STATE OF SOUTH DAKOTA
William J. Janklow, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
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GEOLOGICAL SURVEY
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GROUND-WATER STUDY FOR THE CITY OF CLARK, SOUTH DAKOTA

by

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Vermillion, South Dakota
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INTRODUCTION

Present Investigation

At the request of the City of Clark, the South Dakota Geological Survey conducted a ground-water study in the summer of 1972. Additional data were collected and analyzed during 1972 and 1974.

Prior to this study the City was pumping water from three wells within the City limits. These wells were drilled into approximately 30 feet of sand and gravel of glacial origin.

Included in the survey of the Clark area were:

(1) Drilling of 73 auger and 4 rotary wells

(2) Construction of 29 observation wells

(3) Collection and analysis of 100 water samples.

As a result of this study more data on the thickness and areal extent of the shallow sand and gravel in the vicinity of the City were collected. It was found that the thickest shallow sand and gravel was in the vicinity of the City park where the present City wells were located. A very high concentration of chemicals was found in the ground water in the vicinity of an unsealed lagoon used for disposal of waste water from a potato processing plant located approximately one-half mile northeast of the City well field.

The cooperation of the residents of Clark, especially former Mayor Sidney Stacy, City Auditor Vearle Gergen, and Water Superintendent William Jongbloed was appreciated. The project was financed by the South Dakota Geological Survey, Oahe Conservancy Sub-District, and the City of Clark.

Location and Extent of Area

The City of Clark is located in east-central South Dakota in Clark County along the western edge of the Coteau des Prairies division of the Central Lowlands physiographic province (fig. 1).

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Clark area are the results of glaciation late in the Pleistocene Epoch of geologic time. Glacial deposits are collectively called drift and can be divided into till and outwash deposits. Till consists of unsorted material that ranges from boulder to clay size and was deposited directly by the ice. Outwash is a more homogeneous material, consisting primarily of sand and gravel with minor amounts of silt and clay which was deposited by meltwater issuing from a glacier.

Figure 2 shows the location of the test holes drilled in the Clark area. For logs of the test holes, see appendix A.

Figure 3 is a generalized hydrogeological map of the Clark area. The surface outwash deposits vary in thickness from a few feet up to approximately 30 feet thick. There is a buried outwash deposit at a depth of approximately 500 feet and it has a thickness of approximately 25 feet.

Subsurface Bedrock

No bedrock is exposed in the Clark study area. Data obtained from the well logs in this area reveal that Cretaceous

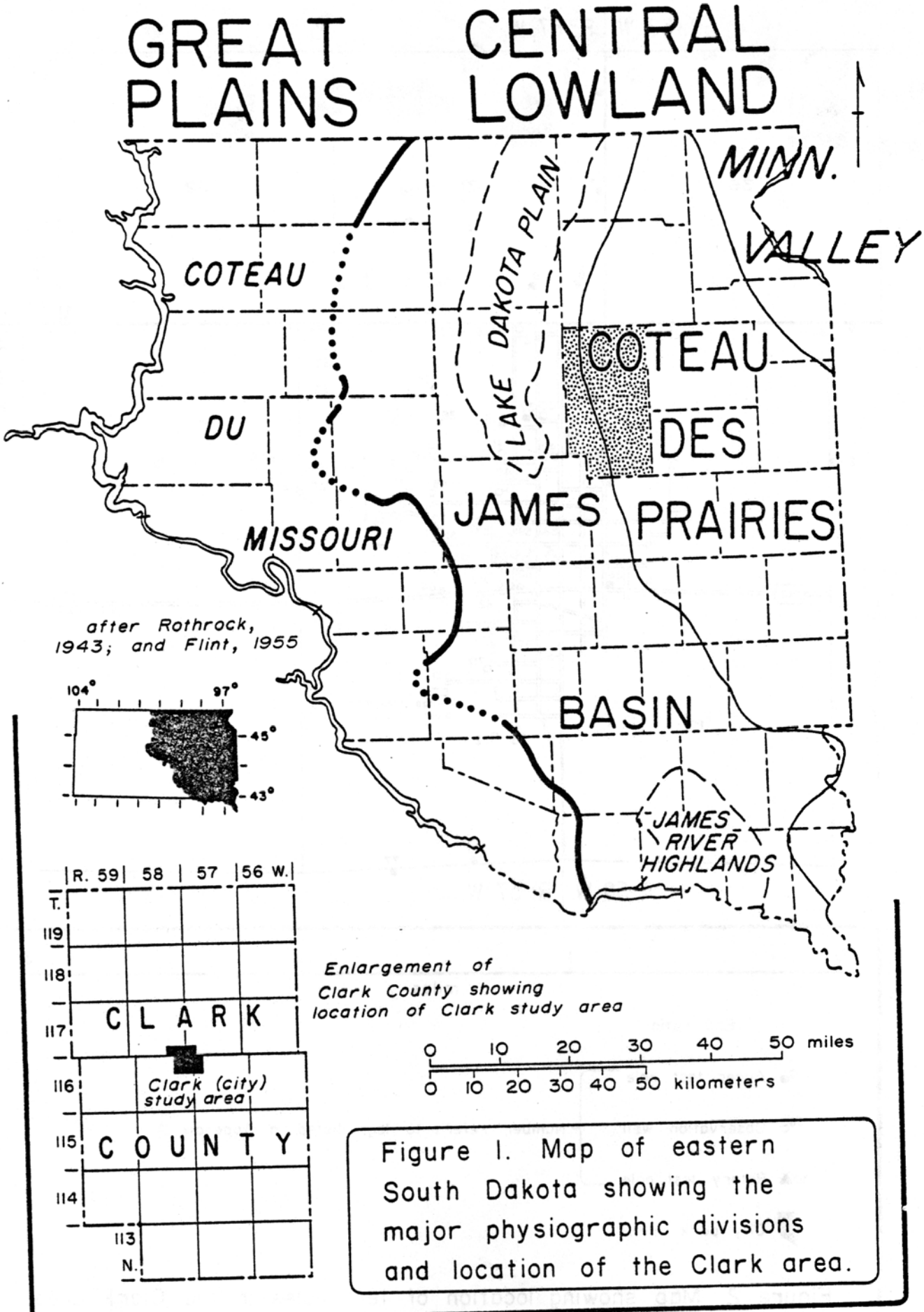
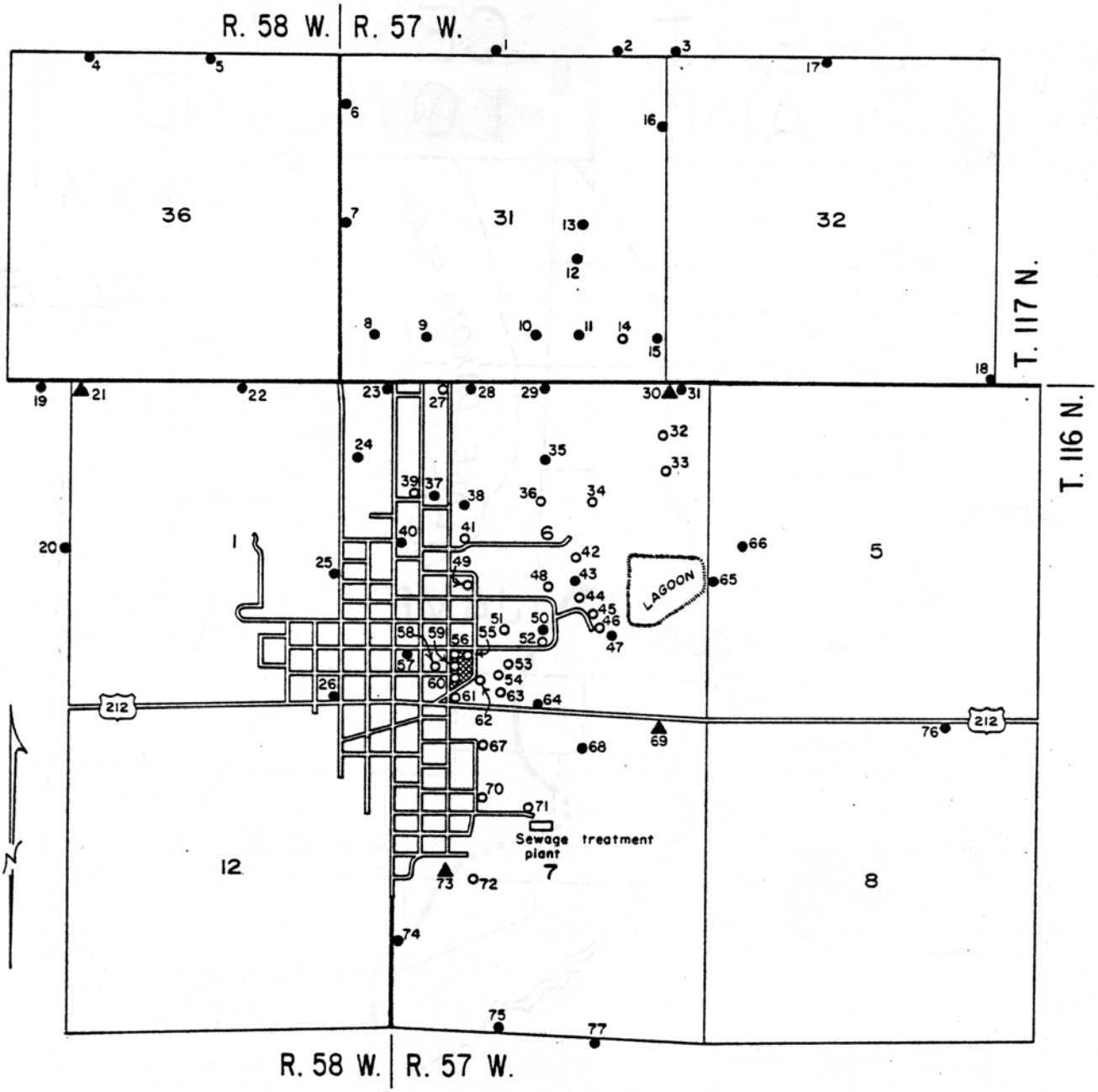


Figure 1. Map of eastern South Dakota showing the major physiographic divisions and location of the Clark area.



0 1 2 3

miles

Explanation

10● Auger test hole

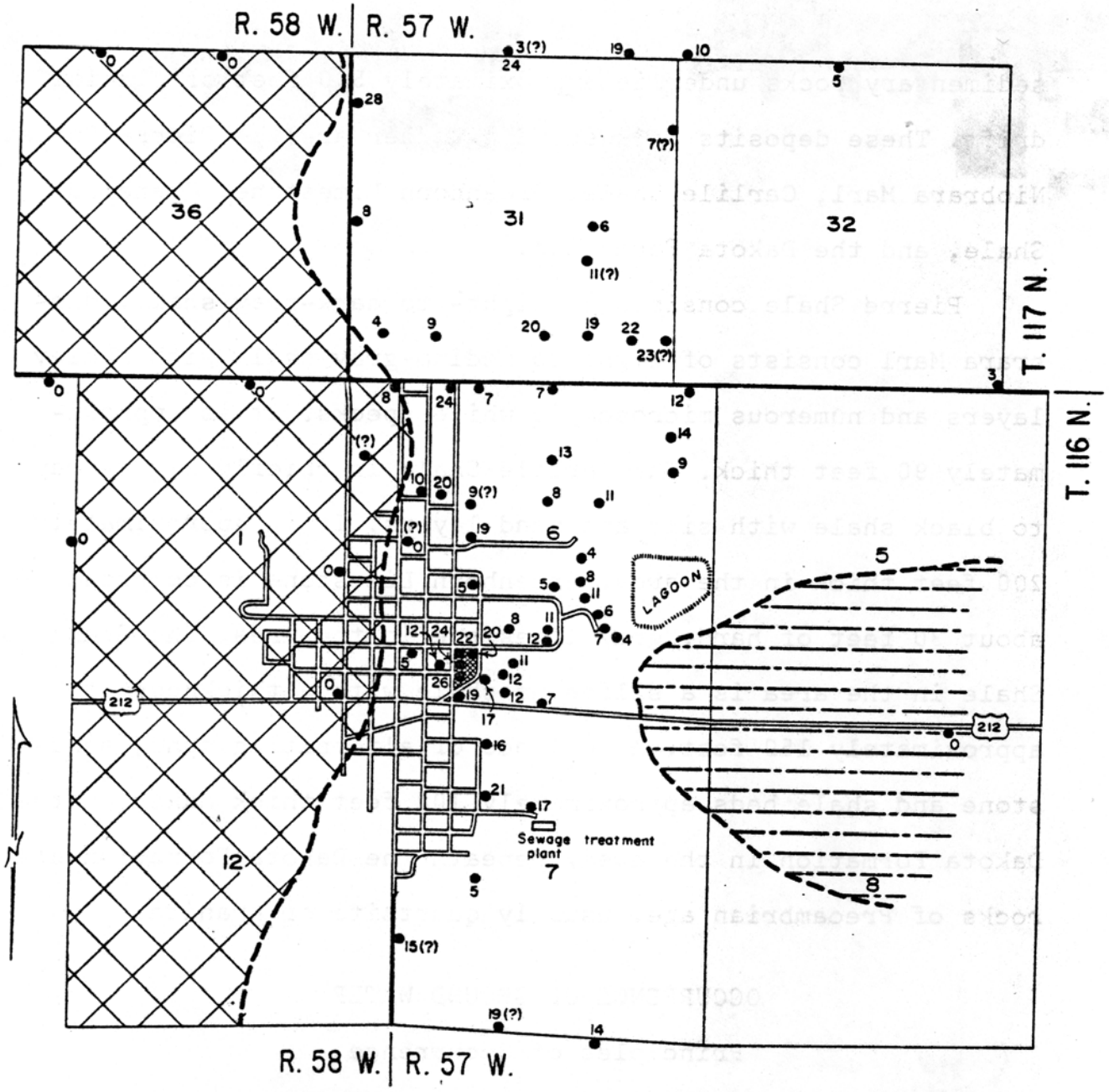
36o Observation well

30▲ Rotary test hole

Number refers to logs listed in Appendix A.

City park

Figure 2. Map showing location of test holes in the Clark area.



0 1 2 3

miles

clay

clay or unsaturated sand and gravel

sand and gravel

20 Test hole, number refers to thickness of saturated sand, in feet.

Boundary line (approximate location)

City park

Figure 3. Generalized hydrogeological map of the Clark area.

sedimentary rocks underlie approximately 500 feet of glacial drift. These deposits in descending order are the Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation.

Pierre Shale consists of light- to dark-gray shale. Niobrara Marl consists of light to medium-gray chalk with shaley layers and numerous microscopic white specks. It is approximately 90 feet thick. The Carlile Shale is chiefly light-gray to black shale with silt and sand layers. It is approximately 200 feet thick in the area. Greenhorn Limestone is composed of about 30 feet of hard, gray limestone in the area. The Graneros Shale in the area is a siliceous shale with a thickness of approximately 150 feet. A sequence of alternating sand, sandstone and shale beds approximately 100 feet thick makes up the Dakota Formation in the area. Beneath the Dakota Formation are rocks of Precambrian age, usually quartzite or granite.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water is defined as water contained in the openings within rocks or sediments below the water table. Practically all open spaces in the rocks that lie below the water table are filled with water. The deposits below the water table are in the zone of saturation. The water table is the upper surface of the zone of saturation and is in equilibrium with atmospheric pressure. Water that occurs in the rocks (and soil) that lie above the water table is in the zone of aeration because some of the

open spaces in this zone are filled with air; the remaining portion contains water. This water is either held by molecular attraction and is returned to the atmosphere by plant use or is moving downward toward the zone of saturation. Water within the ground above the saturated zone moves downward under the influence of gravity, whereas in the saturated zone it moves in a direction determined by the hydraulic gradient.

Contrary to popular belief, ground water does not occur in "veins" that crisscross the land at random. Instead it can be shown that water is found nearly everywhere beneath the surface, but at varying depths.

Nearly all ground water is derived from precipitation in the form of rain, snow, or ice. This water either evaporates, percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward into the ground.

Recharge is the addition of water to an aquifer (a deposit having structures that permit appreciable water to move through it under ordinary field conditions). Recharge to an aquifer is accomplished in four general ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (3) by lateral movement of ground water into the area, and (4) by artificial recharge, which takes place from excess irrigation, seepage from canals, and water purposely applied to augment ground-water supplies.

Discharge of ground water from an aquifer is accomplished in four ways:

(1) By evaporation and transpiration by plants

(2) By seepage upward or laterally into surface bodies of water

(3) By lateral movement of ground water out of the area

(4) By pumping from wells, which constitutes the major artificial discharge of ground water.

Porosity of a rock or soil is a measure of the contained open pore spaces, and is expressed as the percentage of void spaces to the total volume of the rock. Porosity of a sedimentary deposit depends chiefly of:

(1) The shape and arrangement of its constituent particles

(2) The degree of sorting of it particles

(3) The cementation and compaction to which it has been subjected since its deposition

(4) The removal of mineral matter through solution by percolating waters

(5) The fracturing of the rocks, resulting in joints and other openings.

Thus, the size of the material has little or no effect on porosity if all other factors are equal.

Permeability of a rock is its capacity for transmitting a fluid. Water will pass through a material with interconnected pores, but will not pass through material with unconnected pores, even if the latter material has a higher porosity. Therefore,

permeability and porosity are not synonymous terms.

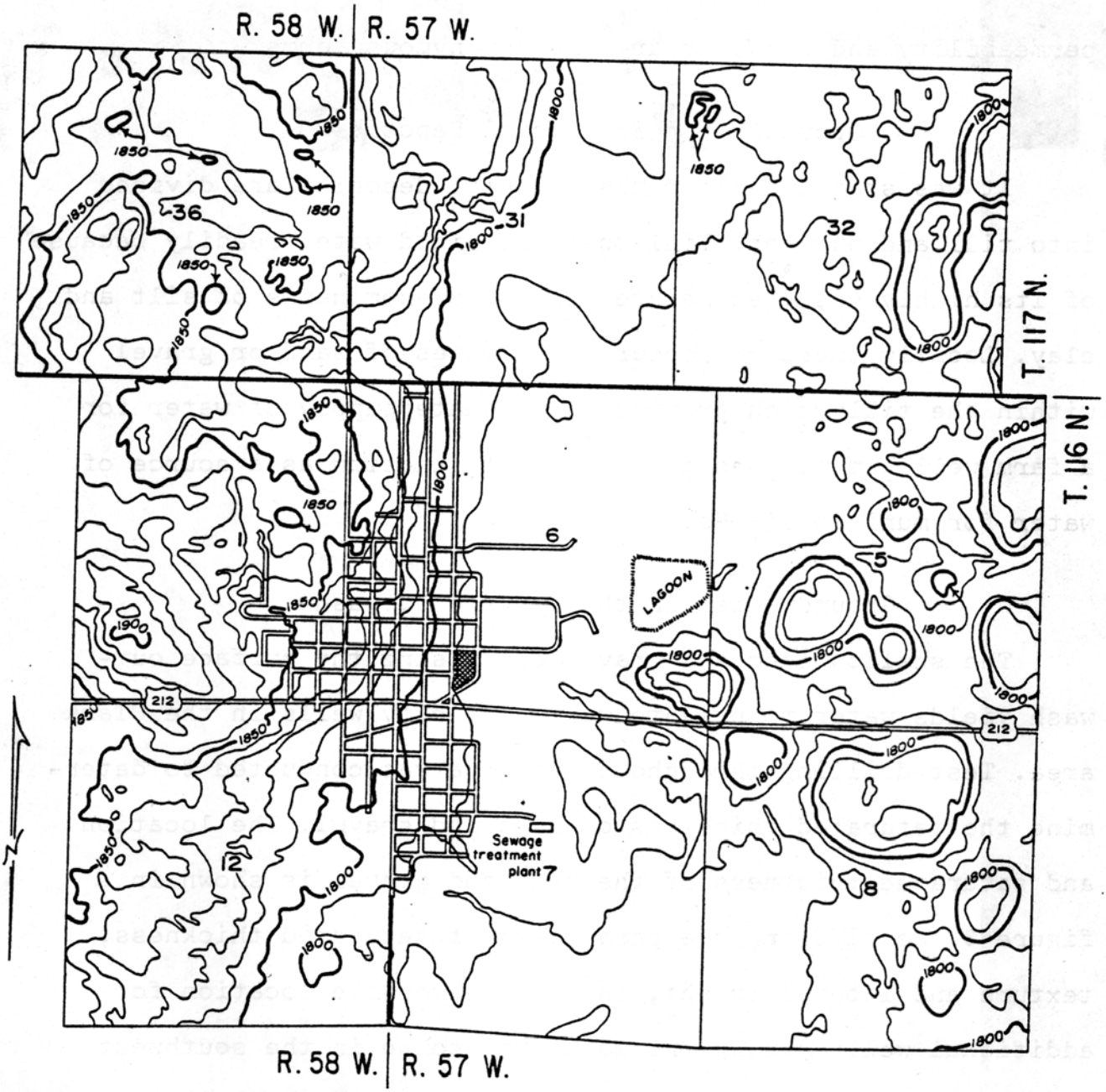
Ground Water in Glacial Deposits

It was stated earlier that glacial deposits are divided into till and outwash. Till does not yield water readily because of its highly unsorted nature and the predominance of silt and clay. Locally there may occur some lenses of sand or gravel within the till which provide an adequate supply of water for a farm well but till as a unit cannot function as a source of water for municipalities.

Ground Water in the Surface Outwash

The shallow sand and gravel comprising the surface outwash yields water to private wells and city wells in the Clark area. Test drilling throughout the area was conducted to determine the saturated thickness of sand and gravel. The location and saturated thickness of the sand and gravel is shown in figure 3. Considering the parameters of saturated thickness, texture and lateral extent, the most favorable location for additional well development was found to be in the southwest corner of section 6, Township 116 N., Range 57 West, in the vicinity of the City Park where as much as 26 feet of saturated sand and gravel is present (fig. 3).

A commercial potato processing plant discharges its effluent into a lagoon built in an area which formerly was a low lying slough area (fig. 4). A study by the South Dakota Geological Survey in 1960 showed that before construction of the lagoon, this area was a ground-water discharge area during



0 1 2 3
miles

Explanation

1850 Contour lines showing elevation above sea level. Contour interval = 10 feet
Elevation indicated every 50 feet.

City park

Figure 4. Topographic map of section 6, T. 116 N., R. 57 W. and vicinity. *(from U. S. Geological Survey topographic maps.)*

periods of low water levels (Wong, 1960). That is, the ground water moved towards the slough and eventually evaporated from its surface. During periods of high water an intermittent stream drained this area (Wong, 1960). Additional test holes and observation wells were constructed in the study area to determine the effect of the effluent on the aquifer within the study area.

Water table maps, figures 5 and 6, constructed for water measurements on November 10, 1972, and June 6-8, 1973, show a high water level in the vicinity of the lagoon compared with the rest of the area. The high (relative to the rest of the area) water level in the vicinity of the lagoon could not be explained by precipitation alone, and it is attributed to the discharge of waste effluent from the potato processing plant. The water table maps show a hydraulic gradient towards the southwest of section 6, where the City wells are located.

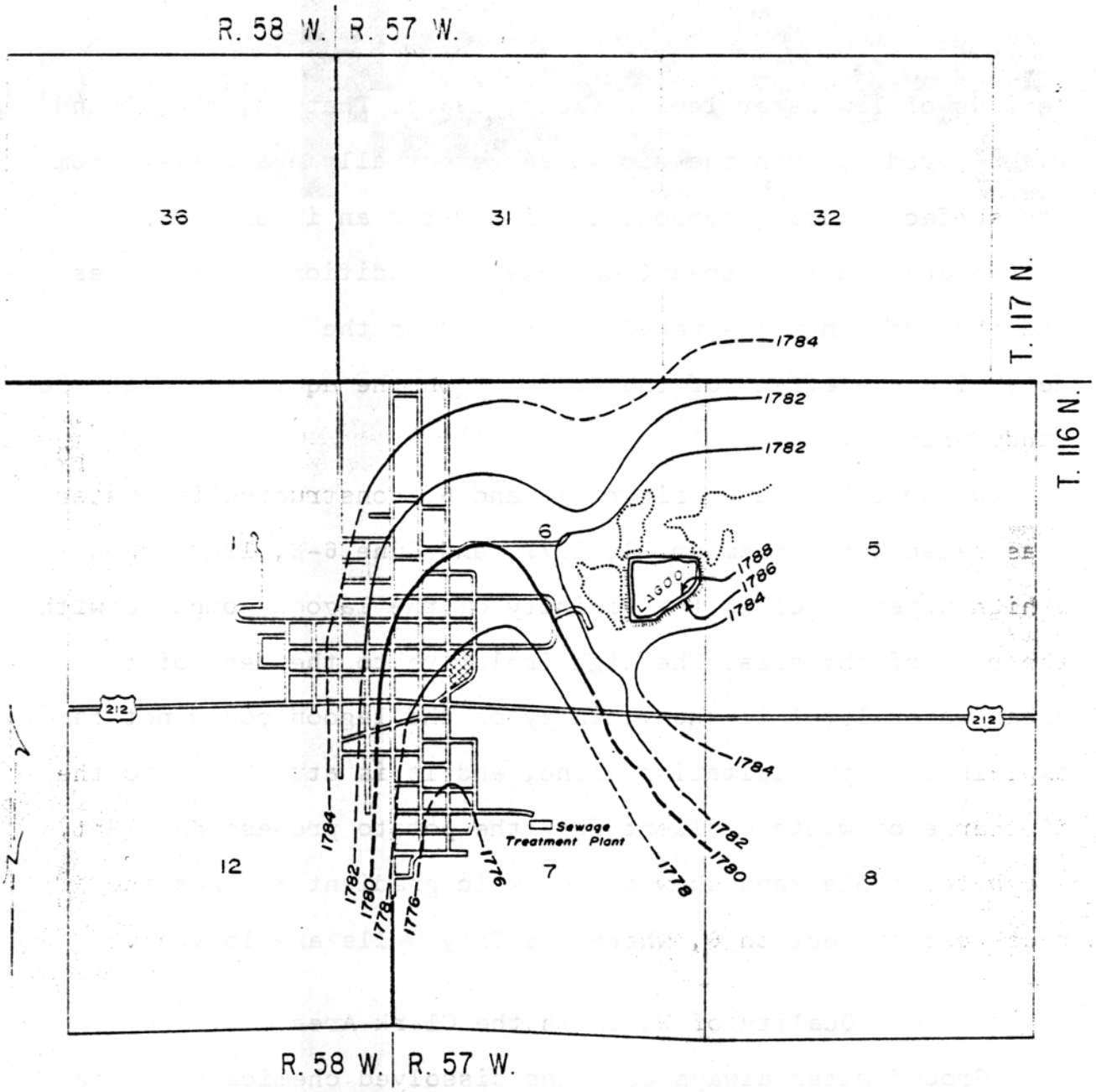
Quality of Water in the Clark Area

Ground water always contains dissolved chemicals. These chemicals are derived from:

(1) The atmosphere as water vapor condenses and falls
(2) The soil and underlying deposits as the water moves downward to the water table
(3) The rocks below the water table.

In general, the more chemical substances the water contains, the poorer its quality will be.

Table 1 lists the amounts of dissolved chemicals in the



0 1 2 3

miles

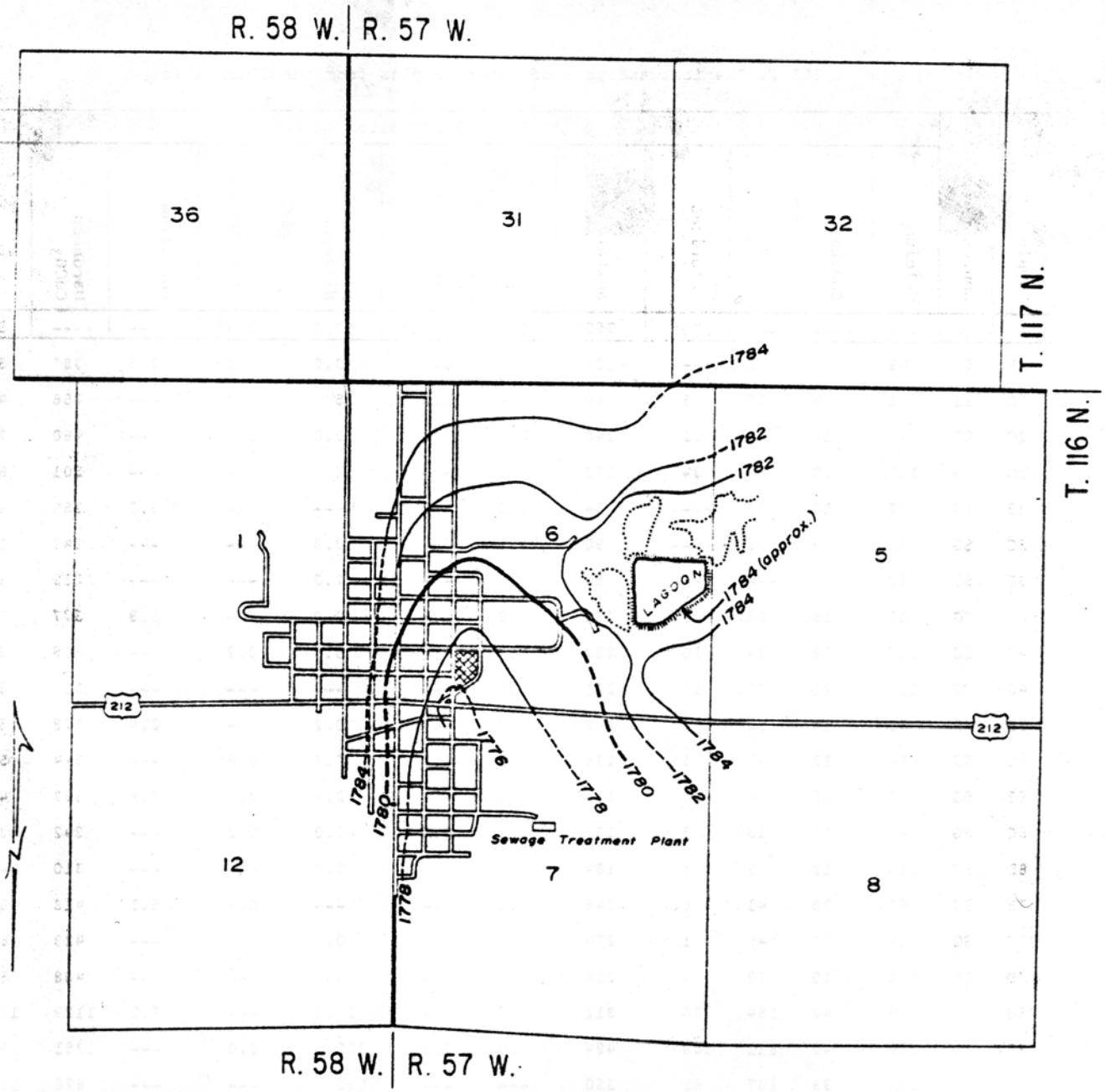
1778 / 1780 — Contour line connecting points of equal elevation. *(dashed where approximately located — contour interval is 2 feet.)*

Approximate boundary of surface water.

For water level measurements see Appendix B.

City park

Figure 5. Water table map of the Clark area — Nov. 10, 1972.



0 1 2 3

miles

1778
1780
Contour line connecting points of equal elevation. *(dashed where approximately located—contour interval is 2 feet.)*

Approximate boundary of surface water.

For water level measurements see Appendix B.

City park

Figure 6. Water table map of the Clark area—June 6-8, 1973.

TABLE 1. Chemical analyses of water samples from the Clark area

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chlorides	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Potassium	Hardness $CaCO_3$	Total Solids
A		---	----	---	250[2]	250[2]	0.3[2]	0.05[2]	10.0[1]	2.4[1]	-----	----	500[2]
1B	SG	69	7	52	----	128	3.0	0.8	0.8	0.2	2.3	387	580
1C	SG	81	4	37	3	90	---	2.0	15	0.2	---	356	492
2C	SG	83	10	61	21	240	1.3	0.5	9.0	0.2	---	460	720
2D	SG	117	10	51	34	173	---	---	7	---	---	501	676
3B	SG	57	10	28	----	54	2.1	0.3	---	---	3.7	259	408
3C	SG	58	9	25	----	90	5.1	0.6	0.0	---	---	249	330
3D	SG	50	9	---	----	50	2.7	---	2.0	---	---	239	308
4B	SG	105	16	28	7	196	0.9	1.2	0.0	---	6.9	377	798
4C	SG	107	19	34	10	232	5.0	1.8	0.0	0.2	---	408	670
4D	SG	119	21	70	17	221	1.8	---	---	---	---	587	658
5B	SG	59	15	56	2	162	0.6	---	0.2	---	2.4	378	596
5C	SG	64	12	45	3	178	3.6	1.5	0.6	0.6	---	344	504
6B	SG	67	15	44	5	188	1.5	---	2.4	0.4	3.4	347	488
6C	SG	42	11	33	3	135	5.1	0.0	0.0	0.2	---	242	390
6D	SG	110	12	9	5	184	---	---	2.0	---	---	310	476
7B	SG	97	20	41	0.6	248	0.9	---	---	0.4	5.1	413	610
7C	SG	94	17	46	1	270	2.4	0.1	0.2	0.2	---	423	602
7D	SG	115	19	29	3	218	1.8	---	---	---	---	408	558
8B	SG	199	42	154	96	312	---	---	10.0	---	7.2	1129	1852
8C	SG	229	40	311	108	434	0.0	0.0	302	0.0	---	1351	1986
8D	SG	174	33	107	62	350	---	---	120	---	---	876	1320
9B	SG	281	64	163	144	764	0.7	---	29	0.2	46.9	1374	2134
9C	SG	231	64	151	158	500	0.2	1.1	70	0.2	---	1196	2115
9D	SG	314	64	156	162	650	---	---	100	---	---	1429	2422
10B	SG	339	165	219	254	786	2.9	---	30	---	17.0	1740	3358
11B	SW	67	230	149	114	266	---	---	0.1	0.5	18.8	780	1600
11C	SW	98	441	239	109	908	0.0	0.0	0.9	0.4	---	1227	2796
12B	SW	92	540	180	103	690	---	---	0.0	---	---	971	2664
13B	SW	52	178	126	132	352	---	---	0.2	2.0	16.6	650	1250
14B	SW	35	1400	7	210	12	5.0	---	0.0	3.0	252	116	4342
15B	SW	47	1500	46	210	10	3.1	---	0.0	---	199.4	306	4326
15D	SW	26	1868	45	285	325	0.9	---	1	12	---	249	5666
16B	SW	66	250	221	96	826	0.2	---	---	0.2	38.7	1074	2148
16C	SW	26	667	297	219	966	0.5	0.0	0.8	0.4	---	1286	3212
16D	SW	27	1093	403	357	1820	0.8	---	2	---	---	1727	5188
17B	SW	308	270	316	113	1642	2.2	---	---	0.2	57.1	2069	3866

TABLE 1 -- continued.

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chlorides	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Potassium	Hardness $CaCO_3$	Total Solids
18B	SG	429	220	463	30	2904	4.4	---	---	0.6	---	2980	4936
18C	SG	518	325	562	90	3498	23	2.7	0.0	0.6	---	3604	6168
18D	SG	342	360	543	117	3288	14	---	1	0.4	---	3091	5602
19B	SG	438	220	278	106	1912	5.0	---	0.4	---	25.8	2236	4138
19C	SG	572	242	369	76	2810	9.2	0.0	0.2	0.8	---	2948	5258
19D	SG	673	330	408	109	3440	14	---	1	0.4	---	3360	5962
20B	SG	330	380	287	139	1840	1.2	---	---	0.4	34.4	2004	3888
20C	SG	260	375	274	226	1278	5.9	0.0	0.0	0.6	---	1776	3388
20D	SG	6	870	321	277	1342	0.7	---	---	0.4	---	1336	3740
21B	SG	81	40	92	15	376	2.2	0.6	---	0.2	10.8	582	964
21C	SG	136	67	167	49	856	14.5	1.1	0.0	0.2	---	1028	1572
22B	SG	242	---	97	43	800	3.1	---	---	---	10.9	1005	1644
22C	SG	153	50	44	16	444	4.1	1.44	0.0	0.6	---	326	924
22D	SG	130	56	5	9	301	2.5	---	1.0	1.0	---	346	804
23B	SG	84	16	37	19	148	1.9	---	0.3	---	3.4	361	534
23C	SG	103	16	58	26	232	5.3	1.7	2.0	0.2	---	494	662
23D	SG	148	19	75	31	325	6.6	---	0.0	1.0	---	677	800
24B	SG	143	19	59	33	334	4.3	---	0.8	0.4	4.9	600	892
25B	SG	150	29	68	42	330	---	---	---	1.5	5.0	656	932
25C	SG	129	24	65	40	374	0.6	0.1	0.0	1.5	---	589	814
25D	SG	171	29	56	47	286	0.5	---	---	0.4	---	659	908
26B	SG	119	49	61	50	256	---	0.1	101	0.7	5.9	547	880
26C	SG	95	22	29	17	158	1.4	0.6	4.1	---	---	357	522
27B	SG	130	40	---	36	334	1.4	0.3	---	---	7.1	662	954
27C	SG	146	39	6	32	328	5.7	1.3	0.0	0.0	---	388	1018
28B	SG	79	24	---	34	82	7.3	0.5	81	---	4.5	363	556
28C	SG	147	57	41	37	220	2.5	0.6	10.0	0.0	---	536	916
28D	SG	135	67	21	67	380	0.2	---	4.0	0.0	---	422	1000
29B	SG	121	23	44	14	172	0.7	0.6	---	---	3.7	483	758
29D	SG	---	23	122	39	263	---	---	0.0	0.0	---	577	742
30B	SG	116	53	---	29	186	1.2	0.7	0.0	0.3	8.2	486	772
31B	SG	169	62	78	57	428	3.4	---	---	---	10.0	742	1182
31C	SG	175	80	60	61	442	3.7	1.6	0.0	0.2	---	634	1282
31D	SG	143	60	32	52	398	---	1.0	0.0	0.0	---	490	1026
32B	SG	128	56	100	36	376	---	---	---	1.0	6.4	733	1072
32C	SG	152	40	253	48	397	0.0	0.0	1.4	0.2	---	---	1056
32D	SG	77	40	---	45	363	0.7	---	1.0	---	---	453	748

TABLE 1 -- continued.

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chlorides	Sulfate	Iron	Manganese	Nitrate Nitrogen	Fluoride	Potassium	Hardness $CaCO_3$	Total Solids
33B	SG	220	41	76	25	662	1.3	0.5	3.4	0.2	5.5	863	1334
33C	SG	189	35	22	22	520	5.2	1.9	9.0	0.2	---	561	1276
33D	SG	148	39	74	25	560	2.5	---	1.0	0.0	---	634	1040
34B	SG	63	11	30	12	96	2.2	---	---	0.4	5.7	279	386
34C	SG	67	8	31	11	74	4.1	0.6	0.0	0.2	---	294	402
34D	SG	80	8	---	9	76	1.3	---	1.0	0.0	---	192	352
35B	SG	198	21	73	76	448	5.6	0.7	---	---	4.5	794	1136
35C	SG	205	19	2?	62	498	8.7	2.0	0.0	0.2	---	520	1204
35D	SG	125	21	71	76	465	8	0.9	1.0	---	---	610	946
36B	SG	200	365	119	768	310	---	---	0.8	---	17.6	997	2478
37B	SW	90	---	113	310	444	---	0.8	0.8	---	33.2	691	1674
38B	BO	79	640	35	192	1566	3.5	---	2.8	0.5	---	342	2746
39B	BO	75	700	---	181	1490	3.0	---	2.8	0.5	---	290	2702
40B	SG	70	18	43	7	132	0.3	---	---	0.2	4.6	352	478
40C	SG	46	13	---	8	74	2.8	1.1	0.0	0.2	---	301	378
40D	SG	41	19	---	2	44	2.0	---	1.0	---	---	291	368
41B	SG	253	56	108	110	860	---	---	---	0.7	11.1	1074	1880
41C	SG	222	43	34	16	730	5.0	0.9	0.0	0.2	---	692	1446
41D	SG	62	51	65	40	369	1.7	---	1.0	---	---	422	708
42B	SG	206	49	34	39	364	0.5	---	---	1.5	7.3	656	968
42C	SG	128	59	94	44	619	---	---	0.0	0.2	---	705	1222
43B	SG	194	39	83	42	486	1.4	---	---	0.2	7.5	929	1194
43C	SG	201	32	85	36	478	3.1	0.6	---	0.2	---	850	1240
43D	SG	202	37	85	58	545	5.6	---	---	---	---	858	1204
44B	SG	203	122	83	29	656	2.1	---	1.4	---	10.5	849	1446
44C	SG	222	100	91	56	670	5.2	0.5	1.2	0.6	---	---	1576
44D	SG	152	100	73	39	647	9.2	---	2.0	---	---	682	1254

Source: SG, shallow gravel; SW, surface water; BO, buried outwash

The numbers under samples refer to the location of water samples and the letters B, C, and D designate the year of collection 1972, 1973, and 1974 respectively.

All the chemicals were analyzed by the South Dakota State Chem Lab except for potassium which was analyzed by the South Dakota Department of Environmental Protection.

Sample A:

[1]United States Environmental Protection Agency "National Interim Primary Drinking Water Regulations" - December 24, 1975 (enforceable limits).

[2]United States Environmental Protection Agency "National Secondary Drinking Water Regulations" - March 31, 1977 (recommended limits).

Location of Water Samples from the Clark Area
(for map location, see fig. 7)

1. SE¼NW¼SE¼SE¼ sec. 31, T. 117 N., R. 57 W., observation well 14, depth of well - 17 feet.

2. NW¼NW¼NE¼ sec. 6, T. 116 N., R. 57 W., R. Neal - 22 feet deep.

3. NE¼SW¼NE¼NE¼ sec. 6, T. 116 N., R. 57 W., observation well 32, depth of well - 16 feet.

4. NE¼NW¼SE¼NE¼ sec. 6, T. 116 N., R. 57 W., observation well 33, depth of well - 9 feet.

5. SW¼NE¼SW¼NE¼ sec. 6, T. 116 N., R. 57 W., observation well 34, depth of well - 10 feet.

6. SE¼NE¼SE¼NW¼ sec. 6, T. 116 N., R. 57 W., observation well 36 depth of well - 11 feet.

7. SE¼SE¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W., observation well 41, depth of well - 19 feet

8. SW¼SW¼NE¼ sec. 6, T. 116 N., R. 57 W., C. Neal - 22 feet deep (barn well).

9. SW¼SW¼NE¼ sec. 6, T. 116 N., R. 57 W., C. Neal - 22 feet deep.

10. NE¼NW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W., observation well 42, depth of well - 10 feet.

11. NE¼SE¼ sec. 6, T. 116 N., R. 57 W., from slough north of the lagoon.

12. NW¼SW¼ sec. 5, T. 116 N., R. 57 W., from slough northeast of the lagoon.

13. NW¼NW¼SW¼ sec. 5, T. 116 N., R. 57 W., from the excavation for the new lagoon.

14. NE¼SE¼ sec. 6, T. 116 N., R. 57 W., east side of the lagoon.

15. NE¼SE¼ sec. 6, T. 116 N., R. 57 W., west side of the lagoon.

16. NW¼SE¼ sec. 6, T. 116 N., R. 57 W., from slough west of the lagoon.

17. SW¼NE¼SE¼ sec. 6, T. 116 N., R. 57 W., discharge from the plant into the lagoon (southwest corner of the lagoon).

18. SW¼SE¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W., observation well 46, depth of well - 8 feet.

19. SW¼SE¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W., observation well 45, depth of well - 10 feet.

20. NE¼SW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W., observation well 44, depth of well - 14 feet.

21. NW¼SW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W., observation well 48, depth of well - 8 feet.

22. NE¼NE¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 52, depth of well - 8 feet.

23. SW¼NE¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 53, depth of well - 16 feet.

24. SE¼NW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., B. and F. Everett - shallow well.

25. NW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., City well, East Park - 32 feet deep.

26. NW¼SW¼NE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 49, depth of well - 10 feet.

27. SW¼NE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 56, depth of well - 20 feet.

28. NE¼NE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 58, depth of well - 22 feet.

29. NW¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 59, depth of well - 21 feet.

30. NW¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 60, depth of well - 16 feet.

31. NW¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 61, depth of well - 21 feet.

32. SE¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W., City well, West Park - 31 feet deep.

33. NW¼SW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 62, depth of well - 20 feet.

34. NE¼SW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 54, depth of well - 15 feet.

35. SE¼SW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W., observation well 63, depth of well - 22 feet.

36. SW¼SW¼SE¼ sec. 6, T. 116 N., R. 57 W., water from under the A and E Motel (ground water?).

37. SE¼SW¼SE¼ sec. 6, T. 116 N., R. 57 W., from culvert east of A and E Motel.

38. NW¼SE¼SE¼ sec. 6, T. 116 N., R. 57 W., potato plant well - 480 feet deep.

39. NW¼NE¼ sec. 7, T. 116 N., R. 57 W., M & M Cafe well - 480(?) feet deep.

40. SW¼NW¼NE¼NW¼ sec. 7, T. 116 N., R. 57 W., observation well 67, depth of well - 14 feet

41. NW¼NW¼SE¼NW¼ sec. 7, T. 116 N., R. 57 W., observation well 70, depth of well - 22 feet.

42. NW¼NW¼SE¼NW¼ sec. 7, T. 116 N., R. 57 W., City well 3 - 31 feet deep.

43. SE¼NE¼SE¼NW¼ sec. 7, T. 116 N., R. 57 W., observation well 71, depth of well - 15 feet.

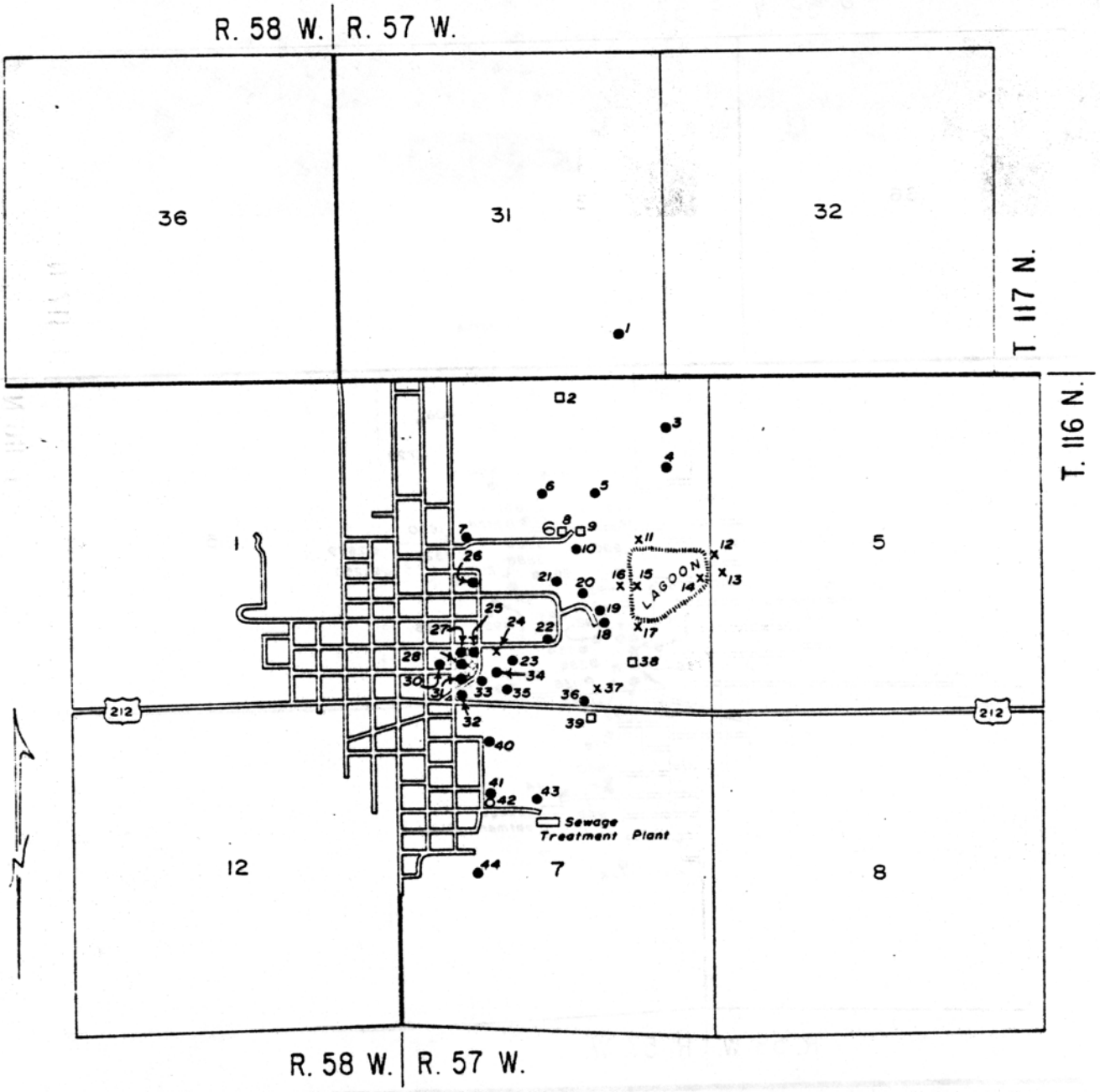
44. NW¼NW¼NE¼SW¼ sec. 7, T. 116 N., R. 57 W., observation well 72, depth of well - 21 feet.

water samples collected in the Clark area (for map location, see fig. 7). The numbers refer to the location of water samples and the letters B, C, and D on table 1 designate the year of collection in June, July, and August, 1972, June 6-8, 1973, and June 6-7, 1974, respectively. Water samples are from the shallow ground water, surface water, and the buried outwash.

Quality of Shallow Ground Water

All water samples in table 1, except for samples from locations 11, 12, 13, 14, 15, 16, 17, 37, 38, and 39 are from shallow ground-water sources. The highest total solids in the water samples collected from shallow ground-water sources was found in the vicinity of the lagoon, which in some cases it exceeded 4,000 ppm (parts per million). Results of water samples numbers 18 and 19 are in table 1. The water samples from a shallow ground-water source at a distance from the lagoon have much less total solids, (see samples 3, 4, 27, 40, 41, and 44). The highest total solids in samples from shallow ground water at a distance from the lagoon was found in location 36. This sample was collected from the crawl space under the A and E Motel. The high total solids in this sample could be attributed to the Motel's septic tank which is located in the vicinity. Figure 8 shows the total solids in samples collected from shallow sources (surface water and shallow ground water) in the area.

The hardness in the samples from the shallow ground-water sources in the area is less than 1,100 ppm except in the vicinity



0 1 2 3

miles

39□ Private well

42○ City well

36● Observation well

14x Surface water

City park

Figure 7. Map showing location of water samples collected in the Clark area.

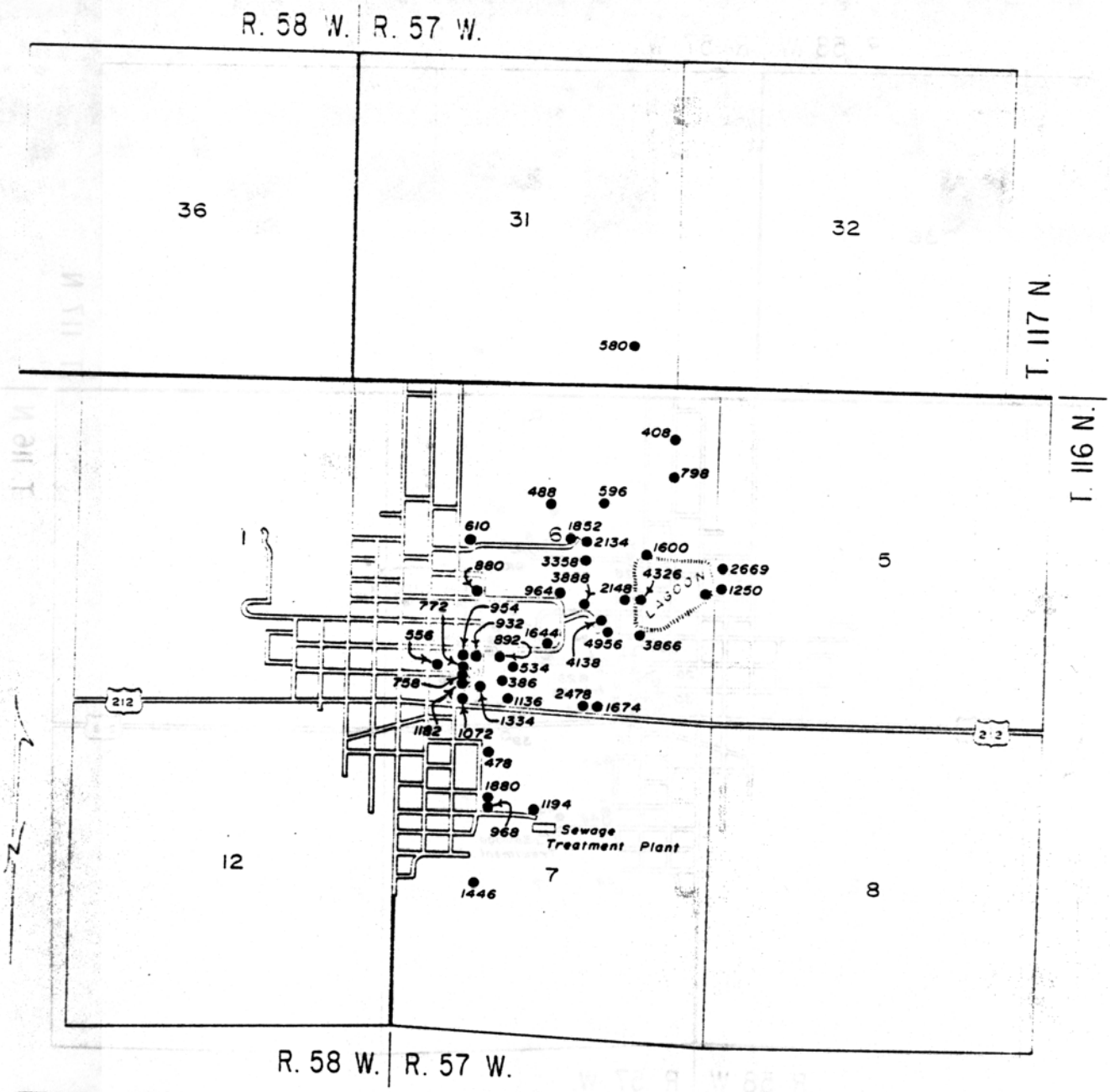


Figure 8. Map showing total solids in water samples from shallow sources in the Clark area—June, July, and August, 1972. *(shallow sources consist of surface water and shallow ground water.)*

of the lagoon where it in some cases exceeds 3,000 ppm (see samples 18 and 19).

Sodium concentration in samples from the shallow ground-water sources is generally low (less than 125 ppm) in the area except in sample 36 and samples collected from the vicinity of the lagoon where it in some cases exceeds 350 ppm.

Potassium in the shallow ground water in the area is less than 13 ppm, except for sample 36 and samples in the vicinity of the lagoon where it exceeds 30 ppm. (The possible source of high concentration of chemicals in the sample 36 was discussed above.)

Samples from locations 1, 8, 9, 10, 26, and 28 had at least one nitrate analysis higher than the recommended limits set by the State of South Dakota. The high nitrate in these samples is attributed to the septic tanks or livestock in the vicinity of these locations.

Quality of Surface Water Samples

Samples in this category are collected from locations 11, 12, 13, 14, 15, 16, 17, and 37. Samples from locations 14 and 15 were collected from the potato processing plant lagoon. The samples collected from the lagoon have in excess of 4,000 ppm total solids, over 190 ppm potassium, more than 1,400 ppm sodium and less than 310 ppm hardness.

Samples 11, 12, and 16 were collected from sloughs next to the lagoon. Sample 13 was collected from the excavation for the new lagoon east of the old lagoon. Sample 17 was collected

at a location where the effluent had seeped through the sand and was enroute as surface water to the slough to the west of the lagoon.

To explain the relatively low hardness in the lagoon effluent (less than 310 ppm) and high hardness in the water in the sloughs and ground water next to the lagoon, the following experiment was conducted.

A water sample was collected from the lagoon and one-half of the sample was analyzed for calcium, hardness, sodium, sulfate, and magnesium. The other half of the sample was poured into a jar with material (sand and gravel with some clay) collected from the bottom of the excavation for the new lagoon. After approximately 12 hours the water was filtered and analyzed for the same chemicals. The following table shows the results.

	Calcium	Hardness	Sodium	Sulfate	Magnesium
Before contact with the aquifer	28	302	1630	318	56
After contact with the aquifer	44	765	1170	331	167

This experiment indicated that the water sample high in sodium concentration undergoes an ion exchange with the clay particles in the aquifer whereby the sodium is absorbed and calcium and magnesium are released.

As a result of this ion exchange the sodium concentration is lowered and the hardness, calcium, and magnesium concentrations are increased.

Thus, as the lagoon effluent seeps through the bottom and sides of the lagoon a change in the effluent chemistry occurs

resulting in a very marked increase in hardness.

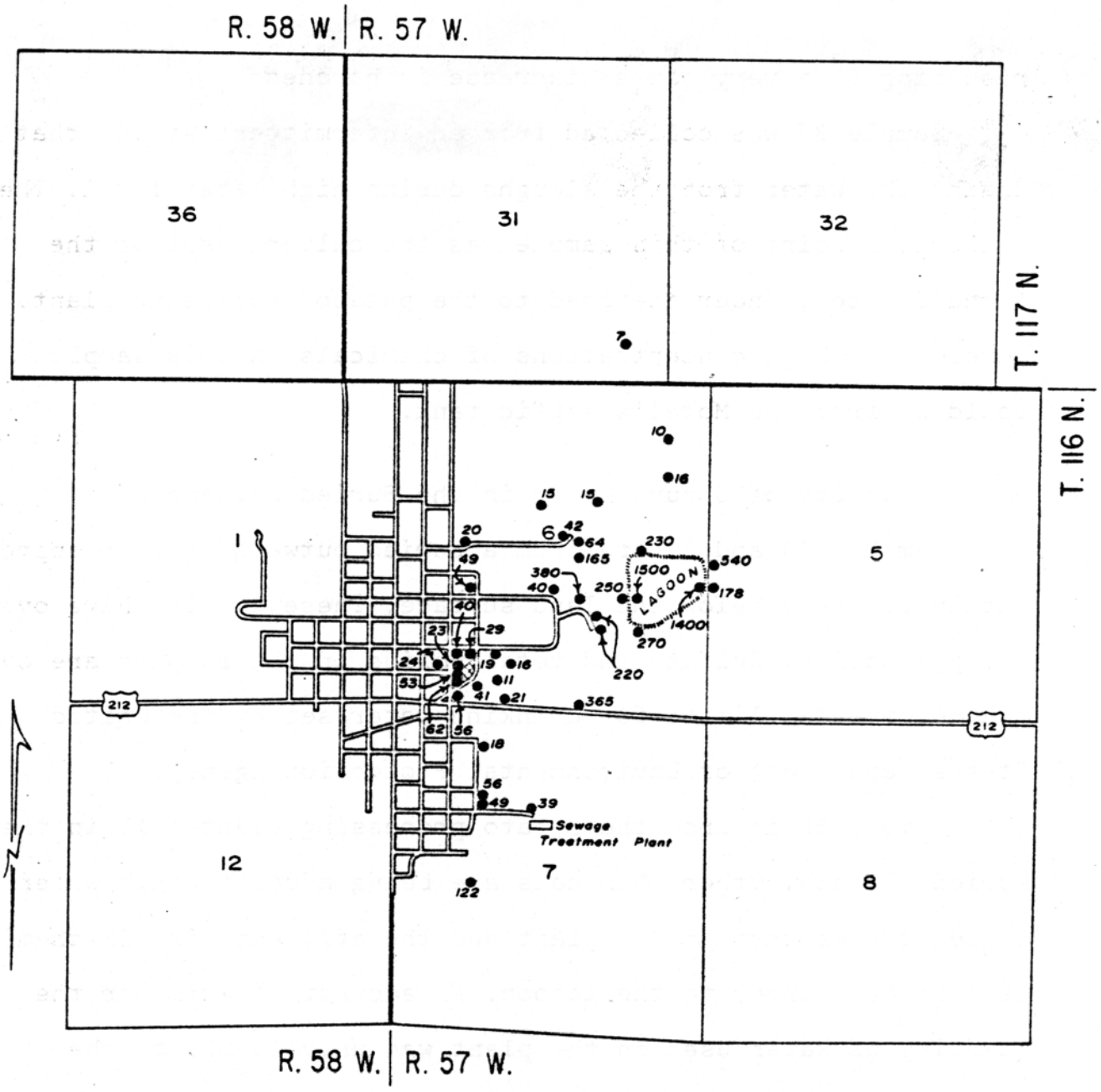
Sample 37 was collected from an intermittent stream that drains the water from the sloughs during high water level. The collection point of this sample was the culvert east of the A and E Motel, under the road to the potato processing plant. Some of the high concentrations of chemicals in this sample could be from the Motel's septic tank.

Quality of Ground Water in the Buried Outwash

Samples 38 and 39 are from a buried outwash aquifer approximately 500 feet below the land surface. These samples have over 600 ppm sodium. Sulfate and total solids in the samples are over the recommended limits for drinking water set by the United States Department of Environmental Protection Agency.

Sample 38 is from the potato processing plant well in the buried outwash. Other chemicals are being added to this water while it goes through the plant and the effluent high in chemicals is discharged to the lagoon. An accurate figure for the quantity of water used in the plant was unavailable to the writer although the design capacity of the plant called for a water consumption of 233 gallons per minute in 1971. Later the water usage was lowered.

Figures 8, 9, and 10 show the total solids, sodium, and hardness concentrations, respectively, in the water samples from shallow sources (surface and shallow ground water) in the Clark area collected in June, July, and August, 1972.



0 1 2 3
miles

250● Water sample *(number is concentration of sodium in parts per million.)*

City park

Figure 9. Map showing concentration of sodium in water samples from shallow sources in the Clark area—June, July, and August, 1972. *(shallow sources consist of surface water and shallow ground water.)*

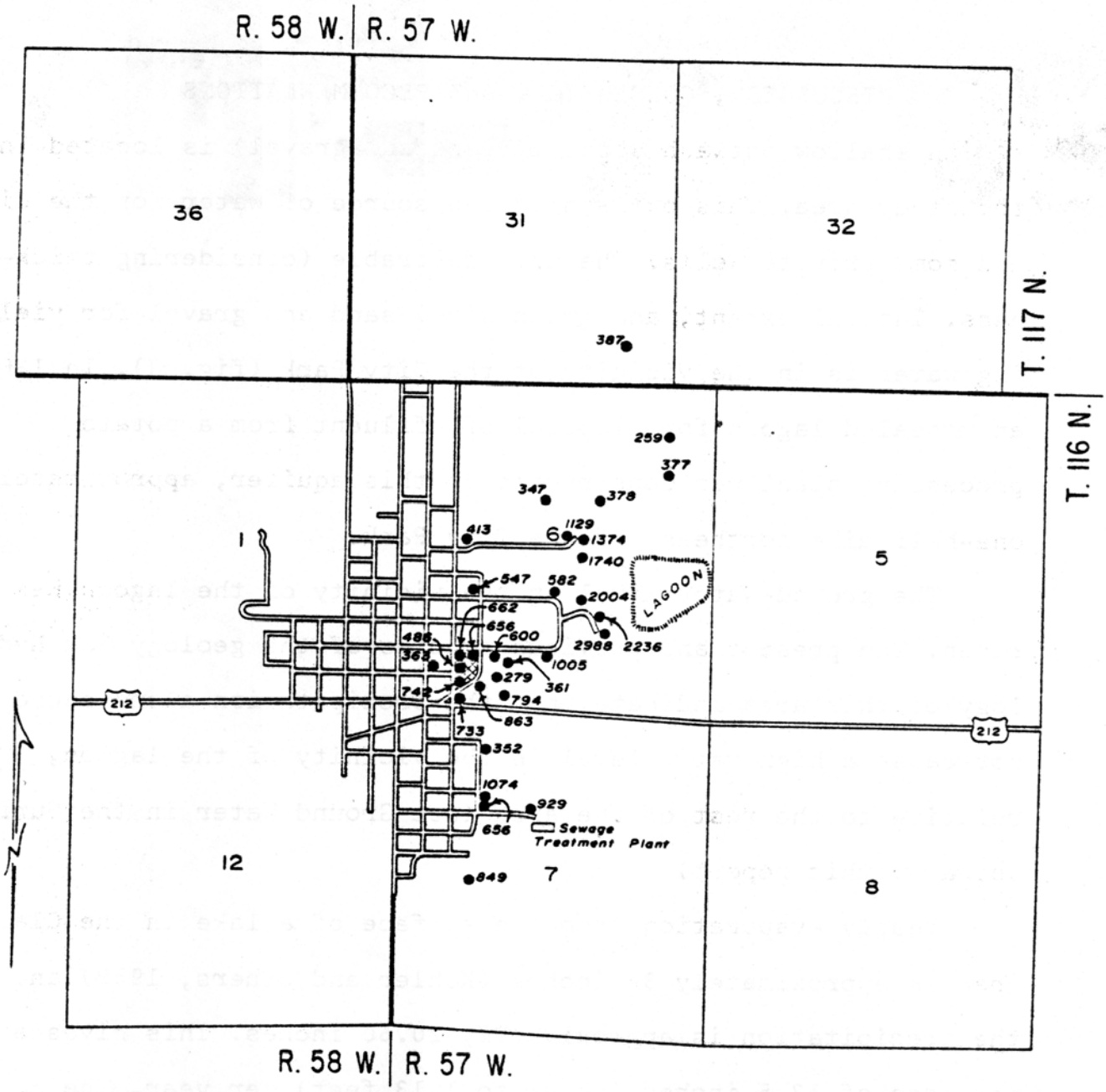


Figure 10. Map showing hardness in water samples from shallow ground water sources in the Clark area—June, July, and August, 1972.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

A shallow outwash deposit (sand and gravel) is located in the study area. This outwash is the source of water for the City and some private wells. The most favorable (considering thickness, lateral extent, and grain size) sand and gravel for yielding water is in the vicinity of the City Park (fig. 3). In 1969, an unsealed lagoon for disposal of effluent from a potato processing plant was constructed on this aquifer, approximately one-half mile northeast of the City Park.

The ground-water level in the vicinity of the lagoon has risen. The present and previous studies of the geology and hydrology of this area indicate that the precipitation alone could not cause a high water level in the vicinity of the lagoon, relative to the rest of the area (see Ground Water in the Surface Outwash, this report).

Yearly evaporation from the surface of a lake in the Clark area is approximately 34 inches (Kohler and others, 1959) and the precipitation is approximately 20.50 inches. This gives a net loss of 13.5 inches (equal to 1.13 feet) per year. The surface area of the lagoon is approximately 25 acres so any water in excess of 28.25 acre feet (25 x 1.13 = 28.25) discharged to the lagoon will not be able to evaporate.

The chemical analyses of surface water and ground water samples in the vicinity of the lagoon indicate a very high concentration of some chemicals (see Quality of Water in the Clark Area, this report) in the aquifer. This is attributed to discharge of effluent from the potato processing plant.

After the field work was completed a summary of the findings was reported to the City and the consulting engineer which included the most promising area in the vicinity of the City Park for additional wells. It was also recommended that if the City should decide to drill additional wells in this area, a pump test should be conducted before the completion of the wells.

In addition, it was also reported to the City and the South Dakota Department of Environmental Protection that the ground water is moving from northeast to southwest in the direction of the City wells (figs. 5 and 6). If the lagoon is not sealed and discharge into it is continued, the degradation of ground water will probably continue. The extent of the area of influence depends on the rate of discharge into the lagoon, local precipitation and the pumping rate of the City wells. Additional wells have been drilled, after the completion of the field work for this study, in the vicinity of the Park to increase the City's water supply.

Quality of surface water and shallow ground water varies seasonally and during low and high precipitation years. Some of the chemicals on table 1 have increased and some have decreased from 1972 to 1974. A longer period of monitoring the quality of water is required to determine the overall change in the water quality without the influence of seasonal and yearly fluctuation due to the precipitation.

It was the understanding of the writer that the South Dakota Department of Environmental Protection was going to monitor the rate of discharge into the lagoon and the quality

of water in the vicinity of the lagoon. It is recommended that monitoring of the quality of water be continued and ground water from the observation wells in the area be collected and analyzed to give an indication if further degradation of ground water is taking place.

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APPENDIX A

Logs of test holes in the Clark area (for map location, see fig. 2)

Test Hole 1
Location: SE¼SE¼SE¼SW¼ sec. 30, T. 117 N., R. 57 W.
Depth to water: 14 feet

0-	1	Soil
1-	5	Gravel, coarse
5-	14	Clay, yellowish-brown, gravelly
14-	15	Sand, yellowish-brown, very coarse
15-	17	Sand, coarse
17-	25	Sand, fine, some clay
25-	33	Sand, fine, clayey
33-	35	Sand, very fine
35-	38	Sand, gray, very fine, clayey
38-	59	Clay, gray

* * * *

Test Hole 2
Location: SE¼SW¼SE¼SE¼ sec. 30, T. 117 N., R. 57 W.
Depth to water: 9 feet

0-	9	Gravel, brown, medium
9-	12	Gravel, brown, coarse
12-	17	Gravel, some coarse sand
17-	28	Sand, unsorted
28-	49	Clay, gray

* * * *

Test Hole 3
Location: SW¼SW¼SW¼SW¼ sec. 29, T. 117 N., R. 57 W.
Depth to water: 10 feet

0-	2	Soil
2-	9	Gravel, brown
9-	18	Sand, brown, coarse
18-	20	Sand, gray, fine
20-	69	Clay, dark gray, sandy

* * * *

Test Hole 4
Location: NE¼NE¼NW¼NW¼ sec. 36, T. 117 N., R. 58 W.
Depth to water: 33 feet

0-	21	Clay, brown, sandy
21-	79	Clay, dark gray, pebbly

* * * *

Test Hole 5
Location: NE¼NW¼NW¼NE¼ sec. 36, T. 117 N., R. 58 W.
Depth to water: 9 feet

0- 1	Soil
1- 10	Clay, dark brown
10- 13	Clay, yellow, compact
13- 16	Sand, medium, clayey
16- 25	Clay, brown
25- 79	Clay, gray

* * * *

Test Hole 6
Location: NW¼SW¼NW¼NW¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 15 feet

0 - 8	Gravel
8 - 13	Sand, brown, coarse
13 - 15	Sand, dark brown, medium to coarse
15 - 18	Sand, yellowish-brown, medium
18 - 30?	Sand, yellowish-brown, unsorted
30?- 43	Sand, gray, some clay
43 - 89	Clay, gray

* * * *

Test Hole 7
Location: NW¼NW¼NW¼SW¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 15 feet

0- 15	Gravel, medium
15- 23	Sand
23- 35	Clay, gray
35- 43	Sand, gray, very fine
43- 57	Clay, gray
57- 64	Clay, dark gray, very compact

* * * *

Test Hole 8
Location: SE¼NW¼SW¼SW¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 9 feet

0- 3	Soil
3- 4	Clay, yellowish-brown
4- 9	Gravel, very coarse
9- 13	Clay, gray
13- 39	Clay, gray

* * * *

Test Hole 9
Location: SW¼NW¼SE¼SW¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 7 feet

0-	2	Soil
2-	4	Gravel, very coarse
4-	16	Gravel, coarse
16-	20	Clay, gray, compact
20-	37	Sand, gray, fine to very fine, compact
37-	59	Clay, gray, compact

* * * *

Test Hole 10
Location: SE¼NW¼SW¼SE¼ sec. 31, T. 117 N., R. 57 W
Depth to water: 4 feet

0-	1	Soil
1-	3	Clay, yellowish-brown, gravelly
3-	4	Gravel, yellow
4-	20	Sand, brown, very coarse
20-	23	Sand, gray
23-	25	Clay, dark gray, compact, sandy
25-	33	Sand, coarse
33-	54	Clay, gray, compact

* * * *

Test Hole 11
Location: SE¼NE¼SW¼SE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 5 feet

0-	2	Soil
2-	5	Clay, yellowish-brown, gravelly
5-	18	Gravel, brown
18-	19	Sand, gray, coarse
19-	22	Sand, compact, with much clay
22-	28	Sand, gray, fine
28-	32	Sand, gray, very fine, with clay
32-	49	Clay, gray, compact

* * * *

Test Hole 12
Location: SE¼NE¼NW¼SE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 10? feet

0-	5	Gravel, brown, coarse
5-	10	Gravel, more uniform size
10-	20	Sand, brown, very coarse
20-	21	Sand, gray, medium, clayey
21-	25	Sand, gray, fine, compact
25-	49	Clay, gray, compact

* * * *

Test Hole 13
Location: NE¼NE¼NW¼SE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 14 feet

0- 2	Soil
2- 19	Gravel, brown, coarse
19- 20	Gravel, much clay
20- 23	Clay, gray
23- 30	Sand, very fine
30- 37	Clay, gravelly
37- 44	Clay, gray

* * * *

Observation Well 14
Location: SE¼NW¼SE¼SE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 10 feet

0- 10	Gravel, brown
10- 19	Sand, yellowish-brown, very coarse
19- 30	Sand, gray, very fine
30- 32	Sand, gray, fine
32- 34	Clay, gray

Constructed an observation well with 17 feet of pipe in the ground.

* * * *

Test Hole 15
Location: SE¼NE¼SE¼SE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 7 feet

0- 2	Soil
2- 11	Gravel, yellowish-brown, coarse
11- 22	Sand, yellowish-brown, very coarse
22- 30	Sand, gray, fine
30- 33	Sand, fine, much clay
33- 38	Clay, gray
38- 50	Clay, gray, compact

* * * *

Test Hole 16
Location: SE¼SE¼NE¼NE¼ sec. 31, T. 117 N., R. 57 W.
Depth to water: 10 feet

0- 1	Soil
1- 12	Gravel, medium
12- 17	Sand?, brown, very coarse
17- 33	Sand, gray, very fine
33- 44	Clay, sandy

* * * *

Test Hole 17
Location: NE¼NE¼NE¼NW¼ sec. 32, T. 117 N., R. 57 W.
Depth to water: 5 feet

0- 6	Sand, very coarse
6- 10	Sand, brown, coarse
10- 74	Clay, gray, gravelly

* * * *

Test Hole 18
Location: SE¼SE¼SE¼SE¼ sec. 32, T. 117 N., R. 57 W.
Depth to water: 6 feet

0- 3	Soil
3- 4	Sand, brown, coarse
4- 6	Sand, yellowish-brown, coarse
6- 9	Sand, yellowish-brown, medium
9- 10	Clay, yellowish-brown
10- 19	Clay, compact

* * * *

Test Hole 19
Location: NW¼NE¼NE¼NE¼ sec. 2, T. 116 N., R. 58 W.
Depth to water: no water measured

0- 20	Clay, yellowish-brown
20- 32	Clay, gray

* * * *

Test Hole 20
Location: NE¼NE¼NE¼SE¼ sec. 2, T. 116 N., R. 58 W.
Depth to water: no water was measured

0- 2	Soil
2- 16	Clay, brown
16- 63	Clay, gray, hit rock at 63

* * * *

Test Hole 21
Location: NW¼NW¼NW¼NW¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: not measured

0- 25	Clay, yellowish-brown, pebbly
25- 32	Clay, brownish-gray, pebbly
32- 97	Clay, gray, pebbly
97-110	Gravel, coarse
110-115	Clay, gray
115-125	Gravel, coarse, lots of shale pebbles
125-135	Sand, coarse, much clay

Test Hole 21 -- continued.

135-162	Clay, gray
162-215	Clay, gray, pebbly
215-220	Gravel, coarse, some clay
220-222	Clay, gray
222-224	Boulder
224-359	Clay, gray, pebbly
359-371	Gravel, coarse
371-389	Clay, gray, pebbly
389-418	Gravel, drills like there is clay with it
418-575	Clay, gray, pebbly
575-591	Gravel, coarse
591-620	Shale

* * * *

Test Hole 22
Location: NW¼NW¼NW¼NE¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: 2 feet

0- 2	Soil
2- 10	Clay, gray
10- 23	Clay, brown
23- 75	Clay, sandy

* * * *

Test Hole 23
Location: NE¼NE¼NE¼NE¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: 12 feet

0- 20	Clay, brown
20- 22	Clay, dark brown
22- 29	Clay, gray
29- 35	Sand, yellowish-brown, very fine
35- 37	Sand, gray, very fine
37- 42	Clay, gray, compact
42- 99	Clay, gray

* * * *

Test Hole 24
Location: SW¼SE¼NE¼NE¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: 14 feet

0- 2	Soil
2- 28	Clay, yellowish-brown
28- 34	Sand, yellowish-brown, coarse
34- 37	Sand, yellowish-brown, very fine
37- 45	Clay, yellowish-brown
45- 68	Sand, gray, very fine
68- 83	Sand, gray, very fine, silty

Test Hole 24 -- continued.

83-117	Sand?, medium, with clay
117-124	Clay, gray, compact

* * * *

Test Hole 25
Location: SE¼NW¼NE¼SE¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: no water was measured

0- 12	Gravel, yellowish-brown
12- 15	Sand, medium to coarse
15- 16	Clay, brown
16- 78	Clay, gray
78- 87	Clay, sandy
87- 99	Clay, gray, compact

* * * *

Test Hole 26
Location: SE¼SW¼SE¼SE¼ sec. 1, T. 116 N., R. 58 W.
Depth to water: 33 feet

0- 5	Gravel
5- 25	Clay, yellowish-brown, sandy
25- 52	Clay, sandy

* * * *

Observation Well 27
Location: NW¼NE¼NW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 7? feet

0- 8	Clay, dark brown, pebbly
8- 15	Sand, very coarse, some clay
15- 19	Sand, very coarse, less clay
19- 29	Sand, gray, very fine
29- 32	Sand, light gray, fine
32- 39	Clay, gray

Constructed an observation well with 17 feet of pipe in the ground.

* * * *

Test Hole 28
Location: NE¼NE¼NW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 7 feet

0- 2	Soil
2- 8	Clay, light gray
8- 10	Clay, yellowish-brown

Test Hole 28 -- continued.

10- 12	Sand, brown, very coarse
12- 17	Clay, yellowish-brown
17- 19	Sand, reddish-brown, very coarse, some clay
19- 22	Sand, gray, very fine
22- 24	Sand, gray, very fine
24- 44	Clay, gray

* * * *

Test Hole 29
Location: NE¼NE¼NE¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 1	Soil
1- 4	Gravel, yellowish-brown, a few large pebbles, some clay
4- 9	Gravel, yellowish-brown, some coarse sand
9- 13	Sand, brown, some gravel, not much clay
13- 14	Sand, yellowish-brown
14- 15	Clay, yellowish-brown
15- 20	Clay, gray
20- 23	Sand, gray, medium
23- 44	Clay, gray, compact

* * * *

Test Hole 30
Location: NE¼NW¼NE¼NE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: not measured

0- 1	Soil
1- 3	Clay, light brown, pebbly
3- 16	Gravel and sand
16- 32	Clay, gray
32- 63	Clay, gray, pebbly
63- 66	Sand, with fine gravel
66-117	Clay, gray, pebbly, sandy
117-136	Sand, with clay
136-185	Clay, gray, pebbly, gravelly
185-255	Clay, light brown, pebbly
255-302	Clay, gray, pebbly
302-348	Gravel, with clay stringers
348-428	Clay, gray, pebbly, hard
428-457	Gravel, fine to medium
457-485	Shale

* * * *

Test Hole 31
Location: NW¼NE¼NE¼NE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 1 foot

Test Hole 31 -- continued.

0- 2	Soil
2- 4	Clay, gray
4- 9	Sand, dark brown, very coarse, some gravel, some clay
9- 11	Sand, brown, less gravel
11- 14	Sand, gray, very coarse
14- 16	Sand, gray, fine
16- 80	Clay, gray

* * * *

Observation Well 32
Location: NE¼SW¼NE¼NE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 2	Soil
2- 7	Clay, sandy
7- 12	Sand, brown, coarse
12- 17	Sand, gray, coarse
17- 19	Sand, gray, fine, not much clay
19- 24	Clay, gray

Constructed an observation well with 16 feet of pipe in the ground.

* * * *

Observation Well 33
Location: NE¼NW¼SE¼NE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4 feet

0- 4	Clay, brown, sandy
4- 7	Gravel, brown, fine
7- 8	Gravel, dark brown, fine, some coarse sand, not much clay
8- 13	Sand, gray, fine to coarse, some clay
13- 19	Clay, gray

Constructed an observation well with 9 feet of pipe in the ground.

* * * *

Observation Well 34
Location: SW¼NE¼SW¼NE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 25 feet

0- 2	Gravel, yellowish-brown, fine
2- 11	Sand, yellowish-brown, coarse
11- 12	Sand, gray, coarse, with clay
12- 14	Sand, gray, coarse

Observation Well 34 -- continued.

14- 29	Clay, gray

Constructed an observation well with 10 feet of pipe in the ground.

* * * *

Test Hole 35
Location: SE¼SE¼NE¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 6 feet

0- 2	Soil
2- 5	Gravel, brown
5- 7	Gravel, brown, some coarse sand
7- 9	Gravel, yellowish-brown, some coarse sand
9- 12	Gravel, yellowish-brown, some coarse sand, more clay
12- 14	Clay?, dark brown, gravelly
14- 16	Sand, medium, some clay
16- 19	Sand, dark gray, medium, much clay
19- 21	Sand, gray, medium
21- 44	Clay, gray, compact

* * * *

Observation Well 36
Location: SE¼NE¼SE¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4.5 feet

0- 3	Soil
3- 5	Clay, gray, sandy
5- 7	Sand, coarse, with clay
7- 10	Sand, brown, less clay
10- 13	Sand, brown, coarse

Constructed an observation well with 11 feet of pipe in the ground.

* * * *

Test Hole 37
Location: SW¼NE¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4 feet

0- 2	Soil
2- 4	Clay, black
4- 13	Gravel, yellowish-brown
13- 19	Sand, light gray, very coarse
19- 20	Clay, gray
20- 25	Sand, gray, fine to medium, compact

Test Hole 37 -- continued.

25- 49	Clay, gray

* * * *

Test Hole 38
Location: SE¼NE¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 6 feet

0- 4	Clay, brown
4- 6	Sand, dark brown, coarse, some clay
6- 9	Sand, brown, very coarse
9- 12	Sand, gray, some clay
12- 14	Sand, dark gray, coarse
14- 15	Sand, very coarse, with clay
15- 17	Sand, gray, fine, with clay, compact
17- 20	Sand, fine, much clay
20- 49	Clay, gray

* * * *

Observation Well 39
Location: SE¼NW¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 8 feet

0- 2	Soil
2- 8	Clay, brown, pebbly
8- 12	Gravel, brown
12- 15	Sand, gray, fine
15- 18	Sand, gray, coarse to very coarse
18- 24	Sand, gray, fine

Constructed an observation well with 18 feet of pipe in the ground.

* * * *

Test Hole 40
Location: SW¼SW¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 24 feet

0- 5	Clay, gray
5- 12	Sand, yellowish-brown, medium
12- 14	Clay, yellowish-brown
14- 24	Clay, gray
24- 28	Sand, gray, very fine
28- 60	Clay, gray
60- 67	Sand, medium
67- 84	Clay, sandy, compact

* * * *

Observation Well 41
Location: SE¼SE¼SW¼NW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 3.3 feet

0-	4	Clay, gray
4-	7	Sand, yellowish-brown, coarse
7-	14	Sand, yellowish-brown, very coarse
14-	15	Sand, brown, with clay
15-	16	Sand, gray, very fine
16-	22	Sand, gray, medium
22-	29	Clay, gray

Constructed an observation well with 19 feet of pipe in the ground.

* * * *

Observation Well 42
Location: NE¼NW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 2.6 feet

0-	1	Soil
1-	4	Clay, gray
4-	6	Clay, brown, sandy
6-	7	Sand, brown, gravelly
7-	11	Sand, brown, coarse
11-	39	Clay, gray

Constructed an observation well with 10 feet of pipe in the ground.

* * * *

Test Hole 43
Location: SE¼NW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 3 feet

0-	2	Soil
2-	4	Clay, gray, medium
4-	6	Sand, brown, coarse
6-	7	Sand, medium
7-	8	Sand, unsorted
8-	12	Sand, gray,medium
12-	39	Clay, gray, compact

* * * *

Observation Well 44
Location: NE¼SW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 2.3 feet

0-	2	Soil
2-	4	Clay, sandy

Observation Well 44 -- continued.

4- 6	Sand, gray, very coarse
6- 8	Sand, brown, very coarse, much clay
8- 13	Sand, coarse, less clay
13- 15	Sand, gray, fine
15- 16	Rock
16- 24	Clay, gray

Constructed an observation well with 14 feet of pipe.

* * * *

Observation Well 45
Location: SW¼SE¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4.6 feet

0- 2	Soil
2- 4	Sand, very coarse
4- 12	Sand, brown, very coarse
12- 15	Sand, gray, medium, compact
15- 16	Sand, more clay
16- 19	Clay, gray

Constructed an observation well with 10 feet of pipe in the ground.

* * * *

Observation Well 46
Location: SW¼SE¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 2 feet

0- 3	Topsoil
3- 4	Clay, brown
4- 10	Sand, brown, very coarse
10- 11	Sand, dark brown, with clay
11- 14	Clay, compact

Constructed an observation well with 8 feet of pipe in the ground.

* * * *

Test Hole 47
Location: NW¼NE¼SW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 3 feet

0- 5	Clay, gray, sandy
5- 7	Sand, brown, coarse
7- 12	Clay, brown
12- 46	Clay, gray

* * * *

Observation Well 48
Location: NW¼SW¼NW¼SE¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 3 feet

0- 7	Sand, coarse, with clay
7- 8	Sand, medium
8- 29	Clay, brown, compact

Constructed an observation well with 8 feet of pipe.

* * * *

Observation Well 49
Location: NW¼SW¼NE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 5	Clay, brown
5- 10	Sand, brown, very coarse
10- 12	Clay, gray, compact
12- 15	Clay, gray

Constructed an observation well with 10 feet of pipe.

* * * *

Test Hole 50
Location: SE¼SE¼NE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 2	Soil
2- 7	Clay, brown
7- 12	Sand, dark brown, with clay
12- 14	Sand, coarse
14- 18	Sand, gray, very coarse
18- 22	Clay, gray
22- 29	Clay, gray, compact

* * * *

Observation Well 51
Location: NE¼NW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4.1 feet

0- 2	Soil
2- 7	Clay, brown, sandy
7- 12	Sand, coarse, fine gravel
12- 13	Clay, gray
13- 15	Sand, medium, some clay
15- 19	Clay, gray, compact

Constructed an observation well with 11 feet of pipe in the ground.

* * * *

Observation Well 52
Location: NE¼NE¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 3.1 feet

0- 2	Clay, gray
2- 4	Clay, yellowish-brown
4- 11	Sand, brown, very coarse
11- 13	Clay, gray
13- 16	Sand, gray, fine
16- 19	Clay, gray

Constructed an observation well with 8 feet of pipe in the ground.

* * * *

Observation Well 53
Location: SW¼NE¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 1.2 feet

0- 2	Soil
2- 7	Clay, yellowish-brown, sandy
7- 10	Sand, dark gray, very coarse
10- 14	Sand, gray, very fine
14- 18	Sand, coarse
18- 34	Clay, gray

Constructed an observation well with 16 feet of pipe in the ground.

* * * *

Observation Well 54
Location: NE¼SW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 4 feet

0- 4	Clay, yellowish-brown
4- 7	Sand, yellowish-brown, very coarse
7- 9	Sand, gray, very fine
9- 13	Sand, very coarse, clayey
13- 16	Sand, very coarse, less clay
16- 29	Clay, gray

Constructed an observation well with 15 feet of pipe in the ground.

* * * *

Observation Well 55
Location: SE¼NE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 10 feet

0- 8	Gravel, yellowish-brown

Observation Well 55 -- continued.

8- 9	Sand, brown, fine
9- 10	Clay, gray
10- 14	Sand, brown, very coarse
14- 18	Sand, gray, very coarse, some clay
18- 22	Sand, coarse to fine gravel
22- 24	Sand, gray, some clay
24- 30	Sand, very coarse
30- 34	Clay, gravel

Constructed an observation well with 22 feet of pipe in the ground.

* * * *

Observation Well 56
Location: SW¼NE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 15 feet

0- 3	Gravel, brown, fine
3- 15	Sand, brown, medium, with clay
15- 37	Sand, very coarse, not much clay
37- 39	Clay, gray

Constructed an observation well with 20 feet of pipe in the ground.

* * * *

Test Hole 57
Location: SW¼NW¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 20? feet

0- 15	Gravel, yellowish-brown
15- 20	Sand, yellowish-brown, medium
20- 23	Sand, dark brown, coarse
23- 25	Sand, yellow, very coarse
25- 29	Clay, gray

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Observation Well 58
Location: SW¼NE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 15 feet

0- 9	Gravel
9- 13	Clay, yellow
13- 15	Sand, yellow
15- 22	Sand, brown, very coarse
22- 27	Sand, gray, not much clay
27- 34	Clay, gray

Observation Well 58 -- continued.

Constructed an observation well with 22 feet of pipe in the ground.

* * * *

Observation Well 59
Location: NW¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 10.8 feet

0- 8	Sand, yellow, medium, silty
8- 11	Clay, gray
11- 28	Sand, very coarse, unsorted
28- 35	Sand, gray, medium
35- 39	Clay, gray

Constructed an observation well with 21 feet of pipe in the ground.

* * * *

Observation Well 60
Location: NW¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 10 feet

0- 7	Gravel, brown, some clay
7- 9	Clay, yellow
9- 12	Sand, yellow, medium
12- 14	Sand, yellow, coarse
14- 21	Sand, very coarse
21- 36	Sand, very coarse, some gravel
36- 39	Clay, gray

Constructed an observation well with 16 feet of pipe in the ground.

* * * *

Observation Well 61
Location: SE¼SE¼SW¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 9.7 feet

0- 3	Soil
3- 5	Gravel
5- 9	Sand, yellowish-brown, fine
9- 12	Clay, yellowish-brown
12- 26	Sand, very coarse, fine gravel
26- 31	Sand, medium and fine
31- 38	Clay, gray

Constructed an observation well with 21 feet of pipe in the ground.

* * * *

Observation Well 62
Location: NW¼SW¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 10 feet

0- 3	Soil
3- 12	Gravel, fine, much clay
12- 14	Gravel, gray, fine, less clay
14- 16	Gravel, very coarse
16- 19	Sand, very coarse, with clay
19- 23	Sand, gray, very coarse, not much clay
23- 27	Sand, gray, fine
27- 29	Clay, gray

Constructed an observation well with 20 feet of pipe in the ground.

* * * *

Observation Well 63
Location: SE¼SW¼SE¼SW¼ sec. 9, T. 116 N., R. 57 W.
Depth to water: 11? feet

0- 4	Clay, gray
4- 6	Sand, brown, coarse, with clay
6- 8	Clay, brown
8- 11	Clay, gray
11- 17	Sand, brown, coarse
17- 18	Sand, gray, fine
18- 23	Sand, gray, coarse
23- 24	Clay, gray

Constructed an observation well with 22 feet of pipe in the ground.

* * * *

Test Hole 64
Location: SE¼SE¼SE¼SW¼ sec. 6, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 3	Clay, gray
3- 5	Clay, yellow
5- 8	Sand, brown, coarse, with clay
8- 12	Sand, dark gray, coarse
12- 24	Clay, gray

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Test Hole 65
Location: SW¼NW¼NW¼SW¼ sec. 5, T. 116 N., R. 57 W.
Depth to water: 6 feet

0- 2	Soil

Test Hole 65 -- continued.

2- 6	Clay, yellowish-brown
6- 10	Sand, brown, very coarse
10- 12	Clay, yellow
12- 24	Clay, gray

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Test Hole 66
Location: SE¼SW¼SW¼NW¼ sec. 5, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 2	Soil
2- 5	Clay, yellow, sandy
5- 7	Sand, yellowish-brown, coarse, some clay
7- 10	Sand, coarse, not much clay
10- 13	Clay, brown
13- 18	Clay, gray

* * * *

Observation Well 67
Location: SW¼NW¼NE¼NW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 3	Soil
3- 7	Sand, brown, medium
7- 21	Sand, gray, very coarse
21- 29	Clay, gray

Constructed an observation well with 14 feet of pipe in the ground.

* * * *

Test Hole 68
Location: SE¼NW¼NW¼NE¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 5 feet

0- 2	Soil
2- 5	Clay, brown
5- 9	Sand, yellowish-brown, very coarse, much clay
9- 39	Clay, gray

* * * *

Test Hole 69
Location: NE¼NW¼NE¼NE¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: no water measured

0- 3	Soil
3- 5	Clay, dark brown, silty

Test Hole 69 -- continued.

5- 13	Clay, brown, sandy
13- 17	Clay, gray
17- 20	Clay, brownish-gray, sandy, pebbly
20- 65	Clay, gray, sandy, pebbly with a few thin sand and gravel stringers at 61 feet

* * * *

Observation Well 70
Location: NW¼NW¼SE¼NW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 12 feet

0- 4	Soil
4- 12	Sand, brown, fine
12- 16	Sand, brown, medium
16- 24	Sand, gray, coarse
24- 27	Sand, gray, more clay
27- 33	Sand, gray, coarse, some clay
33- 39	Clay, gray

Constructed an observation well with 22 feet of pipe in the ground.

* * * *

Observation Well 71
Location: SE¼NE¼SE¼NW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 4 feet

0- 3	Soil
3- 4	Clay, yellowish-brown
4- 7	Sand, brown, coarse
7- 11	Sand, brown, medium
11- 12	Sand, brown, fine
12- 15	Sand, gray, fine
15- 21	Sand, gray, coarse
21- 24	Clay, gray

Constructed an observation well with 15 feet of pipe in the ground.

* * * *

Observation Well 72
Location: NW¼NW¼NE¼SW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 16 feet

0- 2	Soil
2- 4	Clay, brown
4- 15	Sand, yellow, medium
15- 16	Clay, yellow

Observation Well 72 -- continued.

16- 18	Sand, brown, medium
18- 22	Sand, gray, medium
22- 24	Sand, gray, fine
24- 29	Clay, gray

Constructed an observation well with 21 feet of pipe in the ground.

* * * *

Test Hole 73
Location: SW¼SE¼SW¼NW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: not measured

0- 2	Soil
2- 17	Clay, light brown, pebbly
17- 21	Sand, gray
21- 26	Clay, gray
26- 31	Sand, gray
31- 45	Clay, gray
45-168	Clay, gray, sandy, pebbly
168-170	Gravel
170-250	Clay, light brown, pebbly
250-289	Clay, gray, pebbly
289-328	Sand and gravel, with coal
328-459	Clay, gray, hard
459-476	Clay, gray, gravelly
476-504	Gravel, fine to medium, drills like there is some clay
504-530	Shale

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Test Hole 74
Location: SW¼SW¼NW¼SW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 35? feet

0- 2	Soil
2- 10	Clay, yellowish-brown
10- 22	Clay, gray, compact
22- 37	Sand, gray, coarse, some clay
37- 42	Clay, gray, gravelly
42- 53	Sand, gray, fine, some clay
53- 55	Clay, yellowish-brown
55- 79	Clay, gray
79- 90	Clay, gray, gravelly
90- 97	Gravel
97-104	Clay, dark gray

* * * *

Test Hole 75
Location: SE¼SW¼SE¼SW¼ sec. 7, T. 116 N., R. 57 W.
Depth to water: 6 feet

0-	2	Soil
2-	6	Clay, light gray, sandy
6-	10	Sand, yellowish-brown, medium
10-	14	Clay, brown
14-	29	Sand, gray, fine
29-	61	Clay, gray
61-	80	Clay, gray, sandy

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Test Hole 76
Location: NE¼NE¼NW¼NE¼ sec. 8, T. 116 N., R. 57 W.
Depth to water: no water?

0-	7	Sand, yellowish-brown, medium
7-	13	Sand, fine
13-	29	Clay, gray, compact

* * * *

Test Hole 77
Location: NW¼NE¼NW¼NE¼ sec. 18, T. 116 N., R. 57 W.
Depth to water: 10 feet

0-	5	Clay, gray
5-	7	Clay, yellowish-brown
7-	10	Sand, brown, very fine
10-	24	Sand, gray, very fine
24-	65	Clay, gray, pebbly

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APPENDIX B

Water Level Measurements in the Clark area
(see figs. 5 and 6)

Observation Well Number	Elevation (top of observation well)	November 10, 1972 Depth to Water (in feet)	November 10, 1972 Elevation	June 6-7, 1974 Depth to Water (in feet)	June 6-7, 1974 Elevation
14	1797.86	13.35	1784.51	13.31	1784.55
27	1795.26	10.79	1784.47	10.65	1784.61
32	1789.89	7.97	1781.92	7.59	1782.30
33	1787.42	5.31	1782.11	5.47	1781.95
34	1789.60	6.30	1783.30	6.18	1783.42
36	1790.95	9.62	1781.33	9.20	1781.75
39	1796.68	14.51	1782.17	14.38	1782.30
41	1788.74	8.04	1780.70	7.95	1780.79
42	1787.51	4.93	1782.58	4.83	1782.68
44	1788.50	5.43	1783.07	5.57	1782.93
45	1789.20	7.16	1782.04	7.09	1782.11
46	1786.61	4.45	1782.16	4.67	1781.94
48	1785.99	5.80	1780.19	5.59	1780.40
49	1786.56	7.74	1778.82	7.28	1779.28
51	1785.42	7.38	1778.04	-----	-------
52	1784.38	5.56	1778.82	5.56	1778.82
53	1783.43	5.49	1777.94	5.36	1778.07
54	1785.87	8.19	1777.68	8.25	1777.62
55	Was destroyed	-----	-------	-----	-------
56	1793.72	15.55	1778.17	15.74	1777.98
58	1795.66	17.43	1778.23	17.41	1778.25
59	1793.00	Filled	-------	-----	-------
60	1790.80	12.90	1777.90	13.34	1777.46
61	1791.20	15.17	1776.03	16.42	1774.78
62	1788.68	11.06	1777.62	11.59	1777.09
63	-------	10.03	-------	10.40	-------
67	-------	8.29	-------	8.13	-------
70	1789.06	11.60	1777.46	11.11	1777.95
72	-------	15.99	-------	15.18	-------