domestic use. The most obvious effect of drinking water too high in mineral content is usually diarrhea.

The total mineral content or dissolved solids of waters that were assayed has been estimated by the following formula:

$$\text{Dissolved solids} = 30 + 1.73CO_3 + 0.86HCO_3 + 1.48SO_4 + 1.62Cl.$$

The symbols represent the amounts in parts per million of the constituents determined by field assay, 30 being arbitrarily added for silica. In most of the results the figure for dissolved solids thus calculated does not equal the sum of the estimated scale-forming and foaming constituents (s+f). This disagreement is caused partly by error of assay, which is magnified by the methods of computation; it is caused mostly, however, by the necessary assumptions in the formulas, which, though they may cause some large numerical differences, do not destroy the comparative usefulness of the estimates. The total hardness as $CaCO_3$ of waters for which that determination was not made has been estimated thus: $H=2.5Ca+4.1Mg$. The waters have been classified as to mineral content by the following rating:

Rating for total solids.

Total solids (parts per million).		Class.
More than—	Not more than—	
....	150	Low.
150	500	Moderate.
500	2,000	High.
2,000	....	Very high.

The chemical character of the waters is suggested by expressing in symbols the predominant acid and basic radicles. The designation calcium (Ca) indicates that calcium and magnesium are predominant among the bases, and sodium (Na) that sodium and potassium are predominant, the application of either term being an assumption of the presence of the minor base; similarly the use of carbonate (CO_3), sulphate (SO_4), or chloride (Cl) shows which acid radicle is predominant. Combination of the two designations classifies the water by type; for example, the combined designation "sodium chloride" (Na–Cl) indicates that the water is a salt water; the designation Ca–SO_4 represents a gypsiferous water.

The rating under the heading "Quality for domestic use" is based entirely on the mineral content of the supplies and has no reference whatever to the possibility of pollution by sewage or other dangerous waste. As no bacteriologic examinations of the waters or sanitary inspections of the surroundings of the wells were made, no opinion as to the hygienic quality of the supplies can be given except in relation to their content of mineral matter. The waters in the table of analyses (pp. 175–177) classed as unfit for domestic use are too strongly mineralized to be drinkable; they exceed 1,500 parts per million in content of chlorine or 2,000 parts in content of sulphate, or are high in these constituents and also exceed reasonable limits in their contents of carbonate and bicarbonate. The waters classed as bad closely approach the limits of potability. Most of those classed as poor are drinkable but have a distinct taste of alkali or are excessively hard. Most of those classed as fair have little or no distinct taste but are too hard to be entirely acceptable.

About one-third of the ground waters tested in these two counties may be considered good or fair for domestic use and slightly less than one-half are bad or unfit. About half the wells supplied chiefly from the Cook Mountain formation yield waters that may reasonably be considered good or fair. The proportion of good waters is somewhat smaller for the Myrick formation, though some of the best supplies are from that formation. In general, the waters of the Myrick are lower in sulphate and chloride than those of the Cook Mountain, but rather higher in carbonate and too high in total mineral content to be satisfactory.

QUALITY FOR IRRIGATION.

Water that contains much alkali is injurious to crops, because through evaporation the alkali gradually accumulates in the upper layers of the soil and eventually becomes so strongly concentrated that it is poisonous. The comparative value of the waters for irrigation has been estimated by applying the formulas developed by Stabler [1] for calculating the "alkali coefficient," which is defined by him as the depth in inches of water which on evaporation would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops. Whether injury would result from the application of that quantity to any particular piece of land depends on several factors besides the alkali coefficient, namely, methods of irrigation, the crops grown, and the character of the soil and drainage conditions, and it should be clearly understood that the alkali coefficient takes no account of such factors. Waters relatively high in their content of alkali may be used without damage on a loose soil with free drainage, and some with still greater content of alkali may be applied to carefully selected land that is thoroughly underdrained by tiling or some similar means.

The alkali coefficients (k) computed by means of the following formulas are given in the tables of analyses:

$$k = \frac{2{,}040}{Cl} \text{ if } Na - 0.65\,Cl \text{ is zero or negative.}$$

$$k = \frac{6{,}620}{Na + 2.6Cl} \text{ if } Na - 0.65\,Cl \text{ is positive but not more than } 0.48\,SO_4.$$

$$k = \frac{662}{Na - 0.32Cl - 0.43SO_4} \text{ if } Na - 0.65Cl - 0.48SO_4 \text{ is positive.}$$

The value of sodium (Na) for use in these formulas has been computed from the results of the field assays by means of the formula $Na = 0.41HCO_3 + 0.83CO_3 + 0.71Cl + 0.52SO_4 - 0.5H$, in which H represents the total hardness as $CaCO_3$.

[1] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 177, 1911.

The value of the waters for irrigation has been expressed in words by use of the following classification, which is based on ordinary irrigation practice in the United States:

Classification of irrigation waters.

k.	Class.	Remarks.
More than 18	Good	Have been used successfully for many years without special care to prevent alkali accumulation.
18 to 6	Fair	Special care to prevent gradual alkali accumulation has generally been found necessary except on loose soils with free drainage.
5.9 to 1.2	Poor	Care in selection of soils has been found to be imperative and artificial drainage has frequently been found necessary.
Less than 1.2	Bad	Practically valueless for irrigation.

Though a few scattered waters in Lasalle and McMullen counties might be considered fair for irrigation, most of the waters contain too much alkali to make it advisable to irrigate with them, and many are unfit for that purpose. The salt waters that might perhaps be used would have to be applied with unusual and expensive provisions for drainage in order to prevent the accumulation of alkali, and the large quantities that would have to be applied frequently in order to prevent concentration of alkali by evaporation would doubtless render pumping out of the question.

Two-thirds of the waters tested are classed as poor, only four as fair, and none as good for irrigation. Nearly half exceed 2,500 parts per million in their estimated content of mineral matter, and one-quarter exceed 4,000 parts. In other words, though a few waters have been found that might be applied to land without causing undue accumulation of alkali, the majority could not be used for any length of time under ordinary conditions of irrigation. It should be understood that these statements refer only to the character of the waters themselves and not to the condition of the soils that are irrigable or the crops that might be planted.

Artesian waters carrying very great quantities of soluble matter are used for irrigation in certain oases of Sahara Desert,[1] where vegetables sensitive to alkali are successfully irrigated with water containing as much as 8,000 parts per million of soluble salts, half of which in some waters is sodium chloride. That concentration is equivalent to about 2,400 parts per million of chlorine. Twelve of the ground waters examined in Lasalle and McMullen counties contain more than that amount of chlorine, and several others contain at least half as much. Special attention may be called to the fact that thorough drainage and frequent irrigation with very large quantities of water are essential where water having a high content of salt is

[1] Means, T. H., The use of alkaline and saline waters for irrigation: U. S. Dept. Agr. Bur. Soils Circ. 10, July 1, 1903. See also Proceedings of first conference of engineers of the Reclamation Service: U. S. Geol. Survey Water-Supply Paper 93, p. 255, 1904.

applied to land in order that accumulation of alkali may not destroy the fertility of the soil. Such notable decrease in the duty of water is particularly expensive, and the value of the crops must be high to justify the additional cost of drainage.

It has been suggested that highly mineralized waters may be safely used for irrigation where land is relatively cheap by rotation of the fields irrigated. A field may be irrigated one or two years, after which it is planted for two or three years to crops that do not require irrigation. This resting of the soil during the interval in which it is not irrigated is believed to give the soluble alkali salts a chance to be leached out with the aid of the rainfall. After the land has rested for some years it is again planted to irrigated crops. It may be possible to use in this way some of the strong waters of this area without injury to the crops, but whether they can thus be profitably utilized will depend on the cheapness of the land and the ease with which the water can be obtained. Much land is of course required under these conditions, and the expense of ditching and furrowing the larger tracts is greater than that with a water free from alkali.

QUALITY FOR BOILER USE.

The chief troubles caused by mineral matter in waters used in boilers are scale formation, foaming, and corrosion. When water is heated under pressure and concentrated by evaporation, as in a steam boiler, certain substances go out of solution and solidify on the flues and crown sheets or within the tubes. These deposits of scale or sludge increase fuel consumption because they are poor conductors of heat, and they also increase the cost of boiler repairs and attendance because they have to be removed. If the accumulation is too great the boiler may explode. Corrosion is caused by the solvent action of acids on the iron of the boiler, and acids freed in the boiler by the deposition of basic radicles as hydrates are probably the chief cause of corrosive action. Foaming is the formation of masses of bubbles on the surface of the water and in the steam space above the water, and it is intimately connected with priming, which is the passage from the boiler of water mixed with steam. Foaming usually results when the concentration of alkali salts or of suspended matter in the boiler becomes too great.

The following formulas, adapted from those of Stabler,[1] have been used for computing the probable scale-forming ingredients (s), the probable foaming ingredients (f), both in parts per million, and the tendency to cause corrosion (c). If silica (SiO_2) was not reported the value 30 has been arbitrarily used for it in the first formula.

$$s = SiO_2 + 2.95\ Ca + 1.66\ Mg.$$

$$f = 2.7\ (Na + K).$$

[1] Stabler, Herman, op. cit., p. 171.

c.—If $0.0828\ Mg - 0.0336\ CO_3 - 0.0165\ HCO_3$ is positive the water is corrosive (C). If $0.0828\ Mg + 0.0503\ Ca - 0.0336\ CO_3 - 0.0165\ HCO_3$ is negative no corrosion will occur because of the mineral constituents of the water (NC). If $0.0828\ Mg - 0.0336\ CO_3 - 0.0165\ HCO_3$ is negative but $0.0828\ Mg + 0.0503\ Ca - 0.0336\ CO_3 - 0.0165\ HCO_3$ is positive corrosion may or may not occur (?).

The following similar formulas have been applied to the field assays:[1]

$s = 30 + H.$

$f = 2.7\ (Na + K).$

c.—If $0.033\ CO_3 + 0.016\ HCO_3$ equals or exceeds 0.02 H no corrosion is likely to occur (NC). If 0.004 H exceeds $0.033\ CO_3 + 0.016\ HCO_3$ corrosion is likely to occur (C). If $0.033\ CO_3 + 0.016\ HCO_3$ is less than 0.02 H but greater than 0.004 H corrosion may or may not occur (?).

In these formulas SiO_2, Ca, Mg, Na, K, CO_3, HCO_3, and H represent, respectively, the amounts in parts per million of silica, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, and total hardness as $CaCO_3$, as determined by analysis.

The value of waters in respect to their scale-forming ingredients may be expressed in words as follows:

Classification of waters in respect to scale.

Scaling constituents (parts per million).		Classification.	Remarks.
More than—	Not more than—		
....	90	Good......	Unlikely to cause excessive formation of scale.
90	200	Fair.......	May be used without much trouble if boiler is cleaned regularly, but could be improved by softening.
200	430	Poor......	Use attended by formation of much scale and softening advisable.
430	680	Bad.......	Treatment before use imperative.
680	....	Very bad..	Almost useless in raw state, and softening attended by formation of excessive foaming constituents.

The waters have been classified rather liberally in respect to their content of foaming ingredients. Waters containing more than 800 parts of alkali salts are likely to cause trouble by foaming, and, though supplies containing as much as 1,700 parts per million of foaming constituents have been used in boilers, it is usually more economical to incur considerable expense in replacing such supplies by better ones.

Few of the waters in Lasalle and McMullen counties are bad for boiler use because of excessive content of scale-forming ingredients, and probably few would cause corrosion through deposition of mag-

[1] Dole, R. B., Rapid examination of water in geologic surveys of water resources: Econ. Geology, vol. 6, p. 340, 1911.

nesium. The chief objection to their use in boilers is their great content of alkali salts, which would cause excessive foaming and, even with the better ones, unreasonable loss by the necessity of frequent blowing down to prevent undue concentration in the boilers. Complaint has also been made that boiler waters carrying large amounts of sodium salts cause corrosion, possibly by electrolysis. Railroads traversing this area use surface water for boiler supply wherever it is obtainable.

COMPARISON WITH SURFACE WATERS.

The chemical composition and the quality of water from several rivers in southern Texas and New Mexico are shown in the following table in order that comparison may be made between the usefulness of the ground waters of Lasalle and McMullen counties and that of supplies from these large well-known streams. The figures represent the average condition of the streams as determined by analyses, made under the direction of W. H. Heileman, of samples collected at each station for one year or more. Nueces River traverses the part of Texas under consideration, but no analyses of the water of that stream or its tributaries are available.

Average quality of the water of certain streams in southwestern United States.

[Parts per million.]

	Rio Grande at San Marcial, N. Mex., May 28, 1905, to Apr. 27, 1907.[a]	Rio Grande at Laredo, Tex., Aug. 1, 1905, to Aug. 2, 1906.[b]	Hondo River near Roswell, N. Mex., Mar. 26 to Aug. 4, 1905.[c]	Pecos River near Carlsbad, N. Mex., May 22, 1905, to Apr. 30, 1907.[d]	Colorado River near Austin, Tex., Aug. 1, 1905, to July 27, 1906.[e]
Silica (SiO_2)	....	29	....	....	18
Iron (Fe)	....	[f]3.6	....	....	[f]3.1
Calcium (Ca)	70	104	149	381	52
Magnesium (Mg)	14	23	30	95	17
Sodium and potassium (Na+K)	61	119	39	299	49
Carbonate radicle (CO_3)	.5	.0	2.9	.3	.0
Bicarbonate radicle (HCO_3)	166	178	149	155	195
Sulphate radicle (SO_4)	136	228	352	1,197	42
Chlorine (Cl)	41	164	39	462	59
Nitrate radicle (NO_3)	.3	....	1.2	.03	....
Total hardness as $CaCO_3$	232	354	496	1,340	200
Dissolved solids	438	791	782	2,720	321
Estimated scale-forming ingredients	250	370	520	1,310	200
Estimated foaming ingredients	160	320	105	810	130
Probability of corrosion	(?)	(?)	(?)	Corrosive.	(?)
Quality for boiler use	Poor.	Poor.	Bad.	Bad.	Fair.
Quality for domestic use	Fair.	Fair.	Fair.	Poor.	Good.
Alkali coefficient (inches)	40	12	44	4.4	34
Quality for irrigation	Good.	Fair.	Good.	Poor.	Good.
Mineral content	Moderate.	High.	High.	Very high.	Moderate.
Chemical character	Ca-SO_4.	Ca-SO_4.	Ca-SO_4.	Ca-SO_4.	Ca-CO_3.

[a] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 105, 1911.
[b] Dole, R. B., The quality of surface waters in the United States, Part I: U. S. Geol. Survey Water-Supply Paper 236, p. 96, 1909.
[c] Stabler, Herman, op. cit., p. 52.
[d] Idem, p. 86.
[e] Dole, R. B., op. cit., p. 56.
[f] $Fe_2O_3+Al_2O_3$.

These figures show that the large rivers of Texas are much better in quality than the ground waters of Lasalle and McMullen counties. The Rio Grande at Laredo usually carries less than 800 parts per million of dissolved mineral matter and seldom more than 1,000 parts, often containing as little as 500 parts per million. Its water averages less than 400 parts per million of scale-forming and 400 parts of foaming ingredients and could be used for irrigation if moderate precautions were taken to prevent accumulation of alkali. The water of the Colorado of Texas is still lower in mineral ingredients, being essentially a carbonate water that is acceptable for boiler use and for irrigation and contains too little mineral matter to interfere with its use as a domestic supply. The strongest surface water noted in the table is that of Pecos River at Carlsbad, N. Mex., analyses of which are introduced because it has been extensively used for irrigation. The Pecos at Carlsbad furnishes a calcium sulphate water containing about 2,700 parts per million of dissolved mineral matter. It is distinctly different from the ground waters of the three counties under discussion in that it is a gypsiferous water, or in other words it carries in solution the land plaster that is used to correct black alkali conditions. In accordance with the classification that has been applied to the ground waters it would be rated as poor for irrigation, and published comments on its use apparently justify that classification. It is stated [1] that the water of the lower Pecos is so heavily charged with mineral salts that its use in irrigation requires the most careful handling. The following is a statement of conditions around Carlsbad: [2]

> The chief difficulty as regards Pecos River is the large quantity of gypsum and alkaline salts carried in solution. * * * Much of the land already brought under irrigation has been injured by being waterlogged or by an accumulation of gypsum near the surface, mostly due to unskillful use of water in irrigation. It is believed, however, that by careful consideration of all these matters it will be found practicable to plan and construct irrigation and drainage systems so as to reclaim large bodies of arid land without ultimately injuring it by the alkaline waters.

Dr. R. F. Hare, chemist of the New Mexico Agricultural Experiment Station, states that the water of Pecos River contains white alkali but that the amount does not seem to be sufficient to affect the use of water for irrigation seriously except in certain localities where poor drainage permits the water table to rise too near the surface and to cause accumulation of alkali by evaporation of water brought to the surface by capillarity.[3] An opinion of investigators of the Bureau of Soils[4] is, however, unfavorable. It is quoted with

[1] U. S. Recl. Service First Ann. Rept., p. 259, 1903.
[2] U. S. Recl. Service Second Ann. Rept., p. 63, 1904.
[3] Hare, R. F., and Mitchell, S. R., The composition of some New Mexico waters: New Mexico Agr. Exper. Sta. Bull. 83, p. 73, 1912.
[4] Means, T. H., and Gardner, F. D., The soils of the Pecos Valley, N. Mex.: U. S. Dept. Agr. Div. Soils Circ. 3, quoted by Hare, R. F., op. cit., p. 76.

the amounts converted into parts per million in order that they may be compared with other figures of this report.

The average condition of this water is not good, as it contains about 3,000 parts per million of soluble matter, of which over half are harmful salts—the condition of the water varying from 2,000 parts to 5,000 parts per million. With 5,000 parts per million, or one-half of 1 per cent, the solution contains one-fourth of 1 per cent of harmful salts, 1 per cent being the limit of endurance of crops. There is considerable salt already in the soil, therefore but little evaporation is required at such times to concentrate the soil mixture beyond the limit of endurance. Furthermore, with the conditions so near this limit, vegetation is not as healthy or as thrifty as could be desired, and crops are subject to disease.

The results of using this water are noted particularly because it is one of the most strongly mineralized waters extensively used for irrigation in this country; experience with it therefore indicates to some extent what might be expected from the use of the stronger waters of the area under consideration. The water of Pecos River apparently gives much trouble because of its high content of alkali under the conditions at Carlsbad. If the use of this gypsiferous water is followed by too great accumulation of alkali under the methods of irrigation ordinarily practiced in the Southwest, the ground waters of Lasalle and McMullen counties, many of which are salty or black alkali waters with alkali coefficients less than 1, could not be classed as suitable for use in irrigation, and those that by reason of somewhat lower content of alkali are not entirely unfit for use could safely be applied only to land where unusual provisions have been made for preventing the accumulation of poisonous salts in the soil.

IRRIGATION WITH GROUND WATER.

There is a widespread but erroneous impression that it is practicable to reclaim by irrigation from artesian wells all the land in Lasalle and McMullen counties. In most places in these counties flowing wells can be obtained by drilling into one or more of the water-bearing formations that have been described, and nearly everywhere pump wells can be obtained. The results of the investigation indicate that irrigation on a small scale is practicable west of the fault line (see Pl. VIII), but that irrigation of more than a small part of the total acreage even of this area is impracticable because the supply is inadequate and much of the water is injurious to crops.

The practical exhaustion of an artesian reservoir is accomplished not by complete removal of its water but by reduction of the head to such a level that the cost of bringing the water to the surface becomes too great. Gradual reduction of the head invariably results when an artesian reservoir is exploited, every well that makes a draft on the reservoir reducing the pressure somewhat. In irrigation districts and in cities numerous wells drilled close to one another and heavily drawn upon interfere seriously with one another and produce a radical lowering of the water level. Wells near the limits of the flowing-well area generally cease to flow when extensive developments are made; then subsequent pumping further depresses the water level. Moreover, the pressure is lowered by improperly cased wells that discharge artesian water into the upper sands.

At Fort Worth there has been a lowering of the water level of more than 100 feet in the last 30 years; at Alta Loma, in Galveston County, more than 30 feet in 18 years; in the vicinity of Carrizo Springs, Dimmit County, many wells that formerly overflowed are now nonflowing.

In Lasalle County every possible precaution should be taken to conserve the ground waters that are of suitable quality for irrigation. Every well should be adequately cased down to the lowest water-bearing sand, the higher sands with lower head being excluded to prevent the escape of the lower waters into the higher sands. Abandoned wells should be plugged at the bottom with cement to prevent escape of water from the lower to the upper sands and thus to protect the pressure and retard the depression of the water level.

From the community's standpoint it is reckless to permit each landowner to put down as many wells as he pleases, for numerous wells on a single farm usually involve waste of the artesian water. A larger acreage can be irrigated with a given number of wells and a larger total supply can be developed if the wells are spaced sufficiently far apart—say one on each half section of land—than if they are grouped with a well on each 10 acres. Close spacing of wells results in interference among them, with consequent rapid depression of the water table and the attendant disastrous results. This effect does not manifest itself where wells are so spaced that each one is beyond the cone of interference of the others, and this spacing can be best obtained in Lasalle County by putting wells no closer together than one on each half section.

When flowing wells are not in use the interests of the community require that they be shut off. It is as illogical to permit flowing wells to run continually and to expect them to maintain their flow as it would be to open the fire hydrants in a city and then expect the pressure to be maintained. The need is imperative for cooperative or legal action to protect the water supply for use in permanent irrigation and to restrain individuals from acts conflicting with the permanent interests of the community.

The analyses of the water obtained at various levels in the well 1½ miles west-northwest of Fowlerton (see analyses 75–83, pp. 176–177) indicate that the water in the upper beds is much poorer than that in the Myrick formation, 1,870 to 1,957 feet below the surface. This condition is believed to prevail generally in Lasalle County and the northwestern portion of McMullen County. The water from the Cook Mountain and Mount Selman formations is much poorer in quality than the water from the Myrick. In Dimmit County the Myrick supplies water poor for irrigation in most places, but the Escondido formation supplies water that is suitable for irrigation.

All wells should be properly cased in order to shut off the undesirable upper waters completely and thus to preserve the purity of the lower waters. Where many wells are driven through both sands in a small area, as in an irrigation district, the resulting commingling of the poorer and the better waters injures the better water. Fortunately the danger of contamination of a district as a whole is not so great under these conditions in these counties as where the better water lies above the poorer and is under less head.

Even though wells are cased the mistake is often made of perforating the casing opposite each water-bearing sand in the expectation that the total supply will be increased thereby. This is poor practice in the area under consideration, because it either affords an opportunity for the commingling of the water from different horizons or weakens the pressure of the water from the lower sands, thus allowing the water to escape into the upper sands instead of rising to the surface. The only safe practice in these counties is to carry the well to the base of the Myrick or Escondido formations, to obtain in the bottom of the well a considerable thickness of coarse sand, to case to the top of this sand, and to observe every precaution in having a tight joint where the casing is set.

WELL DATA AND WATER ANALYSES.

In the following tables are given a list of wells in Lasalle and McMullen counties and detailed information concerning these wells and analyses of the water from most of them. The wells are grouped first by counties and then within the counties alphabetically by the post offices near which they are located.

Data of wells in Lasalle and McMullen counties, Tex.

No.	Location.	Owner.	Depth of well.	Diameter of well.	Depth to water-bearing sand.	Horizon of water-bearing stratum.	Height of water above (+) or below (−) surface.	Flow per minute.	Approximate elevation of mouth of well above sea level.	Year completed.
	Lasalle County.		*Feet.*	*Inches.*	*Feet.*		*Feet.*	*Gallons.*	*Feet.*	
1	Artesia, 400 yards south of	T. J. Alderman	160	5	142–160	Cook Mountain	Flow (1903) No flow (1913)	2 (1903)	439	1903
2	Artesia, 200 yards west of	J. W. McInnes	300±	6	270	do	0		443	1903(?)
3	Artesia, ½ mile south of	Pruitt Commission Co.			(?)		No flow.		440	
4	Artesia, 150 yards northeast of.	M. H. Baine	120	6	100–120	Cook Mountain	−20 (1913)		433	1888
5	Artesia, 1½ miles east of	George B. Wiltse	475	7⅝–6	400	do	−27 (1913)		449	
6	Artesia, 3 miles southwest of, on Las Reices Creek.	E. W. Alderman	200		180–200	do	−8 (1913)		440	1911
7	Artesia Wells, ½ mile south of.	J. M. Ramsey	250		230–250	do	Flow (1913)	5 (1913)	440	1908
8	Artesia Wells, 300 yards southwest of.	A. G. Salmon	165	6–5	90–165	do	−26 (1913)	*a* 15	447	1909
9	Artesia Wells, 900 feet southeast of depot.	C. C. Hurley	194	6–4	100	do	−15 (1913)	*a* 10	442	1913
10	Artesia Wells, ½ mile northwest of.	Lasalle Land & Fig Co.	330	6	85–200	do	−28 (1913)	*a* 60 (1913)		1903 ?)
11	Artesia Wells, ½ mile north of	E. Neil Johnston	200	6	80–185	do	−35 (1913)	*a* 75	454	1912
12	Artesia Wells, 1 mile southeast of.	R. L. Hendrickson	248		248±	do	Flows.	5 (1913)	450	1909(?)
13	Artesia Wells, 1½ miles south of.	R. C. Maxwell	170	6	170(?)	do	−20 (1913)		455	1909
14	Artesia Wells, 1¼ miles south of.	John Robuck	193	6–5	140–160	do	−38 (1913)	*a* 8	440	1900
15	Artesia Wells, 1¼ miles southeast of.	J. M. Ramsey	450		430	do	+⅛ (1913)	24 (1913)	445	1900
16	Artesia Wells, 3 miles east of.	do	300		250	do	Flow (1913)	8 (1913)	430	1905
17	Artesia Wells, 7 miles northwest of.	John Hicks	150	6	70–140	do	+35 (1906) −35 (1913)		475	1906
18	Artesia, 100 yards west of	J. W. McInnes	487	7	487(?)	Mount Selman and Cook Mountain.	+9 (1902) +2 (1913)	45 (1902)	439	1902
19	Artesia, 500 yards south of	T. J. Alderman	500	6	(?)	Mount Selman (?)	+2 (1913)		450	1904
20	Artesia Wells, 100 feet north of.	Asherton & Gulf Ry	400±	6	400(?)	do	0		437	1909
21	Artesia Wells, 5 miles west of.	J. Lynn Jones	130	6	10 0–130	Mount Selman	−70 (1913)	*a* 16	525	1913
22	Artesia, 1 mile northwest of	C. H. Bever	1,560(?)	10–6	1,560(?)	Myrick	+2 (1913)	60 (1913)	450	
23	Atlee, 600 feet northwest of	T. A. Coleman		6	(?)			(*a*)	521	
24	Cotulla, Courthouse Square	Lasalle County	165	8–6	40–110	Cook Mountain	−30 (1913)		440	1908
25	Cotulla, 400 yards northwest of	J. T. Carr	100	6	90	do	−48		436	1906
26	Cotulla, ¾ mile northeast of	W. N. Guinn	105	6	35–80	do	−35		445	1908
27	Cotulla, 1 mile north of	L. W. Gaddis	127		100	do	−40 (1913)		435	
28	Cotulla, 4 miles northeast of	Roy Lewis	100±		100±	do	No flow.	15	485	

29 b30	Cotulla, 12½ miles northeast of; ½ mile northwest of Bolton.	E. C. Hatton	290	5 3/16–4 3/16	254–290	do	−20		430	1912
31	Cotulla, 13 miles northeast of; 1½ miles north of Bolton.	L. S. Elwell	200	5 3/16–4 3/16		do	−30	a 40	400	1908
32	Cotulla, 1¼ miles southwest of.	Joseph Cotulla	330		330	Mount Selman	+4 (1913)	5 (1913)	425	
33	Cotulla, 300 feet south of depot.	International & Great Northern Ry.	1,008±		1,008(?)	Myrick (upper part)	+6 (1890) +2 (1913)		432	1882(?)
34	do	do	1,008±		1,008(?)	do	+6 (1890) +2 (1913)		432	1882(?)
35	Cotulla, 8 miles northwest of, at old Armstrong ranch house.		767±		767±	do	Flow (1902)		471	
36	Cotulla, 8½ miles east of; 2½ miles northeast of Bolton.	O. S. Dewees	2,000	8	1,800±	Myrick	+25 (1913)	160	375	1913
37	Cotulla, about 10 miles east-northeast of, on Dewees ranch.	do	1,850		(?)	Myrick (?)				Old.
38	Cotulla, 12 miles northeast of.	do	1,800	8	1,775–1,800(?)	Myrick	+25 (1913)	60	435	1913
39	Cotulla, 1 mile west of	Joseph Cotulla, sr.	2,424		1,200–1,965	Myrick and upper part of Escondido.	+22 (1913)		425	1913
40	do	do	2,424		1,600–2,424	Myrick to basal part of Escondido.	Flow (1913)	1,000±(1913)		
41	Encinal, 150 feet southwest of.	T. A. Coleman	350		350(?)	Cook Mountain		(a)	550	
42	Encinal, 300 feet northeast of.	International & Great Northern Ry.	800	13–8	350–450	do	−70 (1913)	a 83	550	1908
43	Encinal, 300 feet southwest of.	G. M. Berry	146	6	116–146	do		0 (1913)	550	1902
44	Encinal, 600 feet south of	J. W. McMullen	350	6	348	do	−70 (1913)		550	1906
45	Encinal, ¾ mile northeast of, on sec. 498.	G. A. Welhausen	300		300±	do	−60 (1913)		545	1905
46	Encinal, ¾ mile north of	do	375		375(?)	do	−50 (1913)		555	1908
47	Encinal, 1½ miles west of	do	300		300(?)	do	−50 (1913)		565	1900
48	Encinal, 3 miles west of	do	275		275	do	−45 (1913)		575	1908
49	Encinal, 3 miles northeast of	Atlas R. Munn	175		160	do	−38 (1913)		530	
50	Encinal, 3 miles northwest of, in sec. 694.	G. A. Welhausen	258		258(?)	do	−30 (1913)		565	1896
51	Encinal, 5 miles northwest of, in sec. 650.	do	275		275(?)	do	−50 (1913)		565	1907
52	Encinal, 7 miles northeast of	S. S. Charles	506	5	490–506	do	−40 (1913)		510	1907
53	Encinal, 7 miles northwest of.	Ted Watkins	284	6	120–252	do	−110 to −130	a 7	575	1906
54	Encinal, 20 miles east of	Callaghan Land & Pasture Co.	1,975		200–1,348	Cook Mountain and Mount Selman (?).	Flow (1913)	100 (1913)	325	1913
55	Fowlerton, 5½ miles southwest of.	A. L. Warner			204–218	Yegua			400	1913
56	Fowlerton, 5¼ miles northwest of.	Tennessee Garden Well.	340		340(?)	Cook Mountain			355	
57	Fowlerton, 7½ miles southwest of, at Dull ranch house.	Gus Jones	300 or 400		400(?)	do	−5		354	
58	Fowlerton, 3 miles west of	Fowler Bros. Land Co.	310	6		do	Flow (1906) −6 (1913)	12 (1906) 0 (1913)	328	1906

a Nonflowing well; pumped.

b Same well as No. 29 after casing had been repaired.

Data of wells in Lasalle and McMullen counties, Tex.—Continued.

No.	Location.	Owner.	Depth of well.	Diameter of well.	Depth to water-bearing sand.	Horizon of water-bearing stratum.	Height of water above (+) or below (−) surface.	Flow per minute.	Approximate elevation of mouth of well above sea level.	Year completed.
	Lasalle County—Continued.		*Feet.*	*Inches.*	*Feet.*		*Feet.*	*Gallons.*	*Feet.*	
59	Fowlerton, 5 miles west of	Fowler Bros. Land Co.	295	6		Cook Mountain		4 (1906) 0 (1913)	335	1906
60	Fowlerton, 2½ miles southwest of.	do	366	6		do		4 (1906) 0 (1913)	352	1906
61	Fowlerton, 3 miles northwest of.	do	300	6		do		4 (1906) 0 (1913)	345	1906
62	Fowlerton, 5 miles northwest of.	do	720	6		Mount Selman (?)	Flow (1906) No flow (1913)	30 (1906) 0 (1913)	335	1906
63	Fowlerton, 6½ miles west of	do	1,000	6–4	1,000(?)	do	+3 (1913)	200	330	1908
64	Fowlerton, 7⅛ miles northwest of.	do	1,400		770–990	do		160	338	
65	Fowlerton, 7⅛ miles northwest of, on east side of Frio River.	do	1,400	6	770–990	do		160	338	
66	Fowlerton, 6½ miles west of; 1 mile northeast of Dull ranch.	do	1,000		1,000(?)	do				
67	Fowlerton, 6½ miles west of	do	1,000		1,000(?)	do				
68	Fowlerton, 7½ miles northwest of.	Gus Jones	1,000	4	1,000(?)	do	+3±		340	
69	Fowlerton, 13 miles northwest of, 6 miles northeast of Bolton.	Mrs. Helen Irwin	797	6	797(?)	do	+30 (1913)	160 (1913)	375	1906
70	Fowlerton, ¼ mile west of	Fowler Bros. Land Co.	1,857	8–4	1,390–1,857	Myrick	+70	600	336	1911
71	Fowlerton, ¼ mile west of, Hotel well No. 3.	do			(?)	do				
72	do	do	2,056		1,900–2,053	do	+100 (1913)	500	336	1912
73	do	do	2,056		1,900–2,053	do				
74	do	do	2,056		1,900–2,053	do				
a75	Fowlerton, 1½ miles west-northwest of.	do	1,957		342–373	Cook Mountain	Flow (1913)	5 (1913)	336	1914
b76, 77	do	do	1,957		495–523	do	Flow (1913)	10± (1913)	336	1914
c78	do	do	1,957		1,050–1,142	Mount Selman	Flow (1913)	20± (1913)	336	1914
79	do	do	1,957		1,400–1,427	Myrick (upper part)	+65 (1914)	40± (1914)	336	1914
80	do	do	1,957		1,870–1,957	do	+81 (1914)	217 (1914)	336	1914
d81–83	do	do	1,957		1,870–1,957	do	+81 (1914)	217 (1914)	336	1914

84	Fowlerton, 4½ miles northwest of.	....do	1,792		1,775–1,792	....do	Flow (1913)	175 (1913)	335	1912
85	Fowlerton, 3 miles southwest of.	D. C. Richardson, jr.	1,850	8	1,500–1,850	....do		450 (1913)	355	
86	....do	....do	1,850	8	1,500–1,850	....do		450 (1913)	355	
87	Gardendale, ¼ mile east of	Fred R. Zeigler	300	6	300(?)	Cook Mountain	−125		575	1908
88	Gardendale, 1 mile east of	J. L. Tinsley	301	8–6	150–260	....do		e 100 (1913)	570	1910
89	Gardendale, 1 mile east of, in sec. 81.	Jake Goodman	300	8–6	150–250	....do	−175 (?)	e 40	570	1909
90	Gardendale, ¾ mile southeast of.	J. R. Burnett	200	7	153–157	....do			570	1913
91	....do	....do	200	7	f 195–200	....do	−135 (1913)		570	1913
92	Gardendale, 1 mile east of	T. W. Arnison	295	6½	247–295	....do	−120 (1913)		590	1908
93	Gardendale, 1 mile northeast of.	J. W. Cain	372	6⅝	140–380	....do		e 40+		
94	Gardendale, 2± miles northeast of.	Fritz Schneebli	308	8–6	308	....do	−94	e 40	575	1908
95	Gardendale, public square	Gardendale colony	2,360	14–2	1,700±	Myrick	−40	e 40	582	1909
96	Millett, 1 mile east of	W. C. Atkinson	1,465(?)	4	1,465(?)	....do	Flows.		450	
97	Woodward, 3 miles west of	A. Y. Armstrong	182	6	182	Mount Selman	−50 (1913)		495	1898
98	Woodward, 3¼ miles southwest of.	J. B. Ownby and Mrs. E. K. Payne.	760		760(?)	Myrick (upper part)	+37 (1913)		490	1893
99	Woodward, 3½ miles southwest of.	....do	760		760(?)	....do	+37 (1913)		490	1893
100	Woodward, 1½ miles southeast of.	Creamer & Ireland	1,720	8	1,250–1,500	Myrick (middle and basal parts).	+32	700	480	1910(?)
101	....do	....do	1,720	8	1,250–1,500	....do	+32	700	480	1910(?)
102	Woodward	Woodward Vichy Co.	1,587		1,587	Myrick	{+25 (1905) +8 (1913)}	(g)	510	1905(?)
103	....do	....do	1,587		1,587	....do	{+25 (1905) +8 (1913)}	(g)	510	1905(?)
	McMullen County.									
104	Crowther, 3 miles northeast of.	Boston-Texas Corporation.	100±		100(?)	Fayette	−60±		310	
105	Crowther, 1 mile southwest of.	....do	750±	12	750(?)	Yegua	Flows.		240	1902
106	Crowther, 2 miles southeast of.	....do	(?)		(?)	Yegua (?)				
107	Crowther, 2 miles south of	....do	(?)		(?)					
108	Crowther, near	....do		8	523	Yegua				
109	Crowther, 1 mile south of	....do	525		525	....do				
110	Crowther, 1¼ miles south of	....do	1,340	6	640–1,300	Yegua and Cook Mountain	+30	100		1902
111	....do	....do	1,728	12–4	640–1,728	Yegua to Mount Selman	Flows.	400±	240	1902
112	Crowther, near	....do	900±		900±	Cook Mountain	Flows.	200		1902
113	Tilden, ½ mile east of	W. H. Martin	31	60	28	Pleistocene	−28	e 1		1898
114	Tilden, 10 miles east of	C. E. Byrne	58	6	30–58	Pleistocene (?)	−30		256	1907

[a] Fowler Bros. Land Co., well No. 7; "Well baled for one-half hour, when water became so low and muddy that drilling was resumed; sample not a true one—mixed with slush water." Nos. 75–83 represent analyses of water from the same well.
[b] True sample of water from sand at 495–523 feet.
[c] Not a fair sample of water from the sand at 1,050–1,142 feet.
[d] True sample of water from this level; Nos. 81–83 are assays of the same sample.
[e] Nonflowing well; pumped.
[f] A lower sand in the well from which No. 90 was collected.
[g] Flow 15 gallons in 1913; yield on pumping, 125 gallons.

Data of wells in Lasalle and McMullen counties, Tex.—Continued.

No.	Location.	Owner.	Depth of well.	Diameter of well.	Depth to water-bearing sand.	Horizon of water-bearing stratum.	Height of water above (+) or below (−) surface.	Flow per minute.	Approximate elevation of mouth of well above sea level.	Year completed.
	McMullen County—Con.		*Feet.*	*Inches.*	*Feet.*		*Feet.*	*Gallons.*	*Feet.*	
115	Tilden, 7 miles south of	W. A. Lowe	54	48	35	Fayette	−26 (1913)	(*a*)	265	1910
116	Tilden, 9 miles southwest of	Hugh Fitzpatrick	34	60–48	30	do	−14 (1913)		235	1893
117	Tilden, 12 miles east of		(?)		280–300	do				
118	do	S. A. Hopkins (?)	195	4¼–3¾	65–135	do	+15 (1897) Flow (1913)	10–15 (1897)	225	1897
119	Tilden, 8 miles northeast of	C. R. Byrne	741		694–734	Yegua (upper part)	+4 (1913)	200–300	256	1908
120	Tilden, 5 miles southeast of	Two Rivers Ranch Co.	700±	2½–1¼	640±	do	Flow.		430	1905(?)
121	Tilden, 10 miles east of	Herman Borchers	900			Yegua (?) (upper part)	Flow (1907) No flow (1913)		355	1907(?)
122	Tilden, 7 miles southwest of	W. A. Lowe			588	Yegua			375	
123	Tilden, 12 miles northeast of, north of Frio River.	Jacob heirs	627	10	611–627	do	No flow.		245	
124	Tilden, 6 miles northeast of	Dilworth Bros	350	4¼		do	Flows.		325	1893(?)
125	Tilden, 8 miles northeast of, north bank of Frio River.	C. R. Byrne	945		563–935	Yegua and Cook Mountain	Flows.		225	
126	Tilden, public square	McMullen County	920±	$5\frac{3}{16}$–3	(?)	Cook Mountain (?)	Flows.		255	1902(?)
127	Tilden, 4½ miles east of	Two Rivers Ranch Co.	2,305		1,040–2,175	Cook Mountain to Myrick	Flows.		252	
128	Tilden, 6¼ miles southeast of	do	3,002		2,986–3,002	Myrick	Flows.		420	1910
129	Tilden, 4½ miles east of	do	2,800±		2,157–2,175(?)	Myrick (upper part)				
130	Tilden, 11 miles south of	John Fitzpatrick	72	48	72		−46			
131	Zella	Mr. Pumphries	2,105		2,050–2,105	Myrick			375	1914

a Nonflowing well; pumped.

Analyses of ground waters of Lasalle and McMullen counties.

[Parts per million except as otherwise designated.]

No.	Date of analysis.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total dissolved solids.[a]	Scale-forming constituents.[b]	Foaming constituents.[b]	Probability of corrosion.[c]	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (inches).[b]	Quality for irrigation.	Mineral content.	Chemical character.
1	Mar. 3, 1913	.....	0.0	.....	.....	500	66	106	362	388	126	1,400	160	1,400	N. C.	Poor	Fair	3.0	Poor	High	Na-Cl.
2	June 1, 1913	.....	.0	.....	.....	500	9	211	246	459	92	1,350	120	1,400	do.	do.	do.	2.7	do.	do.	Do.
3	Mar. 4, 1913	.....	.0	.....	.....	540	31	158	431	367	78	1,450	110	1,500	do.	do.	do.	2.8	do.	do.	Na-SO_4.
4	June 28, 1913	.....	.0	.....	.....	790	24	137	689	617	156	2,200	190	2,100	(?)	Bad	do.	2.2	do.	Very high.	Do.
5	do.	.....	.0	.....	.....	540	19	163	415	396	76	1,450	110	1,500	N. C.	Poor	do.	2.8	do.	High	Do.
6	do.	.....	.0	.....	.....	480	14	249	492	258	154	1,400	180	1,300	do.	do.	do.	3.6	do.	do.	Do.
7	do.	.....	.0	.....	.....	670	29	163	626	412	80	1,800	110	1,800	do.	do.	do.	2.5	do.	do.	Do.
8	do.	.....	.0	.....	.....	670	34	153	655	454	160	1,950	190	1,800	do.	Bad	do.	2.7	do.	do.	Do.
9	do.	.....	.0	.....	.....	650	19	166	600	474	162	1,850	190	1,800	do.	Poor	do.	2.8	do.	do.	Do.
10	Dec. 8, 1913	.....	.....	.....	.....	590	.0	269	444	469	166	1,700	200	1,600	do.	do.	do.	2.7	do.	do.	Na-Cl.
11	Mar. 3, 1913	.....	.0	.....	.....	610	.0	284	626	372	198	1,800	230	1,600	do.	do.	do.	3.0	do.	do.	Na-SO_4.
12	do.	.....	.0	.....	.....	660	.0	149	574	508	118	1,850	150	1,800	do.	Bad	do.	2.6	do.	do.	Do.
13	June 28, 1913	.....	.0	.....	.....	1,050	.0	295	919	739	154	2,850	180	2,800	do.	do.	Bad	1.6	do.	Very high.	Do.
14	Mar. 3, 1913	.....	.0	.....	.....	320	.0	294	313	160	150	1,000	180	860	do.	Poor	Fair	4.9	do.	High	Do.
15	June 28, 1913	.....	.0	.....	.....	590	29	180	574	319	74	1,600	100	1,600	do.	do.	do.	2.7	do.	do.	Do.
16	do.	.....	.0	.....	.....	700	19	180	511	522	44	1,800	70	1,900	do.	Bad	do.	2.1	do.	do.	Na-Cl.
17	do.	.....	.0	.....	.....	320	.0	443	372	188	352	[d]1,250	380	860	do.	do.	Poor	6.6	Fair	do.	Na-SO_4.
18	do.	.....	.0	.....	.....	590	14	210	475	405	80	1,600	110	1,600	do.	Poor	Fair	2.6	Poor	do.	Do.
19	Jan. 16, 1913	.....	.0	.....	.....	450	13	210	238	387	92	1,400	120	1,200	do.	do.	do.	3.0	do.	do.	Na-Cl.
20	do.	.....	.7	20	12	530	122	248	398	306	[b]99	[d]1,388	110	1,400	do.	do.	do.	2.5	do.	do.	Na-SO_4.
21	June 28, 1913	.....	2.0	.....	.....	610	.0	366	1,252	1,180	2,050	4,100	2,080	1,600	C.	Unfit	Bad	1.7	do.	Very high.	Ca-SO_4.
22	Mar. 3, 1913	.....	4.0	.....	.....	1,500	66	861	431	1,264	70	3,550	100	4,000	N. C.	do.	do.	.7	Bad	do.	Na-Cl.
23	Mar. 4, 1913	.....	3.0	.....	.....	720	13	77	756	724	468	2,400	500	1,900	C.	Poor	Poor	2.5	Poor	do.	Na-SO_4.
24	Mar. 3, 1913	.....	.0	.....	.....	1,600	.0	173	626	1,980	410	4,300	440	4,300	(?)	Unfit	Unfit	.9	Bad	do.	Na-Cl.
25	Jan. 16, 1913	.....	.0	.....	.....	1,400	.0	189	1,104	1,071	54	3,550	80	3,800	N. C.	do.	Bad	1.1	do.	do.	Na-SO_4.
26	do.	.....	.0	.....	.....	850	.0	298	864	449	73	2,300	100	2,300	do.	Bad	do.	2.0	Poor	do.	Do.
27	Mar. 3, 1913	.....	.0	.....	.....	330	.0	347	383	152	234	1,150	180	890	do.	Poor	Good	5.7	do.	High	Do.
28	Jan. 16, 1913	.....	7.0	.....	.....	880	.0	212	362	979	185	2,350	210	2,400	(?)	Bad	Bad	1.6	do.	Very high.	Na-Cl.
29	Mar. 4, 1913	.....	.0	.....	.....	830	35	302	690	491	64	2,150	90	2,200	N. C.	do.	Fair	1.8	do.	do.	Na-SO_4.
30	June 28, 1913	.....	.0	.....	.....	660	43	347	552	299	34	1,700	60	1,800	do.	do.	do.	2.0	do.	High	Do.
32	Mar. 4, 1913	.....	.0	.....	.....	1,050	110	176	574	834	42	2,550	70	2,800	do.	do.	Bad	1.3	do.	Very high.	Na-Cl.
33	....	16	.03	24	10	([e])	1.0	776	882	752	[b]101	[d]3,657	120	3,300	do.	Unfit	do.	1.1	Bad	do.	Na-SO_4.
34	Jan. 16, 1913	.....	.4	24	12	1,636	4.0	281	788	1,846	[b]108	[d]4,846	120	4,400	do.	do.	Unfit	.9	do.	do.	Na-Cl.
35	Mar. 27, 1902	.....	.....	5.5	.5	953	.0	605	236	745	16	[d]2,291	50	2,600	do.	Bad	Fair	1.1	do.	do.	Do.
36	Mar. 4, 1913	.....	.0	.....	.....	640	62	729	173	304	26	1,500	60	1,700	do.	do.	do.	1.4	Poor	High	Na-CO_3.

[a] Calculated unless otherwise indicated.
[b] Calculated.
[c] C., corrosive; N. C., noncorrosive; (?), corrosion uncertain or doubtful; values calculated.
[d] Determined.
[e] Sodium (Na), 1,046 parts; potassium (K), 191 parts.

Analyses of ground waters of Lasalle and McMullen counties—Continued.

No.	Date of analysis.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).[a]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total dissolved solids.[a]	Scale-forming constituents.[b]	Foaming constituents.[b]	Probability of corrosion.[c]	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (inches).[b]	Quality for irrigation.	Mineral content.	Chemical character.
37				3.0	1.5	462	481		83	89	[b] 14	1,150	40	1,200	N. C.	Poor	Poor	1.7	Poor	High	$Na-CO_3$.
38	Mar. 4, 1913		.0			1,550	44	999	626	1,126	34	3,700	60	4,300	do	Unfit	Bad	.7	Bad	Very high.	Na-Cl.
39	June 28, 1913		.9			530	82	771	132	123	30	1,250	60	1,400	do	Poor	Fair	1.6	Poor	High	$Na-CO_3$.
40	do		.0			250	58	278	125	68	42	660	70	680	do	do	Good	3.8	do	do	Do.
41	Mar. 4, 1913		1.0			550	22	149	690	310	212	1,700	240	1,500	(?)	do	Poor	4.3	do	do	$Na-SO_4$.
42	do		1.0			470	26	185	756	167	282	1,600	310	1,300	(?)	do	do	7.3	Fair	do	Do.
43	June 28, 1913		.0			1,100	5.0	205	1,723	793	930	4,050	960	3,000	C.	Unfit	Bad	2.1	Poor	Very high.	Do.
44	Mar. 4, 1913		1.0			560	.0	180	626	404	250	1,750	280	1,500	(?)	Poor	Poor	4.1	do	High	Do.
45	June 28, 1913		.0			980	.0	88	984	893	384	3,000	410	2,700	C.	Bad	Bad	2.0	do	Very high.	Do.
46	do		.0			600	.0	225	765	335	262	1,900	290	1,600	(?)	Poor	Poor	4.0	do	High	Do.
47	do		2.4			280	.0	274	254	168	176	910	310	760	N. C.	do	Fair	5.7	do	do	Do.
48	do					440	.0	298	574	213	264	1,500	290	1,200	(?)	do	Poor	5.3	do	do	Do.
49	do		1.8			760	10	321	919	299	130	2,150	160	2,100	N. C.	Bad	Fair	2.4	do	Very high.	Do.
50	do		.0			450	.0	308	626	160	222	1,500	250	1,200	do	Poor	do	5.0	do	High	Do.
51	do		1.2			510	.0	333	689	196	238	1,650	270	1,400	do	do	Poor	4.4	do	do	Do.
52	do		.0			1,450	38	327	1,060	1,060	54	3,650	80	3,900	do	Unfit	Bad	1.0	Bad	Very high.	Na-Cl.
53			.0			230	.0	293	103	216	204	780	230	620	do	Poor	Fair	5.6	Poor	High	Do.
55	Dec. 8, 1913					12,900	.0	925	1,292	18,580	2,610	32,850	2,650	35,000	(?)	Unfit	Unfit	.1	Bad	Very high.	Do.
56				32	10	1,700	249		1,298	1,450	[b] 121	4,750	140	4,600	N. C.	do	do	1.0	do	do	Do.
57	Jan. 16, 1913		1.3	118	22	3,086	.0	172	1,394	3,896	[b] 385	[d] 8,590	420	8,400	(?)	do	do	.5	do	do	Do.
63	Mar. 4, 1913		.0			1,700	88	1,188	328	1,386	26	3,950	60	4,600	N. C.	do	do	.6	do	do	Do.
64				44	15	2,122	264		1,404	2,040	[b] 172	5,870	180	5,700	do	do	do	.8	do	do	Do.
65	Mar. 4, 1913		.0			1,900	52	1,679	383	1,376	28	4,350	60	5,100	do	do	do	.5	do	do	Do.
66	Jan. 16, 1913		.0			1,550	13	1,714	256	1,030	25	3,550	60	4,200	do	do	do	.6	do	do	$Na-CO_3$.
67	Mar. 4, 1913		.0			1,500	92	1,269	328	1,066	26	3,500	60	4,100	do	do	Bad	.6	do	do	Do.
68	Jan. 16, 1913		.0			1,750	47	1,305	246	1,519	28	4,050	60	4,800	do	do	Unfit	.5	do	do	Na-Cl.
69	Mar. 4, 1913		.0			510	57	747	140	134	28	1,200	60	1,400	do	Poor	Fair	1.6	Poor	High	$Na-CO_3$.
70	Jan. 16, 1913		.2	12	4.0	1,339	40	1,196	256	1,162	[b] 46	3,636	75	3,600	do	Unfit	Bad	.7	Bad	Very high.	Na-Cl.
71		16	[e] 4.4	3.5	1.1	[d] 1,220	715		228	871	[b] 13	[d] 3,063	30	3,300	do	do	Unfit	.8	do	do	$Na-CO_3$.
72	Jan. 16, 1913		.9	16	8.0	808	96	1,214	176	346	[b] 73	[d] 2,248	90	2,200	do	Bad	Bad	1.1	do	do	Do.
73	Mar. 4, 1913		.0			940	106	1,175	222	379	30	2,150	60	2,500	do	do	do	.9	do	do	Do.
74	Mar. 14, 1913			5	3.0	980	62	1,412	199	482	[b] 25	[d] 2,420	50	2,600	do	do	do	.9	do	do	Do.
75	Jan. 8, 1913					2,650	.0	283	1,380	2,650	120	6,600	150	7,200	do	Unfit	Unfit	.5	do	do	Na-Cl.
76	do					1,800	24	386	1,214	1,450	46	4,550	80	5,000	do	do	Bad	.8	do	do	Do.
77	do					1,850	24	382	1,214	1,490	46	4,600	80	5,000	do	do	do	.8	do	do	Do.
78	do		.8			2,500	24	775	756	2,545	100	6,000	130	6,700	do	do	Unfit	.5	do	do	Do.
79	Jan. 5, 1914					1,750	.0	1,520	362	1,351	80	4,050	110	4,700	do	do	Bad	.6	do	do	Do.
80	Jan. 17, 1914		.0			990	65	1,250	286	396	10	2,300	40	2,700	do	Bad	do	.9	do	do	$Na-CO_3$.
81	Mar. 14, 1914			5.0	3.0	874	65	1,264	206	395	[b] 25	[d] 2,188	50	2,400	do	do	do	1.0	do	do	Do.
82	do		.0			1,100	53	1,295	430	420	9.0	2,550	40	2,900	do	do	do	.9	do	do	Do.

83	.....do.......			4.0	3.0	895	63	1,286	202	422	*b* 22	*d* 2,145	50	2,400	..do...	..do...	..do...	1.0	..do...	...do......	Do.
84	Mar. 4, 1913		.0			1,000	.0	1,224	208	583	16	2,350	50	2,800	..do...	..do...	..do...	.9	..do...	...do......	Do.
85				3.0	2.0	2,079	1,316		349	1,400	*b* 16	5,100	40	5,600	..do...	Unfit.	Unfit.	.4	..do...	...do......	Na-Cl.
86	Mar. 4, 1913		.0			1,750	101	1,188	362	1,422	28	4,050	70	4,700	..do...	..do...	..do...	.6	..do...	...do......	Do.
87	Mar. 14, 1914		6.0			250	.0	181	372	102	176	900	210	680	(?)	Poor..	Fair...	12	Fair...	High......	Na-SO4.
89	Dec. 8, 1913					400	.0	430	247	469	470	1,550	500	1,100	(?)	Bad...	Poor..	4.0	Poor..	...do......	Na-Cl.
90	June 28, 1913		.0			490	.0	313	1,147	405	1,040	2,650	1,070	1,400	N. C..	Unfit.	Bad...	4.3	..do...	Very high.	Ca-SO4.
91	.....do.......		1.0			680	.0	352	1,061	328	488	2,450	520	1,800	(?)	Bad...	Poor..	4.3	..do...	...do......	Na-SO4.
92	.....do.......		1.4			460	14	396	427	205	162	1,350	190	1,200	N. C..	Poor..	Fair...	3.1	..do...	High......	Do.
93	Mar. 3, 1913		1.0			340	.0	410	238	188	176	1,050	220	920	..do...	..do...	..do...	3.7	..do...	...do......	Na-CO3.
94	Jan. 16, 1913		2.0			430	.0	336	323	286	164	1,250	190	1,200	..do...	Bad...	Poor..	3.3	..do...	...do......	Na-Cl.
95	.....do.......		.5	14	4.0	396	56	656	110	118	*b* 51	*d* 1,146	80	1,100	..do...	..do...	Fair...	2.1	..do...	...do......	Na-CO3.
96	Mar. 4, 1913		.0			490	40	630	154	184	28	1,150	60	1,300	..do...	Poor..	do...	1.8	..do...	...do......	Do.
97		79	*f*.1	499	1.6	(*g*)		50	2,916	2,390	1,255	*d* 8,222	1,500	5,500	C......	Unfit.	Unfit.	.7	Bad...	Very high.	Na-SO4.
98	Mar. 3, 1913		.0			1,050	118	747	276	740	46	*h* 2,500	80	2,800	N. C..	Bad...	Poor..	1.0	..do...	...do......	Na-Cl.
99	.....do.......		.0			1,050	.0	910	256	740	28	2,400	60	2,800	..do...	..do...	..do...	1.0	..do...	...do......	Do.
100	Jan. 16, 1913		.3	10	4.0	246	30	350	104	92	*b* 41	*d* 768	65	660	..do...	Poor..	Good..	3.8	Poor..	High......	Na-CO3.
101	Mar. 3, 1913		.0			390	.0	670	108	100	24	930	50	1,100	..do...	..do...	..do...	2.0	..do...	...do......	Do.
102		14	(*i*)	3.0	6.0	*d* 350	15	618	107	104	47	*dj* 1,012	30	950	..do...	..do...	Poor..	2.4	..do...	...do......	Do.
103	Jan. 16, 1913		.0			650	28	452	136	535	23	1,550	50	1,800	..do...	Bad...	..do...	1.6	..do...	...do......	Na-Cl.
104	.....do.......		11	210	20	1,011	.0	148	1,060	1,132	*b* 607	*d* 3,600	680	2,700	C......	Unfit.	Bad...	1.7	..do...	Very high.	Do.
105	.....do.......		.0			4,250	10	474	1,726	4,457	67	10,250	100	11,000	N. C..	..do...	Unfit.	.3	Bad...	...do......	Do.
106	.....do.......		.0			2,350	.0	363	313	2,938	66	5,550	100	6,400	..do...	..do...	..do...	.5	..do...	...do......	Do.
107	.....do.......		.0			4,450	.0	68	54	6,304	157	10,500	190	12,000	(?)	..do...	..do...	.3	..do...	...do......	Do.
113	.....do.......		.0			290	.0	334	202	347	384	1,200	410	810	(?)	Poor..	Poor..	5.6	Poor..	High......	Do.
114	.....do.......		.0			1,400	.0	601	1,312	846	260	3,050	290	3,800	N. C..	Unfit.	Bad...	1.2	..do...	Very high.	Na-SO4.
115	June 28, 1913		1.0			170	29	244	98	20	36	460	65	460	..do...	Poor..	Good..	5.5	..do...	Moderate..	Na-CO3.
116	Dec. 8, 1913					95	.0	274	7.0	94	176	430	210	260	..do...	..do...	Fair...	11	Fair...	...do......	Ca-CO3.
117	Jan. 16, 1913		.0			6,050	.0	904	25	8,262	390	14,250	420	16,000	..do...	Unfit.	Unfit.	.2	Bad...	Very high.	Na-Cl.
119	.....do.......		.0			4,850	.0	473	26	6,660	188	11,250	220	13,000	..do...	..do...	..do...	.3	..do...	...do......	Do.
122	Mar. 14, 1914		.0			2,700	.0	1,232	.0	3,197	126	6,250	160	7,300	..do...	..do...	..do...	.4	..do...	...do......	Do.
126	Jan. 16, 1913		1.2	32	16	2,676	.0	622	552	3,458	*b* 146	*d* 7,200	150	7,200	..do...	..do...	..do...	.5	..do...	...do......	Do.
129	.....do.......		.0			3,200	51	383	1,448	3,192	48	7,750	80	8,600	..do...	..do...	..do...	.4	..do...	...do......	Do.
130	Mar. 14, 1914		.0			1,300	.0	400	1,256	885	248	3,650	280	3,600	..do...	..do...	Bad...	1.3	Poor..	...do......	Na-SO4.
131	May 15, 1914		.35	6.0	7.0	375	34	571	106	158	*b* 44	*d* 1,060	60	1,000	..do...	Poor..	Good.	2.3	..do...	High......	Na-CO3.

a Calculated unless otherwise indicated.
b Calculated.
c C., corrosive; N. C., noncorrosive; (?), corrosion uncertain or doubtful; values calculated.
d Determined.
e $Fe_2O_3+Al_2O_3$.
f Aluminum (Al), 9.0 parts.
g Sodium (Na), 2,056 parts; potassium (K), 5.3 parts.
h Nitrate (NO_3), 0.06 part; free carbon dioxide (CO_2), 44 parts; hydrogen sulphide (H_2S), none.
i Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$), 7.6 parts.
j Organic and volatile matter, 18 parts.

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