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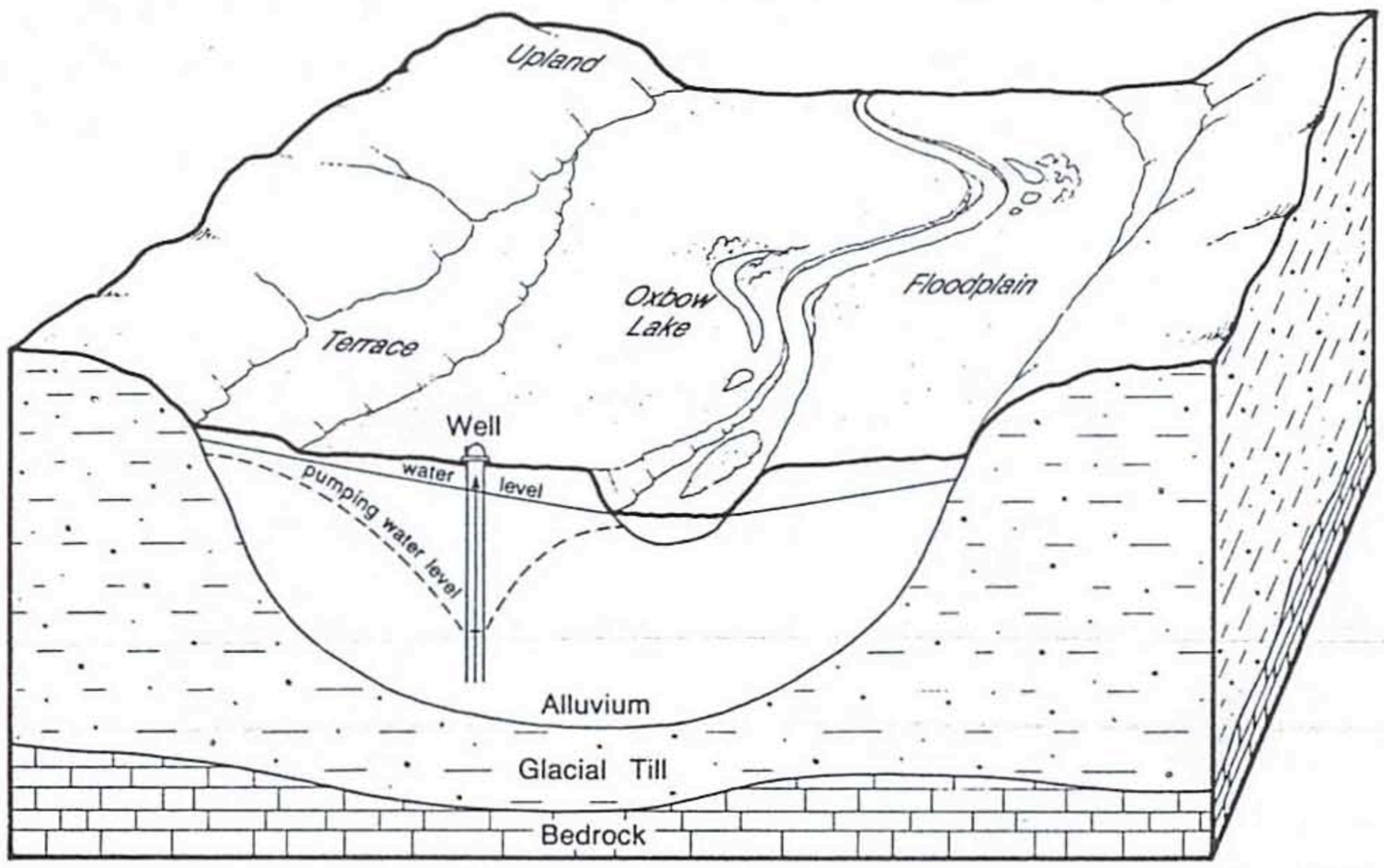
WATER RESOURCES OF THE OCHEYEDAN – LITTLE SIOUX ALLUVIAL AQUIFER

DATA REPORT

Carol A. Thompson



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The publication of this document has been financially aided through a contract with the United States Environmental Protection Agency.

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INTRODUCTION

The purpose of the alluvial aquifer study was to evaluate the geology, hydrology, and water quality characteristics of the Ocheyedan-Little Sioux alluvial system in northwest Iowa. This report presents a compilation of field and other data collected during the course of the study. It has been prepared to supplement the report of investigations, Open-File Report No. 86-3.

LOCATION

The Ocheyedan and Little Sioux rivers are located in northwest Iowa. Figures 1 and 2 show the location of the alluvial systems. The river traverse terraces that have a complex geologic history. The valleys in which the streams flow were formed by meltwaters from Wisconsin glaciers. The alluvial sediments consist of variably thick sands and gravels overlain by soil, silt and clay. These alluvial deposits lies on a variety of glacial materials of Wisconsinan age and older.

PRELIMINARY GEOLOGIC INFORMATION

Appendix A lists well logs, bridge borings, and sand and gravel pit information. These data were compiled from available well logs on file at the Geological Survey Bureau and from records of bridge boring in the files of the Iowa Department of Transportation. Other information was gathered from engineering reports of investigations for rural water systems and municipalities. Lithologic descriptions in this section reflect interpretations by many different sources and are not necessarily consistent with Geological Survey Bureau usage. Figures A-1 and A-2 index the location for this information.

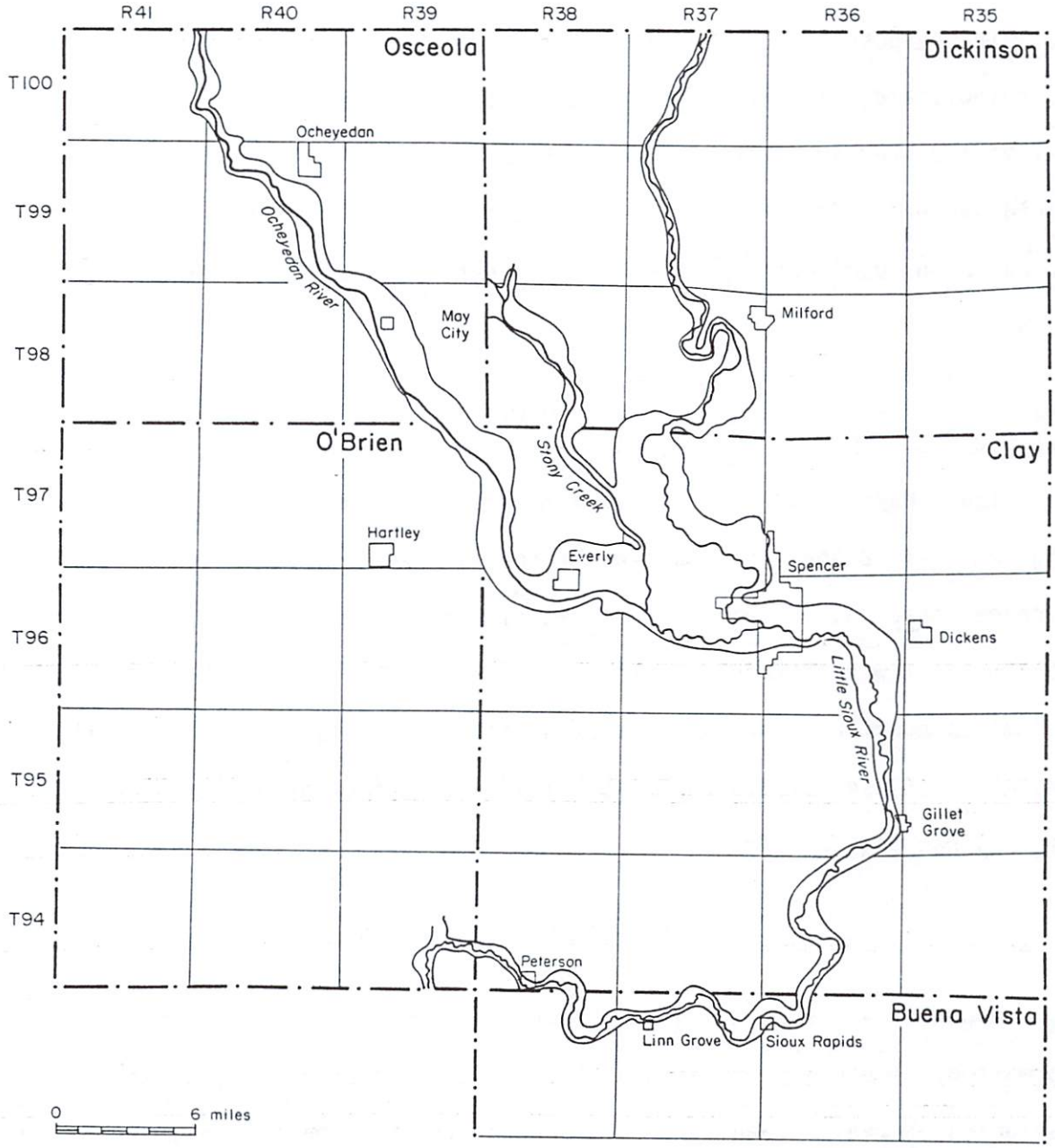


Figure 1. Location map for the Ocheyedan and upper Little Sioux alluvial aquifer.

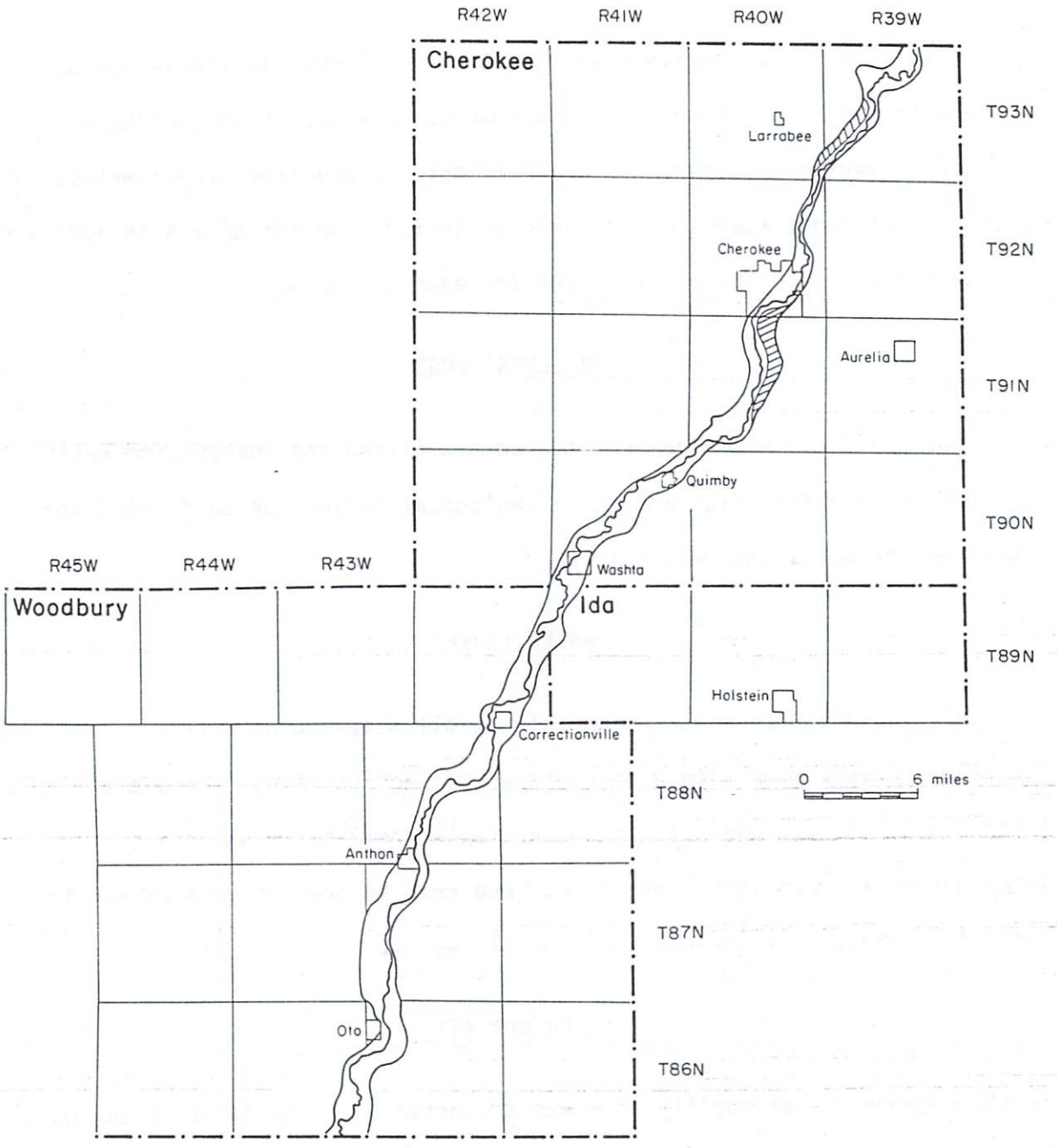


Figure 2. Location map for the lower Little Sioux alluvial aquifer.

SEISMIC SURVEY TECHNIQUES AND RESULTS

Seismic refraction surveys were used to supplement available geologic data and to aid in defining aquifer geometry. Eighteen traverses were completed covering a distance of approximately twenty-five linear miles. A discussion of the seismic methods used is included in Appendix B in addition to interpreted seismic cross-sections for each traverse.

DRILLERS' LOGS

Appendix C contains the logs for test drilling and observation wells. Darwin Evans and Mike Tietgen of the Geological Survey Bureau drilled and installed the wells and test holes.

WATER LEVELS

Water levels were measured monthly at all observation wells. Measurements were made with a steel tape or electric line. The water levels listed represent the depth to the water table from the land surface. Sea level datum was established at all but one well to provide uniform vertical control for water level-elevations for all wells.

WATER QUALITY

Background water quality data was collected from the files of the University of Iowa Hygienic Laboratory, the Iowa Department of Natural Resources, Environmental Protection Division, rural water systems, and municipalities. The constituents listed are all common water quality parameters. Table 1 lists the National Drinking Water Standards and the description and significance of each parameter. Drinking water standards have been established by

TABLE 1. Drinking Water Standards and Significance of Chemical Constituents

	CONSTITUENTS	PRIMARY STANDARDS MCL	PRIMARY STANDARDS RMCL	SECONDARY STANDARDS
		(All analyses in mg/l unless otherwise noted)		
1	Dissolved solids			500
2	Hardness (as $CaCO_3$)			
3	pH			6.5 - 8.5 pH units
4	Specific conductance			
5	Alkalinity			
6	Iron			.3
7	Manganese (Mn)			.05
8	Potassium (K) and Sodium (Na)			
9	Calcium (Ca) and Magnesium (Mg)			
10	Sulfate (SO_4)			250
11	Phosphorus (PO_4)			
12	Chloride (Cl)			250
13	Floride (Fl)	4.0	4.0	
	Nitrogen Series			
14	Nitrate-N	10		
15	Nitrite-N			
16	Organic-N			
17	Ammonia-N			
18	Dissolved Oxygen			
19	Turbidity	1 TU	5 TU	
20	Total coliform	1 organism/100 ml water		
21	Radioactivity	picocuries/l		
	Gross alpa	15		
	Radium 226 (Ra^{226})	3		
	Radium 226 & 228 (Ra^{226}, Ra^{228})	5		
	Strontium 90 (Sr^{90})	10		
	Gross beta (in absence of alpha emitters)	1000		
22	Metals	mg/l		
	Arsenic (As)	0.05		
	Barium (Ba)	1.0		
	Cadmium (Cd)	0.01		
	Chromium (Cr)	0.05		
	Copper (Cu)			1
	Lead (Pb)	0.05		
	Mercury (Hg)	0.002		
	Selenium (Se)	0.01		
	Silver (Ag)	0.05		
	Zinc (Zn)			5

TABLE 1 continued

Description/Significance

1 This refers to all material that is in solution. It affects the chemical and physical properties of water for many industrial uses. High concentrations will have a laxative effect and may cause an objectionable taste.

2 This affects the lathering ability of soap. Primarily caused by calcium and magnesium. Water is generally classified as: 0-100 mg/l as soft; 100-200 mg/l as moderate; anything above 200 mg/l as hard.

3 A chemical expression indicating hydrogen ion activity. A ph of 7.0 is neutral, pH greater than 7.0 is alkaline, pH less than 7.0 is acid.

4 Specific conductance is a measure of the ability of water to conduct an electric current.

5 Alkalinity is defined as the capacity of a solution to neutralize an acid.

6 Iron is objectionable as it may impart an unpleasant taste and may cause discoloration of laundered goods and porcelain fixtures.

7 Objectionable for the same reasons as iron.

8 When combined with chloride, imparts a salty or brackish taste. In the presence of suspended matter, causes foaming in boilers. Important ingredients in human cell metabolism. Low sodium diets are prescribed in the treatment of certain types of heart disease and high blood pressure.

9 Calcium and magnesium cause water hardness. They reduce the lathering ability of soap. They react with bicarbonate and sulfate to form scale in pipes.

10 Commonly has a laxative effect and imparts a bitter taste when concentrations exceed 500 mg/l, particularly when combined with magnesium or sodium. The effect is less when combined with calcium. Persons may become acclimatized to the water, but concentrations above 750 mg/l generally affect everyone. Sulfate combined with calcium causes scale in boilers and water heaters.

11 Phosphorus has been linked to increased eutrophication in lakes and streams. Humans utilize phosphorus in small amounts for bone growth and enzymatic processes.

12 Imparts a salty taste, especially when combined with sodium and potassium.

13 Concentrations of 0.8--1.3 mg/l are effective in reduction of tooth decay, especially in children. Concentrations in excess of 2.0 mg/l will cause mottling of dental enamel.

14 Concentrations of nitrate above the recommended limits may cause cyanosis or methemoglobinemia (blue baby syndrome) when used for feeding infants under one year of age. This disease reduces the ability of the blood to absorb oxygen and may be fatal unless properly treated.

15 Is highly toxic, but in natural situations quickly oxidizes to nitrate. Contains compounds such as protein, peptides, nucleic acid, urea and synthetic organics.

16 Is not always available for reactions.

17 Is a breakdown of organic nitrogen compounds and urea. Ammonia standards applicable to streams are for the protection of aquatic organisms.

18 A measure of the amount of atmospheric oxygen dissolved in water. Groundwater normally has low levels. Surface waters are constantly aerated leading to high levels. Many aquatic organisms need high levels of dissolved oxygen.

19 Is a measure of the waters ability to transmit light.

20 Coliform bacteria are not a health problem themselves, but their prescence may indicate the prescence of other bacteria which can cause health problems. Small amounts of bacteria in drinking water are unsatisfactory. Bacteria can be controlled by chlorination.

21 Groundwater may contain naturally occurring radioactivity. Human exposure to radiation is viewed as harmful, and unnecessary exposure should be avoided. Limits have been set insofar as is technically and economically feasible. Radioactive substances such as strontium and radium tend to bioaccumulate in bone and may lead to bone cancer or leukemia.

22 Can be very toxic in small quantities, exhibiting both acute and chronic effects. May inhibit oxygen transfer, affect the nervous system, damage chromosomes, or interfere with enzyme production or function. Metals are not rapidly excreted and tend to bioaccumulate. Metals are naturally occurring substances that normally occur in very small quantities.

the Environmental Protection Agency as part of the Safe Drinking Water Act (PL 93-523). Primary standards are maximum contaminant levels (MCLs) which are the maximum permissable level of a contaminant in a public water supply. Recommended maximum contaminant levels (RMCLs) are the maximum level of contaminant in drinking water at which no known or anticipated adverse effect in the health of a person would occur and which includes an adequate safety margin. RMCLs are non-enforceable health goals. Secondary standards apply to substances which primarily affect aesthetic qualities related to public acceptance of drinking water. At considerably higher concentrations of these contaminants, health implications may also exist in addition to aesthetic degradation.

APPENDIX A

Preliminary Geologic Information

Well Logs
Sand and Gravel Pits
Bridge Borings

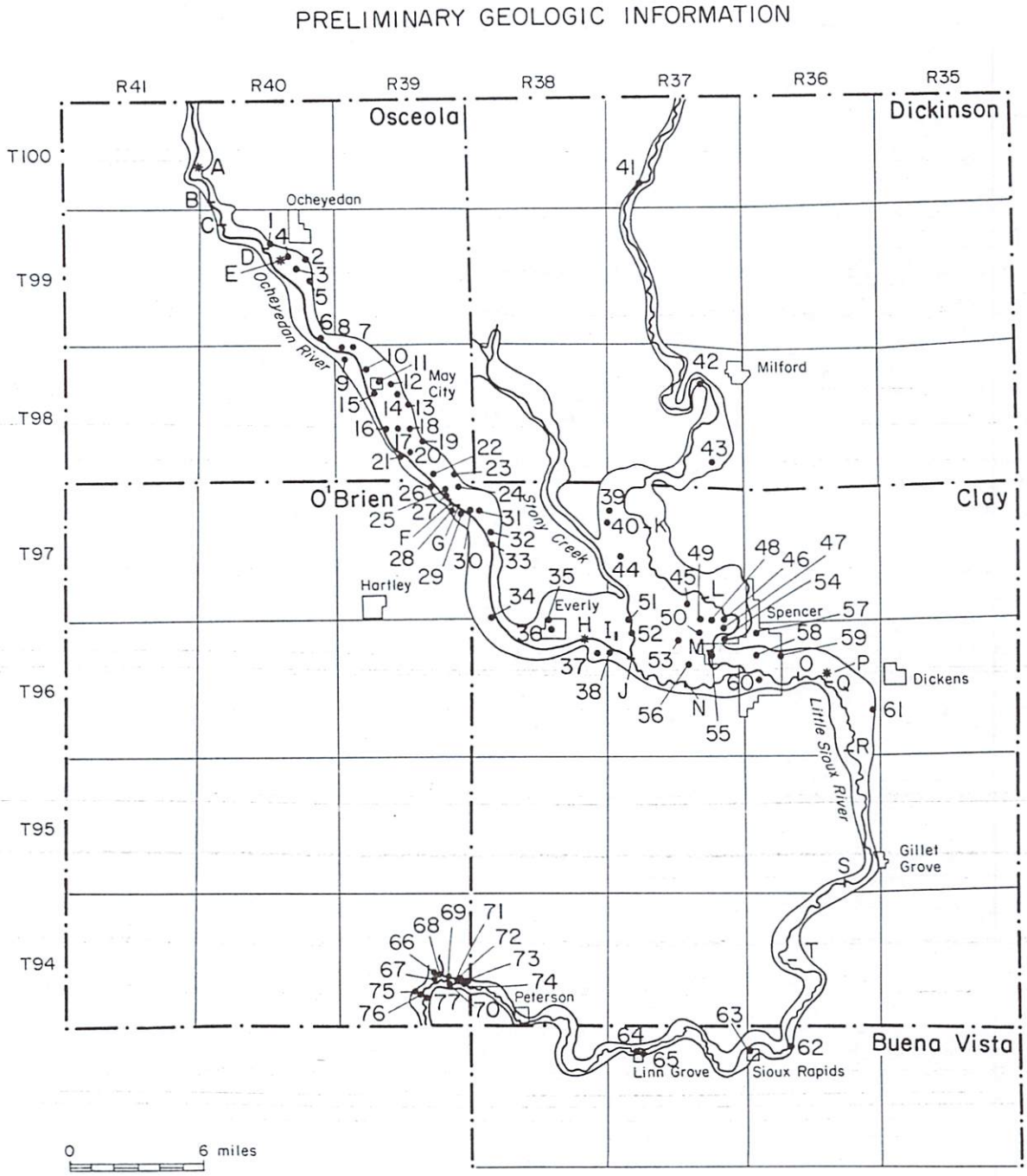


Figure A-1. Location of preliminary geologic data: Ocheyedan and upper Little Sioux.

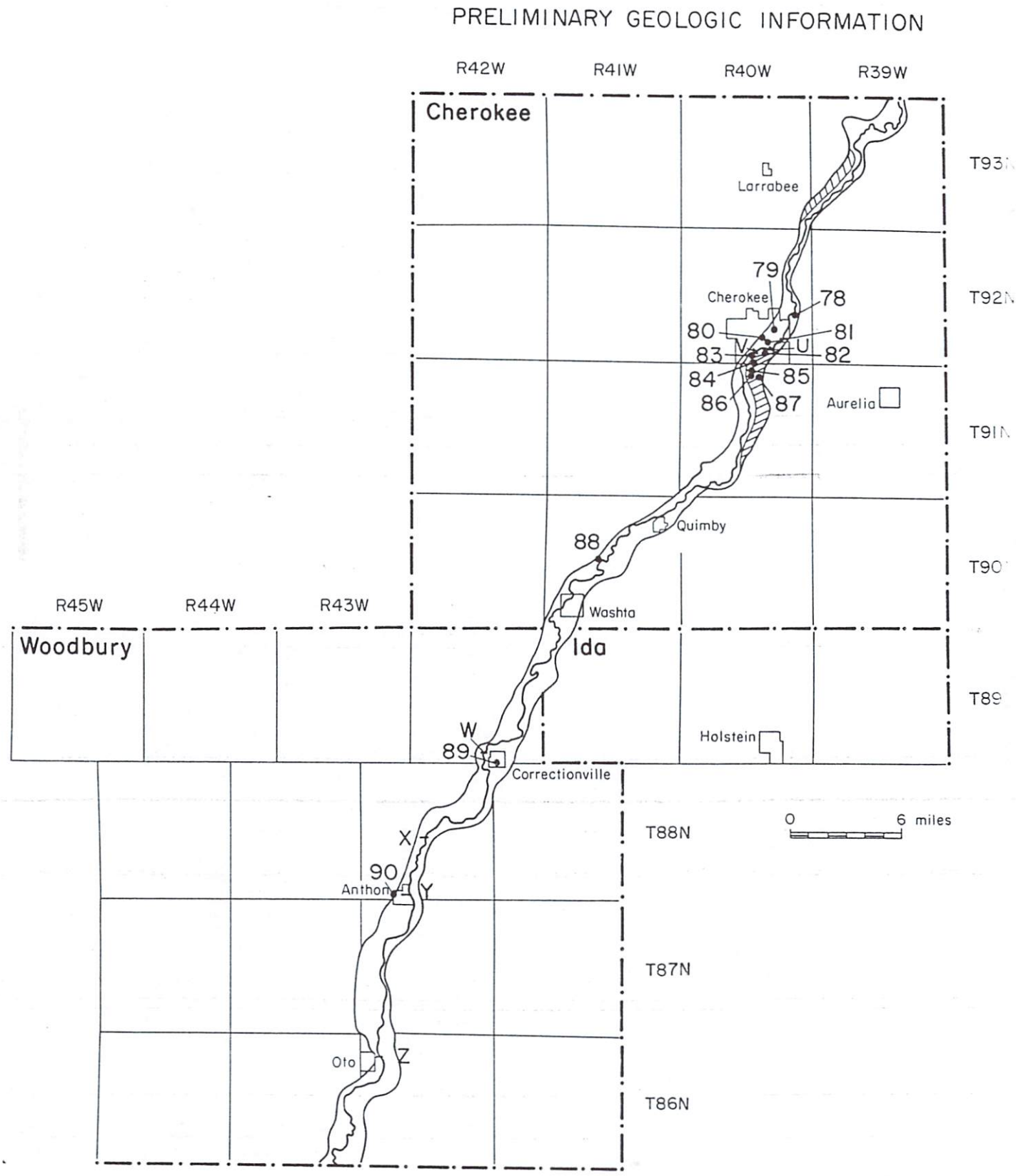


Figure A-2. Location of preliminary geologic data: lower Little Sioux.

Part I.

Well Logs

ABBREVIATIONS

Dak.	Dakota
N/S	No sample
Fm.	formation
SS	sandstone
LS	limestone
Sh	shale
Sd	sand
Bld	boulder
O.U.	oxidized, unleached
U.U.	unoxidized, unleached
w/	with
crs	coarse
f	fine
med	medium
lt	light

WELL LOGS

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
1	----	SW Sec 10 T 99 R 40	1475	0	9	Soil
				9	16	Sand & Gravel
				16	32	Till
				32	41	Sand & Gravel
				41	44	Till
1a	----	SW Sec 10 T 99 R 40	1480	0	3	Soil
				3	4.5	Clay
				4.5	9	Sand
				9	40	Till
				40	46	Sand
				46	55	Till
1b	----	SW Sec 10 T 99 R 40	1478	0	3	Soil
				3	4.5	Clay
				4.5	12	Sand & Gravel
				12	40	Till
				40	57	Sand & Gravel
				57	60	Till
1c	----	SW Sec 10 T 99 R 40	1472	0	8	Soil
				8	15	Sand & Gravel
				15	18	Till
				18	20	Sand & Gravel
				20	40	Sandy Till
				40	57	Sand & Gravel
				57	60	Clay
1d	----	SW Sec 10 T 99 R 40	1476	0	4.5	Soil
				4.5	12	Sand & Gravel
				12	40	Till
				40	57	Sand & Gravel
				57	60	Till
1e	----	SW Sec 10 T 99 R 40	1478	0	4	Soil
				4	5	Clay
				5	9	Sand & Gravel
				9	51	Till
				51	66	Sand & Gravel
				66	70	Till
2	W4222	NE NE NW Sec 14 T 99 R 40	1495	0	5	Soil
				5	50	Till
2a	W4221	SE NE NW Sec 14 T 99 R 40	1490	0	5	Soil
				5	50	Till
3	W4220	NE NE SW Sec 14 T 99 R 40	1475	0	5	Soil
				5	50	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
3a	W4219	NE SE SW Sec 14 T 99 R 40	1470	0	5	Soil
				5	15	Sand
				15	35	Till
				35	45	Sand
				45	50	Till
3b	W4218	SE SE SW Sec 14 T 99 R 40	1470	0	5	Soil
				5	10	Sand
				10	50	Till
3c	W4224	C SW Sec 14 T 99 R 40	1475	0	5	Soil
				5	15	Till
				15	30	Clayey S&G
				30	60	Till
3d	W4225	NW SW SW Sec 14 T 99 R 40	1469	0	5	Soil
				5	25	Sand, Clay
				25	50	Till
4	W4232	NE NW Sec 15 T 99 R 40	1475	0	5	Soil
				5	40	Till
				40	60	Sand & Gravel
4a	W4231	SE NW NW Sec 15 T 99 R 40	1472	0	5	Soil
				5	40	Till
				40	60	Sand & Gravel
				60	65	Till
5	W4223	NE NE NW Sec 23 T 99 R 40	1460	0	5	Soil
				5	20	Sand & Gravel
				20	50	Sandy till
5.5	026	NE NE NE Sec 26 T 99 R 40	1460	0	5	Soil
				5	25	Sand
				25	27	Clay
				27	30	Rocky w/ silt
				30	85	Gravel
				85		Clay
5.5a	---	E, W 1/2 Sec 26 T 99 R 40	1460	0	7	Fill
				7	12	Gravel
				12	16	Mud
				16	44	Gravel & rock
				44		Clay
5.7	035	NE Sec 35 T 99 R 40	1455	0	7	Fill
				7	25	Gravel
				25	35	Rocky, silty
5.7a	----	W 1/2 Sec 35 T 99 R 40	1450	0	8	Fill, dirt
				8	12	Soil

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
5.7a continued				12	20	Gravel
				20	25	Mud
				25	37	Gravel
				37	55	Fine sand
				55	65	Gravel
				65		Clay
6	----	NW NW Sec 36 T 99 R 40	1450	0	10	Soil
				10	30	Sand
				30	47	Gravel
6a	----	NW SW Sec 36 T 99 R 40	1445	0	3	Soil
				3	5	Clay
				5	14	Sand
				14	47	Gravel
				47		Clay
6b	036	NW Sec 36 T 99 R 40	1450	0	5	Soil
				5	25	Gravel
				25	73	Sand
6c	D70-78	NE SE Sec 36 T 99 R 40	1449	0	4	Soil
				4	70	Till
6.5	D74-78	SW SW Sec 31 T 99 R 38	1445	0	3	Soil
				3	42	Silt
6.5a	D75-78	SW SW Sec 31 T 99 R 38	1445	0	3	Soil
				3	22	Peat
7	----	SW NE Sec 6 T 98 R 39	1437	0	2	Soil
				2	42	Gravel
7a	116	SE NE Sec 6 T 98 R 39	1435	0	6	Soil
				6	64	Sand
				64	65	Clay
7b	120	NE NE Sec 6 T 98 R 39	1441	0	8	Sand & Gravel
				8	73	Sand
				73	75	Clay
8	----	NW NW NW Sec 6 T 98 R 39	1446	0	4	Soil
				4	7	Clay & Gravel
				7	50	Gravel
8a	117	NE NW Sec 6 T 98 R 39	1430	0	13	Soil, Clay
				13	45	Sand & Gravel
				45	47	Clay
8b	118	NW NW Sec 6 T 98 R 39	1440	0	5	Soil
				5	49	Sand & Gravel
				49	50	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
8c	119	NW NW Sec 6 T 98 R 39	1440	0	6	Soil
				6	43	Sand & Gravel
				43	45	Clay
9	----	NW NW SW Sec 6 T 98 R 39	1442	0	1	Soil
				1	4	Clay
				4	22	Sand
				22	45	Gravel
9a	114	SW SE Sec 6 T 98 R 39	1438	0	5	Soil
				5	46	Sand & Gravel
				46		Clay
9b	115	NE SW Sec 6 T 98 R 39 W	1438	0	45	Sand & Gravel
				45		Clay
10	----	SW NE NW Sec 8 T 98 R 39	1423	0	5	Soil
				5	37	Sand & Gravel
				37	40	Clay
10a	----	SW NW Sec 8 T 98 R 39	1430	0	3	Soil
				3	44	Sand & Gravel
				44		Clay
11	----	NW SE Sec 8 T 98 R 39	1425	0	4	Soil
				4	30	Gravel
11a	----	NW SE Sec 8 T 98 R 39	1425	0	2	Soil
				2	33	Sand & Gravel
				33	108	Till
				108	112	Sand & Gravel
				112	170	Till
				170	200	Sandy clay
				200	236	Sandy till
				236	262	Shaly clay
				262	390	Shale,SS,LS
				390	520	SS, LS
				520	555	SS, Shale
11b	W24739	SE SE Sec 8 T 98 R 39	1425	0	7	N/S
				7	10	Soil
				10	50	Sand & Gravel
				50	107	Till
				107	127	Gravel
				127	223	Till
				223	253	Sand & Gravel
				253	609	Cretaceous Dakota Fm.
				609		Paleozoic
11c	CPW	SW SE Sec 8 T 98N R 39	1422	0	6	Soil
				6	41.5	Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
11d	79-1	SW SE Sec 8 T 98 R 39	1422	0	5	Soil
				5	49	Sd, crs - fine
				49	-	Clay
11e	79-2	SW Sec 8 T 98 R 39	1420	0	5	Soil
				5	28	Sand & Gravel
				28		Clay
11f	H8	SE SE SE Sec 8 T 98 R 39	1422	0	5	Soil
				5	53	Sd, Crs-med
12	----	NW SW Sec 9 T 98 R 39	1426	0	38	Sand & Gravel
				38	40	Clay
13	----	SW SW Sec 15 T 98 R 39	1419	0	10	Soil
				10	38	Sand
				38	52	Gravel
13a	101	SW SW Sec 15 T 98 R 39	1419	0	3	Soil
				3	24	Sand & Gravel
				24		Clay
13b	102	SW SW Sec 15 T 98 R 39	1419	0	5	Soil
				5	35	Sand & Gravel
				35		Clay
13c	103	SW SW Sec 15 T 98 R 39	1419	0	13	Soil, Clay
				13	56	Sand & Gravel
				56		Clay
14	----	NW NW NE Sec 16 T 98 R 39	1420	0	5	Soil
				5	41	Sand
				41	45	Clayey sand
				45	48	Clay
14a	----	NE NE Sec 16 T 98 R 39	1418	0	8	Mud
				8	39	Gravel
				39	49	Mud
14b	122	NW SE Sec 16 T 98 R 39	1420	0	5	Soil
				5	40	Sand
				40	44	Clayey Sand
				44	47	Clay
14c		SW NE Sec 16 T 98 R 39	1415	0	10	Soil
				10	28	Sand
				28	29	Clay
14d	106	SW SE Sec 16 T 98 R 39	1417	0	4	Soil, silt
				4	20	Sand & Gravel
				20		Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
14e	110	NE NW Sec. 16 T 98 R 39	1422	0	5	Soil
				5	50	Sand & Gravel
				50		Clay
15	----	NE NE Sec 17 T 98 R 39	1425	0	2	Soil
				2	50	Sand & Gravel
				50		Clay
15a	79-3	SW NE Sec 17 T 98 R 39	1420	0	4	Soil
				4	15	Sand, med
				15		Clay
16	----	SE SW Sec 21 T 98 R 39	1405	0	7	Soil
				7	31	Sand
				31		Clay
17	----	SW SW SE Sec 21 T 98 R 39	1413	0	4	Soil
				4	32	Gravel
18	----	NW NW NW Sec 22 T 98 R 39	1405	0	2	Soil
				2	41	Gravel
				41	44	Sand
18a	----	SE SW Sec 22 T 98 R 39	1405	0	6	Soil
				6	14	Sand
				14	30	Gravel
18b	-----	NW SE Sec 22 T 98 R 39	1400	0	5	Soil
				5	35	Sand & Gravel
				35	42	Gray Gravel
18c	-----	NW SE Sec 22 T 98 R 39	1400	0	4	Soil
				4	45	Sand & Gravel
18d	----	NW SW Sec 22 T 98 R 39	1405	0	4	Soil
				4	47	Sand & Gravel
18e	----	NW SW Sec 22 T 98 R 39	1405	0	5	Soil
				5	53	Sand & Gravel
18f	----	NW SW Sec 22 T 98 R 39	1400	0	4	Soil
				4	42	Sand & Gravel
18g	----	NW SW Sec 22 T 98 R 39	1400	0	4	Soil
				4	42	Sand & Gravel
18h	----	NW SW Sec 22 T 98 R 39	1400	0	4	Soil
				4	45	Sand & Gravel
18i	----	NW SW Sec 22 T 98 R 39	1403	0	4	Soil
				4	44	Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
18j	104	NE NW Sec 22 T 98 R 39	1415	0	5	Soil, silt
				5	40	Sand & Gravel
				40		Clay
18k	----	SW SW SW Sec 22 T 98 R 39	1405	0	5	Soil
				5	38	Sd, fine - crs
				38	40	Clay
18l	105	NW NW Sec 22 T 98 R 39	1410	0	6	Soil
				6	42	Sand & Gravel
				42		Clay
18m	104	NE NW Sec 22 T 98R 39	1412	0	5	Soil
				5	40	Sand & Gravel
				40		Clay
18n	----	NW NW Sec 22 T 98 R 39	1415	0	3	Soil
				3	36	Sand, f-med
				36	38	Clay
18o	----	SW SW SW Sec 22 T 98 R 39	1405	0	5	Soil
				5	38	Sand, fine-crs
				38	40	Clay
19	60-78	SW NW Sec 27 T 98 R 39	1402	0	1.5	Soil
				1.5	30	Sand & Gravel
				30	38	Till
19a	8-78	SW NW Sec 27 T 98 R 39	1402	0	8	Soil
				8	37	Sand & Gravel
				37	42	Till
19b	----	SW NW Sec 27 T 98 R 39	1402	0	10	Soil
				10	27	Sand & Gravel
				27	38	Sand & Clay
				38	42	Till
				42	44	Sand & Gravel
				44	238	Till
				238	245	Sand
				245	330	Sandy Clay
				330	364	Shale
				364	382	Clay, SS
				382	415	SS
19c	15-78	SW NW Sec 27 T 98 R 39	1400	0	3	Soil
				3	4	Sand,Soil
				4	38	Sand & Gravel
				38	42	Till
19d	16-78	SW NW Sec 27 T 98 R 39	1402	0	7	Soil
				7	38	Sand & Gravel
				38	42	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
19e	61-78	SW NW Sec 27 T 98 R 39	1401	0	5	Soil
				5	27	Sand & Gravel
				27	35	Till
19f	59-78	SW NW Sec 27 T 98 R 39	1401	0	3	Soil
				3	37	Sand & Gravel
				37	42	Till
20	66-75	NW SW Sec 27 T 98 R 39	1400	0	1.5	Soil
				1.5	18	Sand & Gravel
				18	22	Till
20a	6-78	NW SW Sec 27 T 98 R 39	1398	0	10	Soil
				10	26	Sand & Gravel
				26	30	Till
20b	2-78	SW SW Sec 27 T 98 R 39	1398	0	7	Soil
				7	26	Sand & Gravel
				26	30	Till
20c	3-78	SW SW Sec 27 T 98 R 39	1400	0	7	Soil
				7	25	Sand & Gravel
				25	50	Till
20d	1-78	SW SW Sec 27 T 98 R 39	1400	0	7	Soil
				7	26	Sand & Gravel
				26	80	Till
20e	9-78	SE SW Sec 27 T 98 R 39	1401	0	4	Soil
				4	5	Sandy Soil
				5	14	Sand & Gravel
				14	15	Limestone
				15	32	Till
20f	10-78	SE SW Sec 27 T 98 R 39	1401	0	8	Soil
				8	28	Sand & Gravel
				28	32	Till
20g	67-78	NE SW Sec 27 T 98 R 39	1398	0	3	Soil
				3	16	Sand & Gravel
				16	22	Till
20h	4-78	SW SW Sec 27 T 98 R 39	1398	0	6	Soil
				6	8	Sand Soil
				8	27	Sand & Gravel
				27	40	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
20i	5-78	NW SW Sec 27 T 98 R 39	1398	0	7	Soil
				7	33	Sand & Gravel
				33	35	Till
				35	38	Sand & Gravel
				38	50	Till
21	----	SE SE Sec 28 T 98 R 39	1405	0	4	Soil
				4	6	Gumbo
				6	45	Gravel
21a	79-4	SE Sec 28 T 98 R 39	1405	0	4	Soil
				4	38	Sand, crs-med
				38		Clay
21b	79-5	SE Sec 28 T 98 R 39	1403	0	1	Soil
				1	37	Sd, crs-fine, Gravel
				37		Clay
22	----	SE SE SW Sec 35 T 98 R 39	1390	0	6	Soil
				6	8	Mud
				8	24	Gravel
23	36-78	NW SW Sec 36 T 98 R 39	1400	0	1	Soil
				1	15	Fine sand
				15	26	Sand & Gravel
				26	31	Till
23a	D36-18 18-78	SW SW Sec 36 T 98 R 39	1390	0	4	Soil
				4	37	Sand & Gravel
				37	42	Till
23b	D36-20 20-78	SE SW Sec 36 T 98 R 39	1395	0	7	Soil
				7	40	Sand & Gravel
				40	45	Till
23c	36-9	Sec 36 T 98 R 39	1395	0	8	Soil
				8	37	Sand & Gravel
				37	42	Gray Clay
23d	36-10	NW SW Sec 36 T 98 R 39	1395	0	8	Soil
				8	37.5	Sand & Gravel
				37.5	40+	Gray Clay
23e	D36-14	SW SW Sec 36 T 98 R 39	1393	0	3	Soil
				3	36	Sand & Gravel
				36	38	Gray Clay
23f	D36-17	SW SW Sec 36 T 98 R 39	1393	0	4	Soil
				4	37	Sand & Gravel
				37		Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
23g	D36-19	SW SW Sec 36 T 98 R 39	1391	0	5	Soil, Sandy Soil
				5	37	Sand & Gravel
				37	42	Clay
23h	D36-21	SE SW Sec 36 T 98 R 39	1393	0	7	Soil
				7	40	Sand & Gravel
				40	45	Gray Till
23i	D36-26	SE SW Sec 36 T 98 R 39	1395	0	5	Soil
				5	40	Sand & Gravel
				40	50	Gray till
23j	D36-27	SW SW Sec 36 T 98 R 39	1392	0	3	Soil
				3	4	Sandy till
				4	41	Sand & Gravel
				41	42	Gray till
23k	D36-28	SW SW Sec 36 T 98 R 39	1390	0	3	Soil
				3	4	Sandy clay
				4	38	Sand & Gravel
				38	42	Gray till
23l	OW2	SW SW Sec 36 T 98 R 39	1390	0	2	Soil
				2	37	Sand & Gravel
				37		Till
23m	OW3	SW SW Sec 36 T 98 R 39	1391	0	2	Soil
				2	34	Sand & Gravel
				34		Till
23n	OW4	SW SW Sec 36 T 98 R 39	1392	0	2	Soil
				2	38	Sand & Gravel
				38		Till
23o	OW5	SW SW Sec 36 T 98 R 39	1393	0	3	Soil
				3	41	Sand & Gravel
				41		Till
23p	OW6	SW SW Sec 36 T 98 R 39	1390	0	2	Soil
				2	34	Sand & Gravel
				34		Till
23q	OW7	SW SW Sec 36 T 98 R 39	1390	0	4	Soil
				4	38	Sand & Gravel
23r	OW8	SW SW Sec 36 T 98 R 39	1390	0	4	Soil
				4	34	Sand & Gravel
				34		Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
23s	OW9	SW SW Sec 36 T 98 R 39	1390	0	2	Soil
				2	34	Sand & Gravel
23t	PW	SW SW Sec 36 T 98 R 39	1390	0	3	Soil
				3	38	Sand & Gravel
23u	36-8	NW SW Sec 36 T 98 R 39	1400	0	1	Soil
				1	10	Find Sand
				10	26.5	Sand & Gravel
				26.5	35	Gray Clay
23v	17-78	SW SW Sec 36 T 98 R 39	1392	0	4	Soil
				4	29	Sand & Gravel
				29	32	Till
23w	19-78	SW SW Sec 36 T 98 R 39	1391	0	3	Soil
				3	5	Sand, soil
				5	37	Sand & Gravel
				37	42	Till
23x	21-78	SE SW Sec 36 T 98 R 39	1392	0	7	Soil
				7	40	Sand & Gravel
				40	45	Till
23y	14-78	SW SW Sec 36 T 98 R 39	1392	0	3	Soil
				3	6	Sandy soil
				6	38	Sand & Gravel
23z	28-78	SW SW Sec 36 T 98 R 39	1391	0	3	Soil
				3	4	Sandy clay
				4	38	Sand & Gravel
				38	42	Till
23aa	27-78	SW SW Sec 36 T 98 R 39	1393	0	3	Soil
				3	4	Sand clay
				4	41	Sand & Gravel
				41	42	Till
23bb	26-78	SE SW Sec 36 T 98 R 39	1394	0	3	Soil
				3	5	Sand soil
				5	40	Sand & Gravel
				40	50	Till
23cc	38-78	SW SW Sec 36 T 98 R 39	1395	0	3	Soil
				3	8	Sand
				8	21.5	Sand & Gravel
				21.5	25	Sand
				25	37.5	Gravel
				37.5	81.5	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
23dd	37-78	NW SW Sec 36 T 98 R 39	1395	0	2	Soil
				2	5	Clay
				5	6	Clayey Sand
				6	8	Sand
				8	30	Sand & Gravel
				30	41.5	Till
23ee	D63-78	NE SW Sec 36 T 98 R 39	1397	0	4	Soil
				4	17	Sand & Gravel
				17	25	Till
23ff	D62-78	NE SW Sec 36 T 98 R 39	1397	0	3	Soil
				3	9	Silt
				9	17	Sand & Gravel
				17	22	Till
23gg	D 65-78	NE SW Sec 36 T 98 R 39	1399	0	3.5	Soil
				3.5	16.5	Sand & Gravel
				16.5	21.5	Till
23hh	D 64-78	NE SW Sec 36 T 98 R 39	1398	0	5	Soil
				5	18	Sand & Gravel
				18	22	Till
24	108	NE NW Sec 1 T 97 R 39	1391	0	7	Soil
				7	31	Sand
				31		Clay
24a	109	NW NW Sec 1 T 97 R 39	1388	0	5	Soil
				5	19	Sand
				19		Clay
25	39-78	SE NE Sec 2 T 97 R 39	1390	0	3	Soil
				3	13	Clay
				13	20	Sand & Gravel
				20	32	Till
26	13-78	NW NW Sec 2 T 97 R 39	1391	0	5	Soil
				5	10	Sand
				10	18	Sand & Gravel
				18	32	Till
26a	12-78	NW NW Sec 2 T 97 R 39	1395	0	6	Soil
				6	19	Sand & Gravel
				19	32	Till
26b	11-78	NW NW Sec 2 T 97 R 39	1393	0	8	Soil
				8	19	Sand & Gravel
				19	42	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
27	41-78	NE SE Sec 2 T 97 R 39	1385	0	4	Soil
				4	23	Sand & Gravel
				23	32	Till
27a	25-78	NW SE Sec 2 T 97 R 39	1382	0	6	Soil
				6	19	Sand & Gravel
				19	30	Till
27b	43-78	SE SE Sec 2 T 97 R 39	1386	0	4	Soil
				4	12	Sand & Gravel
				12	22	Till
27c	47-78	SW SE Sec 2 T 97 R 39	1388	0	3	Soil
				3	4	Clay
				4	20	Sand & Gravel
				20	32	Till
27d	46-78	SW SE Sec 2 T 97 R 39	1385	0	3	Soil
				3	4	Clay
				4	15	Sand & Gravel
				15	22	Till
27e	45-78	SW SE Sec 2 T 97 R 39	1385	0	3	Soil
				3	4	Clay
				4	17	Sand & Gravel
				17	22	Till
27f	44-78	SE SE Sec 2 T 97 R 39	1387	0	5	Soil
				5	6	Clay
				6	15	Sand & Gravel
				15	22	Till
27g	42-78	NE SE Sec 2 T 97 R 39	1382	0	4	Soil
				4	7	Silt
				7	21	Sand & Gravel
				21	32	Till
27h	40-78	NE SE Sec 2 T 97 R 39	1382	0	9	Soil
				9	22	Sand & Gravel
				22	32	Till
27i	24-78	NE SE Sec 2 T 97 R 39	1383	0	11	Soil
				11	20	Sand & Gravel
				20	25	Till
27j	23-78	NE SE Sec 2 T 97 R 39	1383	0	4	Soil
				4	6	Clay
				6	8	Sand & Gravel
				8	10	Silt
				10	18.5	Sand & Gravel
				18.5	22	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
27k	22-78	NE SE Sec 2 T 97 R 39	1385	0	4	Soil
				4	5	Sand
				5	12	Silt, Sand
				12	18	Sand & Gravel
				18	32	Till
28	51-78	NE NE Sec 11 T 97 R 39	1385	0	4	Soil
				4	20	Sand & Gravel
				20	82	Till
28a	48-78	NW NE Sec 11 T 97 R 39	1388	0	3	Soil
				3	4	Clay
				4	18	Sand & Gravel
				18	24	Till
28b	49-78	NW NE Sec 11 T 97 R 39	1389	0	3	Soil
				3	4	Clay
				4	21	Sand & Gravel
				21	32	Till
28c	50-78	NW NE Sec 11 T 97 R 39	1389	0	5	Soil
				5	25	Sand & Gravel
				25	72	Till
				72	80	Sandy Clay
				80	90	Till
29	D54-78	NE NE Sec 12 T 97 R 39	1377	0	3	Soil
				3	4	Clay
				4	7	Sand
				7	10	Silt
				10	23	Sand & Gravel
				23	32	Till
29a	D53-78	NE NE Sec 12 T 97 R 39	1378	0	3	Soil
				3	8	Clay
				8	32	Sand & Gravel
				32	42	Till
29b	D58-78	NW NE Sec 12 T 97 R 39	1380	0	3	Soil
				3	5	Clay
				5	29	Sand & Gravel
				29	42	Till
29c	D55-78	NW NE Sec 12 T 97 R 39	1381	0	5	Soil
				5	32	Sand, S&G
				32	42	Till
29d	D52-78	NE NE Sec 12 T 97 R 39	1380	0	4	Soil
				4	17	Sand & Gravel
				17	22	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
29e	D56-78	NW NE Sec 12 T 97 R 39	1380	0	4	Soil
				4	9	Clay
				9	23	Sand & Gravel
				23	35	Till
29f	D57-88	NW NE Sec 12 T 97 R 39	1380	0	4	Soil
				4	5	Clay
				5	28	Sand & Gravel
				28	42	Till
30	125	SE NW Sec 12 T 97 R 39	1380	0	6	Soil
				6	10	Loamy sand
				10	15	Clay
30a	124	NE NW Sec 12 T 97 R 39	1377	0	4	Soil
				4	30	Sand
				30		Clay
31	35-78	NW NW Sec 7 T 97 R 38	1385	0	5	Soil
				5	15	Sand
				15	27.5	Sand & Gravel
				27.5	35	Till
31a	30-78	NW NW Sec 7 T 97 R 38	1380	0	4	Soil
				4	5	Sand
				5	19.5	Sand & Gravel
				19.5	31.5	Till
31b	33-78	SW NW Sec 7 T 97 R 38	1378	0	5	Soil
				5	17	Sand & Gravel
				17	21.5	Till
31c	32-78	SW NW Sec 7 T 97 R 38	1379	0	4	Soil
				4	16	Sand & Gravel
				16	21.5	Till
31d	31-78	NW NW Sec 7 T 97 R 38	1379	0	4	Soil
				4	8	Sand
				8	16.1	Sand & Gravel
				16.1	21.5	Till
31e	29-78	NW NW Sec 7 T 97 R 38	1382	0	3	Soil
				3	6	Sand
				6	14	Sand & Gravel
				14	19.5	Gravel
				19.5	65.4	Till
				65.4	65.7	Limestone
31f	34-78	NW NW Sec 7 T 97 R 38	1382	0	3	Soil
				3	8	Clay
				8	27.5	Sand & Gravel
				27.5	31.5	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
32	126	SW NE Sec 18 T 97 R 38	1379	0	3	Soil
				3	30	Sand
				30	32	Clay
33	127	NW SE Sec 18 T 97 R 38	1377	0	4	Soil
				4	14	Sand
				14	15	Clay
34	W3805	SE NE Sec 6 T 96 R 38	1362	0	3	Soil
				3	8	Clay
				8	11	Sand & Gravel
35	----	SW NW Sec 3 T 96 R 38	1362	0	6	Sand
				6	23.5	Sand & Gravel
				23.5	25	Gravel
35a	----	NW NW Sec 3 T 96 R 38	1359	0	2	Topsoil
				2	7	Yellow clay
				7	11	Medium sand
				11	14	Yellow clay
				14	16	Gray clay
				16	29	Sand & Gravel
				29	32	Gray clay
36	----	SW SW Sec 3 T 96 R 38	1353	0	1.5	Loam
				1.5	14	Sand
				14	18	Till
37	----	NE SE Sec 12 T 96 R 38	1335	0	8	Gumbo
				8	18	Sand & Gravel
				18	30	Till
38	----	NW SW Sec 12 T 96 R 38	1348	0	3.5	Gumbo
				3.5	7	Sand
				7	12	Clay
				12	18	Sand & Gravel
				18	80	Till
39	----	NE SE Sec 13 T 97 R 38	1364	0	2	Soil
				2	4	Clay
				4	47	Sand & Gravel
				47	65	Till
39a	----	NW SE Sec 13 T 97 R 38	1360	0	2	Soil
				2	3	Clay
				3	31	Sand & Gravel
39b	----	SE SE Sec 13 T 97 R 38	1361	0	1	Soil
				1	12	Sand
				12	40	Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
39c	----	SW SE Sec 13 T 97 R 38	1365	0	1	Soil
				1	7.5	Clay
				7.5	22	Sand & Gravel
				22	60	Till
40	----	NE NE SEC 24 T 97 R 38	1361	0	2	Soil
				2	10	Clay, Sandy clay
				10	40	Sand & Gravel
				40	80	Till
40a	----	SE NE Sec 24 T 97 R 38	1365	0	2	Soil
				2	42	Sand & Gravel, some clay
				42	70	Till
41	W14665	SE SW Sec 29 T 100 R 37	1400	0	5	U.U. Till
				5	20	Gravel
				20	25	Silt
				25	30	O.U. Till
42	W12840	SE SW Sec 10 T 98 R 37	1430	0	5	Soil
				5	10	Gravel
				10	385	Till
				385	404	Graneros shale
				404	435	Dak. Sand-stone
43	W14635	NW NW Sec 35 T 98 R 37	1400	0	5	Soil
				5	15	Gravel
				15	20	Till
				20	30	Sand & Gravel
				30	65	Sand
44	----	NE NW Sec 19 T 97 R 37	1360	0	1	Soil
				1	4	Clay
				4	25	Sand & Gravel
				25	26	Till
44a	----	SW NW Sec 19 T 97 R 37	1359	0	2	Clay
				2	6	Clay and gravel
				6	42	Sand & Gravel
				42	70	Till
45	W10639	SW NW Sec 34 T 97 R 37	1341	0	30	Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
45A	B-1	NW NW NW Sec 34 T 97 R 37	1339.6	0	8.5	Med-f sd, crs gravel
				8.5	36	Glacial Clay
				36	41	Med-crs Sand & Gravel, clay
				41	60	Gray glacial clay
45B	B-10	NW NE NE Sec 34 T 97 R 37	1322	0	1	Topsoil
				1	3.5	Lt brown silty clay
				3.5	12	Sd, crs gravel
				12	23	Sand & gravel
				23	32	Sand
				32	37	Glacial clay
46	9-78	NW NE Sec 2 T 96 R 37	1324	0	2	Soil
				2	5	Clay
				5	30	Sand, Sand & Gravel
				30		Till
46a	3-78	SW NE Sec 2 T 96 R 37	1315	0	5	Soil
				5	7	Clay
				7	17	Sand & Gravel
46b	1-78	SW NW NE Sec 2 T 96 R 37	1320	0	3	Topsoil
				3	7	Clay
				7	57	Sand
				57	58	Cobbles, gravel
				58	80	Till
46c	2-78	NE SW NE Sec 2 T 96 R 37	1325	0	3	Soil
				3	5	Clay
				5	28	Sand
				28	31	Clay
				31	48	Sand
				48	80	Till
46d	11-78	NE SW NW Sec 2 T 96 R 37	1324	0	2	Soil
				2	4	Clay
				4	7	Sand
				7	27	Sand & Gravel
				27	52	Silt, till
				52	58	Sand
				58	70	Till
46e	6-78	NW NE NW Sec 2 T 96 R 37	1328	0	2	Soil
				2	3	Clay
				3	15	Sand
				15	42	Sand & Gravel
				42	80	Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
46f	B-1	NW NW NW Sec 2 T 96 R 37	1329	0	3	Soil
				3	4	Clay
				4	10	Sand & Gravel
				10	20	Clay
				20	41	Sand & Gravel
				41	45	Glacial Clay
46g	B-2	NE SE SW Sec 2 T 96 R 37	1316	0	4	Soil
				4	12	Clay
				12	15	Sand & Gravel
				15	36	Glacial Clay
46h	B-4	SE SW NE Sec 2 T 96 R 37	1313	0	4	Soil
				4	9	Sand
				9	31	Glacial Clay
46i	B-5	SW NE NW Sec 2 T 96 R 37	1323	0	2	Soil
				2	14	Clay
				14	17	Sand
				17	22	Silty Clay
				22	39	Sand
				39		Glacial Clay
46J	B-6	NW NE NE Sec 2 T 96 R 37	1323	0	7	Soil
				7	12	Sand
				12	29	Silty clay
				29	42	Sand
				42	47	Glacial clay
46k	B-7	NW NE NW Sec 2 T 96 R 37	1328	0	3	Soil
				3	16	Sand
				16	22	Silty clay
				22	34	Sand
46l	B-2	NW NE NW Sec 2 T 96 R 37	1321.1	0	4	Soil
				4	10	Silt
				10	42	Sand & Gravel
				42	47	Clay
46m	A	SE SW NW Sec 2 T 97 R 37	1323	0	1	Soil
				1	3	Clay
				3	8	Sand & Gravel
				8	65	Silty clay, Sd lenses 55-65
				65	66	Crs Sd, Boulders
				66	80	Clay
46n	E	SE SW NE Sec 2 T 96 R 37	1320	0	1	Soil
				1	4	Clay
				4	23	Sand
				23	80	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
46o	H	SW NE NW Sec 2 T 96 R 27	1324	0	1	Soil
				1	3	Clay
				3	12	Sand & Gravel
				12	37	Clay
				37	80	Sdy Clay
46p	I	SW NW NW Sec 2 T 96 R 37	1327	0	1	Soil
				1	3	Clay
				3	11	Sand & Gravel
				11	28	Clay
				28	43	Sand & Gravel
				43	80	Sandy Clay
46q	K	SW SW NW Sec 2 T 96 R 37	1331	0	1	Soil
				1	3	Clay
				3	4	Sand
				4	24	Sand & Gravel
				24	39	Clay
				39	45	Slight Clay, f. sand
				45	80	Sand & Gravel
				80	90	Clay
46r	O	SE SW NW Sec 2 T 96 R 37	1328	0	1	Soil
				1	3	Clay
				3	8	Sand & Gravel
				8	76	Silty clay
				76	80	Sandy clay
47	B-3	NW SE Sec 2 T 96 R 37	1320	0	3.5	Soil
				3.5	11.5	Clay
				11.5	19.5	Sand
				19.5		Till
48	102	NE NW Sec 2 T 96 R 37	1329	0	3	Soil
				3	68	S & G
48a	K	SW NW Sec 2 T 96 R 37	1329	0	1	Soil
				1	3	Clay
				3	24	Sand, Sand & Gravel
				24	45	Silty clay
				45	80	Sand & Gravel
				80	90	Sandy clay
48b	10-78	SE NW Sec 2 T 96 R 37	1324	0	2	Soil
				2	4	Clay
				4	27	Sand & Gravel
				27		Till

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
49	8-78	NW NE Sec 3 T 96 R 37	1332	0	1.5	Soil
				1.5	4	Sandy clay
				4	17	Sand, Sand & Gravel
				17	32	Till
				32	38	Sand & Gravel
				38	70	Till
49a	5-78	SE NE Sec 3 T 96 R 37	1329	0	1	Soil
				1	2	Clay
				2	14	Sand & Gravel
				14	60	Till
49b	P	SE NE SE Sec 3 T 97 R 37	1333	0	2	Soil
				2	3	Clay
				3	15	Sand & Gravel
				15	80	Clay
49c	R	SW NE NE Sec 3 T 97 R 37	1331	0	2	Clay
				2	3	Clay
				3	13	Sand & Gravel
				13	30	Clay
				30	49	Sand & Gravel
				49	65	Clay
				65	68	Sand
				68	80	Sandy Clay
49d	S	SE NE NE Sec 3 T 97 R 37	1332	0	2	Soil
				2	3	Clay
				3	11	Sand & Gravel
				11	34	Clay
				34	46	Sand & Gravel
				46	62	Sandy Clay Sd lenses 58-61 Boulders 57
				62	64	Sand
				64	80	Sandy Clay
49E	4-78	SE SE NE Sec 3 T 96 R 37	1331	0	1.5	Soil
				1.5	3	Clay
				3	45	Sand
				45	68	Sand & Gravel
				68	80	Till
50	TW1	SE SE Sec 3 T 96 R 37	1332	0	1.5	Soil
				1.5	4	Clay
				4	32	Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
50a	TW2	SW SE Sec 3 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	7	Sand
				7	25	Sand & Gravel
				25	30	Coarse sand
				30	41.5	Coarse S&G
50b	TW3	SW SE Sec 3 T 96 R 37	1331	0	1	Soil
				1	3	Sand
				3	35	Sand & Gravel
50c	B-4	SE SE SE Sec 4 T 96 R 37	1334.2	0	1	Topsoil
				1	33	Sand & Gravel
				33	42	Glacial clay
51	14	NW NE Sec 6 T 96 R 37	1350	0	1	Soil
				1	3	Clay
				3	24.5	Sand & Gravel
				24.5	29.5	Till
52	10	NW SE Sec 6 T 96 R 37	1342	0	30	Sand & Gravel
				30	35	Sand
52a	12	NE SE Sec 6 T 96 R 37	1341	0	1	Soil
				1	2.5	Clay
				2.5	27	Sand & Gravel
				27	32	Till
52b	13	SE SE Sec 6 T 96 R 37	1340	0	1	Soil
				1	2	Clay
				2	28	Sand & Gravel
				28	32	Till
52c	11	NE SE Sec 6 T 96 R 37		0	1	Soil
				1	3	Clay
				3	25	Sand & Gravel
				25	30	Till
53	W15207	NE NE Sec 9 T 96 R 37	1338	0	2	Soil
				2	17	Sand & Gravel
53a	CB1	SW NW Sec 9 T 96 R 37	1334	0	2	Soil
				2	3	Clay
				3	31	Sand & Gravel
				31	58	Clay
				58	63	Sand, clay
				63	74	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
53b	CB2	SW NW Sec 9 T 96 R 37	1334	0	1	Soil
				1	3	Clay
				3	23	Sand & Gravel
				23	48	Clay
				48	50	Sand
				50	59	Clay
				59	63	Sd, Sand & Gravel
				63	74	Clay
53c	CB4	SW NW Sec 9 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	32	Sand & Gravel
				32	52	Clay
				52	64	Clay, some Sand & Gravel
				64	90	Clay
53d	CB5	SW NW Sec 9 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	26	Sand & Gravel
				26	27	Clay
				27	31	Sand & Gravel
				31	80	Clay
53e	CB6	NW SW Sec 9 T 96 R 37	1334	0	1	Soil
				1	3	Clay
				3	25	Sand & Gravel
				25	80	Clay some sand lenses
53f	CB7	NE SW Sec 9 T 96 R 37	1332	0	2	Soil
				2	3	Clay
				3	29	Sand & Gravel
				29	74	Sandy clay
53g	CB8	NE SW Sec 9 T 96 R 37	1332	0	1	Soil
				1	2	Clay
				2	32	Sand & Gravel
				32	35	Clay
				35	39	Sand
				39	45	Clay
				45	47	Sand & Gravel
				47	80	Clay some sand lenses
53h	CB9	NE SW Sec 9 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	31	Sand & Gravel
				31	44	Sandy clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
53i	CB10	NE SW Sec 9 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	31	Sand, Sand & Gravel
				31	44	Sandy clay
53j	CB11	NE SW Sec 9 T 96 R 37	1333	0	2	Soil
				2	3	Clay
				3	27	Sand & Gravel, Boulders 22-24
				27	29	Clay
				29	31	Sand & Gravel
				31	50	Clay
53k	CB12	NE SW Sec 9 T 96 R 37	1333	0	2	Soil
				2	4	Clay
				4	26	Sand & Gravel
				26	28	Clay
				28	31	Sand & Gravel
				31	61	Clay some sand lenses
53l	CB13	NE SW Sec 9 T 96 R 37	1333	0	2	Soil
				2	3	Clay
				3	32	Sand & Gravel Bld @ 26
				32	44	Sandy clay
53m	CB14	NW SW Sec 9 T 96 R 37	1334	0	2	Soil
				2	4	Clay, sand
				4	32	Sand & Gravel
				32	50	Sandy clay
53n	CB15	NW SW Sec 9 T 96 R 37	1334	0	2	Soil
				2	4	Clay, sand
				4	32	Sand & Gravel
				32	34	Clay
				34	35	Sand
				35	44	Clay
				44	48	Sand
				48	51	Sandy clay
53o	CB16	NW SW Sec 9 T 96 R 37	1333	0	2	Soil
				2	4	Clay
				4	31	Sand & Gravel
				31	40	Clay
				40	45	Sand & Gravel
				45	51	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
53p	CB17	SE SW Sec 9 T 96 R 37	1332	0	2	Soil
				2	3	Clay
				3	30	Sand & Gravel
				30	44	Sandy clay
53q	CB18	SW SW Sec 9 T 96 R 37	1334	0	2	Soil
				2	4	Sand, clay
				4	32	Sand & Gravel, coarsening dow
				32	51	Clay
53r	CB19	SW SW Sec 9 T 96 R 37	1334	0	2	Soil
				2	3	Clay
				3	33	Sand and grave coarsening dow boulders at 3
				33	54	Sandy clay
53s	CB20	SW SW Sec 9 T 96 R 37	1333	0	2	Soil
				2	4	Clay
				4	33	Sand & Gravel
				33	51	Clay
53t	CB21	SW SE Sec 9 T 96 R 37	1333	0	2	Soil
				2	4	Clay
				4	31	Sand & Gravel
				31	51	Sandy clay
54	W15879	NE NE Sec 10 T 96 R 37	1322	0	5	Soil
				5	37	Gravel
				37	50	U.U. Till
54a	CB22	SE NE Sec 10 T 96 R 37	1331	0	2	Soil
				2	3	Clay
				3	33	Sand & Gravel
				33	55	Clay
				55	59	Sand & Gravel
				59	62	Clay
				62	63	Sand & boulders
				63	120	Clay, Sand & Gravel lag
54b	CB23	SW NE Sec 10 T 96 R 37	1332	0	1	Soil
				1	2	Clay
				2	29	Sand & Gravel
				29	50	Sandy clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
54c	CB24	SW NE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	35	Sand & Gravel
				35	42	Clay, gravel
				42	43	Sand
				43	50	Clay, gravel
54d	CB25	SW NE Sec 10 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	35	Sand & Gravel
				35	36	Clay, gravel
				36	43	Sand & Gravel
				43	120	Clay, some sand lenses
54e	CB26	NE NE SE Sec 10 T 96 R 37	1332	0	3	Soil
				3	5	Clay
				5	30	Sand & Gravel
				30	40	Clay
54f	CB27	SE NE Sec 10 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	40	Sand & Gravel
				40	50	Clay
54g	CB28	SW NE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	25	Sand & Gravel
				25	57	Clay
				57	62	Sand
				62	80	Clay, Sand & Gravel
				80	118	Clay, bld @ 102
				118	137	Sand
				137	148	Clay, sand lens
				148	160	Shale
54h	CB29	NW SE Sec 10 T 96 R 37	1331	0	1	Soil
				1	3	Clay
				3	29	Sand & Gravel
				29	50	Clay
54i	CB30	NE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	29	Sand & Gravel
				29	48	Clay, Sand & Gravel
				48	50	Sand
				50	70	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
54j	CB31	NW SE Sec 10 T 96 R 37	1329	0	1	Soil
				1	3	Clay
				3	35	Sand & Gravel
				35	50	Sandy clay
54k	CB32	NW SE Sec 10 T 96 R 37	1330	0	1	Soil
				1	3	Clay
				3	26	Sand & Gravel
				26	40	Sandy clay
54l	CB33	NE SE Sec 10 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	27	Sand & Gravel
				27	32	Clay w/ pebbles
				32	40	Clay
54m	CB34	SE SE Sec 10 T 96 R 37	1333	0	1	Soil
				1	3	Clay
				3	38	Sand & Gravel, clay lens at 35
				38	50	Clay
54n	CB35	SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	2	Clay
				2	29	Sand & Gravel
				29	50	Clay
54o	CB36	SW SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	36	Sand & Gravel
				36	50	Sandy clay
54p	CB37	SW SE Sec 10 T 96 R 37	1329	0	1	Soil
				1	3	Clay
				3	29	Sand & Gravel
				29	30	Clay
				30	36	Sand & Gravel
				36	50	Sandy clay
54q	CB38	SW SE Sec 10 T 96 R 37	1330	0	1	Soil
				1	3	Clay
				3	36	Sand & Gravel
				36	50	Clay
54r	CB39	SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	2	Clay
				2	35	Sand, Sand & Gravel
				35	50	Silty clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
54s	CB40	SE SE Sec 10 T 96 R 37	1333	0	1	Soil
				1	2	Sandy soil
				2	4	Sand
				4	36	Sand & Gravel
				36	40	Clay
54t	CB41	SE SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	4	Clay
				4	36	Sand & Gravel
				36	54	Silty clay
54u	CB42	SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	40	Sand & Gravel
				40	50	Sandy clay
54v	CB43	SW SE Sec 10 T 96 R 37	1331	0	1	Soil
				1	3	Clay
				3	37	Sand, Sand & Gravel
				37	50	Sandy clay
54w	CB44	SW SE Sec 10 T 96 R 37	1328	0	1	Soil
				1	3	Clay
				3	37	Sand, Sand & Gravel
				37	50	Sandy clay
54x	CB45	SW SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Sandy clay
				3	20	Sand
				20	21	Clay
				21	39	Sand & Gravel
				39	54	Sandy clay
54y	CB46	SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	41	Sand & Gravel
				41	51	Sandy clay
				51	55	Sand & Gravel
				55	64	Sandy clay
54z	CB47	SE SE SE Sec 10 T 96 R 37	1332	0	1	Soil
				1	3	Clay
				3	43	Sand, Sand & Gravel
				43	54	Sandy clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
55	TW5	NW SW Sec 11 T 96 R 37	1321	0	2.5	Soil
				2.5	7	Sand
				7	22	Sand & Gravel
				22	27	Sand
55a	B-3	SW NE Sec 11 T 96 R 37	1321.1	0	4	Soil
				4	10	Silt
				10	42	Sand & Gravel
				42	47	Clay
55b	B-8	NW NW SW Sec 11 T 96 R 37	1327.2	0	1	Soil
				1	28	Sand
				28	41	Sand & Gravel
				41	42	Clay
55c	B-9	NE SE Sec 11 T 96 R 37	1321.6	0	3	Soil
				3	30	Sand & Gravel
				30	37	Clay
55d	B-2	SW SW NE Sec 11 T 96 R 37	1322	0	3	Soil
				3	5	Sand
				5	12	Silty clay
				12	32	Sand
				32	34	S & G
				34	37	Silty clay
55e	B-3	SE NW Sec 11 T 96 R 37	1318	0	3	Soil
				3	7	Sand
				7	27	Sand & Gravel
				27	30	Clay
55f	B-4	NE NE SW Sec 11 T 96 R 37	1332	0	2	Soil
				2	27	Sand & Gravel
				27	29	Clay
55g	B-5	NE SW Sec 11 T 96 R 37	1320	0	2	Soil
				2	3	Clay
				3	12	Sand & Gravel
				12	15	Silty clay
				15	21	Sand & Gravel
				21	25	Clay
55h	B-6	NW NE SW Sec 11 T 96 R 37	1320	0	4	Soil
				4	12	Sand & Gravel
				12	22	Silty clay, sand lenses
				22	25	Clay
56	W15622	NW NW Sec 15 T 96 R 37	1331	0	5	Soil
				5	25	Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
57	W12499	SW SW Sec 6 T 96 R 36	1330	0	5	Loess
				5	430	Till
				430	485	Gravel
				485	950	Paleozoic Rock LS, Sh, SS
57a	W10645	SW SW Sec 6 T 96 R 36	1325	0	40	Gravel
				40	45	Till
58	W4433	NW SW Sec 7 T 96 R 36	1320	0	10	Soil, Fill
				10	31	Sand
				31	32	Till
59	W7133	SW SW Sec 8 T 96 R 36	1314	0	5	Soil
				5	40	Sand & Gravel
				40	43	Till
59a	W10400	SW SE Sec 8 T 96 R 36	1313	0	2	Soil
				2	11	Sand
				11	37.5	Gravel
				37.5	356	Till
				356	462	Gravel
				462		Paleozoic rock
59b	W11923	SE SW Sec 18 T 96 R 36	1301	0	2	Soil
				2	15	Gravel
				15	185	Till
				185	275	Cretaceous shale
				275	315	Cretaceous Dak. SS
60	W8408	SE SW Sec 18 T 96 R 36	1309	0	5	Soil
				5	50	Gravel
61	----	SW NE Sec 25 T 96 R 36	1300	0	2	Soil
				2	23	Clay, some S & G
				23	40	Sand & Gravel
				40		Till
62	W12819	SW SW Sec 4 T 93 R 36	1295	0	5	Soil
				5	15	Loess
				15	20	Gravel
				20	30	U. U. Till
63	----	SW SW Sec 6 T 93 R 37	1252	0	28	Soil, Sand & Gravel

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
64	----	SE SE Sec 6 T 93 R 37	1252	0	2	Soil
				2	10	Clay
				10	15	Sand
				15	38	Sand & Gravel
				38	40	Till
65	----	NW NW Sec 8 T 93 R 37	1240	0	35	Soil, Sand & Gravel
66	----	NE SW Sec 23 T 94 R 39	1213	0	5	Soil
				5	8	Blue mud
				8	31	Gravel
				31		Clay
67	----	SE SE SW Sec 23 T 94 R 39	1215	0	5	Soil
				5	10	Clay
				10	15	Sand, clay
				15	17	Mud
				17	44	Course gravel
				44		Blue clay
68	----	SE NE SW Sec 23 T 94 R 39	----	0	2	Soil
				2	15	Sand clay
				15	18	Clay, gravel
				18	34	Coarse gravel
				34		Blue clay
69	----	SE SE SE Sec 23 T 94 R 39	1213	0	6	Soil
				6	10	Clay
				10	15	Fine sand
				15	38	Gray gravel
				38		Rock
70	----	SW NW NW Sec 25 T 94 R 39	1213	0	2	Soil
				2	12	Clay
				12	20	Rusty gravel
				20	47	Gravel
				47		Blue clay
71	----	SW SE SE SW Sec 24 T 94 R 39	----	0	2	Soil
				2	12	Clay
				12	34	Rocks, gravel
				34		Blue Clay
72	----	SE SE SW Sec 24 T 94 R 39	1215	0	6	Soil
				6	10	Clay
				10	15	Mud
				15	25	Clay

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
73	----	NE SE SW SE Sec 24 T 94 R 39	1222	0	2	Soil
				2	15	Mud
				15	18	Rusty gravel
				18	21	Clay
74	----	NE NW NE Sec 25 T 94 R 39	1212	0	6	Soil
				6	12	Clay, mud
				12	43	Clay, gravel
				43		Clay
75	----	SE SE NW Sec 27 T 94 R 39	1222	0	5	Soil
				5	15	Yellow clay
				15		Blue clay
76	----	SE NW SE Sec 27 T 94 R 39	----	0	6	Soil
				6	15	Clay
				15	42	Red rusty gravel
				42		Boulders
77	----	SW NE SE Sec 27 T 94 R 39	1218	0	6	Soil
				6	9	Sand
				9	40	Clay
78	W12854	NE SE SW Sec 24 T 92 R 40	1189	0	5	Soil
				5	22	Gravel
79	W12538	NW SW SW Sec. 26 T 92 R 40	1194	0	10	Soil
				10	15	Gravel
				15	100	Till
				100	210	Dak. SS
				210	212	Dak. Sh
80	W12568	NW SE SE Sec 27 T 92 R 40	1194	0	15	Soil
				15	40	Gravel
				40	55	Till
81	----	SE SW SW Sec 26 T 92 R 40	1175.5	0	16	Soil
				16	38	Sand & Gravel
				38	50	Till
				50	80	Sand
				80	200.5	SS
82	W10455	NE NE SE Sec 34 T 92 R 40	1170	0	5	Soil
				5	25	Gravel
				25	140	Till
				140	145	Gravel
				145	255	Cretaceous Dak. SS/Sh
				255	259	Chert

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
83	----	NW NE SW Sec 34 T 92 R 40	1192	0	3	Cinder
				3	4	Soil
				4	27.5	Sand & Gravel
				27.5	91	Till
				91	120	Sand & Gravel, Till
				120	148	Till
				148	196	Sand
				196	222	SS
				222	250	Sh
84	W23095	SE SW Sec 34 T 92 R 40	1193	0	3	Soil
				3	5	Sand & Gravel
				5	100	Till
				100	150	Till, sand
				150	255	Sand, till
				255	270	Cretaceous chert
85	W16819	SW NE NW Sec 3 T 91 R 40	1215	0	7	Soil
				7	10	Sand & Gravel
				10	120	Till
				120	175	Shale
				175	250	SS
				250	260	Chert
86	----	SE NW Sec 3 T 91 R 40	1215	0	2	Soil
				2	10	Sand & Gravel
				10	115	Till
				115	175	Shale
				175	265	SS
87	----	SW SW NE Sec 3 T 91 R 40	1220	0	6	Soil
				6	110	Till
				110	115	SS
				115	153	Shale
				153	253	SS, Sh
				253	255	Chert
88	W8995	SW SW Sec 16 T 90 R 41	1180	0	2	Soil
				2	15	Sand
				15	80	Till
				80	100	Silt
				100	180	Sand

Map Location	Other Designation	Location	Elevation ft.	From	To	Lithology
89	W8854	SE SE SE SE Sec 34 T 88 R 42	1129	0	5	Silt
				5	10	N/S
				10	20	Sand
				20	30	Gravel
				30	105	Till
				105	148	Sand
				148	153	Shale
				153	185	SS
				185	187	Shale
90	W1302	NW SW SE Sec 32 T 88 R 43	1130	0	25	Loess
				25	50	Sand & Gravel
				50	95	Till
				95	160	S & G

Part II.

Sand and Gravel Pit Information
Bridge Borings

Map Location	Location	From	To	Lithology
A	Section 30 T 100 R 40	0	4	Clay
		4	10	Gravel
B	Section 31 T 100 R 40	0	6	Clay
		6	14	Sand, Gravel and Till
C	Section 9/16 T 99 R 40	0	1	Overburden
		1	6	Gravel
		6		Clay
D	Section 5/8 T 99 R 40	0	8	Clay Fill
		8	14	Silty Clay
		14	16	Sand and Gravel
		16		Glacial Clay
E	Section 23 T 99 R 40	0	6	Clay
		6	7	Gravel
F	Section 1/2 T 97 R 39	0	10	Silty Clay
		10	15	Clayey Sand
		15	18	Silty Clay
		18	24	Silty Glacial Clay
		24	36	Sandy Glacial Clay
		36	42	Glacial Clay
G	Section 1/2 T 97 R 39	0	2.2	Clay
		2.2	5.2	Sandy Clay
		5.2	14.2	Clay
		14.2	18.2	Sand and Gravel
		18.2	37.2	Till
H	NE Section 11 T 96 R 38	0	6	Soil
		6	13	Sand and Gravel
I	Section 1/6 T 96 R 38/37	0	5	Clay
		5	20	Sand and Gravel
		20		Till
J	Section 7 T 96 R 37	0	15	Clay
		15	21	Sand and Gravel
		21		Till
K	Section 8/17 T 97 R 37	0	9	Sandy clay
		9	18	Sand and Gravel
		18	43	Till
		43	55	Sand and Gravel
L	Section 27/34 T 97 R 37	0	6	Clay
		6	12	Sand and Gravel
		12	43	Till

Map Location	Location	From	To	Lithology
M	Section 11 T 96 R 37	0 19 28	19 28	Clay Sand and Gravel Till
N	Section 15/16 T 96 R 37	0 13 36	13 36	Clay Sand and Gravel Till
O	Section 16/17 T 96 R 36	0 13 19	13 19 51	Clay Sand and Gravel Clay
P	Section 15 T 96 R 36	0 4	4 24	Soil Sand and Gravel
Q	Section 15/22 T 96 R 36	0 12.5 20.5	12.5 20.5 53	Clay Sand and Gravel Clay
R	Section 2/35 T 95/96 R 36	0 15	15	Sandy clay Till
S	Section 34/35 T 95 R 36	0 5 20	5 20	Clay Gravel Till
T	Section 17/20 T 94 R 36	0 6 12 31 32.5	6 12 31 32.5 59.5	Clay loam Silty sand Gravelly sand Gravel Clay
U	Section 35 T 92 R 40	0 14.5 23 56 59.5 82	14.5 23 56 59.5 82 90	Bridge floor to water Sandy clay Coarse bouldery sand Boulders Till Coarse sand
V	Section 34 T 92 R 40	0 3 7 15 30	3 7 15 30 50.5	Sandy clay Fine sand Sandy clay Sand Gravel
W	Section 34 T 89 R 42	0 3.5 10.5 18.4 23.5 58.2 59.6	3.5 10.5 18.4 23.5 58.2 59.6 67.0	Silt Silty clay Silty sand Sand Gravel, boulders Boulders Till

Map Location	Location	From	To	Lithology
X	Section 21 T 88 R 43	0	2.5	Silty clay
		2.5	21	Silt
		21	23.8	Gravelly sand and silt
Y	Section 33 T 88 R 43	0	3.2	Sandy loam
		3.2	13.7	Sandy clay
		13	20	Clayey sand
		20	32	Sand and gravel, clay
		32	47	Sand and gravel
Z	Section 6/7 T 86 R 43	1086.44	1061.34	Bridge floor to water
		1061.34	1058.24	Water
		1058.24	1056.44	Silt
		1056.44	1048.44	Sand and gravel
		1048.44	1043.94	Gravel, sand
		1043.94	1040.94	Boulders
		1040.94	1030.44	Bouldery gravel
		1030.44	1025.44	Gravel
		1025.44	1020.44	Boulders
		1020.44	1002.41	Bouldery gravel

APPENDIX B

Seismic Refraction

Seismic refraction methods have been commonly used by engineers and geologists for shallow subsurface investigations. Details of seismic refraction theory can be found in general geophysical exploration texts such as Dobrin (1976) and Musgrave (1967). Seismic refraction theory is based on the fact that sound waves travel at different velocities through different earth materials. An energy source (hammer blow, explosive) is used to generate sound waves which propogate through earth materials. These waves are bent (refracted) at the contacts between different velocity layers of earth materials, and then travel horizontally just below the contact. As the waves propagate along the contact they are continually refracted back to the surface. Figure B-1 schematically shows the raypaths followed by refracted sound waves in an ideal alluvial system.

For field measurements, a set of receivers (geophones) is placed at uniform distances from the seismic source. These receive the refracted energy created by the source, and create a continuous trace on the seismograph record. A distinct break occurs on the seismic trace at the time of arrival of the first wave (Fig. B-2). Geophones closest to the source may receive direct wave arrivals, those traveling directly along the land surface (path A-B-E-H on Fig. B-1). The first energy received by the geophones furthest from the source is from the second layer along path A-C-D-E. Even though the distance along path A-E at the surface is shorter, the waves traveling the segment C-D are accelerated and will arrive first. More distant geophones in the line will receive energy from the till layer along path A-J-K-L. The arrival time information, recorded by a seismograph, and the distance of the geophone from the source, can be used to plot the relationship of time versus distance (Fig. B-3). This is used to calculate average layer velocities.

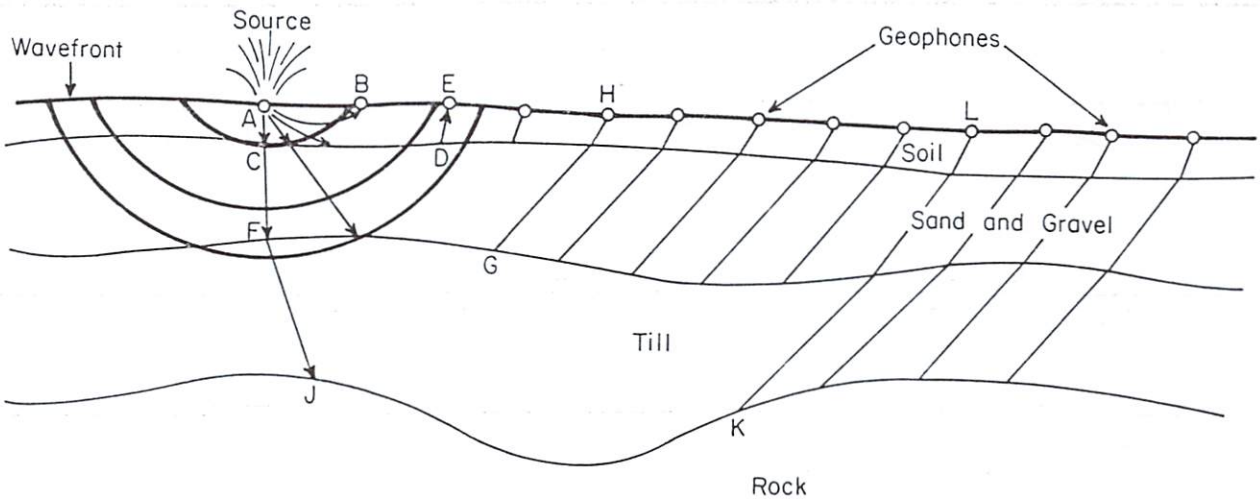


Figure B-1. Schematic of sound wave propagation through a typical alluvial sequence. Letters refer to discussion in text.

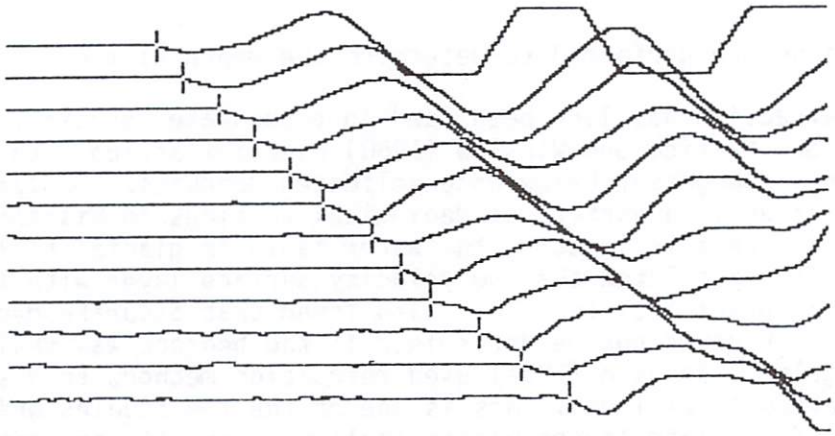


Figure B-2. Typical seismogram. Tic marks indicate time of arrival of wave on each channel.

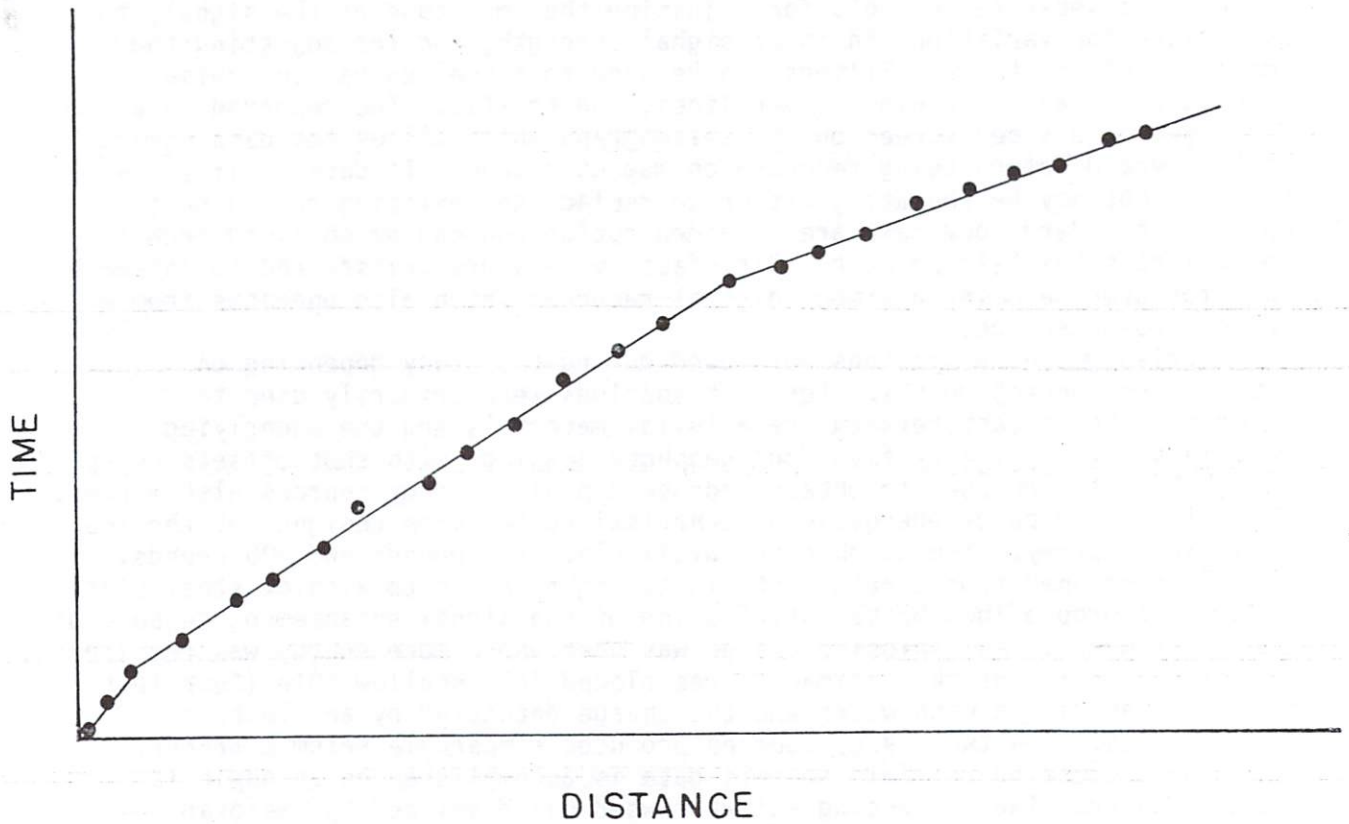


Figure B-3. Idealized time-distance graph. Each slope segment represents refractions from a particular interface. The velocity of the unit is equal to the inverse of the slope.

Other calculations are performed to determine the depth of the refracting surface.

Seismic refraction has long been used in groundwater studies. Bonini and Hickock (1958) and Warrick and Winslow (1960) used refraction methods to delineate bedrock topography below unconsolidated deposits. Woolard and Hanson (1954) worked in a variety of geological settings in Wisconsin, and had relatively good success in locating the water table in glacial till. McGinnis and Kempton (1961) correlated the low velocity surface layer with the geologic weathered zone in glacial tills. They also found that accurate depth to and velocity of bedrock could not be determined if the bedrock was shallow (10-20 feet) and irregular. Johnson (1954) used refraction methods to distinguish between till layers in Illinois. His is one of the few studies which attempted to differentiate layers within shallow unconsolidated materials. Staub (1969) evaluated the method of seismic refraction to solve geologic problems in Iowa. He used statistical methods to establish confidence levels on the results and to show where additional data was needed.

Equipment and Field Methods

Refraction data were collected using a Geometrics 12-channel signal-enhancement seismograph which operates from a 12-volt power source. Each channel has separate controls for adjusting the amplitude of the signal, to compensate for variations in input signal strength, and for adjusting the amplitude of the trace. Filters can be used to cancel extraneous noise, such as that caused by wind, power lines, and traffic. The recorded data are displayed on a video screen on the seismograph which allows the data quality to be checked before being recorded on magnetic tape. If data quality are poor, a shot may be repeated, either to replace the existing record or to enhance it. Hard copy data are an added option and can be obtained from the instrument's built-in printer. Satisfactory data are transferred to cassette tape for storage using a Nimbus digital recorder which also operates from a 12-volt power source.

Varied geophone spacings were used during the study depending on anticipated contact depths. Ten-foot spacings were primarily used to determine the contact between the alluvial materials and the underlying materials. Ten to fifty-five foot geophone spacings with shot offsets of up to 1,300 feet were used to obtain bedrock depths. Energy sources also varied. The primary source of energy is a mechanical weight drop designed at the Iowa Geological Survey. Two weights are available: 125 pounds and 300 pounds. These are dropped from a height of six to eight feet onto a thick steel plate. The weight drop allows better utilization of the signal enhancement feature of the seismograph. An explosive charge was used where more energy was required to reach deeper bedrock. Primacord was placed in a shallow hole (four feet) the hole was filled with water and the charge detonated by an electric blasting cap. The two energy sources produced comparable seismic traces.

The processing of field seismic data is accomplished on an Apple II microcomputer. The processing software used was developed by Exploranium/ Geometrics of Canada, and has routines for auto-picking first breaks on seismic traces, interpretation of time-distance plots, depth, unit thickness, unit velocity computation, and a generalized reciprocal method for determining unit depths on irregular surfaces. The use of a portable computer allowed processing to be accomplished in the field and immediate verification of the accuracy of the seismic field data. Adjustments to the field arrangment (geophone spacings, shot offset) were made where targeted horizons were not observed in the data.

Results and Findings

Seismic Results

Three hundred and seventy total spreads (456 shots) were run at 19 different locations (approximately 25 linear miles). Figures B-4 and B-5 show the location of each traverse.

There were considerably more problems in interpretation of the refraction data than had been anticipated. Direct wave arrivals, indicating surficial material velocities, were observed only when geophone spacings of less than 10 feet were used. Figure B-6a is a time-distance plot (T-X) showing good fit to the data and recognizable slope breaks. It was infrequent, however, that all of the points could be fit to a straight line segment. Often, the best possible fit would have required a curved surface (Fig. B-6b), which results from either an irregular refractor surface or laterally, varying velocities. Another common occurrence was displacement of time-distance segments (Fig. B-6c). McGinnis and Heigold (1974) also observed this effect, and attributed it to the presence of a stepped refracting surface at the edge of a buried valley. A third problem involves slope change. Frequently, the time-distance plot will exhibit an increase in slope which may be attributable to laterally, varying velocities (Fig. B-6b,c).

Domzalski (1956) discussed at some length the problems inherent in shallow-refraction investigations. One of his discussions concerns changes in surface material velocities caused by firing a shot, while another deals with the type of surface materials in which the geophones are placed. These effects can cause arrival times to be delayed by up to 2 milliseconds and change computed velocities by 100 feet/second. There are other problems which arise because, unlike in theory, the materials are not homogeneous or isotropic, especially in alluvial systems. There are horizontal and vertical variations in the velocity of the overburden as well as changes in thickness. Murphy (1977) used a combination of refraction and resistivity methods to study alluvial terrain in Louisiana, and found definite effects related to laterally varying velocities such as offsets and slope changes in time-distance plots. The bedrock refractor in most cases is irregular and weathered, either of which can greatly affect depth computations for shallow refractors.

A major problem, which is all too prevalent in Iowa, is the lack of sufficient velocity contrast between most unconsolidated materials. Sand and gravel (outwash material) have been observed to have velocities around 5000-6000 ft/sec. Glacial tills usually had velocities between 6000 and 8000 ft/sec. Observed bedrock velocities averaged between 7000-9000 ft/sec. -- Cretaceous sandstones and shales. Such close materials' velocities presents two problems. First, the slope break changes on time-distance curve can be very subtle and difficult to identify. Second, the necessary velocity contrasts might not be reached at the interface, but rather within a formation. This was found to occur frequently within the glacial till.

Discussion

Data from each area along the valley had unique problems and interpretations achieved various levels of accuracy. Ocheyedan 1(01) (Fig. B-7) is located just above the boundary of the Des Moines Lobe, the area of the latest Wisconsinan ice advance. Here the sands and gravels may be discontinuous or intermixed with sandy, supraglacial till. The sand and gravel is thin along the traverse. Several interfaces within the till

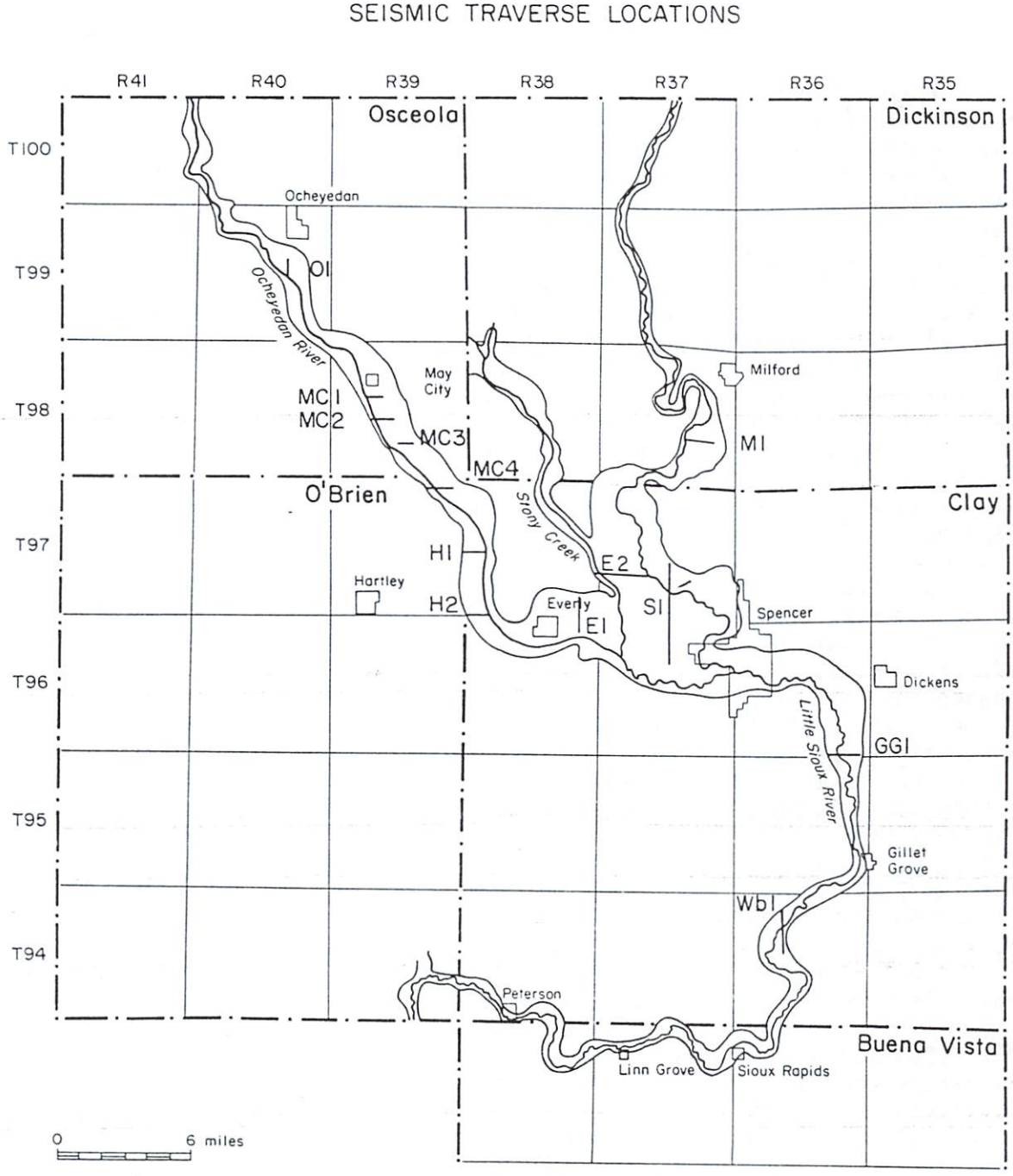


Figure B-4. Seismic traverse locations - Ocheyedan and upper Little Sioux valleys.

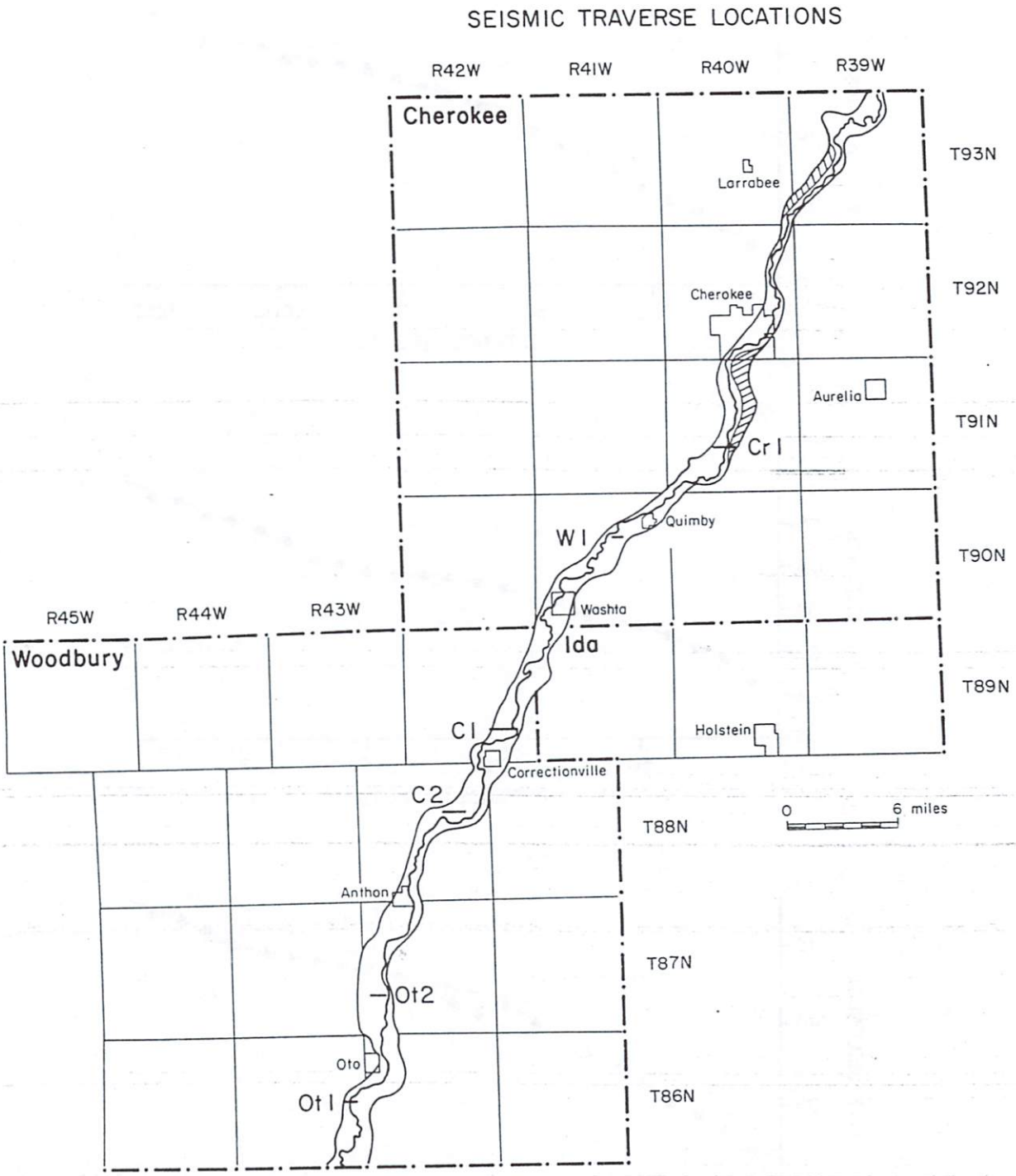
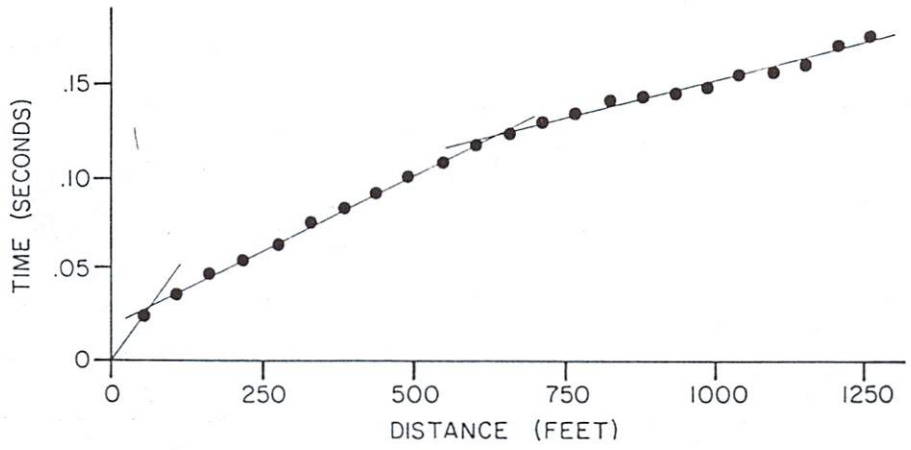
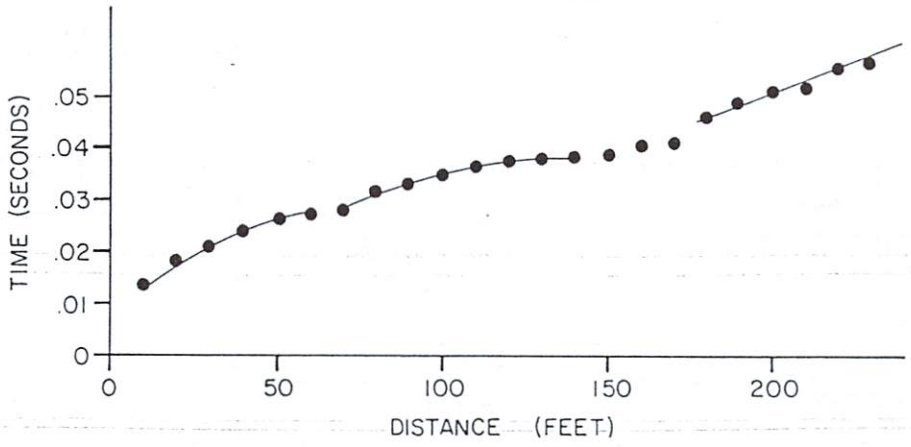


Figure B-5. Seismic traverse locations - lower Little Sioux valley.





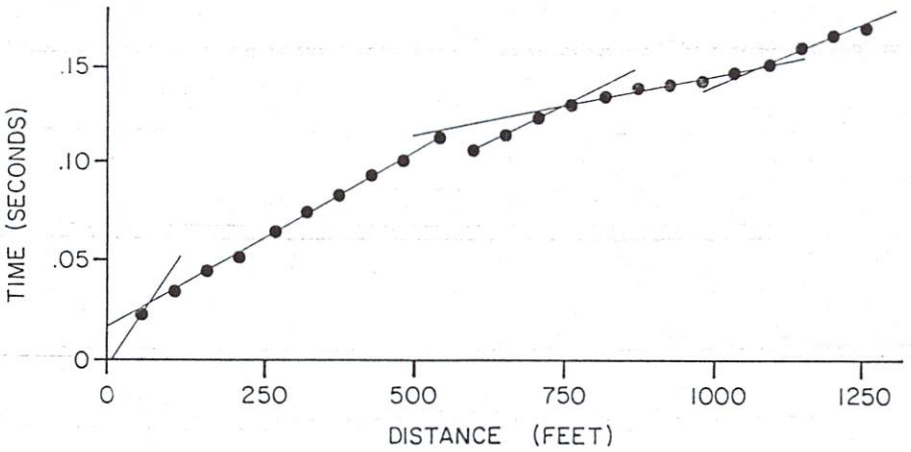


Figure B-6a,b,c. Examples of time-distance plots.

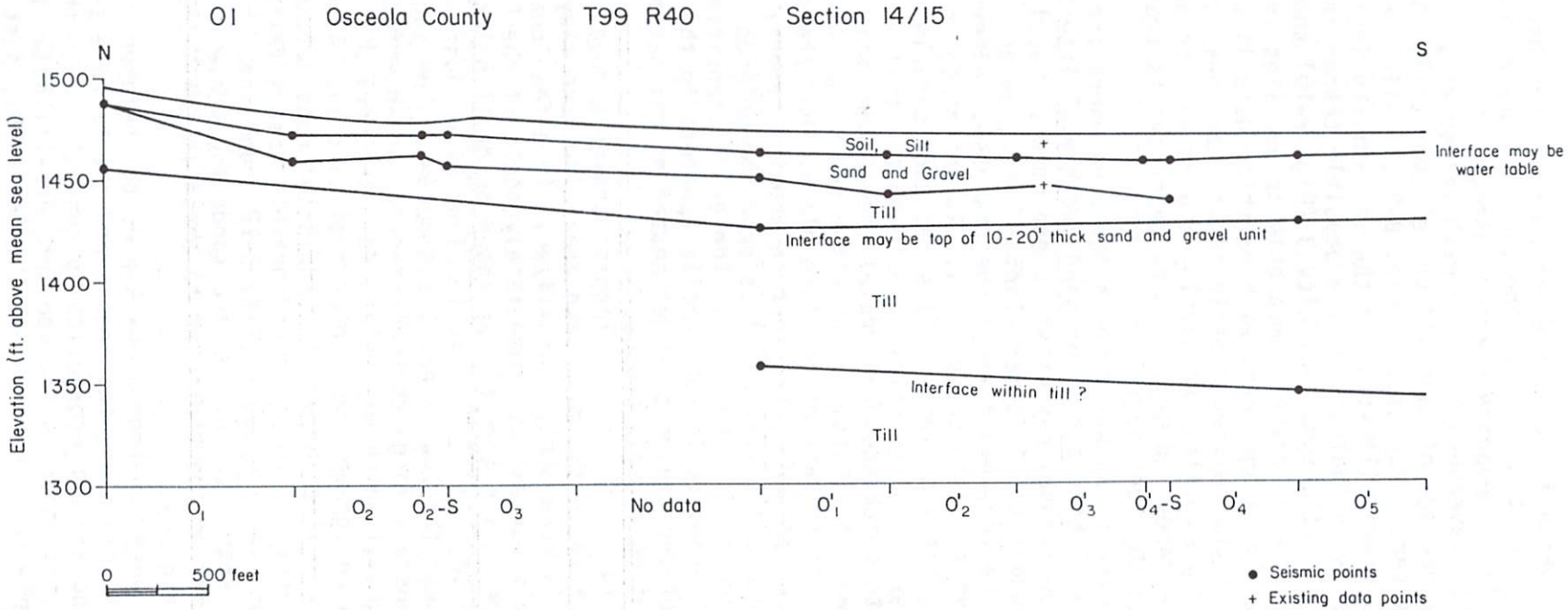


Figure B-7. Seismic profile section: Ocheyedan 1.

can be detected, which if not for existing data, may have been misinterpreted. The interface between the soil and the sand and gravel is not well defined, due in part, to the large geophone spacings used.

Below the O1 traverse a broad outwash valley exists. May City 1 (Fig. B-8) shows a thick package of sand and gravel over till. Good agreement with existing data is seen. May City 2 (Fig. B-9), a mile south of MC1, shows thinner sand and gravel illustrating the variability in thickness within the alluvium. There is an indication of a possible change in sand and gravel textures within the alluvium. May City 3 (Fig. B-10) shows a thickening and thinning of the sand and gravel comparable to profiles in present day braided outwash systems. Again agreement with existing data is good. May City 4 (Fig. B-11) also shows a channelized profile in till as does Hartley 1 (Fig. B-12). All of the May City profiles and Hartley 1 were done in an area where the valley is wide. The sands and gravels were deposited as braided outwash in a position close to the ice margin.

Hartley 2 (Fig. B-13) was done in the area where the outwash valley enters the former glacial lake plain. The sand and gravel interface is not as clearly defined and a deep channel may exist at one point. Everly 1 (E-1) (Fig. B-14) is within the boundaries of former glacial Lake Spencer. Again, a large channel may exist along the northern half of the traverse. Alternately, this may be an area of lake clays or mixed sandy tills. An interface is detectable within the till. A drilling transect west of E1 shows considerable variation in the thickness and lithology of the materials overlying the till which range from thin sand and gravel to thick sand and gravel interbedded with clay lenses. Everly 2 (Fig. B-15), between the Little Sioux River and Stoney Creek, was run across a large terrace, which is part of the lake plain. The sand and gravel varies considerably in thickness across the terrace showing several channel-like features. West of Stoney Creek, the traverse laps onto the uplands. A layer of sandy pedisediment is present on the slope. The exact transition from hillslope sediments to alluvial deposits is not readily apparent in the seismic records. However, the layer of pedisediment is delineated on the seismic records and its nature was determined by soil probes.

Spencer 1 (Fig. B-16) was the longest traverse done, approximately 4 1/2 miles, and is located in the main lake area. No lake clays were detected and the till surface is moderately channelized. In a few locations deeper sand and gravel channels may exist. Immediately south of the Little Sioux River the sand and gravel thins abruptly as shown by drill holes. Milford 1 (Fig. B-17) traverses a terrace of the Little Sioux River just below the Des Moines Lobe margin and near the Iowa Great Lakes outlet. The sand and gravel thickens to the east where a large channel exists. An interface was detected within the sand and gravel which may relate to a textural discontinuity. To the west, a thin sand and gravel rests over a silty clay. A seismic interface is seen in this unit. Gillet Gravel 1 (Fig. B-18) runs across the valley, below its southward diversion. The sand and gravel appears fairly uniform, but two till interfaces are seen. Webb 1 (Fig. B-19) runs from the floodplain onto a preserved terrace segment. The terrace sands and gravels are highly variable in thickness and may not be connected to those in the floodplain. Two till interfaces are again seen.

No traverses were run from Sioux Rapids to Cherokee. Little access to the river area is available along this reach and the terrace segments sit high above the river and are not hydraulically connected with the floodplain. Below Cherokee, the valley, which is incised into Pre-Illinoian tills, is broad and linear with multiple terraces. Washta 1 (Fig. B-20), just above Washta, runs across a low terrace. The sand and gravel is thin and one interface within the till is seen. Correctionville 1 (Fig. B-21) shows a thin sand and gravel over-

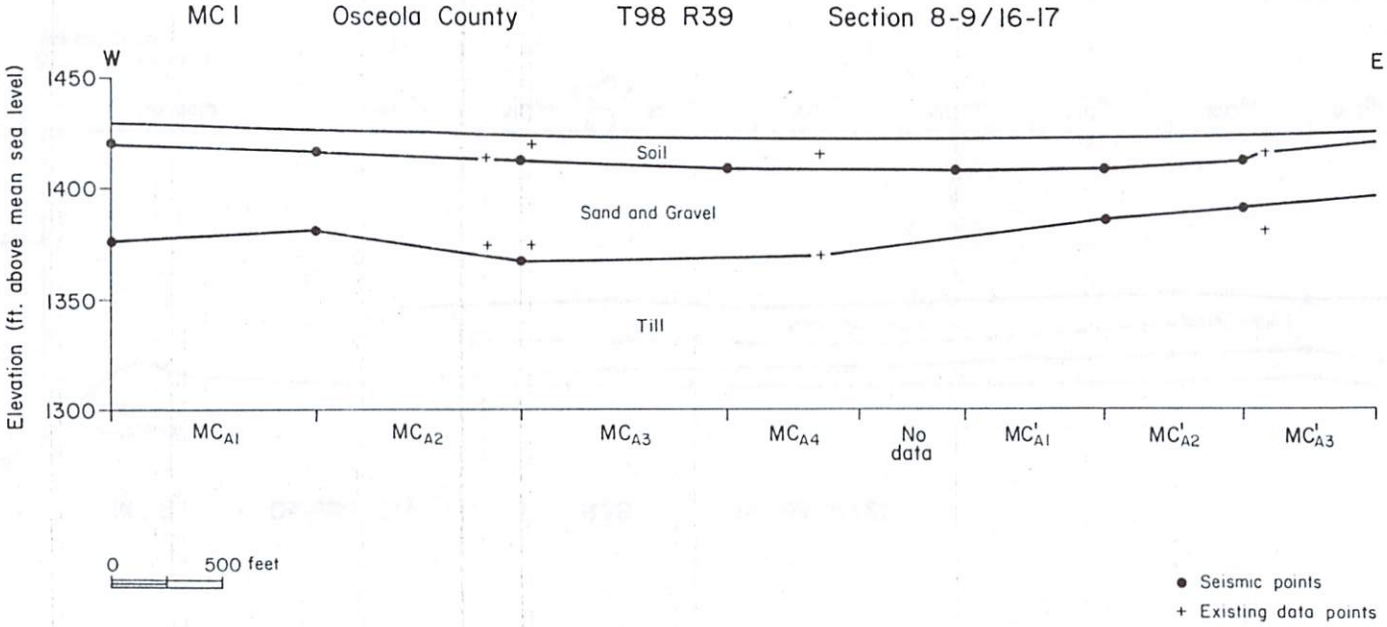


Figure B-8. Seismic profile section: May City 1.

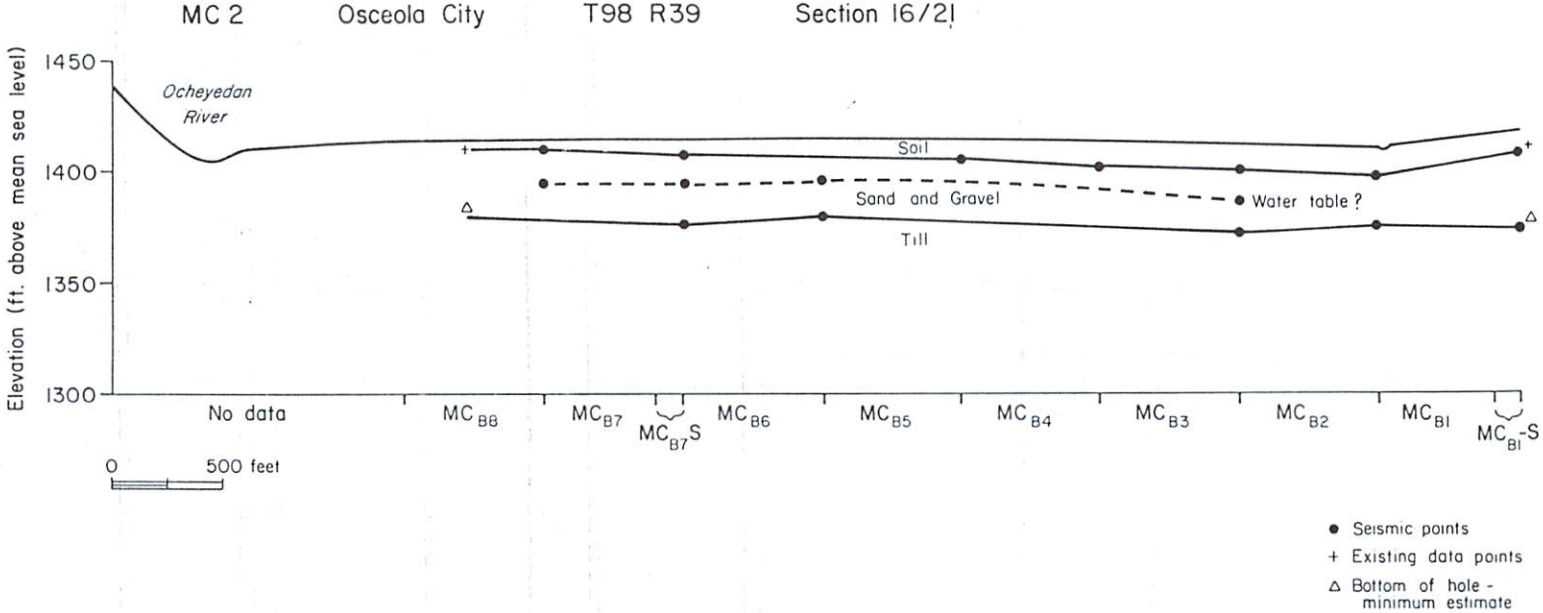


Figure B-9. Seismic profile section: May City 2.

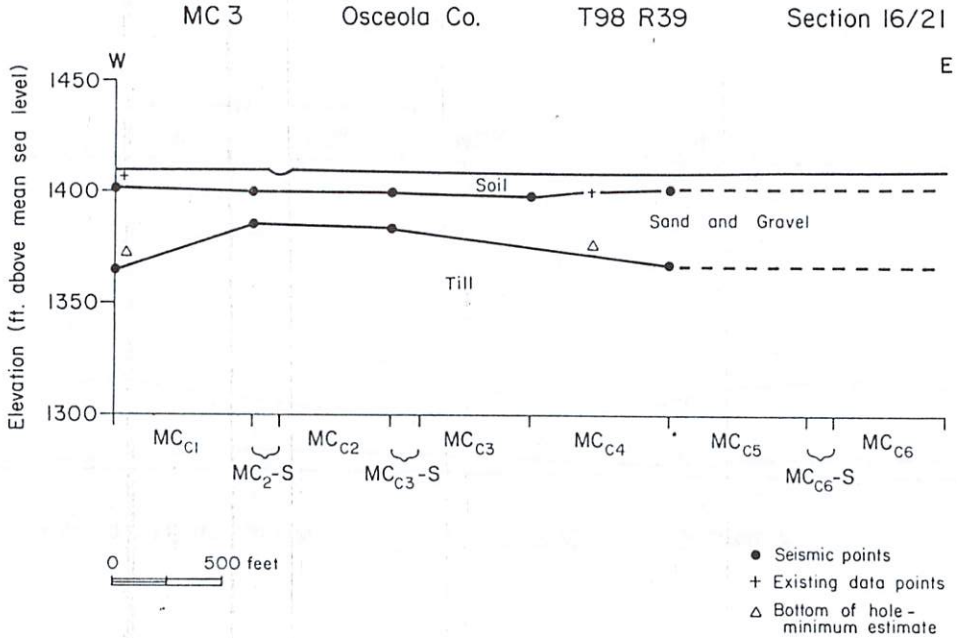


Figure B-10. Seismic profile section: May City 3.

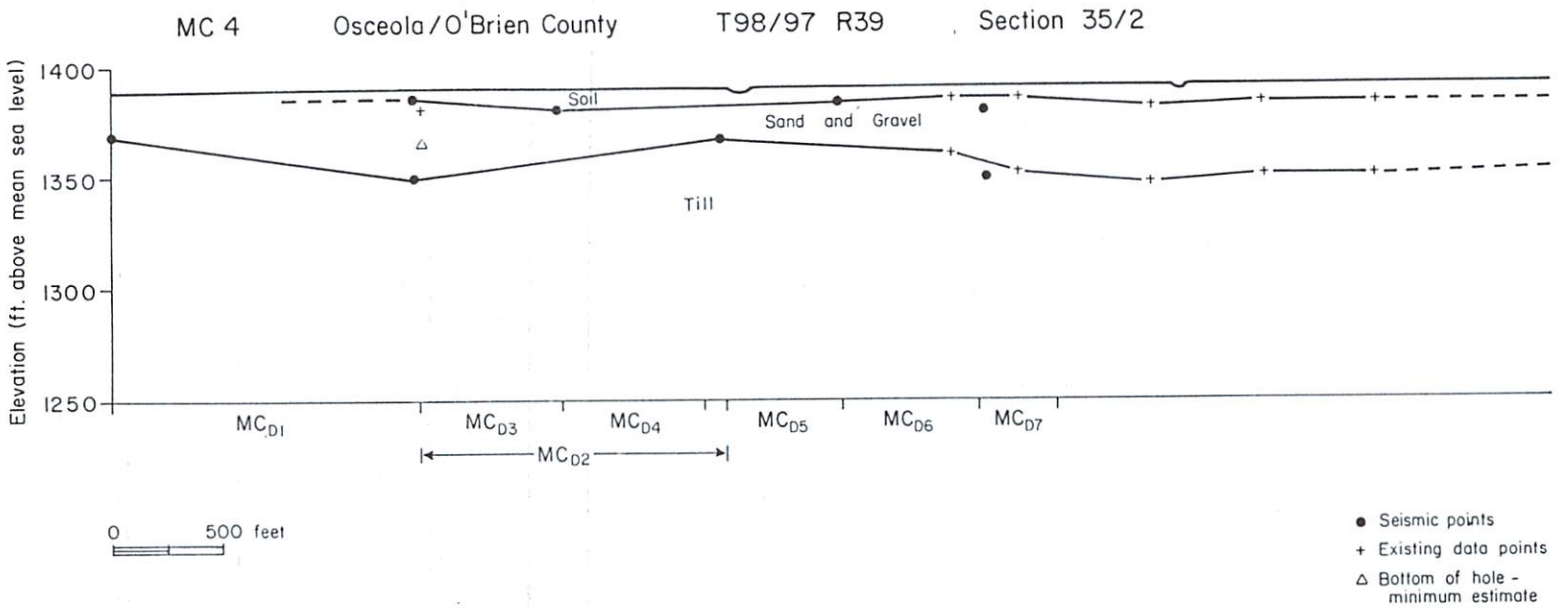


Figure B-11. Seismic profile section: May City 4.

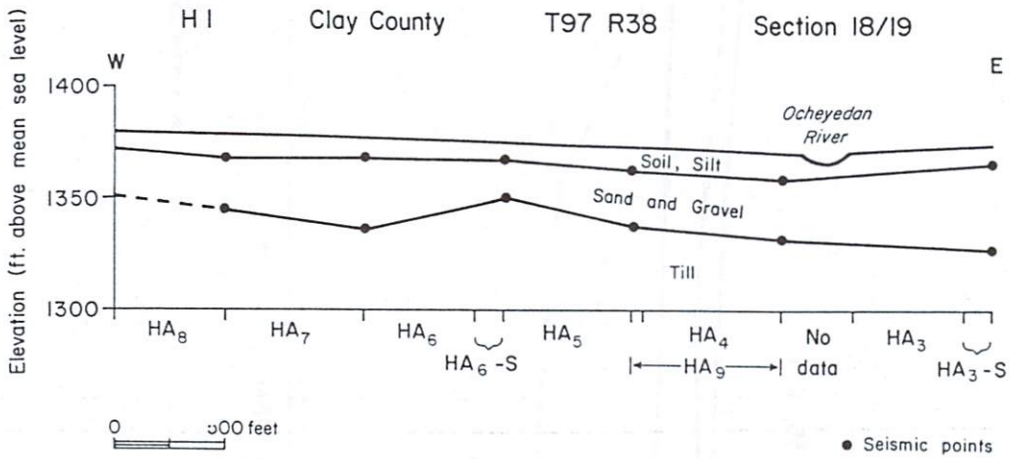


Figure B-12. Seismic profile section: Hartley 1

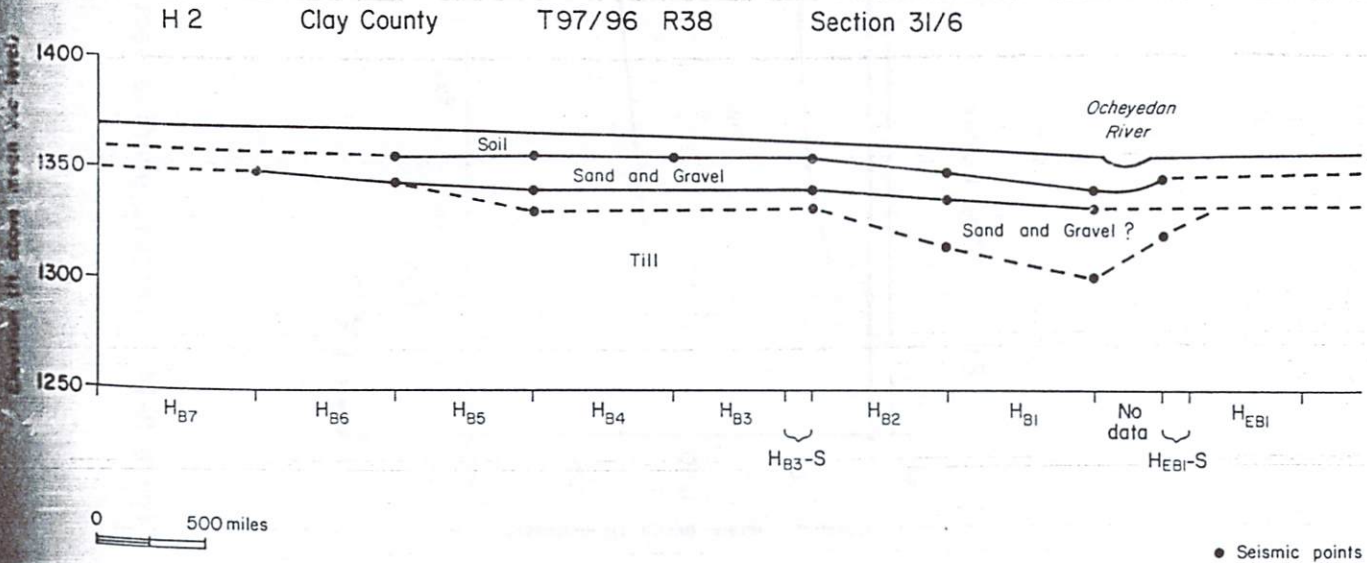


Figure B-13. Seismic profile section: Hartley 2.

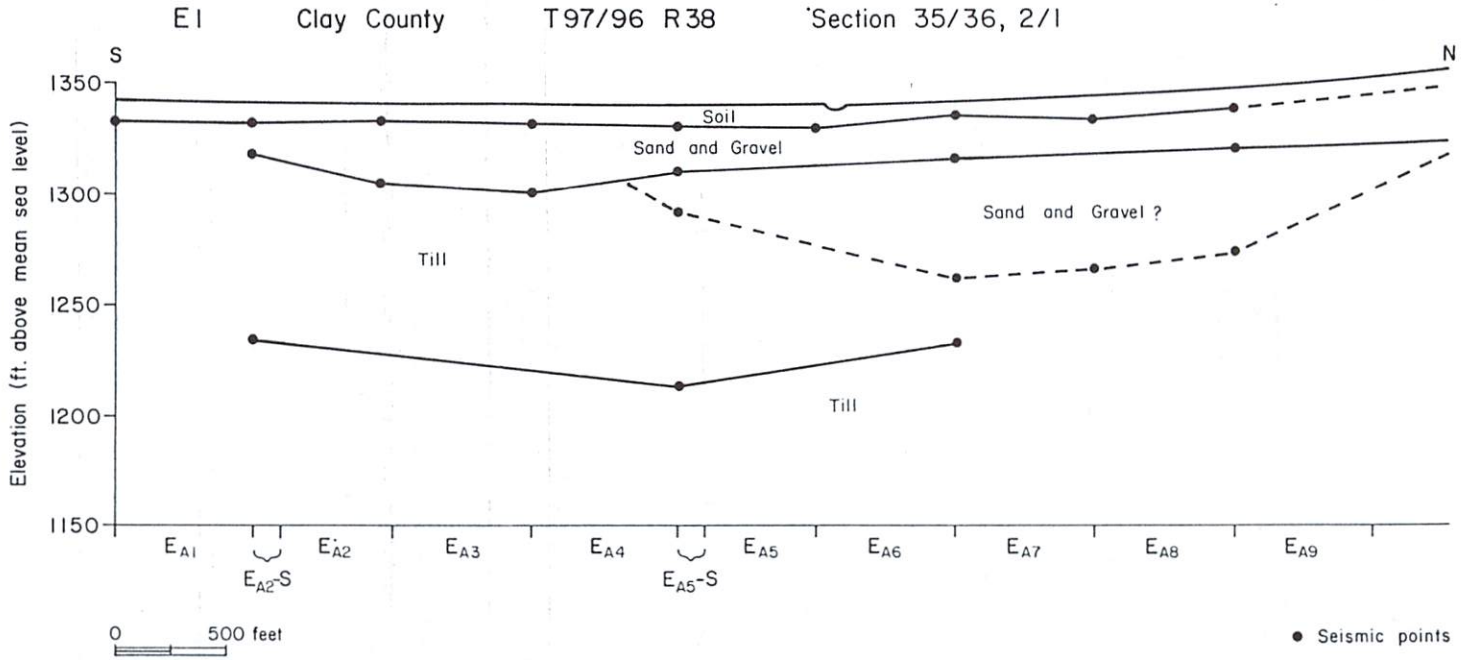


Figure B-14. Seismic profile section: Everly 1.

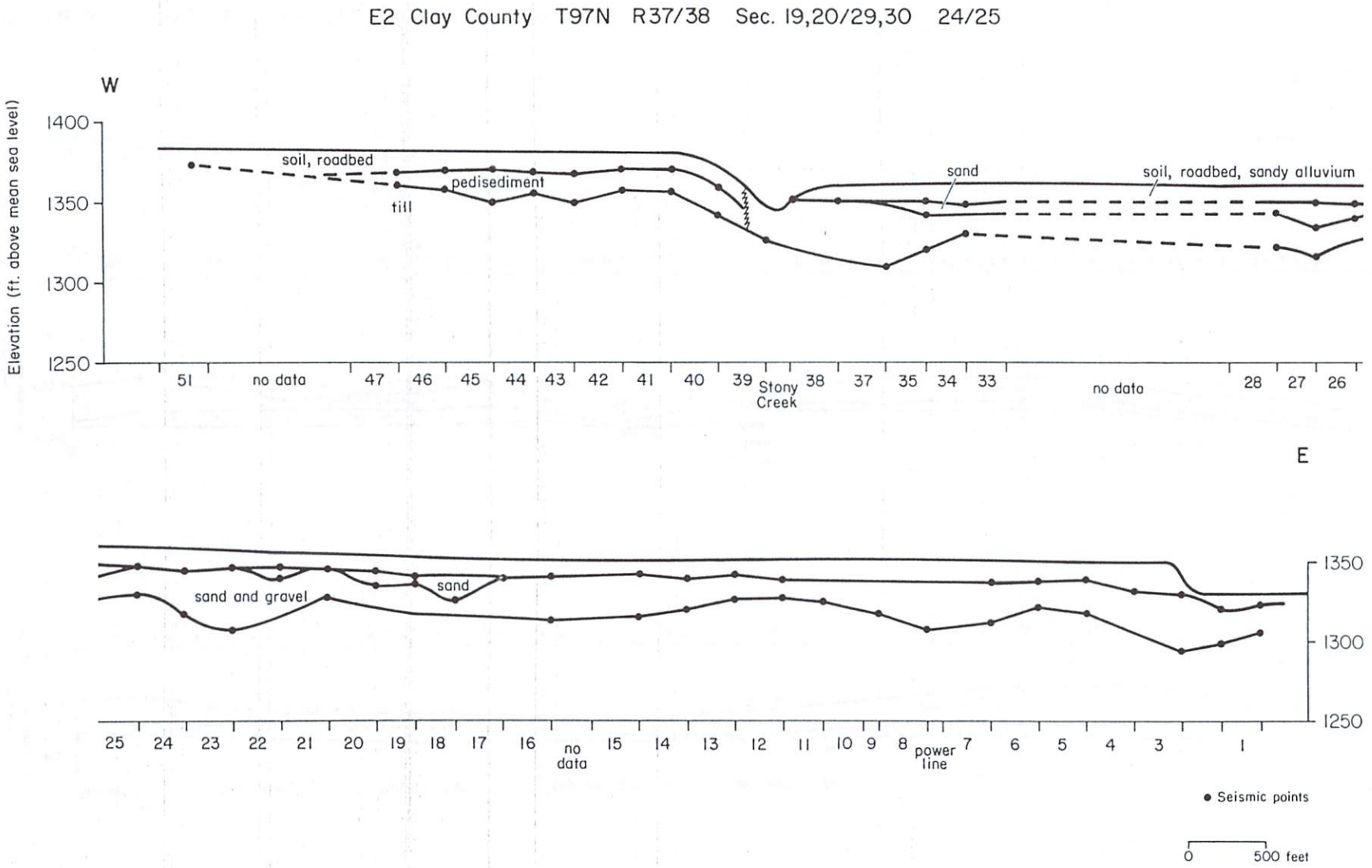


Figure B-15. Seismic profile section: Everly 2.

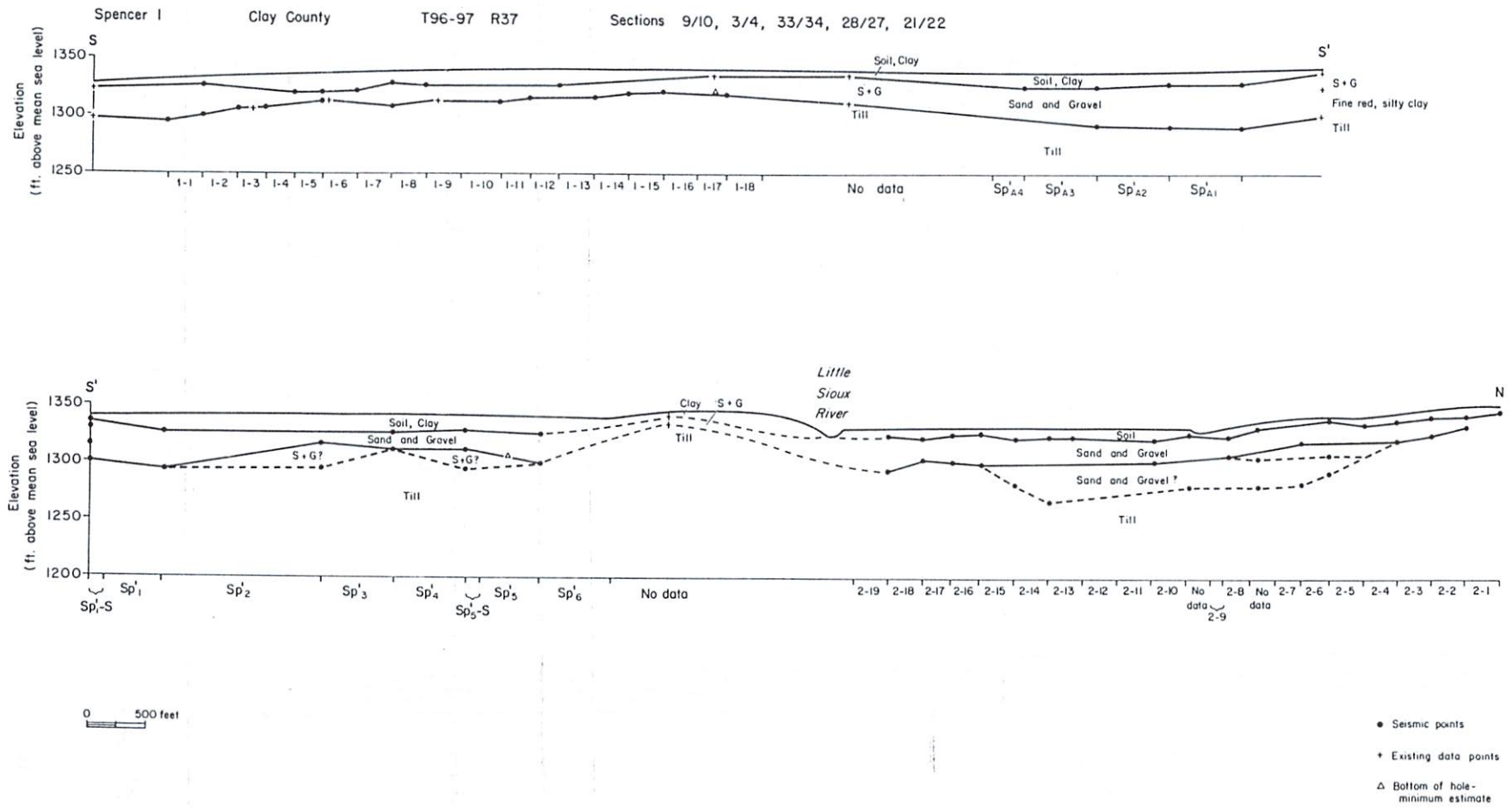


Figure B-16. Seismic profile section: Spencer 1.

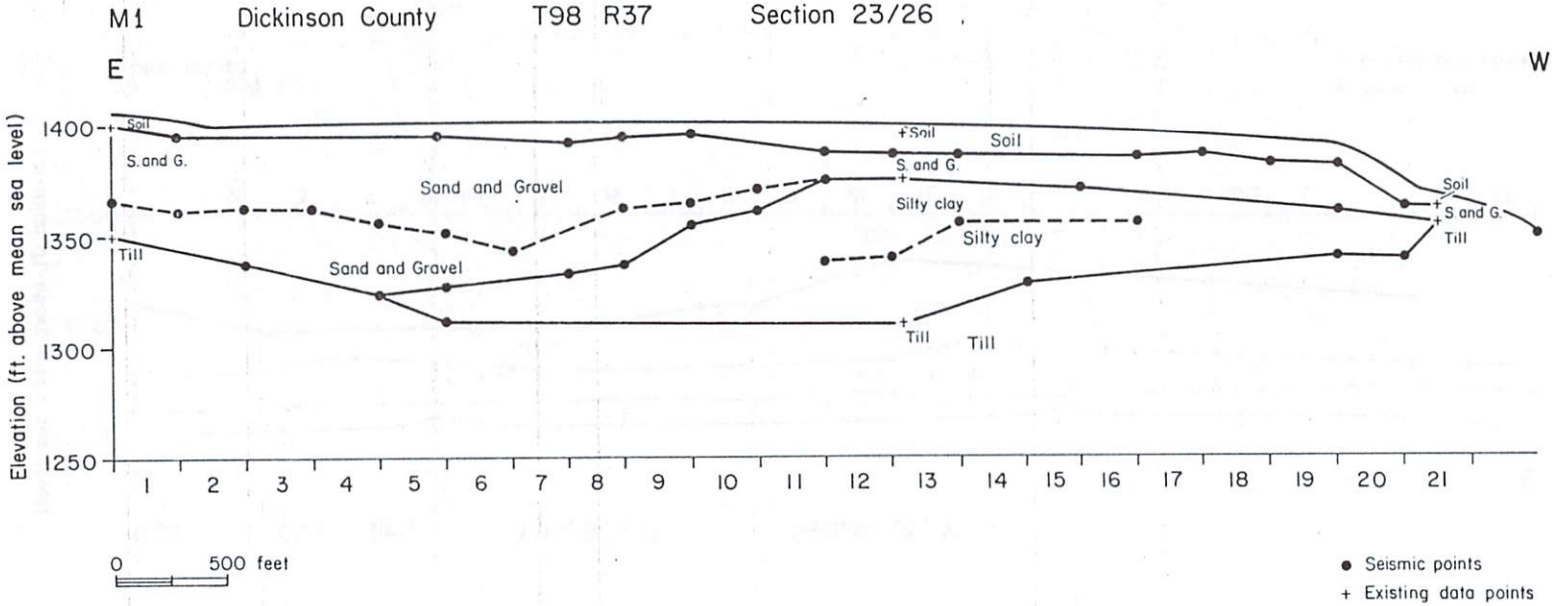


Figure B-17. Seismic profile section: Milford 1.

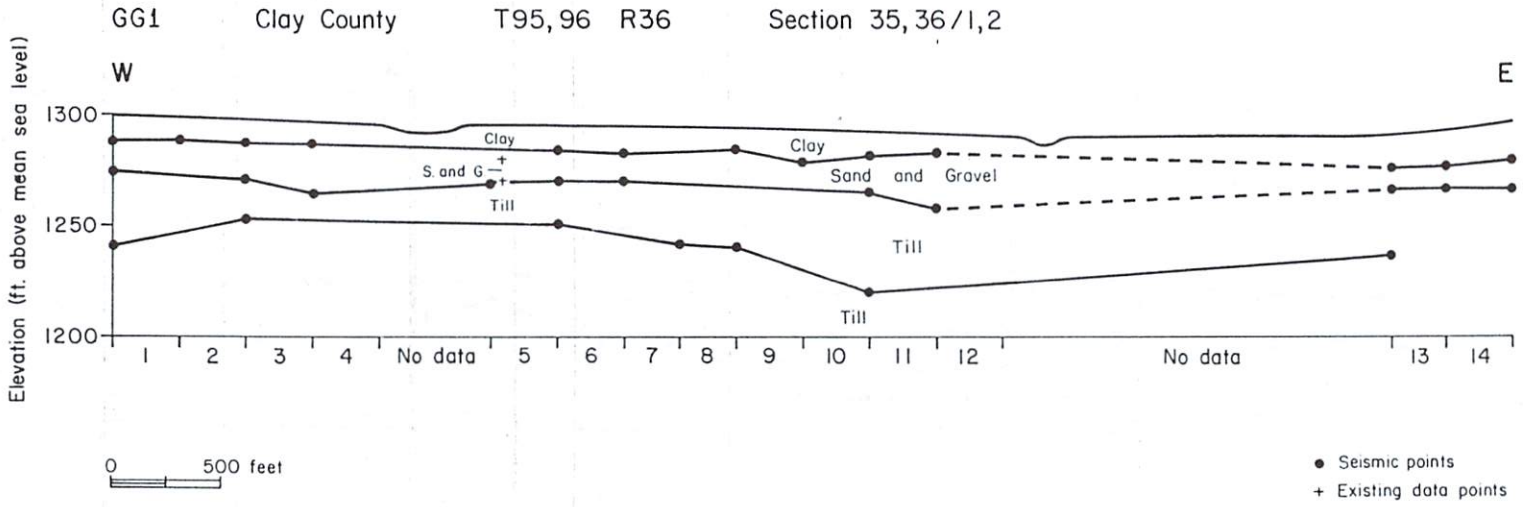


Figure B-18. Seismic profile section: Gillet Grove 1.

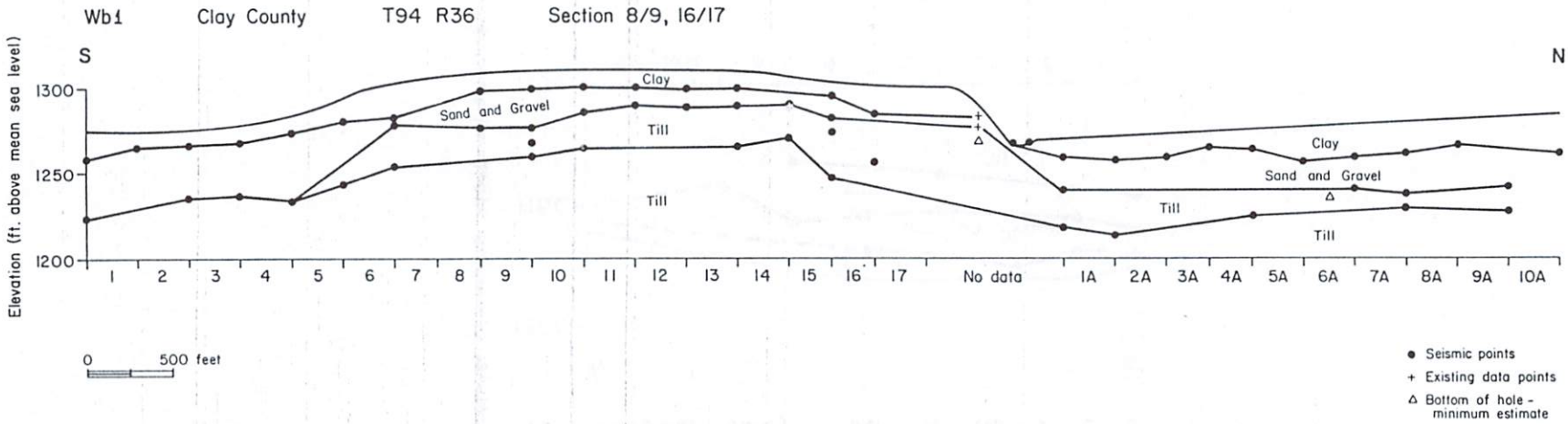


Figure B-19. Seismic profile section: Webb 1.

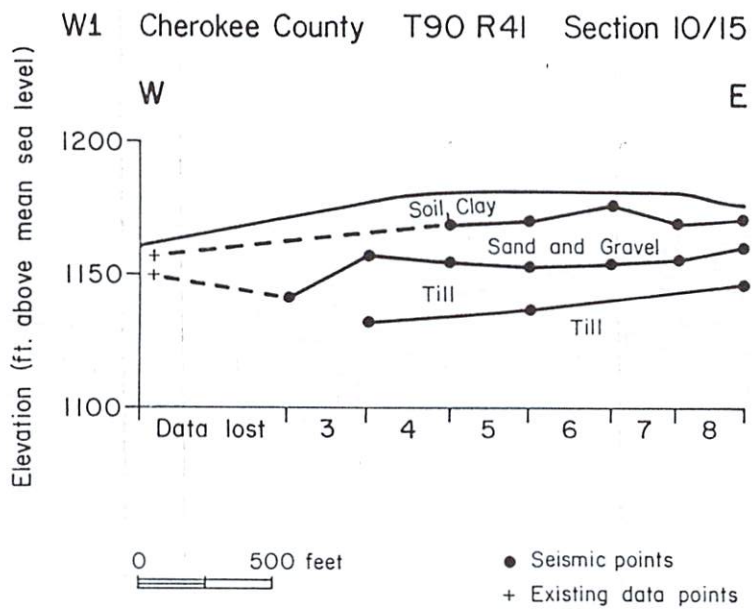


Figure B-20. Seismic profile section: Washta 1.

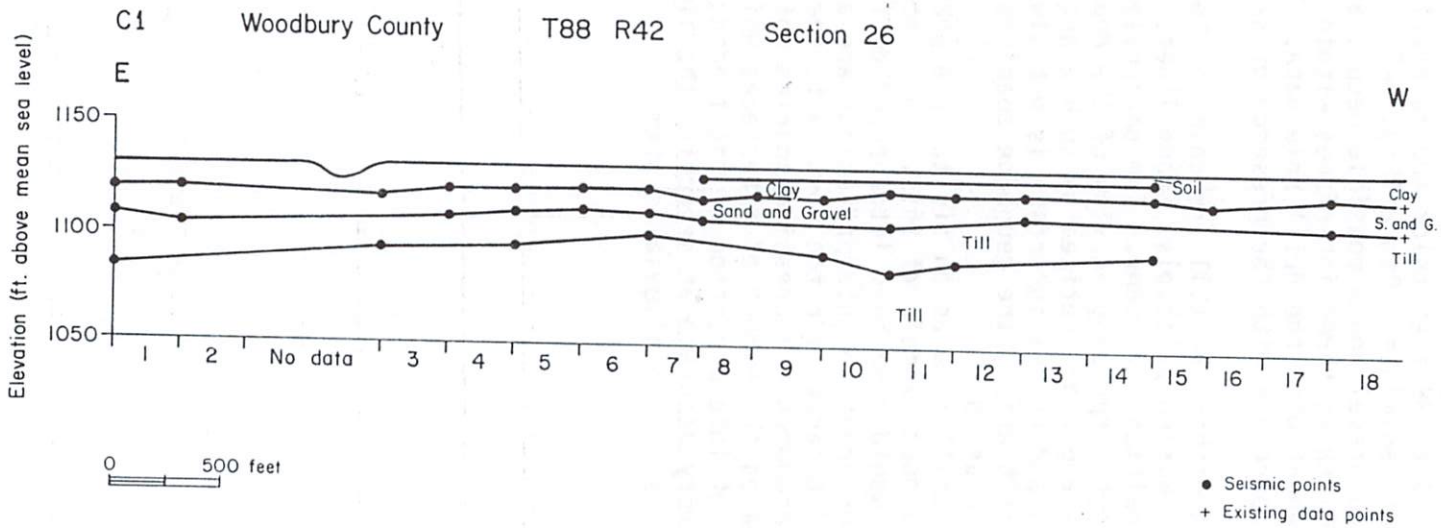


Figure B-21. Seismic profile section: Correctionville 1.

lain by a thin clay. A continuous interface within the till is detectable. Correctionville 2 (Fig. B-22) shows a channelized profile in till. The sand and gravel ranges from 18 to 38 feet thick and is overlain by a thick package of fine-grained alluvial sediments. Oto 2 (Fig. B-23) shows thickening and thinning of the sand and gravel and a possible deep channel incised into the till. Oto 1 (Fig. B-24) shows three interfaces within the sand and gravel which are in good agreement with the drill hole data. Higher seismic velocities below the sand correlate with the presence of sandstone and shale in the drill hole.

Several interfaces within the till are common. These may be due to a variety of situations. Buried paleosols, stone lines, "Cherokee clays" and other seismic discontinuities may occur. The channelized nature of the till-alluvium interface is not surprising in view of the depositional environment. Braided outwash streams are characterized by such changes in cross section profile. The soil/sand and gravel interface is not always accurate especially when shallow. In this situation, the geophone spacings are too large to permit reliable interpretation.

The importance of drill data as an aid to interpretation cannot be overemphasized. Oto 1 is a good example of this. Four interfaces are identified and without drill data would have been interpreted differently. In the absence of drill data, conservative interpretations are always made. Water tables are not observed because, for the most part, they are shallow and not detectable by field procedures. Decreasing spacing while leading to better resolution, also increases the number of interfaces which are seen. This increases the difficulty of interpretation of the findings. In all, the seismic data has proven to be very accurate at detecting the lithologic breaks which form the major components of the alluvial system.

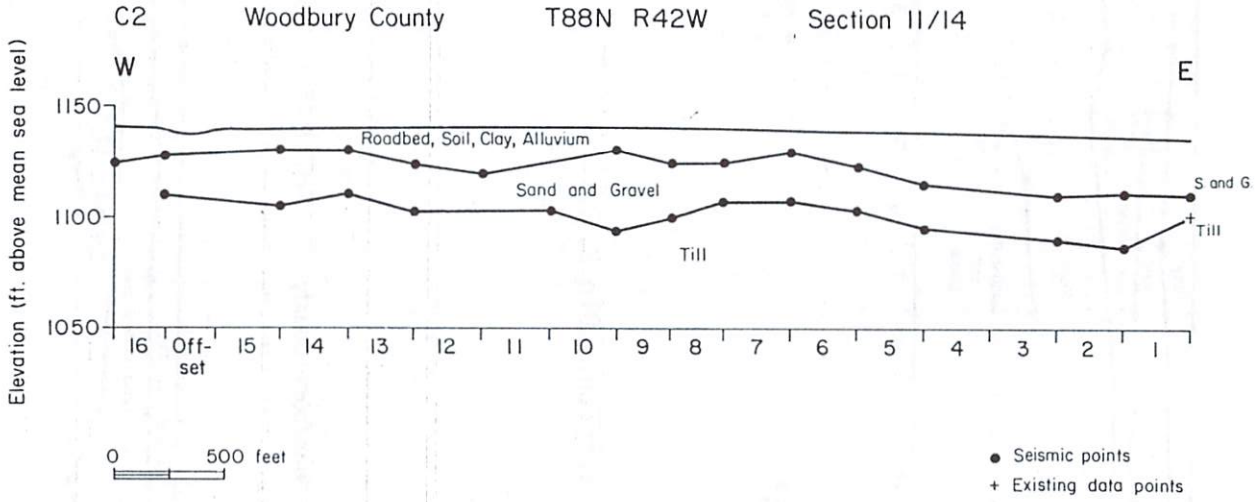


Figure B-22. Seismic profile section: Correctionville 2.

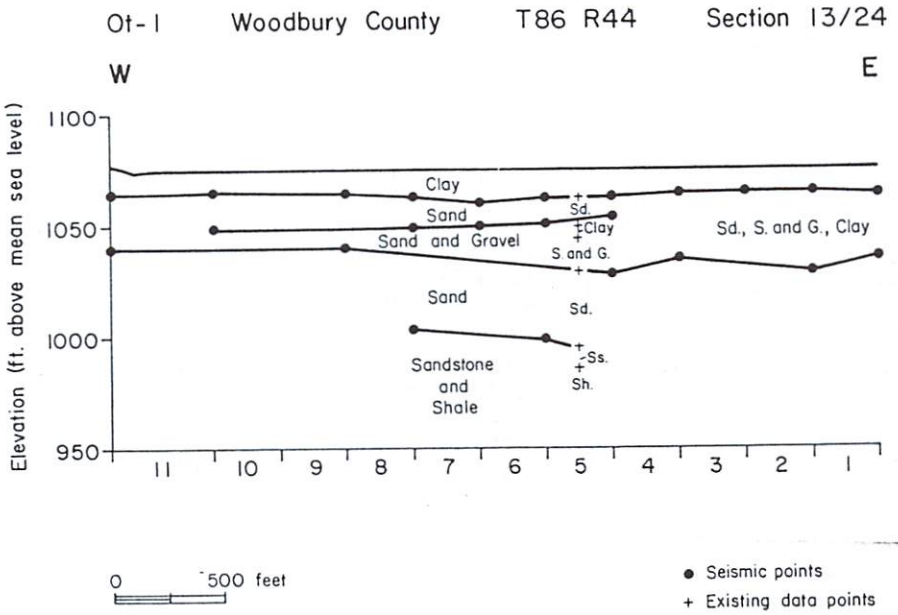


Figure B-23. Seismic profile section: Oto 2.

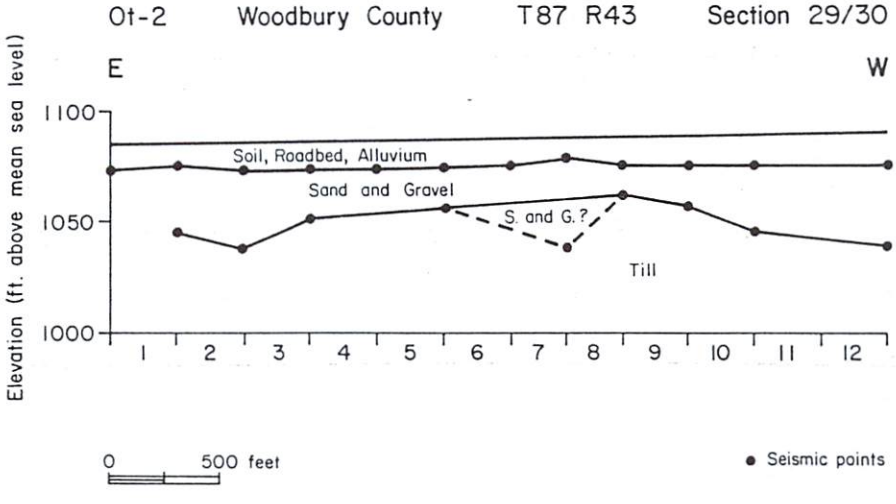


Figure B-24. Seismic profile section: Oto 1.

APPENDIX C

Drillers' Logs

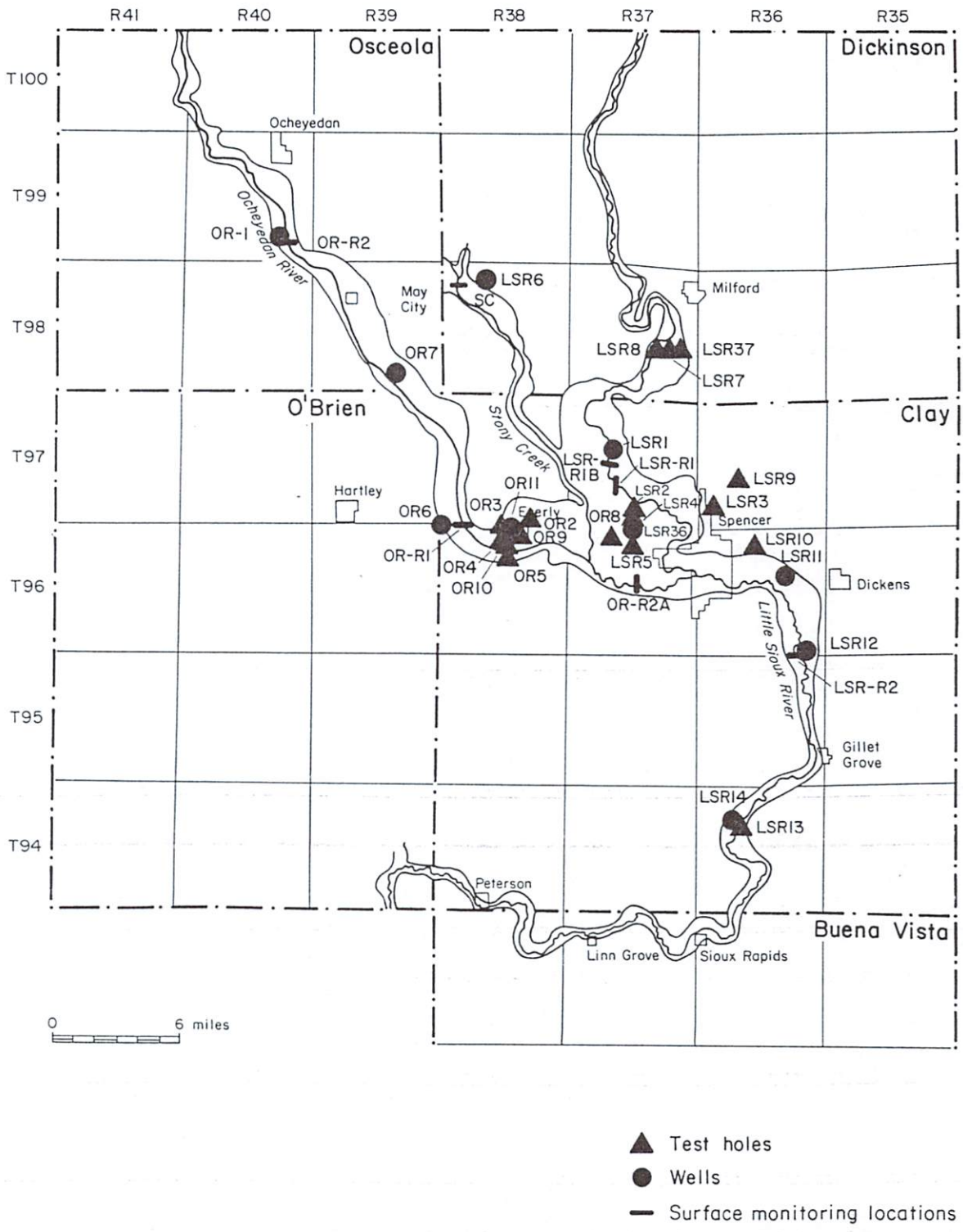


Figure C-1. Well and test hole locations: Ocheyedan and upper Little Sioux.

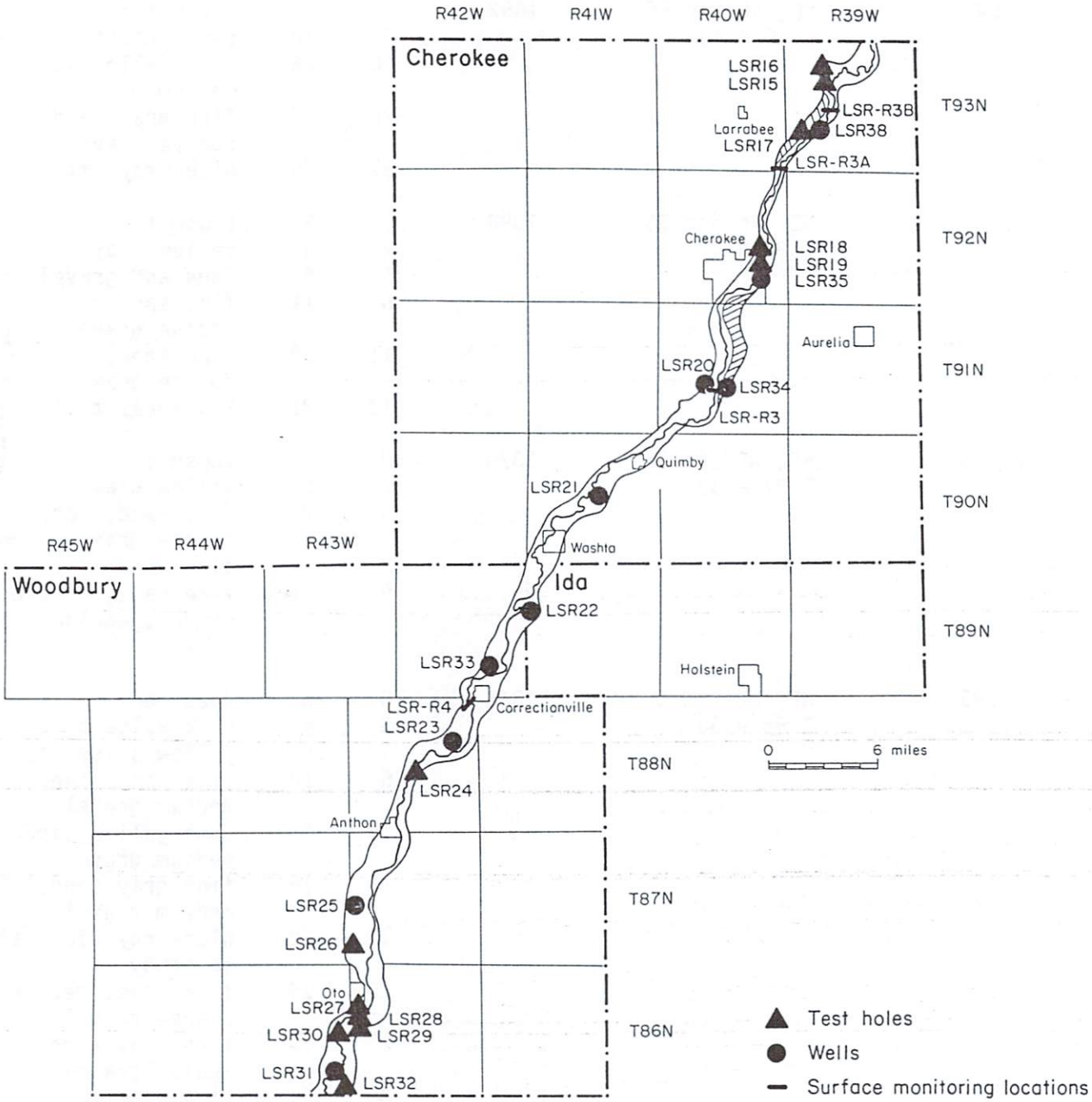


Figure C-2. Well and test hole locations: lower Little Sioux.

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
OR1	SE, SE Sec 26 T 99 R 40	1452	0	1	topsoil
			1	10	sand, coarse gravel
			10	26	fine yellow sand, medium gravel
			26	67	fine gray sand, coarse gravel
			67	70	blue-gray till
OR7	NE, NE Sec 34 T 98 R 39	1398	0	2	topsoil
			2	5	yellow clay
			5	6	sand and gravel
			6	11	fine sand, coarse gravel
			11	18	fine sand, coarse gravel
			18	21	blue-gray till
OR6	NE, NE Sec 36 T 97 R 39	1370	0	2	topsoil
			2	5	yellow clay
			5	9	fine sand, very coarse gravel, some clay
			9	21	fine sand, coarse gravel, boulders at base
OR3	NE, NE Sec 4 T 96 R 38	1365	0	3	road bed
			3	4	dark silty clay
			4	6	yellow silty clay
			6	10	fine brown sand, medium gravel
			10	15	fine yellow sand, medium gravel
			15	18	fine gray sand, medium gravel
			18	20	blue-gray clay, silty to sandy
			20	25	fine sand, medium to coarse gravel
			25	30	fine gray sand, medium gravel
			30	41	blue-gray till
OR11	NW, NW Sec 3 T 96 R 38	1361	0	3	yellow silty clay
			3	16	fine yellow sand, coarse gravel
			16	19	graded yellow to blue-gray silty and sandy clay
			19	24	fine gray sand, coarse gravel

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(OR11 continued)			24	25	gray sand and sandy clay
			25	30	sand, coarse gravel
			30	35	blue-gray till
OR9	SW, NE Sec 3 T 96 R 38	1355	0	4	topsoil, yellow silty and sandy clay
			4	8	fine sand, medium gravel
			8	13	fine sand, coarse gravel
			13	26	blue-gray till
OR4	SE, SE Sec 9 T 96 R 38	1352	0	6	road bed
			6	9	dark silty and sandy clay
			9	13	fine sand, coarse gravel
			13	21	blue-gray till
OR5	NE, NE Sec 9 T 96 R 38	1350	0	10	road bed, topsoil
			10	15	fine yellow sand, coarse gravel
			15	27	fine tan sand, coarse gravel
			27	40	blue-gray till
			40	44	fine gray sand, medium gravel
			44		blue-gray till
OR10	NE, SE Sec 9 T 96 R 38	1355	0	14	road bed
			14	16	gray silty clay
			16	18	fine gray sand and gravel, some clay layers
			18	21	fine gray sand, coarse gravel
			21	30	fine yellow sand, coarse gravel
			30	43	fine yellow sand, coarse gravel, oxidized
			43	55	blue-gray till
OR2	NW, NW Sec 35 T 97 R 38	1356	0	3	road bed, topsoil
			3	6	yellow-gray clay
			6	9	fine brown sand, medium gravel
			9	16	fine gray sand, coarse gravel

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(OR2 continued)			16	18	gray silty and sandy clay
			18	24	fine sand, very coarse gravel
			24	27	blue-gray sandy silty clay
			27	33	fine sand, coarse gravel, mixed clay layers
			33	60	blue-gray sandy gravelly till.
LSR6	NW, NW Sec 17 T 98 R 38	1415	0	2	topsoil
			2	4	brown silty sandy clay
			4	12	fine yellow sand, coarse gravel
			12	19	fine gray sand, coarse gravel
			19	20	black till
			20	35	fine to coarse olive sand, silt or clay streaks
			35	36	olive clay
			36	43	fine to coarse olive sand
			43	47	olive silty sandy clay
			47	55	blue-gray till
LSR7	NE, NW Sec 26 T 98 R 37	1400	0	3	topsoil
			3	5	brown sandy clay
			5	25	fine yellow sand, coarse gravel, oxidized
			25	33	yellow silty clay, sand layers
			33	55	blue-gray silty clay
			55	60	fine to coarse sand, sandy clay
			60	65	silty sandy clay
			65	70	gravel
			70	96	silty sandy clay, limestone boulders at base
			96	101	blue-gray till
LSR8	NE, NW Sec 27 T 98 R 37	1370	0	3	no sample
			3	4	sandy clay
			4	6	fine tan sand and gravel

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR8 continued)			6	9	fine brown sand and gravel
			9	12	fine yellow sand, coarse gravel
			12	21	blue-gray till
LSR1	NE, SE Sec 17 T 97 R 37	1353	0	3	sandy topsoil
			3	10	fine brown sand, very coarse gravel
			10	20	fine tan sand, very coarse gravel
			20	22	yellow gray silty clay
			22	28	brown very fine to medium sand
			28	51	gray very fine to coarse sand, wood
			51	54	gray sandy silty clay
			54	94	fine tan sand, fine to medium gravel
			94	97	blue-gray till
LSR2	NE, NE Sec 33 T 97 R 37	1340	0	4	road bed, sandy topsoil
			4	10	fine brown sand, coarse gravel
			10	14	fine gray sand, coarse gravel
			14	17	olive till, silty sandy clay
			17	25	blue-gray till
			25	27	fine to medium sand
			27	41	blue-gray till
LSR4	SE, NE Sec 33 T 97 R 37	1337	0	3	road bed
			3	5	yellow silty sandy clay
			5	10	fine brown sand, coarse gravel
			10	17	fine yellow sand, coarse gravel
			17	20	gray sand and gravel
			20	39	very fine sand, silty clay layers
			39	42	gray fine sand, gravel
			42	51	blue-gray till
			51	57	gray very fine to coarse sand
			57	60	blue-gray till, sand and gravel layers
			60	70	blue-gray till

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
LSR 36	NW, NW Sec 4 T 96 R 37	1138	0	3	road bed, topsoil
			3	6	yellow silty clay
			6	9	yellow-brown fine sand, medium gravel
			9	15	yellow fine sand, medium gravel
			15	26	gray fine sand, medium gravel
			26	43	gray silty clay
			43	44	sand, medium gravel
			44	51	blue-gray till
LSR 5	NE, SE Sec 4 T 96 R 37	1337	0	3	road bed
			3	4	silty sandy clay
			4	6	brown fine sand, medium gravel
			6	15	yellow fine sand, medium gravel, coarse at base
			15	27	gray fine sand, coarse gravel
			27	55	blue-gray till
			55	78	blue-gray till with sand and gravel layers
			78	81	olive till
LSR 3	SW, SE Sec 30 T 97 R 36	1336	0	4	road bed, topsoil
			4	7	yellow clay
			7	10	yellow clay, fine sand streaks
			10	12	yellow clay
			12	14	gray clay
			14	15	olive silty clay
			15	27	gray silty clay
			27	30	yellow fine sand, coarse gravel
			30	37	gray fine sand, coarse gravel
			37	40	blue-gray till
			40	42	gray fine sand, medium gravel
			42	50	blue-gray till
LSR 9	NE, NE Sec 20 T 97 R 36	1338	0	3	road bed, topsoil
			3	5	yellow-brown sandy clay
			5	18	yellow-brown till
			18	19	yellow-gray till
			19	21	olive to blue-gray till

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
LSR 10	SE, SE Sec 4 T 96 R 36	1312	0	2	road bed
			2	7	dark clay
			7	17	sandy gravelly clay, wood
			17	20	silty sandy clay
			20	31	very fine sand, silt
			31	57	fine sand, coarse gravel
			57	70	blue-gray till, sand and gravel layers
			70	81	blue-gray till, some sand and gravel
LSR 11	NW, NW Sec 14 T 96 R 36	1300	0	2	sandy topsoil
			2	3	sandy gravelly clay
			3	8	yellow fine sand, coarse gravel
			8	17	gray fine sand, very coarse gravel
			17	30	blue-gray till
LSR 12	SE, SW Sec 35 T 96 R 36	1290	0	4	Fill
			4	11	brown silty clay
			11	14	fine sand, coarse gravel, shells, clay layers
			14	20	fine sand, coarse gravel, shells
			20	28	blue-gray till
LSR 14	NE, SE Sec 8 T 94 R 36	1373	0	3	topsoil
			3	7	gray clay
			7	11	gray silty clay
			11	12	brown silty clay
			12	14	green silty clay
			14	15	fine sand, brown oxidized medium gravel
			15	23	yellow fine sand, coarse gravel
			23	31	gray fine sand, coarse gravel, boulders at base
			31	41	blue-gray till, sand and gravel streaks
LSR 16	NW, SW Sec 8 T 93 R 39	1209	0	6	road bed, topsoil
			6	10	brown silty clay
			10	17	yellow silty clay
			17	21	gray silty clay
			21	25	yellow fine sand, coarse gravel, clay layers

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR16 continued)			25	26	yellow silty sandy clay
			26	28	gray-green silty clay
			28	35	brown fine sand, coarse gravel
			35	81	yellow fine sand, very coarse gravel
			81	84	yellow oxidized clay, shale
			84	87	black and green clay or shale
			87	90	green clay, gray silty shale
LSR 15	SW, SW Sec 8 T 93 R 39	1208	0	5	road bed
			5	8	brown silty clay
			8	10	gray silty clay
			10	15	yellow silty clay
			15	18	tan silty clay
			18	21	brown silty clay
			21	22	yellow silty sandy clay
			22	25	green silty clay
			25	31	green silty clay, sand and gravel layers
			31	37	yellow fine sand, coarse gravel, wood
LSR 38	SW, SW Sec 20 T 93 R 39	1190	0	3	topsoil
			3	11	gray silty clay
			11	13	blue-gray silty sandy clay, wood
			13	16	fine sand, coarse gravel
			16	19	gray-green silty clay
			19	22	fine sand, fine gravel, wood, some clay
			22	51	gray fine sand, very coarse gravel
			51	60	gray clay, brown shale
LSR 17	NW, SW Sec 30 T 93 R 39	1225	0	4	road bed, topsoil
			4	6	brown sandy clay
			6	14	orange fine sand, coarse gravel
			14	32	yellow fine sand, coarse gravel
			32	41	blue-gray till

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
LSR 18	SE, SW Sec 23 T 92 R 40	1218	0	2	topsoil
			2	4	brown sandy clay
			4	12	fine sand, very coarse gravel, boulders
			12	15	yellow-brown till
			15	18	blue-gray till
			18	20	fine sand and gravel, yellow-brown till
			20	25	blue-gray till
			25	30	olive to blue-gray clay
			30	35	blue-gray clay
LSR 19	NE, SE Sec 26 T 92 R 40	1190	0	2	topsoil
			2	4	brown silty clay
			4	5	yellow silty sandy clay
			5	8	fine sand, very coarse gravel
			8	15	gray clay
			15	21	green and blue-gray clay
LSR 35	SE, SE Sec 26 T 92 R 40	1180	0	5	road bed
			5	12	gray silty clay
			12	16	yellow fine sand, medium gravel
			16	18	blue-gray silty clay
			18	22	yellow fine sand, coarse gravel
			22	54	brown fine sand, coarse gravel
			54	57	blue-gray clay
LSR 20	SE, SE Sec 21 T 91 R 40	1165	0	3	gray silty clay
			3	6	gray-brown silty clay
			6	9	yellow silty clay
			9	14	gray and yellow silty clay
			14	16	yellow silty clay
			16	20	blue-gray to green silty clay
			20	30	brown fine sand, very coarse gravel
			30	52	tan fine sand, very coarse gravel
			52	58	blue-gray clay
LSR 34	SE, SE Sec 21 T 91 R 40	1209	0	19	yellow to brown oxidized fine sand, very coarse gravel
			19	20	yellow till or sandy clay

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR 34 continued)			20	25	blue-gray sandy clay or till
			25	41	blue-gray sandy till
			41	46	gray fine to coarse sand
			46	50	blue-gray sandy till
			50	65	sand and gravel, thin layers of clay or till
			65	73	blue-gray till, gravel layers
			73	76	gray clay
LSR 21	NW, NW Sec 15 T 90 R 41	1162	0	2	topsoil
			2	4	brown silty clay
			4	5	brown silty clay, gravel
			5	10	brown fine sand, coarse gravel
			10	13	yellow fine sand, coarse gravel
			13	41	blue-gray till
LSR 22	NW, NW Sec 18 T 89 R 41	1145	0	7	gray silty clay
			7	8	yellow silty clay
			8	18	yellow fine sand, coarse gravel
			18	28	yellow fine sand, fine gravel
			28	35	blue-gray till, clay
LSR 33	NW, NE Sec 27 T 89 R 42	1135	0	4	topsoil, fill
			4	7	gray silty clay
			7	10	yellow-gray silty clay
			10	13	yellow silty clay
			13	15	gray sandy, gravelly, silty clay
			15	18	yellow fine sand, coarse gravel
			18	26	yellow oxidized fine sand, coarse gravel
			26	30	blue-gray till
LSR 23	SE, SE Sec 11 T 88 R 43	1134	0	10	yellow fine sand, very coarse gravel, boulders
			10	20	orange fine sand, very coarse gravel, boulders
			20	33	yellow fine sand, coarse gravel

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR 23 continued)			33	34	yellow clay or till, boulders
			34	40	blue-gray till
LSR 24	SE, NW Sec 22 T 88 R 43	1107	0	4	road bed, topsoil
			4	5	gray-brown silty clay
			5	10	gray silty clay
			10	15	gray-tan silty sandy clay, sand layers
			15	30	blue-gray silty clay, wood
			30	34	blue-gray fine sand, coarse gravel
			34	40	yellow fine sand, very coarse gravel
			40	47	yellow oxidized fine sand, very coarse gravel
			47	54	yellow fine sand, coarse gravel
			54	61	blue-gray till
LSR 25	SE, NE Sec 19 T 87 R 43	1090	0	3	silty topsoil
			3	13	fine to coarse sand, blue-gray silty clay, wood
			13	16	fine to coarse sand, blue-gray silty clay, shells, wood
			16	24	gray fine sand and gravel, shells, boulders at base
			24	30	yellow-gray clay
			30	36	blue-gray clay, wood, cemented sand layer
			36	41	blue-gray sandy clay or till
LSR 26	NE, NE Sec 31 T 87 R 43	1100	0	8	brown silty clay
			8	20	yellow silty clay
			20	27	very soft silty yellow clay
			27	37	yellow fine sand, coarse gravel
			37	42	orange oxidized fine sand, coarse gravel
			42	50	blue-gray till
			50	51	green clay
			51	55	blue-gray sandy clay or hard till
			55	57	gray-green clay layered with cemented sand grains

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR 26 continued)			57	70	very fine to coarse gray-green sand
			70	87	fine gray-green sand grading to fine sand and gravel
			87	88	gray clay
			88	89	gray-green clay, sand and gravel layers
			89	92	fine sand and gravel, some gray clay
			92	100	gray-green clay, medium to coarse sand and gravel layers
			100	105	gray clay
			105	110	fine to medium tan sandstone
			110	112	coarse tan sandstone with gray shale streaks
			112	115	coarse tan sandstone with gray shale streaks
			115	117	very well cemented sandstone
			117	118	very silty, sandy shale
			118	120	fine gray sandstone
			120	121	gray-tan shale
LSR 27	NW, SW Sec 18 T 86 R 43	1082	0	5	road bed, topsoil
			5	12	gray-brown silty clay
			12	18	yellow silty clay
			18	20	gray silty clay
			20	26	green silty clay
			26	33	gray-green silty sandy clay, fine to coarse sand layers
			33	45	gray fine sand, coarse gravel
			45	50	fine yellow sand, medium gravel
			50	55	fine olive sand, brown oxidized coarse gravel
			55	68	fine to coarse gray green sand, gravel
			68	69	gray gravelly shale
			69	75	fine to coarse yellow sandstone
			75	84	gray shale, trace of coal at top
			84	88	reddish-brown shale
			88	90	gray shale

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
(LSR 27 continued)			90	92	maroon shale
			92	100	olive shale
LSR 28	NW, NW Sec 18 T 86 R 43	1096	0	4	road bed, loess
			4	9	fine yellow sand and gravel
			9	11	gray silty clay, oxidized layers
			11	15	yellow silty clay
			15	19	yellow silty clay, sand layers
			19	24	yellow and orange oxidized fine sand and gravel
			24	30	fine yellow sand, medium gravel
			30	36	gray silty clay, sand layers
			36	44	yellow oxidized fine sand, very coarse gravel
			44	55	blue-gray till
LSR 29	SW, SW Sec 18 T 86 R 43	1132	0	3	road bed
			3	35	yellow loess, snail shells
			35	50	very fine to coarse sand
			50	55	yellow oxidized silty sandy clay
			55	64	gray silty clay
			64	67	yellow sand, gravel, boulders
			67	75	blue-gray till
LSR 30	NE, NW Sec 24 T 86 R 44	1075	0	3	road bed
			3	14	gray silty clay, very fine sand layers
			14	26	fine to coarse gray sand, wood, shells, some clay
			26	28	blue-gray silty clay
			28	30	green silty clay
			30	46	fine yellow sand, coarse gravel
			46	80	fine to coarse green sand
			80	88	very coarse sandstone, thin shale layers
			88	99	gray sand, shale
			99	101	reddish-brown shale

IGS Well No.	Location	Elevation (ft.)	From	To	Lithology
LSR 31	NE, NE Sec 36 T 86 R 44	1070	0	5	gray silty clay
			5	7	gray-tan silty clay
			7	10	gray silty clay
			10	16	yellow silty clay
			16	19	green silty clay
			19	21	fine sand, coarse gravel
			21	23	green silty clay
			23	25	fine sand, coarse gravel, some clay
			25	32	blue-gray silty clay
			32	34	gray silty clay
			34	38	fine yellow oxidized sand, very coarse gravel, boulders
			38	44	very fine to coarse olive-green sand
LSR 32	NE, NE Sec 36 T 86 R 44	1076	0	3	road bed
			3	6	gray silty clay
			6	12	dark gray silty clay
			12	24	yellow silty clay
			24	26	green silty clay
			26	35	fine yellow sand, very coarse gravel
			35	40	fine to coarse yellow sand, some cemented
			40	75	fine yellow sand and gravel, lightly cemented
			75	81	fine to coarse well cemented yellow sandstone, gray shale at base

APPENDIX D

Water Level Data

WATER LEVELS - LITTLE SIOUX AND OCHEYEDAN ALLUVIAL SYSTEMS

	LOCATION	SCREENED INTERVAL	JUL 15-18 1985		AUG 6 1985		AUG 19-20 1985		SEP 10-12 1985	
			WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)
1	OR-1U	7-9	5.8	1445.8			7.2	1444.4	6.6	1445.0
2	1M	26-30	5.9	1445.8			7.2	1444.5	6.7	1445.0
3	1L	54-58	5.9	1445.8			7.3	1444.4	6.7	1445.0
4	OR-R2	SURFACE							18.9	1442.1
5	OR-7U	6-7	5.6	1393.2			5.9	1392.9	5.2	1393.6
6	7L	12.5-16	5.5	1393.3			5.9	1392.9	5.0	1393.8
7	OR-6	16.5-19.	4.1	1366.5			5.8	1364.8	4.6	1366.0
8	OR-11U	10-13			5.8	1356.5	6.2	1356.1	6.2	1356.1
9	11L	26-30			7.8	1354.5	8.1	1354.2	7.7	1354.6
10	OR-R2A	SURFACE								
11	LSR-6	11-18	9.4	1408.0			10.4	1407.0	10.7	1406.8
12	SC	SURFACE							16.6	1405.1
13	LSR-R1B	SURFACE								
14	LSR-1U	16-17	9.0	1341.2			12.8	1337.4	9.4	1340.4
15	1L	85-90	12.6	1337.6			13.0	1337.2	16.2	1337.6
16	LSR-36U	6.0-8			5.5		5.9			
17	36L	22-25.5			5.7		5.8			
18	LSR-11	15.5-18	3.6	1295.4			3.9	1295.1	2.1	1297.0
19	LSR-12	17-19	7.6	1284.3			9.0	1282.9	D/C	
20	LSR-14	22-28	8.0	1271.3			9.2	1270.1	6.7	1272.5
21	LSR-R3B	SURFACE								
22	LSR-38U	23.5-29.					11.1	1180.9	8.8	1183.2
23	38L	44-50					11.2	1180.9	8.7	1183.4
24	LSR-35U	20.5-22.			15.5	1162.0	15.7	1161.5	15.5	1161.9
25	35M	35.5-37.			15.1	1162.0	17.7	1161.4	15.4	1161.8
26	35L	50-52			15.1	1162.1	15.7	1161.5	15.5	1161.8
27	LSR-34U	17.5-19			16.2	1190.0	16.3	1189.9	15.0	1191.2
28	34L	53-63			15.4	1190.9	15.6	1190.7	15.9	1190.4
29	LSR-R3	SURFACE								
30	LSR-20U	20-23	7.6	1146.6			9.5	1144.7	8.5	1145.7
31	20L	42-48	7.7	1146.5			9.5	1144.7	8.5	1145.7
32	LSR-21	12-13	6.4	1156.6			7.0	1156.0	6.6	1155.8
33	LSR-22	23-26	11.2	1133.2			12.3	1132.2	6.6	1137.7
34	LSR-33	24-25.5			8.6	1125.7	9.0	1125.3	8.9	1125.4
35	LSR-4R	SURFACE							7.5	1104.0
36	LSR-23	28-31	16.5	1113.1			17.5	1112.1	17.4	1112.3
37	LSR-25	19-24			7.9	1121.4	8.4	1120.9	8.5	1120.5
38	LSR-31	34-37.5			12.1	1059.5	12.3	1059.3	11.3	1060.3

WATER LEVELS - LITTLE SIOUX AND OCHEYEDAN ALLUVIAL SYSTEMS

	OCT 15-18 1985		NOV 12-14 1985		DEC 26 1985		JAN 22 1986		FEB 18 1986		MAR 19 1986	
	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)
1	5.8	1445.8	6.1	1445.6	6.3	1445.3	6.6	1445.0	6.8	1444.8	2.6	1449.0
2	5.9	1445.8	6.2	1445.5	6.4	1445.3	6.6	1445.1	6.9	1444.8	3.6	1448.1
3	5.9	1445.8	6.2	1445.5	6.4	1445.3	6.6	1445.1	6.9	1444.8	3.9	1447.9
4	18.9	1442.1	18.4	1442.6								
5	4.7	1394.1	5.1	1393.0	5.3	1392.8	5.5	1392.6	5.8	1393.0	2.4	1396.4
6	4.2	1394.3	4.9	1393.9	5.3	1393.5	5.3	1393.5	5.7	1393.1	2.2	1396.6
7	3.7	1366.9	4.2	1366.4	4.3	1366.3	4.5	1366.1	5.1	1365.5	3.4	1367.2
8	6.4	1355.9	6.7	1355.6	7.0	1355.3	7.3	1355.0	7.6	1354.7	10.0	1352.3
9	7.7	1354.6	8.1	1354.2	8.6	1353.7	8.7	1353.6	9.7	1352.6	8.3	1354.0
10	3.6	1315.3										
11	10.7	1406.8	10.8	1406.7	10.6	1406.8	10.8	1406.6	11.0	1406.4	10.2	1407.2
12	16.0	1405.7										
13	12.4	1320.1	11.5	1321.0	8.6	1323.9						
14	9.4	1340.8	9.9	1340.3	10.3	1339.9	10.7	1339.5	11.3	1338.9	10.2	1340.0
15	12.7	1337.5	12.8	1337.4	13.1	1337.1	13.3	1336.9	13.7	1336.5	12.7	1337.5
16	3.8		4.9						6.2		5.8	
17	3.8		5.0						6.7		5.7	
18	1.9	1297.1	1.8	1297.2	2.3	1296.7	2.4	1296.6	3.9	1295.1	1.0	1298.0
19												
20	6.0	1273.3	7.4	1271.9	7.0	1272.3	7.4	1271.9	8.0	1271.3	FLOODED	
21	21.9	1151.8	22.6	1151.1								
22	8.2	1183.8										
23	8.3	1183.8	9.4	1182.7								
24	14.2	1163.0	14.5	1162.7	13.5	1163.7	13.9	1163.3	14.3	1162.9	7.1	1170.1
25	14.1	1163.0	14.5	1162.6	13.4	1163.7	13.9	1163.2	13.3	1162.8	7.0	1170.1
26	14.2	1163.0	14.2	1163.0	13.5	1163.7	14.0	1163.2	14.4	1162.8	7.1	1170.1
27	16.7	1189.5	16.9	1189.3	17.1	1189.1	17.2	1189.0	17.3	1188.9	16.7	1189.5
28	16.2	1190.1	16.6	1189.7	16.8	1189.5	16.9	1189.4	17.0	1189.3	16.2	1190.1
29	28.8	1144.9										
30	7.7	1146.5	8.3	1145.9	7.4	1146.8	8.0	1146.2	8.4	1145.8	1.6	1152.6
31	7.7	1146.5	8.3	1145.9	7.5	1146.7	8.0	1146.2	8.4	1145.8	1.6	1152.6
32	7.5	1155.5	7.5	1155.5					7.7	1157.2	6.8	1156.2
33	13.2	1131.2	13.4	1131.0	13.7	1130.7	13.7	1130.7			12.9	1131.6
34	9.0	1125.3	9.3	1125.0	9.7	1124.6	9.5	1124.8	9.5	1124.8	7.5	1126.8
35	8.1	1104.6										
36	17.4	1112.2	17.5	1112.1	17.6	1112.0	17.6	1112.0	17.2	1112.2	15.3	1114.3
37	8.9	1120.4	9.1	1120.2	8.9	1120.4	9.0	1120.3	9.5	1119.8	7.4	1121.9
38	11.0	1060.6	11.8	1059.8			11.9	1059.7	12.3	1059.3	6.0	1065.6

WATER LEVELS - LITTLE SIOUX AND OCHEYEDAN ALLUVIAL SYSTEMS

	APR 14 1986		MAY 21 1986		JUN 18 1986		JUL 23 1986		AUG 20 1986	
	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)	WATER LEVEL (Feet)	WATER LEVEL (NGVD)
1	2.5	1449.2	2.2	1449.4	5.1	1446.5	5.0	1446.6	6.0	1445.6
2	3.1	1448.6	2.7	1449.0	4.3	1447.4	5.1	1446.6	6.1	1445.7
3	3.3	1448.4	2.8	1448.9	4.4	1447.3	5.2	1446.5	6.1	1445.6
4										
5	3.9	1394.9	4.5	1394.3	4.8	1394.0	4.6	1394.2	5.3	1393.5
6	3.6	1395.3	4.3	1394.5	4.5	1394.5	4.3	1394.5	5.2	1393.6
7	3.3	1367.3	2.8	1367.8	4.0	1366.6	3.9	1366.7	4.4	1366.2
8	6.3	1356.0	4.3	1358.0	6.4	1355.9	4.7	1357.6	5.7	1356.6
9	7.3	1355.0	6.1	1356.2	5.1	1367.2	6.5	1355.8	6.9	1355.4
10			4.9	1316.6	3.4	1315.1				
11	9.7	1407.7	8.9	1408.6	9.3	1408.1	9.4	1408.0	10.0	1407.4
12										
13									13.0	1319.5
14	9.0	1341.2	7.4	1342.8	8.5	1341.7	8.8	1341.4	9.3	1340.9
15	12.3	1337.9	10.8	1339.4	11.4	1338.8	11.7	1338.5	12.0	1338.2
16			2.8		3.6		3.6		4.9	
17			2.7		3.6		3.9		4.9	
18	1.7	1297.3	-0.3	1299.3	2.7	1296.3	2.3	1296.7	2.5	1296.5
19										
20	2.1	1277.2	0.4	1278.9	5.5	1273.8	6.5	1272.8	7.3	1272.0
21			16.4	1157.3	21.5	1152.2	22.7	1151.0		
22			2.6	1189.4	8.3	1183.7	8.5	1183.6	9.5	1182.5
23			2.7	1189.4	7.3	1184.8	8.5	1183.6	9.5	1182.6
24	7.3	1169.9	6.9	1170.3	10.0	1167.2	12.7	1164.8	14.2	1163.3
25	7.3	1169.8	6.9	1170.2	10.0	1167.2	12.4	1164.7	14.0	1163.1
26	7.4	1169.8	7.0	1170.2	10.0	1166.2	12.5	1164.7	14.0	1163.2
27	16.8	1189.4	16.3	1189.9	16.1	1190.2	16.4	1189.9	15.7	1190.5
28	16.6	1189.7	15.8	1190.5	15.5	1190.8	15.7	1190.6	11.7	1194.6
29			23.8	1149.9					30.6	1143.07
30	2.4	1151.8	1.8	1152.4	4.3	1150.0	6.4	1147.8	7.8	1146.4
31	2.4	1151.8	1.8	1152.4	4.3	1149.9	6.4	1147.8	7.8	1146.4
32	4.8	1158.2	4.5	1158.6	5.5	1157.5	3.5	1159.5	7.3	1155.7
33	12.6	1131.8	9.6	1134.8	9.9	1134.5	10.9	1133.5	11.9	1132.5
34	7.4	1126.9	6.7	1127.6	6.7	1127.7	8.1	1126.2	8.7	1125.6
35			13.6	1110.1					6.8	1089.7
36	15.4	1114.2	14.1	1115.7	15.9	1113.7	15.9	1113.7	16.8	1112.8
37	7.0	1122.3	5.7	1123.6	5.8	1082.1	7.1	1080.9	8.2	1079.8
38	7.5	1064.1	5.8	1065.8	8.8	1062.8	9.9	1061.7	10.9	1060.7

APPENDIX E

Water Quality Data

Table E-1. Municipal and Other Public Alluvial Water Analyses (Source: UHL)
Iowa Geological Survey
Tabulation of Water Analyses

(Dissolved constituents in parts per million)

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Ocheyedan	9/25/53	36	668	1.3	8.0	119.5	41.6	--	0.92	0.25	9.0	146.9	366	0.32	470	754	7.8
(hand dug)	6/9/58	28	701	1.2	11.1	138.0	50.8	0.07	5.1	0.4	19.5	164.0	442	0.1	554	981	7.4
Ocheyedan #1	2/8/60	32	399	2.2	5.4	87.2	23.8	0.14	0.6	0.25	6.0	79.8	268	.06	316	581	7.5
	1/15/62	32	383	2.2	5.2	72.8	28.2	0.1	1.4	0.25	9.0	98.6	244	<0.02	298	560	7.5
	3/12/62	32	383	2.2	5.2	72.8	28.0	0.1	1.4	0.25	9.0	98.6	244	<0.02	298	560	7.5
	9/7/67	32	370	2.0	6.6	72.0	26.2	0.1	<.1	0.2	5.0	88.0	250	<0.05	288	570	7.4
	7/23/71	32	397	3.2	6.7	75.6	27.2	0.12	1.2	0.25	16.0	84.0	266	<0.02	301	580	7.5
	12/9/75								<5.0								
	1/20/76								14.0								
	3/18/76	33	408	2.0	5.4	82.0	35.0	0.06	21.0	0.2	24.0	77.0	256	0.01	349	640	7.5
	5/8/76								30.0								
	6/15/76								35.0								
	7/6/76								30.0								
	9/29/75	32	412	1.7	5.7	81.0	34.0	0.07	0.5	0.2	19.0	68.0	277	<0.01	342	630	7.6
	8/25/82	32	387	3.1	8.6	78.0	29.0	0.08	17.0	0.2	18.0	71.0	245	0.03	314	610	7.4
	9/29/75								30.0								
	12/31/75								25.0								
	2/17/76								20.0								
	3/26/79								113.0								
	4/2/79								85.0								
	4/2/79								78.0								
	4/10/79								73.0								
	4/30/79								56.0								
	5/14/79								59.0								
	6/25/79								43.0								
	7/9/79								43.0								
	8/13/79								33.0								
	12/15/81								8.0								
	8/23/82								18.0								
	5/9/83								32.0								
	9/27/83								17.0								
	7/23/84								8.0								
	7/24/84								<5.0								
Melvin 2	1/8/74	37	489	2.0	16.0	98.0	32.0	0.36	0.5	0.25	24.0	140.0	317	1.9	360	720	6.6
	3/22/77		471	1.9	5.0	99.0	29.0	0.45	<0.1	0.25	15.0	120.0	276	1.8	371	670	7.4

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Melvin 2	6/11/80		432	<0.1	6.0	94.0	28.0	0.52	<0.1	0.3	10.0	130.0	271.0	1.7	354	690	7.5
	9/16/82		448	2.0	6.9	95.0	28.0	0.40	0.3	0.2	8.5	110.0	284.0	1.8	356	670	7.4
Everly	9/2/82	16	572	35.0	15.0	120.0	36.0	<0.01	56.0	0.2	49.0	46.0	354.0	<0.01	448	880	7.2
Everly #1	1/27/55	25	439	3.0	7.5	94.5	28.7	0.0	12.0	0.2	13.0	78.4	275.7	0.20	563	830	7.3
	2/3/58	25	572	6.0	12.2	108.0	35.5	0.47	9.6	0.2	37.0	115.0	317.0	0.10	461	680	7.5
	10/21/65	25	576	2.8	11.5	102.0	32.1	0.2	13.6	0.2	25.5	78.6	293.0	0.08	516	782	7.6
	5/15/68	25	461	3.0	10.0	92.8	28.2	<0.05	18.0	0.2	16.0	99.0	277.0	<0.02	572	820	7.4
	2/26/75	25	563	4.6	14.0	110.0	37.0	0.31	40.0	0.2	40.0	120.0	322.0	<0.01	439	653	7.3
Everly #2	1/25/65	32	337	2.3	5.0	75.2	19.4	0.28	6.2	0.2	4.0	57.1	264.0	1.4	268	523	7.1
	12/4/67	32	390	2.6	7.2	86.4	25.3	0.34	3.7	0.2	9.0	68.0	296.0	1.7	320	600	7.4
	9/21/70	32	405	1.8	6.9	92.8	23.3	0.30	9.0	0.25	14.0	75.0	307.0	1.4	328	610	7.4
Everly #3	3/22/77	20	566	3.0	15.0	110.0	36.0	<0.01	50.0	0.2	40.0	77.0	346.0	<0.01	433	870	7.2
	4/20/77								48.0								
	8/2/77								54.0								
	10/17/77								50.0								
	11/15/77								50.0								
	12/13/77								57.0								
	2/21/78								54.0								
	3/19/78								58.0								
	5/15/78								55.0								
	6/5/78								65.0								
	7/12/78								62.0								
	9/12/78								70.0								
	10/11/78								69.0								
	11/6/78								66.0								
	12/5/78								56.0								
	1/10/79								69.0								
	2/13/79								65.0								
	2/27/79								71.0								
	3/12/79								64.0								
	4/10/79								58.0								
	5/9/79								61.0								
	6/12/79								72.0								
	7/2/79								69.0								
	8/21/79								42.0								
	9/5/79								63.0								
	10/15/79								64.0								
	11/6/79								66.0								
	12/3/79								62.0								
	1/7/80								66.0								

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Everly #3	2/5/80								75.0								
	3/4/80								147.0								
	3/11/80								75.0								
	5/23/80	20	647	19	14.0	130	38.0	<0.01	85.0	0.2	76.0	70	340	<0.01	481	980	7.3
	7/5/81								77.0								
	8/12/81								66.0								
	9/2/81								65.0								
	10/13/81								64.0								
	11/16/81								57.0								
	12/7/81								60.0								
	1/13/82								63.0								
	2/8/82								65.0								
	3/2/82								67.0								
	6/8/82								75.0								
	7/6/82								80.0								
	8/3/82								61.0								
	8/25/82	20	572	3.5	15.0	120	36.0	<0.01	56.0	0.2	49.0	46	354	<0.01	448	880	7.2
	9/1/82								56.0								
	10/5/82								54.0								
	11/3/82								54.0								
	12/8/82								53.0								
	1/17/83								62.0								
	2/15/83								61.0								
	3/15/83								57.0								
	4/19/83								65.0								
	5/11/83								58.0								
	6/1/83								79.0								
	6/1/83								82.0								
	7/11/83								61.0								
	1/4/84								56.0								
	3/13/84								66.0								
	5/7/84								47.0								
	7/11/84								40.0								
	8/8/84								37.0								
Spencer #1	12/14/60	45	1368	4.6	12.3	349	65.2	1.95	0.4	0.35	12.0	764	410	7.0	1140	178	7.3
	5/26/67	45	2310	9.3	80.0	448	94.8	4.2	0.4	0.2	21.0	100	354	0.2	1511	280	7.3
Spencer 71-1	2/23/76	35	305	2.3	3.2	67	22.0	0.34	<0.1	0.2	2.0	53	238	2.6	263	476	7.4
	7/20/82	35	518	5.0	4.0	120	28.0	0.5	4.3	0.2	3.0	181	275	1.5	406	770	7.15
Spencer #2	12/14/60	45	1871	4.1	10.7	412	99.9	4.78	0.2	0.2	3.0	1030	425	7.3	1440	213	6.9
	5/26/67	35	1620	65.0	51.0	316	69.7	2.1	0.4	0.2	33.0	83	351	0.16	1078	190	7.3
Spencer 71-2	2/28/76	39	374	2.1	3.1	82	28.0	0.23	7.0	0.2	3.0	92	251	0.3	321	570	7.5
	1/25/80	39	362	1.2	4.3	81	19.0	0.71	3.9	0.3	6.5	74	243	1.1	284	500	7.4

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Spencer #3	12/14/60	45.0	1411	4.0	12.1	323.0	75.8	2.12	0.3	0.2	30.0	776	349	6.3	1120	1700	7.0
	5/26/67	45.0	1870	4.8	19.0	381.0	82.9	3.2	0.4	0.15	50.0	970	238	7.1	1293	2100	7.4
Spencer 71-3	2/23/76	38.0	332	2.1	4.2	72.0	24.0	0.32	3.9	0.1	3.0	70	238	7.1	282	450	7.4
Spencer #4	12/14/60	45.0	1985	6.1	27.1	424.0	102.0	4.65	0.3	0.1	91.0	1054	373	5.5	1480	2050	7.3
	5/26/67	45.0	2620	6.2	22.0	533.0	122.0	6.2	1.1	0.15	73.0	1400	359	0.12	1833	2800	7.2
Spencer (Eaton)	2/23/76		384	2.3	5.7	78.0	28.0	0.02	2.3	0.2	6.5	100	242	2.3	314	550	7.5
Spencer 76-2	12/10/82	35.0	424	2.6	4.4	93.0	26.0	0.08	15.0	0.2	14.0	73	295	0.16	340	650	7.2
Iverson Farm	12/19/69	24.0	508	10.0	11.0	108.0	25.3	<0.05	85.0	0.2	13.0	80	289	<0.02	373	760	7.1
Spencer Airport	12/19/69	25.0	314	3.0	4.2	74.0	16.5	0.39	1.1	0.2	3.0	74	239	0.28	253	470	7.2
Spencer Country Club	12/19/69	30.0	495	2.6	9.6	103.0	29.2	<0.05	62.0	0.2	10.0	100	295	<0.02	377	730	7.1
Spencer Sand Pit	9/30/68	Surface Water	324	2.6	3.8	65.6	20.4	0.11	0.4	0.15	4.0	95	195	0.32	248	470	7.8
	2/23/76	Surface Water	363	2.0	6.7	73.0	27.0	0.13	0.4	0.2	8.0	93	216	0.15	291	560	7.5
Spencer - B2	9/25/73	44.5			30.0	188.0	92.0	0.35	0.0		12.0	70		2.27	280		7.5
Spencer - B3		46.5			49.0	244.0	122.0	0.15	49.0		24.0	93		5.25	366		7.4
Spencer - B4		41.5			43.0	180.0	102.0	0.6	14.0		17.0	73		2.5	282		7.7
Spencer - B5	9/28/73	36.5			81.0	152.0	138.0	1.0	0.4		14.0	85		9.6	290		7.6
Spencer - B6	9/28/73	41.5			24.0	216.0	96.0	0.35	9.0		14.0	71		5.1	312		7.5
Spencer - B7	9/25/73	51.5			14.0	184.0	88.0	0.15	0.0		11.0	65		1.0	272		7.45
Spencer - B8	9/28/73	41.5			41.0	236.0	122.0	1.0	1.8		24.0	108		1.75	358		7.4
Spencer - B9		36.5			21.0	186.0	94.0	0.8	0.0		8.0	79		0.7	280		7.6
Spencer - B10	9/24/73	36.5			90.0	268.0	122.0	0.1	110.0		35.0	55		3.9	390		7.5
Spencer - 1-69	12/18/69	50.0			106.0	360.0	144.0	1.2	0.0		40.0	330		0.26	504		6.9
Osceola-O'Brien RWS - S#2	1/13/81	45.0	459	2.6	12.0	99.0	36.0	0.6	12.0	0.4	20.0	92	326	0.04	396	730	7.25
RWS - S#2 Florine	1/13/81	45	644	3.3	13.0	99.0	36.0	0.05	12.4	0.51	20.0	90	348	0.07	395	790	7.7
RWS - S#4	1/15/81	36.5	317	<0.1	2.6	85.0	29.0	0.12	23.0	0.3	2.5	38	313	0.12	332	590	7.55
RWS R-2	8/24/81	38.0		3.0	14.0	104.0	34.0	0.3	0.04		28.0	138	298	0.42	400	859	7.1
RWS H-1	9/3/81	52.5						0.35	0.06		14.0		268	2.43		750	7.5
RWS H-2	11/4/81	43.0		2.0	11.0	64.0	58.0	0.1	0.07		22.0	153	278	1.85		750	7.9
RWS - H2	1/15/81	43	544	1.8	4.0	84.0	29.0	0.11	21.7	0.51	5.1	42	333	0.08	329	608	7.3
RWS - H2	1/15/81	43	317	<0.1	2.6	85.0	29.0	0.12	23.0	0.3	2.5	38	313	0.12	332	590	7.4
RWS R-1	11/4/81	40.0		1.0	8.0	128.0	43.0	0.05	0.08		26.0	242	266	0.32		850	7.7
RWS - Anderson	1/12/81		773	2.4	5.2	121.0	38.0	0.52	0.0	0.3	6.3	112	420	1.6	458	799	7.3
RWS - Anderson	1/12/81		534	0.6	4.7	130.0	39.0	0.58	1.0	0.3	4.0	120	408	3.4	492	810	7.3
RWS - H01	1/15/81	43	504	0.8	5.5	120.0	37.0	<0.01	37.0	0.3	6.5	64	397	<0.01	444	780	7.4
Gillett Grove #1	5/9/77	40.0	641	1.2	6.2	140.0	39.0	<0.01	13.0	0.3	42.0	96	410	0.16	503	900	7.2
	3/17/80	40.0	525	<0.1	7.3	130.0	35.0	0.01	14.0	0.4	32.0	75	416	<0.01	475	860	7.1
	9/17/82	40.0	595	1.2	13.0	130.0	35.0	<0.01	14.0	0.2	24.0	70	446	0.07	464	890	7.1

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Gillett Grove	5/31/83								36.0								
	7/18/83								24.0								
	10/19/83								15.0								
	1/19/84								14.0								
	5/1/84								18.0								
	8/6/84								22.0								
Clay County																	
RWS - #1	2/13/79	37.0	299	<0.1	2.9	63.0	23.0	0.33	0.2	0.3	2.0	60	244	1.5	255	490	7.55
RWS - #2	9/29/80	42.0	330	2.6	2.7	66.0	22.0	0.28	10.0	0.2	5.0	53	221	1.0	258	490	7.7
RWS - #3	11/8/80	32.0	349	0.3	4.4	84.0	26.0	0.37	16.0	0.2	7.5	75	255	0.42	318	580	7.75
RWS - #4	9/24/80	32.0	339	2.5	4.1	74.0	25.0	0.29	3.0	0.3	9.0	71	248	0.97	290	530	7.85
RWS - #2A	1/4/79		277	2.3	3.0	62.0	22.0	0.83	1.1	0.3	2.0	51	234	2.6	252	460	7.5
Sioux Rapids #1	12/22/57	28.0	604	2.3	16.1	118.0	35.5	<0.05	26.1	0.25	18.0	144	337	<0.02	440	847	
	4/17/62		595	2.6	15.0	121.0	34.0	<0.05	41.4	0.25	17.0	151	329	<0.02	442	874	
Sioux Rapids #1	4/14/67		601	2.6	15.0	128.0	369	<0.05	33.0	0.25	17.0	150	383	<0.02	472	920	7.1
	2/10/70								55.0								
	11/24/71		633	3.6	16.0	140.0	39.4	<0.02	42.0	0.25	21.0	160	368	<0.02	481	920	7.4
	5/8/74								60.0								
	11/5/74								45.0								
	12/2/74								45.0								
	8/6/75								45.0								
	10/8/75								50.0								
	11/12/75								45.0								
	1/12/76								45.0								
	4/8/76		619	1.8	13.0	130.0	43.0	<0.01	32.0	0.2	24.0	120	376	<0.01	494	910	7.25
	5/12/76								45.0								
	6/9/76								45.0								
	7/14/76								55.0								
	8/11/76								50.0								
	6/28/78								31.0								
	11/13/78								55.0								
	11/27/78								53.0								
	12/18/78								44.0								
	2/26/79								36.0								
	3/19/79								33.0								
	6/19/79								64.0								
	9/11/79								57.0								
	11/13/79	28							36.0					0.2	430		
Sioux Rapids # 2	2/8/79	54	606	0.5	20.0	120.0	39.0	002	38.0	0.4	27.0	120	382	0.01	458	930	7.1
	11/13/79								43.0					0.1	430		
	7/13/82		512	3.0	13.0	120.0	33.0	001	33.0	0.3	22.0	98	361	<0.01	425	870	6.9

Town and Well Number	Date	Depth (ft)	Diss. Solids	K	Na	Ca	Mg	Mn	NO_3	F	Cl	SO_4	HCO_3	Fe	Hard-ness	Conduct-ance (micro-mohs)	ph
Linn Grove #1	2/26/69		677	4.6	16.0	136.0	37.7	1.4	3.9	0.3	68.0	140	407	4.7	495	1000	7.0
	6/26/77		570	2.0	34.0	120.0	40.0	0.4	2.2	0.35	23.0	130	393	2.0	440	850	7.65
Linn Grove #2	8/4/49	31	604			185.0	37.5	2.1	0.0	0.3	9.0	115	434	0.1	471	872	7.1
	1/9/59		642	3.2	27.4	150.0	45.2	0.56	18.0	0.3	<5.0	164	451	0.56	560	889	7.0
	2/27/69		1130	9.7	32.0	162.0	74.1	0.19	0.2	0.3	<5.0	470	488	5.8	710	1400	6.8
	6/26/74		567	3.3	24.0	120.0	4.1	1.1	5.3	0.35	2.5	130	427	0.34	448	830	7.5
	5/9/77		609	3.7	29.0	140.0	39.0	0.56	2.0	0.3	35.0	96	456	5.0	515	900	7.15
	12/9/82		576	3.4	23.0	120.0	40.0	0.91	17.0	0.4	32.0	94	427	22.0	476	890	7.1
Linn Grove #3	5/9/77	35	666	4.1	14.0	140.0	42.0	1.3	0.3	0.3	42.0	110	481	0.24	535	970	7.05
	7/13/82		629	4.7	18.0	58.0	40.0	1.1	0.6	0.3	38.0	100	246	0.66	313	1110	6.9
Washta #1	12/6/34	28	847		37.3	27.5	37.6	0.0	24.0	1.0	38.0	155	303	0.0	457		7.2
	6/11/46		730			32.0	157.0	0.0	21.0	0.2	43.0	178	310		524		7.0
	12/1/60		683	2.8	18.3	31.3	147.0	<0.05	0.3	0.2	24.0	167	378	<0.02	496	960	7.3
Washta #2	1/5/61	38	514	1.5	12.7	27.7	114.0	<0.05	11.9	0.2	12.0	92	344	<0.02	400	770	7.4
	1/23/67		498	2.1	11.0	27.2	112.0	<0.05	27.0	0.2	8.0	98	364	0.10	392	780	7.4
	7/2/74		619	3.0	9.3	38.0	140.0	<0.01	58.0	0.2	36.0	94	378	0.11	500	960	7.5
Correctionville-2L	5/9/74	26	564	6.2	8.2	120.0	35.0	<0.01	66.0	0.2	10.0	98	332	13.0	400	790	7.5
	5/12/75		454	5.0	14.0	100.0	30.0	<0.01	18.0	0.25	12.0	97	296	0.01	358	690	7.45
Correctionville-2W	5/9/74	26	688	4.4	27.0	140.0	42.0	0.06	7.1	0.2	25.0	200	393	0.08	520	1100	7.4
	5/12/75		659	4.8	29.0	130.0	40.0	0.02	6.7	0.3	25.0	180	326	0.02	485	930	7.25
Correctionville-2N	5/9/74	26	563	2.0	12.0	110.0	34.0	<0.01	43.0	0.3	13.0	120	329	0.06	400	790	7.45
	5/12/75		532	3.2	21.0	110.0	44.0	<0.01	28.0	0.3	17.0	100	371	0.06	402	790	7.35
Correctionville-Combined	4/20/59	26	730	3.1	23.4	156.0	27.5	<0.05	72.0	0.35	22.0	184	327	0.1	504	906	
	9/26/66		645	3.9	19.0	136.0	32.8	<0.05	49.0	0.1	19.5	150	364	0.2	475	930	
Oto #2	6/27/54	65	727	5.8	12.0	155.0	43.7	1.1	0.0	0.2	22.0	144	490	1.5	571	903	7.2
	5/5/59		563	4.9	13.3	146.0	39.6	1.0	1.3	0.3	18.0	122	470	0.68	528	836	
	3/27/63		726	5.5	14.4	162.0	45.2	1.0	4.5	0.3	24.0	152	498	0.24	592	1070	
	2/4/69		607	6.6	16.0	156.0	41.3	1.1	1.6	0.2	18.0	150	510	1.2	560	1000	6.9
	8/2/73		704	3.0	17.0	180.0	49.0	0.9	1.4	0.25	36.0	160	586	0.99	630		7.3
	7/10/74		708	5.8	19.0	170.0	46.0	0.7	2.6	0.25	34.0	130	544	1.1	640	1100	7.25
	9/12/81		722	5.1	18.0	160.0	39.0	1.2	3.1	0.3	28.0	130	533	0.53	563	1700	6.8

Table E-2. Alluvial Metals and Radioactivity Analyses (Source: UHL, IGS)

(Metals in mg/l, Radioactivity in Pci/l)

	Date	As	Ba	Cd	Cr	Cu	Pb	Hg	Se	α	^{226}Ra	Sc^{90}	β	$^{222}Radon$
Spencer 1	7/20/82	<.01	.1	<.001	<.01	.01	<.01	<.001	<.01					
Spencer 1	2/23/76	<.01	<.1	<.001	<.01	<.01	<.01	<.001		1.2			7	
Spencer 2	2/28/76	<.01	<.1	<.001	<.01	<.01	<.01	<.001		1.4			3	
Spencer 3	2/23/76	<.01	<.1	<.001	<.01	<.01	<.01	<.001		2.8			5	
Spencer 4	2/23/76	<.01	.1	<.001	<.01	.03	<.01	<.001		2.1			9	
Spencer 6	12/10/82	<.01	.1	<.001	<.01	<.01	<.01	<.001	<.01	<.1			2	20
Spencer Sand Plt	2/23/76	<.01	<.1	<.001	<.01	<.01	<.01	<.001					5	
Ocheyedan 1	8/25/82	<.01	<.1	<.001	<.01	<.01	<.01	<.001		2.5			4	11
Ocheyedan 1	3/18/76	<.01	<.1	<.01	<.01	.06	<.01	<.001		3.8	0.2		5.6	
Ocheyedan 1	9/29/76	<.01	<.1	<.01	<.01	<.01	<.01	<.001		0.8			13	<.47
Everly 1	2/26/75	<.01	.1	<.01	<.01	.01	<.01	<.001		0		.62	11	
Everly 2	9/21/70	<.01	.4	<.01	<.01	<.01	<.01							
Everly 3	3/22/77	<.01	.1	<.01	.01	.03	<.01	<.001	<.01	3.3			6	
Everly 3	5/23/80	<.01	.2	<.001	<.01	<.01	<.01	<.001	<.01	1.2			10	
Everly 3	9/12/82	<.01	.2	<.001	<.01	<.01	<.02	<.001	<.01	1.1			3	
Everly 3	8/25/82	<.01	.2	<.001	<.01	<.01	<.02	<.001	<.01	1.1			3	13
Clay Cnty RWS #1	2/13/79	<.01	.2	<.01	<.01	<.01	<.01	<.001	<.01					
Clay Cnty RWS #2	9/29/80	<.01	.1	<.001	<.01	.02	<.01	<.001	<.01	2.2	0.3		6	
Clay Cnty RWS #3	11/8/80	<.01	.2	<.001	<.01	<.01	<.01	<.001	<.01	0.7			<.5	
Clay Cnty RWS #4	9/24/80	<.01	.1	<.001	<.01	.15	<.01	<.001	<.01					
Osceola O'Brien RWS #2	1/13/81	<.01	.1	<.002	<.01	<.01	<.01	<.001	<.01					

Table E-3. Private Alluvial Water Analyses (Source: UHL)
(Analyses in mg/l)

No.	Location	Well Depth	Bacteria	Nitrate	Iron	Hardness	Date
1	T99N R40W Sec. 8	25'	16+	25	0.2	330	11/74
2	T99N R40W Sec. 14	18'	0	29		470	4/83
3	T99N R40W Sec. 23	38'	16+	160	0.1	760	7/75
4	T99N R40W Sec. 27	27'	0	160	<.1	690	3/76
5	T97N R38W Sec. 13	15'		115	0.3	400	5/80
			0				5/80
				117	<.1	380	6/80
				112	<.1	370	6/80
				99	<.1	360	6/80
				98	<.1	350	7/80
6	T97N R38W Sec. 13	15'		26			5/80
				26			5/80
				26			6/80
				26			6/80
				27			6/80
7	T97N R38W Sec. 24	18'		115	0.3	400	5/80
			16+				5/80
				46			5/80
				89	<.1	400	6/80
				112	.6	460	6/80
				112	1.6	450	6/80
				99	1.9	470	7/80
8	T97N R38W Sec. 31	15'	9.2	30	<.1	330	4/75
		20'	0	20	<.1	420	4/75
		20'	5.1	5	0.1	460	4/75
		25'	16+	170	<.1	540	12/78
9	T97N R37W Sec. 18			85			5/80
				82			5/80
				85			6/80
				88			6/80
				85			6/80
10	T97N R37W Sec. 20	18'	9.2	62	<.1	320	6/79
		20'	0	32	<.1	440	1/77
11	T97N R37W Sec. 31	?	16+	33			11/82

No.	Location	Well Depth	Bacteria	Nitrate	Iron	Hardness	Date
12	T97N R36W Sec. 9	15'	0	40	<.1	390	1/75
		18'	0	14	<.1	430	6/76
		12'	0	30	<.1	320	6/79
		?	0	29	<.1	310	4/80
		15	0	42	<.1	350	5/81
13	T97N R36W Sec. 10	15'	0	15	<.1	220	11/80
14	T97N R36W Sec. 14	15'	0	6	.4	320	3/80
15	T97N R36W Sec. 16	25'	0	<5	.1	300	4/80
16	T97N R36W Sec. 17	30'	2.2	250	<.1	410	8/80
17	T96N R37W Sec. 10	30'	0				6/81
18	T96N R37W Sec. 14	?	0	23			6/83
19	T96N R36W Sec. 15	20'	0	<5			4/82
		25'	16+	94	.2	400	5/78
20	T96N R36W Sec. 36	20'	0	92	<.1	440	3/78
21	T88N R43W Sec. 16	?		370			5/80

Table E-4. Sampling Locations for River Quality Data

Station 1	Little Sioux River	T100N R37W Sec. 15/16
Station 2	Little Sioux River	T98N R37W Sec. 11
Station 3	Little Sioux River	T98N R37W Sec. 14/23
Station 4	Little Sioux River	T96N R37W Sec. 14
Station 5	Ocheyedan River	T96N R37W Sec. 15/16
Station 6	Ocheyedan River	T96N R37W Sec. 13
Station 7	Little Sioux River	T96N R36W Sec. 18
Station 8	Little Sioux River	T96N R36W Sec. 16/17
Station 9	Little Sioux River	T95N R36W Sec. 34/35
Station 10	Little Sioux River	T93N R37W Sec. 5/6
Station 11	Little Sioux River	T93N R37W Sec. 5
Station 12	Little Sioux River	T94N R39W Sec. 32
Station 13	Little Sioux River	T93N R39W Sec. 16/21
Station 14	Little Sioux River	T92N R40W Sec. 26
Station 15	Little Sioux River	T91N R40W Sec. 21/28
Station 16	Little Sioux River	T90N R41W Sec. 30/31
Station 17	Little Sioux River	T89N R42W Sec. 1
Station 18	Little Sioux River	T87N R43W Sec. 8
Station 19	Little Sioux River	T86N R44W Sec. 13/24
Station 20	Little Sioux River	T85N R44W Sec. 16

Table E-5. Water Quality Analyses--Little Sioux and Ocheyedan Rivers (Source: UHL)

(All values in mg/l unless otherwise specified)

County	No.	Date	Temp (C°)	pH[a]	Nitrate N	Nitrite N	Org. N	Amm. N	Tot. Alk.	Tot. P	Cl	Turb.[b]	Diss. Oxygen	Hardness	Conductance[c]	Fecal/100 ml Coliforms
Dickinson	1	8/4/75	31.0	8.1	0.3	0.033	3.5	0.04	262	0.25	18	38	16.7	228	990	1,100
		10/13/75	21.0	8.2	0.7	0.019	1.4	0.22	245	0.14	5.5	19	18.6	---	1120	5,900
		5/24/76	27.0	8.3	0.3	0.03	1.1	0.08	266	0.14	12	22	15.4	476	890	50
		8/14/79	18.0	7.5	1.9	-----	1.1	0.04	162	0.24	10	3.1	3.4	---	460	10
Dickinson	2	10/13/75	20.0	8.3	2.3	0.026	2.8	0.14	183	0.28	16	31	21.8	---	600	200
		5/24/76	20.0	8.25	1.3	0.09	1.5	0.11	215	0.13	20	40	19.2	380	720	440
		8/14/79	19.0	7.9	2.6	-----	1.5	0.04	163	0.27	12	18	7.1	---	510	1,200
Dickinson	3	8/4/75	29.0	9.05	0.7	0.27	3.1	0.01	159	1.0	27	44	22.9	248	610	110
		10/13/75	20.0	8.4	0.1	0.069	2.2	0.01	247	1.2	26	67	15.6	---	690	400
		5/24/76	22.0	8.4	1.3	0.12	1.6	0.11	216	0.44	22	16	21.4	352	690	80
		8/14/79	20.5	7.55	2.8	-----	1.4	0.09	165	0.34	14	20	6.9	---	500	720
Clay	4	10/13/75	20.0	8.35	0.3	0.025	2.4	0.1	168	0.33	17	30	18.5	---	550	400
		5/24/76	21.0	8.4	2.5	0.1	1.4	0.08	223	0.16	22	16	17.5	348	690	40
		8/14/79	19.5	7.95	2.6	-----	1.2	0.11	159	0.40	13	27	7.1	---	500	640
Clay	5	8/15/79	14.0	8.25	5.4	-----	0.99	0.53	253	0.23	28	35	9.1	---	820	8,000
Clay	6	8/4/75	29.0	8.54	1.4	0.03	1.1	0.19	205	0.14	19	18	10.2	376	740	800
		10/13/75	20.5	8.25	2.3	0.035	0.71	0.02	198	0.05	18	12	12.3	---	700	50
		5/24/76	17.0	8.05	10.0	0.08	1.2	0.09	223	0.2	23	33	10.6	484	860	1,400
Clay	7	10/13/75	20.5	8.25	1.6	0.03	1.3	0.22	198	0.17	18	22	15.0	---	660	510
		5/24/76	19.0	8.1	8.2	0.08	1.4	0.08	252	0.17	23	29	11.5	446	820	1,600
		8/14/79	18.0	8.0	3.2	-----	1.2	0.09	169	0.31	14	32	7.2	---	530	1,400

County	No.	Date	Temp (C°)	pH[a]	Nitrate N	Nitrite N	Org. N	Amm. N	Tot. Alk.	Tot. P	Cl	Turb.[b]	Diss. Oxygen	Hardness	Conductance[c]	Fecal/100 ml Coliforms
Clay	8	8/5/75	23.0	8.2	0.6	0.035	2.8	0.09	183	0.42	32	31	5.9	248	740	16,000
		10/14/75	14.0	7.95	1.3	0.072	1.7	0.88	200	0.44	32	22	6.4	---	750	12,000
		5/25/76	17.0	8.05	8.3	0.11	1.4	0.26	259	0.31	29	37	9.0	448	860	950
		8/14/79	20.0	8.05	3.3	-----	1.3	0.12	171	0.40	21	34	7.5	---	580	1,500
Clay	9	10/14/75	15.0	8.3	1.4	0.055	1.8	0.12	213	0.31	25	22	9.2	---	690	400
		5/25/76	16.0	8.1	9.4	0.14	1.4	0.19	250	0.15	28	27	9.2	430	830	12,000
		8/14/79	18.0	8.1	3.5	-----	1.7	0.11	176	0.41	23	55	8.3	---	590	2,000
Buena Vista	10	8/14/79	18.0	8.5	4.0	-----	1.8	0.09	186	0.42	18	65	8.2	---	600	2,500
Buena Vista	11	10/14/79	15.5	8.2	0.7	0.038	2.0	0.19	187	0.24	29	30	11.2	---	660	400
		5/25/76	15.0	8.05	5.7	0.12	1.5	0.16	231	0.16	29	27	10.0	372	720	800
		8/14/79	18.0	8.2	4.5	-----	1.5	0.12	203	0.43	21	60	8.3	---	640	2,600
Clay	12	8/5/75	30.0	8.5	<0.1	0.05	2.5	0.03	162	0.29	32	53	10.6	216	630	400
		10/14/75	14.5	8.25	0.7	0.03	2.2	0.06	189	0.27	26	30	11.1	---	670	100
		5/25/76	16.0	8.2	5.5	0.95	1.7	0.05	232	0.26	30	35	10.8	368	740	920
		8/14/79	18.0	8.2	5.2	-----	2.0	0.09	227	0.45	23	60	8.4	---	710	3,500
Cherokee	13	10/14/75	15.5	8.4	0.6	0.03	2.3	0.05	193	0.24	24	30	13.6	---	660	<100
		5/25/75	17.0	8.25	5.3	0.074	2.2	0.02	234	0.33	29	80	11.6	364	740	1,500
		8/14/79	17.0	8.3	5.2	-----	1.7	0.09	233	0.41	24	60	8.7	---	730	1,900
Cherokee	14	8/5/75	26.0	8.65	<0.1	0.007	2.6	<0.01	147	0.29	27	53	13.2	260	570	1,200
		10/14/75	16.0	8.55	0.5	0.029	2.4	0.04	177	0.21	21	31	15.8	---	610	100
		5/25/76	18.0	8.25	7.0	0.069	2.4	0.02	254	0.41	24	90	10.8	380	740	4,400
		8/14/79	20.5	8.25	5.0	-----	2.3	0.09	240	0.62	26	60	8.8	---	720	3,200
Cherokee	15	8/5/75	27.0	8.7	<0.1	0.007	2.6	0.19	140	0.31	26	57	16.4	258	560	1,000
		10/14/75	18.0	8.6	0.4	0.03	2.5	0.02	160	0.32	24	36	22.6	---	610	<100
		5/25/76	20.0	8.25	6.7	0.092	2.4	0.08	246	0.45	29	90	14.0	372	740	5,600
		8/14/79	26.5	8.3	4.7	-----	1.9	0.25	233	0.48	27	60	7.8	---	710	1,600

County	No.	Date	Temp (C°)	pH[a]	Nitrate N	Nitrite N	Org. N	Amm. N	Tot. Alk.	Tot. P	Cl	Turb.[b]	Diss. Oxygen	Hardness	Conductance[c]	Fecal/100 ml Coliforms
Cherokee	16	10/14/75	16.5	8.7	0.2	0.022	2.6	0.01	149	0.28	22	31	17.4	---	580	<10
		5/25/76	19.0	8.05	6.4	0.11	2.6	0.15	235	0.44	23	100	10.0	360	710	5,600
		8/14/79	20.0	8.2	4.1	----	1.7	0.3	222	0.5	28	70	7.8	---	700	2,600
Woodbury	17	10/14/75	17.5	8.65	0.3	0.024	2.6	0.02	157	0.25	23	29	17.7	---	610	10
		5/25/76	19.0	8.0	5.5	0.15	2.8	0.39	234	0.61	23	100	9.6	360	660	9,600
		8/14/79	20.0	8.25	3.4	----	1.7	0.13	233	0.48	28	65	8.2	---	710	2,200
Woodbury	18	10/14/75	17.5	8.55	0.3	0.025	2.5	0.05	171	0.25	22	30	17.0	---	630	2,200
		5/25/76	19.0	7.9	4.4	0.13	2.8	0.45	220	0.52	23	90	8.6	346	700	5,100
		8/14/79	20.5	8.25	3.3	----	1.8	0.1	237	0.51	28	70	7.3	---	730	2,400
Woodbury	19	10/14/75	18.5	8.25	0.1	0.01	2.6	0.05	145	0.25	22	333	18.9	---	570	200
		5/25/76	19.0	7.95	4.1	0.13	2.8	0.48	217	0.59	23	120	8.6	342	680	10,000
		8/14/79	20.0	8.3	3.5	----	1.8	0.12	240	0.51	33	80	7.8	---	750	1,300
Monona	20	10/14/75	17.0	8.35	0.1	0.006	2.7	0.06	141	0.26	22	36	21.0	---	570	60
		5/25/76	20.0	8.0	3.9	0.12	3.0	0.38	210	0.65	22	120	13.1	332	660	8,800
		8/14/79	20.0	8.3	3.5	----	1.7	0.1	242	0.54	28	75	8.1	---	720	1,400

[a] Measured in pH units
[b] Measured in turbidity units
[c] Measured in micromohs

Table E-6. Metals and Pesticides Analyses - Little Sioux and Ocheyedan Rivers (Source UHL)

(All values in mg/l unless otherwise designated)

Station	Date	As	Ba	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Sc	Zn	Dieldrin[a]	Atrazine[a]
1	10/15/75	--	0.1	<0.01	<0.01	<0.01	----	----	0.02	<0.01	----	0.06	--	--
	5/24/76	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.01	--	--
	8/14/79	<0.01	<0.1	<0.001	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.02	0.008	0.43
3	5/24/76	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.03	--	--
4	10/13/75	--	0.1	<0.01	<0.01	<0.01	----	----	0.02	<0.01	----	0.09	--	--
	5/24/76	<0.01	0.1	<0.01	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.01	--	--
5	10/13/75	--	<0.1	<0.01	<0.01	<0.01	--	----	0.02	<0.01	----	<0.01	--	--
6	5/24/76	<0.01	0.1	<0.01	0.01	<0.01	0.05	<0.001	<0.1	<0.01	<0.01	0.05	--	--
7	10/14/76	--	0.1	<0.01	<0.01	<0.01	--	----	<0.01	<0.01	----	0.03	--	--
8	10/14/75	--	0.1	<0.01	<0.01	<0.01	--	----	<0.01	<0.01	----	0.02	--	--
	5/25/76	<0.01	0.1	<0.01	0.01	<0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.02	--	--
	8/14/79	<0.01	<0.1	<0.001	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.02	0.008	0.44
9	5/25/76	<0.01	0.1	<0.01	<0.01	<0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.02	--	--
11	10/14/75	--	0.1	<0.01	<0.01	<0.01	----	----	0.02	<0.01	----	0.03	--	--
12	5/25/76	<0.01	<0.1	<0.01	<0.01	<0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.08	--	--
13	8/14/79	<0.01	0.1	<0.001	0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	0.02	0.005	0.25
14	5/25/76	<0.01	0.1	<0.01	<0.01	0.01	<0.01	<0.001	<0.1	<0.01	----	0.02		
	8/14/79	<0.01	0.1	<0.001	<0.01	<0.01	<0.01	<0.001	<0.1	<0.01	<0.01	0.02	0.006	0.27
15	10/14/75	--	0.1	<0.01	--	<0.01	----	----	0.02	<0.01	----	0.02	--	--
	5/25/76	<0.01	0.1	<0.01	<0.01	<0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.03	--	--

a) Concentrations in PPB

Station	Date	As	Ba	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Sc	Zn	Dieldrin[a]	Atrazine[a]
17	5/25/76	<0.01	0.1	<0.01	<0.01	<0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.02	--	--
19	10/14/75	--	0.1	<0.01	<0.01	<0.01	--	--	0.02	<0.01	--	0.02	--	--
	8/14/79	<0.01	0.1	<0.001	<0.01	<0.01	<0.01	<0.001	<0.01	<0.01	<0.01	0.03	0.005	0.21
20	5/25/76	0.01	0.2	<0.01	<0.01	0.01	0.01	<0.001	<0.1	<0.01	<0.01	0.04	--	--

a) Concentrations in PPB

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