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RESULTS OF TEST DRILLING BY CITY OF GALVESTON

November 1941 to June 1942

By

B. A. Barnes

Prepared in cooperation with the United States Department of the Interior, Geological Survey, and the City of Galveston, Texas

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Introduction

Since 1931 when funds have permitted, the Texas Board of Water Engineers, in cooperation with the United States Geological Survey, has carried out a program of ground-water studies in the Houston-Galveston areas Texas. The work in Galveston County, until December 1938, had been of a reconnaissance nature, carried on in connection with the more detailed Houston program. In December 1938 the City of Galveston appropriated $2,500, which was matched with an equal amount by the United States Geological Survey and the Texas Board of Water Engineers for a ground-water investigation of Galveston County and surrounding areas. This was followed by a second appropriation of $2,500 in September 1940, which was also matched.

An intensive program of field work was carried out from December 1938 until August 1939. As a result of that investigation a test well drilling program was recommended and carried through on funds allotted by the city of Galveston. Test wells were put down as follows: No. 1 in the Alta Loma well field; No. 2, two and one-half miles northwest of Alta Loma; No. 3 at Hitchcock; No. 3a, offset well to No. 3 at Hitchcock. The results of the drilling, with conclusions, are given in a report to the city of Galveston dated April 1, 1941, entitled "Results of Test

Drilling by City of Galveston and conclusions", by B. A. Barnes. The main conclusions in the report having to do with the development of a new water well field are as follows:

(1) The clays underlying the main water-bearing sand are neither thick nor continuous.

(2) Salty water has invaded the Alta Loma field and this invasion has been materially expedited by over-pumping in the field itself. The wells should have been more widely spaced and the individual wells should have been more lightly pumped.

(3) No more pumping should be done in the Alta Loma field or in closely adjacent areas.

(4) New wells should be located well to the outside of the present field. Some locality to the northwest near test well 2, it is believed, would be suitable; the indications for obtaining a satisfactory supply seem reasonably good also toward the north and west of Alta Loma.

(5) The new wells in no case should be pumped at more than a rate of one million gallons a day each.

(6) Before the location of each of the new wells is definitely fixed a small test hole should be drilled and an electrical log obtained.

On that report as a basis a program of well exploration and well development in the area north and northwest of Alta Loma was formulated. As worked out with R. W. Owens, Superintendent of the Galveston Water Department, and George Sager, Jr. of Ford, Bacon and Davis, Consulting

Engineers for the City, the original plan for this program contemplated the drilling of five test wells and five production wells. Four of the test wells were to be drilled as a guide to the production wells at sites tentatively selected for the latter and the fifth was to be drilled as an exploratory well. One of the production wells, it was decided, should be put down at the location of test well num 2 (Galveston County No. 689) of the previous drilling program. The location of the other four was to be determined by the results of the test drilling. The program was started on November 30, 1941 and finished about June 1, 1942, the writer serving in an advisory capacity during this period.

Factors influencing the choice of sites for test drilling

A few of the factors influencing the selection of sites for the developing of a new well field in this area were as follows: The new well field should be located about two miles from the Alta Loma field. The chloride in the water produced from each new production well should be as low as possible. The production wells should be spaced approximately one mile apart, and the yield of each well should not exceed one million gallons a day. The purpose of the last two qualifications is to limit the depth of the cone of depression produced by the combined pumpage from all the wells. The danger of salt water invasion and the pumping costs all should be less than they would be with closer spacing and heavier pumping.

The geological conditions both areally and in the immediate vicinity of each new production well must be favorable for development. Information had to be obtained regarding the continuity of the main water-bearing sand, the thickness and permeability of the sand, the character and thickness of the material separating the main water-bearing sand from the salt water sands below and the stratigraphic position and thickness of the sands containing salt water, and the position

and concentration of any salt water encountered in the main water-bearing sand itself.

Some of the economic factors that had to be considered included the availability of existing roads, cost of necessary new road construction, length and cost of pipe lines and availability and cost of real estate needed for production well sites.

Twelve test wells were drilled during this program (1-4 to 12-15 1/ inclusive), three of which were cased and screened at selected horizons for use as observation wells and the remainder plugged with cement and abandoned. Test wells 1-4, 3-6, 4-7, and 5-8 were drilled to explore the conditions at sites tentatively selected for production wells which with the development of a well at the location of test well 2 constituted the originally proposed five production wells. Test 2-5 was drilled to establish the continuity and thickness of the main sand and to determine the quality of water contained in the main sand some distance updip from the new well field. Upon the completion of test well 4-7 it was decided to reject this location as unsuitable for well development and because of this rejection the engineers for the city considered as uneconomical the development of a well at test number 2, making two additional production well sites necessary.

Further testing for these additional locations was transferred to the east of the Alta Loma-Dickinson road because of the existence of country roads, near the proposed sites and because of the high chloride found in tests 2-5 and 4-7. The additional sites selected for testing were about 0.7 mile east of test wells 5-8 and 1-4, at the locations of 6-9 and 11-14, respectively.

After test well 6-9 had determined the existence of favorable ground-water conditions at that location it was thought that information concerning the continuity and thickness of the main sand and the quality of water in the sand some distance to the east and southeast was necessary. This was especially needed in view of the fact that high chloride water was known to exist in the main sand to

1/ Wells are designated 1-4,3-6 etc. The first number in each of these combinations (1 for example) represents the number of the well in the Ford, Bacon and Davis program and the second(4) represents its number in the combined series starting with the 3 wells of the first program.

the east and southeast. It was for these reasons that test wells 7-10 and 9-12 were drilled. Well 8-11 was drilled about two miles southeast of well 2-5 to determine the southeast extension of the high chloride water that had been encountered in test well 2-5.

In the latter part of the program, due to an estimated increase in the demand for water, both the city and consulting engineers considered it advisable to drill an additional or sixth production well. Because of the additional pipe line required and the estimated higher chloride of the water the location of test well number 2 was considered less desirable than sites either to the north or south of the 5 locations already tentatively selected. Test wells 10-13 and 12-15 were drilled in an effort to find a more suitable location for the sixth production well. Neither of these sites was found to be as favorable for a production well as the site at test well 2, and therefore the sixth production well was drilled at the latter site.

Results of tests with conclusions

(See map for location of wells)

Well 1-4

Location - This well is located ½ mile south of Dickinson Bayou, about 900 feet east of the Dickinson-Alta Loma road, and 4 miles northwest of the Alta Loma well field.

Main water-bearing sand - According to the electrical log the main sand in this well is 140 feet thick, and is located from about 632 to 772 feet below the surface. The well was cased and cemented. Water samples pumped through screens at 721 to 731 and 760 to 770 feet below the surface contained chlorides of 140 parts per million and 178 parts per million respectively. (See table for complete analyses.)

Sediments below the main water-bearing sands - At 772 to 828 feet below the surface, immediately below the main sand, there is approximately 56 feet of sandy clay and clay. Following this at about 828 to 883 feet is a 55 foot well developed sand. A water sample was obtained from this sand through a screen at 870 to 880 feet below the surface. The chloride in this sample was 770 parts per million. (See table for complete analyses.)

The remainder of the material to the bottom of the test hole at 1,207 feet, consists mainly of sandy clays, sands and clays and from the appearance of the electrical log the water in the sands becomes progressively saltier with depth.

Conclusions - The ground-water conditions encountered in this test well were considered satisfactory for the development of a production well at this locality. The thickness of the sand is sufficient and the quality of the water contained in the sand is considered satisfactory and in addition the 56 feet of material, separating the main sand from the underlying sands containing brackish or salty water, was thought to be sufficiently thick and impermeable.

Location - This test well was drilled 5 miles west of test well 1-4, about 7½ miles northwest of the Alta Loma well field and 2½ miles north of Algoa.

The first test well drilling program had indicated the possibility of excessive thinning of the main water-bearing sand in the area to the northwest of test well number 2. Due to this possibility test well 2-5 was drilled to determine the continuity of the main water-bearing sand and the quality of the water in the sand several miles up-dip from both the Alta Loma field and the proposed new field north of Alta Loma.

Main water-bearing sand - At this location the main sand is well developed between about 626 and 718 feet below the surface. This thickness, (about 92 feet) however, may not represent the full section of the sand, as the exact position of the top of the sand is somewhat obscure. The sand may extend from about 598 to 718 feet below the surface, which would give a thickness of approximately 120 feet. A water sample obtained by the drill-stem method from 709-714 feet below the surface, or within about four feet of the bottom of the sand, showed 458 parts per million og chloride. (See table for complete analysis.)

Sediments below main water-bearing sand - With the exception of a thin sand from about 760 to 777 feet practically all of the first 100 feet of sediments underlying the main sand appears to be dense clay. The first sand of any importance is a 40 foot sand between about 818 and 858 feet below the surface. The remaining material to the total depth of 1,220 feet is predominantly sand and sandy clays with interbedded clays.

No water samples were obtained below the base of the main sand but from the appearance of the electrical log the quality of the water in the sands is believed to become progressively worse with depth.

Conclusions - The information obtained from this well indicated that the main water-bearing sand, although rather thin, does not pinch-out in this direction. This conclusion is also substantiated by electrical logs of oil tests in the Hastings and League City Oil Fields to the northwest and northeast of this test well.

The high chloride content of 458 parts per million at the base of the sand was very disappointing as it previously had been thought that the sand this far up-dip would contain water much lower in chloride. The electrical log indicates that the water in the top 20 feet of the sand may be slightly better quality, but otherwise it is believed that there is little change throughout the sand.

Well Number 3-6

Location - This well is located 2½ miles northwest of the Alta Loma field, and 1¾ miles south of test well 1-4. This was the second of the original tentatively selected well sites to be explored by test drilling.

Main water-bearing sand - The thickness of the main water-bearing sand in this well is about 106 feet; with the top at about 676 feet and the base at 782 feet below the surface. A drill-stem test water sample, obtained from a sandy section immediately below the base of the main sand, showed 375 parts per million of chloride. However, the sample was contaminated with drilling fluid which was

lower in chloride. It is believed therefore that the actual chloride content of the water in this section is considerably more than 375 parts per million. After the well was cased and cemented another sample of water was pumped from the main sand through a screen at 760 to 770 feet below the surface. The chloride in this sample of water was 380 parts per million.

Sediments below the main water-bearing sand - With the exception of several minor sandy clay members the sediments below the main sand from 782 to 905 feet appear from the electrical log to be fairly dense clays. The first sand of any importance occurs between about 905 and 1,007 feet below the surface. The remainder of the material encountered to the total depth of 1,200 feet consists chiefly of sandy clay and clay.

Conclusions - The water-bearing sand at this location although thinner than was hoped for was considered sufficient for production well development. The thickness of the section of clays and sandy clays separating the main water-bearing sand from the sands below containing highly mineralized water is 125 feet, which was considered satisfactory.

The quality of water at the base of the main sand (380 parts per million) is high for municipal use but from the appearance of the electrical log, the quality of the water materially improves toward the top of the formation. It was believed, therefore, the sand as a whole will yield water containing considerably less than the 380 parts per million of chloride.

Well Number 4-7

Location - This test well was drilled 2 miles southwest of test well 1-4, ½ mile north of test well 2, and 3½ miles northwest of the Alta Loma well field. This was the third of the original tentatively selected production well sites to be tested.

Main water-bearing sand - The thickness of the main sand at this location, 108 feet, is practically the same as in test well 3-6. The top occurs at about 657 feet and the base at 765 feet below the surface. A drill-stem sample of water obtained from the sand between 738 and 749 feet contained 360 parts per million of chloride.

Sediments below the main water-bearing sand - The main sand is underlain by a bed of clay only 8 feet thick (from 765 to 773 feet). Below this is a sand section 82 feet thick (773 to 855 feet) which, from the appearance of the electrical log, is believed to contain water that is rather highly mineralized. The remainder of the material to the bottom at 1,190 feet is chiefly sandy clay, sand and thin clays.

Conclusions - The thickness of the main water-bearing sand (108 feet) was considered satisfactory but the absence of an adequate separating clay between the main sand and the sand below, which apparently contains highly mineralized water, was thought sufficient to condemn this location as unsatisfactory for production well development. The electrical log further indicates that there is not sufficient improvements in the quality of the water toward the top of the sand to greatly reduce the chloride of the average water from the full sand section below that obtained in the drill-stem test.

Well Number 5-8

Location - This well is about 1 mile south of test well 1-4 and 3 miles northwest of Alta Loma, at the fourth and last of the sites originally selected for test drilling for a production well.

Main water-bearing sand - The top of the main sand occurs here at about 665 feet and the bottom at about 773 feet below the surface; a section about 108 feet thick. Two thin beds of clay are present, one at about 700 and the other at about 750 feet. A water sample was obtained by the drill stem method near the base of the sand, between 758 and 764 feet below the surface. This sample contained 284 parts per million of chloride.

Sediments below main water-bearing sand - Immediately below the base of the main sand is 10 feet of clay and then about 18 feet of sand, indicated by the electrical log to contain salt water, and below this thin sand is about 32 feet of clay. The highest sand of any importance lies between about 854 and 895 feet below the surface. The remainder of the material encountered in the test well to the total depth of 1,203 feet consisted chiefly of sand interbedded with sandy clay and some clay.

Electrical log interpretation indicates that each successively deeper sand contains saltier water.

Conclusions - The thickness of the main sand in this test well (108 feet) is probably sufficient for permanent well development although according to the electrical log the basal 20 feet appears to be less permeable than the remainder of the sand.

Although a thin salt water sand occurs about 10 feet below the base of the main sand it was believed that it is not thick enough to warrant the rejection of this site as a permanent production well.

From interpretation of the electrical log it appeared probable that the full section of the main sand would yield water slightly lower in chloride than the 284 parts per million of the drill stem sample.

Well Number 6-9

Location - This well is 1 mile southeast of test well 1-4 and 3 miles north of the Alta Loma well field. This is the first of the supplementary test wells made necessary by the rejection of site of test well 4-7 for production well development.

Main water-bearing sands - The top of the main sand in this test well was encountered at about 655 feet and the base at about 786 feet below the surface; a total thickness of about 131 feet. A drill-stem sample of water obtained from the sand between 762 and 769 feet contained 154 parts per million of chloride. (See table for complete analysis).

Sediments below the main sand - Immediately below the main fresh water sand is a clay about 35 feet thick from 786 to 821 feet below the surface. This in turn is underlain by a salt water sand about 70 feet thick containing minor clays. The remainder of the sediments to the bottom at 1,195 feet is chiefly sandy clay, with interbedded sands and clays.

Conclusions - Both the thickness of the main fresh water sand and the clay separating it from the salt water sands below appear to be favorable

for the development of a production well at this site.

It appears from the electrical log that the water from the full sand section will be somewhat lower in chloride than the 134 parts per million recorded in the drill-stem sample between 762 and 769 feet below the surface.

Well Number 7-10

Location - This test well was drilled 2 miles east-southeast of number 1-4 and 3½ miles northeast of the Alta Loma well field.

The data obtained from the tests made up to this time indicated that it would be desirable to shift several units of the well field about 0.7 mile to the east of the Alta Loma-Dickinson road. This well was the first of two tests that were drilled to obtain information concerning the continuity, thickness and character of the main water-bearing sand. As wells to the east and southeast of this location yield water high in chloride, this well was also drilled to determine whether such water is present at the site of well 7-10.

Main water-bearing sand - At this point the main sand is only 84 feet thick with the top at about 687 and the base at 771 feet below the surface. A drill stem sample of water obtained near the base of the sand between 756 and 765 feet contained 134 parts per million of chloride.

Sediments below the main water-bearing sand - In this well there is about 16 feet of clay separating the main fresh-water sand from a broken sandy section between 787 and 813 feet below the surface. A water sample, collected from this sandy section between 793 and 800 feet, contained 237 parts per million of

chloride, but the fluid recovered in each of the three attempts at a drill-stem test was contaminated with drilling fluid containing fresher water. It is believed, therefore, that the actual chloride content of the water in this section is somewhat higher than 237 parts per million. The remainder of the material encountered in the well to the bottom at 1,199 feet, was chiefly sandy clays and sands.

Conclusions - This test well furnishes information in an area where previously no reliable data had been available. Although the main sand section is thin at this location, electrical logs in League City oil field about 4 miles northwest and test well 9-12 about 3½ miles southeast indicate that this condition may be local.

The water near the base of the main sand in this well is exceptionally low in chloride.

Well Number 8-11

Location - This test is 3½ miles west of test well 1-4 and 5½ miles northwest of the Alta Loma well field, and was drilled to determine the eastward extent of the high chloride water encountered in test well 2-5.

Main water-bearing sand - The main sand here has a thickness of about 88 feet, from 633 to about 721 feet below the surface. Two water samples were collected from the sand, one by the drill-stem method, between 706 and 717 feet, and the other by pumping after the well had been cased and cemented and a screen set from 669 to 677 feet below the surface. The first sample contained 420 and the other 300 parts per million of chloride.

Sediments below the main water-bearing sand - According to the electrical

sandy clay members. Immediately below this clay, from about 752 to 812 feet, is a well developed sand section. The remainder of the material to the bottom of the well at 1,201 feet, with the exception of one rather thick sand at about 870 to 897 feet, appears to be predominantly sandy clay and clay.

Conclusions - Near the base of the sand at 706 to 717 feet the water contains 420 parts per million of chloride, only 38 parts less chloride than was found in test well 2-5, at approximately the same relative position in the sand. The chloride is 300 parts per million about 40 feet higher in the sand at 669 to 677 feet, and according to the electrical log this rather rapid improvement in the quality of the water continues to the top of the sand. Conditions here as regards the quality of the water therefore are believed to be materially better than those conditions encountered in test well 2-5.

Well Number 9-12

Location - This test well was drilled 2½ miles north of Hitchcock and 3½ miles east-northeast of the Alta Loma well field.

In test well 3 at Hitchcock water containing 1,380 parts per million of chloride was obtained in a drill-stem test at 1,021 to 1,023 feet and in addition, the electrical log indicates that the basal 50 to 75 feet of the sand contains high chloride water. At LaMarque the G.H. and H. railroad well (Galveston County No. 205), 914 feet deep, and screened from 873 to 914 feet yields water having 750 parts per million of chloride. Well 9-12 was drilled to determine whether the high chloride water in the lower part of the sand extends into the area north of Hitchcock, and west of LaMarque.

Main water-bearing sand - The main sand in this test is about 152 feet

thick, the top being encountered at about 744 feet and the base at about 896 feet below the surface.

Two water samples were obtained by the drill-stem method, one at 825 to 833 feet, and the other, near the base of the sand, at 877 to 888 feet below the surface. The upper sample contained 158 and the lower one 295 parts per million of chloride.

Sediments below the main water-bearing sand - Below the base of the main sand is a 16 foot clay which in turn is underlain by a six foot sand that, according to the electric log, contains salt water. This clay in turn is followed by interbedded clay and sandy clay to the top of a 17 foot salt water and at 959 feet. The remaining material to the bottom of the well at 1,202 feet is predominantly sand interbedded with sandy clay and clay. The electrical log indicates that the water in the sands becomes progressively saltier with depth.

Conclusions - The thick sand section encountered in this well is probably not exceptional, as the general tendency of the sand is to become thicker to the south and southeast. The chloride content of the water in the sand at this location is encouraging and seems to indicate that the unfavorable conditions which were encountered in test well 3 at Hitchcock and salty water comparable to that yielded by the LaMarque well do not extend this far north and west. The favorable ground-water conditions encountered in this test well indicate this is an additional area for consideration in any further well development.

Well Number 10-13

Location - This test well was drilled 2½ miles south of number 1-4,

and 1½ miles northwest of the Alta Loma well field. (See map).

Prior to the drilling of this well tentative locations had been selected for the drilling of 5 production wells. Due to an estimated increase in the demands for water it was thought advisable, both by the city and consulting engineers, to drill an additional or 6th production well. A considerable saving in pipe line cost could be effected if a suitable location for this additional well could be found near the pipe line serving the other five wells. It was for these reasons that this test and test well 12-15 were drilled, one to explore the area to the south and the other the area to the north of the 5 locations already selected.

Main water-bearing sand - At this location the well developed section of the main sand is about 92 feet thick, the top occurs at about 728 and the base at about 820 feet below the surface. A water sample obtained by the drill-stem method from the base of the sand between 812 and 825 feet contained 450 parts per million of chloride.

Sediments below the base of the main sand - With the exception of several minor sandy sections the sixty feet of material immediately underlying the main sand appears to be a dense clay. Below this to the top of the first sand of any importance, at 1,005 to 1,034 feet, the material is mainly clay and sandy clay. With the exception of a sand at about 1,092 to 1,126 feet the material from 1,034 to the bottom at 1,197 feet is practically all sandy clay and clay. No water samples were collected below the main sand but from the appearance of the electrical log all the sands are believed to contain highly mineralized water.

Conclusions - The sand at this location is relatively thin and the quality of the water in the basal 28 feet of the sand (450 parts per million of chloride)

is very high. According to the electrical log the quality of the water improves toward the top but there is not a sufficient amount of this better quality water to warrant production well development at this location.

Well Number 11-14

Location - This well is about ½ mile east of test well 1-4, and 4 miles north of Alta Loma. The location was one of those tentatively chosen as a site for a production well and the test was drilled to determine its suitability.

Main water-bearing sand - The main water-bearing sand in this well, according to the electrical log extends from about 638 to about 807 feet below the surface, a total thickness of about 169 feet. A water sample obtained from the base of the sand at 794 to 805 feet contained 445 parts per million of chloride.

Sediments below the main water-bearing sand - The first 55 feet of material underlying the main sand consists of clay and sandy clay. Below this between 862 and 886 feet is the first well developed salt water sand. From 886 to the bottom of the well at 1,194 feet the sediments encountered were chiefly sand, sandy clay and clay.

Conclusions - Several conflicting factors influenced the selection of this location for a production well. The thickness of the main sand, thickness of the material separating the main sand from the salt water sands below it are both favorable for well development. The chloride content of the water at the base of the sand is high, but interpretation of the electrical log indicates a rather rapid improvement in the quality of the water toward the top of the sand which would cause the quality of the average water to be acceptable. It would not be advisable however to screen the basal 32 feet of sand. Moreover, addi-

tional tentative well sites were limited by economy of pipe line, length of access roads and the available property.

Well Number 12-15

Location - This well is located ½ mile northeast of test well 1-4, ½ mile south of Dickinson Bayou and 4½ miles north of the Alta Loma well field, and was drilled at an alternate site for an additional or sixth production well.

Main water-bearing sand - Although not very plainly indicated in the electrical log the top of the main sand is assumed to be at about 632 feet, and the base at about 783 feet below the surface, which indicates a thickness of about 151 feet. However, the top 25 feet from 632 to 657 does not appear to be as well developed as the remaining 126 feet of the sand. Two samples of water were obtained in this well; one from 732 to 742 feet contained 838 parts per million of chloride and one from 773 to 783 feet contained 460 parts per million of chloride.

Sediments below the main water-bearing sand - At this location there is practically no separating clay between the main sand and underlying sands containing salt water. The electrical log indicates a 3 to 4 foot clay below the base of the main sand which in turn is underlain by sandy clays and sands to a depth of about 867 feet. The remainder of the material encountered in this test well to a total depth of 1,180 feet is mainly sandy clay and sands with a few interbedded clays.

Conclusions - Similar to the nearby test wells 1-4 and 11-14. A thick sand section was encountered in this well. According to the electrical log the

basal 30 to 35 feet of the sand probably contains water of about the same chloride content at that obtained in the drill-stem test or about 460 parts per million. Because of this and the absence of an adequate separating clay between the main sand and the underlying salt water sands the location was not considered satisfactory for a production well.

Summary

This test drilling program has disclosed conditions that were not heretofore known and confirmed much of the indicative data that was obtained from the first test drilling program. One of the most surprising conditions revealed by this program is the wide variation of the quality of the water in the main sand. Some of the more important facts concerning the main water-bearing sand and its relation to the underlying material are as follows:

The continuity of the main water-bearing sand is one of its outstanding characteristics. Although the thickness ranges between rather wide limits, the sand is not known to pinch out anywhere in Galveston County. Thicknesses encountered during this test drilling program ranged from 84 feet in well 7-10 to 169 feet in well 11-14. In the first test drilling sand sections of 140, 120 and over 250 feet were found in test wells 1, 2 and 3, respectively. Electrical logs of oil tests show sections of sand as thick as 218 feet in the Hitchcock oil field and 337 feet in the Greens Lake Oil field, seven miles southeast and seven miles south of the Alta Loma well field. Thick sand sections are also encountered in the Texas City area. These thick sands at Hitchcock, Greens Lake Oil field and Texas City all indicate a general thickening down the dip at least in the southeastern part of Galveston County.

Permeability figures are not yet available for the new well field, but the specific capacities of the new wells compare favorably with those of the Alta Loma field. The specific capacities of the new wells range from about 20 gallons per minute per foot of drawdown, in well 9, to about 31 gallons per minute per foot of drawdown in well 12.

Wide variations were found in the amount of chloride in the water of the main sand, both laterally and vertically. The chloride in water samples from near the base of the main sand ranged from 458 and 460 parts per million in test wells 2-5 and 12-15 to 184 parts per million in well 7-10. Although water of high chloride was found in test well 2-5, which is updip from the other test wells, it is not believed that this refutes the theory of decreasing chlorides toward the outcrop, but rather stresses the fact that greater variation of chloride in local areas are found than was heretofore thought probable.

In eight wells one sample of water was obtained from the main sand and in test wells 1-4, 8-11, 9-12, and 12-15, two samples were obtained. In each case where two samples were taken the water from near the base of the sand contained the higher chloride. Electrical logs indicate that in all test wells there exists a vertical gradient in the concentration of chloride in the water in the main sand. In some cases this difference from the top to the bottom of the sand is estimated to be small, while in other cases the change is probably several hundred parts per million. The vertical gradient of the chloride concentration found in all the test wells is probably characteristic of the main sand in this locality although the chloride in the basal few feet is partially controlled by local conditions.

The maximum chloride at the base of the sand was not necessarily the deciding factor for selecting sites for the production wells. The estimated rate of change in chlorides and the total change from bottom to top and thickness of the sand had to be considered in selecting sites.

The exploratory drilling showed that the clays underlying the main water-bearing sand are neither thick nor continuous. The interval between the base of the main sand and the top of the first well developed sand containing salt water ranged from 3 or 4 feet in test well 12-15 to about 186 feet in test well 10-13. In fact, further study may indicate that the basal few feet of the sand section in some of the test wells may not belong to main water-bearing sand but to the lenticular section below the main sand in which the separating clays are entirely absent.

All of the sediments below the main water-bearing sand to a depth of about 1,200 feet are lenticular in this area. Nowhere in the area was there encountered a thick sand comparable to the main water-bearing sand and all of the sands below the main sand contain water high in chloride. In test well 1-4 a water sample obtained from near the base (870 to 880 feet) of the 55 foot sand which lies between 828 and 883 feet below the surface contained 770 parts per million of chloride. Information concerning the quality of the water below the main water-bearing sand was obtained in test wells 2 and 3 of the first drilling program. In test well 2 samples of water from 853 to 873 and 1,177 to 1,226 feet contained 1,030 and 1,860 parts per million of chloride, respectively. In test well 3 a water sample from 1,130 to 1,150 feet contained 3,820 parts per million of chloride. In all cases the electrical logs indicated that the water contained in the sands below the base of the main sand is highly mineralized.

The variable thicknesses of sands and concentration of chlorides encountered during this program confirms the advisability of the exploratory drilling as a control measure in locating production wells in this area. During this program three undesirable production well sites were eliminated by advance information furnished by the test drilling, thereby saving the cost of production well develop-

ment at those locations.

The wider well spacing in the new field and the recomended maximum yield of one million gallons per day per well are designed to limit the depth of the cone of depression. The resulting higher water levels will reduce the pumping cost and will retard salt water intrusion.

The low chloride found in the water in test wells 7-10 and 9-12 indicates that possibilities exist for the development of additional ground water to the east and southeast of the new well field. Additional testing in this area would be advisable if further development were contemplated.

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS

	Thickness (feet)	Depth (feet)
Test Well 1-4		
Soil	5	5
Red and yellow clay	14	19
Red clay	31	50
Sandy clay	24	74
Sand	28	102
Red clay	48	150
Sand	21	171
Sandy clay	7	178
Clay	34	212
Sandy clay and shells	56	268
Clay and shells	28	296
Clay, sandy clay and shells	90	386
Sand	8	395
Clay and sandy clay	18	413
Blue clay	25	437
Sand	17	454
Sandy clay	18	472
Sandy clay and sand	28	500
Blue clay and layers of shell	52	552
Clay and shells	33	585
Sand and clay	19	604
Clay and shells	51	655
Clay and sand	18	653
Sand	114	767
Clay and boulders	3	770
Clay and thin sand layers	6	776
Clay and sandy clay	9	785
Sandy clay	5	790
Clay, few shells and lime rocks	20	810
Sandy clay	12	822
Clay	14	836
Sand	18	854
Clay	4	858

	Thickness (feet)	Depth (feet)
Test Well 1-4--Continued		
Sand	30	888
Clay	4	892
Sand	10	902
Clay	84	986
Sandy clay	9	995
Clay	9	1004
Sandy clay and clay	24	1028
Clay	15	1043
Sandy clay and clay	19	1062
Sand	18	1080
Hard clay	17	1097
Sandy clay	40	1137
Clay and shells	38	1175
Clay and sandy clay	21	1196
Sand	14	1210
Clay	2	1212
Test Well 2-5		
Clay and sandy clay, sticky	56	56
Clay and sandy clay streaks	19	75
Sand and sandy clay	14	89
Clay and sandy clay with sand streaks	76	165
Sand (fair)	13	178
Clay and sandy clay	60	238
Clay, streaks of sand	33	271
Sand (poor)	7	278
Shale, some shell	60	338
Shale	40	378
Sand and shale	6	384
Sand and blue clay	54	438
Clay and sandy clay	35	473
Sand (hard)	27	500

(Continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 2-5 -- Continued		
Clay and shells	53	553
Sand and shells	25	578
Sand	1	579
Shale	29	608
Broken sand, shale and shell	17	625
Sand (good)	92	717
Clay	3	720
Sticky shale	36	756
Sand (good)	17	773
Sticky shale	37	810
Sand (broken) (clay lense)	7	817
Sand (cut good)	34	851
Sticky shale	47	898
Sticky shale and layer of rock	2	900
Sticky shale, some shell	22	922
Broken sand and shale	6	928
Sand, few shale streaks	23	951
Layers of shale and sand	33	984
Sand, fine, soft streaks shale	22	1006
Sand, shale and shell	17	1023
Shell and small streaks shale	33	1056
Sand with shell	15	1071
Hard shale	7	1078
Hard shale and shells	90	1168
Shale, few thin sand breaks	11	1179
Hard shale and shell	11	1190
Sand (cut good)	20	1210
Hard sand and shale, some shell	8	1218
Drill stem test at 709-714 feet.		

	Thickness (feet)	Depth (feet)
Test Well 3-6		
Clay	85	85
Fine sand	40	125
Broken clay with shell	65	190
Fine sand	5	195
Broken shale, sand streaks	8	203
Sticky shale	15	218
Sand and shale-breaks	9	227
Tough shale and shell	104	331
Broken shale and sand	17	348
Sandy shale	48	396
Shale (sticky)	17	413
Fine sand	15	428
Shale	19	447
Sand (good)	26	473
Sand (fair)	28	501
Sand, shell and shale breaks	7	508
Sticky shale	53	561
Sandy shale	6	567
Sticky shale	3	570
Sand, shale	14	584
Sand (fine)	10	594
Sandy shale	12	606
Sticky shale	9	615
Sandy shale	49	664
Sand	2	666
Sand and shell	117	783
Shale	3	786
Sand	10	796
Shale, sticky	4	800
Sticky shale	31	831
Sandy layers shale	3	834
Soft sticky shale	25	859
Tough sticky shale	28	887
Sticky shale	19	906

(Continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 3-6--Continued		
Sandy shale	15	921
Fine sand	58	979
Sandy shale	69	1048
Sand	14	1062
Sandy and shale	23	1085
Sand	30	1115
Sand and shale	32	1147
Hard sand	1	1148
Sand	41	1189
Boulder	1	1190
Sticky shale	10	1200
Drill stem test 791-794 feet.		
Test by screen 760-770 feet.		
Test Well 4-7		
Soil	4	4
Red and yellow clay	6	10
Sandy clay	10	20
Sandy clay	2	22
Sand	16	38
Sandy clay	27	65
Clay and sandy clay	15	80
Clay	6	86
Sandy clay and sand	14	100
Clay	6	106
Sandy clay	24	130
Clay	95	225
Sandy clay	30	255
Clay and layers of shell	35	290
Clay and shell layers	25	315
Clay and sandy clay	23	338
Clay	42	380
Sandy clay and clay	30	410
Sandy clay and sand	20	430
Sand	43	473
Clay	84	557
Sand and sandy clay	10	567
Clay and sandy clay	90	657
Sandy clay	9	666

	Thickness (feet)	Depth (feet)
Test Well 4-7--Continued		
Sand and clay layers	4	670
Sand	95	765
Clay	10	775
Hard shale	20	795
Sandy shale	45	840
Sandy clay	2	842
Sand	11	853
Clay	12	865
Clay, sandy clay and shell	17	882
Clay and shell	64	946
Clay, sandy clay and shell	46	992
Clay and shell	46	1038
Fine sand	51	1089
Clay	7	1096
Sandy shale	64	1160
Sand, shell and some shale	11	1171
Sandy clay	21	1192
Clay	8	1200
Test Well 5-8		
Not reported	39	39
Clay, sticky	53	92
Sandy clay	61	153
Sand	13	166
Tough sticky shale	83	249
Sandy clay	112	361
Tough blue shale	35	396
Sand	4	400
Shale and sandy shale	30	430
Sand (good)	39	469
Hard sticky clay	68	537
Hard sticky shale	9	546
Sand	6	552
Sticky shale	14	566
Sand	13	579

(Continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 5-8--Continued		
Sticky shale	20	599
Sandy shale	8	607
Sand	5	612
Sticky shale	16	628
Sandy shale	27	655
Sticky shale	3	658
Sandy shale	15	673
Sand	91	764
Sticky shale	3	767
Sand	2	769
Sticky shale	3	772
Sticky shale	8	780
Shell and sand	7	787
Sticky shale	7	794
Soft sticky shale and layers of shell	78	872
Sandy shale	43	915
Soft sticky shale	95	1010
Sand	26	1036
Soft shale	23	1059
Sand, fine	47	1106
Shale, soft and sandy	69	1175
Sand	2	1177
Shale, soft and sandy	6	1183
Sand and sticky shale	18	1201
Test Well 6-9		
Surface soil	3	3
Clay and gravel	5	8
Red sand	7	15
Clay and sandy clay	77	92
Fine white sand	24	116
Sandy clay and shell	29	145
Clay and sandy clay	315	460
Sandy clay	10	470
Clay	30	500
Clay, shell and sandy clay	18	518
Clay and shells	60	578
Sandy clay	9	587
Clay and shell	25	612
Sandy clay	3	615
Sand	11	626
Clay and shells	11	637
Clay and sandy clay	5	642
Sandy clay	6	648
Clay and sandy clay	18	666
Clay and sand layers	3	669
Sand	13	682
Clay	2	684
Sand	108	792
Clay	35	827
Clay and sand layers	6	833
Sand	7	840
Sandy shale	20	860
Sticky shale	6	866
Sandy shale	32	898
Sticky shale	46	944
Sandy shale	37	981
Shale	34	1015
Sandy shale	35	1050
Fine sand and shell	67	1117
Shale and shell	5	1122
Sand, shale and shell	49	1171
Sticky shale	15	1186
Sandy shale	6	1192
Sticky shale	8	1200
Drill Stem Test 762 to 768 feet.		
Test Well 7-10		
Surface soil	3	3
Clay	5	8
Sandy clay	10	18
Clay and shells	15	33
Red clay	38	71
Blue clay	11	82
Sand	19	101
Sand and sandy clay	15	116
Clay and shells	74	190

(Continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 7-10 -- Continued		
Clay and sandy clay	26	216
Sand and sandy clay	10	226
Soft clay and shells	54	280
Clay and layers of sandy clay and shell	290	570
Sand	9	579
Clay, sand layers	55	634
Clay	43	677
Clay and sandy clay	11	688
Clay and sandy layers	2	690
Sand	82	772
Clay	26	798
Clay and sandy clay	10	808
Sand	5	813
Clay and sandy clay	15	828
Sandy clay and shell	14	842
Clay	16	858
Sand and shell	10	969
Clay	28	896
Sandy clay and shell	14	910
Sandy shale	30	940
Shale	70	1010
Shale and sandy shale	50	1060
Clay, sandy clay and sand	25	1085
Sand, fine	56	1141
Clay and shells	43	1184
Clay, sandy clay and shells	16	1200
Test Well 8-11		
Clay	26	26
Red sand	4	30
Clay	7	37
Sand	6	43
Clay	34	77
Sandy clay, shell and sand	33	110
Clay, shale and shell	90	200
Clay and layers of shell	76	276
Sandy clay	20	296
Clay, and shell	54	350
Sand	30	380
Clay	24	404
Sand and sandy clay	11	415
Sand	48	463
Hard clay	27	490
Sandy clay and shell	15	505
Clay and layers of shell	20	525
Sticky clay	35	560
Clay	20	580
Sandy clay and sand	20	600
Sand	4	604
Clay	6	610
Clay and thin sand layers	23	633
Sand	87	720
Clay	14	734
Sandy clay	1	735
Clay	12	747
Sandy clay	8	755
Sand	5	760
Sandy clay	7	767
Soft clay	6	773
Sandy clay	35	808
Shale	34	842
Sandy shale	8	850
Shale	20	870
Sand	25	895
Shale	12	907
Sandy shale	11	918
Shale	2	920
Sandy shale	17	937
Sandy clay and shell	28	965
Fine sand	3	968
Sandy shale	11	979
Shale and shell	16	995
Shale with sandy streaks	65	1060
Sandy shale and sand	30	1090
Sand, sandy shale and shell	40	1130
Sandy shale and shell	34	1164
Shale	16	1180
Sandy shale and shell	20	1200

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 9-12		
Soil	4	4
Soft clay	11	15
Sandy clay	12	27
Soft clay	8	35
Not reported	46	81
Sand	33	114
Clay	16	130
Clay, shell and gravel	100	230
Clay	10	240
Sandy clay	17	257
Sandy shale and shell	28	285
Shale	27	312
Fine sand	8	320
Sandy shale	74	394
Shale	36	430
Blue shale	23	453
Sand	63	516
Shale	6	522
Sand, hard	22	544
Shale and shell	36	580
Clay and shells	68	648
Sandy clay	8	656
Clay and thin sand layers	20	676
Sand	20	696
Clay, sticky	49	745
Sandy clay	10	755
Sandy clay and sand	7	762
Sand	8	770
Sand	126	896
Sticky clay	10	906
Sticky shale	7	913
Sand	4	917
Shale	10	927
Sand	1	928
Sandy shale	5	933
Shale	21	954
Sandy shale	6	960
Sand	15	975
Sandy shale	5	980
Sandy clay	42	1022
Clay and sand layers	19	1041
Sand	9	1050
Clay, sandy clay, and		

	Thickness (feet)	Depth (feet)
Test Well 9-12--Continued		
Clay, sandy clay, and sand	30	1080
Sand	25	1105
Sandy clay	5	1110
Sand	15	1125
Sandy clay and sand	25	1150
Sandy clay and sand	14	1164
Clay	36	1200
Test Well 10-13		
Not reported	20	20
Red and yellow clay	9	29
Red sand	9	38
Blue clay	47	85
Fine white sand	28	113
Sand and clay layers	8	121
Clay	15	136
Sand	8	144
Sandy clay	6	150
Clay	53	203
Sandy clay	7	210
Clay	37	247
Fine sand, layers of shell	45	292
Clay with shell	22	314
Sandy shale and clay	36	350
Sandy clay and clay	48	398
Sand	6	404
Sandy clay	9	413
Sand	7	420
Sandy clay layers	13	433
Clay and shells	32	465
Sandy clay	17	482
Clay and sandy clay	15	497
Sand	3	500
Clay	2	502
Sand	8	510
Clay	52	562
Sandy clay	6	568
Sand, good	11	579
Clay	9	588
Sand	3	591
Sandy clay	14	605
Clay	19	624
Sandy clay	9	633
Clay and sandy clay	70	703

(continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS -- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 10-13--Continued		
Sand	6	709
Clay	1	710
Sand	1	711
Clay	6	717
Sandy clay	6	723
Sand and clay layers	9	732
Sand	59	791
Clay and thin sand layers	9	800
Sand	21	821
Clay	61	882
Sand	6	888
Clay	29	917
Sandy clay	4	921
Clay, sticky	14	935
Sandy clay	44	979
Sticky clay	30	1009
Fine sand	21	1030
Sand	1	1031
Clay and sandy clay	44	1075
Clay	21	1096
Sandy clay	7	1103
Sand	24	1127
Clay and sandy clay	61	1188
Clay and shells	12	1200
Test Well 11-14		
Soil	3	3
Gray clay	4	7
Brown clay	13	20
Red sand	15	35
Red clay	15	50
Sticky clay	20	70
Red clay	16	86
Sand	30	116
Red clay	44	160
Sand	16	176

	Thickness (feet)	Depth (feet)
Test Well 11-14--Continued		
Clay and shells	34	210
Clay and shells	35	245
Soft sandy clay	11	256
Clay and shell	34	290
Sandy clay	58	348
Clay and sandy clay	23	371
Sand and shells	26	397
Clay and shells	44	441
Sand	5	446
Clay and sandy clay	10	456
Sand	23	479
Clay	20	499
Sandy clay	15	514
Clay	43	557
Sandy clay	17	574
Clay (hard)	70	644
Sand	74	718
Clay	1	719
Sand	86	805
Clay	1	806
Sand	1	807
Clay	9	816
Clay and thin sand layers	4	820
Sandy clay	8	828
Clay	34	862
Sandy clay	3	865
Sand	21	886
Clay	8	894
Clay and sandy clay	84	978
Sand	6	984
Clay and sand layers	16	1000
Clay and sandy layers	18	1018
Clay	11	1029
Sand, fine	14	1043
Sandy clay and clay	23	1066
Sand	34	1100

(Continued on next page)

DRILLERS' LOGS OF TEST WELLS

CITY OF GALVESTON WATERWORKS-- CONTINUED

	Thickness (feet)	Depth (feet)
Test Well 11-14--Continued		
Clay	13	1113
Sandy clay	14	1127
Clay and sandy clay	43	1170
Clay and sandy clay	5	1175
Clay and shells	14	1189
Sand and sandy clay	14	1203
Clay	2	1205
Test Well 12-15		
Soil	2	2
Yellow clay	10	12
Red clay	52	64
Fine sand	33	97
Sandy clay	14	111
Clay	37	148
Sand	4	152
Clay and sand layers	8	160
Clay and sandy clay	13	173
Clay and shells	31	204
Clay, sandy clay and shells	152	356
Sand	33	389
Sandy clay	10	399
Clay	39	438
Sandy clay	9	447
Sand	16	463
Clay and sandy clay	67	530
Sandy clay	3	533
Sand	5	538
Clay and sandy clay	6	544
Sand	4	548
Sandy clay	11	559
Clay	38	597

	Thickness (feet)	Depth (feet)
Test Well 12-15--Continued		
Clay and thin sand layers	28	625
Sandy clay	4	629
Sand	4	633
Clay and sand layers	4	637
Sand	20	657
Clay	1	658
Sand	5	663
Clay	1	664
Sand	121	785
Clay and shells	6	791
Sandy clay	7	798
Sand	8	806
Clay	4	810
Sand and sandy clay	7	817
Sand	21	838
Sand and sandy clay	28	866
Clay and sandy clay	62	928
Clay	34	962
Sandy clay	11	973
Clay and sandy clay	31	1004
Clay and shale	18	1022
Fine sand and shell	28	1050
Sand	10	1060
Clay and shells	16	1076
Clay and sandy clay	12	1088
Sand and sandy clay	24	1112
Clay	46	1158
Clay and sandy clay	22	1180

Analyses of water from City of Galveston Waterworks test wells and five of the new production wells. a/

(Results are in parts per million except pH)

Well	Depth of sampling below surface (ft.)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K) (calc.)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$ (calc.)	pH
1- 4	721-731	Dec. 12, 1941	558	33	.24	16	6.1	188	5.9	320	2	140	.6	0	65	8.1
1- 4	760-770	Dec. 16, 1941	617	20	.13	14	4.9	228	5.9	352	2	178	.5	0	55	8.3
1- 4	870-880	Apr. 7, 1942	1,627	14	1.2b/	30	11	597	0	400	0.8	770	.8	0	120	-
2- 5	709-714	Dec. 13, 1941	1,285	9.4	.96	55	19	353	0	394	12	458	.5	0	216	8.9
3- 6	760-770	Dec. 6, 1942	946	20	.05	25	8.3	334	9.6	326	2	380	.7	0	96	-
3- 6	788-791	Dec. 27, 1941	950	12	.04	19	7.8	341	16	310	9.4	375	.6	0	80	-
4- 7	758-749	Dec. 10, 1942	886	20	.03	27	8.7	306	20	270	5	360	.5	0	103	-
5- 8	758-764	Feb. 2, 1942	822	18	.14	18	6.4	297	0	382	1.9	284	.5	.2	72	-
6- 9	762-769	Jan. 21, 1942	803	18	.07	19	5.0	204	0	347	6.6	154	.8	0	68	-
7-10	756-763	Feb. 7, 1942	591	18	.09	13	3.9	206	0	350	15	134	.7	0	48	-
7-10	793-800	Feb. 12, 1942	851	7.2	.05	15	5.7	296	20	390	18	237	-	0	61	-
8-11	869-877	Mar. 10, 1942	808	29	.13	39	13	251	-	334	.7	300	-	0	151	-
8-11	706-717	Feb. 21, 1942	1,024	8.4	.02	32	12	356	20	314	18	420	.4	0	130	-

a/ No sample was obtained from well 14 as pumping equipment was not installed.

b/ Fe in solution - 0.09
Fe in pptd. - 1.1

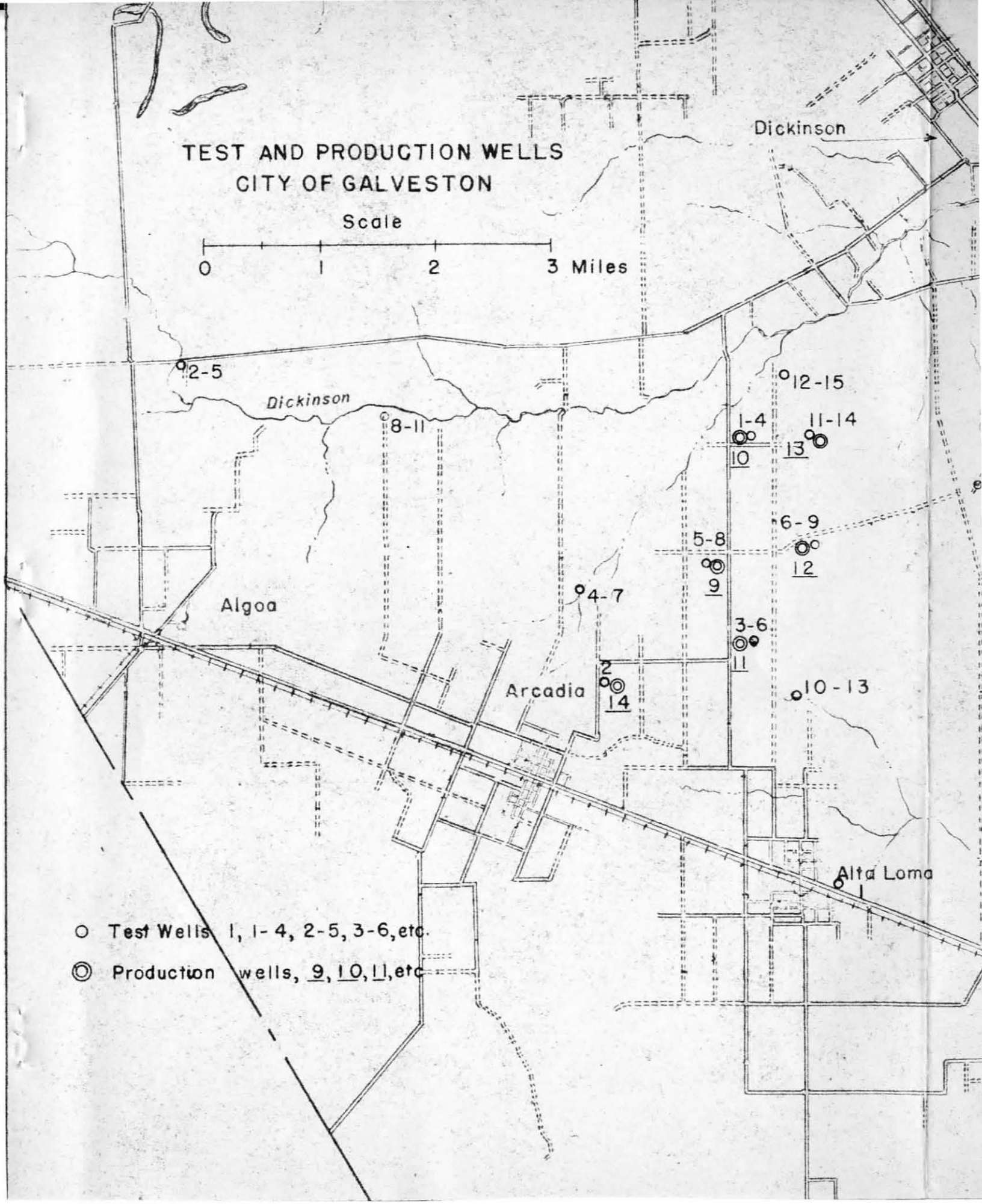
Analyses of water from City of Galveston Waterworks test wells and five of the new production wells--continued a/

(Results in parts per million except pH)

Well	Depth of sampling below surface (ft.)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na + K) (calc.)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total hardness as $CaCO_3$ (calc.)	pH
9-12	825-833	Mar. 15, 1942	599	29	0	12	4.3	217	24	308	3	158	.8	0	48	-
9-12	877-888	Mar. 16, 1942	826	20	0	13	4.7	308	16	336	5.4	295	1.2	0	52	-
10-13	812-825	Apr. 15, 1942	1,052	10	.03	17	6.5	393	0	334	12	450	1.0	0	120	-
11-14	794-805	Apr. 28, 1942	1,075	14	.12	20	7.1	396	0	365	9.4	445	1.2	0	79	-
12-15	732-742	May 8, 1942	731	26	.24	20	6.4	254	0	348	6.0	238	.7	0	78	-
12-15	773-783	May 9, 1942	1,129	14	.13	27	10	401	0	390	9.9	460	.8	0	108	-
9	-	May 28, 1943	711	25	.09	19	5.5	248	0	352	2	224	.7	.8	70	8.0
10	-	do.	576	24	.04	12	3.6	208	0	347	2	146	.8	0	45	8.2
11	-	do.	728	24	.12	17	4.8	261	0	338	3	245	.9	1.2	62	8.2
12	-	May 27, 1943	557	25	.04	13	3.7	198	0	347	2	134	.6	0	48	8.8
13	-	May 28, 1943	594	26	.09	16	4.6	196	0	332	2	170	.8	0	59	8.5

a/ No sample was obtained from well 14 as pumping equipment was not installed.

b/ Fe in solution - 0.09
Fe in pptd. - 1.1


TEST AND PRODUCTION WELLS
CITY OF GALVESTON
Scale
0
1
2
3 Miles
Dickinson
Dickinson
2-5
8-11
12-15
1-4
11-14
10
13
6-9
5-8
12
9
4-7
Algoa
3-6
11
2
14
Arcadia
10-13
Alta Loma
1
Test Wells 1, 1-4, 2-5, 3-6, etc.
Production wells, 9, 10, 11, etc.