AN EXPERIMENTAL INVESTIGATION OF BUILDING SITES

Thesis for the Degree of B. S.

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By

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We take this opportunity to express our appreciation to Mr. Keck for his assistance and advice in the course of this investigation and to the Departments of Physics and Building & Grounds for the use of some of their equipment.

-INTRODUCTION-

The survey discussed in this paper was undertaken in the hope of adding a new tool to the Civil Engineering profession or perhaps, more properly, of developing an additional use for a recently acquired tool. Electrical methods of geophysical prospecting have been applied within the last few years to the solution of certain engineering problems in highway work and dam construction. The purpose of this survey was to determine the applicability of the resistivity method of geophysics to the investigation of the types of material to be encountered in excavation for building foundations. It was believed that if some procedure could be devised for the accurate determination of subsurface conditions by such a method that it would be of considerable benefit to the engineering profession. In addition it was hoped that some knowledge might be gained that would be useful to the science of geophysics.

The areas selected for the survey were proposed future building sites on the college campus, although the required depths of excavation for such buildings are so shallow as to make the value of such methods of investigation debatable. However, it was considered advisable to select actual building sites since that would be one of the necessary conditions under which the method would be used. It was expected that the method would be more applicable to large buildings requiring at least twenty feet or more of excavation since the increase in cost and difficulty of securing samples by boring is a multiple of the increase in depth.

From a list of future building sites secured from the building and grounds department two were selected for investigation. These two were considered by the department to be probably among the first to be constructed. A second consideration in their selection was the difference in conditions presented, one being only a few feet higher than the river and the other about thirty five higher. One location was on the high point between Michigan Ave. and the river west of the College Hospital. This is the site of the proposed new dormitory for girls. The other location was on the south side of the river, west of the Armory road and south of the baseball field. It is planned to erect a fieldhouse on this site.

-SUMMARY-

This report describes the results obtained in a survey of future campus building sites using electrical methods of geophysics. This is the first investigation, as far as is known to the authors, conducted for the purpose of applying geophysical methods to the determination of material to be encountered in shallow excavations. Geophysical methods have been applied to the investigation of subsurface conditions in highway and dam construction.

The four electrode method of Wenner was used with modified and improved type of equipment. The major improvement is the use of an auxiliary potential circuit to eliminate natural ground potentials. Current electrodes were designed which satisfy the assumption used in the derivation of Wenner's formula.

Results were checked with actual samples obtained by a soil auger. The effect of change in moisture content on resistivity readings was investigated.

Mathmatical analysis on the basis of a two layer problem was studied and found to be inadequate for the actual conditions.

Tables of the results obtained at each station are included with Columnar sections for each of the two plots surveyed and sample resistivity curves with an explanation of interpretation.

The investigation points the way to further work along the same line with this and also a second method.

HISTORY OF ELECTRICAL METHODS OF GEOPHYSICS

The first investigations in electrical methods of prospecting were begun by Conrad Schlumberger of Paris, Lundberg and Nathorst of Sweden and Harry Conklin of Missouri in 1912. Other investigators have been instrumental in futhering the development in increasing numbers. The first efforts were directed towards the determination of geologic structures particularly in the petroleum and mining fields.

In recent years several investigators have extended their activities into the field of Civil Engineering. The Schlumberger Electrical Prospecting Company of New York has conducted investigations of proposed dam sites, one of which is reported by I. R. Crosby in an article in Engineering and Contracting, Vol.68 , No. 10.

The U. S. Bureau of Public Roads reported the results of their studies of the application of earth resistivity methods to the problem of determining the volume of rock in highway excavations.# This report also gave a brief review of the results obtained in similar investigations by the Highway Department of Missouri.

Public Roads, Vol. 16, No. 4, June, 1935.

GENERAL

Electrical methods of geophysics may be divided into three classes, the Self Potential, Applied Potential and Resistivity Method. The basic principle of all of these methods is the determination of subsurface material by the study of an electrical field, either natural or applied. The variations in the electrical characteristics of different earth materials result in disturbances of the electrical field and a study of these disturbances makes it possible to deduce subsurface conditions.

The Potential methods have a more restricted field than the resistivity method, being particularly applicable to the mining field. The survey described in this report was conducted by means of earth resistivity measurements which will be described in detail.

The method used is a modification of that developed by Gish and Rooney, based on the theory worked out by Wenner of the U. S. Bureau of Standards.

The apparatus used consists of a source of current, supplied by batteries, four electrodes supplying contact to the ground, a milliammeter, potentiometer, wire and other appurtenances to complete the circuit.

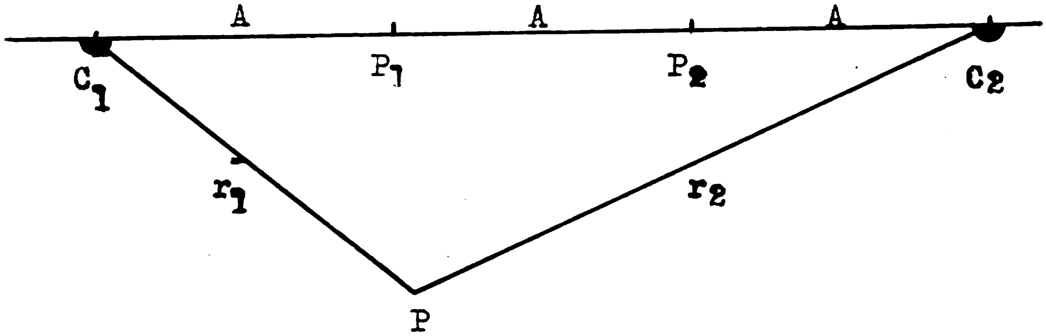
The following proof of Wenners' formula by Dr. L. V. King of McGill University is taken from a textbook, 'Applied Geophysics', by Eve and Keys.

In Fig. 1, C_1 and C_2 are electrodes supplying current to the ground. P_1 and P_2 are potential electrodes spaced so that $C_1P_1=P_1P_2=P_2C_2=A$.

Let V be the potential at any point due to current flow between C_1 and C_2.

V must satisfy $\nabla^2V=0$ in an indefinitely extended homogeneous medium.

Fig. 1.



At a point P distant r_1 and r_2 from electrodes of small dimensions (compared to r_1 and r_2) a solution of $\nabla^2V=0$ is

$$V=\frac{A}{r_1}+\frac{B}{r_2}$$

where A and B are constants.

The surface of the semi-infinite plane is easily seen to be everywhere at right angles to the equipotential surfaces. Consider electrode C_1 to be a small hemisphere; then if p is the specific resistance, the normal current flow is $-\frac{1}{p}\frac{\partial V}{\partial n}$, so that outflow of current from C_1 is

$I=\int\frac{1}{p}\frac{\partial V}{\partial n}dS$ over the electrode.

Neglect the term $\frac{B}{r_2}$ and write $dS = r^2 dw$, where w is a solid angle, then

$$I = -\frac{1}{p}\int \frac{\partial}{\partial r}\frac{A}{r}\, r^2 dw = \frac{A}{p} 2\pi.$$

Hence $A = \frac{pI}{2\pi}$ and by symmetry $B = -\frac{pI}{2\pi}$.

Thus at any point

$$V = \frac{pI}{2}\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$

If P_1 and P_2 be electrodes so that $C_1P_1 = P_1P_2 = P_2C_2 = A$,

$$V_p = \frac{pI}{2\pi}\left(\frac{1}{A} - \frac{1}{2A}\right),$$

$$V_q = \frac{pI}{2\pi}\left(\frac{1}{2A} - \frac{1}{A}\right),$$

$$V_p - V_q = \frac{pI}{2\pi}\,\frac{1}{A},$$

which is Wenner's formula.

This formula is used in the form $p = \frac{2\pi AV}{I}$, where p is the resistivity, A is the electrode spacing, V is the potential and I is the current supplied. This gives the average resistivity to the depth A, the electrode spacing.

This formula is based on the assumption of a homogeneous layer of infinite extent. When this is not the case the value obtained is an average resistivity of the material. Interpretation of the results involves the use of certain emperical rules rather than a strict mathmatical analysis, which is possible in the solution of a two layer problem, since in practice, earth presents a problem of many layers.

The most general method of interpretation is by plotting the average resistivity values obtained against depth. In passing from a layer of one resistivity to another a break or change of slope will appear in the curve. The sign and magnitude of this break will depend upon the relation of the resistivities of the two layers. The depth at which this change of slope occurs will be the approximate depth of the boundary. The prominence of this break in the curve will depend also upon the thickness of the new bed and its depth. Thus a ten foot bed with a resistivity twice that of the overlying material will have the same effect as a much thicker bed at greater depths.

The resistivity of sands, sandstones and other dense rocks is generally much higher than that of clays, shales, etc. Thus a layer of sand underlying clay will produce a sharp rise in the resistivity curve, while the reverse condition will cause a drop in the curve. However, local conditions may affect the resistivity of a given material from one area to another so that definite values of resistivity for the various types of material cannot be established within limits sufficiently close to render accurate quantitative determinations without additional information. This additional information can be secured by boring to obtain actual samples of the material encountered below the surface in the area to be surveyed. The results from the test hole can then be correlated with the resistivity curve obtained at the same point and the information then applied to other resistivity readings taken in the area.

The problem involved in resistivity surveys for the determination of geologic structures is, however, somewhat different from that considered in this report. It consists usually of working to some definite formation which is persistent over the area in question and is of such a nature as to constitute a good electrical marker. The chief requisites of a marker are that the bed be of considerable thickness and possess a value of resistivity differing by a ratio of five or more from the overlying formations. A sandstone formation overlain by shales constitutes such an electrical marker. The depth to this marker is obtained by readings taken at a large number of points in the region covered and then a contour map is constructed which reveals the conformation of the strata.

The survey discussed in this report is concerned with material which is essentially surface soils in which a greater lateral variation is encountered than in rock formations. Consequently it represents a somewhat different problem which necessitates some modification of the interpretations if not entirely new methods of attack.

LOCATION

The plots selected, Fig. 2, were first measured out 150 feet square and stakes set at each corner and the mid-points. A series of levels were then run to obtain the elevation of the plots. Plot No. 1, the site of the girls dormitory, was more uneven than plot No. 2, the field house site, so elevations were taken at each of the staked points.

APPARATUS

The instruments used were those developed by Keck and Dove as a modification of the original Gish-Rooney instruments. The electrical circuit is shown in Fig. 3.

The purpose of each of the parts of the circuit may be more readily understood if the difficulties to be overcome in making earth resistivity measurements are first described. Natural currents are present in practically all parts of the earth which are generally quite variable. Stray currents from power lines are also of frequent occurence. A more serious difficulty is that of polarization at the electrodes.

When two iron stakes are placed in the ground, a galvanic action due to the acids in the soil is set up. This creates a difference in potential between the two electrodes. These effects result in a potential reading commonly termed "ground potential" which must be eliminated from the final readings. Leakage in the instruments or

Electrical Circuit.

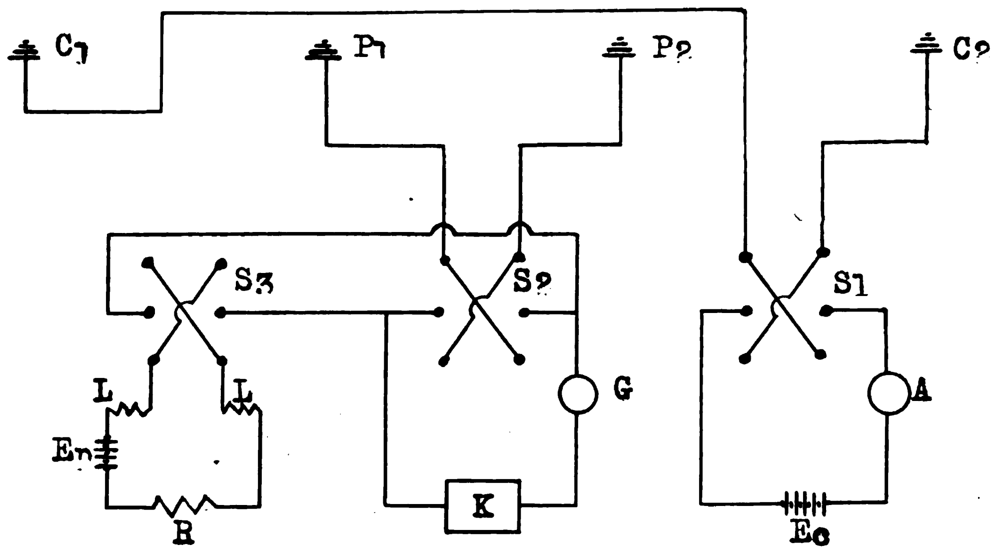


Fig. 3

C1 C2 - Current electrodes

P1 P2 - Potential electrodes

S1 - Current reversing switch

S2 - Potential " "

S3 - Bucking circuit reversing switch

A - Milliammeter

K - Potentiometer

G - Galvanometer

LL - Grid leak resistors

R - Variable resistor

Ec - Power Batteries

Eb - Bucking "

wires is another source of error. Other effects which apply only to alternating current methods are induction between current and potential circuits and the skin effect due to high frequency currents.

Leakage is eliminated by the use of well insulated wires and care in the prevention of dampness in the instrument case. The current and potential circuits should also be kept as widely separated as possible.

The effect of ground potential was eliminated by Gish-Rooney method with a double commutation system. This devise reverses the direct current from the batteries at about thirty times per second as it is applied to the ground. The leads to the meters are so arranged that the current is always in the same direction. This, in effect, introduces a reversed direct current to the ground. This method usually eliminates the ground potentials but involves the use of a correction factor due to the shape of the wave. This correction factor must be determined experimentally.

The system devised by Keck and Dove uses a simple direct current and eliminates the double commutator. Ground potentials are balanced by an opposing potential supplied by an auxiliary circuit. This auxiliary circuit, which they have termed the bucking circuit, is shunted across the potential leads. It embodies a power source, one or more "B" batteries, two resisters of the grid leak type, and a variable resister. Rough adjustments are obtained by varying the auxiliary voltage applied and by using grid leaks of different capacities while exact adjustment is secured with the variable resister which has a range of about 50 ohms.

This method enables the operator to balance out the ground potential immediately before each reading, constituting an accurate control particularly when the ground potential shifts slightly which is often the case. It also eliminates the necessity of a correction factor for the wave form.

The instruments are mounted in a plywood cabinet with hard rubber insulation. The reversing switches are mounted on the stand which carries the batteries and instruments and provides a convenient working table in the field. The wires are carried on four reels mounted in the stand with slip rings making constant contact between the electrodes and the reversing switches.

In the derivation of Wenner's formula, the current electrodes were considered as being hemispheres; this gives the proper distribution of the current so that the lines of equal potential form surfaces of concentric hemispheres.

When the exploration is to go to great depths is not necessary to have hemispherical electrodes but rather a straight rod may be used. This is possible due to the great difference in the length of the electrode and the depth of the exploration. For these depths it is not important to know the near surface conditions so the ununiformity of the potential lines may be neglected.

In this experiment the depth was so shallow that it was necessary to actually get the correct distribution of potential lines, thus necessitating the use of hemispherical electrodes. It was impossible to actually get metal hemispheres so it was necessary to devise something that would give the same results.

Two steel plates approximately six inches in diameter and one half inch thick and three and one half feet of quarter inch tool steel were obtained.

A three sixteenth inch hole was drilled in the center of each plate and six others evenly spaced on a four inch circle about this center. The rod was cut into twelve two and three quarters inch pieces and two three and one half inch pieces. One end of each piece was sharpened and the other end cut and shaped so as to form a tight fit in the holes in the plate. The three and one half inch pins were placed in the center holes and the two and three quarter inch pins in the outside holes. The pins were securley fastened by riveting the end which protruded thru the plate.

This arrangement gave the same effect as a solid hemisphere and made it possible to easily make a good contact with the ground.

It is not necessary to have hemispherical potential electrodes since they are just to get the difference in potential between two points. Nevertheless, it was thought that by using a series of short pins closely spaced, the potential lines would be intercepted as close to the surface as possible at a particular point and with a good contact.

To accomplish this end, two ten inch, one quarter inch square brass bars were drilled with one eighth inch holes spaced at one and one half inch. One eighth inch steel pins, four and one half inches long, were sharpened on one end and the other end inserted in the holes in the bar and securely fastened with sodder. However, after a few trials using these electrodes and single three eighth inch straight rods, it was found that by inserting the single rods into the ground the same distance each time the same results were obtained and the single rods were more convenient to handle.

The field work proceeds in the following manner.

The instruments are taken to a point at which a reading is desired and connections made from the instrument to the reversing switches and batteries. The electrodes are then placed in the ground at the proper spacing for the first reading. In this case the increment of depth was taken as three feet and the first setting of electrodes was at one and one half and four and one half feet each side of the center. The line along which the electrodes are set should be selected so as to be as nearly level as possible.

The potential circuit is then closed by the pushbutton to the galvanometer and the ground potential measured by the potentiometer to determine the magnitude of bucking potential required. Contact is then made to the auxiliary batteries so that an opposing potential is applied and the circuit resistances adjusted until the galvanometer reads zero. The current circuit is then closed and the galvanometer again brought to zero with the potentiometer controls. The value of current and potential are then read on the milliammeter and potentiometer. By means of the reversing switches one or more readings are taken with the current flowing in both directions. The average of these several readings are used in computing the resistivity, thus compensating for instrumental inaccuracies.

The taking of readings in this manner is continued with the electrode spacing increasing by the chosen increment until the desired depth is reached. Thus, values of the average resistivity to each depth are obtained for the station taken. The instruments are then moved to the next station and the procedure repeated.

In this survey borings were made at several of the stations in order to secure samples for the correlation of readings. At two different stations which were taken near the beginning of the survey, readings were taken again three weeks later. Samples were obtained for each station at the same time the readings were taken and the moisture content determined. This was done to determine the effect of change in moisture content upon the resistivity readings.

An attempt was made to apply a different method in obtaining the resistivity readings but insufficient work was done to make it possible to arrive at any definite conclusions. This method will be but briefly described and left with the suggestion that an investigation of its possibilities should be worthwhile.

This system, which might properly be termed the line electrode method, is a further development of the single electrode probe described by Eve and Keys.#

The current is applied to the earth by means of two stationary electrodes one of which is formed by a wire twice as long as the depth to be investigated, connected to the ground by pins at equal intervals. The other electrode may

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be placed anywhere at a distance at least ten times the depth of the probe. The pins composing the line electrode are set so as to have nearly equal contact in order that the distribution of current may be uniform. This is accomplished with a resistance meter or by applying the same potential between each pin and the far electrode and adjusting the pin until the current flow is the same for each.

Readings are then taken along a line at right angles to the line electrode with convenient increments. The instruments used and the method of reading are the same as in the Wenner method except for the manner of changing the electrodes.

Fig. 4 shows a section perpendicular to the line electrode.

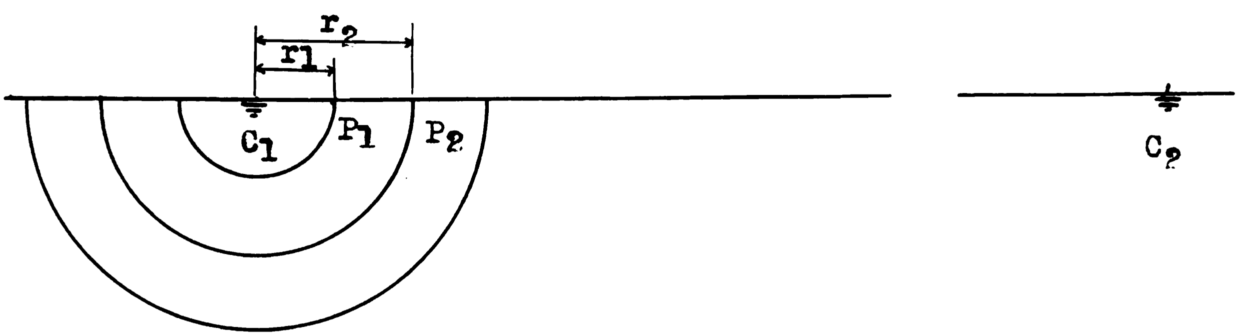


Fig. 4.

P_1 and P_2 are the potential electrodes and the resistivity obtained is that of a cylindrical shell of radii r_1 and r_2.

The formula is $p = \frac{\pi}{\log. \frac{r_2}{r_1}} \frac{E}{I}$ where E is the potential across P_1 and P_2 and I is the current per unit length of the electrode.

The derivation of this formula is very simple.

Assume an infinitesimal shell dr whose area per unit length will be πr; then from Ohm's Law

$$R = \frac{E}{I} \quad \text{and} \quad R = p\,\frac{l}{a}$$

$$R = \int dR = \frac{p}{\pi}\int_{r_1}^{r_2}\frac{dr}{r} = \frac{p}{\pi}\left(\log r_2 - \log r_1\right) = \frac{p}{\pi}\log\frac{r_2}{r_1}$$

$$\frac{p\log\frac{r_2}{r_1}}{\pi} = \frac{E}{I} \quad \text{and}$$

$$p = \frac{\pi}{\log\frac{r_2}{r_1}}\cdot\frac{E}{I}$$

It is obvious that the effect of the surface material is less on the deeper readings than in the Wenner method since it is a smaller percentage of the total volume. Therefore it would seem that this method should be particularly valued in a region where the resistivity of the surface material is very high. Also the distribution of current is the same for all readings taken at the same station.

In the work done in this survey, considerable difficulty was encountered in obtaining uniform contact at the pins of the line electrode. Considering the shallow depths involved it was deemed inadvisable to permit the pins to penetrate very deeply. More investigation is indicated to perfect the technique in the use of this method.

LEVEL NOTES

Plot No.1

Point	+S	H.I.	-S	Elev.
B.M.	9.72	867.73		858.01
T.Pl			4.51	863.22
	4.97	868.19		
A-1			10.61	864.38
A-2			5.87	862.32
A-3			3.81	864.38
B-1			8.19	860.00
B-2			4.73	863.46
B-3			4.23	863.96
G-1			10.68	857.51
G-2			6.56	861.63
G-3			5.49	863.96

Plot No.2

Point	+S	H.I.	-S	Elev.
B.M.	0.30	858.31		858.01
T.P.1	1.61	847.77	12.15	846.16
T.P.2	0.03	836.82	10.98	836.79
River (surface)			12.10	824.72
Plot No.2 (center)			7.09	829.73

PLOT No.1

DATA

A-1

Depth ft.	Current amps.	Potential volts.	Resistivity ohms /cu.ft.
3	.0830	.7060	160
6	.0638	.2250	133
9	.0694	.1717	140
12	.0900	.1766	148
15	.0599	.1084	170
18	.0637	.1053	187
21	.0780	.1223	207
24	.0778	.1171	227
27	.0860	.1265	249
30	.0600	.0843	265

A-2

Depth ft.	Current amps.	Potential volts.	Resistivity ohms /cu.ft.
3	.0850	.5785	128
6	.0940	.2980	119
9	.0859	.1975	130
12	.0534	.0958	134
15	.0500	.0783	148
18	.0480	.0677	160
21	.0550	.0700	168
24	.0720	.0859	180
27	.0706	.0880	211
30	.0740	.0812	207

A-3

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0410	.2854	131
6	.0416	.1456	132
9	.0410	.1034	143
12	.0485	.0930	149
15	.0451	.0776	162
18	.0420	.0635	171
21	.0480	.0677	183
24	.0410	.0510	188
27	.0383	.0441	196
30	(rain)		

G-1

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0800	.4979	117
6	.0680	.2319	128
9	.0785	.1970	142
12	.0717	.1588	168
15	.0589	.1223	196
18	.0757	.1485	223
21	.0649	.1246	253
24	.0629	.1175	282
27	.0642	.1154	305
30	.0533	.0941	333
80	.0543	.0575	533
90	.0899	.0849	535
100	.0893	.0769	535

G-2

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0640	.5874	173
6	.0610	.2714	168
9	.0613	.1743	161
12	.0604	.1339	167
15	.0697	.1260	171
18	.0658	.1065	183
21	.0532	.0783	194
24	.0624	.0878	212
27	.0520	.0708	230
30	.0600	.0760	238

G-3

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0620	.4915	149
6	.0570	.1940	129
9	.0690	.1558	128
12	.0590	.1035	132
15	.0493	.0762	146
18	.0430	.0592	155
21	.0480	.0625	172
24	.0475	.0601	191
27	.0540	.0658	210
30	.0600	.0720	226

D-1

Trial 1

Depth ft.	Current amps.	Potential volts	Resistivity ohms/cu.ft.	% Moisture
3	.2840	1.5465	103	21.65
6	.2673	.8515	120	18.95
9	.2050	.5513	152	16.65
12	.2035	.4350	161	11.29
15	.2050	.3892	178	
18	.0935	.1564	189	9.48
21	.0705	.1110	208	
24	.0940	.1415	227	
27	.0860	.1278	252	
30	.0730	.10498	271	

Trial 2

Depth ft.	Current amps.	Potential volts	Resistivity ohms/cu.ft.	% Moisture
3	.0639	.3232	95	17.90
6	.0625	.2014	121	12.70
9	.0495	.1163	133	17.00
12	.0430	.0858	150	21.25
15	.0463	.0803	163	18.10
18	.0975	.1608	186	10.57
21	.0983	.1496	201	
24	.0505	.0743	222	
27	.0390	.0540	235	
30	.0285	.0387	256	

D-2

Trial 1

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.	Moisture %
3	.0646	.4297	125	20.90
6	.0620	.2267	138	15.00
9	.0610	.1581	147	15.50
12	.0710	.1523	162	16.50
15	.0862	.1591	174	17.60
18	.0676	.1161	185	20.30
21	.0788	.1177	197	9.10
24	.0801	.1120	211	12.80
27	.0695	.0941	230	8.70
30	.0620	.0817	242	

Trial 2

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.	Moisture %
3	.0677	.3937	110	7.85
6	.0763	.2424	120	7.90
9	.0780	,1808	131	8.00
12	.0768	.1445	142	8.15
15	.0835	.1400	158	8.00
18	.0858	.1293	171	7.95
21	.0875	.1222	184	
24	.0485	.0640	199	
27	.0495	.0637	218	
30	.0405	.0497	231	

D-3

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0660	.8294	237
6	.0680	.3229	178
9	.0639	.1881	167
12	.0500	.1085	164
15	.0478	.0777	153
18	.0580	.0812	158
21	.0574	.0709	163
24	.0583	.0682	176
27	.0555	.0623	190
30	.0575	.0622	204

Plot No. 2

A-1

Depth ft.	Current amps.	Potential volts	Resistivity ohms/cu.ft.
3	.0614	.7920	243
6	.0643	.4461	262
9	.0681	.3109	258
12	.0661	.2324	265
15	.0597	.1700	269
18	.0570	.1371	272
21	.0555	.1118	266
24	.0449	.0778	261
27	.0535	.0785	249
30	.0520	.0660	239

A-2

3	.0609	.9256	286
6	.0540	.4466	311
9	.0497	.2467	281
12	.0608	.2150	267
15	.0661	.1887	268
18	.0619	.1451	266
21	.0625	.1238	262
24	.0614	.1070	262
27	.0649	.0980	256
30	.0697	.0924	250

A-3

Depth ft.	Current amps.	Potential volts	Resistivity ohms /cu.ft.
3	.0764	1.1660	288
6	.0789	.5629	269
9	.0735	.3288	263
12	.0832	.2783	252
15	.0852	.2346	260
18	.0740	.1695	259
21	.0772	.1504	257
24	.0659	.1157	264
27	.0750	.1131	257
30	.0725	.0968	252

B-1

3	.0875	1.0180	220
6	.0830	.5764	261
9	.0900	.4139	260
12	.0840	.2767	249
15	.0760	.1903	236
18	.0850	.1693	230
21	.0780	.1360	230
24	.0830	.1270	231
27	.0830	.1131	231
30	.0800	.0978	231

B-2

Depth ft.	Current amps.	Potential volts	Resistivity ohms/fu.ft.
3	.0581	.7660	248
6	.0654	.4296	247
9	.0675	.3116	260
12	.0640	.2196	258
15	.0638	.1731	256
18	.0794	.1769	252
21	.0778	.1486	252
24	.0698	.1094	237
27	.0739	.1007	231
30	.0766	.0949	233

B-3

3	.0270	.5309	176
6	.0645	.3248	190
9	.0600	.2186	207
12	.0660	.1970	225
15	.0645	.1760	257
18	.0625	.1496	271
21	.0670	.1415	279
24	.0665	.1267	287
27	.0605	.1054	296
30	.0600	.0930	293

C-1

Depth ft.	Current amps.	Potential volts	Resistivity ohms/cu.ft.
3	.0540	.7143	249
6	.0508	.3423	254
9	.0515	.2172	239
12	.0596	.1976	250
15	.0560	.1506	254
18	.0553	.1310	268
21	.0527	.1117	279
24	.0520	.0989	287
27	.0479	.0848	300
30	.0503	.0813	304

C-2

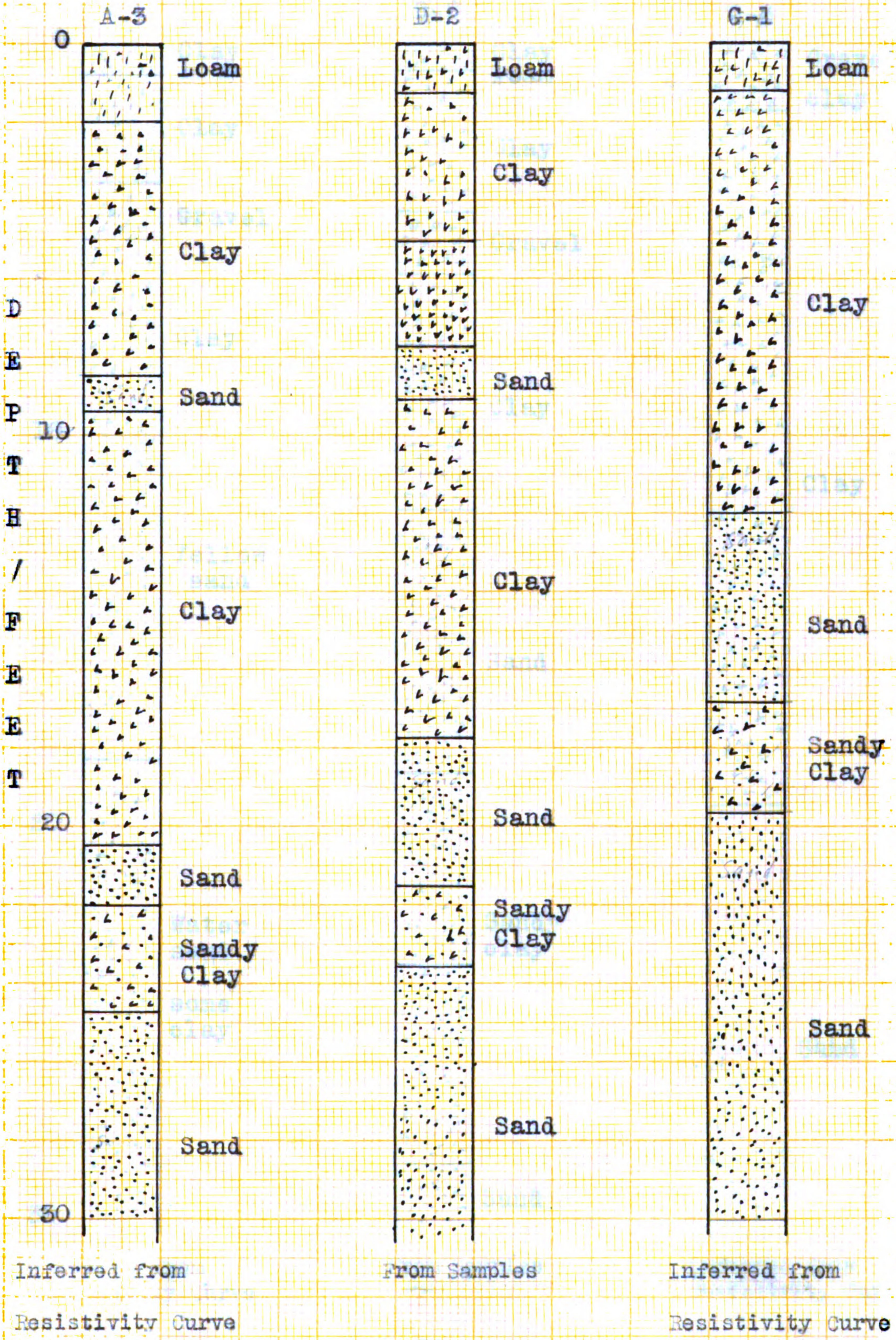
3	.0758	.8448	206
6	.0619	.3575	218
9	.0598	.2449	231
12	.0619	.1995	243
15	.0568	.1616	268
18	.0672	.1680	284
21	.0660	.1473	295
24	.0741	.1479	302
27	.0790	.1423	306
30	.0740	.1193	304

C-3

Depth ft.	Current amps.	Potential volts.	Resistivity ohms/cu.ft.
3	.0512	1.0823	399
6	.0460	.4449	373
9	.0611	.3228	299
12	.0816	.2854	264
15	.0878	.2364	248
18	.0818	.1750	242
21	.0974	.1775	241
24	.0550	.0882	241
27	.0424	.0607	243
30	.0657	.0812	233

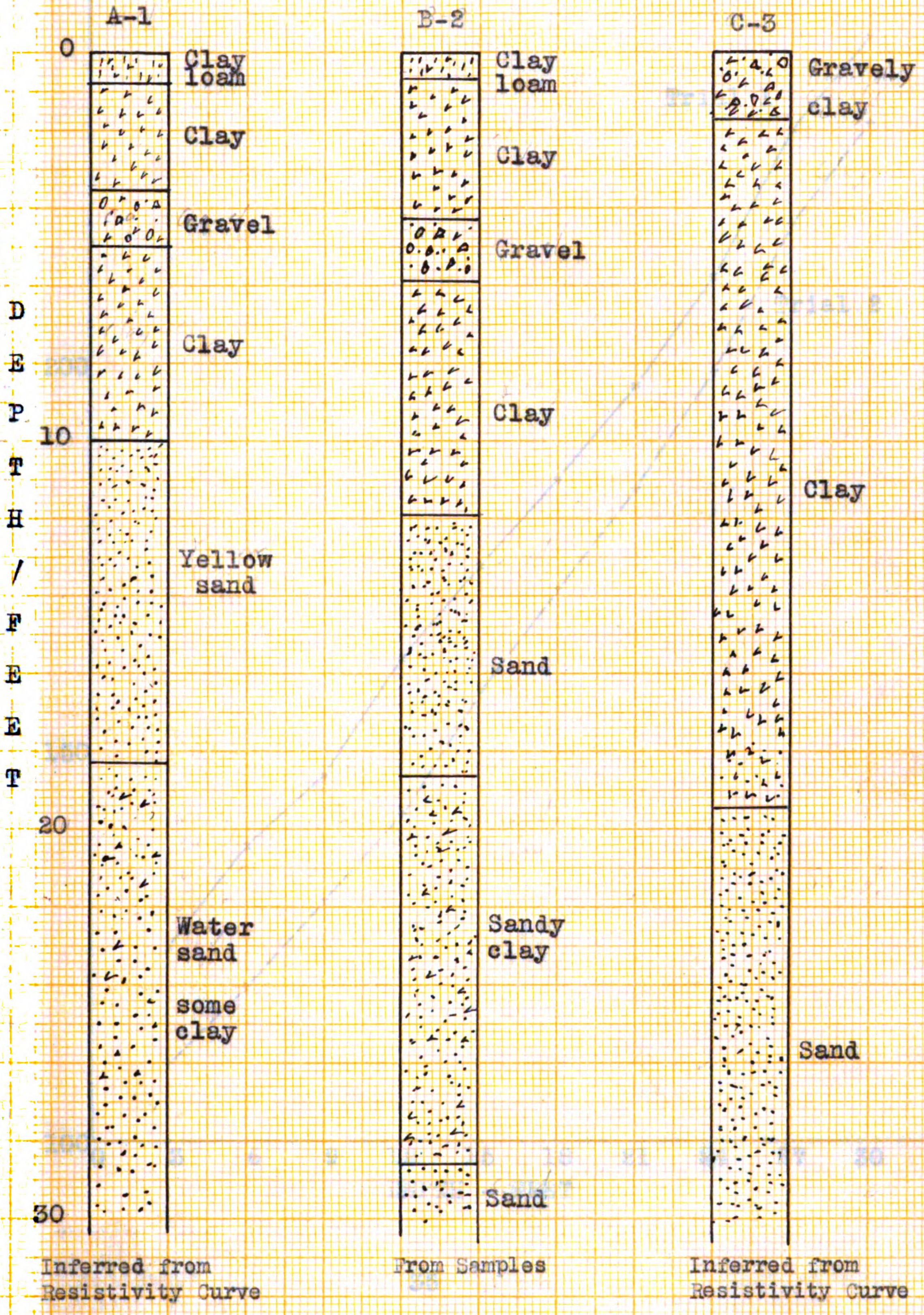
COLUMNAR SECTIONS

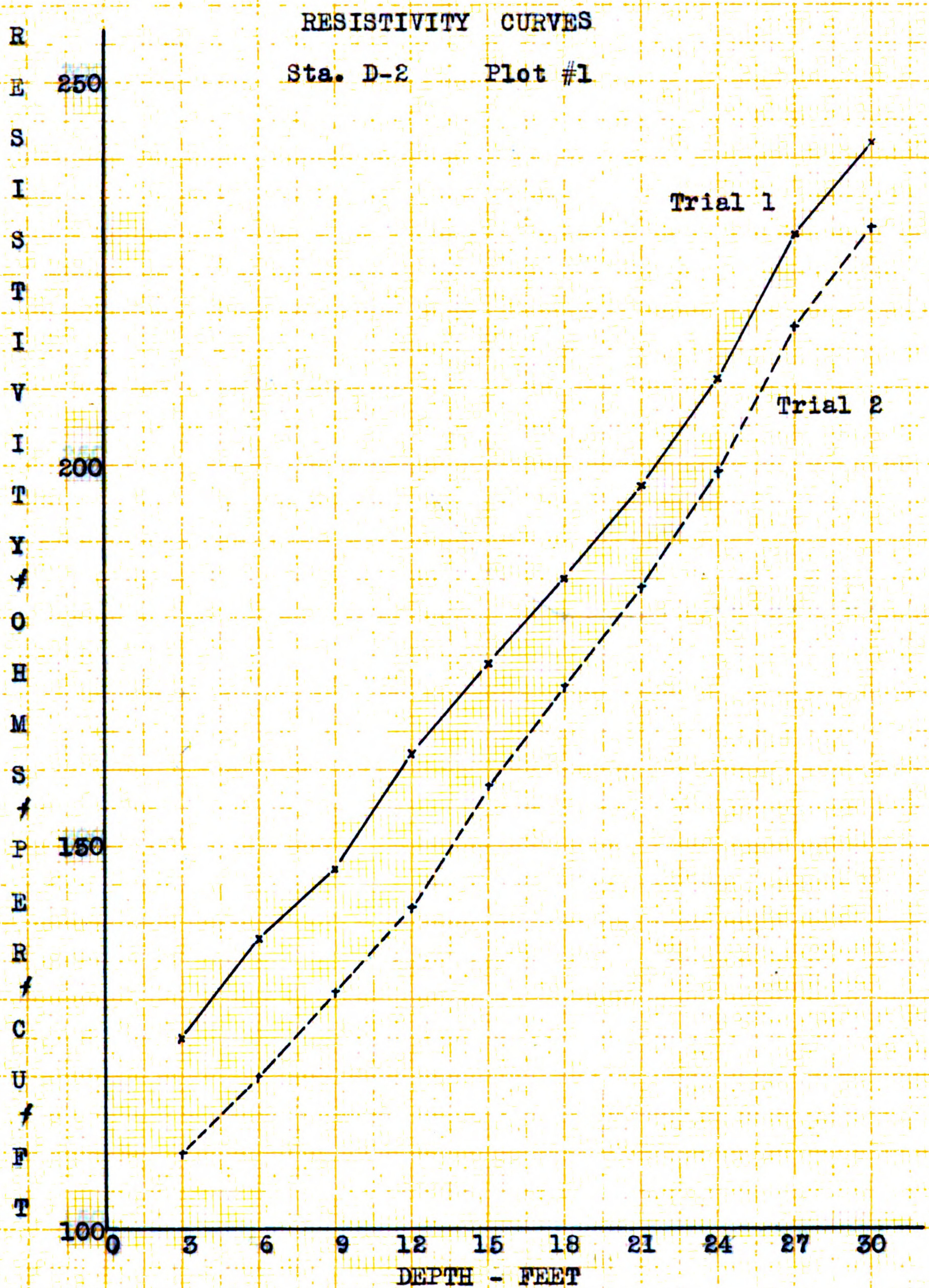
Plot #1



COLUMNAR SECTION

Plot #2




RESISTIVITY CURVES
Sta. D-2 Plot #1
Trial 1
Trial 2
RESISTIVITY / OHMS / PER / CU / FT
250
200
150
100
0
3
6
9
12
15
18
21
24
27
30
DEPTH - FEET


RESISTIVITY CURVE
Sta. B-1 Plot #2
RESISTIVITY/OHMS/PER/CU/FT
300
250
200
150
0
3
6
9
12
15
18
21
24
27
30
DEPTH & FEET

Interpretation of the resistivity readings may be explained by taking a representative curve. The curve for station B-1, plot #2 will be used for that purpose.

The decided rise from depth three to six feet is caused by a layer of high resistivity. The fact that this rise is shown in only one reading indicates a layer of only one and one half to three feet. The curve then drops rapidly as the effect of the underlying clay enters. At fifteen feet the penetration reaches sand which causes a positive increase in slope. The flat slope, rather than a rise, from there on is due to the fact that the penetration has reached the water table and accumulated soil acids have somewhat reduced the resistivity of the sand.

-CONCLUSIONS-

Upon completion of this experiment the following conclusions, based on the results of the survey, were derived.

The method as outlined may be used for shallow depths with a moderate degree of accuracy. For depths less than twenty or twenty five feet in clay, sand or other material free from gravel, more definite information can be secured with a soil auger in approximately the same length of time. For depths greater than twenty five feet, the electrical method has a distinct advantage over the use of a soil auger in that the boring is occasionally hampered by rocks and the auger is awkward to handle.

A reduction in moisture content within the limits observed has the effect of lowering the resistivity curve without appreciably changing the slope. This does not interfere with the interpretation of results thus obviating the necessity of moisture determinations for a survey.

In surveys in areas of glacial drift, such as was encountered in this survey, there is considerable lateral variation in soil materials which must be considered in the interpretation of resistivity readings.

Care must be exercised in the handling and use of the equipment. Electrodes should be inserted in the ground the same distance for every reading and good contacts must be assured. The immediate area should be free from loose pieces of bare wire and any other metal condutors. It was found that the use of a metal tape, in contact with the ground,

affected the readings to an appreciable amount.

For future research in this field, it is suggested that the Line Electrode Method, which has been briefly described in this paper, be thoroughly investigated. Further determination of moisture changes should be obtained over a much longer period of time and for a greater variation in conditions. The variation of weather conditions and length of time in this survey was not sufficient to arrive at any positive or complete conclusions. Readings should be taken with various increments to determine the change in resistivity curves, if any.

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