BOREHOLE ELECTROMAGNETIC SURVEY OF THE ENGINEERING GEOSCIENCE WELL FIELD AT THE RICHMOND FIELD STATION: DATA PRESENTATION

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Introduction

A borehole electromagnetic survey of the Engineering Geoscience well field at the Richmond Field Station was carried out on October 23 and November 7, 1987. The work was performed with a Geonics EM-39 induction logger.

The objective of the survey was to determine the stratigraphy of the site and to obtain background data for comparison with data that may be obtained during future hydrologic experiments. The findings of this investigation are in general agreement with the geology proposed by Pouch,[1] and the resistivity and self-potential logs taken by Asch.[2] However, a more complete picture of the stratigraphy is now possible.

The data is presented as apparent conductivity plots and interpreted in two stratigraphic sections.

Survey Procedure and Equipment Description

The survey was carried out by Seunghee Lee and Dimitri Bevc, under the direction of Professor Alex Becker. Observation wells one through six and the extraction well were logged on October 23 and again on November 7, 1987 (Figure 1). Additional readings were made on the dates of October 28 and November 6 to confirm survey validity.

The procedure at each well on the 23rd of October was to measure the conductivity of the water near the surface of the well, and then to log the hole, recording both in-phase and quadrature components. On the seventh of November, the depth of the water in the well was measured along with the conductivity, and only the quadrature component was recorded. Water depth and conductivity are presented in Table 1. The EM data from the two days was found to be consistent and is presented in Figures 3 through 9.

The Geonics EM-39 operates at a frequency of 39.2 kHz and has an intercoil spacing of 50 cm. A focusing coil is employed to reduce sensitivity to borehole fluid and improve vertical resolution. Peak instrument response occurs at a radial distance of 28 cm from the probe axis and 50% of the response arises from material at radial distances greater than 58 cm. The measured quantities are the quadrature component of the magnetic field, which is in most cases proportional to apparent conductivity, and the in-phase component.[3]

The EM-39 was interfaced with two Hewlett-Packard digital voltmeters and an Hewlett-Packard 300 computer. The probe was lowered and raised by hand. A BEI model H25 optical encoder on the pulley enabled data to be recorded every 3.46 inches. Data was gathered both on the way down and up the hole.

Total time to conduct the entire procedure at one well is approximately 20 minutes. The time required to actually transit the well with the probe is about two to three minutes in each direction. Due to the time constant of the instrument this results in a depth shift of about one foot.[4]

Data Description

The data is presented as plots of apparent conductivity versus depth. The depth scale is one inch to 20 feet. Conductivity is plotted at a scale of one inch to 200 mS/m for Figure 2, and one inch to 100 mS/m for all the other Figures. Figure 2 is a comparison of the logs for observation wells one through five and the extraction well. Correlation between anomalies is evident in these plots. Figures 3 through 9 are comparisons of data gathered on October 23 and November 7 for all the wells.

Examination of the figures reveals the data to be very repeatable. Except for wells four and five which were started two feet below surface, the logs taken on November 7 were all started with the probe center at ground level. The October 23 logs were started with the top of the probe at the top of the casing. This accounts for the different starting points of the plots.

The saturated response evident in the extraction well (Figure 9) is due to wire screens located at depths of 70 to 75 feet and below 100 feet. All of the logs have a strong near surface anomaly in excess of 200 mS/m at approximately the four to ten foot level. This anomaly has been identified with Pouch's "Jacob" layer. The wells were cased in this depth range when the SP and resistivity logs were ran, so no previous data was available for this zone. Surface resistivity data substantiates the existence of this near surface conductive layer (see Appendix).

The anomalies have been named in keeping with Pouch's convention. Feminine names denote inferred aquifer zones and masculine names denote inferred aquitard zones. The inferred aquifers seem to correlate with conductivity lows. Figures 10 and 12 illustrate how these names are assigned and correlated with Pouch's stratigraphy (Figure 11). The data reveals many previously undetected layers, some of the most prominent of which are Hunter, Denali, 17, Kahiltna, and Crosson. These new names were assigned arbitrarily so as to be distinguishable from Pouch's.

The resistivity and SP logs reflect the same character as the induction log. A good example is the SP log of OBS 5, where the character of the curve, particularly below 60 feet follows that of the EM log very closely (Figure 15). This type of correlation is evident in all the logs. There is an unexplained offset in depth between the EM data and the Resistivity/SP data, especially as depth increases. For the extraction well, the SP data shows the sequence Alice, Cliff, Kathy, Deborah to match the EM data very well, but as depth increases the Becky anomaly is offset by about four feet (Figure 16). The Gamma logs correlate to the same degree as the others. Here, the inferred aquifer zones appear to correspond to gamma count highs.

Stratigraphy

Figure 13 is a stratigraphic interpretation of the EM logs along cross-section AA'. The depths and thicknesses are estimated. Aside from the numerous additional layers, there are other significant departures from Pouch's cross-section. The Cliff layer is split into the Cliff and Hunter layers by Deborah, Elias, and Kathy. The latter three layers pinch out somewhere between OBS 1 and 3, where Cliff and Hunter merge. The Kathy layer is replaced by Ruth in OBS 1, and Ruth is present throughout the cross-section. The Ted, Becky, and Tom layers are extended into OBS 1.

Some of the most interesting features along cross-section BB' (Figure 14), are the additional layers between Lisa and Denali at OBS 6 and the pinching out of 17 at OBS 2. This cross-section indicates a dip to the East for the deeper layers.

Conclusion

The results of this survey allow a more complete analysis of the stratigraphy at the Engineering Geoscience well field. The EM data is easier to interpret than the previous logs and was successfully correlated with known structure.

TABLE 1

Well #	Water Level*		Conductivity	
	Depth below ground level feet	Height above sea level feet	11-7 mS/m	10-23 mS/m
1	11.3	7.0	25.9	27.7
2	10.5	8.3	30.0	29.5
3	9.9	8.6	35.5	37.4
4	10.1	8.1	57.0	62.6
5	10.0	8.2	30.7	32.7
6	10.6	7.2	51.2	54.0
EXT	10.1	8.3	32.8	35.0

(*) Water depth relative to ground surface and water elevation relative to mean sea level as measured on November 7, 1987. Conductivity of water in millisiemens per meter as measured on October 23 and November 7, 1987.

References

[1] G. W. Pouch, Hydrogeologic Site Assesment of the Engineering Geoscience Well Field at the Richmond Field Station, Contra Costa County, California. Engineering Geosciences, Department of Materials Science and Mineral Engineering, University of California, Berkeley, 1987.

[2] T. Asch, Engineering Geoscience, Department of Materials Science and Mineral Engineering, University of California, Berkeley 94720. Personal communication November 1987.

[3] J. D. McNeill, Geonics Technical Note TN-20: Geonics EM39 Borehole Conductivity Meter Theory of Operation. Geonics Limited, Mississauga, Ontario Canada, February 1986.

[4] K. C. Taylor and J. W. Hess, Field Evaluation of Geonics EM-39, Water Resources Center, Desert Research Institute, Reno, Nevada, 1987.

Richmond Field Station

Engineering Geoscience Well Field

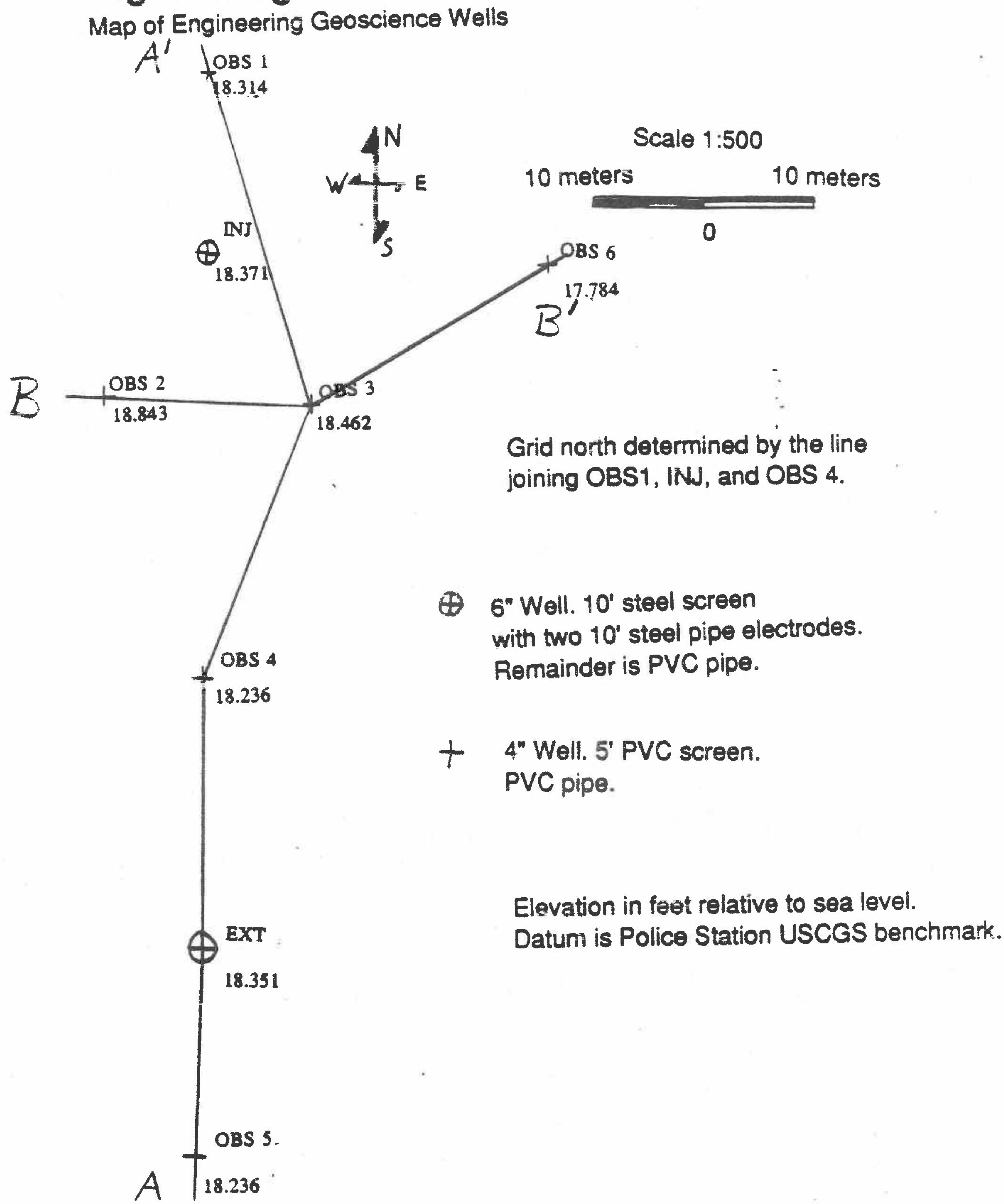

Figure 1. Locations of Engineering Geoscience Wells and cross-sections AA' and BB'.

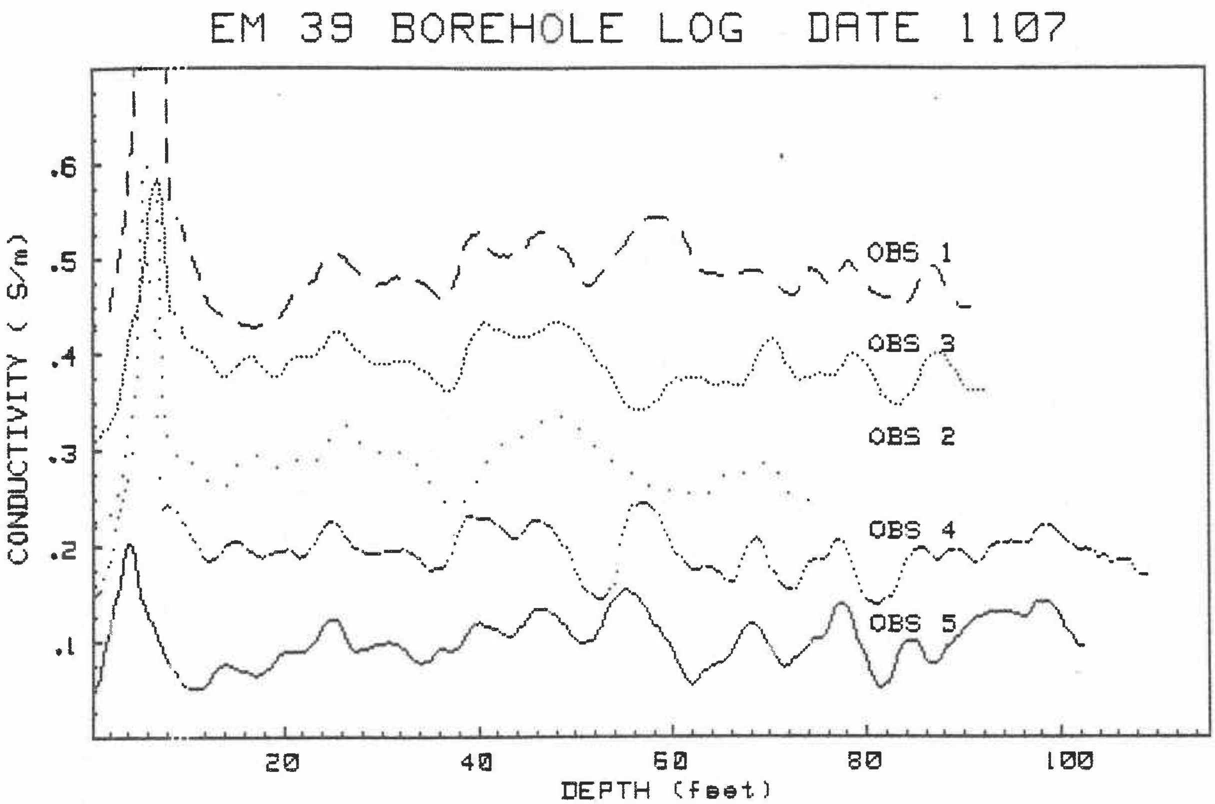

Figure 2a. Comparison of logs for observation wells five, four, two, three, and one (from bottom to top). Successive plots are offset by 100 mS/m. Horizontal scale is 1"=20', vertical scale is 1"=200 mS/m.

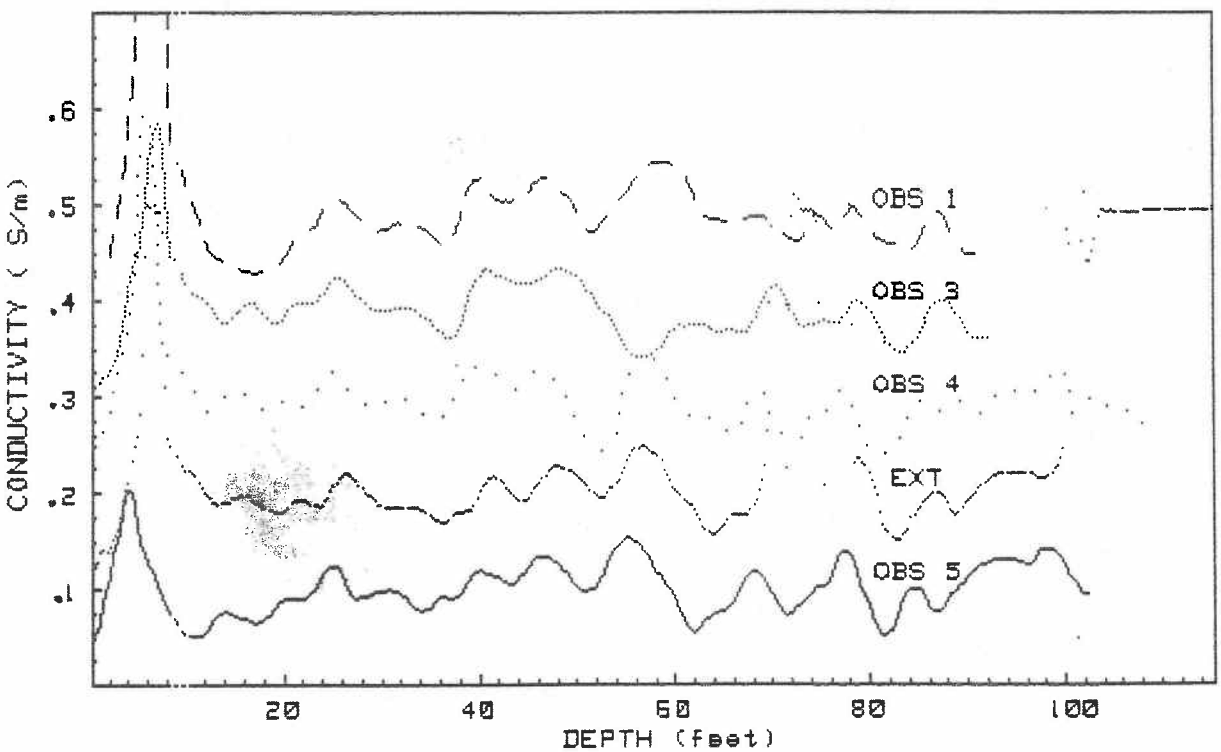

Figure 2b. Comparison of logs for observation well five, extraction, four, three, and one (from bottom to top). Successive plots are offset by 100 mS/m. Horizontal scale is 1"=20', vertical scale is 1"=200 mS/m.

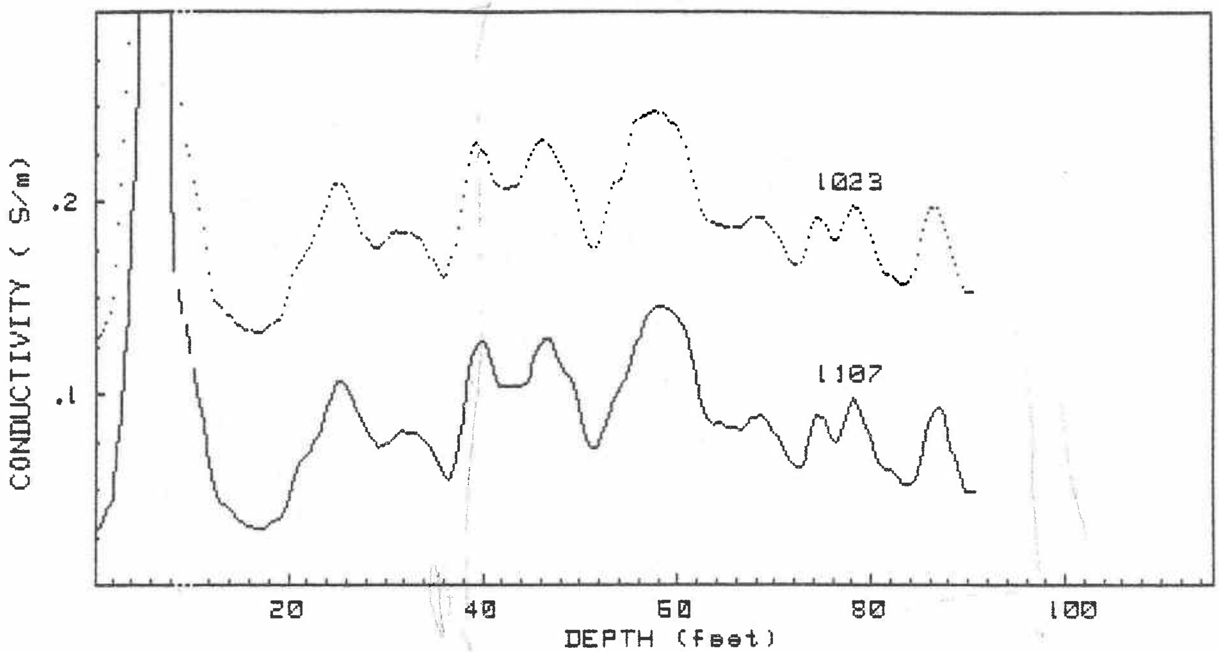

Figure 3. Data from observation well one, taken on October 23 and November 11, 1987. Data for October 23 is offset by 100 mS/m. Horizontal scale 1"=20', vertical scale 1"=100 mS/m.

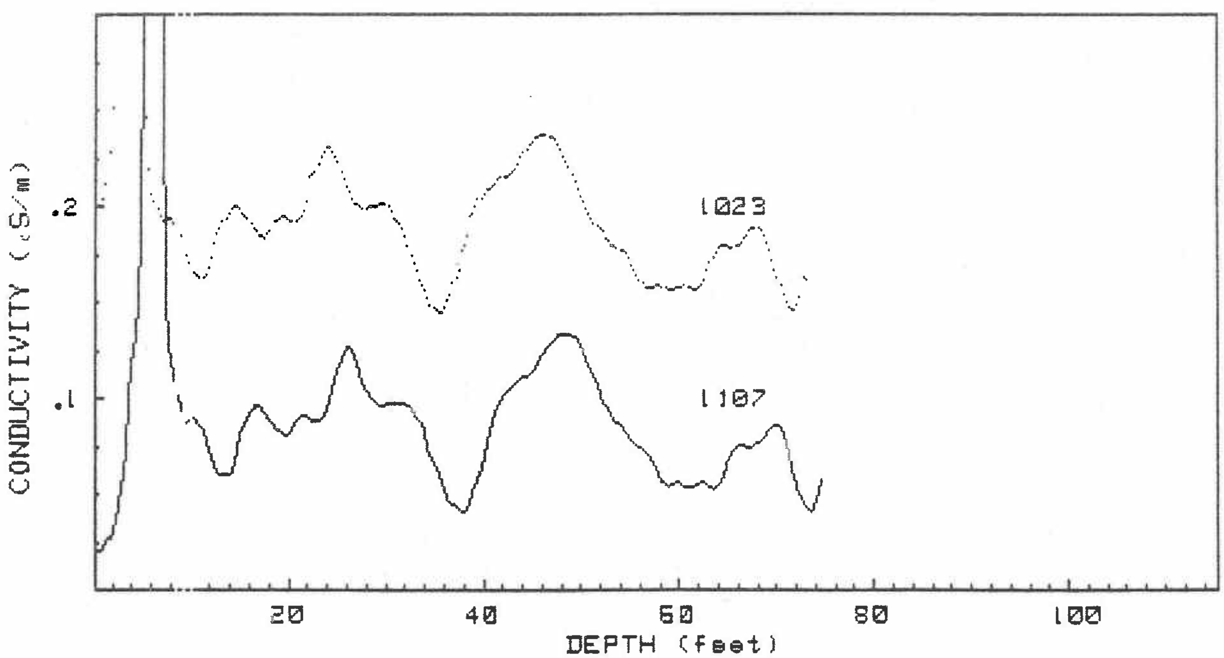

Figure 4. Data from observation well two, taken on October 23 and November 11, 1987. Data for October 23 is offset by 100 mS/m. Horizontal scale 1"=20', vertical scale 1"=100 mS/m.

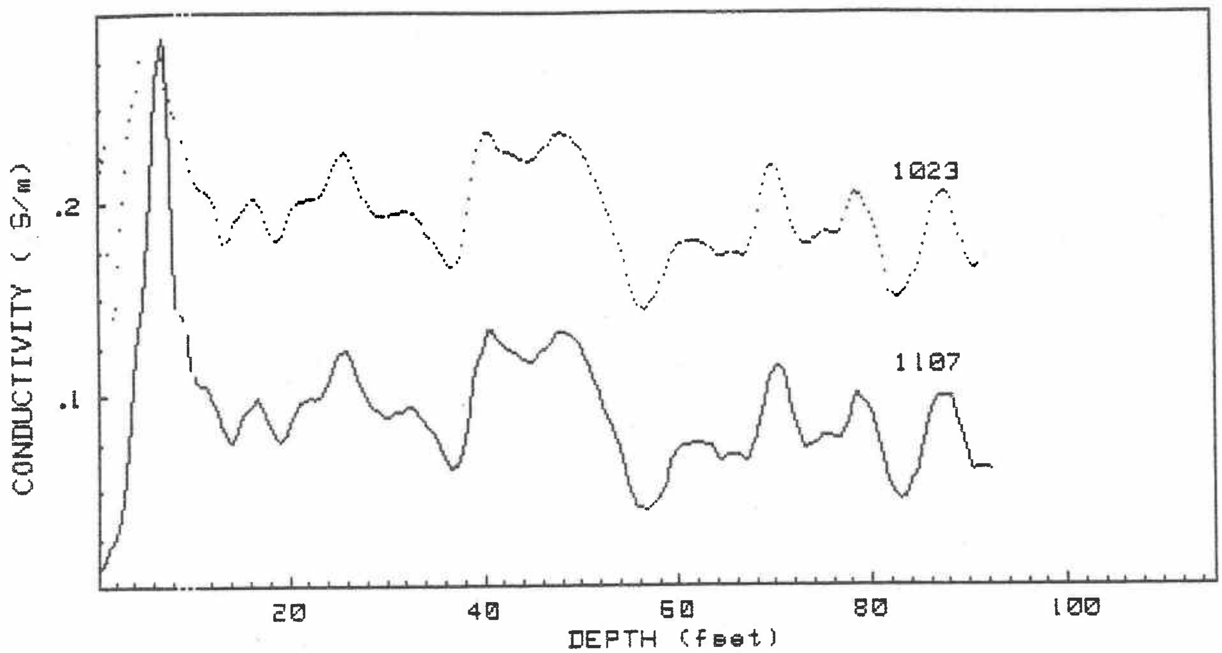

Figure 5. Data from observation well three, taken on October 23 and November 11, 1987. Data for October 23 is offset by 100 mS/m. Horizontal scale 1"=20', vertical scale 1"=100 mS/m.

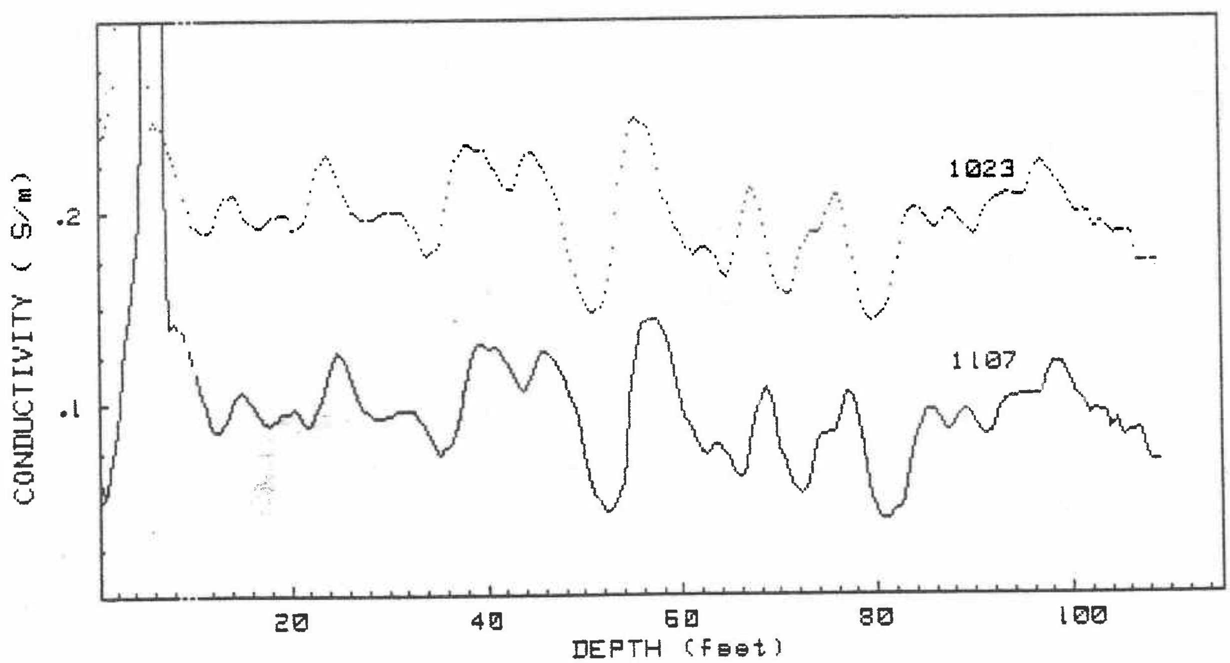

Figure 6. Data from observation well four, taken on October 23 and November 11, 1987. Data for October 23 is offset by 100 mS/m. Horizontal scale 1"=20', vertical scale 1"=100 mS/m.