University of Texas Bulletin

No. 2234: September 8, 1922

Report on

TEXAS ALKALI LAKES

BY

C. MEIGS, H. P. BASSETT, AND G. B. SLAUGHTER

Bureau of Economic Geology and Technology
Division of Economic Geology
J. A. Udden, Director of the Bureau and Head of the Division

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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FOREWORD

The thanks of the University are due Mr. H. A. Wroe, by whom this report has been submitted to the Bureau of Economic Geology and Technology for publication. The authors of the report are consulting engineers of Philadelphia.

It will be noted that the authors of the report have included estimates on plant requirements, cash requirements, cost of production and profits, as well as the probable price of foreign potash. In printing the report, the University assumes no responsibility or obligation as to the accuracy of these estimates. The statements made represent solely the judgment of the engineers who have made the investigation and have written this report. In only a few instances has it seemed advisable to omit personal references contained in the report. Otherwise the text is that of the manuscript furnished.

The report is published in the belief that it represents a distinct contribution to our knowledge of the Alkali Lakes of West Texas.

J. A. UDDEN, Director.

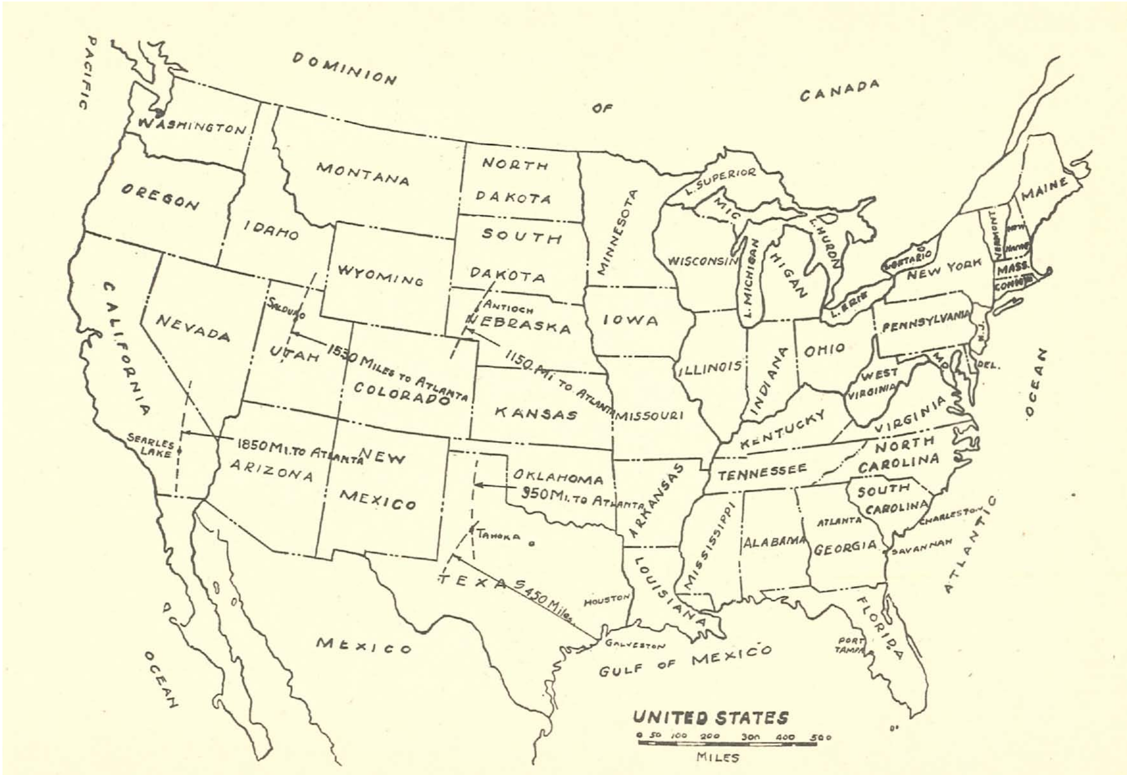


Fig. 1:—Sketch map indicating distance of potash producing localities from market or from water transportation.

REPORT ON TEXAS ALKALI LAKES

BY C. C. MEIGS, H. P. BASSETT AND B. G. SLAUGHTER

GENERAL REMARKS

In the investigation of a property for potash, the following points are the ones which would naturally be borne in mind:

1. A potash content comparing with the very best, readily accessible for treatment.
2. Large supply of raw materials.
3. A combination of salts from which potash may be extracted by known processes and with a minimum expense for reagents.
4. A valuable by-product, easy to separate to commercial purity and for which there is a good market.
5. A location favorable to solar evaporation where evaporation is necessary, as is the usual case.
6. No possible objectionable ingredient in the product.
7. Satisfactory living and labor conditions.
8. Cheapest possible fuel with large amounts available.
9. Proximity to potash markets and supplies.

In looking over the field of present potash sources so far known in this country, one will find as follows:

BRINES

The two sources of potash brines now used are Searles Lake in California and the lakes in northwest Nebraska and Salduro Marsh in Utah (Fig. 1).

Searles Lake

Searles Lake fulfills the first, second, fourth and fifth requirements, but is lacking in the third, sixth, seventh, eighth and ninth points.

It has a high percentage of potash, the supply seems almost inexhaustible; it has borax as a valuable by-product and it is probably the most favored spot in the United States for solar evaporation. However, it has a complex brine containing borates, carbonates, sulphates and chlorides, possible to separate, but requiring delicate chemical control. It has one of the most objectionable impurities for fertilizer, borax, to such an extent that several states have passed stringent laws relating to its presence in fertilizer. It is located in the heart of a desert where fresh water has to be piped for many miles and it is a most undesirable place to live. It is far removed from sources of fuel and other supplies and also from the markets for potash which are practically all in the southeastern states and along the Atlantic seaboard.

The Nebraska Lakes

The Nebraska Lakes fulfill the first, third and reasonably the seventh conditions, but is deficient in the others.

It has brines low in solids, but high in potash content; it is fairly easy to separate the potash to a reasonably high concentration without reagents, and the climate and living conditions are reasonably good. On the other hand, the supply of brine is limited, the location is not favorable to solar evaporation, as the rainfall is fairly high, the humidity is very variable, there are extremes of temperature and the rolling nature of its sandy soil does not lend itself to the economical construction of large basins. While it seems quite possible to extract soda salts from the brines, this has not been done and on account of the comparatively low value of them, it might not pay for the separation. The carbonates contained in the salts have met with objection on the part of fertilizer manufacturers on account of their tending to liberate certain valuable constituents of the mixed fertilizer during the process of manufacture. Fuel from Wyoming is plentiful, but high priced and the location is very far from markets for potash as well as from source of supplies.

Salduro Marsh

The brines in this marsh are very similar to those found in Texas. It fulfills first, second, third, fifth, and sixth conditions, but is deficient in the others, although we consider it the next best potash proposition in the United States. It has no advantage of Texas in the above conditions. Under the fourth condition, it has the same by-products, but there is a limited market for salt in that district and it is not profitable in competition with salt from the solar fields of Salt Lake nearby. A very profitable operation is being conducted on this property, and a recent enlargement of the plant shows that the treatment of brines (almost exactly like Texas as shown later in the report) is proving profitable for potash alone, without the valuable by-products which we can obtain and for which there is a ready market in Texas.

KELP

It has been demonstrated that potash from kelp can not be produced at a profit even under the present relatively high prices.

ALUNITE

Alunite found near Marysvale, Utah, is attractive in respect to conditions two, three, four, six and seven, as there is a large amount available, the salts are fairly simple and easy to separate, it has alumina as a valuable by-product (this has not been produced up to this time, however), the potash product is good, being a sulphate of potash of fairly high purity. The living conditions are also fairly good. It has the objection that it must be quarried and then the material roasted or digested with acid before the extraction process really begins, which adds a heavy expense, practically prohibitive, unless the alumina is recovered, in competition with potash from foreign sources. It is very far from the potash market, sources of fuel and other supplies.

SILICATES

Of the silicates Wyoming leucite is the most promising. It is favorable in respect to points two, three and six. There seems to be a large tonnage, but it is in an insoluble form and the process of volatilization now used requires a very large amount of fuel. It also must be mined or quarried before the process starts which adds a large additional expense. The potash is a rather low grade chloride with no objectionable elements. There are no valuable by-products and it is far removed from potash markets and sources of supplies. It is our belief that it will be very difficult for this location to ship potash so far at a reasonable profit in competition with potash from foreign sources.

GLAUCONITE

Glauconite or green sands of New Jersey are another possible supply and it is our understanding that a company is now preparing to undertake their development. This source fulfills conditions two, six, seven and eight, as there is an enormous deposit, the product being caustic potash is of high value, but of limited demand; it is near large cities with ample labor supply, it has probably the cheapest fuel supply of any potash source and it is right at the markets. However, the potash content is insoluble and must be digested with large amounts of lime under high pressure to bring it into solution and then handled as a caustic through the process. It is an ingenious process, but untried commercially and it is our opinion that many difficulties will remain to be solved in actual operation.

TEXAS BRINES

Practically all potash bearing lakes in Texas have been visited and examined and samples taken of the most promising. Of the entire potash-bearing area, a large proportion containing complicated salts were not considered attractive on account of their not complying with condition three. (For location of lakes examined see Plates 1 and 2 in pocket.)

These brines fulfill conditions one, two, three, four, five and six, also seven and eight better than any source other than the glauconite deposits in New Jersey and for this reason, we believe this source is the most promising potash supply in the United States of those so far reported.

In testing out the lakes, wells were put down at frequent intervals all over them. These wells went to the rock bottom of the lakes in most cases. In practically every case brine rose to the surface and in determining the pumping areas only wells having a flow of two gallons per minute or more were considered. This was determined by pumping the wells with a pitcher pump to see how many gallons per minute could be pumped without lowering the surface of the brine. In most cases 1¼″ wells would furnish more than 20 gallons per minute. The plant of size calculated would require two hundred and twenty-five gallons per minute and it is proposed to take this at a rate of one-half gallon per well per minute. (For location of test wells in lakes see Plates 3, 5, and 7 in pocket and Fig. 8 in text.)

The brine was found in from one to three strata and it is the opinion of all our men who have worked on the lakes that there is an indefinite supply of our requirement in either of the two groups of lakes. The fact that in nearly all cases the brine rises rapidly to the surface and in many cases flows over the top, and that there is the characteristic hissing sound when the brine strata are encountered indicates an abundant supply of brine under some artesian pressure and that the entire mud or silt of the lake bed is moist and permeated with the same salts as contained in the brine. These salts are of about equal strength per cubic foot, are highly soluble, and indicate that the comparatively small amount we will take out should make very little impression on the quantity or quality of the brine. Statements from Dr. Bassett and Mr. Maxwell, one of whom has been on the ground during practically the whole testing period, are included in this report. An interesting phenomenon was noted by Mr Maxwell in some of the wells in No. 2 Double Lakes when he discovered every indication of a definite flow from northwest to southeast. Wands put down in any side would always float to the southeast side, or if put down on that side, would stay. These wells were among the strongest in salts content as well as brine flow. The brine strata is not in sand, but in well defined layers in the silts. The entire silt beds are wet and water percolates slowly through. The past year has been unusually wet and there have been some very heavy rains. Water has not been over six or eight inches deep on the lakes, however, and with one exception, oldest inhabitants say it has never been over one foot deep. That was many years ago when there was a local "water spout" which left a depth of three feet in the center of some of the lakes.

Wells were put down in all lakes at frequent intervals and field potash determinations were made of various strata and of the composite brine. Samples from the wells were sent to the laboratory and accurately analyzed for potassium chloride as shown under "Lake Tests."

Complete composite analyses have been run on samples from lakes as shown later in this report, as well as potash determinations on practically all wells.

These analyses are somewhat lower than analyses of brines taken one year previously. The unprecedented rains of this year have undoubtedly diluted the brines and we have the most unfavorable time that has ever been for making our tests. However, this is on the side of conservatism and we are using these lower figures in our calculations in this report.

After making the tests of No. 1 Double Lake, we found that in pumping the brine required for the experimental work for one well, the brine grew stronger in solids as pumped and also more nearly approximated the average brine. We, therefore, went over a number of representative test holes and rigged up a power pump so as to give a long pumping test and also determine brine content as pumped. The strength was increased and average analyses of these brines after pumping based on 25 per cent anhydrous salts as follows:

KCl	2.10	
NaCl	14.54	NaCl after converting SO_3 17.20
$MgCl_2$	2.18	
$CaSO_4$	0.35	
Na_2SO_4	4.72	

We consider this a typical analysis of the average brines after concentration and use it as a basis of process and production calculations.

GENERAL DESCRIPTION

The properties examined naturally divide into two groups. The Tahoka or Southern Group, located in Lynn and Terry counties, consists of Double Lakes. The Littlefield or Northern Group, located in Hockley, Lamb, Bailey and Cochran counties, consists of Silver Lake, Yellow Lake, Illusion Lake and part of Coyote Lake. The pumping area, or valuable portion of the two groups is discussed later. (Plates 1 and 2 in pocket.)

The two groups are too far apart for one plant and it would be necessary to handle each group with its own reduction plant.

As the brines of the Tahoka group are simpler and contain less of sulphates than the Littlefield group and as the lakes are much nearer together and also to the railroad, we recommend that the first plant be constructed for utilizing brine from them.

The initial capital expenditure would be about $125,000 less on account of saving in pipe lines, solar ponds, etc., and definite data has been obtained on this brine in an experimental plant. The brines coming from the lakes are exactly suited without any treatment other than merely bringing to saturation by solar evaporation.

We are very confident that all brines in the Littlefield Group can be brought to a condition equally as good, but more solar evaporation will be required, with the exception of Coyote Lake which requires concentration to saturation only. To get maximum advantage of the Littlefield lakes, Silver Lake and Coyote Lake should be worked together, pumping to solar ponds on Illusion Lake and at the same time, using the comparatively weak brines of Illusion strengthened by solar evaporation. But for the fact that Illusion Lake is the logical point for solar evaporation ponds, we would not consider it worth working.

A plant at the Tahoka Group should prove just how much can be made of the proposition and a second plant could then be erected at Littlefield based on definite experience at Tahoka.

We have, therefore, made all our calculations based on brine from Double Lakes.

The formation of the various lakes varies considerably, but after a careful investigation, it is our opinion that the following general remarks apply to all the lakes.

The "Alkali Lakes" are not lakes in the true sense of the word, as they are not permanent bodies of water and rarely, if ever, does the water cover the entire surface. They are depressions in the Llano Estacado filled with silt containing brine and crystals of salt.

It is a generally accepted theory that the deposits are ground fed from springs coming from the Permian strata below. According to the Bureau of Economic Geology and Technology of the State of Texas, these depressions were formed when masses of rock salt which occur in the Permian and are known to contain potash were dissolved causing the overlying plain to sink into the depression formed by the removal of the salt beds below. In this sinking process, cracks were made extending down to the Permian as shown on the accompanying sketch made from a pamphlet issued by the Bureau of Geology and Technology quoted below (Fig. 3). The Permian strata can be traced to the higher plains of New Mexico without interruption and are under sufficient hydraulic head to cause a flow through these cracks into the depressions above. The

Permian is not very deep in this section, as the Triassic-Permian contact is exposed in canyons not far distant.

On the origin of these "lakes" a bulletin of the Texas State Bureau of Economic Geology and Technology states in substance:[1]

> The larger depressions of the Llano, none of which have a surface outlet, are known as "alkali lakes" or "salt lakes" although none of them known to the writer is a permanent body of water. . .The bottom of these depressions generally is one hundred to one hundred fifty feet lower than the surrounding uplands and when dry, they are covered with a glittering white efflorescence of salt and alkali and of many rather large crystals of selenite.

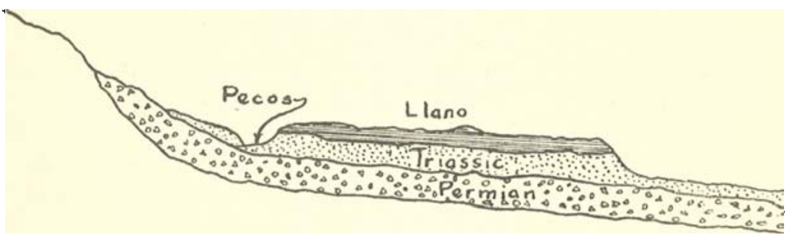


Fig. 2:—Diagramatic representation of the formations of the Staked Plains.

> . . .These depressions have been caused by a sinking of the surface. Beds of salt and gypsum in the under-lying Permian sediments have been removed by solution by the underground waters and caverns thus formed, the caving of the roofs of which has caused the depression of the surface of the Llano. Often one can note the slumping of the surface in a series of benches successively lower in altitude as he approaches the bottom of the depression. Such evidence of slumping can be seen along the road from the railroad station of Littlefield to Yellowhouse Ranch in southwestern Lamb County, as one approaches from the east the basins of Yellow and Illusion lakes and also on the east side of Montezuma or Monument Lake in west-central Bailey County, between the 64-Ranch headquarters and the lake.

[1]University of Texas Bull. 57, pp. 10, 46, 75, and 76, 1915.

Of the water supplied to the Permian strata, we quote from the same:

> "Of the various deposits of the Northern Llano Estacado, only the lower portion of the oldest, the Permian Redbeds, has any continuous connection with strata of the New Mexico mountains. It is true that the Triassic of the northwest side of the Llano has a partial connection with beds outcropping on the southeastern flanks of the Rocky Mountains in the vicinity of Las Vegas, New Mexico, but this connection is more or less broken and it is extremely probable that there is absolutely no artesian flow of any value entering the Triassic beds of the plains from this direction. . . Water derived from rainfall which percolates into porous strata of the Permian, which outcrop in the region between the Pecos River and the eastern New Mexico mountains, is under head sufficient to rise and flow out to the surface when the containing strata are penetrated by a deep drilling on the Llano Estacado."

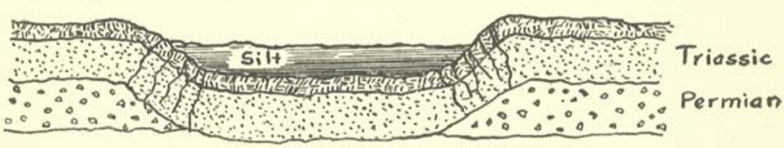


Fig. 3:—Diagramatic representation of depression in the Staked Plains.

Quoting still further from the same source as above, we find the origin of the potash in the Permian strata as follows:

> "The Llano appears to have been the site of the middle of the Permian marine basin. . . The beds of anhydrite, gypsum, rock salt and limestone (generally dolomitic) indicate an arid climate during the latter part of the Permian, at intervals during which the waters of the sea evaporated and thereupon deposited the various minerals which they carried in solution."

The above quotations, taken in conjunction with another pamphlet, now out of print, by Dr. Udden, Director of the

Bureau, on "Potash in the Texas Permian" which gives the results of numerous drillings which have penetrated the Permian and show potash in small but persistent quantity, show, as we believe, just where the potash contents of these deposits come from. They are probably being fed continuously by solutions of low solid content. These in turn have been concentrated by evaporation until the highly impregnated brines and muds are now in place ready for extraction of the valuable salts.

Another proof of the fact that the deposits are fed from below is the universal testimony of people in the vicinity that while the country is at times very arid, the surface of these lakes is always wet and muddy. This would soon evaporate the moisture near the top and leave the muds bone dry if not fed from below. This also apparently refutes the statement that has been made by some that the silts are impervious. It is further proven by the fact that a hole dug into the muds or silt although it may not strike a layer of crystals or sands, will slowly fill with brine.

This is also one of the best indications of the permanency of supply. The evaporation from the moist surface of the lakes should be much greater than from an open body of water of equal area. Still they never become dry. This would seem to show that an amount of brine fully three times plant requirements has been furnished constantly for solar evaporation from Double Lakes, the brine being fed from below by capillary attraction. The same applies to most of the lakes of the Littlefield Group.

PROPERTIES AND TESTS

The lakes were surveyed accurately and base lines run from which wells were located. In this way, check may be made at any time in the future on any or all wells. Considerable difficulty was experienced at first in sinking wells through the very tough silts of the lake beds and various forms of augers and hydraulic jetting were tried. Finally, we devised a very satisfactory rig and have made good progress since.

Accurate maps of the lakes are included in this memorandum and locations of test wells are shown. It will be seen that the lake area was covered very thoroughly. Logs of many wells are also included which show depths at which brine was encountered. Quick potash determinations were made on brine encountered at various levels which were quite uniform, and laboratory tests were run on a large number of wells. These are on tabulation in the memorandum which shows the number of the well corresponding to map, specific gravity, and the percentage of potash. Complete analyses were made on representative wells from each lake, also on composite samples of some lakes and these are shown in tabulations herewith.

In using one of the wells for the experimental plant, we found that the brine was improved by pumping. We, therefore, took six wells located systematically over Double Lake No. 1 as indicated by triangles on the map and made extensive tests to determine the effect of pumping. No decrease in flow was shown, but the brine increased in strength from about 21 Be and the potash percentage was increased in about the same proportion (Plate 3).

Statements from Dr. Bassett, under whose supervision the work was done and of Mr. Maxwell, who had immediate charge of the sinking of wells, are included in this memorandum and it will be noted that they both agree that there is an unlimited amount of brine available for a plant of at least 2000 tons of brine daily.

Samples and analyses were also taken of some of the silts and analysis made from them. These were run for potash only. Results are shown in the tabulation herewith.

LYNN COUNTY GROUP

DOUBLE LAKES

These lakes are shown on map drawing Plate 3 in pocket of this report. This map is from an accurate survey recently made for us by Sylvan Saunders, a civil engineer of Lubbock, Texas, and should be quite accurate. The "pumping area" in which all wells put down gave a free flow of five gallons a minute or more is indicated. Most of the wells gave a flow up to the capacity of the pumps or 20 gallons per minute, practically all the wells in No. 2 Lake giving such flow, while many wells pumped with a power pump could not be lowered by pumping fifty gallons per minute.

Ample area is available at the north end of No. 1 Lake for solar ponds to bring the brine to saturation as required.

The location of wells is clearly shown on the map and analyses together with logs of wells follow.

STATEMENT OF DR. BASSETT

The writer has directed the work of investigating the brine lakes of Lynn County, Texas, known as Tahoka, Double Lake No. 1 and Double Lake No. 2.

All these lakes were surveyed and laid off in sections of 400 feet square and test wells put down to outline the pumping area with the following results:

Tahoka Lake showed about 125 acres of pumping area striking veins at different levels in blue shale. The flow, however, from the different veins was not strong, but the value quite high. A number of these wells were pumped, but only showed an average flow of 0.56 gallons per minute, running about 15 Baumé.

Rock was struck at an average of twenty feet under the surface and in one case an effort was made to go through this, but with the tools at hand, it was impossible and this was given up. It was thought brine might be encountered under this rock, but this was left for future investigation. Tahoka Lake did not look attractive from results obtained.

The next lake investigated was Double Lake No. 1. In this between 400 and 500 acres of pumping area was encountered in the lower portion of the lake, veins being struck in nearly all cases in blue shale at three different levels; at four feet, nine feet and bottom of wells. The brine flowing from all wells tested the same strength and the same potash content. A number of these wells in one portion of this lake seemed to be under pressure and would flow out on surface of lake.

In Double Lake No. 2 almost the entire lake is pumping area with a strong flow. In either of these lakes, we were assured of ten gallons per minute or better and no doubt could furnish 2,000 tons of concentrated brine per twenty-four hours. The general trend of the brine area was from northwest to southeast with rock hills on west side and sand hills on east side.

The flow as stated above being so general, the actual flow was determined in each lake by drilling an eight inch hole and determining the direction a wand would move. It invariably took the direction as stated above.

From these facts, namely formation, direction and determination of flow, it appears that the brine occurs in an underground stream.

The brine grew stronger in solids when pumped for several hours and the solids were very constant in potassium chloride.

The amount of brine is without doubt inexhaustible for a plant using 2,000 tons of brine per day.

STATEMENT BY C. A. MAXWELL

Pursuant with your request, I am detailing in this letter a few of the facts concerning the potash lakes in Lynn and Terry Counties, Texas. It was my privilege to visit these and conduct an investigation of some two months in extent in the spring of this year.

I investigated and put down test wells in three lakes in Lynn County, known as Tahoka Lake, situated eight miles northeast of the little city of Tahoka and Double Lakes Nos. 1 and 2, situated approximately seven and one-half miles northwest of Tahoka.

After investigating Tahoka very thoroughly, we came to the conclusion that there was only about 125 acres out of a total lake area of 1,000 acres that would be available for operation. This 125 acres probably support some 1,000 wells with a continuous capacity of approximately two-tenths of a gallon per minute. We cannot recommend Tahoka Lake as a working proposition until a further investigation is made tending to prove whether or not a considerable vein of potash bearing water is contained under the rock which lies on an average of twenty feet under the entire lake bottom. The surrounding indications seem to show that there should be an abundance of water there. Puncturing the rock might open this up.

The water in the wells in this lake showed an average Baumé of fifteen degrees with one and one-half per cent of the solids, potassium salts. The remainder of the solids being easily recoverable salts, such as sodium chloride, magnesium chloride and sodium sulphate.

Double Lakes are very much larger in extent; the two lakes approximating some 1,500 acres in extent, of which fully two-thirds is pumping area with an almost inexhaustible brine supply. We put down several hundred wells in these lakes and all of these in actual pumping area were capable of delivering five gallons of water per minute or more. In fact, we pumped some of the wells for a period of two days at the rate of fifty gallons per minute per well without any indication of lowering the water in the wells. I believe it would be easily possible to obtain from either one of these lakes, No. 1 or No. 2, 1,000 gallons of water per minute, continuously and this with very few wells. The brine in these lakes averaged from eighteen to twenty degrees Baumé with a potassium content of approximately one and one-half per cent referred to the brine, the remaining solids being salts such as sodium chloride, magnesium chloride, sodium sulphate, etc. I believe it would be possible to continuously support a plant producing six hundred and fifty tons of solid per day from these two lakes.

The above facts are given only after very careful investigation conducted by competent men. The writer was in charge of the investigation and feels that he is competent to make a report on such a proposition, as for over a year he was employed by the Western Potash Company of Antioch, Nebraska, first as superintendent of the construction of their plant and later as plant superintendent in charge of operations.

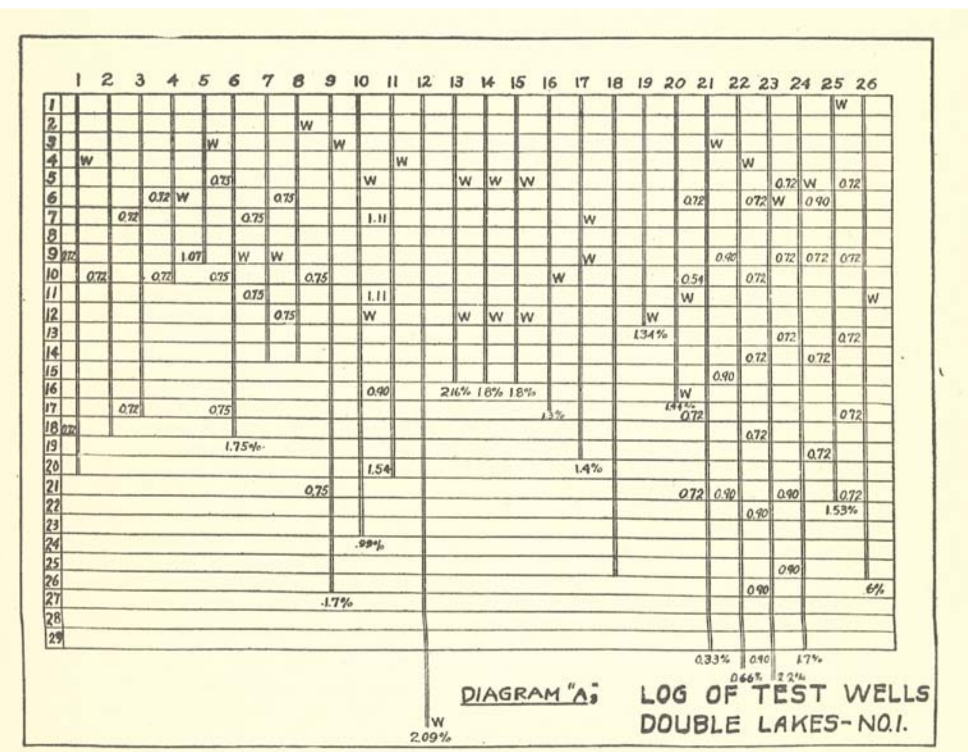


Fig. 4:—Graphic representation of logs of wells in Double Lakes.

Sample of Wells—Double Lake No. 1

Well No.	Specific Gravity	% Solids	% KCl	% KCl 30% Hydrous Basis
6	1.1359	22.5	1.38	1.84
9	1.1210	16.1	1.36	2.54
10	1.0879	12.0	0.98	2.48
11	1.1829	28.5	1.54	1.62
13	1.1679	22.0	1.66	2.25
14	1.1669	21.7	1.43	1.98
15	1.1642	24.0	1.46	1.83
16	1.1662	23.0	1.00	1.30
20	1.1313	17.3	1.15	2.00
22	1.0789	10.3	0.56	1.63
23	1.1903	25.0	1.66	1.99
24	1.1595	22.0	1.32	1.80
25	1.1314	18.1	1.22	2.03

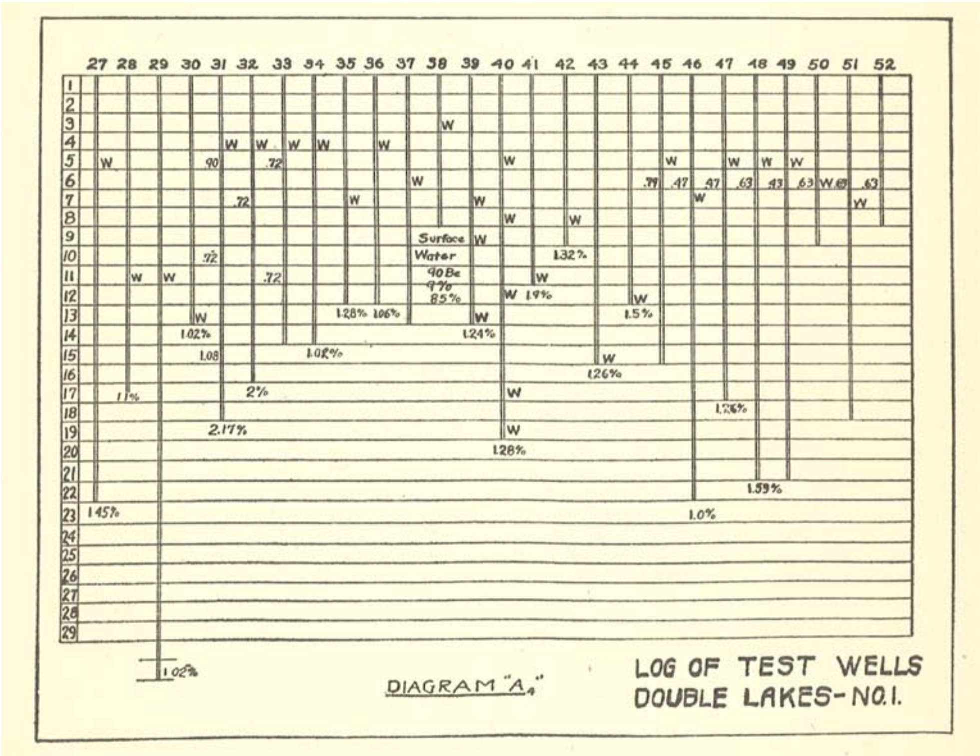


Fig. 5:—Graphic representation of test wells in Double Lake.

27	1.1292	17.4	1.12	1.93
32	1.1750	26.1	1.53	1.76
35	1.1064	15.2	1.02	2.02
40	1.1299	17.1	1.04	1.83
41	1.1321	17.4	1.10	1.90
43	1.1492	20.2	1.26	1.88
46	1.0873	11.3	0.79	1.98
47	1.1083	12.2	0.99	2.44
48	1.1431	20.8	1.35	1.94
				42.97
				Av. 1.95%
Surface Water	1.0692	9.9	0.71	2.15%

Sample of Wells—Double Lake No. 2

Well No.	Specific Gravity	% Solids	% KCl	KCl 30% Hydrous Solids
2	1.15	20.5	1.8	2.63
3	1.2555	34.0	2.77	2.43
4	1.0828	19.2	0.92	1.43
5	1.1686	22.5	1.47	1.96
6	1.1679	22.5	1.39	1.85
7	1.1795	24.3	1.54	1.90
8	1.1802	24.1	1.59	1.98
10	1.1344	19.0	1.37	2.16
11	1.1526	19.9	1.25	1.88
14	1.1672	23.8	1.30	1.63
15	1.1776	23.9	1.43	1.80
16	1.1776	23.7	1.35	1.71
18	1.1721	23.6	1.55	1.97
19	1.1615	22.4	2.20	2.95
20	1.1524	19.9	1.45	2.17
21	1.1989	26.7	1.62	1.82
23	1.1793	24.0	1.43	1.78
26	1.1542	19.8	1.63	2.31
28	1.1598	19.9	1.69	2.54
29	1.1527	19.8	1.37	2.07
32	1.1505	19.6	1.26	1.93
33	1.1479	18.5	1.20	1.94
34	1.1542	19.8	1.55	2.35
36	1.1796	23.2	1.83	2.37
37	1.2076	27.0	1.87	2.07
41	1.1759	23.0	1.35	1.77
42	1.1567	19.7	1.73	2.63

43	1.1495	19.2	1.20	1.87
44	1.1593	19.9	1.82	2.74
51	1.1542	19.3	1.61	2.50
52	1.1547	19.4	1.87	2.90
53	1.1344	19.0	1.58	2.50
				68.55
				Av. 2.14%
Surface Water	1.2394	30.0	1.44	1.44

Complete Analyses—Samples Double Lake No. 1
As Tested

				$CaSO_4$	Na_2SO_4
6	1.38	2.29	7.46	.23	2.99
10	0.97	1.46	6.64	.47	1.69
27	1.11	2.86	4.48	1.83	1.92
35	1.02	1.57	6.19	.42	1.72

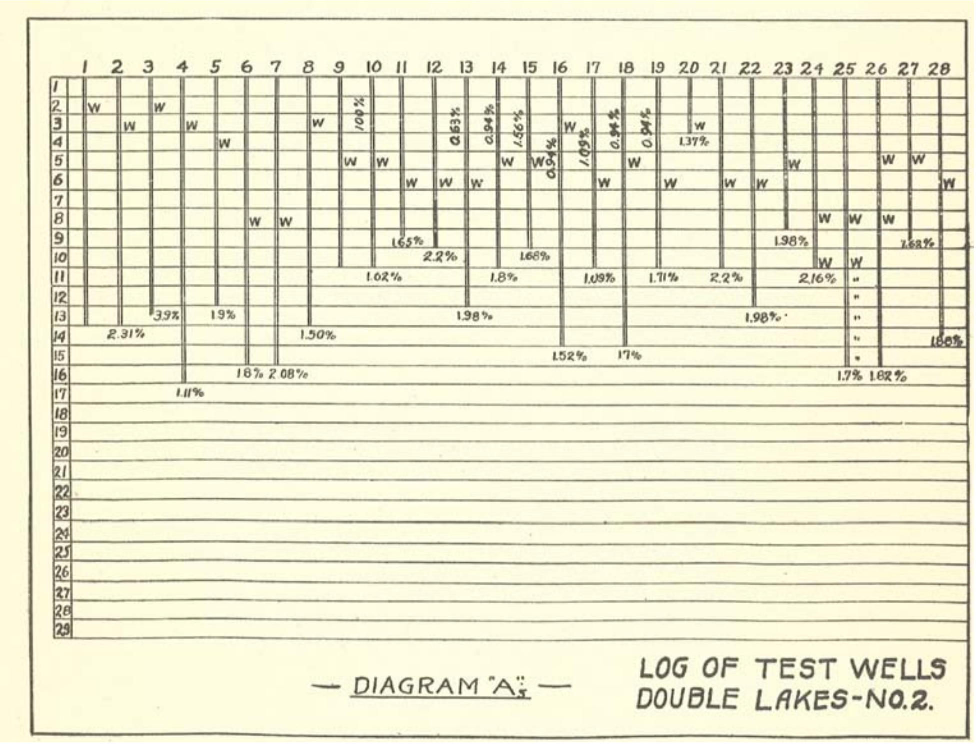


Fig. 6:—Graphic representation of logs of test wells in Double Lakes.

Basis 25% Anhydrous Solids (30% Hydrous)

6	2.4	3.98	12.98	0.40	5.20
10	2.16	3.26	14.81	1.05	3.77
27	2.27	5.86	9.18	3.77	3.94
35	2.34	3.60	14.18	0.96	3.94

Complete Analyses—Samples Double Lake No. 2
As Tested

Well No.	KCl	$MgCl_2$	NaCl	$CaSO_4$	Na_2SO_4
2	1.80	1.11	6.93	2.33	.30
6	1.39	0.93	7.78	1.91	1.57
11	1.25	1.19	5.89	2.28	.79
21	1.62	1.18	12.24	1.05	2.85
25	1.30	1.22	5.55	2.12	1.51

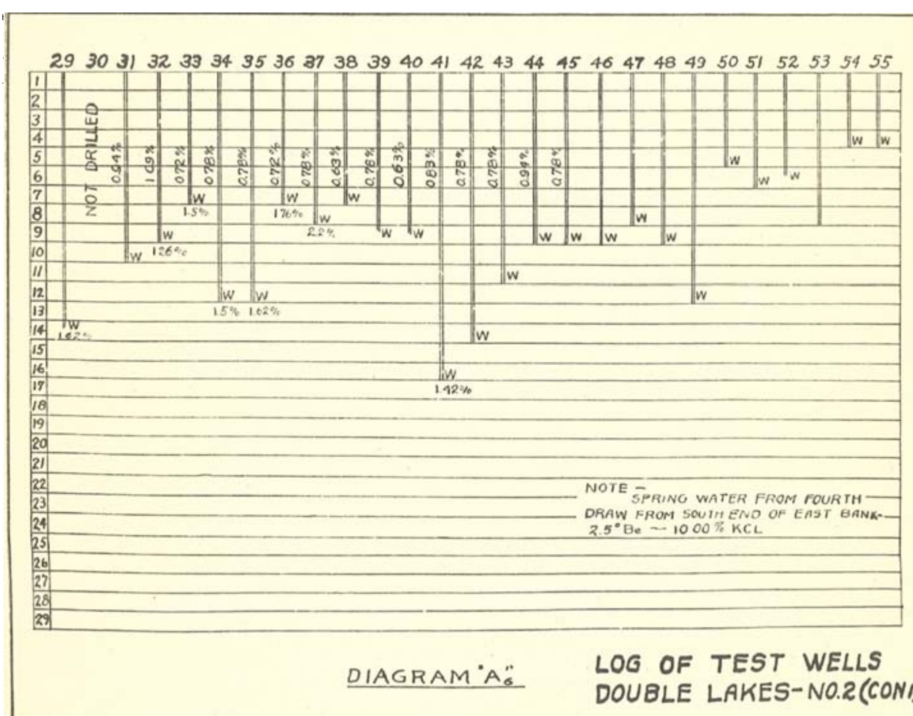


Fig. 7:—Graphic representation of logs of wells in Double Lakes

Basis 25% Anhydrous Solids (30% Anhydrous Solids)

2	2.6	2.22	13.86	4.66	0.60
6	2.55	1.73	14.31	3.53	2.89
11	2.74	2.61	13.00	4.99	1.73
21	2.13	1.60	16.28	1.38	3.66
25	2.78	2.61	11.88	4.54	3.23

Analyses of Silts—Double Lake No. 1

Well No.	% KCI
45	.87
47	.57
51	1.10
48	1.00
49	.84

NORTH GROUP

SILVER LAKE

The location of Silver Lake is clearly shown on the general map included in this memorandum, also on the small map showing location of wells put down. (Plate 2 and Fig. 8.)

Fifteen wells were drilled in this lake to depths ranging from fourteen to forty feet. Clay of varying colors and crystals form the great proportion of the lake contents, sand being found in only one or two wells. Hard rock was not encountered in any of the wells drilled with augers, but was found at about twenty-four feet with the hydraulic rig in the southwest corner of the lake. D-4 which went to forty feet bottomed on an excellent gravel bed. The other wells went to thirty feet, more or less, ending in clay or gypsum. Good flows of brine were found in all the wells, only one vein being found, the depth varying between 3.5 and 9 feet. Brine was also found in the gravel at 40 feet in D-4. This well gave 35 G.P.M. and would have produced fifteen or twenty more gallons could we have run the engine faster. B-4 produced 24 G.P.M. In none of the wells could we lower the brine level with pitcher pumps, the capacity of which is 6-10 G.P.M. A large amount of brine

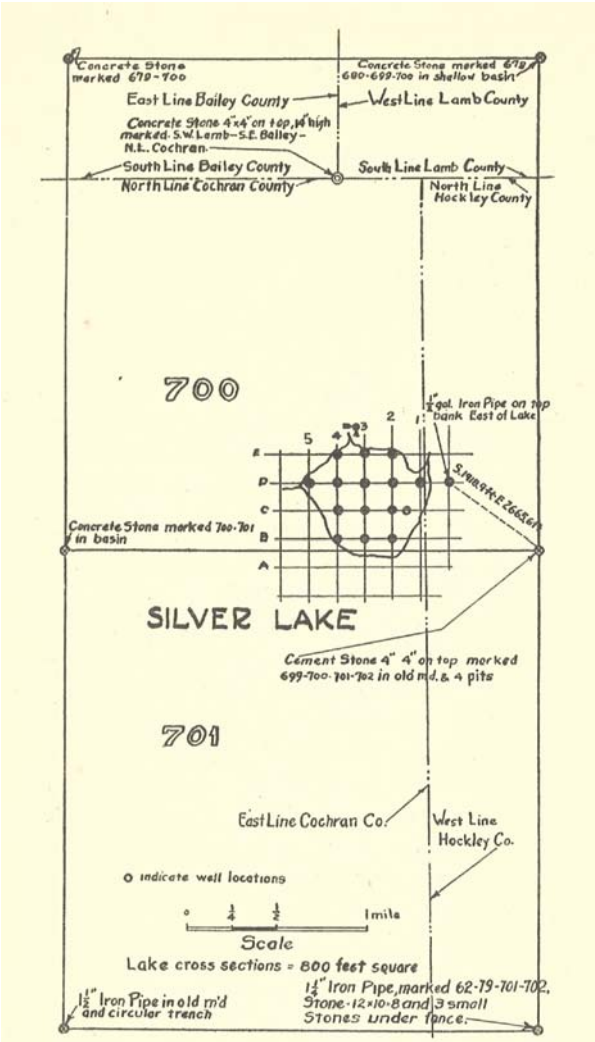


Fig. 8—Silver Lake, showing location of test holes.

is available here. Four-hour pumping tests failed to lower the density or potash content. A fresh water vein was found in E-3, but this offers no difficulty, as the fresh water could easily be cased or plugged off.

The west and north shores are covered with surface seep springs, flowing fresh water to 4° Be. brine. Seep springs of 5-6° Be. are also found on the east shore in the lake bed. The total area of the lake bed, 220 acres by actual survey, is available pumping area.

This lake lies in a hollow bounded on the east by a ridge that rises 100 feet above the lake. The land on all other sides slopes gradually away from the lake. The east and south shores are slightly precipitous, the others sloping. No rock outcroppings are to be found anywhere in the vicinity of the lake. It is 40 feet higher than Littlefield.

While small, this lake shows an unusually good flow of brine. In our judgment, it could probably be counted on to supply continuously about 300 to 350 tons of brine daily.

Analyses of brines from the various wells drilled follow, also complete analysis of composite sample made up from an equal quantity of brine from all the wells. (For logs of wells in this lake see Plate 4 in pocket.)

Sample of Wells—Silver Lake

Well No.	% Solids	% KCl	% KCl 30% Hydrous Solids
B-2	14.3	1.26	2.64
B-3	21.6	1.75	2.64
B-4	22.6	1.52	2.02
C-1-½	13.6	1.34	2.96
C-3	20.6	1.55	2.25
C-4	16.5	1.34	2.43
D-1	16.9	1.60	2.25
D-2	22.5	1.70	2.26
D-3	20.6	1.66	2.40
D-4	21.7	1.62	2.24
E-2	16.6	1.56	2.82
E-3	18.9	1.67	2.65
Average	18.87	1.52	2.44

Complete Analysis of Composite Sample

Total	% by Weight
Hydrous Solids	19.22
Calcium Sulphate	1.45
Sodium Sulphate	7.43
Magnesium Chloride	2.26
Sodium Chloride	4.37
Potassium Chloride	1.52

COYOTE LAKE

The location of this lake is shown on the general map herewith and location of wells drilled is shown on the small individual map included in this memorandum (Plates 2 and 5).

No base line was run through this lake. The wells were numbered as shown on the attached sketch (Plate 5).

Twenty-five wells were drilled in this lake. five being duplicates. Wet sandy-clay composes most of the material. Thick veins of sand, sand and gravel, and sand, gravel and gypsum were found in a large number of wells. The lake is so nearly saturated that all wells had to be cased to keep them open. Four veins were found in the wells sunk with the hydraulic rig and as these were separated a good half mile, we are safe in assuming that four veins run throughout the eastern end. With the augers, we could not be sure of more than two veins. The structure of the lake is so uniform, comparatively speaking, and such an abundance of brine was found that there can be little doubt as to the existence of four veins throughout the lake.

In the draw in the south side, west of the line of the lease, we found veins at 3 feet, 7 feet, 10 feet, and 15 feet, in well AA-1. At well B-1, we found the veins at 8 feet, 10 feet, 16 feet, and 29 feet. The depth of the first brine found was 2 feet to 9 feet, and the wells ran from 4 feet to 30 feet in depth, the average being 15 feet.

In only two wells could we lower the brine below a certain level, the pumps delivering 6 to 10 G.P.M. Well AA-1 was the only open well we put down with the hydraulic rig. We pumped 50 G.P.M. from this well without affecting the level of the brine. Every indication points to a great quantity of available brine in this lake, but it will be a sand-point proposition. (For logs of wells in this lake see Plate 6 in pocket.)

All the brines but two from the north shore ran 23° Be. on the lake. Brines from the south shore of the west end ran 20° to 23°, but those from the north shore of this side dropped to 12° Be. Fresh water springs along the north shore evidently dilute the brines on this side. Lack of time prevented making a more thorough test of the west end.

The whole 285 acres in the east end are good pumping area, with the possible exception of 25 acres in the northeast corner. Two-thirds of the west end would be pumping area also.

Coyote is second only to Silver Lake in richness and quantity of brine, surpassing the latter in quantity. It is 26 miles from Illusion and about 33 miles northwest of Littlefield. Sand points would have to be used. Evaporation ponds apparently could be built on the lake, but only with difficulty on the prairie, on account of the sand. The greatest apparent disadvantage of this lake is its distance from the proposed plant site, but the tremendous quantity of brine available would in all probability offset this. After raising the brine over the high hills on the south and east shores, the flow would be all down hill to Littlefield.

This lake has probably the most satisfactory supply of brine we have encountered in any lake in the district. The numerous veins or brine bearing strata encountered, mostly in coarse sand, assure a very definite supply of brine and its grade is sufficiently high both in solid and in potash content to make it a good commercial proposition.

Samples of Wells—Coyote Lake

Well No.	Solids %	KCl %	KCl 30% Hydrous Solids
A-1	22.0	1.25	1.70
A-2	22.6	1.38	1.83
B-1	23.5	2.35	3.00
B-2	23.3	1.86	2.40
B-3	23.1	1.79	2.32
C-1	24.3	2.05	2.32
C-2	24.2	1.92	2.38
C-3	23.1	2.00	2.59
C-4	23.2	1.81	2.34
D-2	21.1	1.77	2.50
E-1	24.0	1.99	2.48
*X	13.4	0.66	1.50
Z	19.5	1.35	2.08
Average	22.8	1.77	2.33

*This sample omitted in average figures as it is evidently not typical.

Complete Analysis of Composite Sample Coyote Lake

Total	% by Weight
Hydrous Solids	23.32
Calcium Sulphate	0.70
Sodium Sulphate	3.00
Magnesium Chloride	.50
Sodium Chloride	14.49
Potassium Chloride	1.60

YELLOW LAKE

The location of Yellow Lake is shown on the general map in this memorandum and its outline, together with location of wells drilled, is shown on the small map which also includes Illusion Lake (Plates 2 and 7 in pocket).

A base line was run up the east shore of this lake, the course being S. 20° 46′ W. and stakes being set every eight hundred feet.

Twenty-four wells, distributed evenly over the lake, were drilled. The depth averaged 30.5 feet, the brine averaging 8 feet. The deepest well, the one we put through rock, was 51 feet. Sand, clay and crystals fill the lake bed, layers of sand and clay alternating. We tried to penetrate the bed of stiff red clay underlying the lake with hand augers, but the progress was too slow. Two wells were drilled in the Sucker Rod Draw with the hydraulic rig, rock being encountered at 26 feet and 31 feet. One vein only was found in this lake, two veins being noticed, however, in Sucker Rod Draw. The brine flow in Yellow Lake is weak, about 3 G.P.M. for the majority of the wells. No brine of any worth was found beneath the rock in the draw, it running 3° Be.

Taking the area of Yellow Lake as 800 acres, there are 600 acres of pumping area with comparatively small flow.

High hills bound Yellow Lake on the east, sloping away from the lake like those on the east shore of the Tahoka Lakes. The west shore is a plain, six to twelve feet above the lake bed, extending westward three-quarters of a mile to the Casa Amarilla bluff from which Yellow House takes its name.

No rock is visible along the lake shores, though gypsum hills are found in the west side of the north end.

Fresh water springs occur along the entire east shore and in the Sucker Rod Draw, the density being 2-3° Be. The Sucker Rod Springs reads 7.5° Be.

This lake shows such weak brine that we have not considered it necessary to analyze all samples. Representative samples were run for potash and a complete analysis was made on the composite sample. These analyses are shown on the following page. (For logs of wells in Yellow Lake see Plate 8.)

We do not consider Yellow Lake of any value as the cost of obtaining brine in sufficient quantity would be very great. It has no possibilities except by solar evaporation and is so much weaker than other lakes in the district that we would not recommend spending more money on it.

Well No.	% Solids	% KCl	% KCI 30% Hydrous Solids
F-2	13.9	0.84	1,81
Sucker Rod	14.0	0.72	1.54
O-2	14.1	0.68	1.45
J-3	14.6	0.81	1.70
L-1	9.5	0.63	2.00
Average	13.25	0.75	1.70

Analysis of Composite Sample From Wells

Total	% by Weight
Hydrous Solids	13.4
Calcium Sulphate	1.20
Sodium Sulphate	2.34
Magnesium Chloride	0.39
Sodium Chloride	7.22
Potassium Chloride	0.75

ILLUSION LAKE

Illusion Lake is over the ridge, 1500 feet north of Yellow Lake. A base line was run up the east shore on the courses S. 16° 48′ W. stakes being set every eight hundred feet.

Twenty-three wells were drilled in this lake, eight being put down with the hydraulic rig and the others with hand augers. The average depth of wells is 19 feet and the average depth of brine 9.4 feet. Strata of sand, clay and gypsum of varying thickness fill the lake bed. In a well about half way up the lake, 1000 feet from the east bank, we found two veins of good flow, the lower one at 23 feet. We drilled on down below this through red clay and 22 feet of sand to bed-rock at 61 feet, but found no brine below the gravel vein at 23 feet. In hope of finding this gravel stratum throughout a large area of the lake, we put down the eight wells with the hydraulic rig, but found it over an area of less than 150 acres. In the other wells, the brine was found in sand or in open veins through the clay. Taking the area of the lake at 1200 acres, 500 to 600 acres is available pumping area. Flows of 5 to 6 G.P.M. were found in the wells considered as being in this area, which covers almost all the southwestern end and part of the west side of the north end. The planimeter area of this lake is given as 1200 acres, but it is not over 1000 at most. The densities average about 10° Be.

This lake also has a ridge of high hills on its east bank. The west bank rises only twenty to thirty feet above the lake, sloping westward to the bluff north of Yellow House. No rock is found around the lake, the nearest outcrop being about half a mile northeast of it. (For logs of wells in Illusion Lake see Plate 9 in pocket.)

Illusion is 150 feet lower than Littlefield and about 200 feet below Silver Lake.

The brine in Illusion Lake is very weak, both in solids and KCl content, but it might be worked profitably by converting the southwestern end into a battery of evaporatng ponds. Windmills or power pumps could be used for lifting the brine from the wells to the ponds where it could be concentrated to workable strength. This lake is an ideal site for evaporation ponds for the other lakes, as it has the tightest surface soil of any lake we have worked. Brines from Silver and Coyote lakes and possibly other lakes could be mixed here and concentrated, the sodium sulphate and first salt crop being dropped in these ponds. The tight surface and the almost constant wind would make for minimum seepage losses and maximum evaporation. Dikes would have to be built high enough, of course, to take care of the surface water that normally drains into the lake.

The potash content of the brine in this lake is so low that we did not consider it worth while to run individual samples for potash. We, therefore, made two composite samples from all the wells and ran them for check. The composite analysis is shown below:

Total	% by Weight	
Hydrous Solids	9.38	
	Basis 30% Solids	
Calcium Sulphate	0.49	
Sodium Sulphate	2.25	
Magnesium Chloride	0.90	
Potassium Chloride	0.25	1.6%
Sodium Chloride	5.13	

It will be seen that the only possibility in this lake is to evaporate a very large amount of water to a point well above saturation; then treat the concentrated brine. But for its value as a concentrating basin, we would not recommend its consideration as a potash lake.

SOLAR EVAPORATION

In a proposition of this kind, involving the evaporation of large quantities of water, one naturally turns to the possibility of doing this evaporation by natural means without the expenditure of large sums for artificial heat.

In this respect the Llano Estacado is probably more favorable than any other section of the United States except the real desert section. The Bureau of Economic Geology and Technology of the State of Texas has made extensive tests of factors related to this in connection with their investigations of the possibility of irrigation. Their bulletin states in regard to the climate of the Llano:

> "The mean total evaporation from an open body of water during the six months (April 1 to October 1, inclusive) is 53.26 inches, while the average

total rainfall for the same period is 14.41 inches. That is, nearly four times the average rainfall would be evaporated from an open body of water, provided a sufficient supply were furnished to the evaporation agencies. It is this large amount of evaporation which gives to the Llano Estacado really a desert climate. The famous wheat lands of the Dakotas and Minnesota have no greater rainfall than the Llano Estacado, but have only half the evaporation."[1]

From figures obtained from the Bureau together with others from the United States Weather Bureau, we are able to make fairly accurate estimates of the evaporation.

Actual figures on evaporation are available for the six months as stated above from 1907 to 1914, inclusive. These are as follows:

Month	Apr.	May	June	July	Aug.	Sept.	Total
Average Evaporation (in.)	7.39	8.98	9.99	10.9	9.26	7.49	53.20
Average Rainfall (in.)	1.31	2.75	1.79	3.09	2.61	1.67	14.22
Net Evaporation	6.08	6.23	8.20	7.81	6.65	5.82	39.98

It is necessary to calculate the evaporation for the remaining six months. We do this by Dalton's formula.

$$E_h = 1.8 \times C \times S \frac{(1-d)}{b}$$

In which E_h = Evaporation per hour.

C = A constant depending upon wind
  Quiet Air C = .55
  Moderately Agitated C = .71
  Heavy Wind C = .86

S = Maximum tension of water Vapor at the Temperature in inches of mercury (given in a table)

d = Relative Humidity

b = Reading of barometer in inches mercury (26″ at the elevation)

[1]Univ. of Texas Bull. 57, p. 64, 1915.

The wind velocity is fairly high and constant, averaging sixteen miles per hour as follows:

January	15 miles per hour	July	14 miles per hour
February	16 miles per hour	August	15 miles per hour
March	19 miles per hour	September	16 miles per hour
April	19 miles per hour	October	16 miles per hour
May	17 miles per hour	November	15 miles per hour
June	16 miles per hour	December	14 miles per hour

From the above, it will be seen that the winds are very constant and would probably average the condition "Moderately Agitated" for all months.

Using the constant for this (c=.71) and the figures below based on Weather Bureau data for Mean Temperature, Relative Humidity and Average Rainfall, taking the value of S corresponding to Mean Temperature and substituting in the formula—we have the following calculated evaporations.

(April is calculated in the same way and shown for comparison.)

	Mean Temperature	"S"	Relative Humidity	Calculated Evaporation	Average Rainfall	Net Evaporation
April	55.5	.44	53.5	7.24		
October	57.3	.47	64.0	6.26	1.84	4.42
November	46.6	.32	62.5	4.24	0.94	3.30
December	36.5	.22	65.5	3.18	0.83	2.34
January	37.1	.23	63.5	4.12	0.51	3.61
February	36.0	.22	66.0	2.66	0.77	1.89
March	46.8	.32	53.0	5.51	0.55	4.96

Total Net Evaporation Calculated (in.)	20.53
Add Net Evaporation April- September, inclusive	38.98
Total for Year	59.51

Note that calculated evaporation for April is 7.24 as compared with 7.39 actual record.

The minimum net evaporation for the six months evaporation observed was 32 inches as compared with average 38.98 inches.

$$\therefore \quad 32 : 38.98 :: X : 59.51$$

$$X = 49'' \text{ minimum evaporation.}$$

The above calculations are based on Amarillo, about 200 miles north of Tahoka. The humidity is known to be less at Tahoka, but unfortunately, we have no record over long periods. We do have records of temperature at Mt. Blanco in an adjoining county, however, and the average temperatures are as follows:

Amarillo------	56.1°F; Corresponding value of "S"	.46
Mt. Blanco----	60.0°F; Corresponding value of "S"	.51

As "S" is a direct function in the formula, the figure 49 above would really be $51/46 \times 49 = 54$ inches, so the figure we have used for our calculations, 48 inches, should be conservative.

PROCESS OF EXTRACTION

In solar evaporation, we find that after reaching a certain concentration somewhat above saturation, that a film gathers on the top, interfering with further evaporation. While we know that the brine will finally evaporate, we are unwilling to count too much on solar evaporation without extensive tests. There will be no difficulty with evaporation to concentration, however.

We propose, therefore, to build solar concentrating ponds on the lake beds which are fairly tight, and on the construction of which we have data from an experimental pond, and to concentrate the brine to as high saturation as practicable, then pump to the plant and mix with calcium chloride from a subsequent operation for the purpose of changing the sodium sulphate to sodium chloride, finally getting only chlorides to the process. Immediately upon mixing the calcium chloride, the reaction takes place to some extent with a precipitate of calcium sulphate. The reaction is very rapid when heated, so, with additional concentration it will be practically completed in the first effect. The brine is led into the third effect of one set of evaporators where calcium sulphate is precipitated then to the third effect of the second set, then to the second effect of the second set, then to the second effect of the first set, then to the first effect of the first set. In all these effects, salts largely predominating in NaCl (salt) are precipitated, filtered out and washed to desired purity. The next step is to cool the mother liquor which gives us about half the potash as KCl which can be washed to the purity required. The liquor then goes to the first effect where more salt is precipitated with probably some carnallite and upon cooling, nearly all the remaining potassium chloride comes down with magnesium chloride as artificial carnallite. The remaining liquor containing mostly magnesium chloride is concentrated as high as possible in the special finishing pan. The carnallite is decomposed by the well known German method leaving potassium chloride as a solid and magnesium chloride with some potassium chloride in the mother liquor. This mother liquor is concentrated with that just above.

We now heat the concentrated magnesium chloride to redness in a furnace and drive off hydrochloric acid leaving potassium chloride and magnesium oxide. The former is very soluble and the latter insoluble so the complete separation is easy. This filters easily so there is not the difficulty heretofore experienced with magnesium hydroxide. The hydrochloric acid gas is condensed and collected in towers. It is then run into tanks with limestone which is available at the plant site in large quantity making calcium chloride with the evolution of CO_2 gas. This gas can be collected and used for carbonating the magnesium oxide or allowed to escape into the air, as it is harmless.

This process is not practicable without our salt purification processes, as only a portion of the salt would be fit for use and a large amount of potassium chloride and magnesium chloride would be lost in the impurities. Then the potash separation, while possible, would require too close control if it were not possible to take it as it comes and bring it to commercial purity. This separation and purification is already covered by basic patents, held by us.

The process outlined above for production of magnesium oxide has been utilized before, but it was always with a view of making the oxide in the furnace entirely. This is not practical, as it makes a heavy oxide of low value. We do not attempt to drive off all hydrochloric acid, but only such amount as can be driven off at low heat leaching out the remaining magnesium chloride which is very soluble and leaving behind a light fluffy oxide. This process is covered by our patent.

Included in this memorandum is a flow sheet of the process (Fig. 9).

NOTES ON PRODUCTS AND COMPETITION

Foreign Potash

There are numerous potash deposits throughout the world, but the only ones of commercial importance, aside from those developed in this country are in Stassfurt (Germany) and in Alsace, France.

Prior to the war, practically all potash production was controlled by the German Syndicate and this syndicate was supreme in its decision as to the amount to be produced in any district. The development of the Alsatian deposits was retarded in favor of the older Stassfurt deposits, so that there are only eighteen shafts in Alsace as compared with some two hundred in Stassfurt.

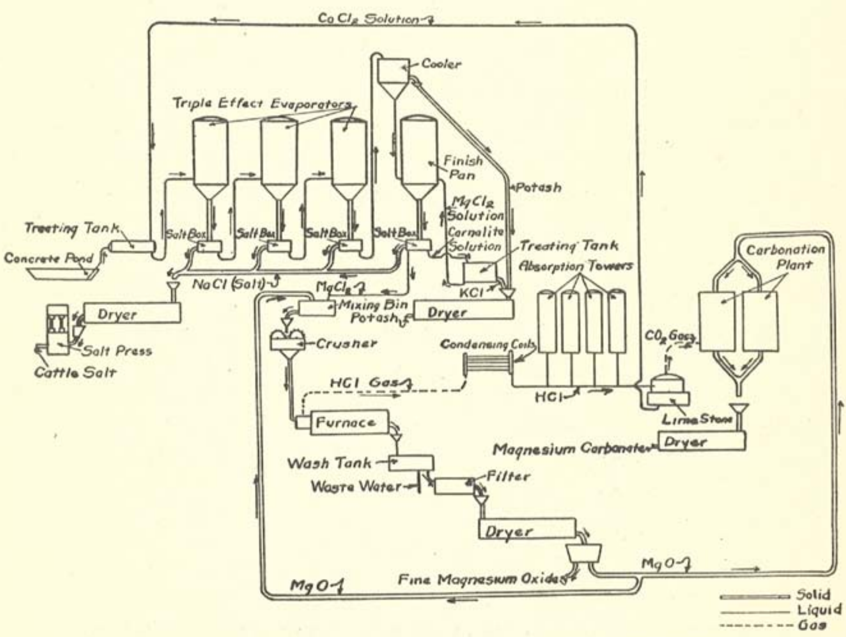
The standard arrangement is two shafts about one thousand feet apart connected underground and a fully equipped shaft with development and refining capacity has a capacity of about eight hundred tons of crude salt mined and treated per day. A complete mine with two fully equipped shafts should produce and treat from 1500 to 1600 tons of crude salts per day or about 200 tons pure K_2O daily.

These deposits are to all intent and purposes inexhaustible. The mines are deep and the cost of mining at present is estimated at $3.50 to $4.00 per ton of crude salts. This crude material is crushed and dissolved in boiling hot mother liquor.

The Alsatian potash occurs principally as an impure sylvanite or a mixture made up of potassium chloride and sodium chloride without the large amount of magnesium chloride and magnesium sulphate present in carnallite. This makes the refining of Alsatian potash cheaper and simpler than the Stassfurt carnallite. However, the relatively valuable magnesium salts are not produced and it is quite likely that their value fully makes up for the difference in cost of refining. The Texas crude salts would be between these two limits.

Mr. W. B. Hicks of the United States Geological Survey states in an article published by permission of the director of the survey:

> "The cost of production from German potash mines in the vicinity of Stassfurt has been stated as about \$20 a ton of muriate of potash (80 per cent grade) before the war. The Kali Syndicate, under the supervision of the German Government, maintains a monopoly, fixes prices and distributes



FLOW SHEET OF PROPOSED PROCESS FOR TREATING TEXAS ALKALI BRINES.

Fig. 9:—Illustrating flow sheet of process proposed for treating Texas alkali brines.

> the product. Prevailing market prices (pre-war) at New York or other eastern points in the United States for ordinary commercial grades of refined salts such as the 80 per cent chloride (muriate of potash) and sulphate were about $40 per short ton, equivalent to $80 a ton of pure K_2O."

From a report recently received from a reliable source by the Bureau of Foreign and Domestic Commerce, we are given considerable first-hand information relative to the potash situation in Stassfurt. Briefly this states that the mines are working at about 85 per cent of normal due to inefficiency of labor and that very little refined product is being produced due to the lack of fuel. Stocks are quite small and the output will barely take care of the domestic requirements and supply the British requirements contracted for. Almost the normal number of men are employed, but the efficiency is quite low. Price of labor has increased to about three times pre-war prices, coal is almost unobtainable and steel and other essential supplies run as much as ten times pre-war costs.

We believe it is conservative to say that present costs are now three times pre-war price, or about $1.20 per unit and that they are not likely to be reduced to less than 80 cents per unit, to which must be added heavy taxes, ocean freights, interest and depreciation, etc., so that the price delivered at American ports is not likely to be less than $1.25 per unit for several years to come. The consensus of opinion of those best posted on the subject seems to be that this price is not likely to fall below $1.50 per unit. (Estimates made in March, 1921.)

Domestic Potash

The potash industry of the United States is a development due largely to war-time necessity.

Prior to the war, this country's requirements of potash amounted to 240,000 short tons of pure K_2O, representing between 900,000 and 1,000,000 tons of crude and refined salts. Domestic production reached its peak in 1918 when

52,135 tons of pure K_2O were produced, representing 192,-587 tons of crude and refined salts. Of this tonnage about 25,000 tons of pure K_2O were produced from Nebraska salts and this source of supply is still the predominate one in this country. Of the remainder, somewhat over 14,000 tons were produced from other brines, mainly from Searles Lake in California.

During 1918, many new plants were constructed and the annual capacity of all plants at the end of 1919 was estimated at 100,000 tons of pure K_2O. However, this production was based on the high prices secured during the war. Early in 1919, practically all potash plants in the country were shut down. Most of the larger plants resumed operation during the fall of 1919, but many have not started up and others will probably not be able to produce potash if the price drops below the present price of $2.25 to $2.50 per unit, so that the output will probably be not over 60,000 tons in 1920.

The process used for recovering potash from brines is still quite crude, but most of the larger plants are considering plans for installing refining plants so as to recover by-products and produce potash of a much higher grade. The future of the American potash industry depends upon the success of these refining processes, as few, if any, of the present operating plants could operate with profit on the present basis under keen competition likely to be encountered when foreign potash is again available.

In an excellent article, "The Potash Industry of the United States and Its Possibilities for Future Production," by Arthur E. Wells of the Bureau of Mines, Washington, D. C., published in the American Fertilizer of October 25, 1919, estimates are given of the costs of production from various sources in this country. In this article Mr. Wells assumes a price for foreign potash for the next three to five years at $1.25 to $1.50 per unit and a synopsis of the possibilities of the various sources is as follows:[1]

[1]In Mr. Wells's article, *American Fertilizer*, October 25, 1919, pp. 63-64, pp. 87-94, and pp. 100-121, the sources of potash are very fully discussed. The extracts given here represent a brief synopsis of his paper.

Nebraska Fields

There are about five large plants that would start up if assured a price of from $1.75 to $2.25 per unit.[1] Estimated ultimate costs delivered at eastern markets $1.25 to $2.00 per unit, based on the possibility of lower costs of coal and oil, greater utilization of solar evaporation, better mechanical equipment, more efficient operation, reduction in royalties and lower freight rates to eastern markets. Even with these reductions, certain plants which must operate on very weak brines will not be able to sell potash in the eastern market for less than $2.00 per unit. The estimate of $1.25 per unit as the minimum cost of production and delivery at eastern points will be realized by only from two to three plants within the next few years and then only under favorable conditions. Should brine of present strength be available for a number of years, it is likely that general costs could be still further reduced in course of time by the production of a sodium salt as a by-product and by various economies in operation. It is estimated that 60,000 tons annually could be produced for two or three years, then gradually reduced to 30,000 tons annually by ten years.

Searles Lake

Brine estimated to contain 20,000,000 tons K_2O. Brine is saturated and salts contain about 7.5 per cent potash. Process has been demonstrated producing a high grade KCl product (about 50 per cent K_2O) which can be produced deducting value of borax produced as by-product, at around 50 cents per unit. It is thought that, even with high freight rate against them, they might eventually sell at $1.00 per unit delivered at eastern points.

Cement Industry

Ultimate possible production K_2O from all cement plants in the United States is 60,000 to 65,000 tons. The present production is less than 5000 tons and the cost of low grade dust 60 cents per unit. This has a very limited market and it would probably be necessary to leach, filter and crystallize out the potash as sulphate or chloride. The estimated cost of refined product is $1.70 per unit.

Feldspathic Materials

There have been started at various times, many projects for the production of potash from potash feldspar, no one of which, at this

[1]All large Nebraska plants were started up later.

time offers much hope of producing any considerable tonnage in competition with other sources or at a cost of less than $2.00 per unit. There are about 5,000,000 tons of finely ground mill tailings available in Colorado carrying 8 to 10 per cent potash. It is quite impossible to figure a cost of less than $2.00 per unit. A process has been proposed making cement as a by-product. Even with cheap raw materials, costs would probably be $1.50 to $1.75 which could be lowered somewhat if a market could be obtained for the special cement produced.

Leucite

About 2,000,000 tons are available in the Wyoming leucites. The Liberty Potash Company is building a plant at a cost of about $1,000,000 for a capacity of 40 to 50 tons of potassium chloride per day using the Sterling-Boyer process. Careful analysis indicates that unless the technical operation of the process proves more difficult than anticipated, within a year or two potash may be produced at this plant as a 60 per cent KCl product at $1.10 to $1.25 per unit including interest and depreciation.

Alunite

The only occurrence of alunite in the United States that has been demonstrated to be of sufficient purity and massive form to warrant development as a source of potash is near Marysvale, Utah. The deposits near Marysvale will run about 9 per cent K_2O on an average. One of the main disadvantages with production of potash in this field is the long haul for finished product, fuel and supplies. One favorable feature is that pure sulphate of potash commands a somewhat higher price per unit than does the muriate or mixed salts. It is extremely doubtful that the potassium sulphate can ever be made at Marysvale and shipped to eastern points for much less than $2.00 per unit unless a process can be worked out for recovering the alumina.

Kelp

From the operating experience of these concerns (ten companies on the Pacific Coast) it can be stated quite definitely that unless some other product or products can be produced, it is very doubtful that an appreciable tonnage of potash can be produced from kelp for less than $2.00 per unit. This high cost, together with freight rates to eastern markets, will prevent the production of potash from kelp in any amount greater than the requirements on the Pacific Coast.

Miscellaneous Organic Sources

The greatest part of the miscellaneous organic sources is from molasses distillery wastes. Estimated total K_2O available from this source 30,000 tons per year. One plant expects to produce around 5000 tons in 1919, about one-third as carbonate and the balance as mixed sulphate and chloride. Other smaller concerns are producing some potash from this source. Present costs are nearly $2.00 per unit, but it is hoped to improve the processes so that they may be decreased.

Other sources are from waste liquors of beet sugar manufacture, wool washings and wood ashes. It is estimated that under stimulus of high prices the production from organic sources might be 6000 to 10,000 tons per year for the next few years.

From the above, it would seem that a production of 100,000 tons might be expected, provided steps were taken to assure a price of at least $2.00 per unit over the next five years and possibly by that time, by improved processes, costs at some plants might be such as to provide a production of a minimum of 75,000 tons in competition with foreign potash.

Potash is now selling at $1.75 to $2.00 per unit. Producers do not anticipate any drop in this price for two years on account of their knowledge of foreign conditions.

With a plant designed to handle 1000 tons of concentrated brine per day, we should make:

Twenty tons pure Potassium Chloride per day or 22.2 tons of 90 per cent KCl. Each ton of 90 per cent KCl contains 56.85 units K_2O.

The values would be as follows:

At Present Prices

56.85 Units, $2.00	$113.70	
*Less Freight	10.00	
	$103.70	
22.2 tons, $103.70		$2,302.00

*We have used $10.00 freight although this will probably be $12.50 to $13.00 to market. Our relatively small production could be sold at interior points to which freight from seaboard would amount to the difference. Nebraska potash is sold f. o. b. Cleveland basis, to which point the freight rate is somewhat less than $10.00.

At Expected Prices

56.85 Units, $1.25	$ 71.06	
Less Freight	10.00	
	$ 61.06	
22.2 Tons, $61.06		$1,356.00

At Pre-War Prices

90% KCl	$ 45.00	
Less Freight	10.00	
	$ 35.00	
22.2 tons, $35.00		$ 777.70

Magnesia

Magnesia is used largely in the rubber industry both as oxide (light calcined) and as basic carbonate. It also has an enormous sale as "85 per cent magnesia" for insulating steam pipes, boilers and vessels of various kinds where heat losses are to be avoided.

By our process, we produce a high grade magnesium oxide and as this is the highest priced commodity, it is to our advantage to sell the entire output as oxide if possible. It has been quite difficult to get accurate information on the amount used, but we have secured information on the amount used in the Akron district and also the percentage of tires and rubber goods made in that district. This information was obtained from one of the leading consulting engineers in the rubber business and is that the Akron district produces 55 per cent of the rubber products of the country and uses fifty tons of magnesium oxide and basic carbonate per day. It is necessary to use precipitated salts, such as we make, for this purpose. On this basis, the country would use about ninety tons daily. The relation of this production to this amount seem to be entirely too high but for the fact that there are relatively few industries producing magnesia and it is largely centered around Philadelphia and in the Magnesia Producers Association. The bulk of their tonnage goes for pipe coverings and perhaps the logical thing to do would be to attempt to arrange for them to handle this output. However, in order to provide for this arrangement or to meet competition, we have decided to allow for only one-half the market value of the magnesium oxide in this report. We feel confident that neither the Magnesia Association nor any other company can afford to crowd out our tonnage by making prices lower.

If necessary to carbonate part of the oxide, we can do so very well as we make very pure CO_2 gas in the last stage of the magnesia process. The additional cost of the magnesia plant would be about $25,000 and we have allowed for this in our estimate and also for the necessary additional labor for carbonating. As one pound of oxide makes about 2.4 pounds of carbonate which is worth about 20 per cent less than one pound of oxide and as there is such a large market for carbonate we think that the allowed values for all oxide would not be reduced by making part of the product as carbonate as this could also be sold sufficiently below the market price to be attractive to induce someone to take the entire output.

One pound of $MgCl_2$ will make 0.421 pound Magnesium Oxide or 1.018 pound Basic Magnesium Carbonate.

Our brine coming to the plant would contain an average of 2.8 per cent $MgCl_2$. Therefore, 100 tons brine will make

$$28 \times 0.421 = 11.8 \text{ tons oxide.}$$

Present Prices

11.8 Tons Oxide

23,600 pounds, $.25 per pound	$5,900.00	
Less one-half	2,950.00	
		$2,950.00

Expected Prices

Mean of Present and Pre-War	$2,360.00	$2,360.00

Pre-War Prices

23,600 pounds, $.15 per pound	$3,540.00	
Less one-half	1,770.00	
		$1,770.00

Salt

This property is located in the heart of a large cattle country which uses a large quantity of salt of cattle grade. The present price of salt in Western Texas is about $22 per ton for cattle salt. One of the gentlemen interested in this proposition sent out letters to several small towns and found that six small towns use a total of 162 cars, or 8100 tons of salt per year as follows:

	Population	Cars Salt Annually
Pecos	1,856	10
Seymour	2,029	5
Hereford	1,750	12
Del Rio	4,000	60
Marfa	2,500	50
San Angelo	10,310	50

These figures merely indicate the enormous possibilities and based on this and other information gathered, this gentleman, who is one of the wealthy cattle and land men of the West, has offered to form a company of ranchers and take the entire output of salt made by the plant.

The nearest sources of salt are Grand Saline, Texas, and around Hutchinson, Kansas. The Kansas salt fields have always been a cheap source of supply and the Texas field a high priced source of supply. Prior to the war, Texas salt sold at about $6.50 per ton f.o.b. works, as compared with $16 now. There is a freight rate of $5.50 to the western cattle country, making the price to wholesalers about $12 per ton delivered prior to the war. At that time, salt from Kansas brought about $2.55 and the present freight rate is $13 or $15.55 per ton delivered, based on pre-war price and present freight rates. Freight rates to points of consumption for 200 tons of salt daily would probably average $4.00 per ton.

Salt is scarce in West Texas now at a price of $22 per ton. Prior to the war, the price was $12.50, but freight rates have increased $1.50, making it $14 at the same price with increased freight rate. Salt is handled in a very low margin and many of the wholesale distributors would be glad to handle the output on a 10 per cent basis.

Values of Salt

From 1,000 tons brine we should make 170 tons of salt

At Present Prices

170 tons, $22.00	$3,740.00	
Less 10%	374.00	
	$3,366.00	
Less Freight, $4.00	680.))	
		$2,686.00
Expected Prices Average of Present and Pre-War		$2,074.00

Pre-War Prices

170 tons, $14.00	$2,380.00	
Less 10%	238.00	
	$2,142.00	
Less Freight		$1,462.00

PLANT REQUIREMENTS

From one hundred to one hundred twenty-five men will be required to operate the plant and the housing of these men would require a large expenditure in bunk houses, cottages, restaurant, store, etc. The town of Tahoka is about seven miles from Double Lakes and we would require a 6-inch wood pipe line of that length to deliver the brine. Tahoka is a well built town. There are numerous brick business buildings and it has a number of good stores, two banks, schools, etc. It is the county seat of Lynn County and has 800 to 1000 population. The people of this town are anxious for the industry and leading citizens have given assurance that the town will donate the plant site together with the right-of-way for pipe lines. Wood pipe line to

Tahoka would cost about $4000 per mile installed at the present high prices.

From experience in Nebraska fields, it would appear that 500 wells with 2″x6′ sand points would be required together with 6″x6″ triplex pumps with 20h.p. fuel oil engines.

By the process outlined, we contemplate evaporating the brine by solar evaporation from the strength as it comes from the wells (about 20 per cent hydrous solids) to 30 per cent hydrous solids corresponding with 25 per cent anhydrous solids. This means the evaporation of 500 tons of water per day by solar evaporation in order to send 1000 tons of 30 per cent water to the reduction plant. The evaporation would be considerably higher in summer than in winter. But we must have pond capacity sufficient to take care of the plant during the months of lowest evaporation.

From our figures on solar evaporation, we find that we must average 4 inches of evaporation per month. Taking the net evaporation for each month and taking 48/60 or 5/6 of this for a minimum, we arrive at the following table:

	Av. Net. Evap.	Min. Evap.	Deficit
April	6.08	4.864	
May	6.23	4.984	
June	8.20	6.560	
July	7.81	6.248	
August	6.65	5.320	
September	5.82	4.656	
October	4.42	3.536	.464
November	3.30	2.640	1.360
December	2.35	1.880	2.120
January	3.61	2.888	1.112
February	1.89	1.512	2.488
March	4.96	3.968	

For a 1000-ton steam evaporation plant, we must have an area sufficient to evaporate 500 tons of water and a storage of one-seventh of our annual requirements. To these figures, we add 20 per cent for seepage losses, etc.

Five hundred tons of water is 1,000,000 pounds or 16,000 cubic feet per day or 5,600,000 cubic feet per year. At

4′ evaporation, we require 1,400,000 square feet of solar ponds, 1200 feet square, divided into four ponds. We get our 20 per cent additional by adding one pond at the end 1200x240 feet.

We use a total of 1000x350=350,000 tons of concentrated brine and as shown above and must provide storage for one-seventh or 50,000 tons. This brine has a specific gravity of about 1.15 and weighs about 72 pounds per cubic foot. We must store 1,400,000 cubic feet which is one foot deep on our solar ponds with 20 per cent to spare, so we are very safe on this. The construction of these ponds is very simple, as the bottoms require no treatment and the walls are quite simple to build. We will require 8880 lineal feet of such wall for the ponds as specified.

We send to the evaporators 1000 tons of brine of which 250 tons are solids and about 40 tons of water stays up finally as water of crystallization, so we actually must evaporate 710 tons of water. This works out for the best separation with two triple effect evaporators and one finishing pan.

All the above will be required for either process considered. We will also require a furnace for decomposing magnesium chloride, a hydrochloric acid recovery system and a calcium chloride apparatus, also filters and tanks for filtering and washing the magnesium oxide. As potash has two very definite shipping seasons, we have also provided for a warehouse to store four months run.

To evaporate the amount of brine specified with other requirements of steam requires 100 tons of coal daily or about 1800 boiler horsepower.

All the above is based on a plant to handle 1000 tons of concentrated brine daily. We are also submitting figures on a 500-ton plant.

ESTIMATED CASH REQUIREMENTS

1,000 Tons 25% Brine Capacity Evaporating Plant
Second-Hand Boilers and New Equipment

	1000 Ton Plant	500 Ton Plant
Foundations and Grading	$ 20,000	$ 15,000
Track	5,000	5,000
Boilers	50,000	25,000
Piping, Feedwater Pumps, Etc.	6,000	4,000
Setting up 3,500 settings 20,000	23,500	15,000
Stokers Erected	22,500	15,000
Coal and Ash Handling with Bin	16,000	14,000
Evaporators Erected with Condensers and Fume Lines	60,000	30,000
Piping, Pumps, Etc.	22,500	11,250
Salt Boxes, 12, With Pump and Accessories	15,000	7,500
Dryers, 4, $6,000	24,000	18,000
Elevators, Crushers, etc.	6,000	4,000
Oil Storage Tanks	6,000	4,000
Shop Equipment	10,000	6,000
Motors, Generators, Engine Wiring, Etc.	20,000	15,000
Sand Points, Wells, Piping, Pumps, Etc.	16,500	11,250
7 Miles Wood Pipe, $4,000	28,000	28,000
Solar Pond	25,000	15,000
Plant Pond	14,000	10,000
Cooling Tower	6,000	5,000
Salt Presses, Etc.	39,000	26,000
Tanks, Coolers, Etc.	9,000	7,000
Autos, Trucks, Etc.	6,000	6,000
Buildings	80,000	55,000
Engineering and Interim Expense	54,000	45,000
	$584,000	$397,000

Additional for Magnesia Plant

	1000 Ton Plant	500 Ton Plant
Elevators and Conveyors	$ 6,000	$ 6,000
Furnace	10,000	9,000
HCl Plant	15,000	15,000
Tanks, Gas Holder, Etc.	6,000	5,000
Carbonating Plant	7,000	6,000
Filters, Tanks, Etc.	8,000	6,000
Quarry Equipment	8,000	5,000
Bins, Sacking Devices, Dryer, Etc.	10,000	6,000
Building and Storage	30,000	20,000
	$100,000	$ 78,000

Recapitulation of Cash Requirements
1,000 Ton Plant (Using Equipment Except Boilers)

Plant Cost	$584,000	
Payment on Lakes	100,000	
Magnesia Plant	100,000	
Working Capital	200,000	
		$984,000

500 Ton Plant (New Equipment Except Boilers)

Plant Cost	$397,000	
Payment on Lakes	100,000	
Magnesia Plant	78,000	
Working Capital	125,000	
		$700,000

RECAPITALIZATION OF VALUES

Present Prices

	1,000 Ton Plant	500 Ton Plant
Potash	$2,302	$1,151
Magnesia	2,950	1,475
Salt	2,686	1,343
	$7,938	$3,969
Less 15% Plant Losses	1,190	595
	$6,748	$3,374

Expected Prices

	1,000 Ton Plant	500 Ton Plant
Potash	$1,356	$ 678
Magnesia	2,360	1,180
Salt	2,074	1,037
	$5,790	$2,895
Less 15% Plant Losses	869	434
	$4,921	$2,461

Pre-War Prices

Potash	$ 777	$ 389
Magnesia	1,770	885
Salt	1,462	731
	$4,009	$2,005
Less 15% Plant Losses	601	301
	$3,408	$1,704

COST OF PRODUCTION

	1,000 Ton Plant	500 Ton Plant
Coal—		
100 Tons	$ 700	$
60 Tons		420
Labor—		
124 Men, $6	746	
87 Men, $6		522
Fuel for Oil Engines and Dryers	100	70
Supplies	200	130
General Expense and Sales	250	200
Limestone	30	15
Superintendent, Chemical and Unforeseen	74	50
	$2,100	$1,407

Labor Detail

	Men	Men
Boilers	6	4
Evaporators	4	2
Pumps	2	2
Salt Boxes	12	8
Coolers	4	2
Treating	4	4
Dryers and Sackers	16	12
Hydraulic Operators	24	12
Shops and Fitters	10	7
Bull Gang	18	12
Office	4	4
Lake	4	4
Magnesia Plant	16	14
	124	87

ESTIMATED PROFITS

	1,000 Ton Plant	500 Ton Plant
Cash Requirements	$ 690,000	$600,000
or	834,000	
Present Prices		
Value of Products (Est. Cash Req.)	$ 6,748	$ 3,374
Less Process Royalty 3%	202	100
Less Costs (Cost of Prod.)	2,100	1,407
	$ 4,446	$ 1,867
350 Days Profit	$1,556,100	$653,450
Expected Prices		
Value of Products (Est. Cost Req.)	$ 4,921	$ 2,461
Less Process Royalty 3%	148	73
	$ 4,773	$ 2,388
Less Costs (Cost of Prod.)	2,100	1,407
	$ 2,673	$ 981
350 Days Profit	$ 935,550	$343,350
Pre-War Prices		
Value of Products	$ 3,408	$ 1,704
Less Process Royalty 3%	102	51
	$ 1,675	$ 1,653
Costs (Cost of Prod. Less 20%)	1,675	1,126
	$ 3,306	$ 1,653
350 Days Profit	$ 570,850	$184,450

EXPERIMENTAL PLANT

The object of this test, which was made on brines from Double Lake No. 1, was to do the actual salt separations on a semi-commercial scale as we had done them in the laboratory. The plant consisted of barrels or drums where tanks would be used in a large plant, two steam boilers, coil separators, pumps, filter and centrifugal. Three outlines were run.

The first, applicable to treating salts evaporated by solar evaporation, consisted of evaporating salts to dryness, puting them into solution of hot NaCl brine, cooling to obtain potash, further evaporating to obtain salt, cooling to obtain potassium chloride and carnallite, decomposing carnallite with water to get potassium chloride, precipitating magnesium chloride in the mother liquor with sodium carbonate to get basic magnesium carbonate.

The second consisted of precipitating the magnesium chloride in the incoming lake brines to basic magnesium carbonate by adding sodium carbonate to the heated brine, evaporating the liquor and precipitating salt until potash, then concentrating the liquor in order to obtain salt as before and cooling to get nearly all the remaining potash, and finally returning the liquor to the incoming brine.

The third consisted of evaporating lake brines and precipitating salt until potash began to come down, cooling to get a crop of potash, re-evaporating to get a crop of carnallite, decomposing carnallite with hot water to get potassium chloride, thus leaving a mother liquor containing nearly all magnesium chloride with a very small per cent of potassium chloride.

All the tests above were conducted under the personal supervision of Dr. Bassett and came out exactly as he expected.

Owing to the fact that it was impossible to make proper analyses of the washed salts, wash liquors, etc., in the field and proper washing filters could not be provided without great expense, it was decided to send 100 pounds of each salt to the laboratory and wash it up on a large scale, keeping careful record of the results. No difficulty whatever was experienced in washing these to commercial purity in two ordinary washes. The final product (magnesium carbonate) was filtered and washed to high purity at the experimental plant. Samples of magnesium carbonate, salt and potash made are now at our laboratory.

The first process is that contemplated by our original report except that we used sodium carbonate to precipitate magnesium chloride to basic carbonate instead of using lime in digestors, as we found we could get sodium carbonate cheaply in crude trona and a pure lime could be obtained only at a distance and at great expense. We do not recommend this process on account of the lack of absolute knowledge of complete evaporation in solar ponds as explained before. The process was entirely satisfactory.

The second process is the one we would use in a steam evaporating plant and this worked splendidly throughout.

The third process is the same as the first except we did not precipitate the magnesium, but left it in the final liquor which was concentrated to solid hydrous magnesium chloride.

This magnesium hydroxide was run in a small rotary furnace in our experimental laboratory here in Philadelphia, carrying out the process in detail on a semi-commercial scale. The run was entirely satisfactory and demonstrated the commercial feasibility of the process beyond any doubt.

Before actually starting construction, we would suggest that the entire process be run in a small steam evaporating plant. This test could be run at one of the universities where a small evaporator is available, or such an evaporator could be purchased and used later in a pilot plant. We have all other apparatus necessary.

It should be the policy to use solar evaporation to the limit, but we do not feel like recommending it for complete evaporation at first. It will be an economical method of increasing production and can be counted on to do much more than we have calculated on in these figures.

The experimental plant was to determine on a semi-commercial scale whether or not salts could be separated with predominating ions so that they could be easily washed to purity. Dr. Bassett is entirely satisfied with the results and no doubt remains in his mind as to the thorough practicability of the process without close chemical control.

CONCLUSIONS

After looking over every field of potash production in the United States, we strongly recommended this location to our clients about two years ago and since that time, we have worked almost continuously on process work and development work on the proposition...The value of the salt has proven much better than expected and there is a most steady and increasing demand for this locally. Freight increases on salt are in favor of the proposition and almost offset the effect of these increases on fuel and the other commodities produced...Our results, both from a commercial and technical standpoint have been checked up by one of the largest and most successful chemical companies in this country, not with a view of their taking it up, as they are in a different line, but to get their unbiased opinion of our report as a whole. This was possible through one of our connections largely interested in the chemical company and their report was entirely favorable. The patent situation was also laid before one of the best experts on chemical patents after having been first gone into exhaustively by our Dr. Sadtler, who is himself one of the leading experts of the United States, and it has been reported as highly satisfactory.

We have been conservative throughout in figuring our costs, as we are quite sure that the plant could be operated on less labor and fuel than counted in the estimate of cost. We have made every effort to be conservative in this report, however.

By taking in both groups of lakes, you apparently have a very large reserve for future extension. We recommend starting on the Tahoka group for the reasons outlined before and future extensions may be made as determined...

While this has been referred to as a "potash proposition" the fact is that two other valuable products are made which gives it a decided advantage over other American potash plants in operation, only one of which has produced by-products up to this time...

Either the salt or magnesia is more valuable than the potash. The outstanding feature that we want to emphasize is that the salt should pay for all operating and overhead expenses and the other products represent net profits. The potash is a valuable by-product for which there is a very much larger demand than the amount that will likely be produced in this country for many years to come. Magnesia apparently can be produced so cheaply as compared with any processes now in use that it could be shipped right into Philadelphia in competition...

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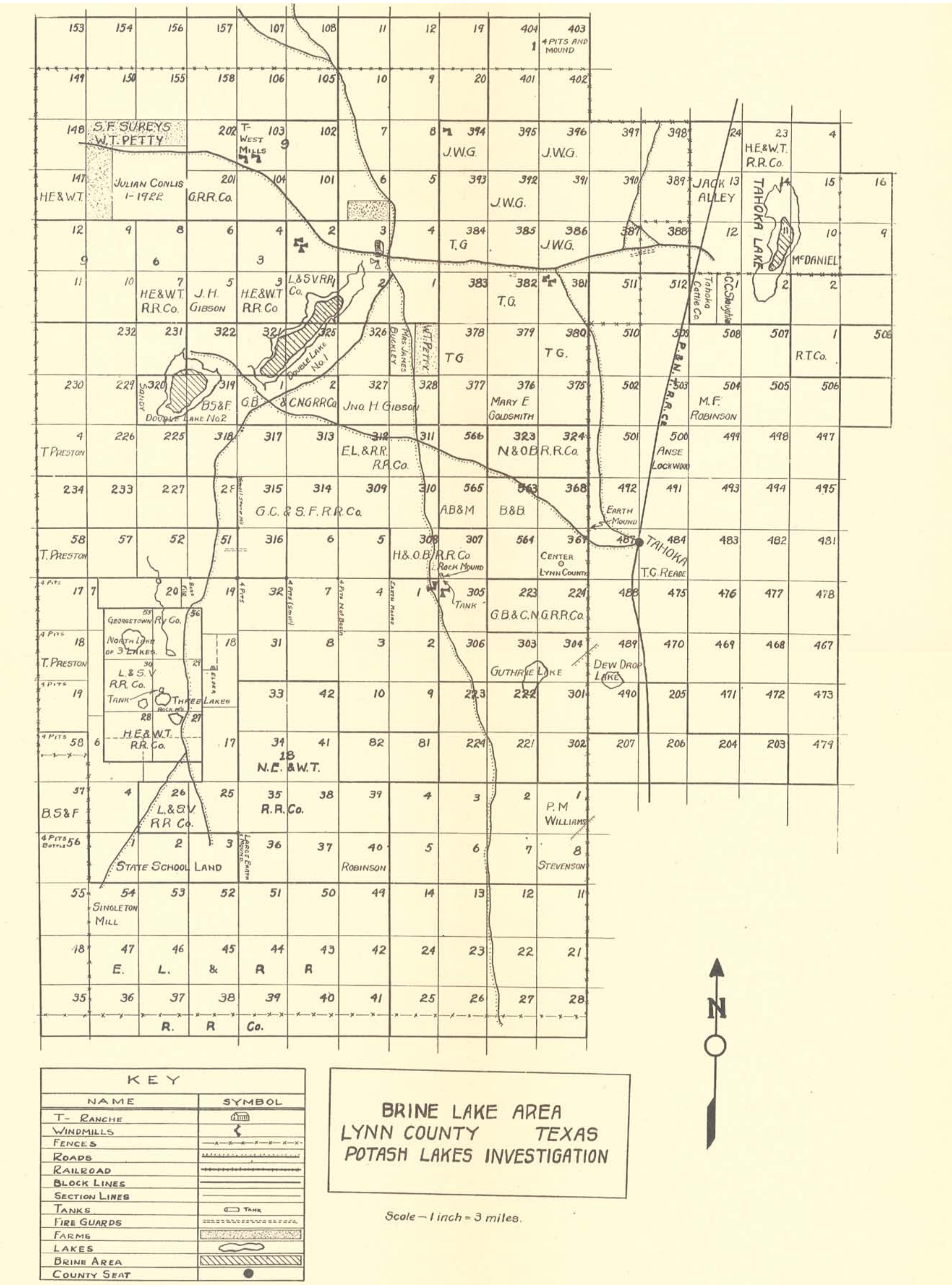
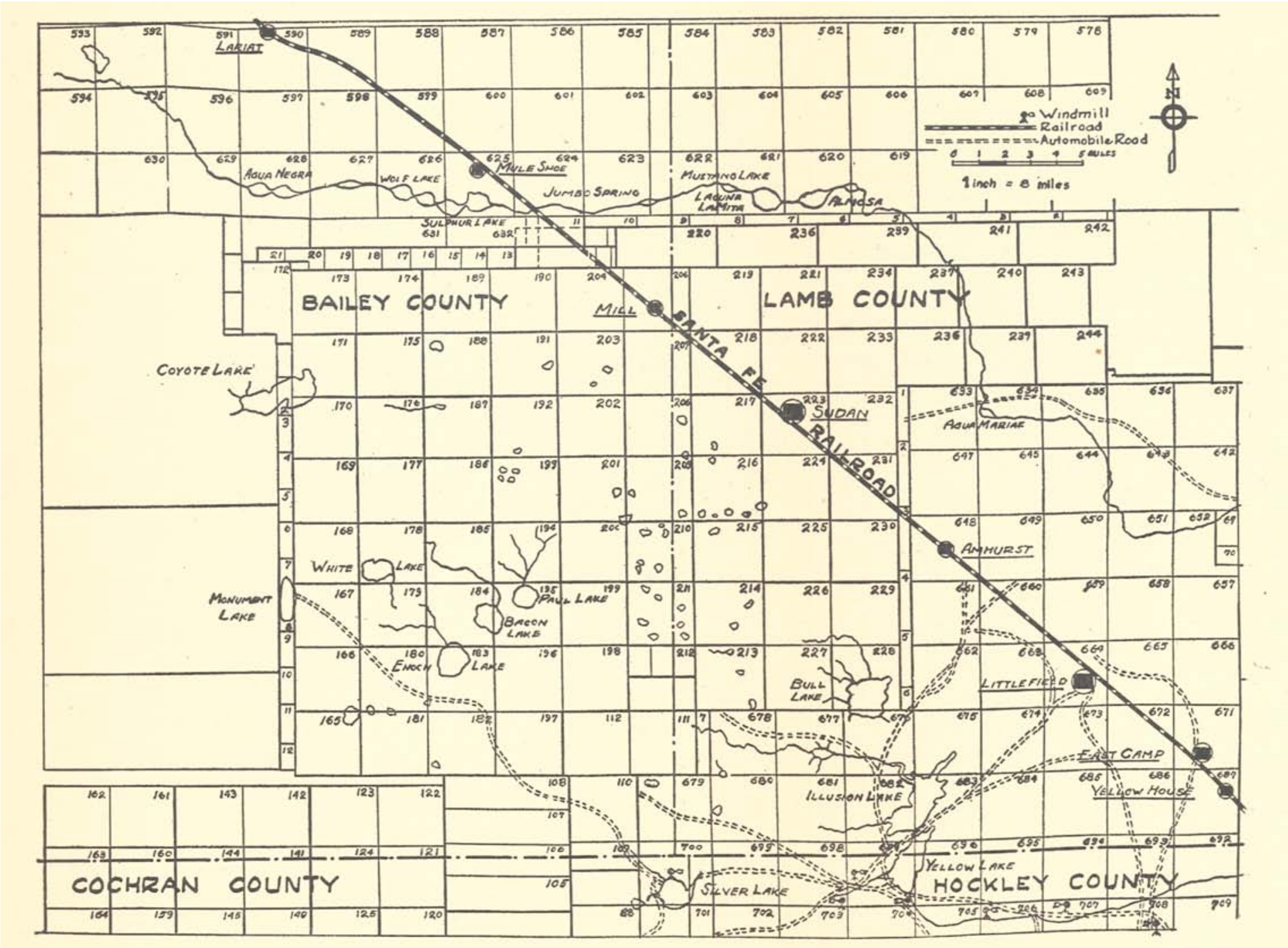
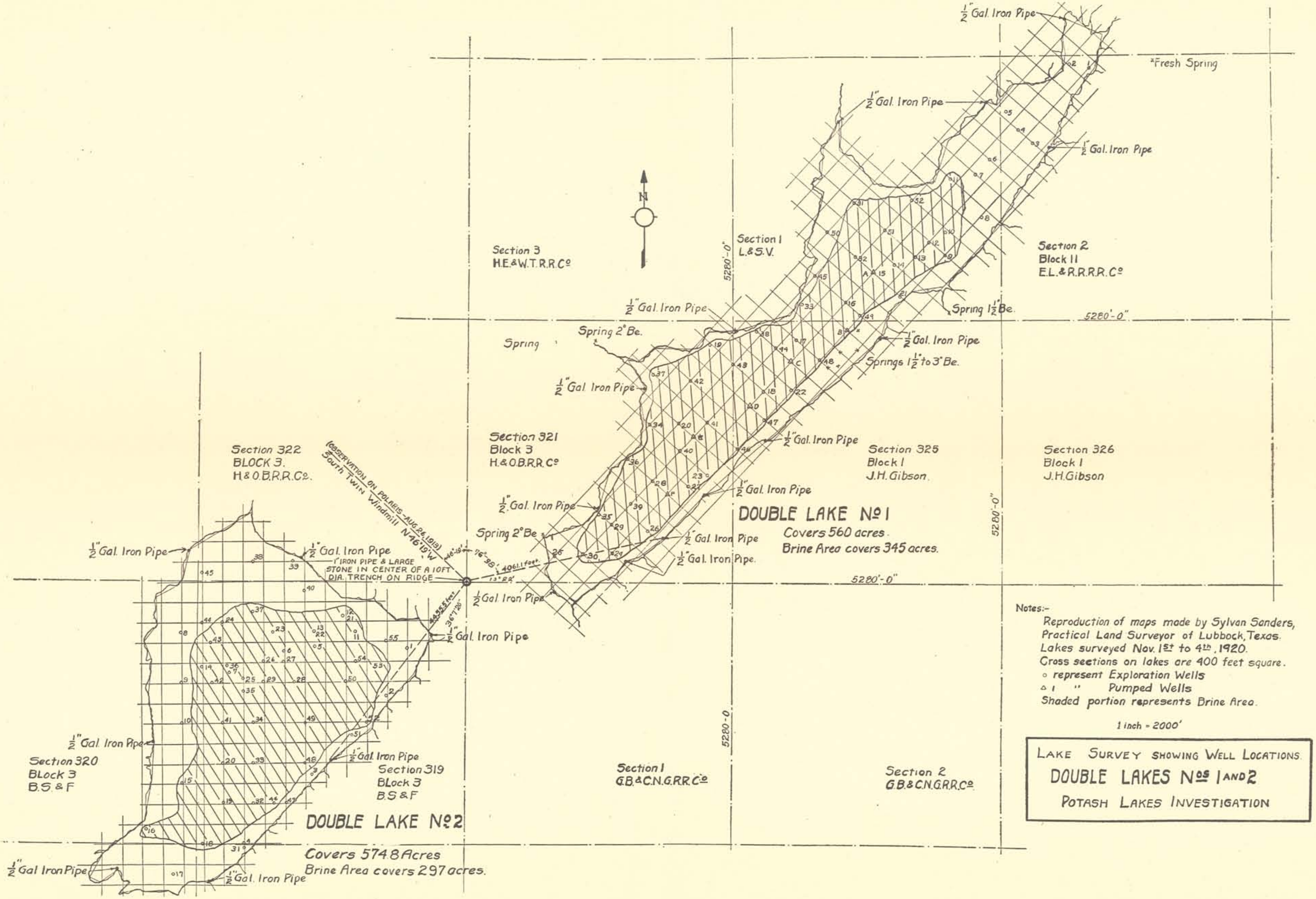


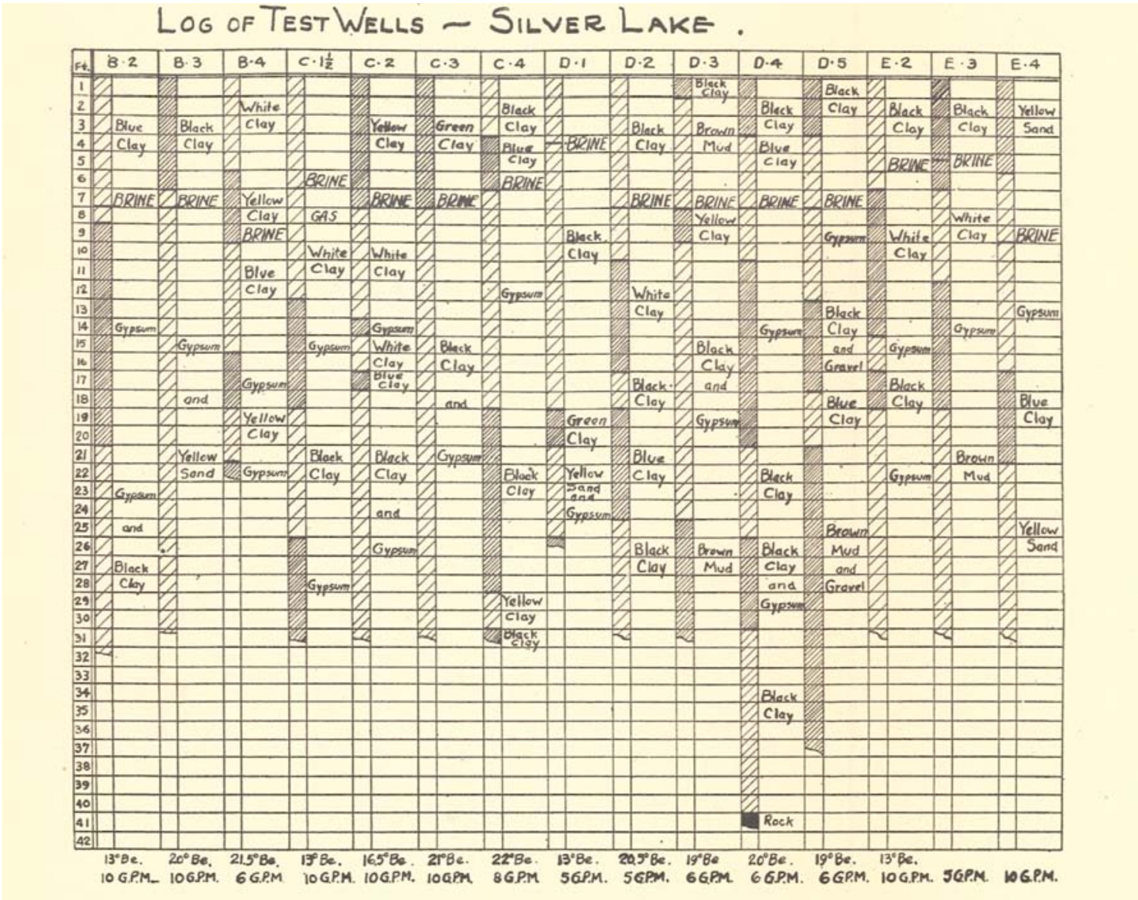
Sketch map to show location of brine lakes in Lynn County



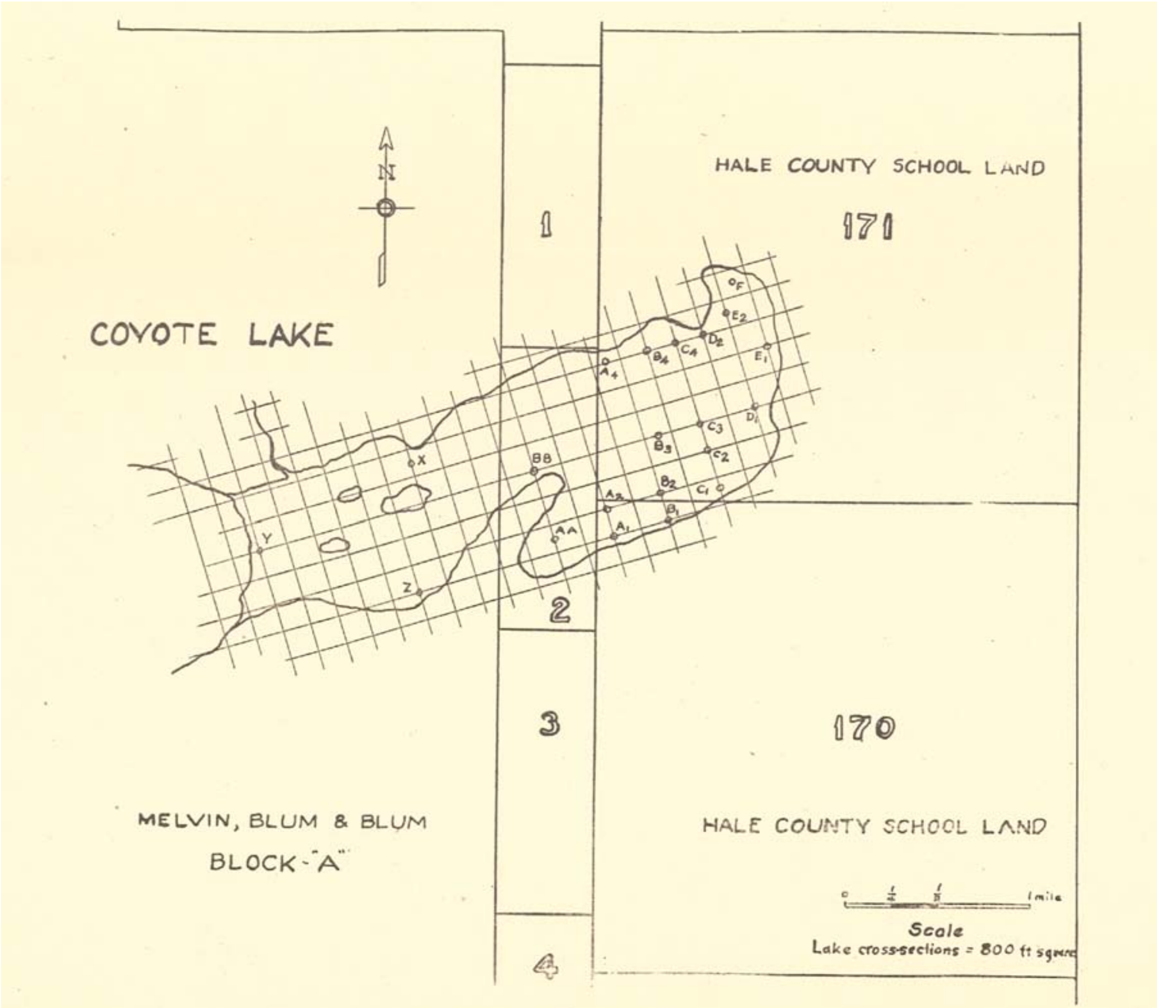
Sketch map to show location of Lakes in Bailey and Lamb Counties



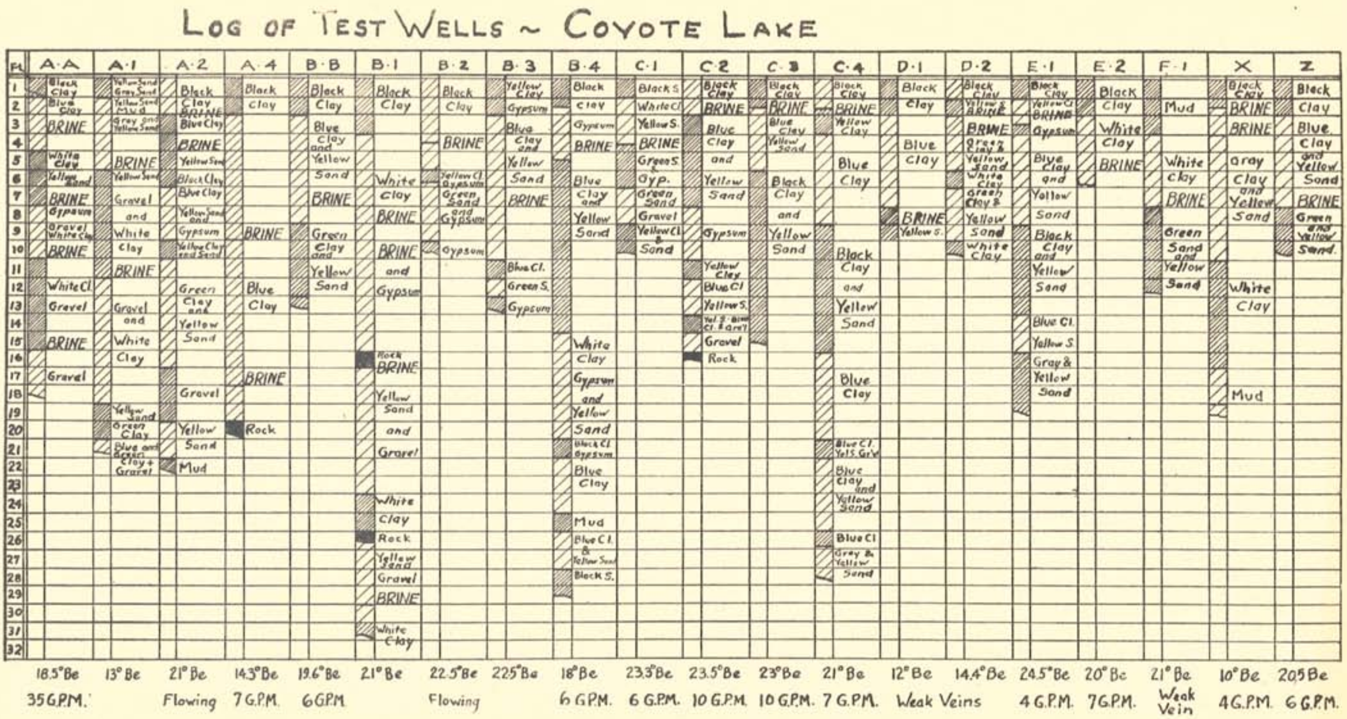
Map of Double Lakes showing the location of test wells



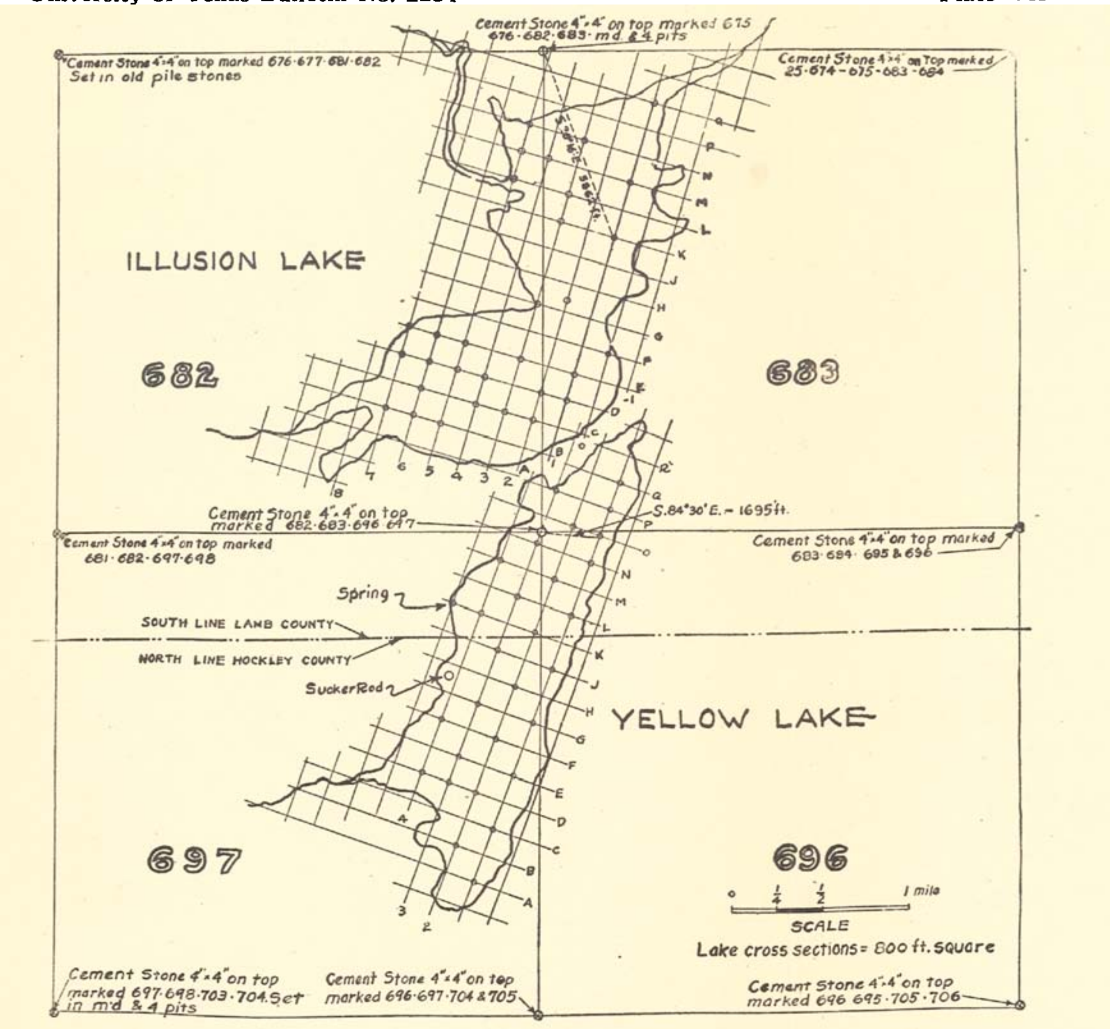
Graphic Representation of Logs of Test Wells in Silver Lake



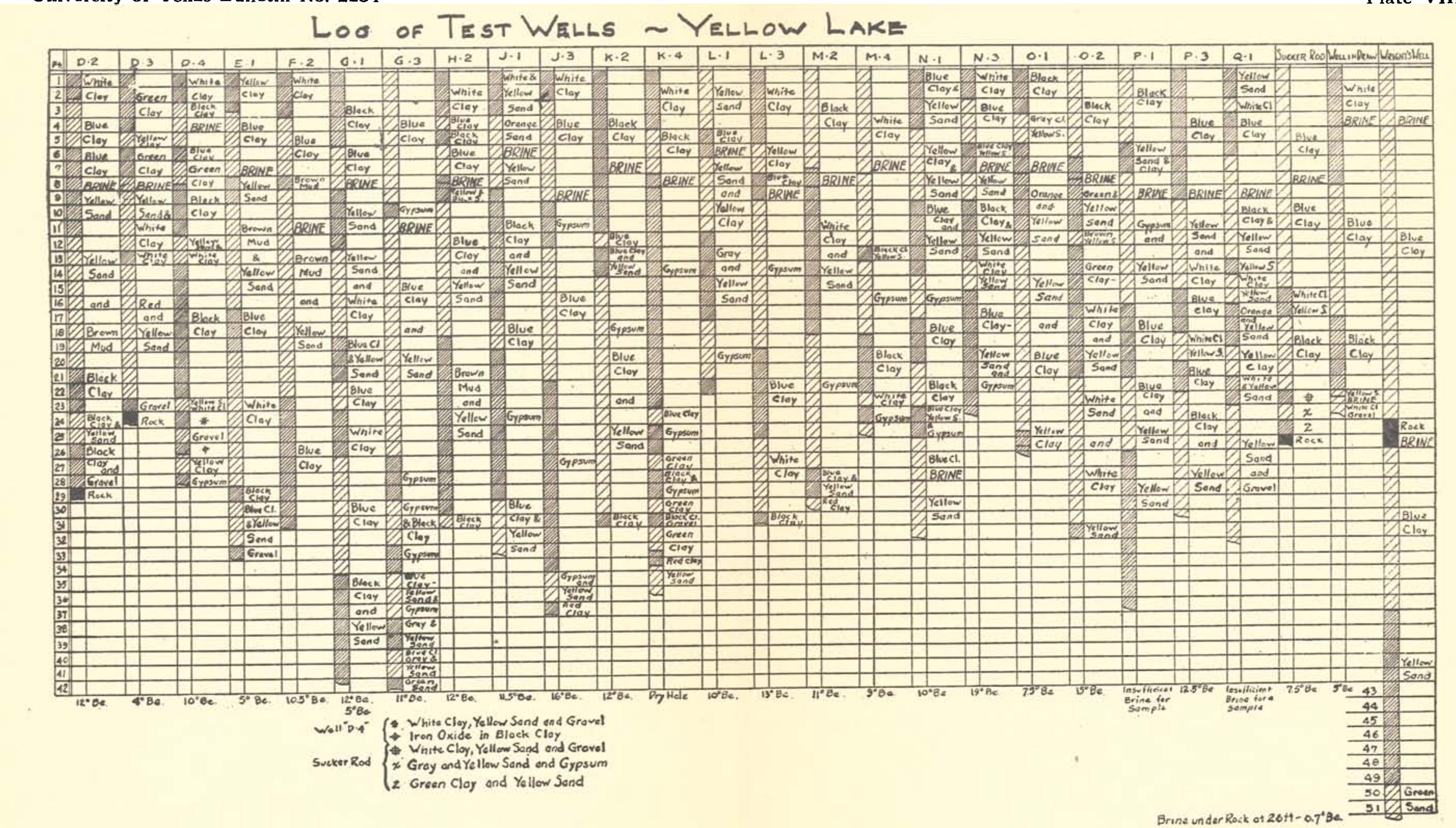
Coyote Lake showing location of test wells



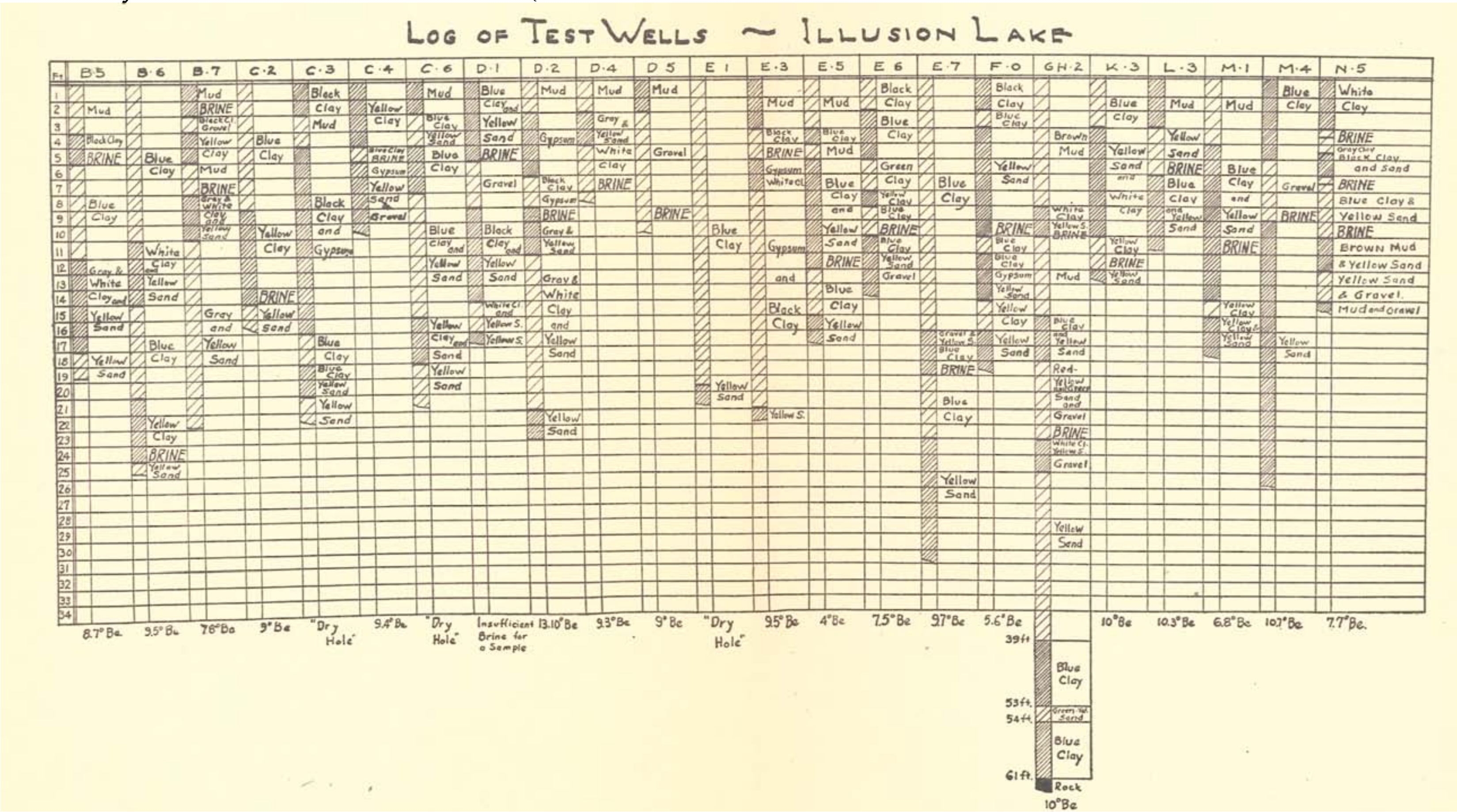
Graphic logs of test wells in Coyote Lake



Illusion and Yellow Lakes showing location of test wells



Graphic logs of test wells in Yellow Lake



Graphic logs of test wells in Illusion Lake