TEXAS BOARD OF WATER ENGINEERS

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Contamination Report No. 5

Reconnaissance Report on Alleged Contamination of California Creek Near Avoca, Jones County, Texas

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CONTENTS

FIGURES

TABLES

SUMMARY OF CONCLUSIONS

Available data and field observations in the North Avoca oil field in Jones County indicate that relatively shallow permeable zones in Permian rocks, which originally contained waters of moderate-to-high salinity, have been invaded by natural gas and brine from deeper strata. Pressures resulting from this invasion are producing artesian flow at points in the bed of California Creek and from open exploration holes. No ground water suitable for human consumption occurs beneath the area, though a few shallow wells tap water which is suitable for stock and some domestic purposes. No contamination of well waters by brine was reported.

The salty springs on California Creek reportedly appeared after the advent of oil operations in the area, though the exact date of appearance could not be ascertained. Records of the Texas Department of Health indicate springs existed in the area in 1949, the waters having approximately one-half the present chloride content but a greater estimated flow at that time. Since this was several years prior to requirement of injection wells for brine disposal in the area, the springs were probably caused by leakage from wells.

The flow of California Creek below all observed springs was estimated to be 15 gallons per minute and was derived entirely from salty springs and seepage along the channel and banks of the stream between points 2 and 5, figure 1. Spring flow sampled at point 7 contained 43,800 parts per million of chloride ion and 20,300 ppm of sodium ion, concentrations which are comparable to those found in oil-field brines in the area. This brine is continually concentrating

the water in pools below the spring-seep area by displacing fresher waters derived from previous storm runoff. A chloride concentration of 43,800 ppm in water flowing at a rate of 15 gpm is equivalent to a daily increment of four tons of chloride ion, all of which ultimately enters the Clear Fork of the Brazos River.

Gas and oil associated with springs and seepage from old core holes indicates that subsurface leakage from wells tapping oil- and gas-bearing strata is responsible for the artesian flowing pressure and consequent contamination of California Creek, possibly augmented by the effects of brine injection wells. Points of leakage could not be determined during this investigation.

Before further detailed study of the problem is made, it is recommended that the oil well on the A. E. Olson lease in the North Avoca field, operated by Baker, Camp, and Davis, be checked to determine the source of gas and water escaping outside the surface casing. It is also recommended that the fluid level in selected wells tapping each of the two oil producing horizons be determined to ascertain whether oil reservoir pressures are adequate to cause the observed artesian phenomena in this area.

If leakage from oil horizons is responsible for the spring flow, as indicated, it has occurred long enough for existing pressures in shallow strata to reflect the hydrostatic effects of leakage. Determination of artesian pressures prevailing in the first artesian aquifer below land surface might reveal the locations of artesian "highs", thereby indicating general areas where leakage is occurring. This, however, could be accomplished only by a costly test-drilling program.

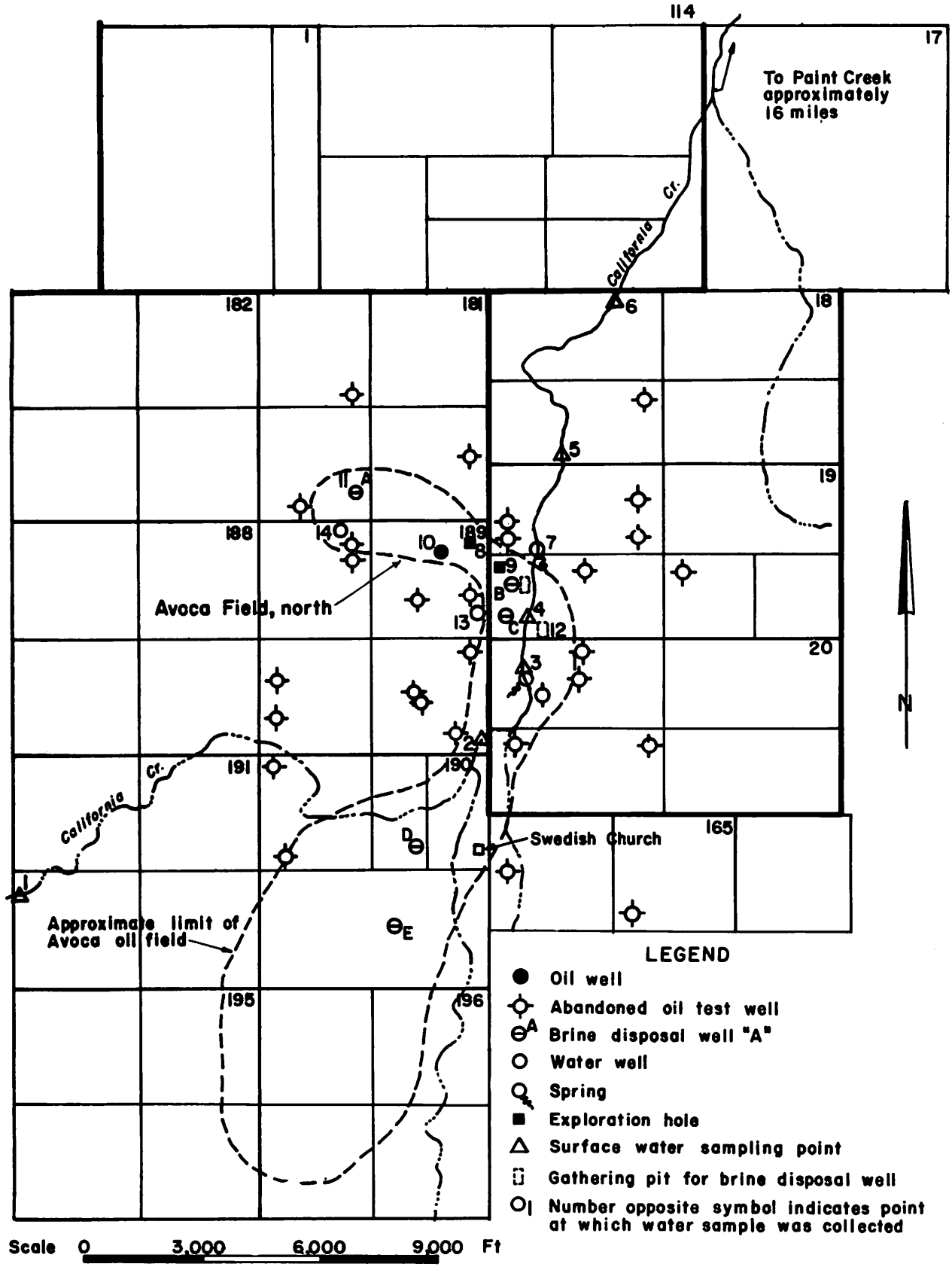

FIGURE 1 - MAP SHOWING LOCATION OF SELECTED WELLS, SPRINGS, EXPLORATION HOLES AND SAMPLING POINTS IN THE AVOCA OIL FIELD, JONES COUNTY, TEXAS

INTRODUCTION

At the July meeting of the Texas Pollution Advisory Council, the Texas Game, Fish, and Oyster Commission reported a fish-kill on Paint Creek below its confluence with California Creek, and on the Clear Fork of the Brazos River, in Haskell and Throckmorton Counties. Game Warden H. B. Iverson attributed this to a quick, flushing rise on California Creek resulting from a six-inch rain on the upper reaches of the stream, which he reported to be heavily contaminated by salty springs along the banks and channel in the Avoca field area. However, this opinion was undocumented by chemical analyses of water because samples were not obtained until several days after the quick rise. These samples contained insufficient chlorides to cause a fish-kill.

At the request of the Texas Game, Fish, and Oyster Commission and in consideration of established evidence of contamination of ground and surface water in the area surrounding the salt springs in California Creek, the Board of Water Engineers conducted a reconnaissance investigation to determine the extent and nature of the contamination.

The investigation concerned an area of approximately two square miles in the north and central parts of the Avoca oil field (figure 1) in the northeastern corner of Jones County, where oil has been produced since the late thirties and early forties from depths ranging from approximately 2,200 to 3,300 feet. Field work performed during the period July 17-19, inclusive, included a water-well inventory, geological reconnaissance, inspection of brine disposal operations, and selected sampling of waters for chemical analysis.

Appreciation is expressed to District Game Warden H. B. Iverson, to local landowners, and employees of the oil industry for guidance and

information, and to the Texas Department of Health for supplying a 1949 reconnaissance report on the springs in California Creek which contained helpful information.

GENERAL GEOLOGY AND OCCURRENCE OF GROUND WATER

The area investigated lies in the Osage Plains region of west-central Texas, near the eastern margin of the Permian Basin. It is drained by California Creek, a tributary of the Clear Fork of the Brazos River. The flow of the stream is perennial downstream from the area investigated and intermittent above the area.

Available information indicates that large amounts of native salt (sodium chloride) are not present in rocks dissected by California Creek in this region. Along the stream the area is underlain to shallow depths by Recent alluvium, consisting primarily of fine sand and clay. Beneath the alluvium is the eroded surface of Permian rocks of the Clear Fork group which are principally limestones and dolomites. Data obtained do not reveal the hydrologic features of rocks in the first 100 feet of the geologic section beneath the alluvium.

Electrical logs which start at 100 feet below land surface or deeper indicate that Permian strata at the 300-foot level dip slightly north of west at the rate of 20 to 30 feet per mile. It is likely that the shallower beds exhibit a similar attitude. No evidence of faulting was seen in exposures of bedrock in the immediate area of the investigation, but thrust faulting of Permian strata is evident on the Texas Geologic Map at points several miles downstream from the springs on California Creek.

Limited data were obtainable concerning the occurrence of ground water in the area. Local persons report that potable water is unavailable but that in places ground water in the alluvium is suitable for stock. Analyses of water samples obtained in the area (wells 13 and 14, table 1) and the scarcity of water wells tend to confirm these reports.

QUALITY OF WATER

Ground Water

Analyses 13 and 14, table 1, indicate, respectively, the quality of ground water occurring in alluvium along California Creek and, probably, in very shallow Permian rocks. The chloride ion concentration is 510 ppm in well 13 and 1,070 ppm in well 14. The latter was the only water well in use in the area studied. Chloride concentrations in both wells are above limits recommended for human consumption.

Analyses 7-10, table 1, were made on ground waters for which the stratigraphic sources are uncertain. All samples were taken from points where artesian pressure was producing flow or maintaining fluid levels a few inches below ground level. Escaping gas was noted at each location. Comparison of these analyses with analyses of brine from the two producing horizons of the North Avoca field (table 1) indicates similarity between analyses 7 and 10 and the brine analyses, but little similarity is evident between the quality of the brine and the waters represented by analyses 8 and 9.

Surface Water

Water samples were taken from six points (figure 1) on California Creek in studying observed spring flow and seepage in the area. Some

samples were taken from pools where little or no flow was evident and others were taken from shoal areas where slight flows were evident.

Chloride ion concentrations of the six samples ranged widely, from 69 ppm at a point (no. 2, figure 1) above all observed springs where no flow was evident to 6,780 ppm at a point below all observed springs (no. 5, figure 1). Analyses of these samples do not reveal the quality of the base flow of the stream; however, they indicate that highly saline water enters the stream between points 2 and 5.

Observations along the banks and channel of California Creek revealed one spring flowing salt water (43,800 ppm chlorides) and natural gas. Evidence of several others was indicated by gas bubbles emerging from pools along the stream. Estimates of stream and spring flow in this area indicate that the base flow of the creek immediately below the spring-seep area, estimated to be 15 gpm, is maintained entirely by the springs and seepage. A chemical analysis applicable to this flow was unobtainable because most of the indicated spring flow enters the stream through the bottoms of pools. Assuming that the analysis of water from the spring at point 7 represents the quality of the base flow in this area, approximately four tons of chloride ion are discharged by the springs and seeps each day, all of which ultimately enters the Clear Fork of the Brazos River.

In periods of extended drought, evaporation may precipitate salt (sodium chloride) in the stream channel, which will be dissolved and flushed downstream by subsequent storm runoff.

BRINE PRODUCTION AND DISPOSAL

Pit disposal of brine was practiced in the Avoca field for approximately 13 years, ending in 1953 or 1954 when the Texas Railroad

Commission ordered subsurface disposal of all brine produced in this field and others in Jones and surrounding counties.

Reports submitted to the Texas Railroad Commission by operators in late 1957 indicate production of 822 barrels of brine per day in the North Avoca field and 1,400 barrels per day from a part of the Avoca field (a different oil reservoir) which is near the area studied. All of this brine was reported to be disposed to injection wells. Current production rates are estimated to equal or exceed the 1957 reported rates and all brine is now disposed to wells.

Brine is produced from two horizons in the North Avoca field, one at approximately 2,200 feet, the other at approximately 3,300 feet. The oil-brine production ratio in the field ranges between 1/200 and 1/50. The Avoca field produces oil from depths below 3,000 feet. The oil-brine ratio was not obtained for this field.

Four disposal wells (figure 1) nearest the spring-seep area were visited and records were checked concerning well construction and operational methods. Exact data on construction and disposal zones were not obtainable but most of the wells are reportedly abandoned oil wells which dispose brine to zones below producing horizons. Data obtained are summarized in table 2. Well "A", disposing approximately 500 barrels per day, is the only well employing high injection pressure. Wells "B" and "C" were reported to be disposing brine under pump pressure at 8 and 100 pounds of pressure, respectively; well "D" reportedly disposes approximately 1,400 barrels of brine per day by gravity flow.

Before brine is injected into these wells, it is pumped from oil wells into unlined earthen gathering pits or into metal or wooden gathering tanks. Where earthen pits (figure 1) are used, brine is

continually being introduced into the alluvium and moves into California Creek.

Annular disposal of brine under high pressure beneath surface casing set at shallow depths could cause artesian springs and seeps, but it is reportedly not practiced in wells of this area.

EVIDENCE OF ABNORMAL PRESSURES IN SHALLOW STRATA

The salty springs in the banks and channel of California Creek which are associated with natural gas are considered strong evidence of leakage from oil horizons because natural ground waters are indicated to contain only a small fraction of the mineralization contained by the spring waters. The creek channel, incised into Permian bedrock, appears to be an escape area for gas confined in shallow strata which probably emerges from natural fracture systems in the rocks.

Oil, gas, and salt water were observed escaping in the cellar of a producing oil well (no. 10, figure 1) and in two reportedly uncased, abandoned exploration holes (nos. 8 and 9, figure 1). Similar seepage reportedly occurs sporadically in two other abandoned holes. The fluid level stood several inches below land surface in all except one (well 8), which flowed onto the surface. These seepages may be related to the same source which causes the springs in California Creek. However, the spring flow contains gas but, apparently, no oil. The leakage at wells 8 and 9 reportedly appeared in late 1957 or early 1958. Well 9 initially flowed fresher water which was suitable for stock but the flow gradually diminished.

Surface seepage of oil and gas are either due to leakage from producing oil horizons through wells or test holes, or to natural

phenomena. The latter is considered unlikely because evidence obtained indicates high pressures did not exist in shallow strata in this area prior to the advent of oil development. Records of a cable-tool exploration hole drilled by the Humble Oil and Refining Company on the A. E. Olson lease in 1941 in the North Avoca field indicate that high pressure was not encountered in any shallow stratum. No water was encountered, exclusive of shallow alluvial water, above a depth of 900 feet.

Reportedly, oil and gas accumulations have been encountered at depths less than 200 feet at several points in the general area. When developed, they were rapidly depleted indicating that the gas and oil probably were not native to strata in which found but probably came from deeper horizons.

Possible Causes of Abnormal Pressures in Shallow Strata

Possible causes of observed artesian leakage are: (1) natural high pressure in shallow strata containing native, non-commercial accumulations of brine and hydrocarbons, (2) disposal of brine under high pressure through injection wells, and (3) leakage from producing oil reservoirs.

The first possibility is unlikely because the exploration hole on the A. E. Olson lease logged no oil or gas or high pressures above the first producing horizon in the North Avoca field. Brine injection wells, in themselves, cannot be considered a direct cause of observed artesian phenomena because no hydrocarbons are injected with the brine. Leakage of brine and hydrocarbons from producing horizons through wells and exploration holes is, therefore, the probable source of hydrocarbons escaping at the surface.

Reservoir pressures may be entirely responsible for artesian springs and seepage or they may result from reservoir pressures augmented by the effects of brine injection wells. Improperly constructed injection wells under high pressure may cause intercommunication of fluids through uncased, exploration holes and through the annulus in producing and abandoned oil wells. Reportedly, the annulus of several producing wells of the area is under pressure at the well head which indicates that fluid intercommunication is possible through those wells. Many open, abandoned, exploration holes are reported to exist in the area.

Insufficient authentic data were obtainable concerning injection wells used in the area to fully evaluate them as a possible cause of artesian leakage.

Possibilities for Corrective Action

Assuming reservoir leakage to be responsible for high pressures, leaking wells or holes must be identified in order to initiate corrective action. Should many leaking wells exist, individual identification will be difficult unless re-entry of all abandoned holes and checking of all producing wells is required. Should the sources of leakage be few and localized, however, the general areas of occurrence might be delineated by mapping the artesian pressure surface of confined fluids occurring in the first artesian aquifer beneath land surface. This should reveal piezometric "highs" which would indicate general areas in which to start checking producing wells and abandoned holes for possible leakage. Should injection wells be at least partially responsible for abnormal pressures, the plan would also indicate which disposal wells should be suspected of improper construction or operation.

However, a costly cable-tool test-drilling program would be required to obtain the necessary data.

It is recommended that the gas, oil, and water observed escaping from the cellar of the producing oil well at point 10, figure 1, be investigated. Since the chloride concentration in the fluid sampled at this point correlates closely with concentrations found in reservoir brine (table 1), and because gas and oil are present, reservoir leakage may be the source of this pressure. However, a casing-head leak may be permitting the escape of hydrocarbons observed at this point.

It is recommended that the fluid levels in this well and others nearby be determined to establish whether oil reservoir pressures alone are adequate to produce artesian springs. If not, injection wells should be considered the probable cause.

Table 2.--Selected brine disposal wells in the Avoca oil field, Jones County, Texas

Well symbol (figure 1)	Location	Operator's name	Reservoir designation and approximate depth	Type of well	Injection interval (ft. below ground)	Reported disposal pressure (psi)	Reported disposal volume (bpd) 2/
A	E. W. Rosenquist property, approximately 900' NSL and 2,500' EWL of Blk. 181, BBB & C Survey.	Baker, Camp and Davis	Avoca, north; 3,300'	Abandoned oil test well	Unknown	1/ 400-600	250
B	A. E. Olson property, approximately 150 EWL and 1,200' NSL of Blk. 19 H & TC Survey.	T. L. Wheeler estate	Avoca, north; 3,300'	Well drilled for disposal purposes 1/	1,388-1,404	1/ 8	122
C	A. E. Olson property, approximately 200' NSL and 150' EWL of Blk. 19, H & TC Survey.	Eugene Nourse	Avoca, north; Swastika sand; 2,200'	Unknown	Unknown	1/ 100	200
D	F. Olsen property, approximately 1,500' WEL and 2,500' SNL of Blk 190, BBB & C Survey	Walsh & Watts	Avoca; depth unknown	Unknown	Unknown	Gravity drainage from 20' elevated tank	1,360
E	J. W. Hollums et al, approximately 2,500' WEL and 1,250' NSL of Blk 190, BBB & C Survey.	Humble Oil & Refining Co.	Avoca; depth unknown	Unknown	Cambrian strata at approximately 5,000'	Unknown	3,628

1/ Information obtained from pumper.
2/ All figures are from operator's reports to Railroad Commission in Autumn of 1957.

Table 1.--Partial chemical analyses of water from selected wells, springs, exploration holes, and California Creek, in the Avoca oil field, Jones County, Texas (Continued)

Sample Number	Sampling point	Location of point	Constituents in parts per million: Chloride	Sodium	Silica	Calcium	Magnesium	Bicarbonate	Sulphate	Specific conductance	Remarks
8	Abandoned exploration hole seeping oil, gas and water in cultivated field.	On A. E. Olson property 100' west of F.A.S. highway 142, 1 mile south of intersection of F.A.S. highways 142 and 600.	560	1,520	15	519	410	198	5,060	8,920	Sample taken from shallow seepage standing in cultivated field; affects approximately 250 sq. ft.; hole is not visible, but gas bubbles and oil indicate location.
9	Reported abandoned exploration hole containing gas, oil & water, in cultivated field.	On A. E. Olson property 100' east of F.A.S. highway 142, 200 yards south of seep described in item 8, above.	1,040	1,440	14	488	375	545	3,730	8,940	Sample taken from an 18" hole in field; fluid level was 2" below ground level with gas escaping and oil on top of water. Seep appeared in last 3-6 months and, at first, flowed water suitable for stock.
10	Cellar of a producing oil well.	A. E. Olson property, 330' out of the northeast corner of Block 189, BBB&C Survey.	64,700	34,200	12	5,350	1,350	126	1,410	110,000	Gas was bubbling through water covered by a film of oil in the cellar of the well.
11	Brine disposal well operated by Baker, Camp and Davis.	E. W. Rosenquist property, 900' from south line and 2,500' from west line of Block 181, BBB&C Survey.	62,500	32,700	13	5,080	1,390	112	1,370	107,000	Well disposes all brine produced from 3,300' pay zone on the Almquist and Olson leases. Sample taken from leak in line at well head.
12	Brine discharge line from separator.	A. E. Olson property, 200 yards east of residence in southwest corner of H&TC Survey, Blk. 3, sec. 19.	61,300	31,200	--	5,250	1,580	74	13	105,000	Brine discharges to pit gathering brine produced from Swastika sand on A. E. Olson lease; from there it is pumped into a disposal well.
13	Leaking concrete-lined cistern 23' deep.	A. E. Olson residence, 100' west of the east line and 1,900' south of the north line of Blk. 189, BBB&C Survey.	510	Na+K 488	--	468	176	208	1,980	4,620	Sample taken from a disconnected cistern, which reportedly developed leaks and now contains only ground water. Water level was 17.4' below ground level.
14	Dug water well 29' deep, equipped with pressure pump.	At residence of Burger Haterius approximately 2,100' east of west line and 100' south of north line of Blk.189, BBB&C Survey, ½ mi. west of F.A.S. highway 142.	1,070	Na+K 579	--	282	189	332	920	5,250	Sample was taken from tap at pressure tank; well used for stock and lawn only.