U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

A Direct-Current Resistivity Survey of the Beaver Dam Wash Drainage in Southwest Utah, Southeast Nevada, and Northwest Arizona.

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Open-File Report 94-676

1994

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INTRODUCTION

The drainage basin of Beaver Dam Wash covers an area of about 2,000 square kilometers and is part of the Virgin River Basin. It is located in Washington County, southwest Utah; in Clark and Lincoln Counties, southeast Nevada; and in Mojave County, northwest Arizona. Beaver Dam Wash is sparsely inhabited and its water resources are largely undeveloped and little known. However, it is located within one of the fastest-growing areas in the western United States, near the fast growing city of St. George, Utah, which has doubled its population in the past decade, the burgeoning city of Mesquite, Nevada, and near the towns of Bunkerville, Nevada, and Beaver Dam and Littlefield, Arizona. Furthermore, Beaver Dam Wash is only about 130 km northeast of Las Vegas, Nevada, perhaps the fastest growing city in the West. The water supply required to support the area's increasing municipal, industrial, agricultural, rural, and domestic needs is a vital local concern. The States of Utah, Nevada, and Arizona want to know if Beaver Dam Wash can supply some of the water for present and future needs.

In September 1992, the Utah Division of Water Resources, the Nevada Department of Conservation and Natural Resources, and the Arizona Department of Water Resources, asked the U. S. Geological Survey to conduct a hydrologic reconnaissance of Beaver Dam Wash, and to prepare a report summarizing information on its water resources. Other State and local agencies that contributed funding for the project include: the Utah Division of Water Rights, the Washington County Water Conservancy District, Utah, the City of St. George, Utah, the Las Vegas Valley Water District, Nevada, and the Virgin Valley Water District, Nevada. The U. S. Bureau of Land Management also supplied funds in the early phase of the project to compile available data. Additional State and local agencies that served on an informal technical review committee to assess the project progress include: the Colorado River Commission of Nevada, the Southern Nevada Water Authority, the Cities of Mesquite and Henderson, Nevada, and the Bunkerville Irrigation Company, Nevada.

An important part of the project was to collect information on the poorly-known ground-water system of Beaver Dam Wash in order to define aquifers; estimate the volume and quality of ground water; and to evaluate the potential effects of ground-water development on ground-water levels, ground-water quality, surface water, and on riparian areas in perennial reaches of the stream in the Wash. In the study area, the subsurface material within the upper 500 m is mainly composed of the Muddy Creek Formation (Longwell, 1928; Longwell and others, 1965; Kowallis and Everett, 1986) which is a group of basin-fill deposits comprised of fluvial and lacustrine sandstones, siltstones, and mudstones.

In October 1993, the U.S. Geological Survey (USGS) made a direct-current resistivity survey in the Beaver Dam Wash area. The survey covered approximately 700 square kilometers, consisted of 45 Schlumberger soundings (Kunetz, 1966; Zohdy and others, 1974), and was completed in two weeks. During the survey, a representative from the Bureau of Land Management accompanied the crew to assure the safety of the eastern Mojave Desert Tortoise (Gopherus agassizii) and the preservation of its habitat. Accordingly, all work was conducted along roads, which limited access to some parts of the area. In addition to the resistivity survey, a seismic-refraction survey was made by Donald H. Schaefer, USGS, Carson City, Nevada. The purpose of these geophysical surveys was to help estimate: a) the total thickness of the unconsolidated basin fill, b) the thickness of the saturated fill, c) the lithology of the fill, and d) the quality of ground water in the basin fill and in the alluvium. In addition, the results of the surveys were to help select the locations of a few deep test holes. Subsequent to the resistivity survey, four test holes were drilled by the USGS; three were located near certain sounding stations, and the fourth was located outside the resistivity-survey area. Copies of the drilling-sample logs and the electric logs are available at the USGS office in Salt Lake City, Utah.

This report is concerned with the results of the direct-current resistivity survey and with some of the test-drilling results. It does not include results from the seismic-refraction survey. Among other topics, we present a brief description of the Schlumberger sounding method, the field data and the interpretation of the 45 Schlumberger-sounding curves, six interpreted-resistivity cross sections, and six interpreted-resistivity maps at depths ranging from 10 to 500 m.

THE SCHLUMBERGER SOUNDING METHOD

Figure 1 shows a schematic diagram of the symmetric Schlumberger electrode configuration with two current electrodes (A and B) and two potential electrodes (M and N). The current-electrode spacing (*AB/2*) is defined as half the distance between the current electrodes A and B, and the potential-electrode spacing (*MN/2*) is defined as half the distance between the potential electrodes M and N. The figure also shows an electric-current power supply, an ammeter for measuring the electric current, and a potentiometric chart recorder for measuring the potential difference. The arrows indicate the direction of expanding the distance between the current electrodes.

Electrical Resistivity

For the symmetric-Schlumberger array, the electrical resistivity, ρ, is calculated from the equation:

$$\rho = \pi \frac{(AB/2)^2 - (MN/2)^2}{MN} \frac{\Delta V}{I} \qquad (1)$$

where,

$(AB/2)$ = half the distance between current electrodes A and B,
$(MN/2)$ = half the distance between potential electrodes M and N,
ΔV = potential difference measured between the potential electrodes M and N,
I = electric current injected into the ground via the current electrodes A and B.

If the ground is composed of an infinitely-thick, homogeneous, and isotropic medium, then the calculated resistivity will be the true resistivity of that medium (the ground), otherwise the calculated resistivity is called an apparent resistivity. In general, for a heterogeneous medium, the apparent resistivity depends on the geometry, the spacing, and the orientation of the electrode array with respect to lateral inhomogeneities, and it also depends on the spatial distribution of materials with different electrical resitivities. An estimate of the true resistivity of subsurface materials at various depths, is calculated from the apparent resistivities and the electrode spacings using a variety of interpretation methods.

Schlumberger Sounding Procedure

To make a Schlumberger sounding, the distance between the current electrodes is increased at a succession of logarithmically nearly equal increments (usually at the rate of about 7 points per decade) and the apparent resistivity is calculated at each current-electrode spacing using equation (1). The distance between the potential electrodes is held fixed for a succession of expanding current-electrode spacings. The current-electrode expansion is periodically stopped, the distance between the potential electrodes is increased, and the apparent resistivity is recalculated at the increased potential-electrode spacing; then, the expansion of the distance between the current electrodes is resumed. The purpose of periodically expanding the distance between the potential electrodes is to maintain an adequate level of signal (potential difference) between the potential electrodes. The condition that $(AB/2)$ must be greater than or equal to five times $(MN/2)$ is maintained in order to adequately approximate a measurement of the electric field (which is the gradient of the electric potential) at the center of the electrode array.

A plot of the apparent resistivity against the current-electrode spacing $(AB/2)$, on log-log scale, is called a sounding curve. Each set of apparent-resistivity points calculated at a fixed distance between the potential electrodes, as the current-electrode spacings are expanded, is called a segment. In practice, a field-Schlumberger sounding curve is usually composed of two to four segments, depending on the maximum current-electrode spacing reached. Overlapping segments may not coincide with each other either because of variation in probing depth, resulting from changing the AB/MN ratio at the end of one segment and the beginning of another (Deppermann, 1954; Zohdy and others, 1974) or, more commonly, because of lateral inhomogeneities. The direction and magnitude of a discontinuity between two segments and the change in the ratio of AB/MN at the discontinuity often indicate the cause of the discontinuity. See Appendix 1 for details of electrode-spacing measurement procedures and for a brief description of the equipment used in this survey. Also see Appendix 2 for values of the current-electrode spacings listed beneath the plot of each field-sounding curve.

Principles of Sounding Interpretation

The interpretation of a sounding curve consists of finding an earth model composed of materials with different resistivities such that the computed sounding curve for the model matches the field-sounding curve. Such a model is only one amongst many other models yielding sounding curves that fit the observed curve equally well. This non-uniqueness is referred to as equivalence. Common sense and geologic constraints based on typical measured resistivities often help eliminate many mathematically-equivalent models from being considered.

In this survey, we used a method for the automatic-interpretation of sounding curves (Zohdy, 1989; Zohdy and Bisdorf, 1989) that finds a geologically reasonable earth model composed of horizontal, laterally homogeneous and isotropic, layers. Using this method, the theoretical sounding curve computed for a layered-earth model will always fit the *digitized-sounding* curve very well, provided the digitized-sounding curve adequately represents a horizontally layered medium. The derivation of a digitized-sounding curve from a field-sounding curve is explained in the section on data processing and interpretation.

DATA ACQUISITION PROCEDURE

The sounding curves were plotted in the field as the measurements were made. We always use this procedure in order to identify and correct errors made by the operator or the crew, to recognize spurious readings caused by man-made structures (fences, buried pipes, etc.), by current leakage from damaged cable insulation, or by equipment malfunction.

At the end of each sounding, a test for current leakage (Zohdy, 1968) was made by disconnecting one of the current electrodes, at the site of the electrode, and then attempting to make a reading using high impressed voltage. This procedure tests current leakage in the cable leading to the disconnected current electrode. Next, the disconnected current electrode is reconnected, the other current electrode is disconnected, and the test is repeated. Neither a current flow, in the disconnected current line, nor a potential difference, between the potential electrodes M and N, should be measured during the leakage test of either current cable. It is interesting to note that with most commercial equipment it is not possible to test for current leakage in the above manner. Indications of minor current leakage were observed during a few tests in the form of minor spikes on the potentiometric chart recorder but with immeasurable current on the ammeter. See section on *soundings affected by man made objects* for specifics on soundings affected by current leakage and see Appendix 1 for additional details on data acquisition procedure.

For safety purposes, at the beginning and near the middle of the survey, the crew were reminded of proper safety procedures to be followed during an electrical survey, in general, and during the current-leakage test, in particular. Clear-radio communication is an essential safety requirement during deep resistivity surveys.

DATA PROCESSING AND INTERPRETATION

Data processing of the field-sounding curves consisted of:

a) Converting the current-electrode spacings (*AB/2*) from feet to meters.

b) Shifting the field-curve segments obtained with fixed potential-electrode spacings (*MN/2*) upward or downward to obtain a continuous unsegmented curve. In general, the segment measured with the largest potential-electrode spacing is kept fixed in position and the other segments are shifted up or down.

c) Sampling the continuous unsegmented curve at the rate of 6 logarithmically-equally-spaced points per logarithmic cycle to obtain a digitized-sounding curve. Sampling the apparent resistivities is done from right to left, starting at the largest current-electrode spacing.

The reason for sampling the field curve at the rate of 6 logarithmically-equally spaced points per decade, is to speed up the calculation of the various theoretical-sounding curves during the iterative curve-fitting process (Zohdy, 1973). Each point on a theoretical sounding curve is calculated by convolving a set of kernel-function points (Ghosh, 1971; Zohdy, 1975) with a set of filter coefficients. Points on the kernel-function curve, for a given layering model, are computed using a recursive formula. The filter coefficients that we use were generated at the rate of 6 points per decade (O'Neill, 1975) and there are 20 coefficients in the filter. If the points on a theoretical-sounding curve are selected at logarithmically equally spaced abscissas, at the rate of 6-points per decade, then the required number of kernel-function points will be much smaller than the number for an unequally spaced set of points. Specifically, for m equally spaced points on the sounding curve, the required number of n kernel-function points is given by:

$$n = 20 + m - 1, \tag{2}$$

whereas for m unequally spaced points on the sounding curve, the required number of n kernel-function points is given by :

$$n = 20 \times m. \tag{3}$$

For example, to compute 15 *equally spaced points* (m = 15 in equation (2)), on a theoretical sounding curve, at the rate of 6-points per decade, only 34 kernel-function points must be calculated. In contrast, to compute 15 *unequally spaced points*, on a theoretical-sounding curve (m = 15 in equation (3)), 300 kernel-function points must be calculated.

FIELD CONDITIONS

At the time of the survey (October 1993), the field conditions in the study area were generally favorable for making direct-current resistivity soundings. The weather was generally good, and effects of man-made objects such as gas lines, metal water lines, fences with metal posts, metal-sheathed telephone cables, and grounded power-line posts, were not severe except at a few sounding stations (which are discussed in a separate section below).

At a few places, near-surface caliche layers made it difficult to drive the electrodes into the ground, and limited the amount of current injected into the ground. This limitation, however, did not present a major obstacle because we were using high-power equipment and the high-contact resistance at the current electrodes did not prevent us from expanding any of the soundings to the desired current-electrode spacings.

A few high-voltage power lines exist in the area. We used power-line service roads to make soundings in places where it was necessary to obtain information. By orienting the sounding line parallel to the high-voltage power line we reduced (but did not eliminate) electromagnetic coupling with the sounding cables and hence reduced the noise in the direct-current measurements. However, by running the sounding line beneath the power line, we increased the likelihood for the current to split, and to be re-injected in the ground (following Kirchhoff's law, or first rule, (Halliday and Resnik, 1963, p.706)) via the grounding of the power-line towers. Current splitting and re-injection results in reducing the signal if a current electrode is close to a grounding post and results in increasing the signal if a potential electrode is close to a grounding post. For a few measurements we had to move the location of the current electrodes away from the nearest tower to minimize this effect.

FIELD DATA

The field-sounding curves and their interpretations are given in Appendix 2. The soundings are numbered consecutively from Beaver Dam 1 to Beaver Dam 45. All sounding curves were processed and interpreted using an automatic interpretation computer program (Zohdy, 1989; Zohdy and Bisdorf, 1989). The result of the interpretation program of each sounding is a step-function curve that shows the interpreted variation of resistivity with depth beneath the sounding station. We refer to the resistivities in such a model as interpreted resistivities. Most sounding curves were easily interpretable in terms of horizontally stratified earth models, except for a very few that were affected by man-made objects or by geologic lateral inhomogeneities, as explained in the next two sections.

Longitude and latitude coordinates of the sounding stations are given in Appendix 3. These coordinates were projected into Universal Transverse Mercator coordinates for plotting purposes on computer-generated maps. Station locations and the direction of current-electrode expansions are shown in Figure 2. Most soundings were expanded to maximum current-electrode spacings, *AB/2*, that ranged from 914 m to 3,657 m (3,000 ft to 12,000 ft).

SOUNDINGS DISTORTED BY MAN-MADE OBJECTS

Distorted sounding curves often are defined as curves which do not resemble those measured over horizontally stratified media. The term "distorted", however, is used here to describe only those sounding curves that are affected by man-made objects, by current leakage, or by measurement errors. Metallic objects such as buried metallic pipelines, fences with metal posts or with grounded wire mesh, or power lines with grounded posts, distort a sounding curve. These distortions become especially significant when this type of a linear man-made object is *discontinuous* and the sounding line is expanded *parallel* to it. On the other hand, 60 Hz interference from a power line is strongest when the sounding line is expanded *perpendicular* to the power line.

Sounding 21 is shown in Appendix 2 with no interpretation because it was strongly distorted by the presence of a buried metallic chain-link mesh connected to metal posts made of railroad rails. The wire mesh and the metal posts extruded above the ground by about 0.25 m and were hidden by brush. The buried wire mesh was located southwest of the sounding station, extended from a distance of about 20 m to a distance of about 75 m from the center of the electrode array, and ran parallel to the sounding line at a distance of about 2 m. The sharp rise of the sounding curve (from *AB/2* of about 30 m to about 70 m) and then the sudden drop at *AB/2* = 91 m (300 ft) is caused by the buried wire mesh and not by geologic inhomogeneities. In effect, for the current electrode spacings from about 30 to 70 m, the wire mesh progressively channeled a larger portion of the electric current and deposited it close to the potential electrodes, thus generating much larger than normal potential-difference signals. It is interesting to note that with this layout (of wire mesh, current, and potential electrodes), a low-resistivity material (the metallic wire mesh) generates a high-apparent resistivity anomaly. When the current electrode was located farther away from the end of the wire mesh, the apparent resistivity dropped. Sounding 21 was discontinued upon observing this behavior on the sounding curve and subsequent discovery of the buried wire mesh.

Sounding 29 was distorted at the last measurement by the presence of a power line. The calculated apparent resistivity was too small (about 7.4 ohm-m), but when the measurements were repeated after moving the current electrode laterally and away from the tower of the power line, the calculated apparent resistivity became more reasonable (about 24.5 ohm-m). Similarly, sounding 35 was distorted at two measurements by a power line; but here, the distortion was manually smoothed and the sounding was interpreted as shown in Appendix 2.

Minor current leakage was observed during the current-leakage test made at the end of soundings 5, 6, 9, 12, 14, 16, 28, 37, and 39. In particular, the terminal branches of soundings 14 and 16 may have been affected by current leakage; the curves of the other soundings do not show visible distortions.

SOUNDINGS AFFECTED BY LATERAL GEOLOGIC INHOMOGENEITIES

On some sounding curves we observed the formation of minor, sometimes *very subtle*, cusps caused by lateral-geologic inhomogeneities (see for example soundings 6, 7, 16, 18, 32, 35, 36, 37, and 39). Cusps are formed on a sounding curve as the current electrodes are moved across lateral inhomogeneities during the sounding expansion. There are two types of cusps: upward-pointing cusps and downward-pointing cusps. For a vertical contact (Zohdy, 1970 and 1980) separating two materials with different resistivities, an upward-pointing cusp is formed as a current electrode crosses from low to high resistivity and a downward-pointing cusp is formed when a current electrode crosses from high to low resistivity.

Cusps observed at short current-electrode spacings are usually caused by small, near surface, lateral inhomogeneities such as boulders and buried-stream channels; whereas, cusps observed at large current-electrode spacings are usually caused by much larger inhomogeneities, such as buried ridges or faults (assuming that the cusps are not caused by inaccurate measurements). Small, near surface, lateral inhomogeneities of natural origin, of medium-resistivity contrast, and that are located at a large distance from the center of the sounding, do not affect the measurements to any measurable degree when they are crossed by one of the current electrodes. Similarly, large, lateral inhomogeneities buried at depths larger than the electrode spacing, do not cause the formation of cusps. In this survey, the formation of cusps was not as significant as in certain other surveys (Zohdy and Bisdorf, 1993) where cusps were used to map the location of possible faults.

On sounding 15, the "sharp" maximum between current-electrode spacings of $AB/2$ = 60 and 300 ft is probably caused by the limited lateral extent of the resistive layer responsible for the formation of that maximum (Alfano, 1959; Zohdy and others, 1974). The portion of the sounding curve near the "sharp" maximum can be fitted only approximately by a horizontally layered model.

GENERAL DESCRIPTION OF INTERPRETED-RESISTIVITY CROSS SECTIONS

Six interpreted-resistivity cross sections were made using the Kolor-Map & Section program (Zohdy, 1993) and were edited and annotated using the commercial program Deluxe Paint III (Silva, 1989). Of these six cross sections, five are oriented east-west or nearly northeast-southwest and are approximately transverse to the axis of Beaver Dam Wash, and one is oriented nearly north-south and is approximately parallel to and east of the Wash. The cross sections are based on straight-line distances between sounding stations. Each cross-section figure includes a key-map showing the location of the particular cross section marked in red.

The title of each cross section is based on the numbers of the two sounding stations located at the beginning and at the end of the cross section. On the cross sections, the locations of the sounding stations are indicated by triangles placed at the surface of a locations of the sounding stations are indicated by triangles placed at the surface of a simplified topography. The simplified topography consists of straight-line segments connecting the elevations of successive sounding stations.

The interpreted-resistivity contours shown on the cross sections are derived from the step-function layering model of each sounding as follows:

1) The step-function curve, showing the variation of interpreted resistivity with depth, is sampled at the logarithmic center of each horizontal and vertical segment (Zohdy, 1989; Zohdy, 1993). These sampled resistivities are considered as points on a curve representing a model of continuous variation of resistivity with depth. This model is assumed to be electrically equivalent to the original step-function model because the width of the steps, on logarithmic scale, is reasonably small.

2) The sampled points on the continuous interpreted-resistivity function are used to calculate the contours on the cross sections.

Depths at which the continuous interpreted-resistivity function is sampled are shown on the cross sections as black points beneath each sounding station. The location of the deepest sampled point beneath each sounding station shows the "maximum probing depth" of that particular sounding. Here, we define the "maximum probing depth" as 1.5 times the depth to the top of the last, "infinitely thick", layer. White areas (with question marks) beneath some soundings indicate that these areas are deeper than the maximum-probing depth beneath these soundings. An area beneath a shallow sounding may not be shown in white if that sounding is flanked on each side by nearby deep soundings and the interpolated data between the two deep soundings show a laterally smooth pattern of contour lines.

The interpreted-resistivity contours are approximately equally spaced on a logarithmic scale. The following contour levels were used: 10, 15, 20, 30, 45, 70, 100, 150, 200, 300, 450, 700, and 1,000 ohm-m. The same contour levels were used in contouring the interpreted-resistivity maps at various depths (to be discussed in a subsequent section) and the same color scheme was used in generating the cross sections and the maps.

Long cross sections, that are several kilometers in length, are presented in two parts on the same page: an upper part, which shows the top portion of the cross section vertically exaggerated ten times (to show the near surface geoelectrical layering in more detail); and a lower part, which shows the complete cross section with no vertical exaggeration. Short cross sections are presented without vertical exaggeration.

On all cross sections, the depth to the deepest 70 or 100 ohm-m contour represents a reasonable interpreted depth to the top of a high-resistivity geoelectric basement (possibly Paleozoic limestone and dolomite beds) which underlies low to medium-resistivity materials (probably the Muddy Creek Formation). The determination of the exact depth to basement (without additional knowledge from deep wells) is subject to the various possibilities of equivalent-multilayer models (Zohdy and others; 1974, Zohdy, 1989).

EAST-WEST AND NORTHEAST-SOUTHWEST CROSS SECTIONS

The following five cross sections are oriented east-west or nearly northeast-southwest and they either cross Beaver Dam Wash or terminate at it. The cross sections are described in their order of location from north to south.

Cross Section 45-40

Figure 3 shows two electrically equivalent interpreted-resistivity representations of cross section 45-40. This cross section is approximately 6.5 km in length and is located entirely in the state of Utah. Sounding 45 (at the west end) was made in Beaver Dam Wash and sounding 40 (at the east end) was made near the foothills of Beaver Dam Mountains. The two cross-section representations are not vertically exaggerated.

We are presenting two electrically equivalent interpretations because all the soundings on this cross section detect a high-resistivity electric basement, which is probably composed of Paleozoic limestone, with a resistivity of about 500 to 1,000 ohm-m, and we want to illustrate the effect of constraining the bottom-layer resistivity on the interpreted structures and on the interpreted resistivities and thicknesses of the overlying layers. Note for example that the thickness of the low and medium-low resistivity layers (<10, 10-15, 15-20, 20-30, and 30-45 ohm-m) is larger in most parts of the constrained cross section than on the unconstrained cross section. This is an expected result, because within certain limits of the variation in the basement resistivity, the higher the resistivity of the basement the thicker and/or less resistive the layer above it must be so that the constrained cross section remains equivalent to the unconstrained one.

Both constrained and unconstrained interpretations for soundings 45, 43, 42, and 41 are given in Appendix 2. Constrained interpretations are designated by the suffix F in the title of the interpreted sounding (to indicate a Fixed last-layer resistivity).

The upper part of the figure shows the interpreted-resistivity cross section with no constraints on the interpretation of the sounding curves, whereas the lower part of the figure shows the cross section with the resistivity of the last layer constrained to 600 ohm-m. The reason for selecting a resistivity of 600 ohm-m for the last layer is because the unconstrained interpretation of sounding 40 (located on the east side of the cross section) yielded a last-layer resistivity of 580 ohm-m. A layer with a resistivity of about 600 ohm-m may represent fractured limestone saturated with fresh water. It should be noted, however, that the resistivity of this bottom layer could have been constrained to a much higher value (for example, 2,000 ohm-m) and very good fits to all the sounding curves on the cross section would have been obtained, and in this case the 2,000 ohm-m material would probably represent a rock with little or no water in it. The indeterminacy of the last-layer resistivity is caused by the presence of a low-resistivity layer in the middle of the geoelectric section and by the inadequate length of the last branch on the sounding curves. Very large, and impractical, current-electrode spacings would be required to measure the asymptotic value of the last-layer resistivity. Note also that the last branch on the sounding curves was not manually extrapolated to larger spacings for either mode of interpretation, a technique sometimes used to obtain a slightly different equivalent model, or to estimate a minimum depth to basement for soundings whose last branch does not rise at an angle of 45 degrees (Zohdy, 1969).

Both cross sections show a low-resistivity material sandwiched between two higher resistivity layers. This layer probably represents the Muddy Creek Formation. Beneath soundings 45, 43, and 42 its resistivity ranges from 15 to <10 ohm-m which indicates that it probably does not represent a good aquifer and is probably composed of clays or it may be composed of poorly sorted sand and gravel with a large content of clay and may be saturated with slightly saline water (about 1,000 mg/l in dissolved-solids concentration?). To the east of sounding 42, and beneath sounding 41, the low-resistivity layer changes to a layer of moderate resistivity (30 to 70 ohm-m); and further east, beneath sounding 40, it changes to a layer of moderately-high resistivity (70-200 ohm-m). This resistivity range is usually indicative of a higher percentage of coarser materials and/or better quality water.

A near-surface layer with resistivities between 200 and 500 ohm-m exists in the eastern part of the cross section. It may be as thick as 300 m beneath sounding 40, then it gradually thins to the west as the topography drops to lower elevations. This layer probably represents an alluvial fan composed of sand, gravel, and cobbles, with at least an upper part of unsaturated material. Beneath sounding 43, in the western part, the resistivity of this layer decreases to about 70-100 ohm-m, which is probably caused by a decrease in coarser materials. This layer, also, is probably unsaturated.

The presence of a fault between soundings 40 and 41 may be inferred from the bend in the contours of the high-resistivity materials; however, different contouring algorithms (Zohdy, 1993) can be used to de-emphasize or eliminate this bend in the contours (see examples and a discussion on geoelectrically-inferred faults using sounding data *in* Zohdy and Bisdorf, 1994).

Cross Section 35-41

Figure 4 shows interpreted-resistivity cross section 35-41 which is approximately 16.7 km long. The southwest part, from sounding 35 to sounding 32, is in Nevada and the northeast part, from sounding 31 to sounding 41, is in Utah.

The upper part of the figure shows the top 250 to 600 m vertically exaggerated 10 times. The simplified topography, west of Beaver Dam Wash, especially between stations 31 and 30 does not approximate the detailed topography adequately. The detailed topography, near sounding 30, consists of a relatively narrow, asymmetric, steep-sided channel, with the steeper part being between soundings 31 and 30. The lower part of the figure shows the cross section to an average depth of about 750 m without vertical exaggeration.

The cross sections show a near-surface layer of high-resistivity materials (200 to >450 ohm-m), with a thickness ranging from about 50 to 200 m. This layer probably represents unsaturated alluvial deposits of sand, gravel, and cobbles. It is underlain by materials having a moderately-high resistivity (45-200 ohm-m) which probably represent alluvial deposits, some of which may be saturated with good-quality water. Some of this material also may be the unsaturated part of the Muddy Creek Formation. This moderately-high-resistivity layer is underlain by medium-low- to medium-resistivity materials (15 to 45 ohm-m), which probably represent the saturated part of the Muddy Creek Formation.

Beneath sounding 30, located in Beaver Dam Wash near the center of the cross section, the interpreted resistivity in the top 50 meters is in the 45 to 200 ohm-m range, which probably represents the fresh-water-saturated alluvial channel fill of the Wash. From a depth of 50 to 150 m, the interpreted resistivity remains moderate (30 to 45 ohm-m) which probably indicates that in this part of the Muddy Creek Formation (?) the clay content is moderate and that the water is fresh. To the east, beneath soundings 29 and 36, and to the west, beneath soundings 33 and 32, the interpreted resistivity of the Muddy Creek Formation (?) is less than 20 ohm-m, which typically indicates increased clay content and/or increased dissolved-solids concentration in the ground water. The same decrease in interpreted resistivity occurs at greater depths (>150 m) beneath sounding 30. The greater depth to the low resistivity material beneath sounding 30 may represent a recharge of fresh water from the Wash at the shallower depths.

Beneath sounding 35, in the western part of the cross section, all subsurface materials have an interpreted resistivity of >45 ohm-m, which typically indicates layers with low clay content and ground water of good quality. Sounding 35 is also located about half a kilometer from an outcrop of a consolidated rock, and therefore the higher resistivities may indicate the detection of weathered consolidated rocks at shallow depths.

A fault may exist between soundings 30 and 29, as indicated by the vertically-exaggerated change in the depth to the various <150 ohm-m contours beneath sounding 29 as compared to those beneath sounding 30. But because of the 10 times vertical-exaggeration factor, the contouring algorithm used, and the absence of additional soundings between 29 and 30, the nature of this apparent offset is speculative.

Cross Section 26-24

Figure 5 shows interpreted-resistivity cross section 26-24. This short cross section is approximately 3.7 km long and it lies entirely in the state of Utah. On this cross section, the 45 ohm-m contour may approximately coincide with the water table and thus represent the upper surface of a layer of relatively good-quality water in the Muddy Creek Formation (?). The 15 ohm-m contour may approximately coincide with the top of a clayey and/or brackish-water-saturated zone of the Muddy Creek Formation. Beneath sounding 26, at the southwest end of the cross section, the depth to the 15 ohm-m contour is only about 50 meters. At the northeast end of the cross section, beneath sounding 24, the 45 to 70 ohm-m material, at a depth of about 800 m, may actually represent a geoelectric basement with a much higher resistivity (600 ohm-m) and may represent Paleozoic limestone. An equivalent model in which the geoelectric-basement resistivity is constrained to 600 ohm-m (or greater) was not calculated.

Cross Section 4-5

Figure 6 shows interpreted-resistivity cross section 4-5. This cross section is approximately 16.7 km long and it extends across the states of Nevada (sounding 4), Arizona (soundings 3 to 7), and Utah (soundings 6 and 5). The upper part of the figure shows the top 400 to 600 meters of the cross section vertically exaggerated 10 times and the lower part shows the top 1,000 m with no vertical exaggeration. Note that the topography in the vicinity of Beaver Dam Wash (near sounding 10) is simplified and does not represent the detailed topography adequately. In reality, sounding 10 is located in a relatively narrow and steep sided channel.

In the northeastern part of the cross section (beneath soundings 5, 6, and 7), the high-resistivity materials (300 to >1,000 ohm-m) most likely represent dry sand, gravel, and boulders comprising a thick alluvial fan. The medium- to medium-high resistivity material of 45 to 200 ohm-m beneath soundings 5 and 6 may represent a coarse part of the Muddy Creek Formation (?), and may be saturated with fresh water. Beneath sounding 5, there is an indication on the cross section of a high-resistivity electric basement at a depth of about 600 m (see vertically unexaggerated lower part of the figure).

West of sounding 6, the main part of the subsurface (at depths greater than about 50 to 200 m) is characterized by medium-low resistivity materials of 10 to 20 ohm-m. The zone with a resistivity of less than 15 ohm-m, which extends in depth to several hundred meters, probably represents clayey materials in the Muddy Creek Formation (?) saturated with brackish water. The zone of medium resistivity (30 to 100 ohm-m), overlying the primarily low-resistivity layer, may represent Muddy Creek Formation (?), or a younger material, saturated with fresher water and with less clay.

Southwest of Beaver Dam Wash, from sounding 1 to sounding 4, the Muddy Creek Formation crops out or is at shallow depths (3 to 10 meters). In this part of the cross section, materials with resistivities of greater than about 45 ohm-m may represent unsaturated Muddy Creek Formation. Beneath sounding 3, a high-resistivity material at a depth of about 300 m was detected. We made sounding 39, to the northeast of sounding 3, in the hope that we may again find this unexpected high-resistivity feature, but sounding 39 did not detect this material at a comparable depth. It is possible that this high-resistivity feature is unreal and that it may have been artificially generated on the curve of sounding 3 by the proximity of both a current, and, more important, a potential electrode to a grounded power-line tower. On the other hand, if it is real then it may represent a large buried block of a resistive rock (limestone?), possibly a slide block from the range front.

It is interesting to note that cross section 4-5 spans the northeast structural margin of the Mesquite Basin, where on the basis of gravity, aeromagnetic, and seismic data, a concealed high-angle normal fault, with a throw exceeding 12 km, reaches shallow depths near station 7 in the vicinity of the Arizona-Utah border (H.R. Blank, USGS, written communication, 1994).

Subsequent to the resistivity survey, a test hole "Welcome Creek Pipeline" was drilled by the USGS to a depth of 249 m (818 ft) at sounding 23, which is located about 2.1 km north-northwest of sounding 6 (see Figures 6 and 2). The sample log suggested that the test hole penetrated the Muddy Creek Formation at a depth of about 103 m (338 ft). The water level was measured at a depth of 233 m (764 ft). The electric logs indicate that the top 143 m (470 ft) are composed of an alternating sequence of beds of medium and medium-high resistivities (80 to 250 ohm-m). Within this sequence, there is a 10-m zone extending from a depth of about 97 to 107 m (320 to 350 ft) which is composed of three thin layers of low and medium resistivities (10, 100, and 50 ohm-m). The depth to this zone (from 97 to 107 m) correlates with the depth (103 m) to the top of the Muddy Creek Formation as estimated from the drill-hole cuttings; however, the sequence of alternating medium- and medium-high-resistivity materials of 80 to 250 ohm-m continues beneath this 10-m zone to a depth of 143 m (470 ft) where there is a clear break on the electric-log resistivities and a set of more electrically-homogeneous materials begins, and this may be the actual top of the Muddy Creek Formation. Thus from a depth of 143 to 168 m (470 to 550 ft) the resistivity drops and shows a more homogeneous material with a resistivity in the range between 50 and 100 ohm-m, and from a depth of about 168 m (550 ft) to the bottom of the well at 249 m (818 ft) the resistivity gradually diminishes from about 35 to 15 ohm-m. The depth to the water level, at 233 m, is not reflected on the electric logs by any noticeable change in apparent resistivity.

According to the interpretation of sounding 23 (see Appendix 2), which is located at the site of the test hole, it is very likely that the 15 ohm-m layer encountered at the bottom of the test hole is underlain by higher resistivity materials, averaging about 60 ohm-m, to a depth of about 500 m (where the resistivity drops to about 25 or 30 ohm-m and then at a depth of about 1,000 m it rises again, to about 80 ohm-m, signaling the detection of a geoelectric basement of high resistivity). The reason for predicting a possible increase in resistivity beneath the 15 ohm-m material, at the bottom of the test hole, is that the interpretation of sounding 23 does not show the detection of a 15 ohm-m material near the depth of 250 m. On the other hand, in the interpreted model for sounding 23, the presence of the medium-resistivity material of about 55 to 70 ohm-m, extending from a depth of about 160 to 500 m, is not clearly depicted on the sounding curve (by visual inspection). This implies that perhaps we should consider other, more obvious, equivalent models. The calculation of several electrically-equivalent models (Zohdy and Bisdorf, 1989) showed that the *average* resistivity in the depth range from about 150 to 500 m still must be greater than 15 ohm-m even for models that were forced to include 15 ohm-m layers in that depth interval.

Cross Section 20-16

Figure 7 shows interpreted-resistivity cross section 20-16. This cross section is approximately 13 km long and is located entirely in the state of Arizona, roughly parallel to Interstate Highway 15. Sounding 21, located to the southwest of sounding 20 (see Figure 2), is not included on this cross section nor is it included on the location map in Figure 7, because (as mentioned earlier) sounding 21 yielded a highly distorted curve that was not interpreted (see Appendix 2). The upper part of Figure 7 shows the top 400 m of the cross section vertically exaggerated 10 times, and the lower part of the figure shows the top 1,000 m without vertical exaggeration. Note that in the vicinity of Beaver Dam Wash, the simplified topography does not adequately represent the detailed topography.

The upper 20 to 70 m on most of the cross section (except at sounding 18 in Beaver Dam Wash) is characterized by high and medium-high resistivity materials of about 100 to >450 ohm-m. These materials most likely represent unsaturated sand and gravel deposits. A fault may exist between soundings 19 and 17 as evidenced by the sudden change in the depth to the 45 ohm-m contour in the upper-part of the figure. However, because a significant bend in the line of the cross section occurs between soundings 19 and 17 (see map on Figure 7), and because the upper part of Figure 7 shows the cross section vertically exaggerated ten times, the existence of this fault is uncertain. The major part of the subsurface is characterized by medium to low-resistivity materials (<10 to 45 ohm-m). The zones mapped as <20 ohm-m materials, and especially those with interpreted-resistivity of less than 10 ohm-m, probably represent clay-rich sediments and/or sediments saturated with poor-quality water in the Muddy Creek Formation.

Beneath sounding 17 a thick zone with a medium interpreted resistivity of 30 to 45 ohm-m extends from a depth of about 60 to 500 m. This thick zone is interpreted as a zone with better-quality water and/or as a zone with a larger percentage of sand and gravel layers than the zones with lower resistivities, at comparable depths to the east and west. The interpretation of sounding 17 also indicates that at depths greater than about 500 meters, the interpreted resistivity decreases quickly to less than 10 ohm-m (probably representing the presence of clays and/or saline-water-saturated sediments in the Muddy Creek Formation).

Subsequent to the resistivity survey, test hole USGS #5A was drilled by the U. S. Geological Survey near sounding 17 to a depth of 599 ft (182.5 m). Apparent-resistivity data from the electric logs (64-inch normal, 16-inch normal, and lateral) are shown in color inside the test-hole symbol on Figure 7. The top 12 m (40 ft) are cased with PVC and are shown on the test-hole symbol with a vertically striped pattern. Resistivities in the upper part of the electric logs (upper 70 m) correlate very well with the interpreted resistivities from sounding 17. The lower parts of the lithologic and electric logs also agree with the interpretation of sounding 17 in the sense that a sequence of layers with alternating moderately-high and low resistivities on the electric logs are represented by a single thick layer of medium resistivity on the sounding interpretation. The lithologic and electric logs show that the section is composed of sand and gravel layers of moderately-high resistivity (50 to 125 ohm-m) alternating with clay layers of low resistivity (10 to 12 ohm-m). These alternating moderately high- and low-resistivity layers (detected on the electric logs) are relatively thin with respect to their depth of burial and cannot be individually resolved on a conventional sounding curve, even if they laterally extend to very large distances. Thus, the sequence of alternating moderately high- (50 to 125 ohm-m) and low-resistivity layers (10 to 15 ohm-m) are combined into an electrically equivalent layer with a logarithmic average resistivity of 30 to 45 ohm-m, as given by the interpretation of sounding 17. This type of equivalence between a multilayer- and a single-layer portion of a geoelectric section is very common. The important fact to remember is that if a layer of higher or lower resistivity is encountered in the drill hole then a layer of lower or higher resistivity, respectively, should be encountered at a subsequent depth, so that their average resistivity would correspond to the interpreted resistivity obtained from the electrical-sounding interpretation. It should also be noted that if these individual thin layers of high and low resistivity continue to alternate to large depths and provided they extend horizontally to significant distances, then the thickness of the composite layer predicted from the interpretation of the sounding curve will be larger than the actual thickness by a factor equal to the coefficient of macro-anisotropy of the composite layer (Bhattacharya and Patra, 1968; Maillet, 1947; Zohdy and others, 1974).

In test-hole USGS #5A, the measured depth of the water table was 270 ft (82 m). The dissolved-solids concentration in a water sample from the test hole was 382 mg/l, which represents good-quality water, and is well below the maximum drinking-water-standard level of 1,000 mg/l. The water-quality test corroborates the sounding interpretation and in fact, the dissolved-solids concentration was less than a speculated level of about 500 to 600 mg/l on the basis of observed relations between resistivity and dissolved-solids concentration in other field areas.

Higher resistivities, below depths of 20 to 70 m, and better-quality ground water west of Beaver Dam Wash contrast with generally lower resistivities and poorer-quality ground water east of the Wash. Analysis of ground-water samples collected from wells tapping the Muddy Creek Formation (?) east of the Wash indicate that the dissolved-solids concentration there is in the range of 1,200 to 2,500 mg/l (Michael Enright, USGS, oral communication, 1994). These data along with water-level data (which indicate that the water-table gradient slopes to the west from Beaver Dam Wash (W. F. Holmes and Michael Enright, USGS, written communication, 1994)) indicate that Beaver Dam Wash recharges the Muddy Creek Formation and the better-quality water west of the Wash is a result of this recharge.

NORTH-SOUTH CROSS SECTION

Cross-Section 44-38

Figure 8 shows interpreted-resistivity cross section 44-38. This cross section is approximately 43 km long and roughly parallels Beaver Dam Wash. The northern part of the cross section is in Utah and the southern part is in Arizona. Similar to cross section 4-5, it crosses the concealed structural margin of Mesquite Basin, probably midway in the large gap between soundings 25 and 9 (H.R. Blank, USGS, written communication, 1994). The upper part of Figure 8 shows the top 900 to 1,200 m vertically exaggerated 10 times, and the lower part shows the entire cross section without vertical exaggeration. The rise and fall in topography between soundings 44 and 25 represents the traversing of a large alluvial fan, originating in the foothills of Beaver Dam Mountains.

Sounding 44, at the north end of the cross section, is located in Beaver Dam Wash. Subsequent to the resistivity survey, at approximately 900 ft north and 960 ft west of sounding 44, the USGS drilled the Jackson Wash test hole to a depth of 979 ft (298 m). The interpretation of sounding 44 is in very good agreement with the electric logs (16-inch normal, 64-inch normal, and lateral), as shown in Figure 8 by the colors of resistivity values inside and outside the test-hole symbol. Both data sets show that the major part of the geoelectric section is composed of low-resistivity materials (about 10 to 15 ohm-m). Close examination of the electric logs shows that only a few thin layers have resistivities as high as 20 ohm-m in the depth interval from about 100 to 700 ft (30.5 to 213 m). Near the bottom of the hole, however, from about 820 to 875 ft (250 to 267 m) and from 940 to 955 ft (286 to 291 m), there are two medium-high resistivity layers of about 80 and 90 ohm-m, respectively, separated by low resistivity materials of about 7 ohm-m. From the bottom of the deeper medium-high resistivity layer to the bottom of the logged portion of the hole, that is from 955 to 977 ft (291 to 298 m), the apparent resistivity on the electric logs drops from 90 ohm-m to 15 ohm-m.

On the basis of cuttings obtained during the drilling of the Jackson Wash test hole, S. A. Thiros and W. F. Holmes (USGS, Salt Lake City, Utah, written communication, 1994) report that the bottom part of the well is composed of a greenish-gray shale. Shales typically have low resistivities (<15 ohm-m).

The interpretation of sounding 44 (see Appendix 2) shows the detection of an "infinitely" thick last layer of medium-high resistivity material (85 ohm-m) at a depth of about 300 m (about 980 ft). The rise in interpreted resistivity from about 11 and 13 ohm-m, to 28 ohm-m, and then to 85 ohm-m begins at a depth of about 206 m (676 ft). This broad depth range (200 to 300 m) correlates with the depths to the two resistive layers, detected on the electric logs, which extend from 250 to 267 m (820 to 875 ft) and from 286 to 291 m (940 to 955 ft), respectively. Although these two resistive layers are overlain, separated, and underlain by low resistivity layers, the interpretation of sounding 44 indicates that the low-resistivity (15 ohm-m) layer, at the bottom 22 ft of the test hole, is undoubtedly underlain by more resistive layers; because if it is not, then the last branch on the curve of sounding 44 would not have risen. In the area of sounding 44, man-made objects that could have affected the curve of sounding 44 were absent, and current leakage was not detected upon completion of the sounding process. Therefore, the curve of sounding 44 almost unequivocally shows the presence of thick high-resistivity layers at depths below 300 m.

The dissolved-solids concentration in a water sample from the Jackson Wash test hole was 421 mg/l, indicating good-quality water. This is a pleasant surprise because most of the materials in the test hole have low resistivities (10 to 15 ohm-m), in this case reflecting the abundance of clay layers rather than poor-quality water. On the other hand, the abundance of clay layers means that only a few layers of sand with good permeability exist.

Beneath the topographic high, from soundings 42 to sounding 24 (Figure 8), the geoelectric cross section is characterized by medium-high- and high-resistivity materials (100 to 700 ohm-m) in the upper part of the section. These materials most likely represent unsaturated, alluvial-fan materials composed of sand, gravel, and boulders. Similar deposits are shown beneath soundings 37 and 38, at the southern end of the cross section.

Beneath the alluvium, most of the cross section is characterized by low and medium-low resistivities (<10 to 20 ohm-m). These layers are most likely composed of clay and silt with a few sand layers, and thus do not represent potentially good aquifers (especially the <15 ohm-m materials). In the middle part of the cross section, beneath sounding 24, the materials in the depth range from about 150 to 350 m have resistivities from 30 to 70 ohm-m. Therefore, these materials may represent a zone with relatively more sand and gravel layers; and where saturated they should represent a good aquifer.

A geoelectric basement, with a medium-high-interpreted resistivity of 45 to 200 ohm-m, is detected in the northern and southern parts of the cross section. This is the same layer discussed above in relation to the layers encountered near the bottom of the Jackson Wash test hole. From north to south, the depth to this layer increases to the south of sounding 44, it decreases beneath sounding 28, then it increases again to the south of sounding 28. Beneath soundings 9, 11, and 12, which are located to the south of sounding 28 and to the south of 25, this resistive layer is not shown on the cross section down to a depth of about 1,000 m. Nevertheless, there is subtle evidence of its detection on the curves of soundings 9 and 11 (see Appendix 2). Larger current-electrode spacings would have been necessary at soundings 9, 11, and 12 to obtain more complete information about its depth in this area (or the last branches on these 3 soundings could have been extrapolated manually to larger spacings, and the soundings would have been reinterpreted, with reduced confidence, under that assumption; but this was not done). Similarly, the relatively-low-interpreted resistivity of 45 to 70 ohm-m for the bottom layer beneath soundings 27, 24, and 37 is caused by the "relatively short" current-electrode spacings at those stations. We believe that the resistivity of the bottom layer, at those locations, is higher than indicated.

INTERPRETED-RESISTIVITY DEPTH MAPS

Figure 9 shows six interpreted-resistivity maps at depths of 10, 20, 50, 100, 200, and 500 m. Sounding-station locations are shown on the maps either as open squares or as small-solid squares. Open squares represent soundings that were expanded to sufficiently large current-electrode spacings to probe to the depth indicated on the given map (these are named "deep soundings" on the figure). Small solid squares represent soundings that were not expanded to sufficiently large current-electrode spacings to probe to the depth indicated on the given map (these are named "shallow soundings" on the figure). On the 200 m depth map there is one "shallow-sounding" station and on the 500 m depth map there are several. On the 500 m depth map, in the north and in the west, some areas are shown in white because the shallow soundings in those areas do not probe to the 500 m depth and because they are located far from the nearest deep sounding.

The maps in figure 9 show the dominance of high-resistivity materials (100 to 1,000 ohm-m) at shallow depths (10 and 20 m depth maps) reflecting the presence of shallow caliche beds and unsaturated materials, some of which is alluvial-fan sediments. The area of high-resistivity materials diminishes and recedes from west to east at successively larger depths. This demonstrates that the thickness of high-resistivity materials is larger in the east than in the west which probably reflects the presence of alluvial-fan sediments deposited from Beaver Dam Mountains located to the east of the survey area. In general, the maps show a slightly arcuate northwest-southeast trend separating higher-resistivity materials in the east and northeast from lower resistivity materials in the west and southwest. The sharp resistivity gradient, clearly depicted on the 50 and 100 m depth maps, identifies the edge of the alluvial fans which seem to control the course of Beaver Dam Wash.

In the southeastern part of the survey area, near soundings 14, 15, and 16 (see Figure 2 for location), the low-resistivity anomaly, shown progressively developing on the 50, 100, and 200 m depth maps, is inferred to correspond to an area characterized by poorer-quality water. This inference is based on knowing that near sounding 13 (west of sounding 14, see Figure 2 for location) the water quality is poor and knowing that springs near the mouth of the Virgin River gorge have poor-quality water.

On all maps: a) Materials with interpreted resistivities of less than 20 ohm-m probably represent clayey sediments with low permeability and/or sediments saturated with average to poor-quality water (the lower the resistivity the larger the amounts of clay layers and the lower the chance for layers with good-quality water). b) Materials with 30 to 45 ohm-m probably represent silty sands or an alternating sequence of clean sand and clay beds. c) Materials with interpreted resistivities in the 45 to 200 ohm-m range, probably represent beds with greater amounts of sand and gravel layers, and where they occur below the water table they probably represent aquifers with good-quality water.

SUMMARY AND CONCLUSIONS

The direct-current resistivity survey has shown that subsurface materials in the Beaver Dam Wash area may be divided into five geoelectrical units. These five units and what they may represent geologically and hydrogeologically are described, from low- to high-resistivity materials, as follows:

1) Low- to medium-low resistivity materials (7 to 15 ohm-m) generally represent clay-rich sediments or may represent sand and gravel layers saturated with brackish to saline water. Test drilling near sounding 44 showed that, in that area, these interpreted resistivities indeed correspond to thick clay and silty clay sediments, but that there were also a few thin sand and gravel layers at depth and that the water quality in those layers was good.

2) Medium-low resistivity materials (15 to 30 ohm-m) probably represent silty sand layers with a significant amount of clay (50%?). Such materials are generally not very good aquifers, because of the possibility of high clay content.

3) Medium-resistivity materials (30 to 70 ohm-m) probably represent sand and gravel deposits with some clay content. Test-hole USGS #5A drilled near sounding 17 showed that a part of the 30 to 45 ohm-m material was formed of 100 ohm-m sand layers alternating with 10 ohm-m clay layers, which combine to form a 30-45 ohm-m macro-anisotropic geoelectric

layer. The top part of the saturated section of the Muddy Creek Formation typically falls in this resistivity range.

4) Medium-high-resistivity materials (70 to 200 ohm-m) probably represent: a) coarse sand and gravel layers saturated with fresh ground water when found at the base of the alluvial fans, b) unsaturated Muddy Creek Formation, or c) a thick geoelectric basement (limestone?) when found underlying the thick, low-resistivity, unconsolidated part of the basin fill. Where this geoelectric basement is at a depth of less than 1,000 m (about 3,000 ft), its medium-high resistivity indicates that it may consist of layers saturated with fresh water and therefore may be worth investigating with deep test holes. On the other hand, where this geoelectric basement is covered with thick low-resistivity materials (of about 10 ohm-m), it becomes difficult to evaluate its true resistivity with confidence, and it is possible that its true resistivity is much higher than 1,000 ohm-m, in which case it probably represents consolidated rocks with little or no fracture porosity. The Jackson Wash test hole, located near sounding 44 (Figure 2), showed that there were sand layers and a shale layer near the bottom of the hole where the geoelectric-basement was predicted from the interpretation of sounding 44. These layers do not represent a solid basement rock of very-high resistivity and therefore a much deeper test hole will be desirable if the study of deep aquifers is warranted.

5) High-resistivity materials (200 to >1,000 ohm-m) mostly represent near-surface caliche layers, and sand, gravel, and cobble layers forming the top part of alluvial fans. These layers are unsaturated.

ACKNOWLEDGMENTS

We wish to thank our colleagues Dwight L. Schmidt and H. Richard Blank for supplying us with pertinent geologic literature and for their informative discussions about the geology of the area. We also wish to thank our colleagues Louise Pellerin and H. Richard Blank for reviewing the manuscript, and Walter F. Holmes for informally reviewing the manuscript.

COMPUTERS AND PERIPHERALS

The sounding interpretations were made on a 386 IBM-compatible computer using the automatic interpretation program developed by Zohdy and Bisdorf (1989). The station-location map was generated by digitizing the sounding locations on seven 7.5 minute USGS topographic maps, using a program developed by Selner and Taylor (1992). The resulting location map was annotated using DesignCAD 2-D (American Small Business Computers, 1992) and printed on an HP LaserJet-4m printer. The resistivity maps and cross sections were generated in color on an Amiga 3000 computer using the Kolor-Map & Section program (Zohdy, 1993) and were edited and annotated using Deluxe Paint III (Silva, 1989). All color maps and cross sections were printed on a Canon Color Bubble-Jet printer BJC-600.

The tabulations and log-log plots of the sounding curves, shown in Appendix 2, were made by using the data files from the automatic interpretation program to generate graphics and text files compatible with WordPerfect 5.1 (WordPerfect Corporation, 1990). This was done using a program written by the second author in Microsoft BASIC version 7.0 (Microsoft Corporation, 1989). The output was printed on an HP LaserJet III printer.

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APPENDIX 1

Electrode-Spacing Measurements

All current- and potential-electrode spacings were measured in feet and later converted to meters during data processing and interpretation. Current-electrode spacings (*AB/2*) from 10 to 100 ft were measured using a cloth tape. The current-electrode spacings at 140 ft and at 200 ft were measured using markings on the laid-out potential-electrode cable. Current-electrode spacings greater than 200 ft were measured using truck-mounted "precision-foot-odometers", which measure the distance in feet.

In this survey, most of the field-sounding curves were composed of three segments or fewer. A segment on a sounding curve is defined as a sequence of measurements made with increasing current-electrode spacings (*AB/2*) at fixed potential-electrode spacings (*MN/2*). The segments on the field-sounding curves correspond to fixed *MN/2* spacings of: 2, 20, and 200 ft (0.61, 6.1, and 60.9 m), respectively.

On each sounding curve, the first segment was obtained by successively expanding the current-electrode spacing (*AB/2*) from 10 ft to 100 ft with the potential-electrode spacing (*MN/2*) held fixed at 2 ft. At *AB/2* = 100 ft, the *MN/2* spacing was expanded from 2 ft to 20 ft and the second segment on the sounding curve was obtained by successively expanding *AB/2* from 100 to 1,000 ft. At *AB/2* = 1,000 ft, the *MN/2* spacing was expanded from 20 ft to 200 ft and the third segment of the sounding curve was obtained by successively expanding *AB/2* from 1,000 ft up to 12,000 ft (see sounding 23). Most soundings were expanded to maximum current-electrode spacings that ranged from 3,000 to 8,000 feet. Where the discontinuity between two segments was pronounced, additional measurements were made so that the two segments would overlap by two points on each segment.

A few soundings were expanded to current-electrode spacings that were longer than the available straight-line distance by following the turn in the road (see for example soundings 3C, 4C, 36C, and 39C; the suffix C indicates that the soundings were corrected). These four soundings were corrected for non-linear geometry using a method that the first author developed for making soundings along winding roads in the Medicine Lake area, California (Zohdy and Bisdorf, 1990). On most corrected soundings the corrections were minimal.

Trucks and Other Equipment

Three trucks were used for making the resistivity survey: an instrument truck (a carryall) that remained stationary at the center of the sounding, and two pickup trucks that were used to lay out and pick up the current cable. Communication between operator and crew was maintained using 90-watt FM radios. A 4-KVA generator was used for the current-power supply and a potentiometric-chart recorder was used for measuring the potential difference between the potential electrodes. Transformers were used to step up the impressed voltage as needed (up to 1,000 volts), a current-control instrument was used to convert the alternating current to direct current and to control the electric-current intensity, and filters were used to filter electrical noise. Electrical noise is caused most commonly by power lines, transformers on power-line poles, electric pumps, wind, and by telluric currents (natural earth currents). These parts of the resistivity equipment were built by the USGS. Stainless-steel electrodes were used for current and for potential electrodes.

APPENDIX 2

Field and Interpreted Sounding Curves

On the following pages, the data for each sounding curve includes:

1) A sounding title (Beaver Dam), which is an abbreviation for the name of the survey area, followed by a sequential sounding number. The following suffixes are used to indicate special processing of the sounding data:

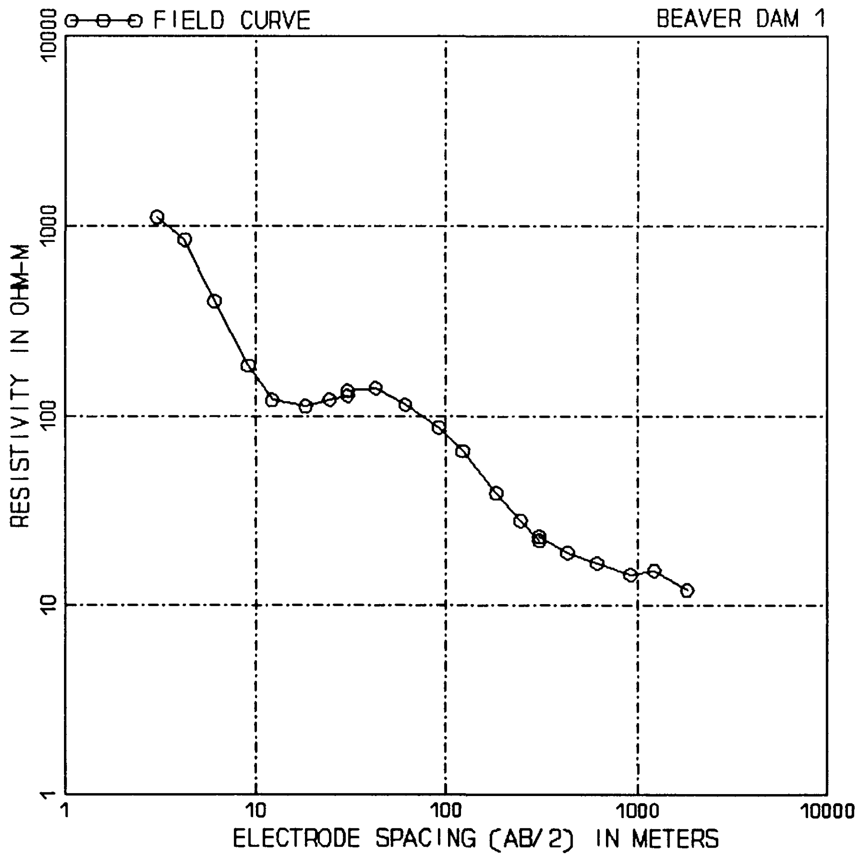
S -- sounding curve smoothed prior to interpretation,
C -- last few measurements corrected for a non-linear electrode geometry,
F -- last-layer resistivity Fixed (constrained) to a given value.

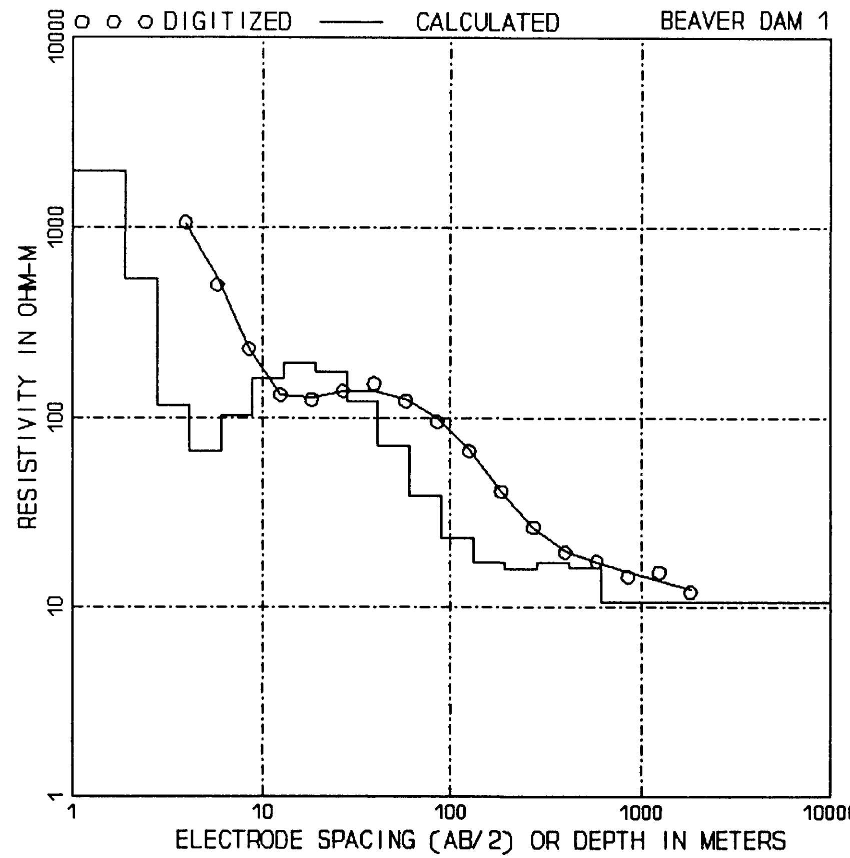
2) A tabulation of the current-electrode spacings (*AB/2*) in meters (and in feet, the primary unit used in the field) and corresponding apparent resistivities in ohm-meters.

3) A log-log plot of the field sounding data. Data points of each set made with the same potential-electrode spacing (*MN/2*) are connected with a solid line to form a segment on the curve. Measurements were made with the potential-electrode spacings fixed at 2, 20, and 200 ft (0.61, 6.1, and 60.9 meters).

4) A tabulation of the automatically interpreted layering; with depths in meters (and in feet) and corresponding interpreted resistivities in ohm-meters.

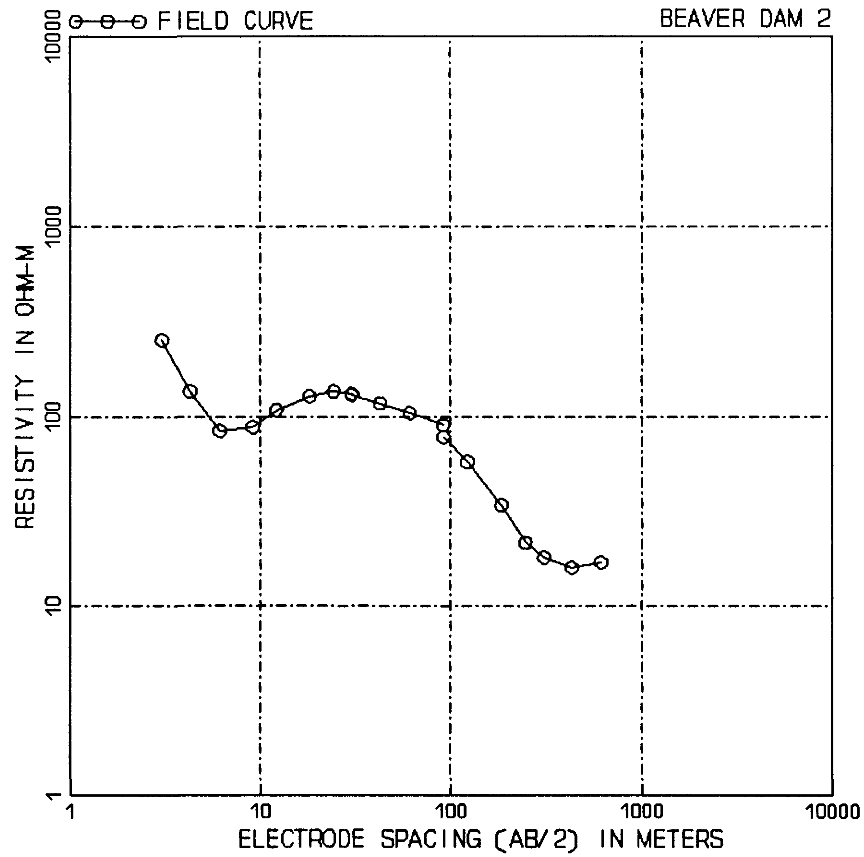
5) A log-log plot of the output of the automatic interpretation program. Circles represent the shifted and then digitized sounding curve. The step-function curve represents the interpreted layering model. The continuous curve represents the theoretical sounding curve calculated from the layering model. Note that the abscissa is used to represent the current-electrode spacing for both the digitized and calculated sounding curves as well as the interpreted depth to the various layers. Similarly, the ordinate is used to represent the digitized and calculated apparent resistivities as well as the interpreted resistivity of the various layers in the step-function model.



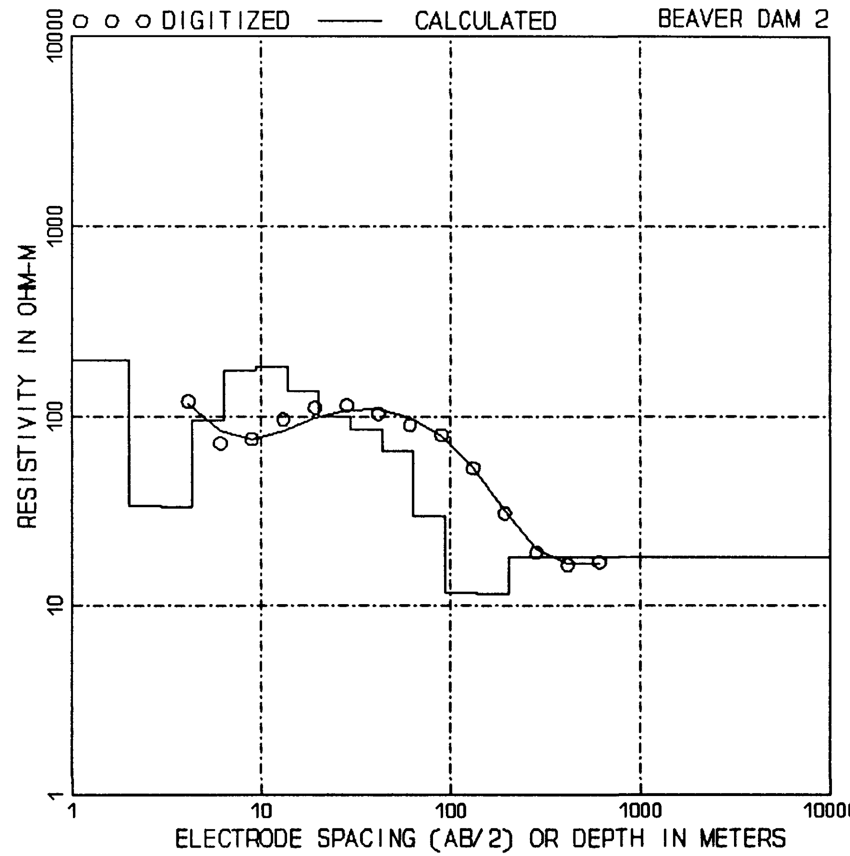


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	1113.00	91.44	(300.00)	87.00
4.27	(14.00)	850.00	121.92	(400.00)	65.00
6.10	(20.00)	400.00	182.88	(600.00)	39.00
9.14	(30.00)	184.00	243.84	(800.00)	28.00
12.19	(40.00)	121.00	304.80	(1000.00)	22.00
18.29	(60.00)	112.00	304.80	(1000.00)	23.00
24.38	(80.00)	122.00	426.72	(1400.00)	19.00
30.48	(100.00)	128.00	609.60	(2000.00)	16.70
30.48	(100.00)	136.00	914.40	(3000.00)	14.50
42.67	(140.00)	140.00	1219.20	(4000.00)	15.30
60.96	(200.00)	114.00	1828.80	(6000.00)	12.00

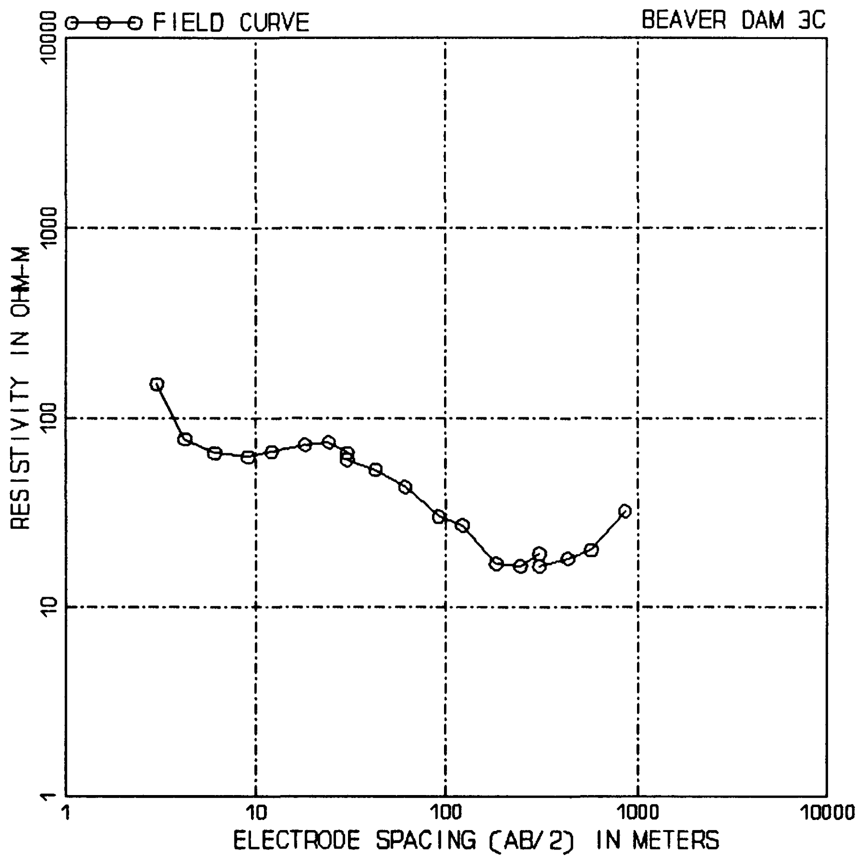
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.91	(6.28)	1975.34	41.25	(135.35)	120.85
2.81	(9.22)	536.41	60.55	(198.66)	70.82
4.13	(13.53)	116.53	88.88	(291.60)	38.65
6.06	(19.87)	66.92	130.46	(428.01)	23.12
8.89	(29.16)	102.69	191.49	(628.23)	17.21
13.05	(42.80)	160.75	281.06	(922.12)	15.84
19.15	(62.82)	194.17	412.54	(1353.49)	17.11
28.11	(92.21)	173.58	605.53	(1986.65)	16.11
			99999.00	(99999.00)	10.60



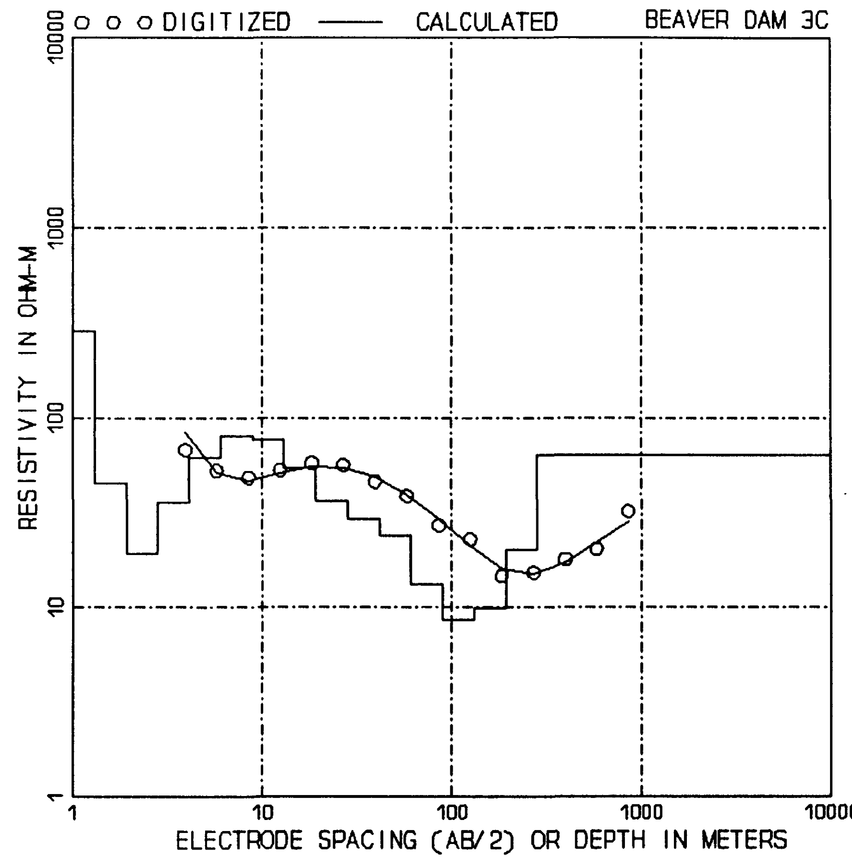
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	252.00	60.96	(200.00)	104.00
4.27	(14.00)	135.00	91.44	(300.00)	90.00
6.10	(20.00)	84.00	91.44	(300.00)	78.00
9.14	(30.00)	88.00	121.92	(400.00)	57.50
12.19	(40.00)	108.00	182.88	(600.00)	34.00
18.29	(60.00)	128.00	243.84	(800.00)	21.60
24.38	(80.00)	135.00	304.80	(1000.00)	18.00
30.48	(100.00)	132.00	304.80	(1000.00)	18.00
30.48	(100.00)	130.00	426.72	(1400.00)	16.00
42.67	(140.00)	117.00	609.60	(2000.00)	17.00



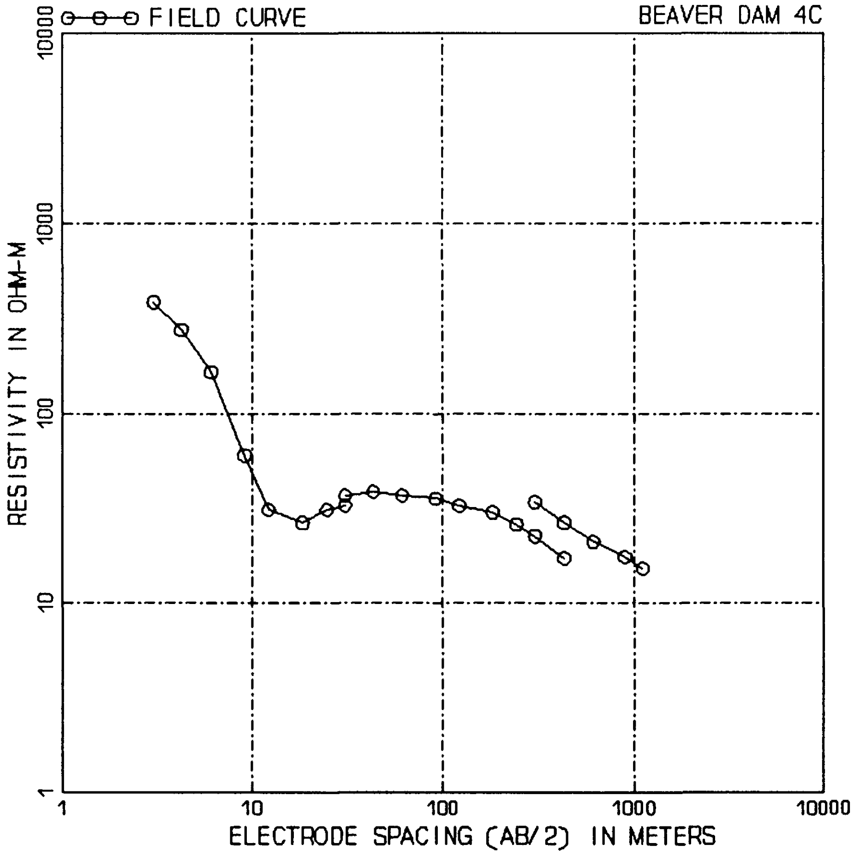
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.02	(6.62)	196.21	29.63	(97.20)	99.09
2.96	(9.72)	33.41	43.49	(142.67)	85.27
4.35	(14.27)	32.95	63.83	(209.41)	65.66
6.38	(20.94)	94.90	93.69	(307.37)	29.67
9.37	(30.74)	173.15	137.51	(451.16)	11.68
13.75	(45.12)	181.91	201.84	(662.22)	11.49
20.18	(66.22)	135.76	99999.00	(99999.00)	18.11



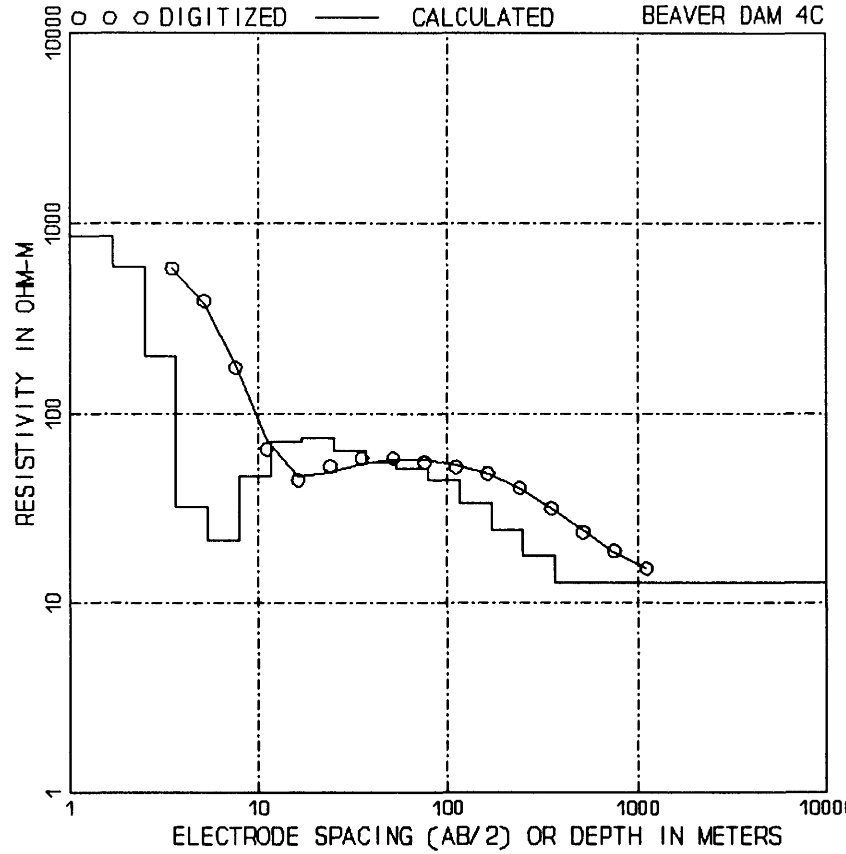
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	150.00	60.96 (	200.00)	43.00
4.27 (	14.00)	77.00	91.44 (	300.00)	30.00
6.10 (	20.00)	65.00	91.44 (	300.00)	30.00
9.14 (	30.00)	62.00	121.92 (	400.00)	27.00
12.19 (	40.00)	66.00	182.88 (	600.00)	17.00
18.29 (	60.00)	72.00	243.84 (	800.00)	16.50
24.38 (	80.00)	74.00	304.80 (	1000.00)	19.10
30.48 (	100.00)	65.00	304.80 (	1000.00)	16.50
30.48 (	100.00)	60.00	426.72 (	1400.00)	18.00
42.67 (	140.00)	53.00	563.58 (	1849.00)	20.00
			852.53 (	2797.00)	32.00



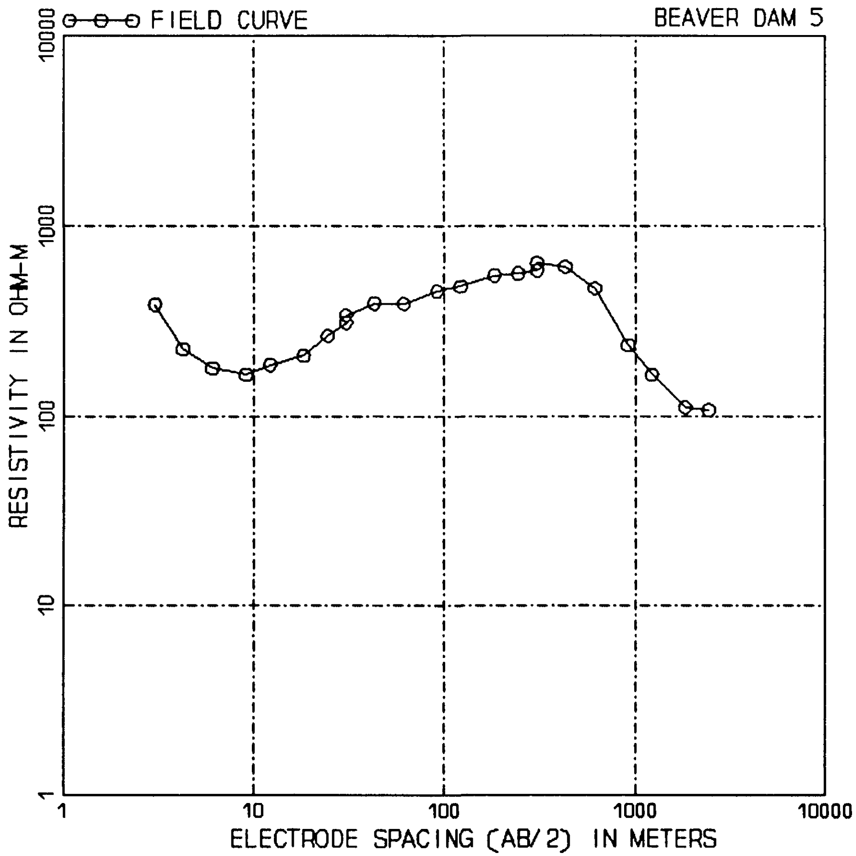
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.31 (	4.30)	283.72	28.23 (	92.61)	36.25
1.92 (	6.31)	44.94	41.43 (	135.93)	29.12
2.82 (	9.26)	19.22	60.81 (	199.52)	23.98
4.14 (	13.59)	35.45	89.26 (	292.86)	13.32
6.08 (	19.95)	61.85	131.02 (	429.86)	8.54
8.93 (	29.29)	80.47	192.31 (	630.95)	9.85
13.10 (	42.99)	76.12	282.28 (	926.11)	20.26
19.23 (	63.10)	54.55	99999.00 (	99999.00)	63.00



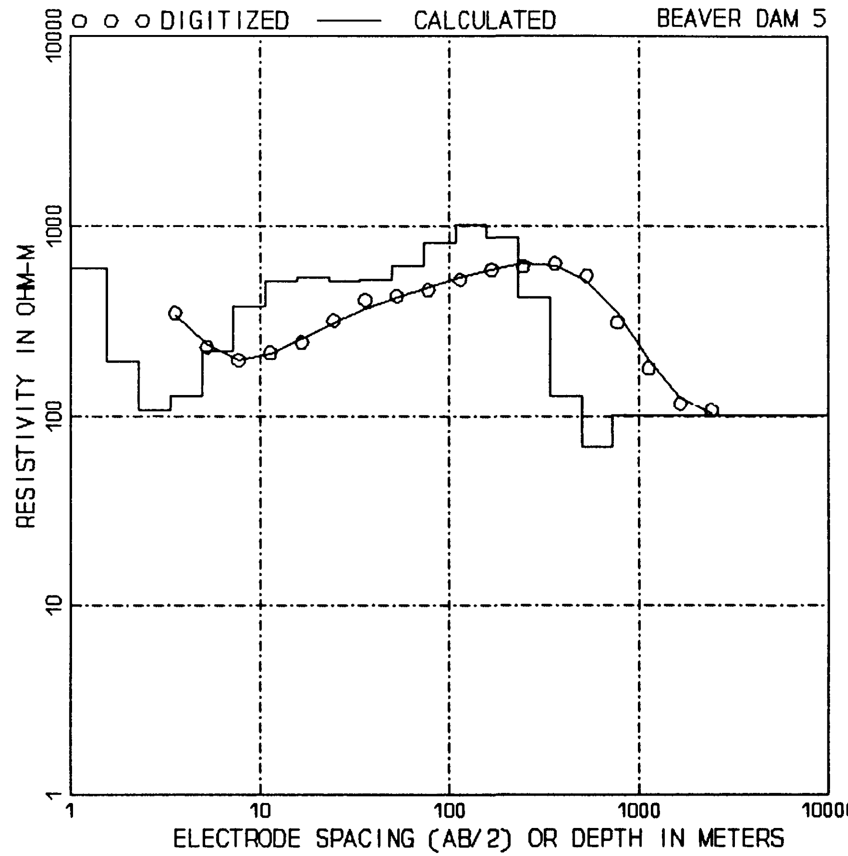
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	385.00	91.44	(300.00)	35.50
4.27	(14.00)	275.00	121.92	(400.00)	32.50
6.10	(20.00)	165.00	182.88	(600.00)	30.00
9.14	(30.00)	60.00	243.84	(800.00)	26.00
12.19	(40.00)	31.00	304.80	(1000.00)	22.60
18.29	(60.00)	26.50	434.04	(1424.00)	17.20
24.38	(80.00)	31.00	304.80	(1000.00)	34.00
30.48	(100.00)	32.70	434.04	(1424.00)	26.50
30.48	(100.00)	36.70	617.22	(2025.00)	21.00
42.67	(140.00)	38.50	898.86	(2949.00)	17.50
60.96	(200.00)	37.00	1107.34	(3633.00)	15.20



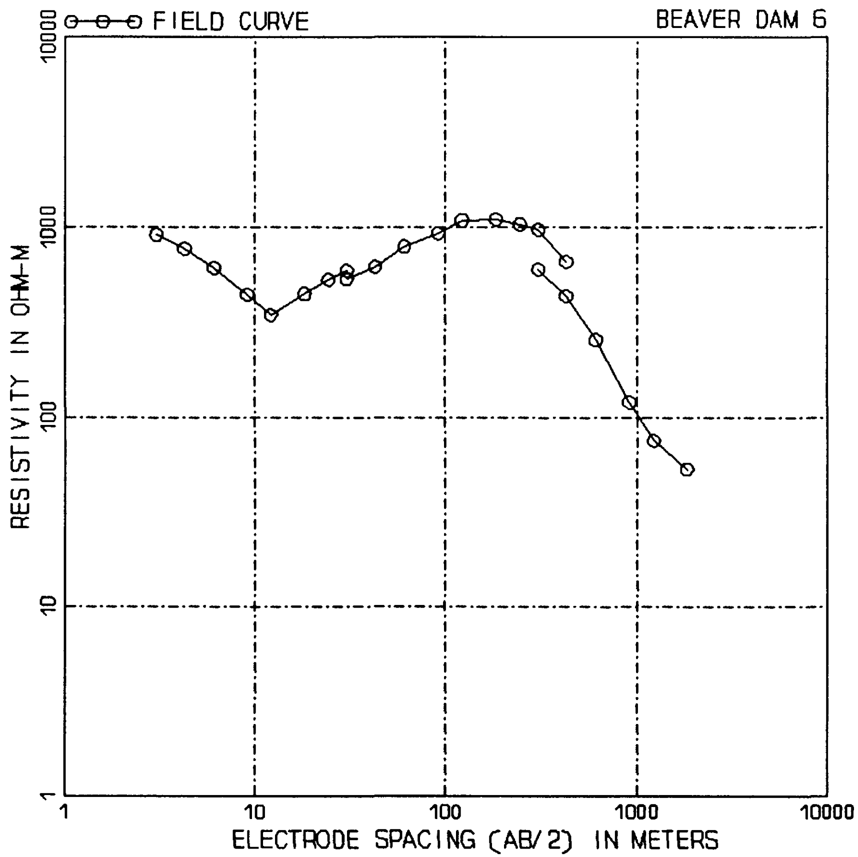
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.70	(5.58)	860.89	36.66	(120.29)	63.74
2.50	(8.20)	593.90	53.82	(176.56)	55.24
3.67	(12.03)	199.18	78.99	(259.16)	51.04
5.38	(17.66)	32.27	115.94	(380.39)	44.39
7.90	(25.92)	21.38	170.18	(558.34)	33.55
11.59	(38.04)	46.69	249.79	(819.54)	24.24
17.02	(55.83)	70.64	366.65	(1202.92)	17.81
24.98	(81.95)	73.88	99999.00	(99999.00)	12.77

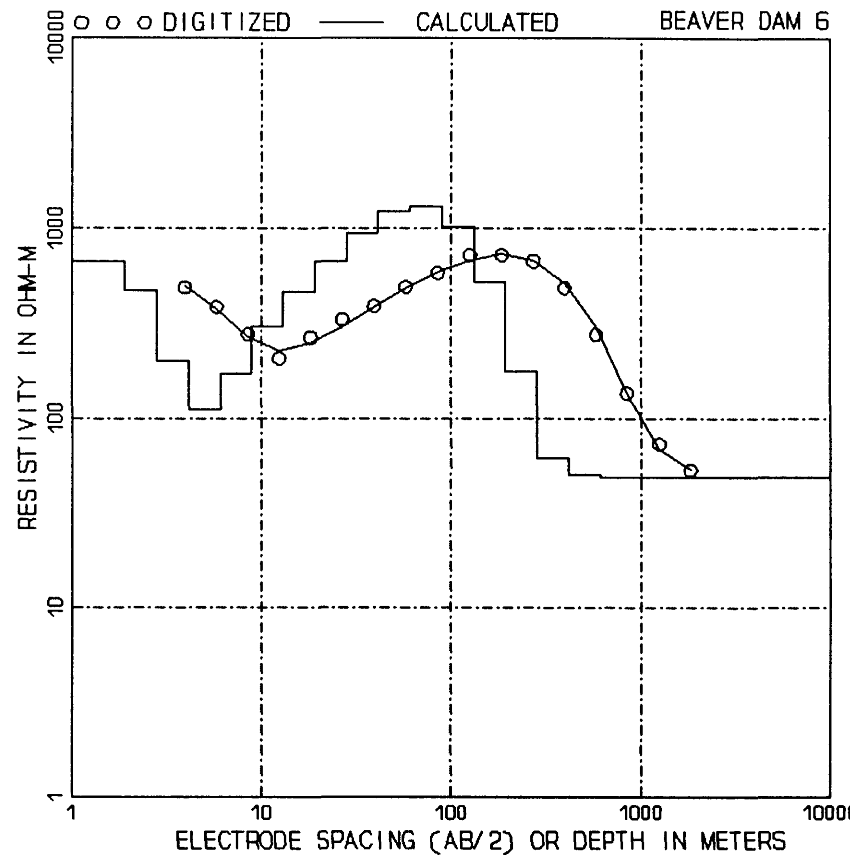


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	385.00	91.44	(300.00)	453.00
4.27	(14.00)	225.00	121.92	(400.00)	480.00
6.10	(20.00)	178.00	182.88	(600.00)	550.00
9.14	(30.00)	165.00	243.84	(800.00)	563.00
12.19	(40.00)	186.00	304.80	(1000.00)	585.00
18.29	(60.00)	208.00	304.80	(1000.00)	640.00
24.38	(80.00)	265.00	426.72	(1400.00)	610.00
30.48	(100.00)	310.00	609.60	(2000.00)	470.00
30.48	(100.00)	340.00	914.40	(3000.00)	235.00
42.67	(140.00)	392.00	1219.20	(4000.00)	165.00
60.96	(200.00)	390.00	1828.80	(6000.00)	111.00
			2438.40	(8000.00)	107.00



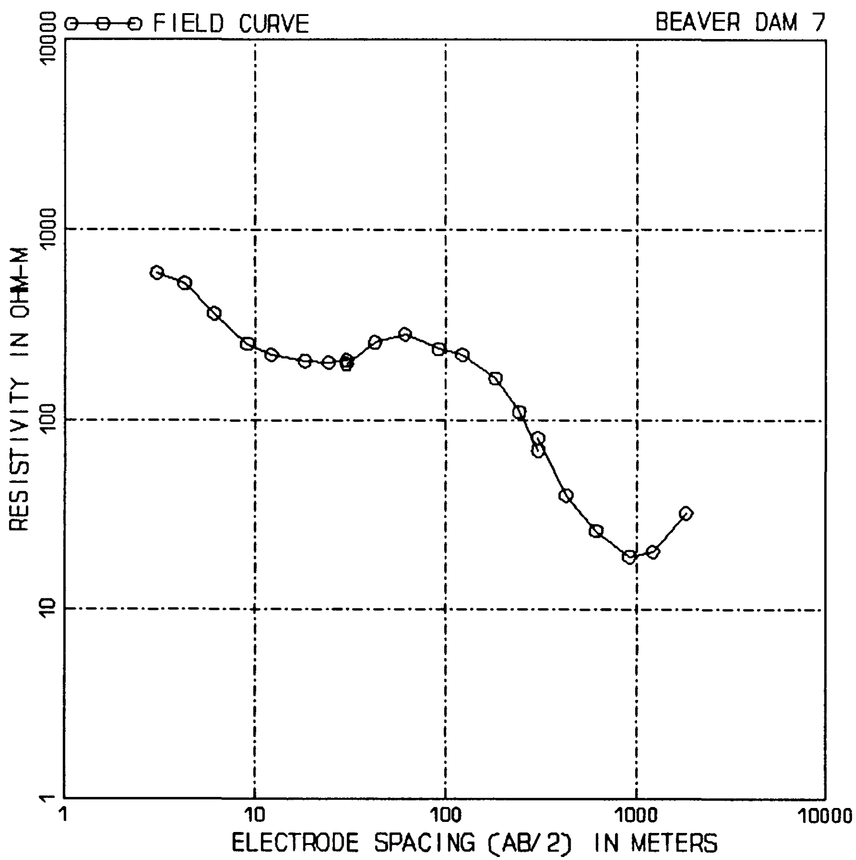
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.57	(5.14)	597.69	49.51	(162.42)	520.59
2.30	(7.54)	192.66	72.66	(238.40)	619.29
3.37	(11.07)	107.66	106.66	(349.92)	824.02
4.95	(16.24)	127.95	156.55	(513.61)	1015.43
7.27	(23.84)	220.52	229.78	(753.88)	872.08
10.67	(34.99)	379.45	337.27	(1106.54)	417.68
15.65	(51.36)	512.54	495.05	(1624.19)	126.39
22.98	(75.39)	539.04	726.64	(2383.98)	68.23
33.73	(110.65)	511.19	99999.00	(99999.00)	101.37

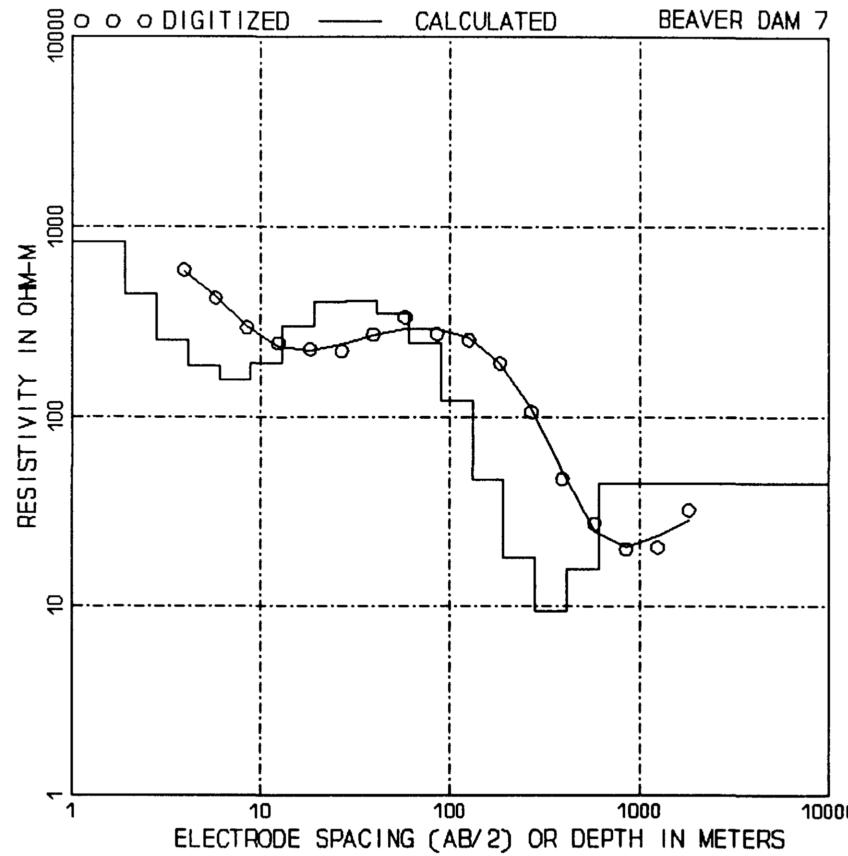




AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	910.00	91.44	(300.00)	930.00
4.27	(14.00)	770.00	121.92	(400.00)	1090.00
6.10	(20.00)	610.00	182.88	(600.00)	1100.00
9.14	(30.00)	440.00	243.84	(800.00)	1040.00
12.19	(40.00)	345.00	304.80	(1000.00)	970.00
18.29	(60.00)	445.00	426.72	(1400.00)	660.00
24.38	(80.00)	530.00	304.80	(1000.00)	600.00
30.48	(100.00)	590.00	426.72	(1400.00)	435.00
30.48	(100.00)	535.00	609.60	(2000.00)	255.00
42.67	(140.00)	620.00	914.40	(3000.00)	120.00
60.96	(200.00)	790.00	1219.20	(4000.00)	75.00
			1828.80	(6000.00)	53.00

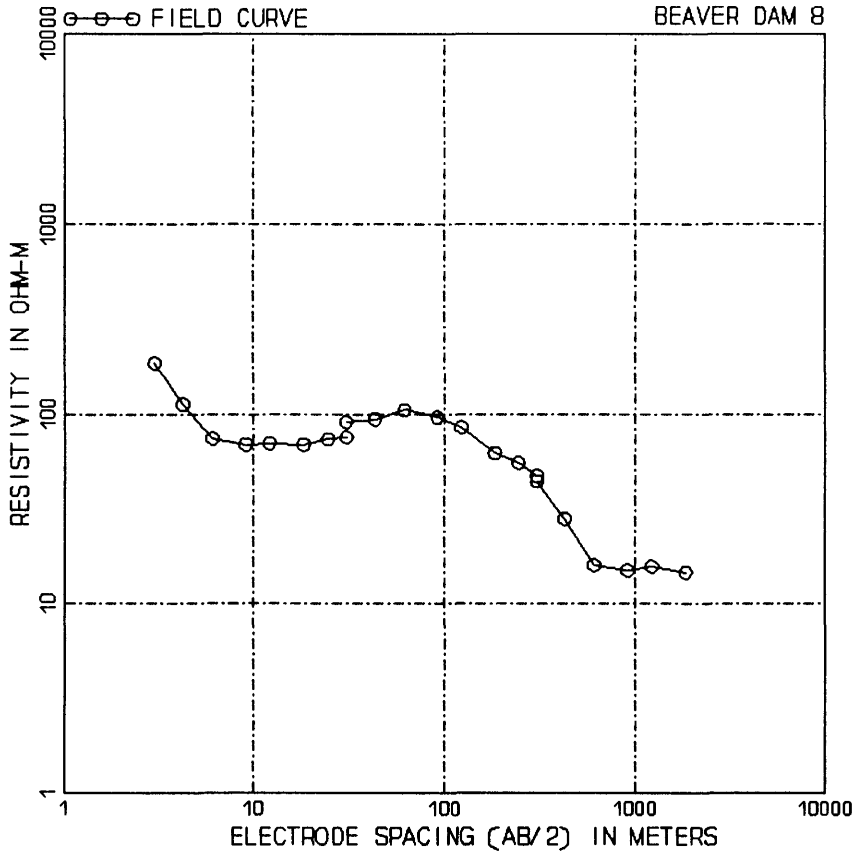
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.91	(6.28)	668.53	41.25	(135.35)	948.84
2.81	(9.22)	471.29	60.55	(198.66)	1232.75
4.13	(13.53)	200.37	88.88	(291.60)	1309.85
6.06	(19.87)	111.20	130.46	(428.01)	1018.15
8.89	(29.16)	169.85	191.49	(628.23)	522.91
13.05	(42.80)	305.21	281.06	(922.12)	177.73
19.15	(62.82)	465.01	412.54	(1353.49)	61.86
28.11	(92.21)	670.08	605.53	(1986.65)	49.95
			99999.00	(99999.00)	48.74



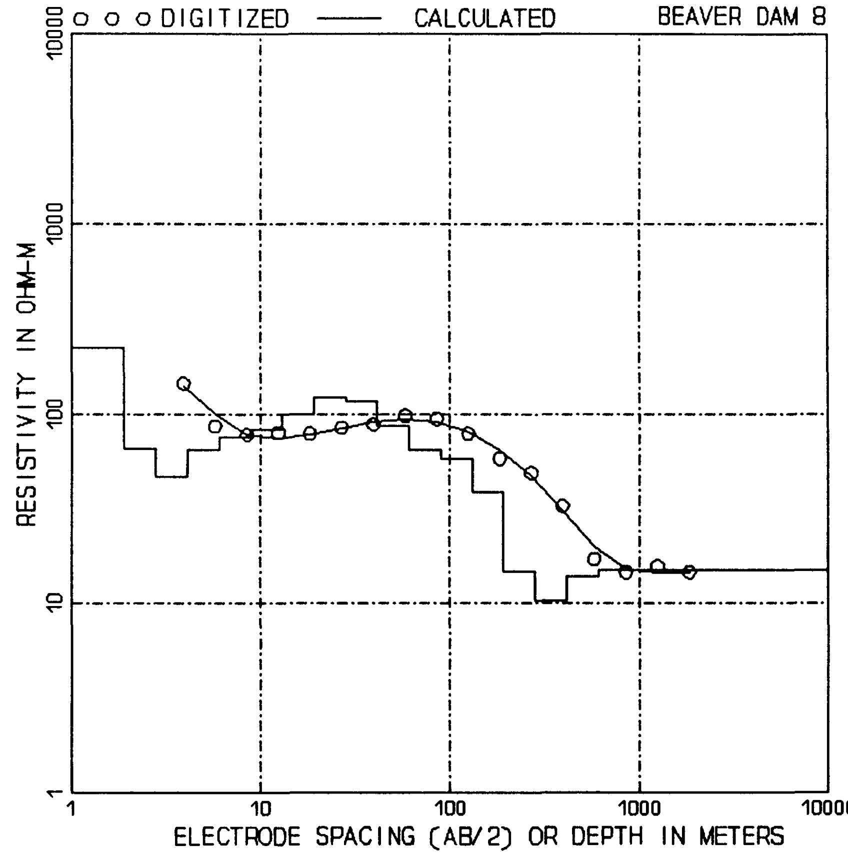


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	590.00	91.44	(300.00)	235.00
4.27	(14.00)	520.00	121.92	(400.00)	220.00
6.10	(20.00)	360.00	182.88	(600.00)	165.00
9.14	(30.00)	250.00	243.84	(800.00)	110.00
12.19	(40.00)	220.00	304.80	(1000.00)	69.00
18.29	(60.00)	204.00	304.80	(1000.00)	80.00
24.38	(80.00)	200.00	426.72	(1400.00)	40.00
30.48	(100.00)	205.00	609.60	(2000.00)	26.00
30.48	(100.00)	196.00	914.40	(3000.00)	19.00
42.67	(140.00)	255.00	1219.20	(4000.00)	20.20
60.96	(200.00)	282.00	1828.80	(6000.00)	32.00

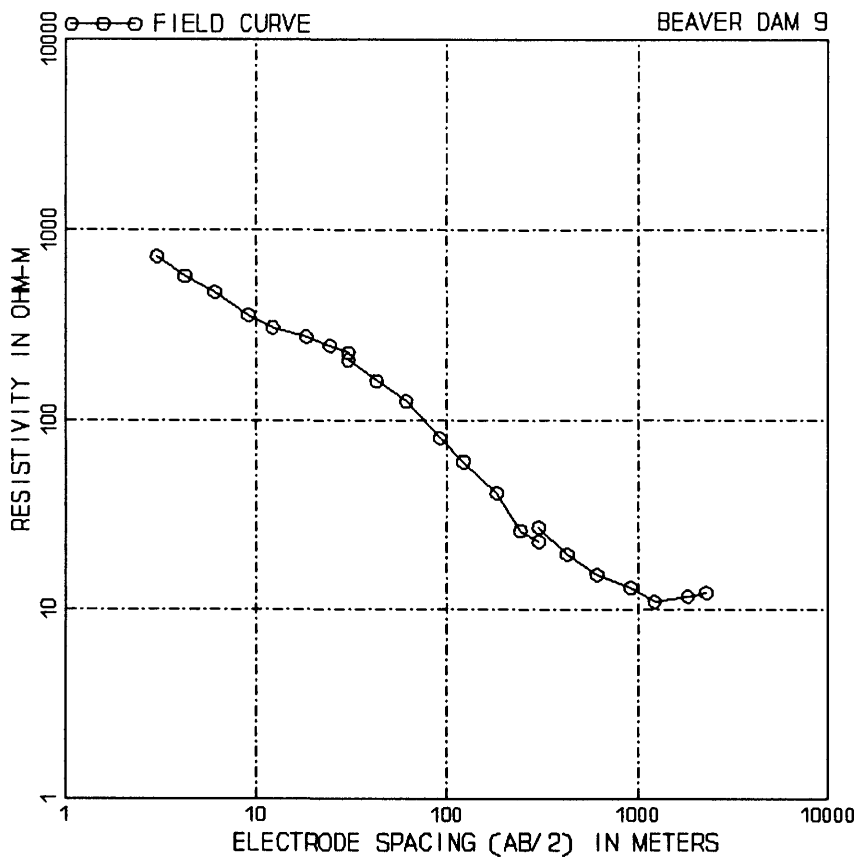
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.91	(6.28)	835.56	41.25	(135.35)	408.74
2.81	(9.22)	438.14	60.55	(198.66)	350.18
4.13	(13.53)	251.28	88.88	(291.60)	244.26
6.06	(19.87)	184.26	130.46	(428.01)	122.08
8.89	(29.16)	154.64	191.49	(628.23)	46.77
13.05	(42.80)	189.76	281.06	(922.12)	18.11
19.15	(62.82)	300.31	412.54	(1353.49)	9.43
28.11	(92.21)	399.61	605.53	(1986.65)	15.65
			99999.00	(99999.00)	44.73



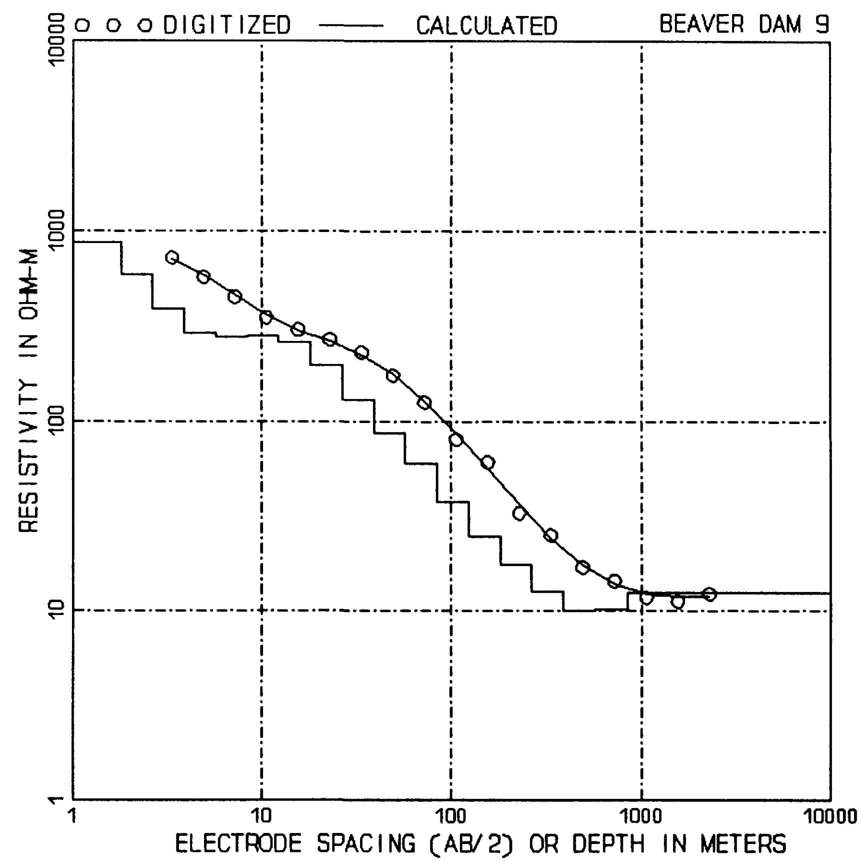
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	185.00	91.44	(300.00)	96.00
4.27	(14.00)	112.00	121.92	(400.00)	85.00
6.10	(20.00)	74.00	182.88	(600.00)	62.00
9.14	(30.00)	69.00	243.84	(800.00)	55.00
12.19	(40.00)	70.00	304.80	(1000.00)	47.00
18.29	(60.00)	69.00	304.80	(1000.00)	44.00
24.38	(80.00)	73.50	426.72	(1400.00)	28.00
30.48	(100.00)	75.00	609.60	(2000.00)	16.00
30.48	(100.00)	91.00	914.40	(3000.00)	15.00
42.67	(140.00)	94.00	1219.20	(4000.00)	15.70
60.96	(200.00)	105.00	1828.80	(6000.00)	14.60



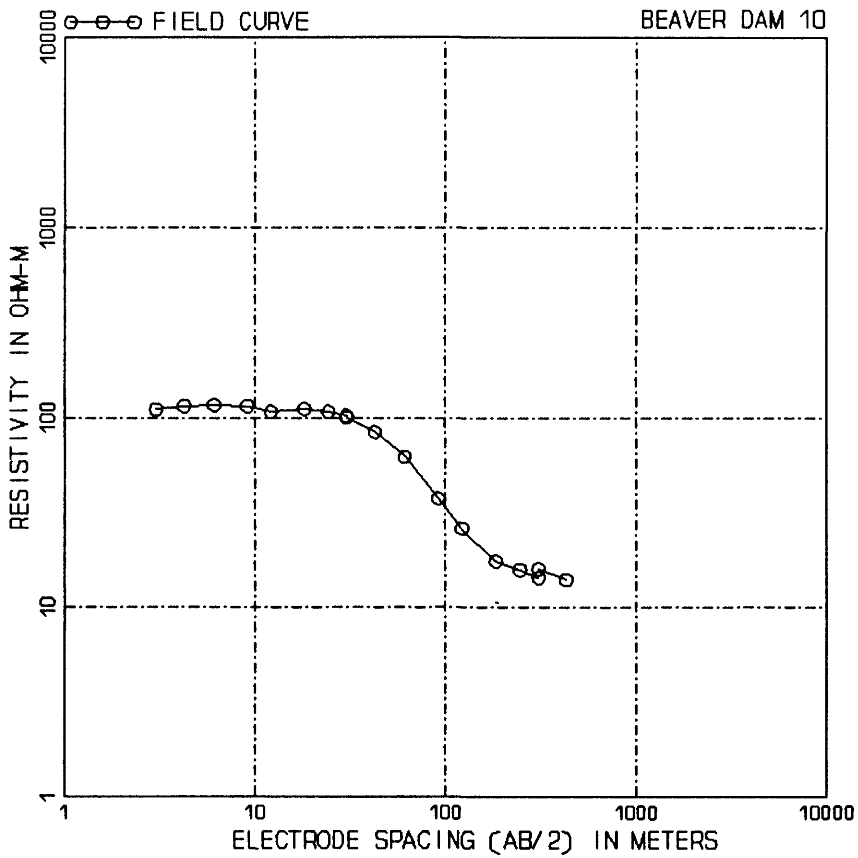
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.91	(6.28)	221.75	41.25	(135.35)	116.38
2.81	(9.22)	65.09	60.55	(198.66)	86.06
4.13	(13.53)	46.66	88.88	(291.60)	64.23
6.06	(19.87)	64.51	130.46	(428.01)	57.77
8.89	(29.16)	75.10	191.49	(628.23)	38.72
13.05	(42.80)	82.25	281.06	(922.12)	14.82
19.15	(62.82)	100.04	412.54	(1353.49)	10.26
28.11	(92.21)	120.90	605.53	(1986.65)	13.82
			99999.00	(99999.00)	15.05



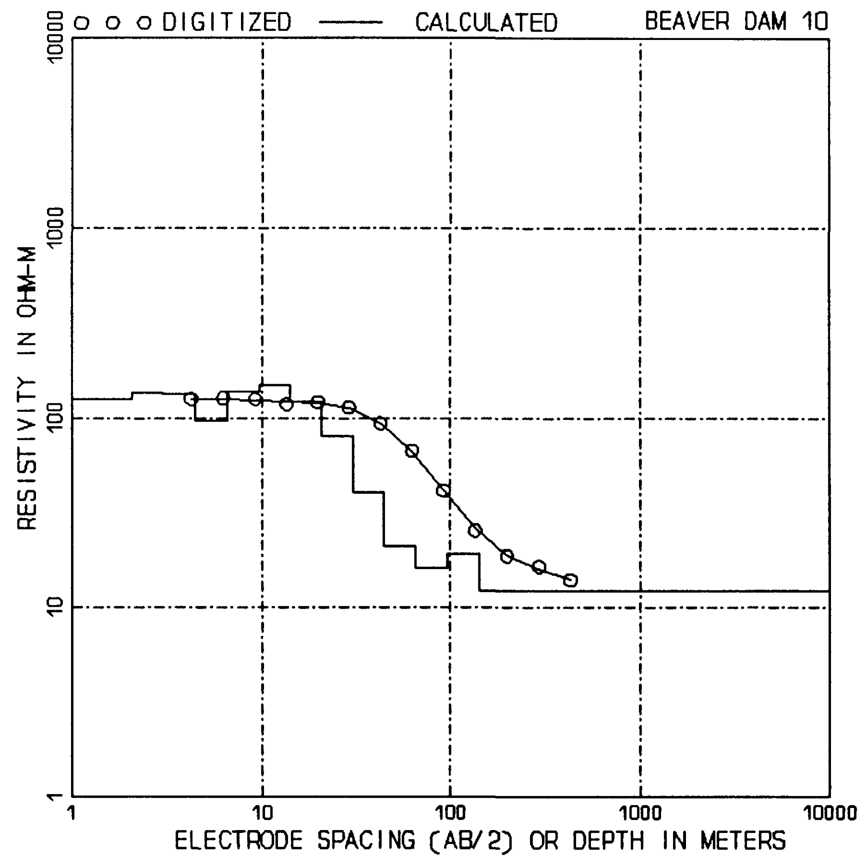
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	725.00	91.44	(300.00)	80.00
4.27	(14.00)	570.00	121.92	(400.00)	60.00
6.10	(20.00)	470.00	182.88	(600.00)	41.00
9.14	(30.00)	355.00	243.84	(800.00)	26.00
12.19	(40.00)	305.00	304.80	(1000.00)	22.80
18.29	(60.00)	272.00	304.80	(1000.00)	27.00
24.38	(80.00)	245.00	426.72	(1400.00)	19.50
30.48	(100.00)	225.00	609.60	(2000.00)	15.20
30.48	(100.00)	205.00	914.40	(3000.00)	13.00
42.67	(140.00)	160.00	1219.20	(4000.00)	11.00
60.96	(200.00)	125.00	1828.80	(6000.00)	11.70
			2286.00	(7500.00)	12.30



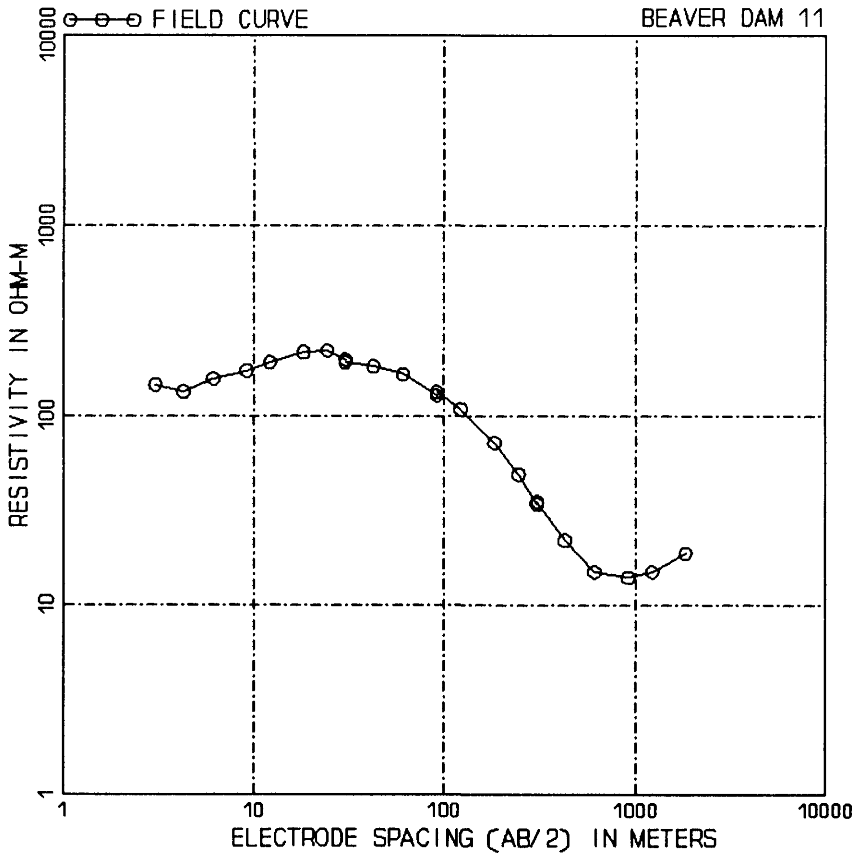
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.81	(5.94)	870.41	57.30	(187.98)	86.57
2.66	(8.73)	593.70	84.10	(275.92)	59.63
3.90	(12.81)	386.14	123.44	(405.00)	37.67
5.73	(18.80)	289.95	181.19	(594.46)	24.57
8.41	(27.59)	275.12	265.95	(872.55)	17.56
12.34	(40.50)	282.36	390.36	(1280.72)	12.68
18.12	(59.45)	258.54	572.98	(1879.84)	10.01
26.60	(87.25)	196.29	841.01	(2759.23)	10.19
39.04	(128.07)	129.90	99999.00	(99999.00)	12.43



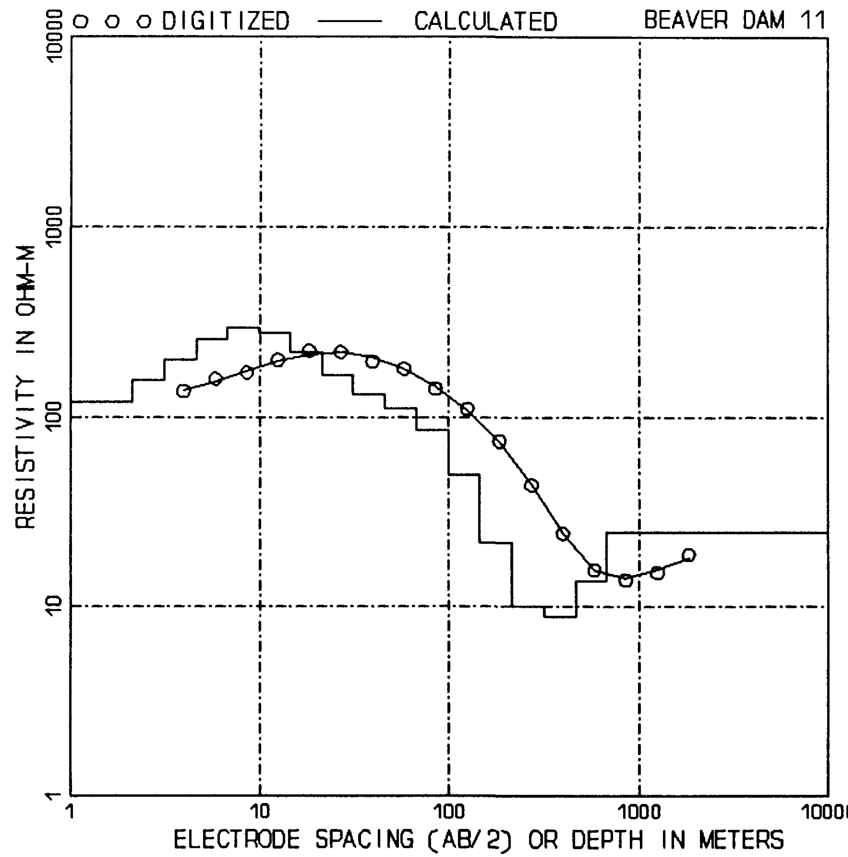
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	110.00	42.67	(140.00)	84.00
4.27	(14.00)	115.00	60.96	(200.00)	62.00
6.10	(20.00)	116.00	91.44	(300.00)	37.50
9.14	(30.00)	115.00	121.92	(400.00)	26.00
12.19	(40.00)	107.00	182.88	(600.00)	17.50
18.29	(60.00)	111.00	243.84	(800.00)	15.80
24.38	(80.00)	107.00	304.80	(1000.00)	14.35
30.48	(100.00)	102.00	304.80	(1000.00)	16.00
30.48	(100.00)	100.00	426.72	(1400.00)	14.00



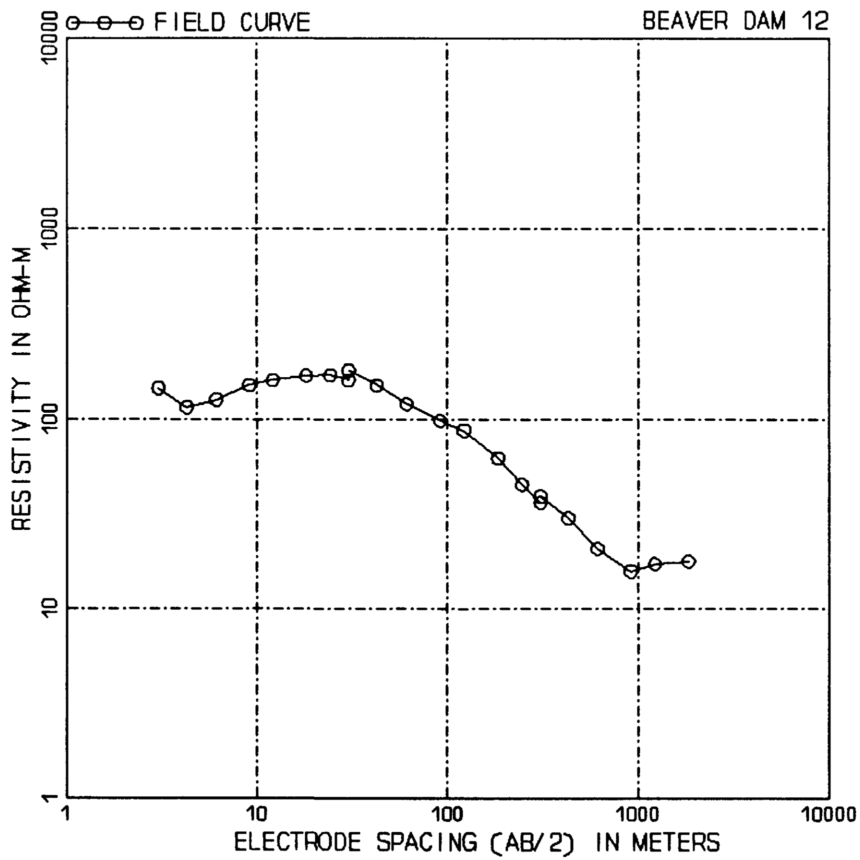
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.07	(6.80)	124.66	20.74	(68.04)	122.12
3.04	(9.99)	134.94	30.44	(99.87)	80.26
4.47	(14.66)	132.37	44.68	(146.59)	40.70
6.56	(21.52)	96.91	65.58	(215.16)	21.08
9.63	(31.58)	137.61	96.26	(315.81)	16.30
14.13	(46.36)	148.21	141.29	(463.55)	19.10
			99999.00	(99999.00)	12.35

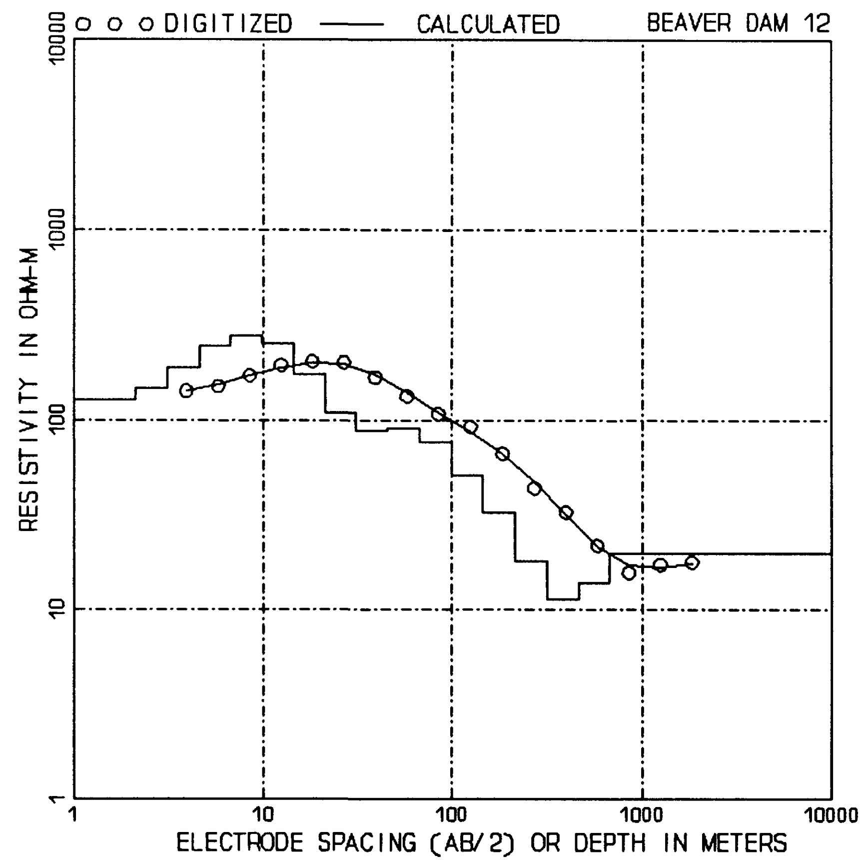


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	145.00	91.44 (	300.00)	128.00
4.27 (	14.00)	133.00	91.44 (	300.00)	133.00
6.10 (	20.00)	156.00	121.92 (	400.00)	108.00
9.14 (	30.00)	172.00	182.88 (	600.00)	72.00
12.19 (	40.00)	190.00	243.84 (	800.00)	49.00
18.29 (	60.00)	215.00	304.80 (	1000.00)	34.00
24.38 (	80.00)	220.00	304.80 (	1000.00)	35.20
30.48 (	100.00)	197.00	426.72 (	1400.00)	22.00
30.48 (	100.00)	190.00	609.60 (	2000.00)	15.00
42.67 (	140.00)	181.00	914.40 (	3000.00)	14.00
60.96 (	200.00)	165.00	1219.20 (	4000.00)	15.00
			1828.80 (	6000.00)	18.80



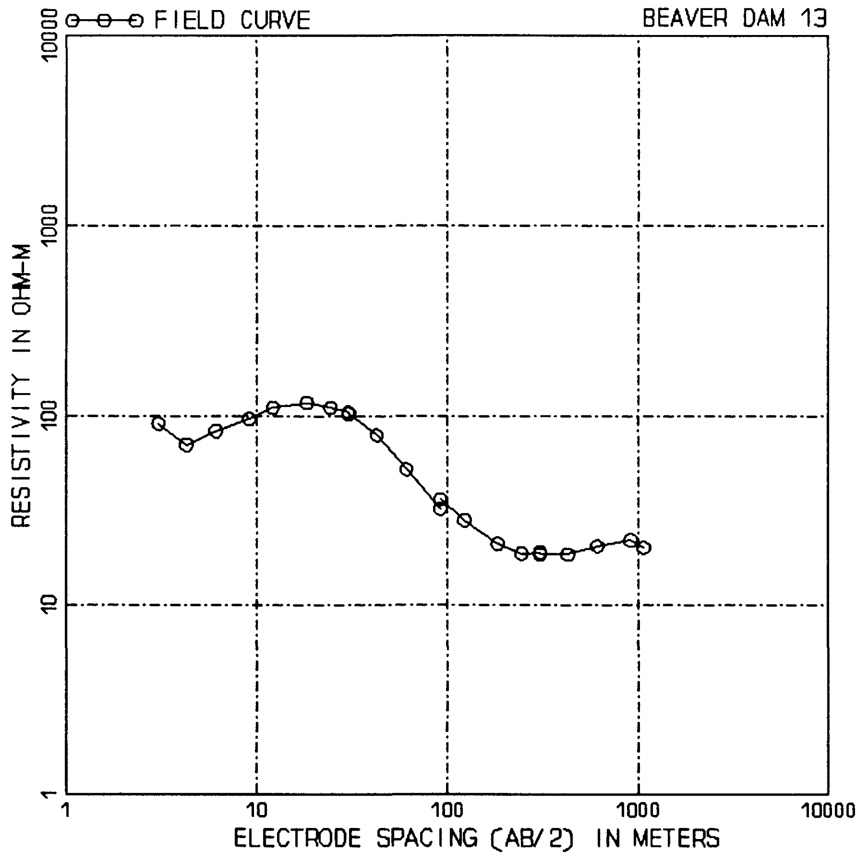
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
2.13 (	6.98)	120.37	45.84 (	150.39)	131.07
3.12 (	10.25)	155.91	67.28 (	220.74)	110.68
4.58 (	15.04)	201.29	98.76 (	324.00)	85.25
6.73 (	22.07)	255.42	144.95 (	475.57)	49.76
9.88 (	32.40)	293.16	212.76 (	698.04)	21.72
14.50 (	47.56)	277.48	312.29 (	1024.58)	10.07
21.28 (	69.80)	220.06	458.38 (	1503.88)	8.81
31.23 (	102.46)	164.92	672.81 (	2207.39)	13.67
			99999.00 (	99999.00)	24.69



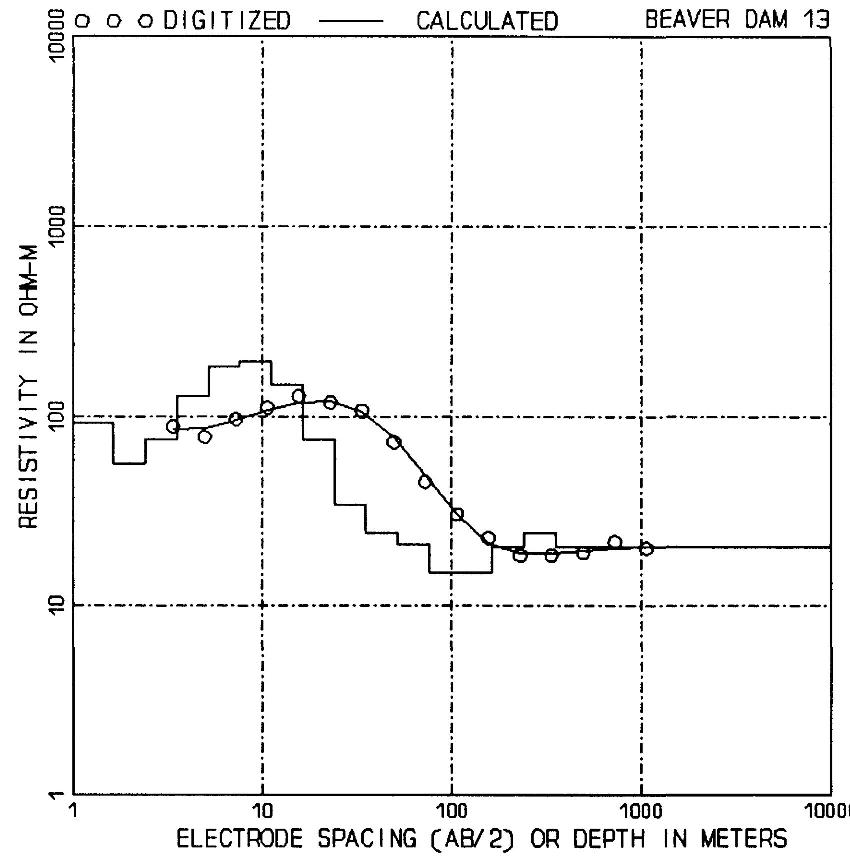


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	145.00	91.44 (	300.00)	98.00
4.27 (	14.00)	115.00	121.92 (	400.00)	87.00
6.10 (	20.00)	126.00	182.88 (	600.00)	62.00
9.14 (	30.00)	150.00	243.84 (	800.00)	45.00
12.19 (	40.00)	160.00	304.80 (	1000.00)	36.40
18.29 (	60.00)	168.00	304.80 (	1000.00)	39.00
24.38 (	80.00)	170.00	426.72 (	1400.00)	30.00
30.48 (	100.00)	160.00	609.60 (	2000.00)	20.70
30.48 (	100.00)	180.00	914.40 (	3000.00)	15.80
42.67 (	140.00)	150.00	1219.20 (	4000.00)	17.20
60.96 (	200.00)	120.00	1828.80 (	6000.00)	17.80

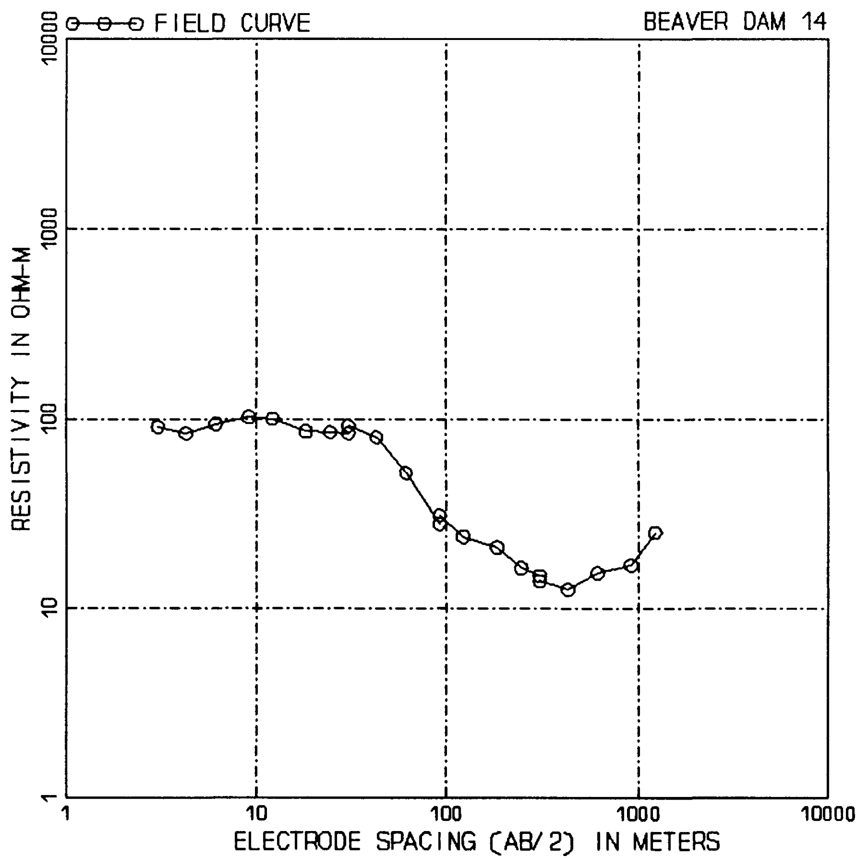
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
2.13 (	6.98)	128.19	45.84 (	150.39)	87.46
3.12 (	10.25)	146.56	67.28 (	220.74)	90.27
4.58 (	15.04)	188.16	98.76 (	324.00)	76.90
6.73 (	22.07)	243.20	144.95 (	475.57)	50.89
9.88 (	32.40)	277.25	212.76 (	698.04)	32.66
14.50 (	47.56)	251.45	312.29 (	1024.58)	17.93
21.28 (	69.80)	174.84	458.38 (	1503.88)	11.40
31.23 (	102.46)	109.37	672.81 (	2207.39)	13.82
			99999.00 (	99999.00)	19.70



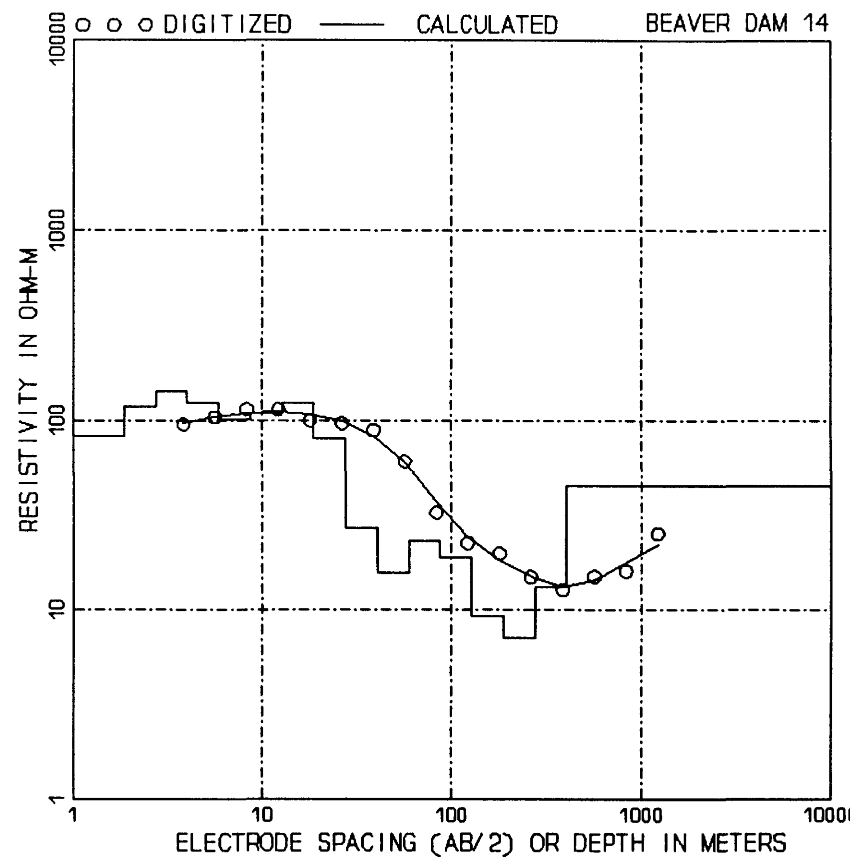
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	91.00	91.44	(300.00)	32.00
4.27	(14.00)	70.00	91.44	(300.00)	36.00
6.10	(20.00)	83.00	121.92	(400.00)	28.00
9.14	(30.00)	96.00	182.88	(600.00)	21.00
12.19	(40.00)	110.00	243.84	(800.00)	18.70
18.29	(60.00)	117.00	304.80	(1000.00)	19.00
24.38	(80.00)	110.00	304.80	(1000.00)	18.50
30.48	(100.00)	104.00	426.72	(1400.00)	18.50
30.48	(100.00)	102.00	609.60	(2000.00)	20.50
42.67	(140.00)	79.00	914.40	(3000.00)	22.00
60.96	(200.00)	52.00	1066.80	(3500.00)	20.10



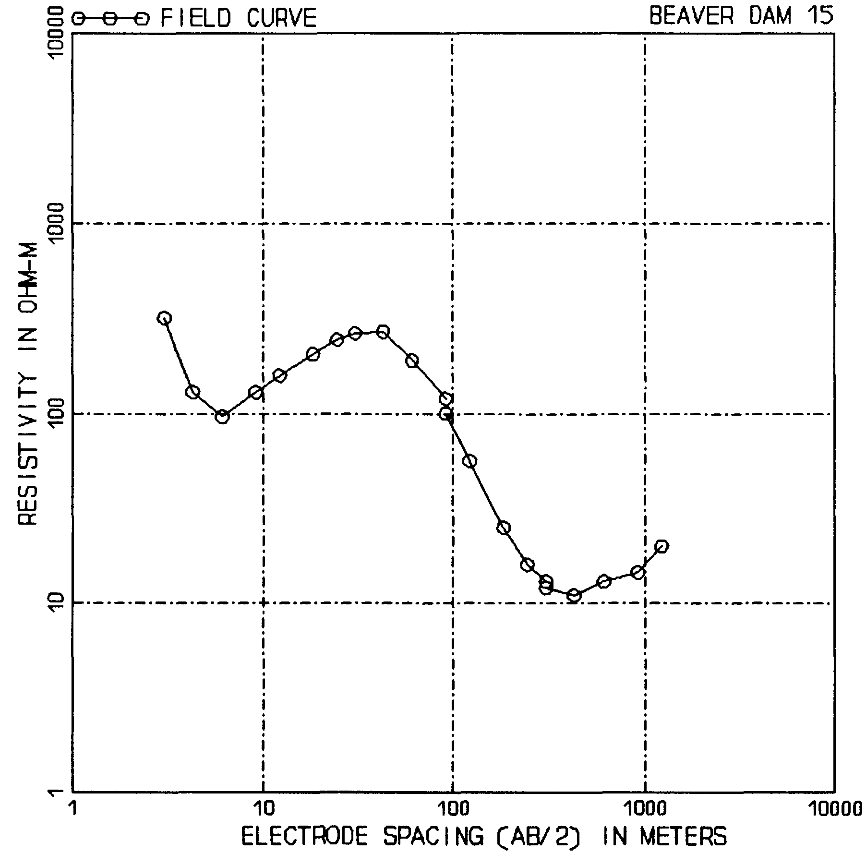
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.64	(5.38)	91.35	35.32	(115.89)	34.17
2.41	(7.90)	56.40	51.85	(170.10)	24.06
3.53	(11.59)	74.77	76.10	(249.67)	21.03
5.18	(17.01)	127.94	111.70	(366.47)	15.07
7.61	(24.97)	181.78	163.95	(537.90)	15.00
11.17	(36.65)	193.22	240.65	(789.53)	20.43
16.40	(53.79)	145.45	353.23	(1158.88)	24.09
24.07	(78.95)	75.09	99999.00	(99999.00)	20.32



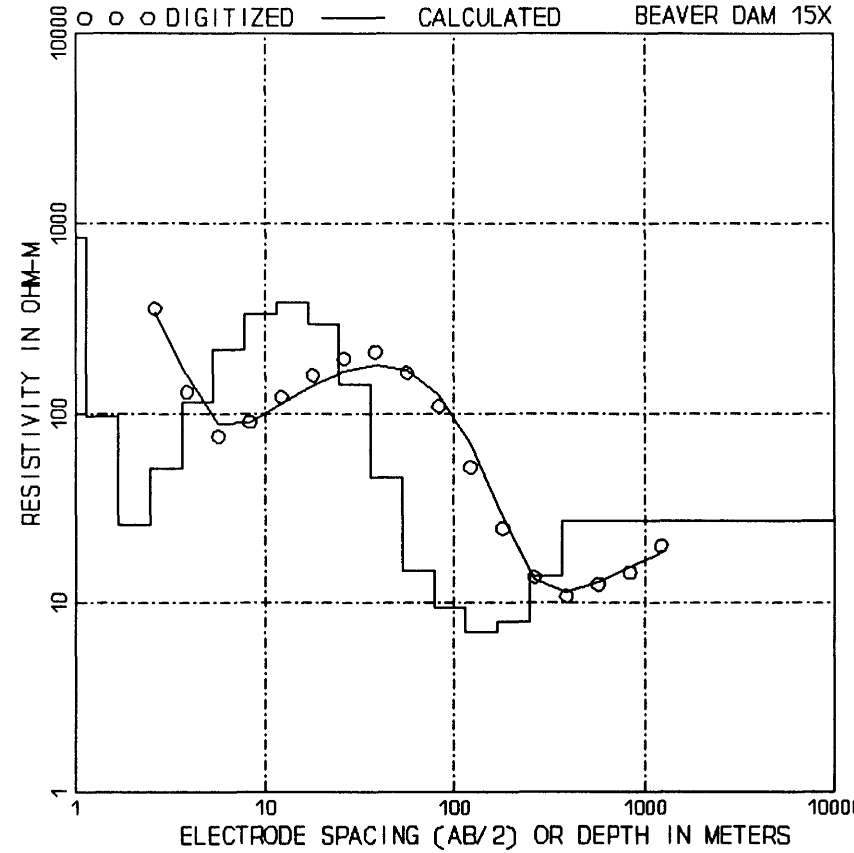
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	91.00	91.44	(300.00)	28.00
4.27	(14.00)	84.00	91.44	(300.00)	31.00
6.10	(20.00)	94.00	121.92	(400.00)	24.00
9.14	(30.00)	102.00	182.88	(600.00)	21.00
12.19	(40.00)	100.00	243.84	(800.00)	16.40
18.29	(60.00)	86.00	304.80	(1000.00)	14.90
24.38	(80.00)	85.00	304.80	(1000.00)	14.00
30.48	(100.00)	84.00	426.72	(1400.00)	12.60
30.48	(100.00)	92.00	609.60	(2000.00)	15.40
42.67	(140.00)	80.00	914.40	(3000.00)	17.00
60.96	(200.00)	52.00	1219.20	(4000.00)	25.20



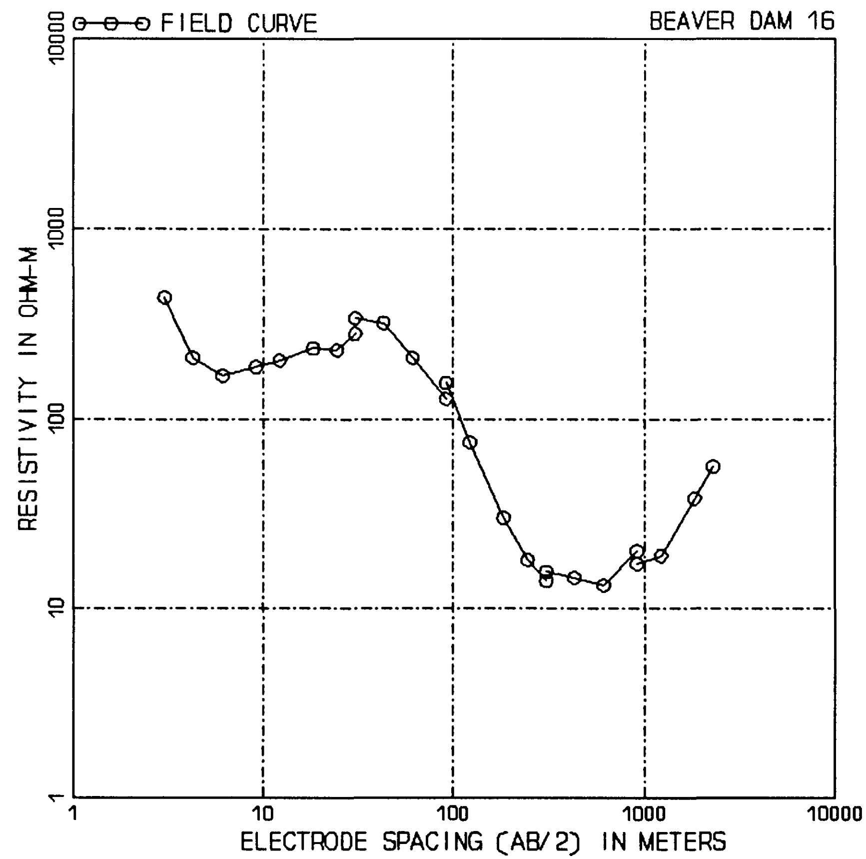
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.87	(6.15)	83.15	40.37	(132.44)	26.94
2.75	(9.02)	118.35	59.25	(194.40)	15.63
4.04	(13.24)	141.90	86.97	(285.34)	23.16
5.93	(19.44)	123.93	127.66	(418.82)	19.03
8.70	(28.53)	100.61	187.37	(614.75)	9.28
12.77	(41.88)	108.36	275.03	(902.33)	7.11
18.74	(61.47)	124.34	403.69	(1324.43)	13.24
27.50	(90.23)	80.58	99999.00	(99999.00)	45.33

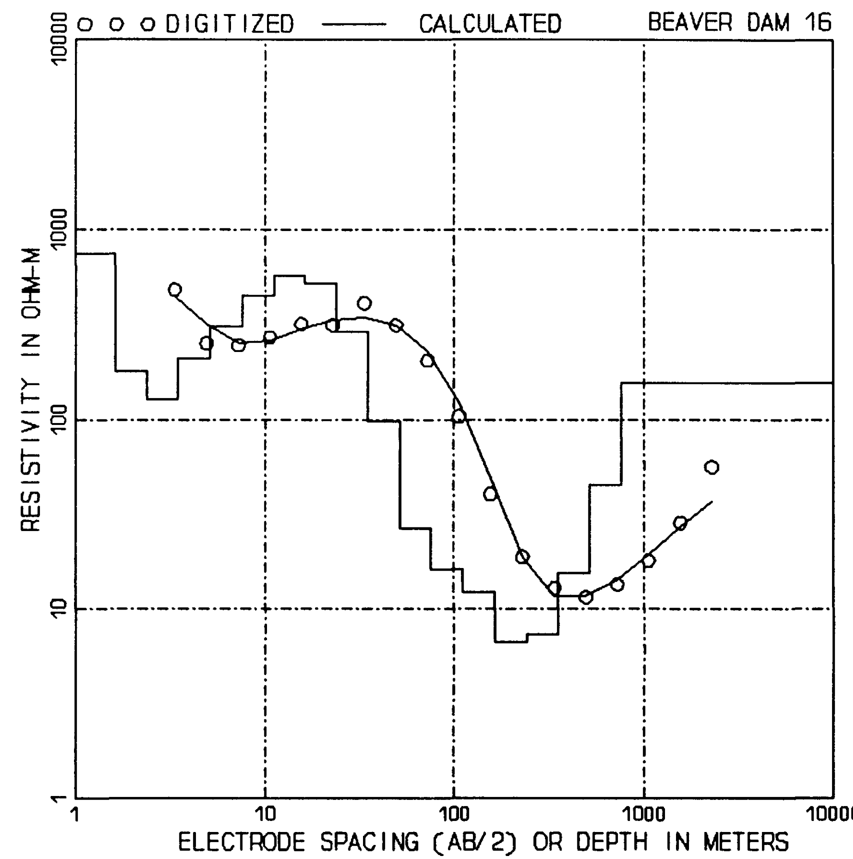


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	318.00	91.44 (	300.00)	120.00
4.27 (	14.00)	130.00	91.44 (	300.00)	100.00
6.10 (	20.00)	96.00	121.92 (	400.00)	56.00
9.14 (	30.00)	130.00	182.88 (	600.00)	25.00
12.19 (	40.00)	158.00	243.84 (	800.00)	16.00
18.29 (	60.00)	205.00	304.80 (	1000.00)	13.00
24.38 (	80.00)	245.00	304.80 (	1000.00)	12.00
30.48 (	100.00)	265.00	426.72 (	1400.00)	11.00
30.48 (	100.00)	265.00	609.60 (	2000.00)	13.00
42.67 (	140.00)	270.00	914.40 (	3000.00)	14.50
60.96 (	200.00)	190.00	1219.20 (	4000.00)	20.00



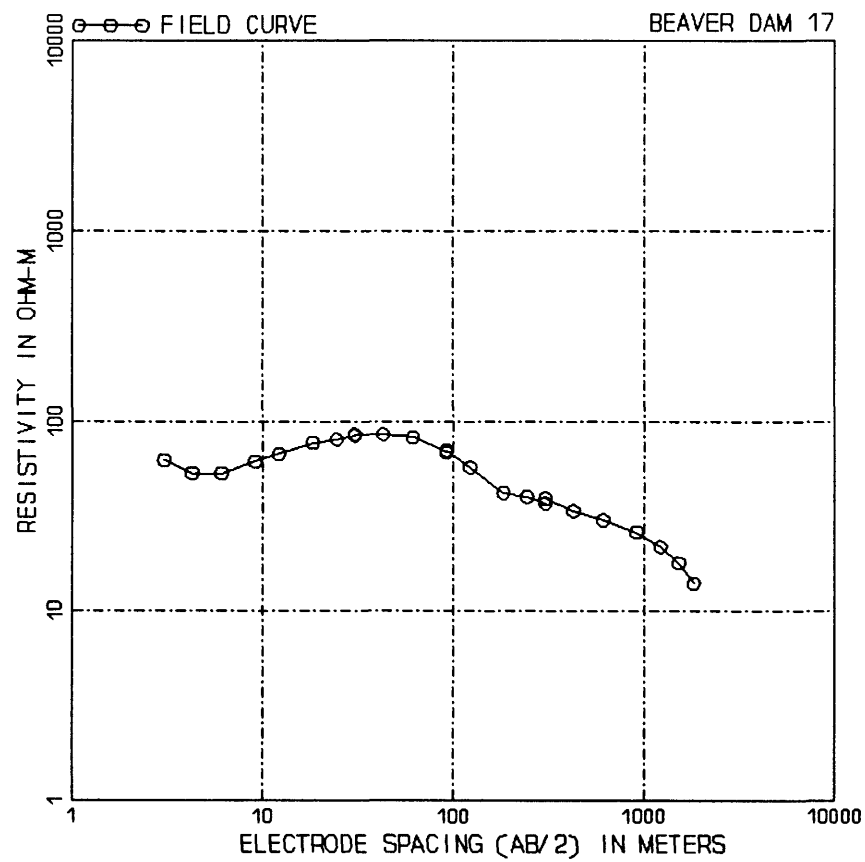
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.15 (	3.77)	839.21	24.75 (	81.21)	292.94
1.69 (	5.53)	96.37	36.33 (	119.20)	142.33
2.48 (	8.12)	25.96	53.33 (	174.96)	45.61
3.63 (	11.92)	50.92	78.27 (	256.81)	14.65
5.33 (	17.50)	114.02	114.89 (	376.94)	9.36
7.83 (	25.68)	215.83	168.64 (	553.27)	6.99
11.49 (	37.69)	333.23	247.53 (	812.09)	7.98
16.86 (	55.33)	380.56	363.32 (	1191.99)	13.91
			99999.00 (	99999.00)	27.14



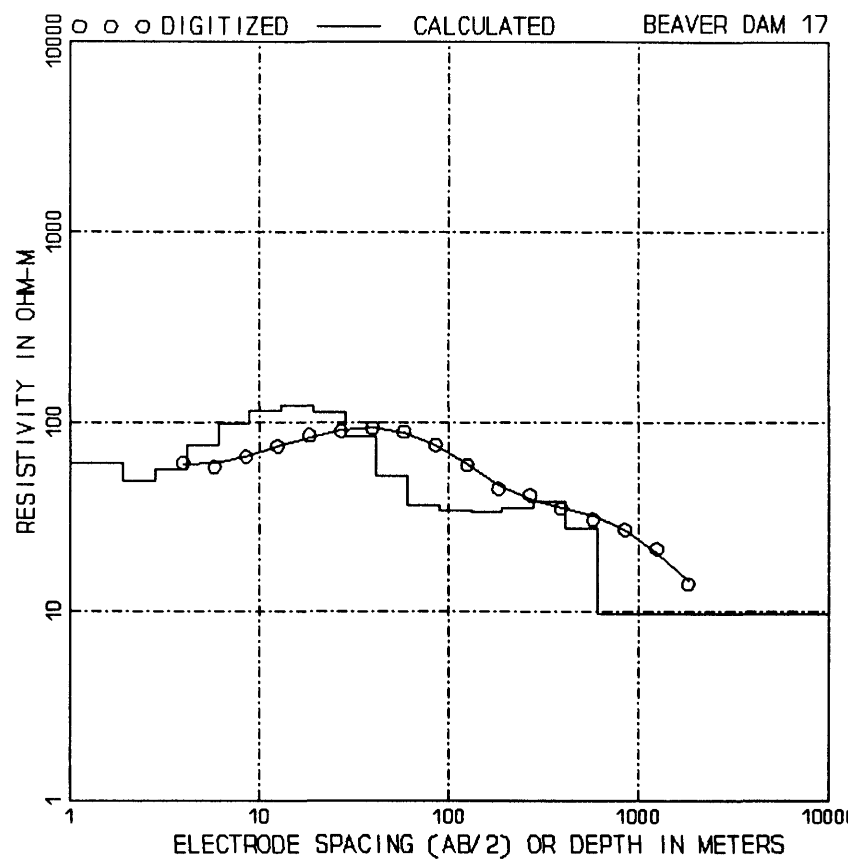


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	435.00	91.44 (	300.00)	155.00
4.27 (	14.00)	210.00	121.92 (	400.00)	75.00
6.10 (	20.00)	168.00	182.88 (	600.00)	30.00
9.14 (	30.00)	187.00	243.84 (	800.00)	18.00
12.19 (	40.00)	203.00	304.80 (	1000.00)	14.00
18.29 (	60.00)	235.00	304.80 (	1000.00)	15.60
24.38 (	80.00)	230.00	426.72 (	1400.00)	14.50
30.48 (	100.00)	280.00	609.60 (	2000.00)	13.30
30.48 (	100.00)	340.00	914.40 (	3000.00)	20.10
42.67 (	140.00)	320.00	914.40 (	3000.00)	17.20
60.96 (	200.00)	210.00	1219.20 (	4000.00)	19.00
91.44 (	300.00)	128.00	1828.80 (	6000.00)	38.00
			2286.00 (	7500.00)	56.00

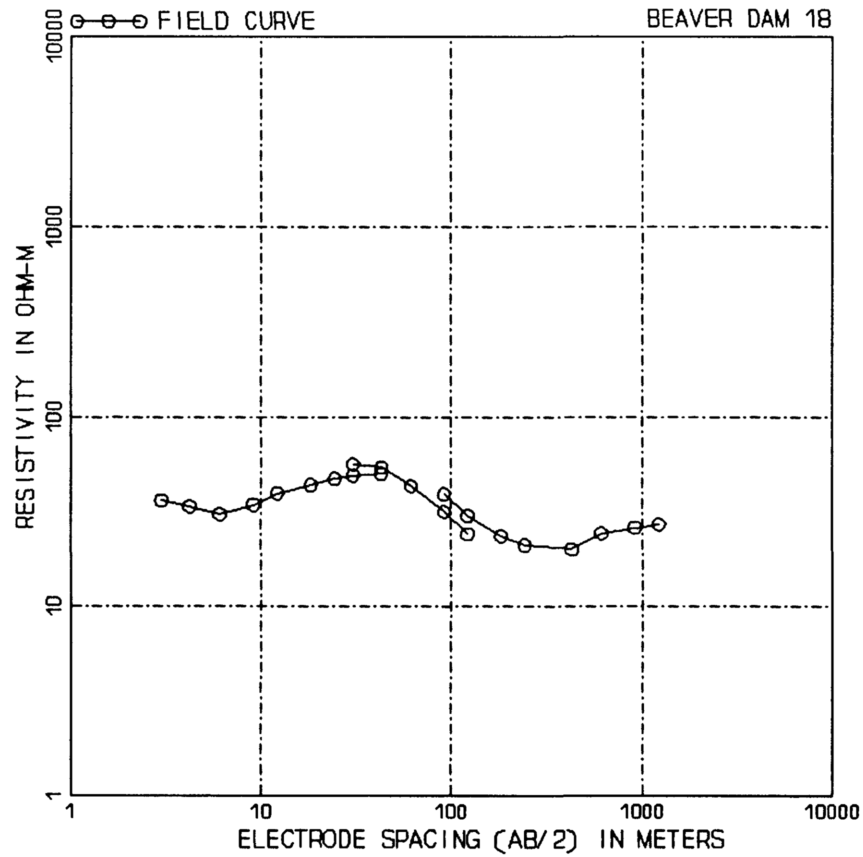
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.63 (	5.35)	746.00	51.57 (	169.19)	97.63
2.39 (	7.85)	180.15	75.69 (	248.33)	26.79
3.51 (	11.53)	128.30	111.10 (	364.50)	16.09
5.16 (	16.92)	209.19	163.07 (	535.01)	12.19
7.57 (	24.83)	310.78	239.36 (	785.29)	6.64
11.11 (	36.45)	444.63	351.33 (	1152.65)	7.34
16.31 (	53.50)	572.05	515.68 (	1691.86)	15.48
23.94 (	78.53)	519.50	756.91 (	2483.31)	45.34
35.13 (	115.27)	289.97	99999.00 (	99999.00)	155.90



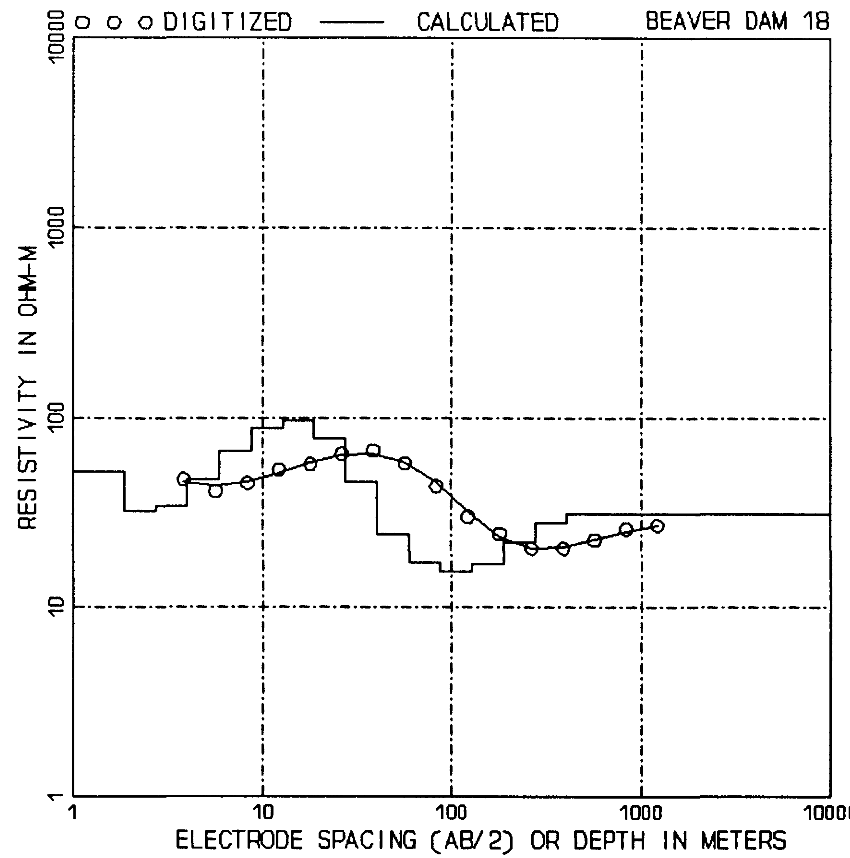
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	62.00	91.44 (	300.00)	70.00
4.27 (	14.00)	53.00	121.92 (	400.00)	57.00
6.10 (	20.00)	53.00	182.88 (	600.00)	42.00
9.14 (	30.00)	61.00	243.84 (	800.00)	40.00
12.19 (	40.00)	67.00	304.80 (	1000.00)	36.90
18.29 (	60.00)	77.00	304.80 (	1000.00)	39.00
24.38 (	80.00)	80.00	426.72 (	1400.00)	33.50
30.48 (	100.00)	84.00	609.60 (	2000.00)	30.00
30.48 (	100.00)	85.00	914.40 (	3000.00)	26.00
42.67 (	140.00)	85.00	1219.20 (	4000.00)	21.80
60.96 (	200.00)	82.00	1524.00 (	5000.00)	17.90
91.44 (	300.00)	68.00	1828.80 (	6000.00)	14.00



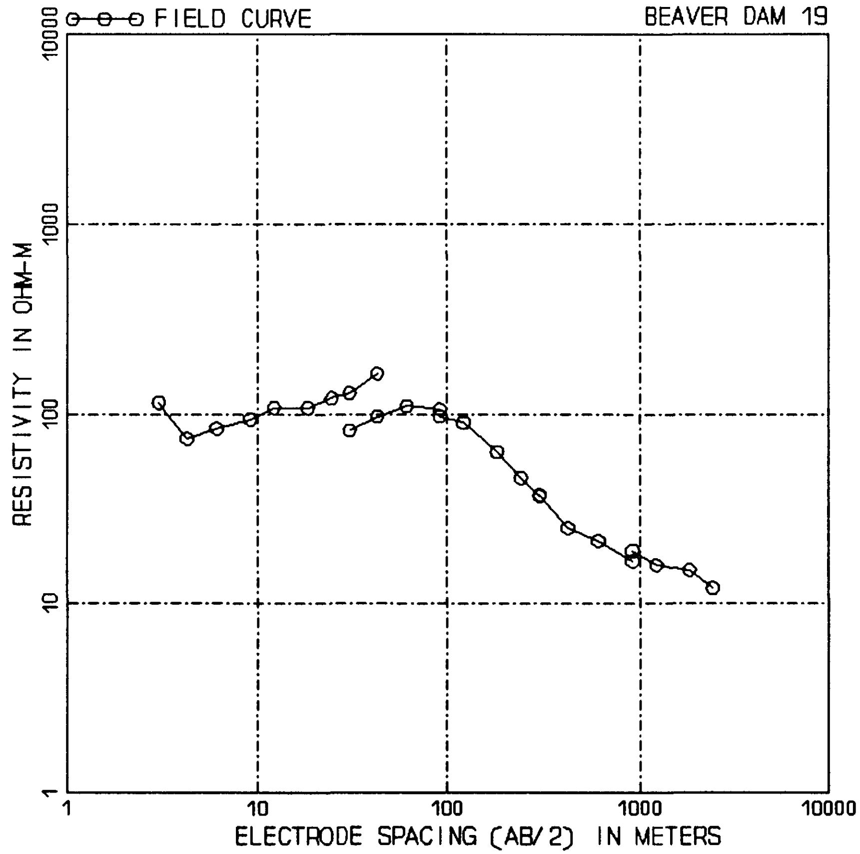
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.91 (	6.28)	60.69	41.25 (	135.35)	83.49
2.81 (	9.22)	48.43	60.55 (	198.66)	51.94
4.13 (	13.53)	55.66	88.88 (	291.60)	36.56
6.06 (	19.87)	75.61	130.46 (	428.01)	34.22
8.89 (	29.16)	97.67	191.49 (	628.23)	33.59
13.05 (	42.80)	114.47	281.06 (	922.12)	35.29
19.15 (	62.82)	121.88	412.54 (	1353.49)	38.16
28.11 (	92.21)	112.44	605.53 (	1986.65)	27.58
			99999.00 (	99999.00)	9.68



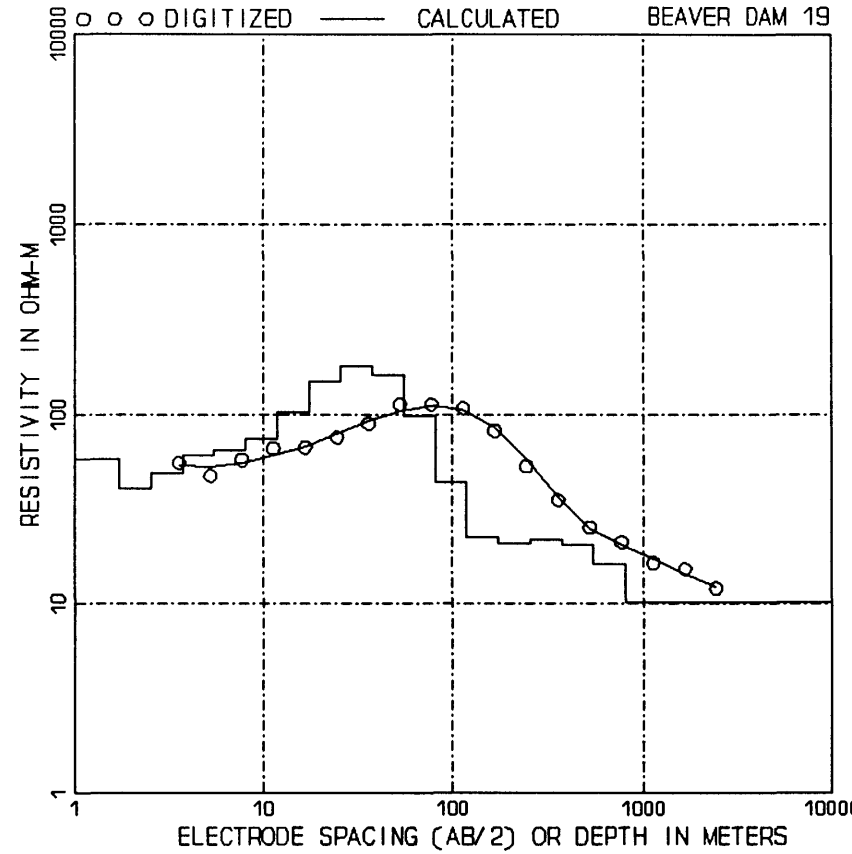
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	36.00	60.96	(200.00)	43.00
4.27	(14.00)	33.50	91.44	(300.00)	31.50
6.10	(20.00)	30.60	121.92	(400.00)	24.10
9.14	(30.00)	34.30	91.44	(300.00)	39.00
12.19	(40.00)	39.50	121.92	(400.00)	30.00
18.29	(60.00)	43.50	182.88	(600.00)	23.50
24.38	(80.00)	47.00	243.84	(800.00)	21.00
30.48	(100.00)	49.00	426.72	(1400.00)	20.00
42.67	(140.00)	50.00	426.72	(1400.00)	20.00
30.48	(100.00)	56.00	609.60	(2000.00)	24.20
42.67	(140.00)	54.00	914.40	(3000.00)	26.00
			1219.20	(4000.00)	27.00



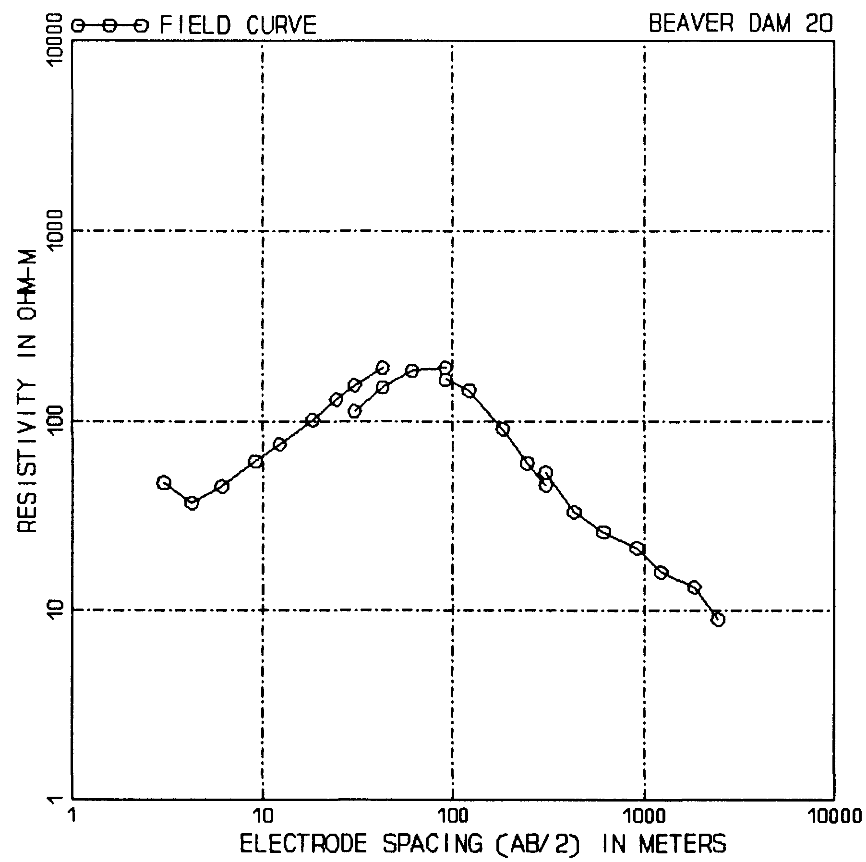
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.87	(6.15)	52.02	40.37	(132.44)	45.59
2.75	(9.02)	32.29	59.25	(194.40)	24.32
4.04	(13.24)	33.94	86.97	(285.34)	17.14
5.93	(19.44)	47.31	127.66	(418.82)	15.51
8.70	(28.53)	66.41	187.37	(614.75)	16.99
12.77	(41.88)	87.63	275.03	(902.33)	22.08
18.74	(61.47)	96.70	403.69	(1324.43)	27.88
27.50	(90.23)	78.21	99999.00	(99999.00)	31.29



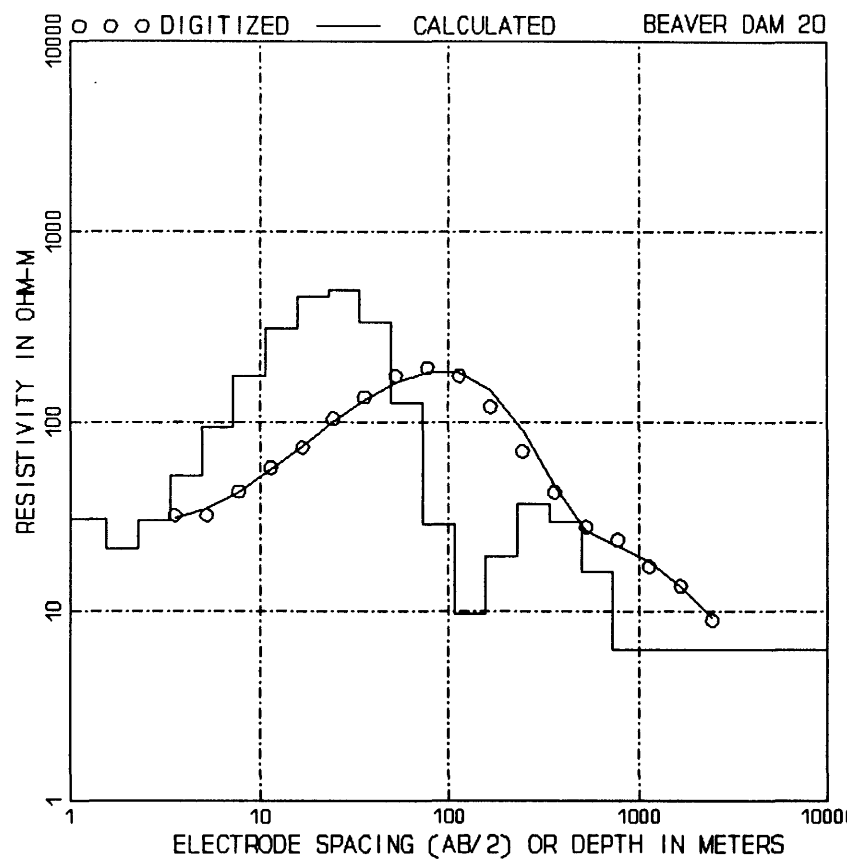
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	115.00	91.44	(300.00)	97.00
4.27	(14.00)	74.00	121.92	(400.00)	90.00
6.10	(20.00)	84.00	182.88	(600.00)	63.00
9.14	(30.00)	94.00	243.84	(800.00)	46.00
12.19	(40.00)	108.00	304.80	(1000.00)	37.00
18.29	(60.00)	108.00	304.80	(1000.00)	37.50
24.38	(80.00)	121.00	426.72	(1400.00)	25.00
30.48	(100.00)	129.00	609.60	(2000.00)	21.50
42.67	(140.00)	164.00	914.40	(3000.00)	16.70
30.48	(100.00)	82.00	914.40	(3000.00)	19.00
42.67	(140.00)	97.00	1219.20	(4000.00)	16.00
60.96	(200.00)	110.00	1828.80	(6000.00)	15.00
91.44	(300.00)	106.00	2438.40	(8000.00)	12.00



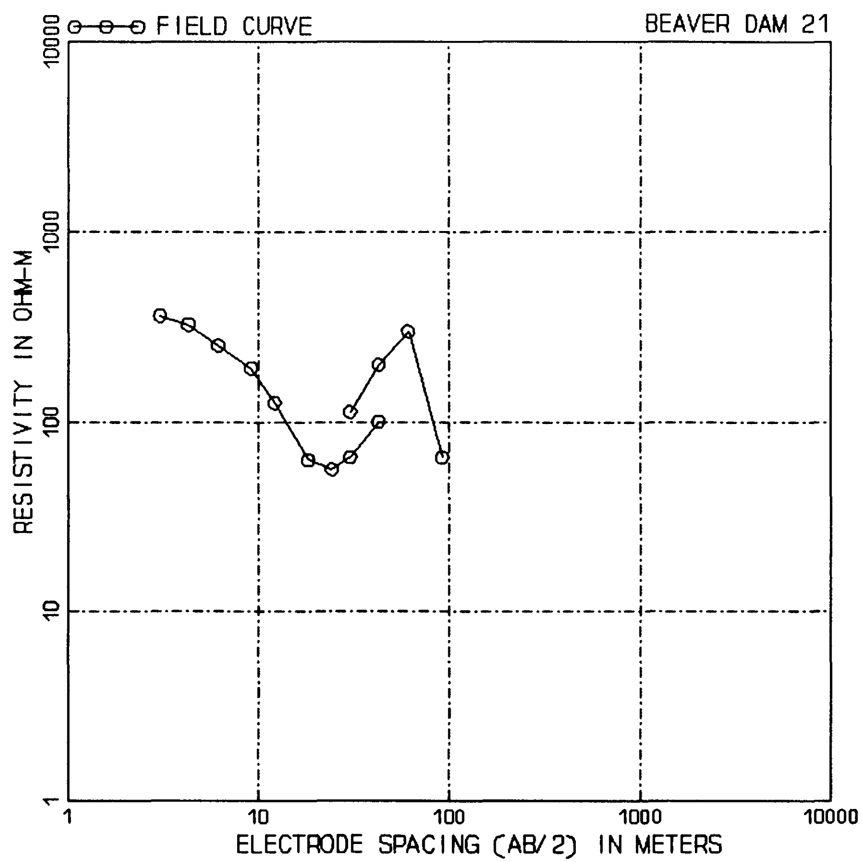
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.74	(5.71)	57.48	55.01	(180.46)	160.29
2.55	(8.38)	40.36	80.74	(264.89)	97.75
3.75	(12.29)	48.34	118.51	(388.80)	43.78
5.50	(18.05)	60.91	173.94	(570.68)	22.58
8.07	(26.49)	64.82	255.31	(837.64)	20.72
11.85	(38.88)	73.93	374.75	(1229.49)	21.90
17.39	(57.07)	103.13	550.06	(1804.65)	20.34
25.53	(83.76)	148.78	807.37	(2648.86)	16.25
37.47	(122.95)	179.68	99999.00	(99999.00)	10.10



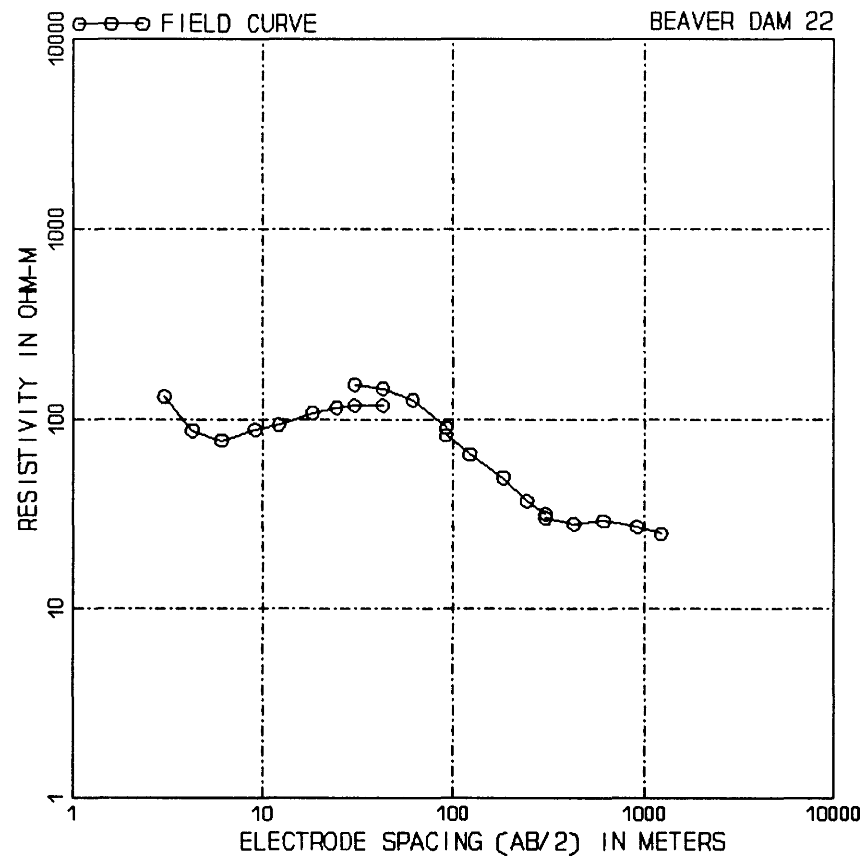
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	47.00	91.44 (	300.00)	165.00
4.27 (	14.00)	37.00	121.92 (	400.00)	145.00
6.10 (	20.00)	45.00	182.88 (	600.00)	91.00
9.14 (	30.00)	61.00	243.84 (	800.00)	60.00
12.19 (	40.00)	75.00	304.80 (	1000.00)	46.00
18.29 (	60.00)	101.00	304.80 (	1000.00)	53.50
24.38 (	80.00)	130.00	426.72 (	1400.00)	33.00
30.48 (	100.00)	154.00	609.60 (	2000.00)	26.00
42.67 (	140.00)	190.00	914.40 (	3000.00)	21.50
30.48 (	100.00)	112.00	914.40 (	3000.00)	21.50
42.67 (	140.00)	150.00	1219.20 (	4000.00)	16.00
60.96 (	200.00)	184.00	1828.80 (	6000.00)	13.30
91.44 (	300.00)	190.00	2438.40 (	8000.00)	9.00



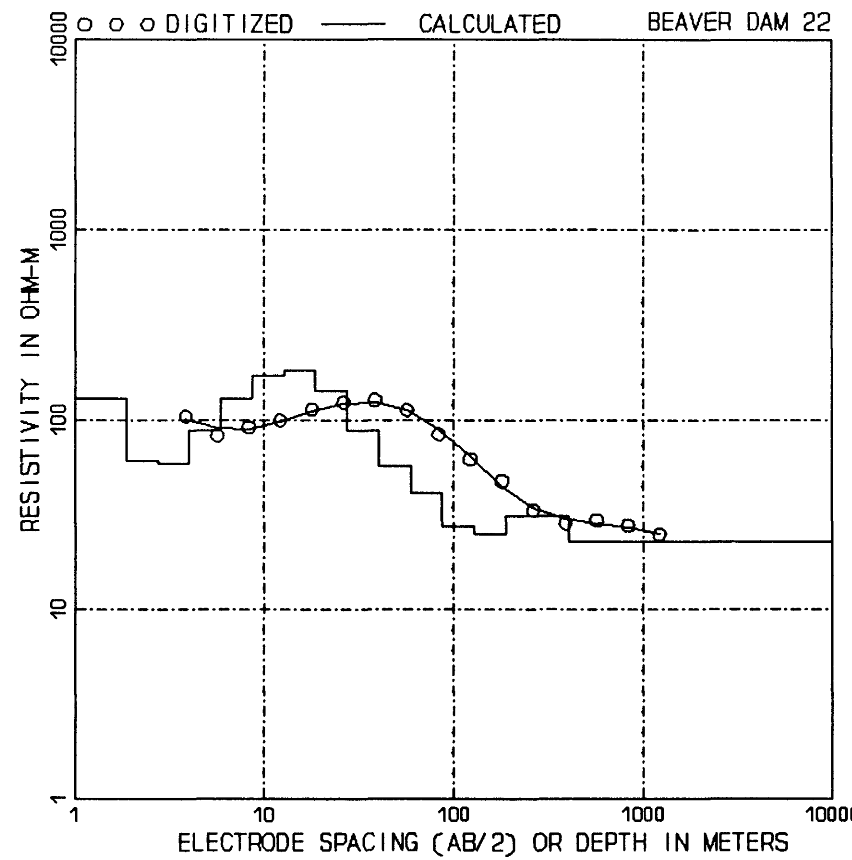
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.57 (	5.14)	30.55	49.51 (	162.42)	332.41
2.30 (	7.54)	21.27	72.66 (	238.40)	125.28
3.37 (	11.07)	30.20	106.66 (	349.92)	28.58
4.95 (	16.24)	52.02	156.55 (	513.61)	9.67
7.27 (	23.84)	93.91	229.78 (	753.88)	19.49
10.67 (	34.99)	174.71	337.27 (	1106.54)	37.04
15.65 (	51.36)	308.32	495.05 (	1624.19)	29.65
22.98 (	75.39)	456.74	726.64 (	2383.98)	16.18
33.73 (	110.65)	492.02	99999.00 (	99999.00)	6.24



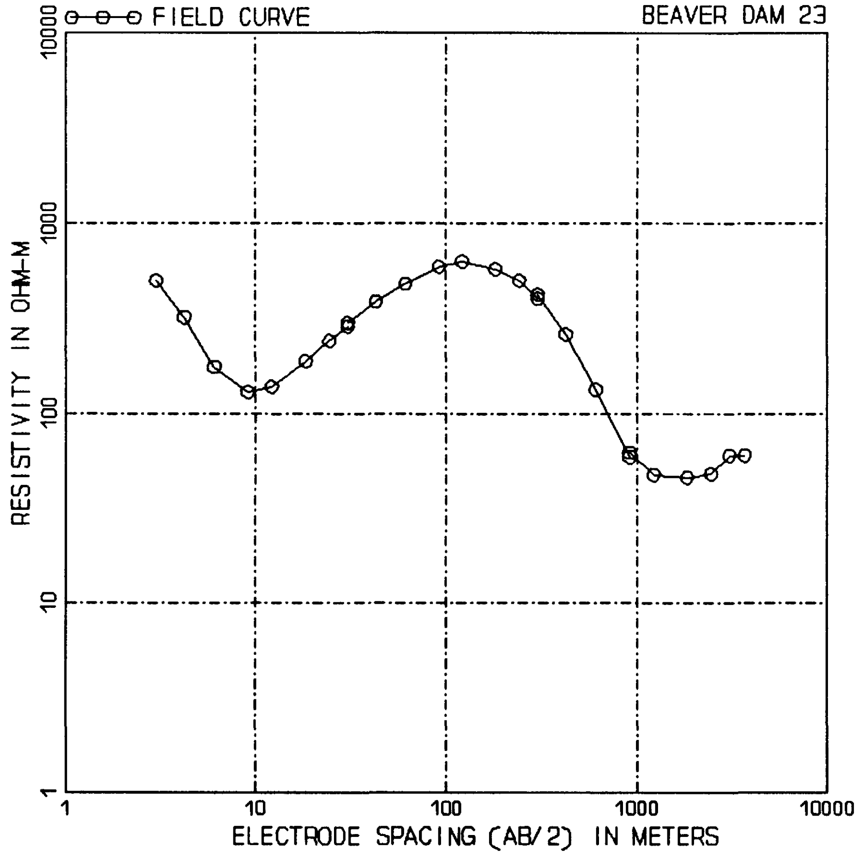
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	362.00	24.38 (	80.00)	56.00
4.27 (	14.00)	325.00	30.48 (	100.00)	65.00
6.10 (	20.00)	252.00	42.67 (	140.00)	100.00
9.14 (	30.00)	192.00	30.48 (	100.00)	113.00
12.19 (	40.00)	126.00	42.67 (	140.00)	200.00
18.29 (	60.00)	63.00	60.96 (	200.00)	300.00
			91.44 (	300.00)	65.00



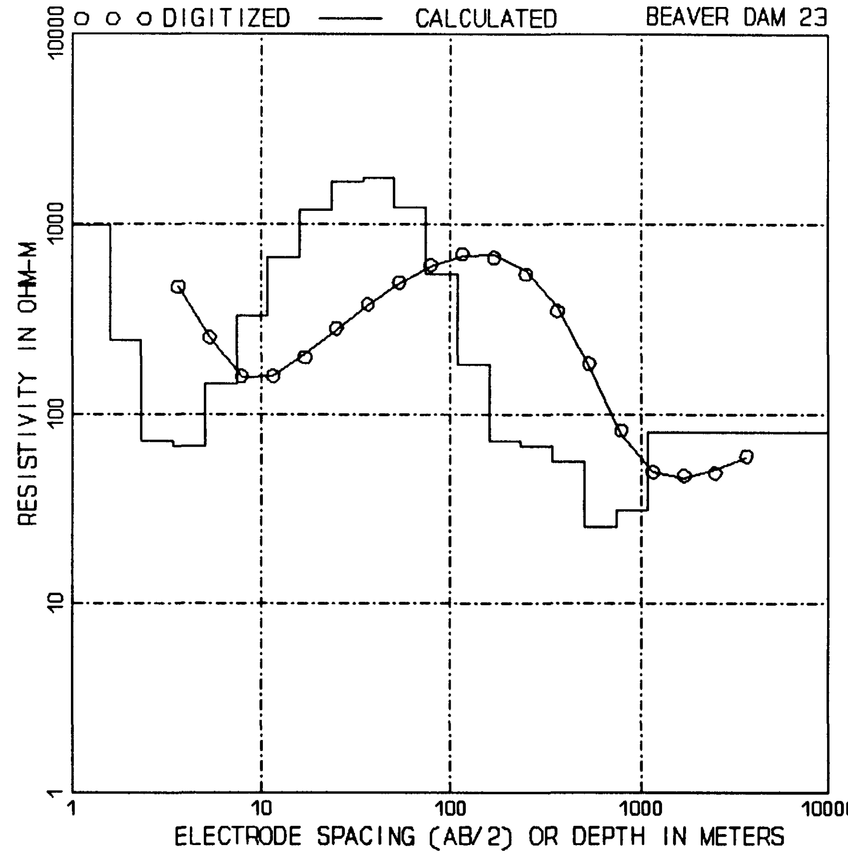
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	131.00	60.96	(200.00)	126.00
4.27	(14.00)	87.00	91.44	(300.00)	90.00
6.10	(20.00)	77.00	91.44	(300.00)	82.00
9.14	(30.00)	88.00	121.92	(400.00)	65.00
12.19	(40.00)	93.00	182.88	(600.00)	49.00
18.29	(60.00)	108.00	243.84	(800.00)	37.00
24.38	(80.00)	115.00	304.80	(1000.00)	31.50
30.48	(100.00)	118.00	304.80	(1000.00)	30.00
42.67	(140.00)	118.00	426.72	(1400.00)	28.00
30.48	(100.00)	152.00	609.60	(2000.00)	29.00
42.67	(140.00)	145.00	914.40	(3000.00)	27.00
			1219.20	(4000.00)	24.80



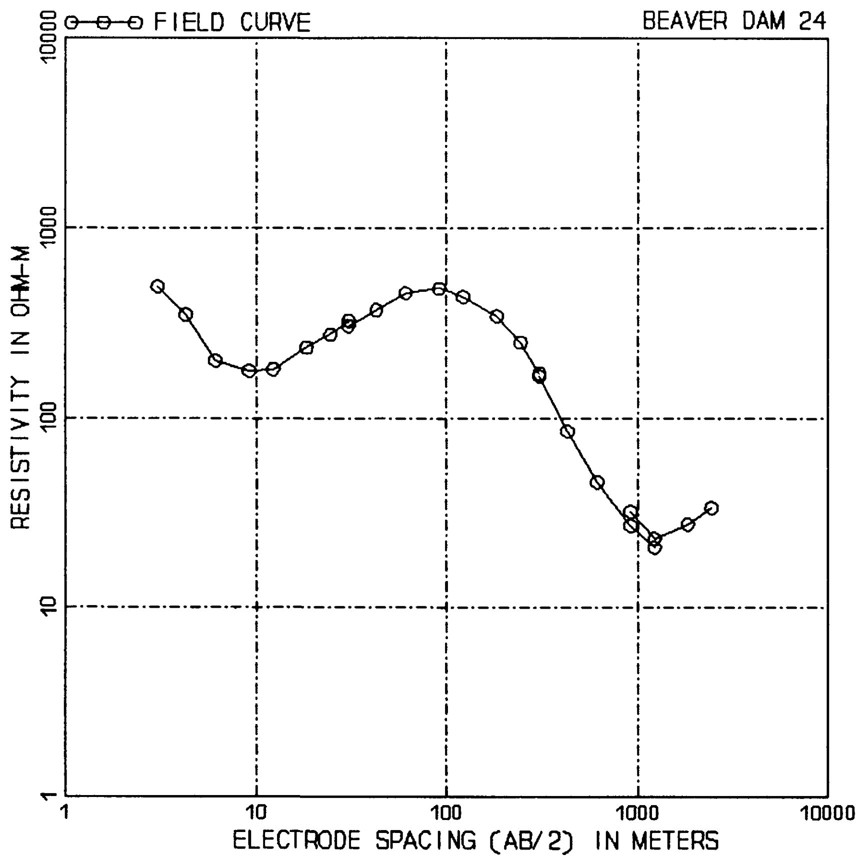
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.87	(6.15)	128.99	40.37	(132.44)	88.17
2.75	(9.02)	60.75	59.25	(194.40)	56.65
4.04	(13.24)	58.88	86.97	(285.34)	40.99
5.93	(19.44)	87.40	127.66	(418.82)	27.27
8.70	(28.53)	130.04	187.37	(614.75)	24.82
12.77	(41.88)	171.98	275.03	(902.33)	31.14
18.74	(61.47)	182.90	403.69	(1324.43)	30.96
27.50	(90.23)	143.02	99999.00	(99999.00)	22.65

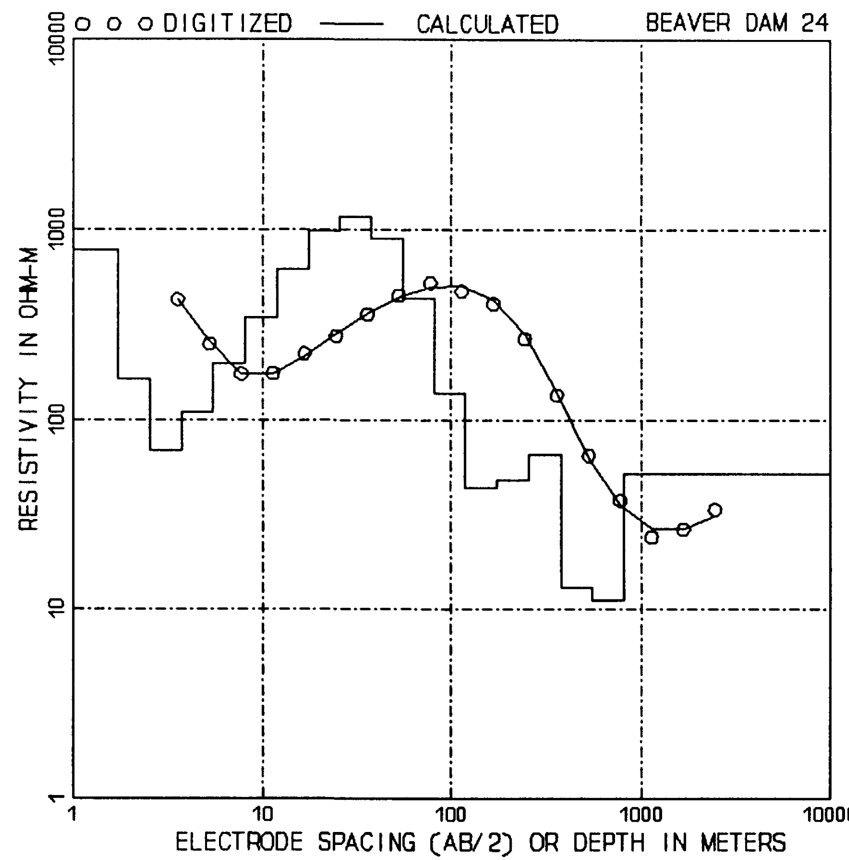


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	500.00	182.88 (	600.00)	575.00
4.27 (	14.00)	320.00	243.84 (	800.00)	500.00
6.10 (	20.00)	175.00	304.80 (	1000.00)	400.00
9.14 (	30.00)	130.00	304.80 (	1000.00)	420.00
12.19 (	40.00)	138.00	426.72 (	1400.00)	260.00
18.29 (	60.00)	188.00	609.60 (	2000.00)	133.00
24.38 (	80.00)	240.00	914.40 (	3000.00)	59.00
30.48 (	100.00)	285.00	914.40 (	3000.00)	62.00
30.48 (	100.00)	300.00	1219.20 (	4000.00)	47.50
42.67 (	140.00)	387.00	1828.80 (	6000.00)	46.00
60.96 (	200.00)	480.00	2438.40 (	8000.00)	48.00
91.44 (	300.00)	590.00	3048.00 (	10000.00)	60.00
121.92 (	400.00)	630.00	3657.60 (	12000.00)	60.00



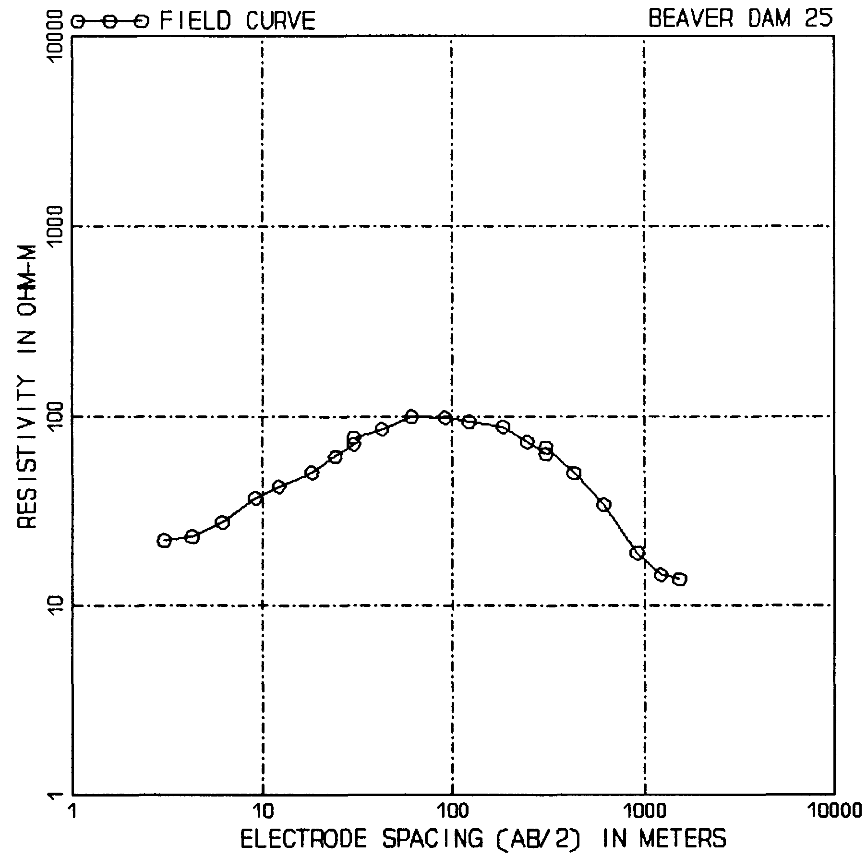
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.60 (	5.25)	988.04	50.59 (	165.98)	1753.62
2.35 (	7.70)	245.69	74.26 (	243.63)	1221.70
3.45 (	11.31)	71.45	109.00 (	357.60)	549.13
5.06 (	16.60)	67.66	159.98 (	524.88)	181.17
7.43 (	24.36)	143.28	234.82 (	770.42)	71.77
10.90 (	35.76)	327.99	344.67 (	1130.82)	67.22
16.00 (	52.49)	669.36	505.91 (	1659.82)	55.67
23.48 (	77.04)	1180.65	742.58 (	2436.28)	25.56
34.47 (	113.08)	1681.89	1089.95 (	3575.97)	31.30
			99999.00 (	99999.00)	79.76



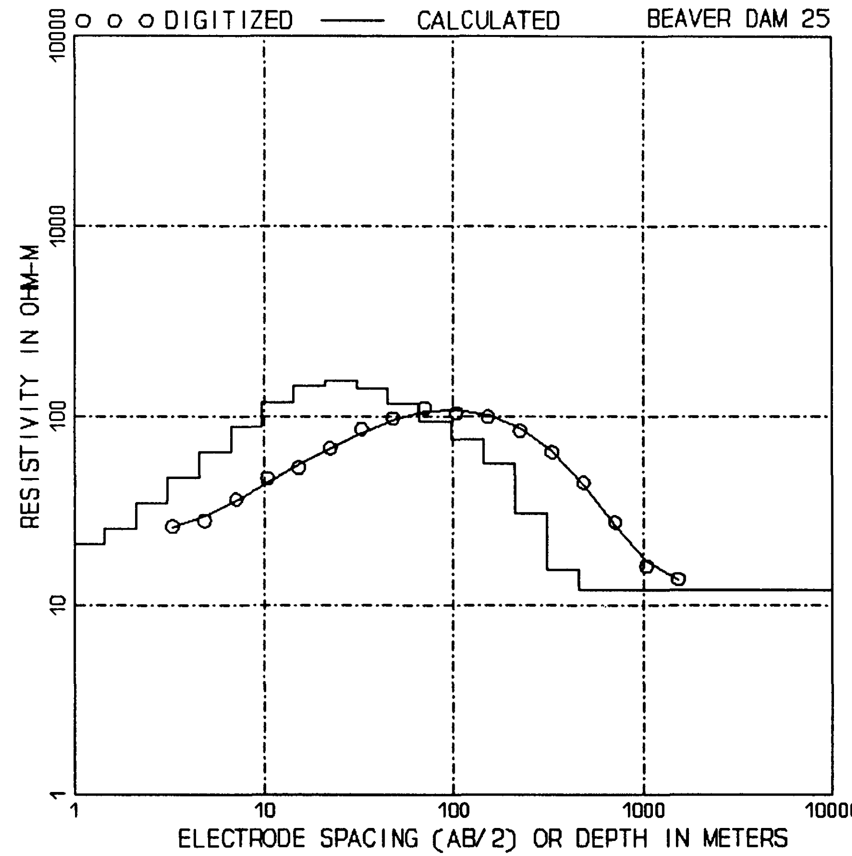


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	490.00	121.92	(400.00)	435.00
4.27	(14.00)	348.00	182.88	(600.00)	344.00
6.10	(20.00)	200.00	243.84	(800.00)	250.00
9.14	(30.00)	177.00	304.80	(1000.00)	172.00
12.19	(40.00)	180.00	304.80	(1000.00)	166.00
18.29	(60.00)	235.00	426.72	(1400.00)	85.00
24.38	(80.00)	275.00	609.60	(2000.00)	46.00
30.48	(100.00)	325.00	914.40	(3000.00)	27.00
30.48	(100.00)	305.00	1219.20	(4000.00)	20.80
42.67	(140.00)	370.00	914.40	(3000.00)	32.00
60.96	(200.00)	455.00	1219.20	(4000.00)	23.00
91.44	(300.00)	480.00	1828.80	(6000.00)	27.50
			2438.40	(8000.00)	33.50

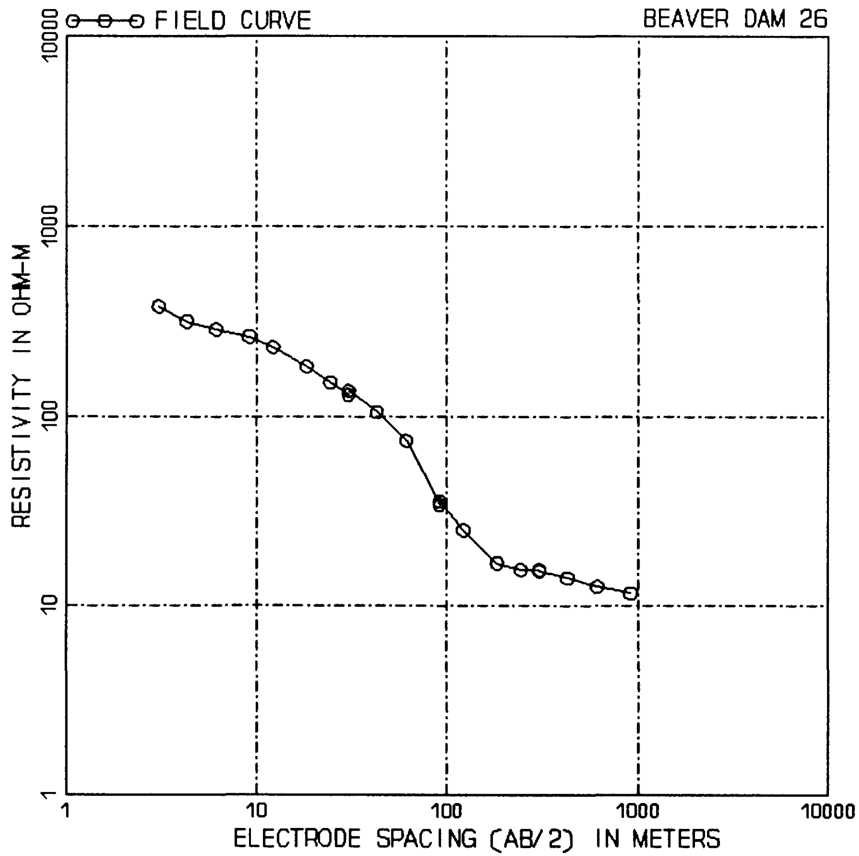
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.74	(5.71)	780.39	55.01	(180.46)	897.85
2.55	(8.38)	162.98	80.74	(264.89)	436.20
3.75	(12.29)	68.81	118.51	(388.80)	138.27
5.50	(18.05)	108.77	173.94	(570.68)	44.06
8.07	(26.49)	195.60	255.31	(837.64)	48.08
11.85	(38.88)	340.82	374.75	(1229.49)	65.58
17.39	(57.07)	618.32	550.06	(1804.65)	12.95
25.53	(83.76)	993.61	807.37	(2648.86)	11.16
37.47	(122.95)	1165.82	99999.00	(99999.00)	51.80



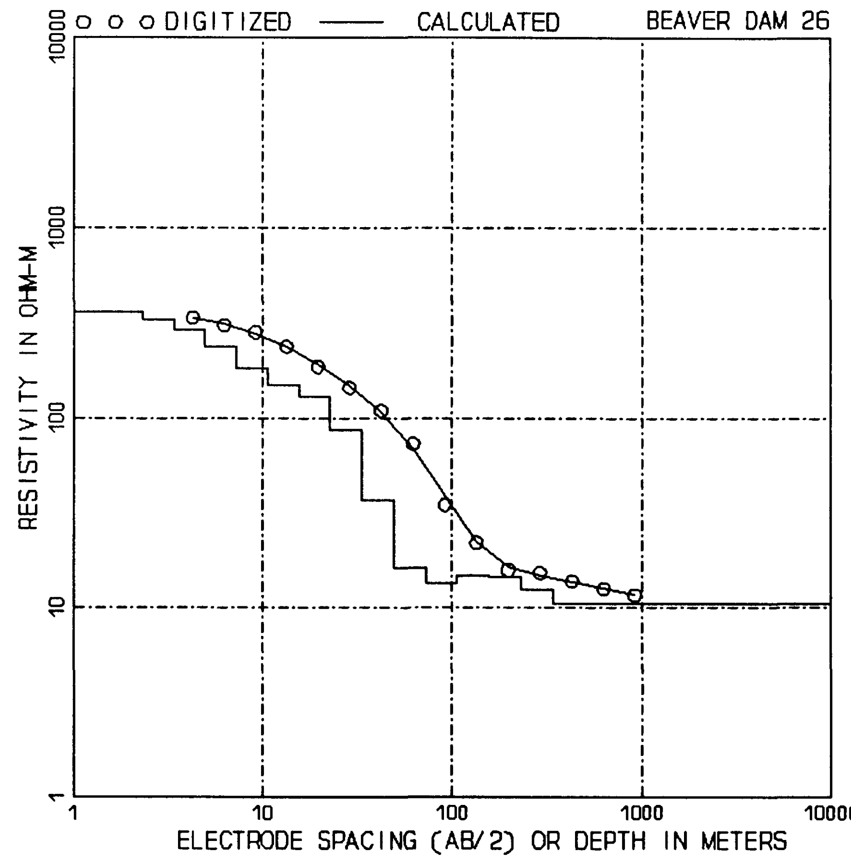
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	22.00	91.44 (	300.00)	98.00
4.27 (	14.00)	23.00	121.92 (	400.00)	93.00
6.10 (	20.00)	27.50	182.88 (	600.00)	88.00
9.14 (	30.00)	37.00	243.84 (	800.00)	73.00
12.19 (	40.00)	42.50	304.80 (	1000.00)	63.00
18.29 (	60.00)	50.50	304.80 (	1000.00)	68.00
24.38 (	80.00)	61.00	426.72 (	1400.00)	50.00
30.48 (	100.00)	70.60	609.60 (	2000.00)	34.00
30.48 (	100.00)	77.00	914.40 (	3000.00)	19.00
42.67 (	140.00)	85.00	1219.20 (	4000.00)	14.50
60.96 (	200.00)	99.00	1524.00 (	5000.00)	13.80



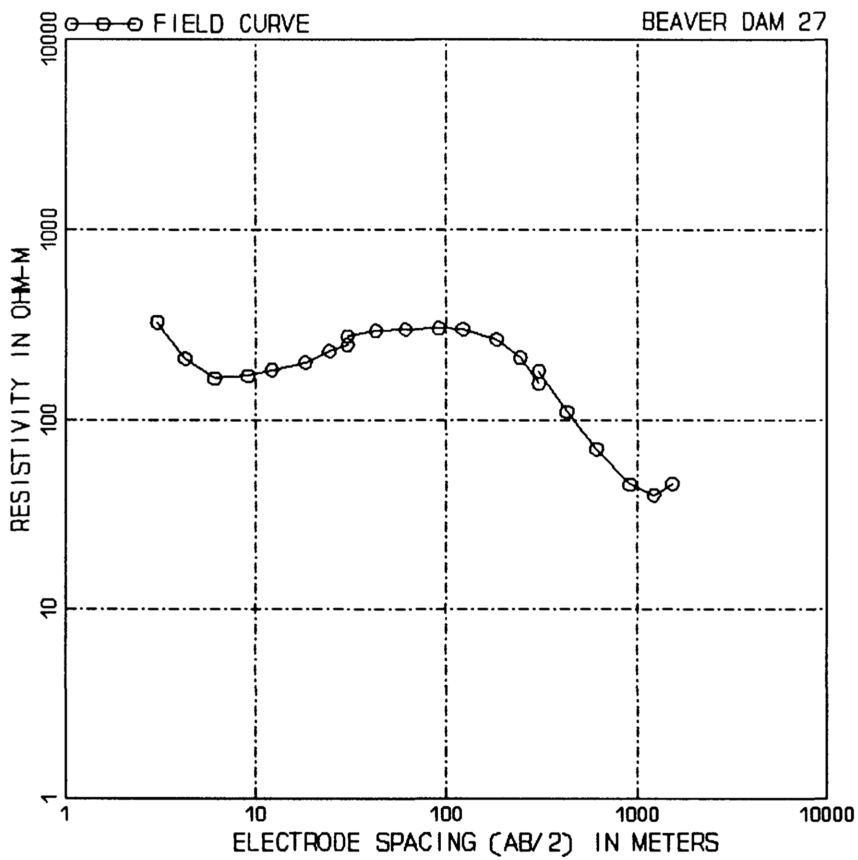
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.44 (	4.71)	21.15	30.94 (	101.51)	152.44
2.11 (	6.92)	25.27	45.41 (	149.00)	139.73
3.09 (	10.15)	34.54	66.66 (	218.70)	115.90
4.54 (	14.90)	47.16	97.84 (	321.01)	93.36
6.67 (	21.87)	64.00	143.61 (	471.17)	75.61
9.78 (	32.10)	88.08	210.80 (	691.59)	55.63
14.36 (	47.12)	117.88	309.41 (	1015.12)	30.57
21.08 (	69.16)	143.80	454.15 (	1489.99)	15.37
			99999.00 (	99999.00)	12.03

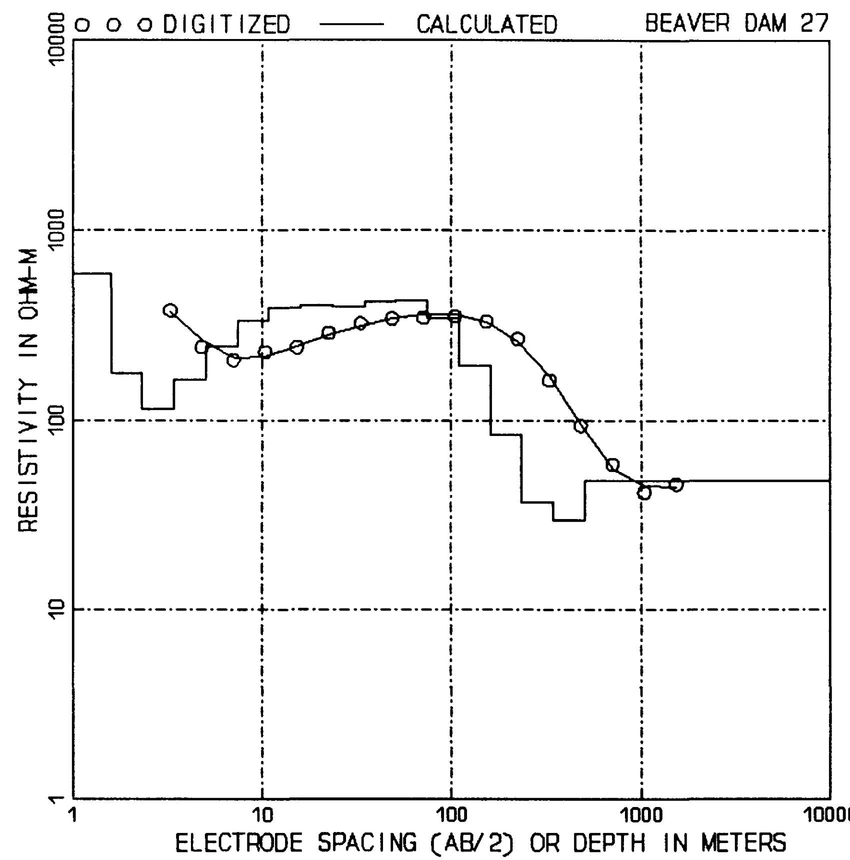


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	378.00	60.96	(200.00)	74.00
4.27	(14.00)	315.00	91.44	(300.00)	34.00
6.10	(20.00)	285.00	91.44	(300.00)	35.50
9.14	(30.00)	262.00	121.92	(400.00)	25.00
12.19	(40.00)	230.00	182.88	(600.00)	16.80
18.29	(60.00)	182.00	243.84	(800.00)	15.50
24.38	(80.00)	150.00	304.80	(1000.00)	15.50
30.48	(100.00)	129.00	304.80	(1000.00)	15.20
30.48	(100.00)	136.00	426.72	(1400.00)	14.00
42.67	(140.00)	105.00	609.60	(2000.00)	12.60
			914.40	(3000.00)	11.60



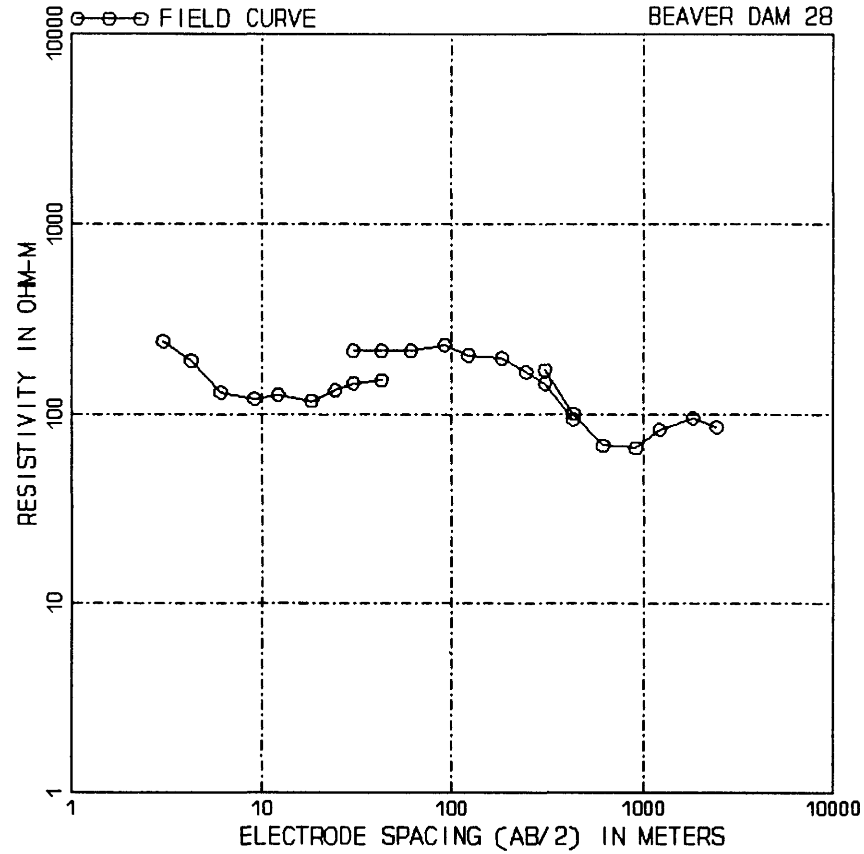
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.29	(7.52)	358.40	33.64	(110.37)	86.91
3.36	(11.04)	326.63	49.38	(162.00)	37.15
4.94	(16.20)	288.65	72.48	(237.78)	16.12
7.25	(23.78)	235.52	106.38	(349.02)	13.43
10.64	(34.90)	181.55	156.15	(512.29)	14.85
15.61	(51.23)	149.63	229.19	(751.94)	14.53
22.92	(75.19)	129.32	336.41	(1103.69)	12.51
			99999.00	(99999.00)	10.53

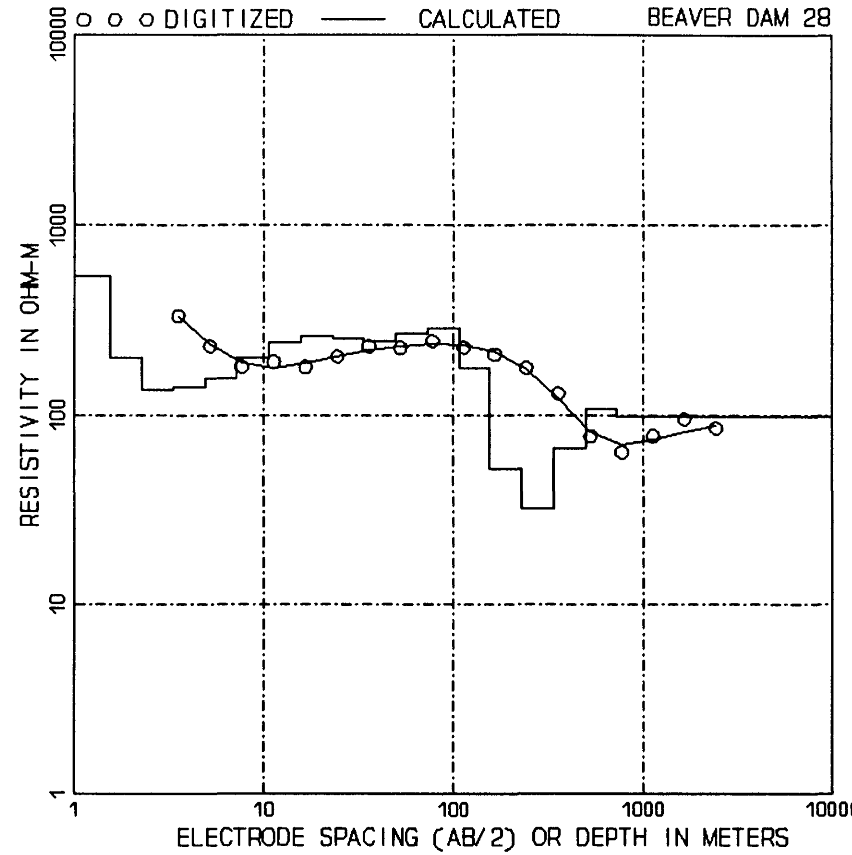




AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	325.00	91.44	(300.00)	302.00
4.27	(14.00)	209.00	121.92	(400.00)	300.00
6.10	(20.00)	165.00	182.88	(600.00)	265.00
9.14	(30.00)	170.00	243.84	(800.00)	212.00
12.19	(40.00)	183.00	304.80	(1000.00)	155.00
18.29	(60.00)	200.00	304.80	(1000.00)	180.00
24.38	(80.00)	230.00	426.72	(1400.00)	110.00
30.48	(100.00)	247.00	609.60	(2000.00)	70.00
30.48	(100.00)	275.00	914.40	(3000.00)	45.50
42.67	(140.00)	293.00	1219.20	(4000.00)	40.00
60.96	(200.00)	298.00	1524.00	(5000.00)	46.00

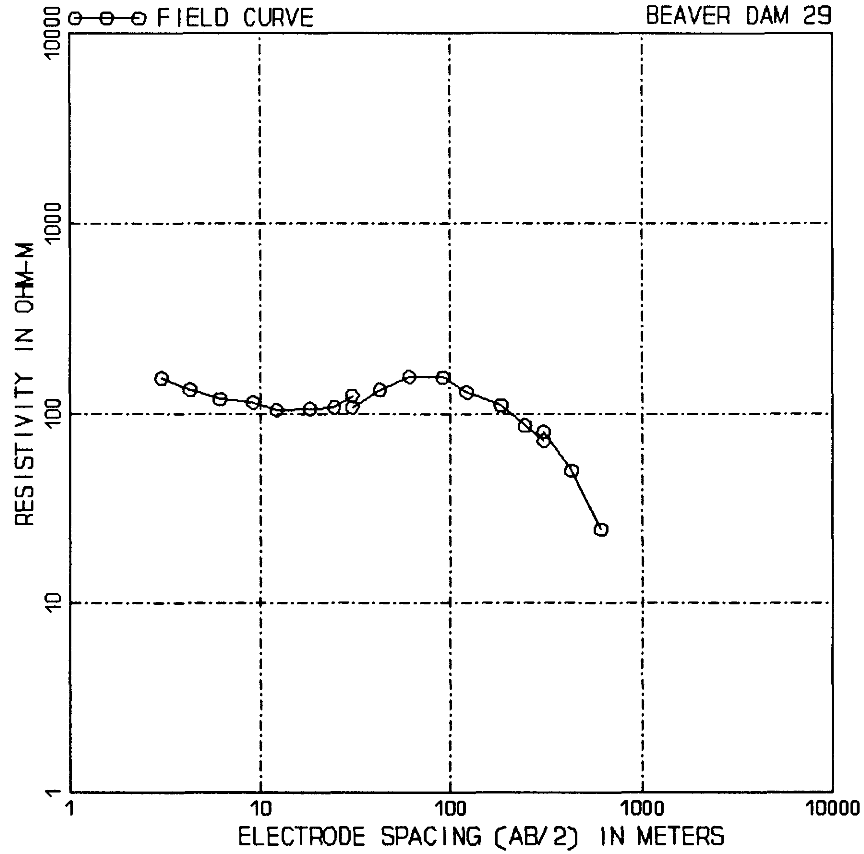
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.60	(5.24)	587.74	34.38	(112.79)	397.19
2.34	(7.68)	176.35	50.46	(165.55)	417.83
3.44	(11.28)	113.69	74.07	(243.00)	429.11
5.05	(16.56)	162.99	108.71	(356.68)	346.51
7.41	(24.30)	244.50	159.57	(523.53)	193.39
10.87	(35.67)	332.30	234.22	(768.43)	83.45
15.96	(52.35)	391.42	343.79	(1127.91)	37.08
23.42	(76.84)	400.66	504.61	(1655.54)	29.61
			99999.00	(99999.00)	47.69



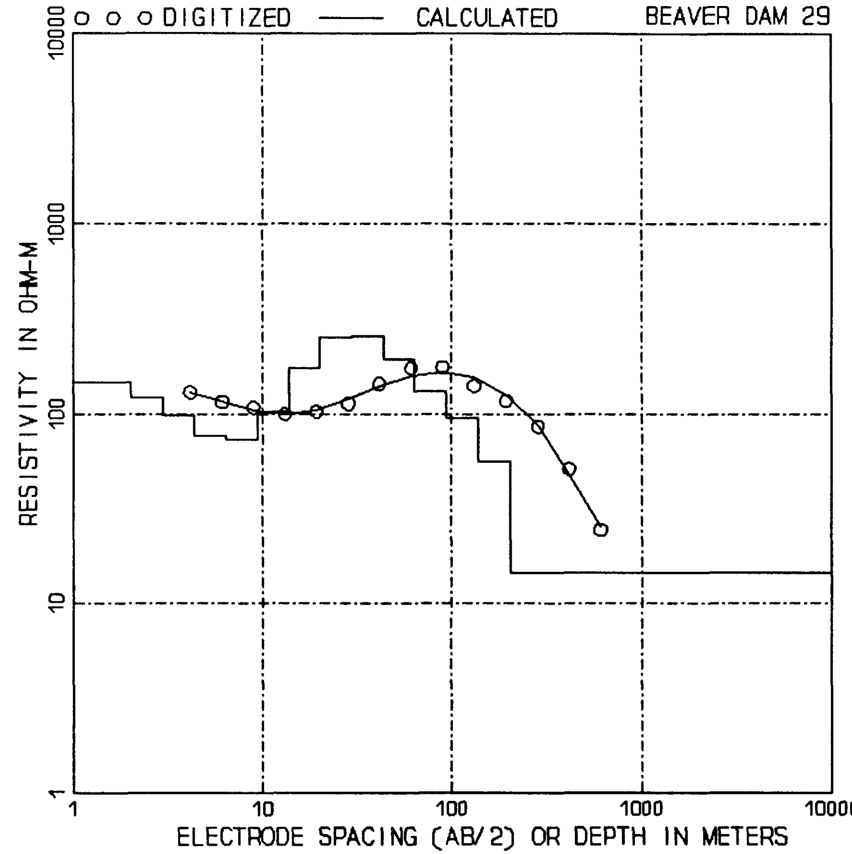


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	240.00	91.44 (	300.00)	231.00
4.27 (	14.00)	190.00	121.92 (	400.00)	204.00
6.10 (	20.00)	130.00	182.88 (	600.00)	196.00
9.14 (	30.00)	120.00	243.84 (	800.00)	166.00
12.19 (	40.00)	126.00	304.80 (	1000.00)	145.00
18.29 (	60.00)	117.00	426.72 (	1400.00)	94.00
24.38 (	80.00)	133.00	304.80 (	1000.00)	170.00
30.48 (	100.00)	145.00	426.72 (	1400.00)	100.00
42.67 (	140.00)	150.00	609.60 (	2000.00)	68.00
30.48 (	100.00)	215.00	914.40 (	3000.00)	66.00
42.67 (	140.00)	215.00	1219.20 (	4000.00)	82.50
60.96 (	200.00)	215.00	1828.80 (	6000.00)	95.00
			2438.40 (	8000.00)	85.00

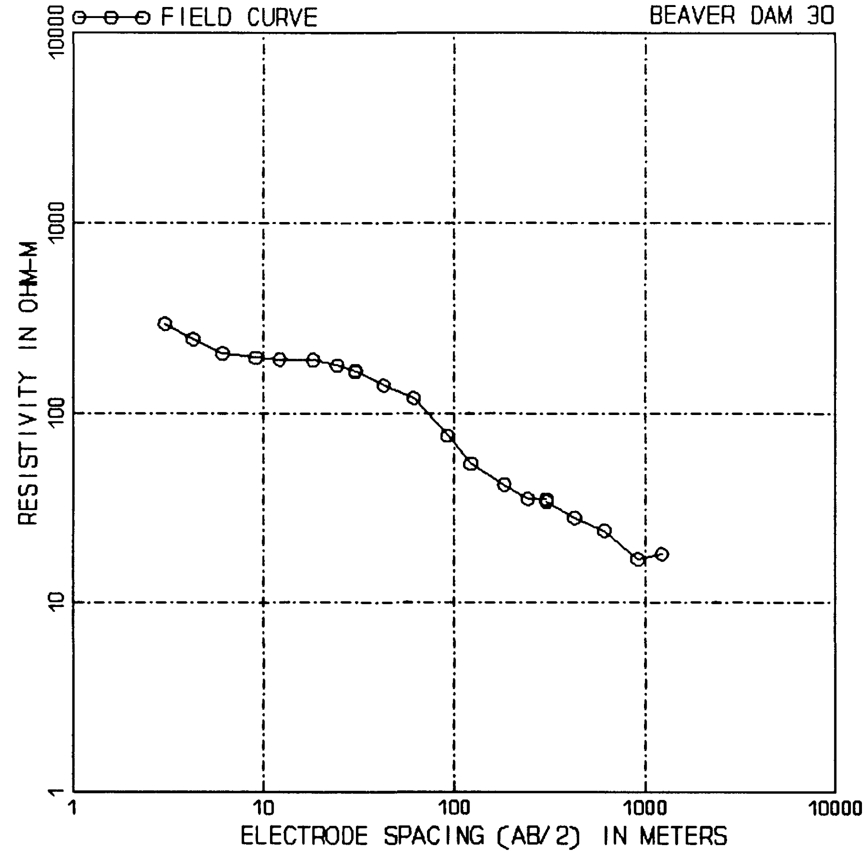
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.57 (	5.14)	535.16	49.51 (	162.42)	243.46
2.30 (	7.54)	200.69	72.66 (	238.40)	268.23
3.37 (	11.07)	134.98	106.66 (	349.92)	286.45
4.95 (	16.24)	139.05	156.55 (	513.61)	175.67
7.27 (	23.84)	156.54	229.78 (	753.88)	51.57
10.67 (	34.99)	199.21	337.27 (	1106.54)	32.12
15.65 (	51.36)	240.82	495.05 (	1624.19)	66.07
22.98 (	75.39)	258.29	726.64 (	2383.98)	108.05
33.73 (	110.65)	250.96	99999.00	(99999.00)	97.57



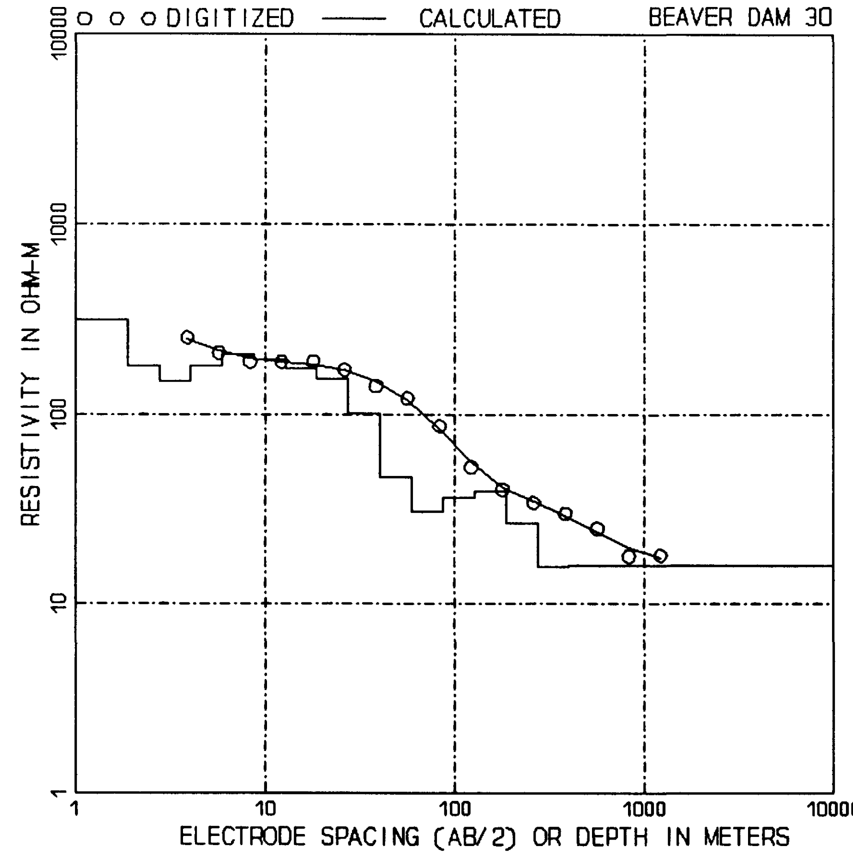
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	153.00	42.67 (	140.00)	133.00
4.27 (	14.00)	133.00	60.96 (	200.00)	156.00
6.10 (	20.00)	119.00	91.44 (	300.00)	155.00
9.14 (	30.00)	114.00	121.92 (	400.00)	130.00
12.19 (	40.00)	104.00	182.88 (	600.00)	110.00
18.29 (	60.00)	106.00	243.84 (	800.00)	86.00
24.38 (	80.00)	108.00	304.80 (	1000.00)	72.00
30.48 (	100.00)	124.00	304.80 (	1000.00)	80.00
30.48 (	100.00)	108.00	426.72 (	1400.00)	50.00
			609.60 (	2000.00)	24.50



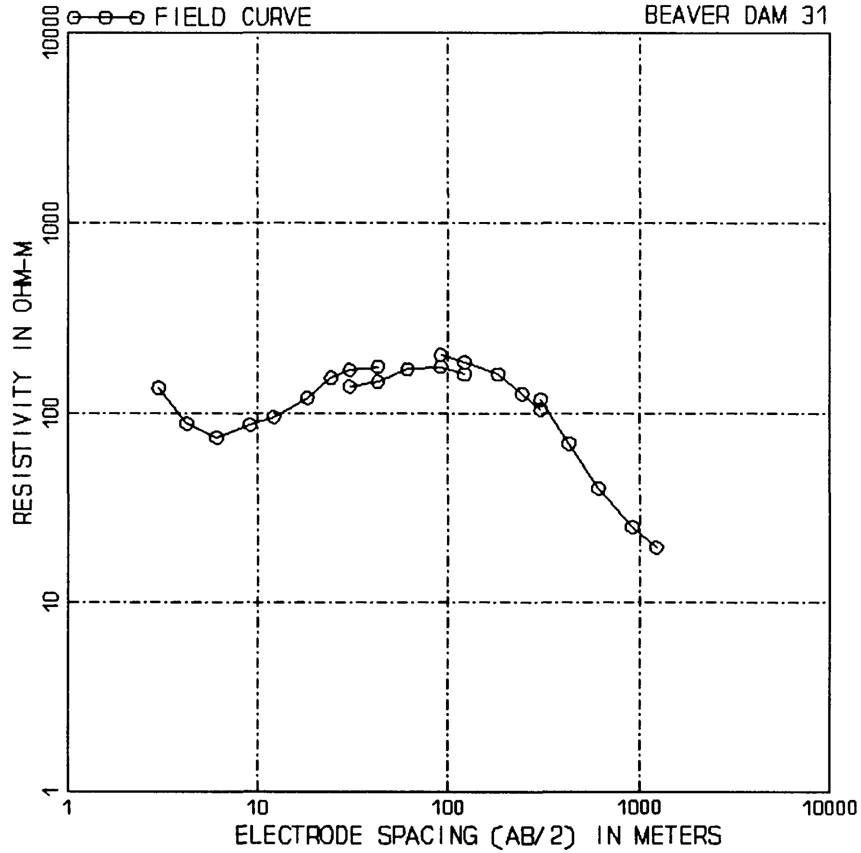
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
2.02 (	6.62)	146.04	29.63 (	97.20)	250.47
2.96 (	9.72)	122.13	43.49 (	142.67)	256.42
4.35 (	14.27)	98.39	63.83 (	209.41)	193.94
6.38 (	20.94)	76.68	93.69 (	307.37)	131.77
9.37 (	30.74)	72.68	137.51 (	451.16)	94.60
13.75 (	45.12)	102.65	201.84 (	662.22)	56.05
20.18 (	66.22)	174.40	99999.00 (	99999.00)	14.57



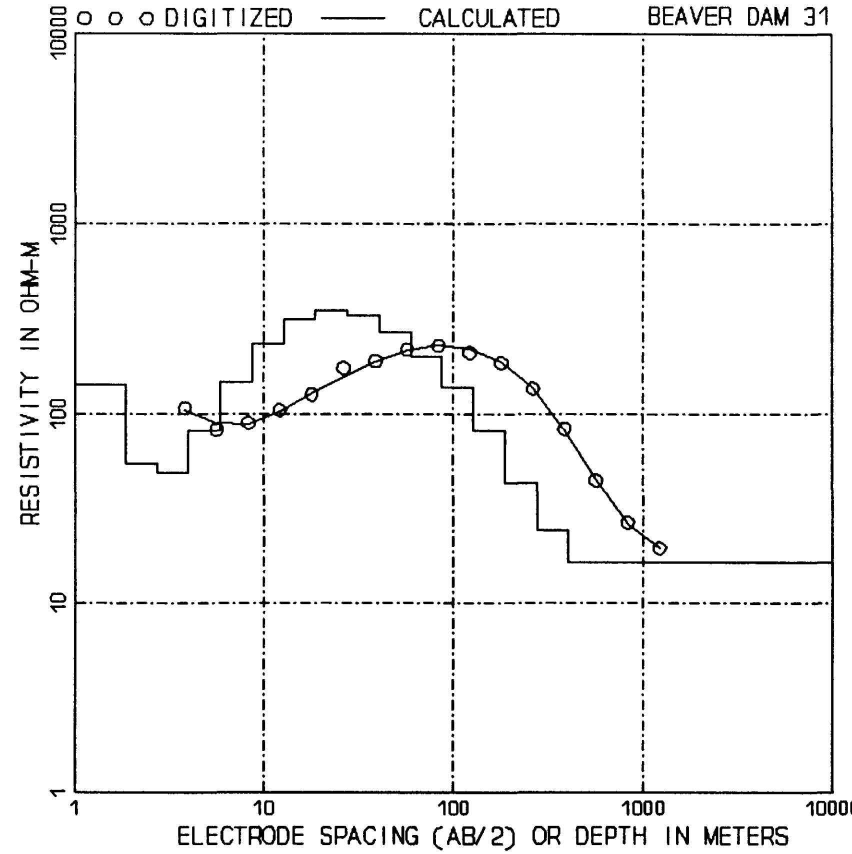
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	295.00	60.96	(200.00)	120.00
4.27	(14.00)	245.00	91.44	(300.00)	76.00
6.10	(20.00)	205.00	121.92	(400.00)	54.00
9.14	(30.00)	195.00	182.88	(600.00)	42.00
12.19	(40.00)	192.00	243.84	(800.00)	35.20
18.29	(60.00)	190.00	304.80	(1000.00)	35.00
24.38	(80.00)	178.00	304.80	(1000.00)	34.00
30.48	(100.00)	165.00	426.72	(1400.00)	28.00
30.48	(100.00)	167.00	609.60	(2000.00)	24.00
42.67	(140.00)	140.00	914.40	(3000.00)	17.00
			1219.20	(4000.00)	18.00



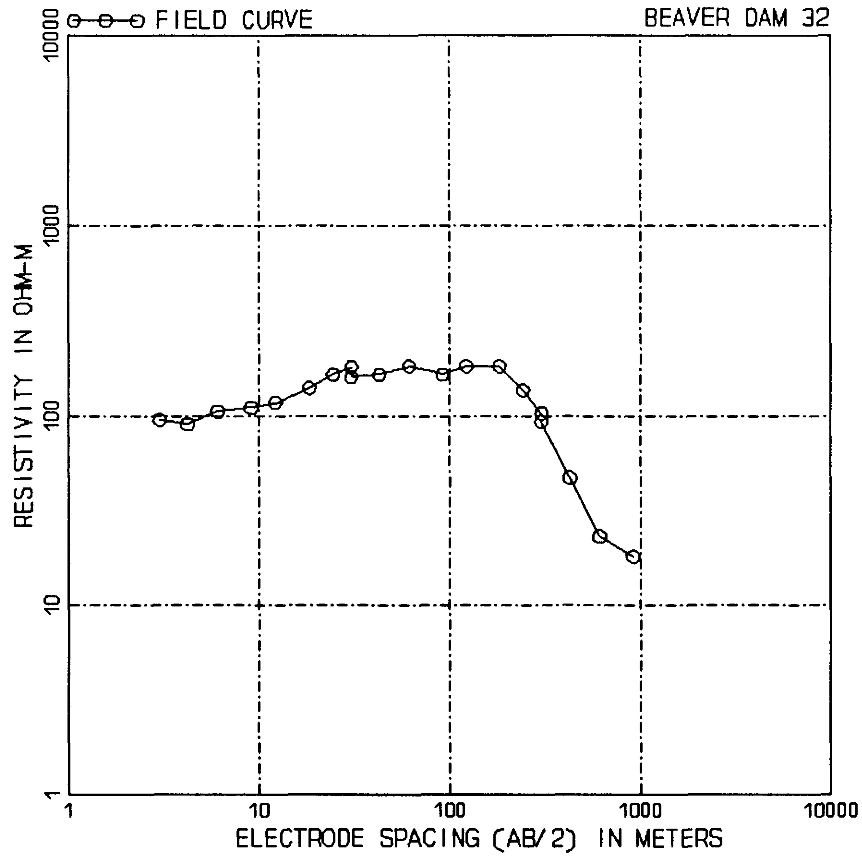
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.87	(6.15)	310.97	40.37	(132.44)	100.48
2.75	(9.02)	179.23	59.25	(194.40)	46.65
4.04	(13.24)	148.24	86.97	(285.34)	30.46
5.93	(19.44)	179.36	127.66	(418.82)	36.17
8.70	(28.53)	206.97	187.37	(614.75)	39.49
12.77	(41.88)	193.26	275.03	(902.33)	26.49
18.74	(61.47)	172.57	403.69	(1324.43)	15.80
27.50	(90.23)	152.80	99999.00	(99999.00)	16.03

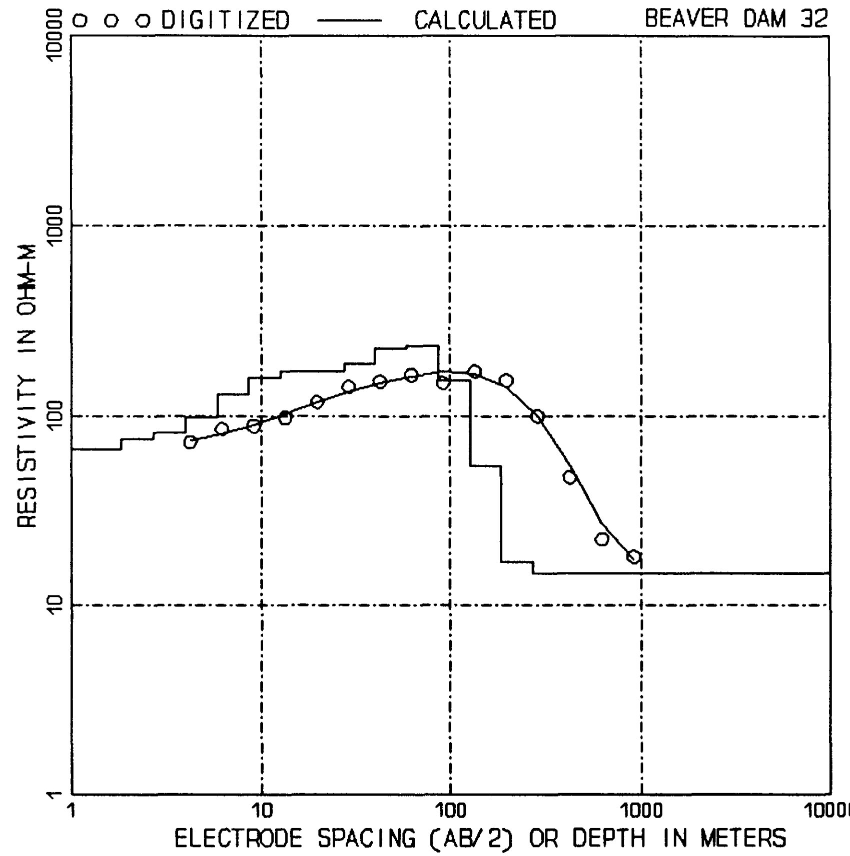


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	135.00	91.44	(300.00)	175.00
4.27	(14.00)	88.00	121.92	(400.00)	160.00
6.10	(20.00)	74.00	91.44	(300.00)	202.00
9.14	(30.00)	86.50	121.92	(400.00)	185.00
12.19	(40.00)	95.00	182.88	(600.00)	160.00
18.29	(60.00)	120.00	243.84	(800.00)	126.00
24.38	(80.00)	153.00	304.80	(1000.00)	104.00
30.48	(100.00)	168.00	304.80	(1000.00)	118.00
42.67	(140.00)	175.00	426.72	(1400.00)	69.00
30.48	(100.00)	138.00	609.60	(2000.00)	40.00
42.67	(140.00)	146.00	914.40	(3000.00)	25.00
60.96	(200.00)	170.00	1219.20	(4000.00)	19.50



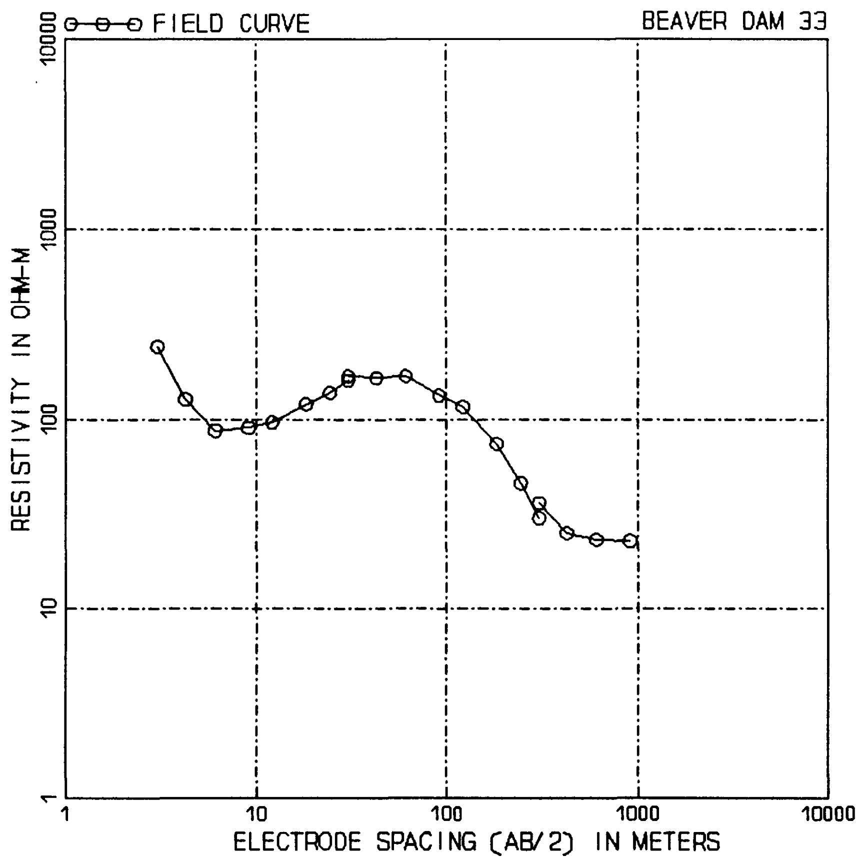
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.87	(6.15)	142.99	40.37	(132.44)	325.66
2.75	(9.02)	54.55	59.25	(194.40)	266.25
4.04	(13.24)	48.65	86.97	(285.34)	199.84
5.93	(19.44)	80.92	127.66	(418.82)	137.65
8.70	(28.53)	146.34	187.37	(614.75)	81.61
12.77	(41.88)	234.32	275.03	(902.33)	42.82
18.74	(61.47)	311.68	403.69	(1324.43)	24.29
27.50	(90.23)	346.80	99999.00	(99999.00)	16.38



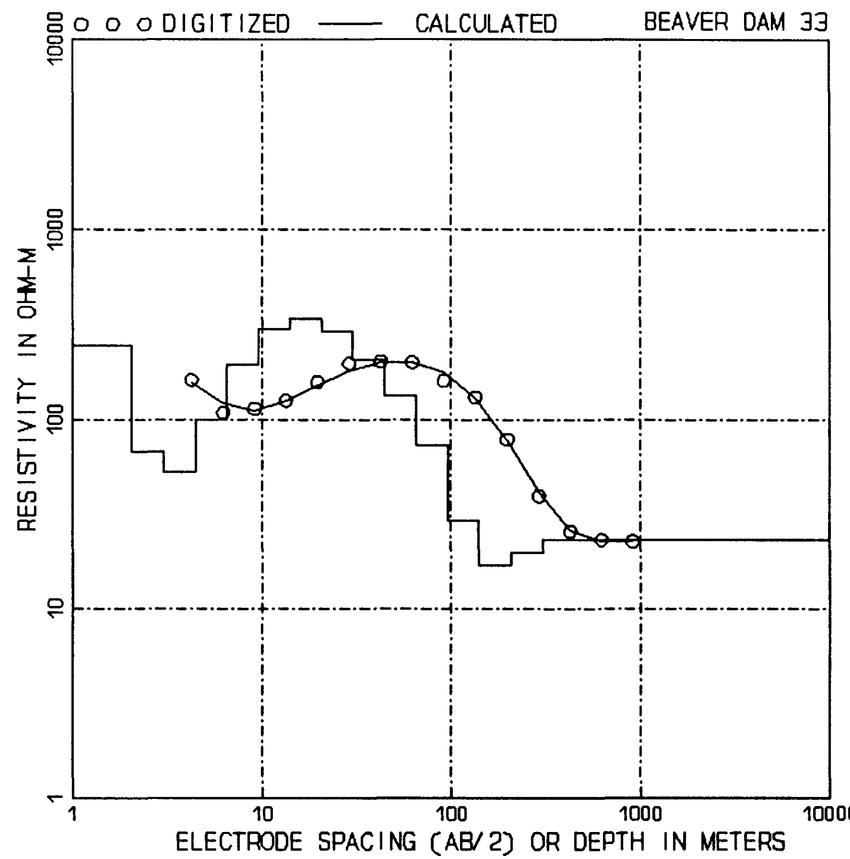


AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	95.00	60.96 (	200.00)	182.00
4.27 (	14.00)	90.00	91.44 (	300.00)	165.00
6.10 (	20.00)	105.00	121.92 (	400.00)	182.00
9.14 (	30.00)	110.00	182.88 (	600.00)	182.00
12.19 (	40.00)	117.00	243.84 (	800.00)	136.00
18.29 (	60.00)	140.00	304.80 (	1000.00)	103.00
24.38 (	80.00)	165.00	304.80 (	1000.00)	93.00
30.48 (	100.00)	180.00	426.72 (	1400.00)	47.00
30.48 (	100.00)	160.00	609.60 (	2000.00)	23.00
42.67 (	140.00)	165.00	914.40 (	3000.00)	18.10

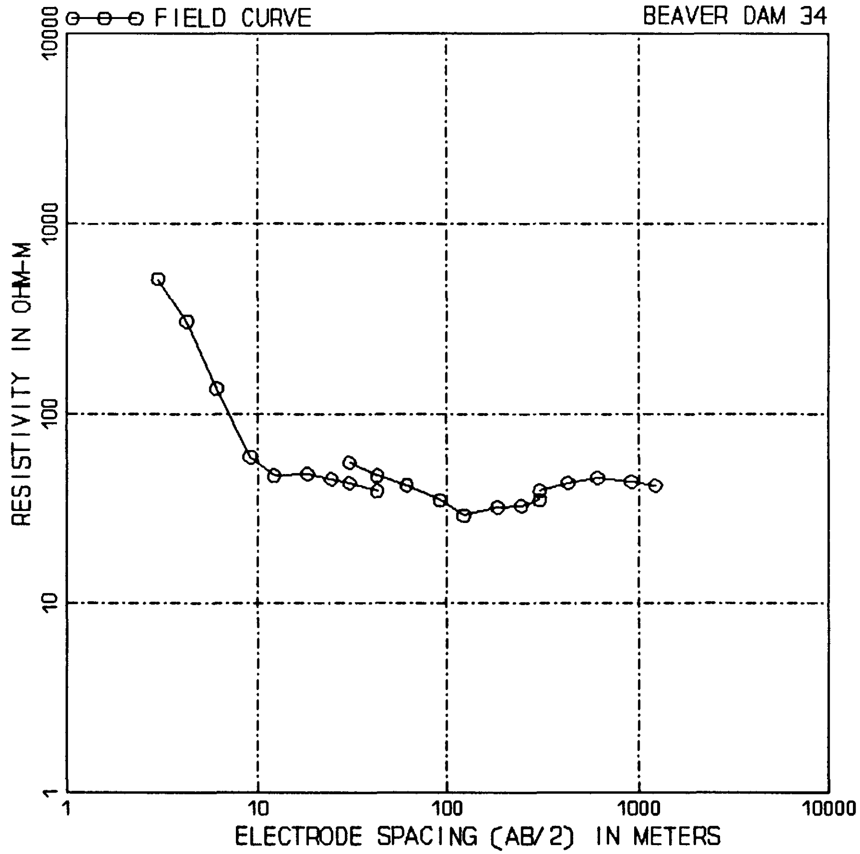
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.86 (	6.09)	66.03	27.25 (	89.40)	171.37
2.72 (	8.94)	74.95	40.00 (	131.22)	187.38
4.00 (	13.12)	81.60	58.71 (	192.60)	225.02
5.87 (	19.26)	98.15	86.17 (	282.71)	232.19
8.62 (	28.27)	128.66	126.48 (	414.95)	153.08
12.65 (	41.50)	159.21	185.64 (	609.07)	54.71
18.56 (	60.91)	171.24	272.49 (	893.99)	17.05
			99999.00 (	99999.00)	14.79

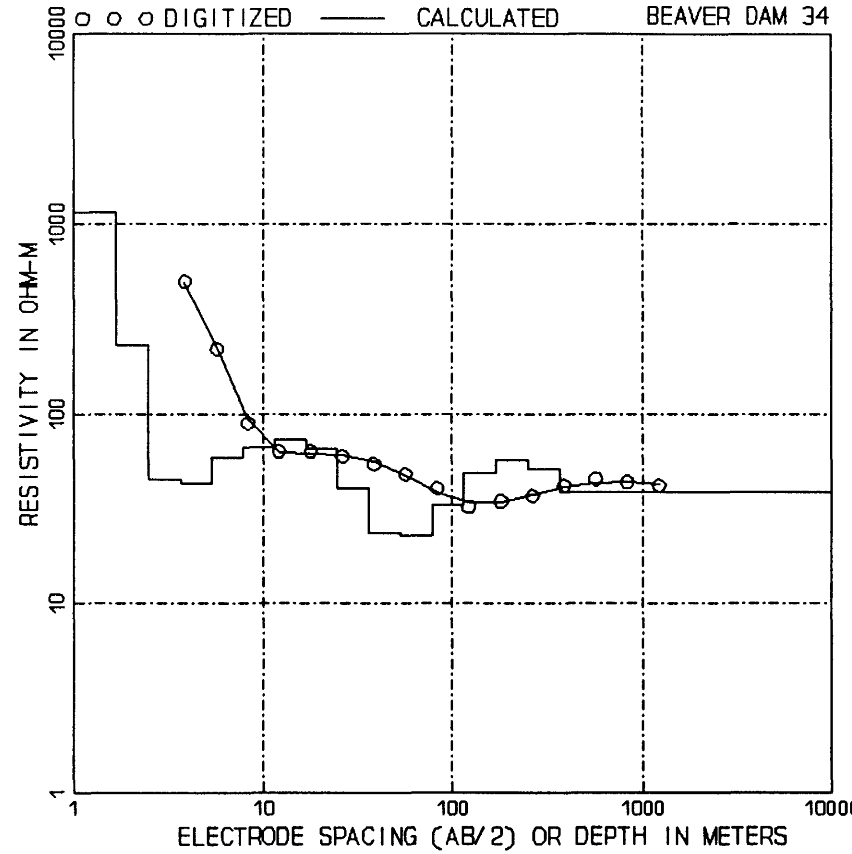


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	240.00	60.96	(200.00)	168.00
4.27	(14.00)	127.00	91.44	(300.00)	133.00
6.10	(20.00)	87.00	121.92	(400.00)	116.00
9.14	(30.00)	90.00	182.88	(600.00)	74.00
12.19	(40.00)	96.00	243.84	(800.00)	46.00
18.29	(60.00)	120.00	304.80	(1000.00)	30.00
24.38	(80.00)	138.00	304.80	(1000.00)	36.00
30.48	(100.00)	160.00	426.72	(1400.00)	25.00
30.48	(100.00)	168.00	609.60	(2000.00)	23.20
42.67	(140.00)	165.00	914.40	(3000.00)	22.70



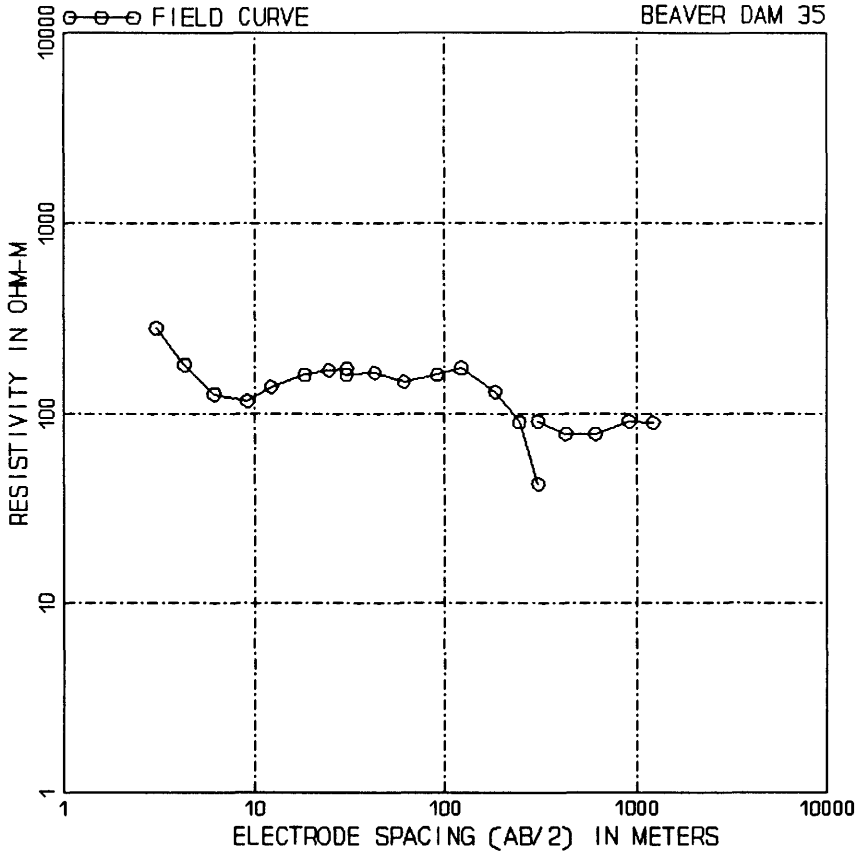
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.06	(6.77)	243.23	30.28	(99.33)	292.12
3.03	(9.93)	67.00	44.44	(145.80)	206.50
4.44	(14.58)	53.06	65.23	(214.01)	133.59
6.52	(21.40)	99.75	95.74	(314.12)	72.44
9.57	(31.41)	193.79	140.53	(461.06)	29.31
14.05	(46.11)	298.37	206.27	(676.74)	16.94
20.63	(67.67)	340.74	302.77	(993.32)	19.77
			99999.00	(99999.00)	23.23



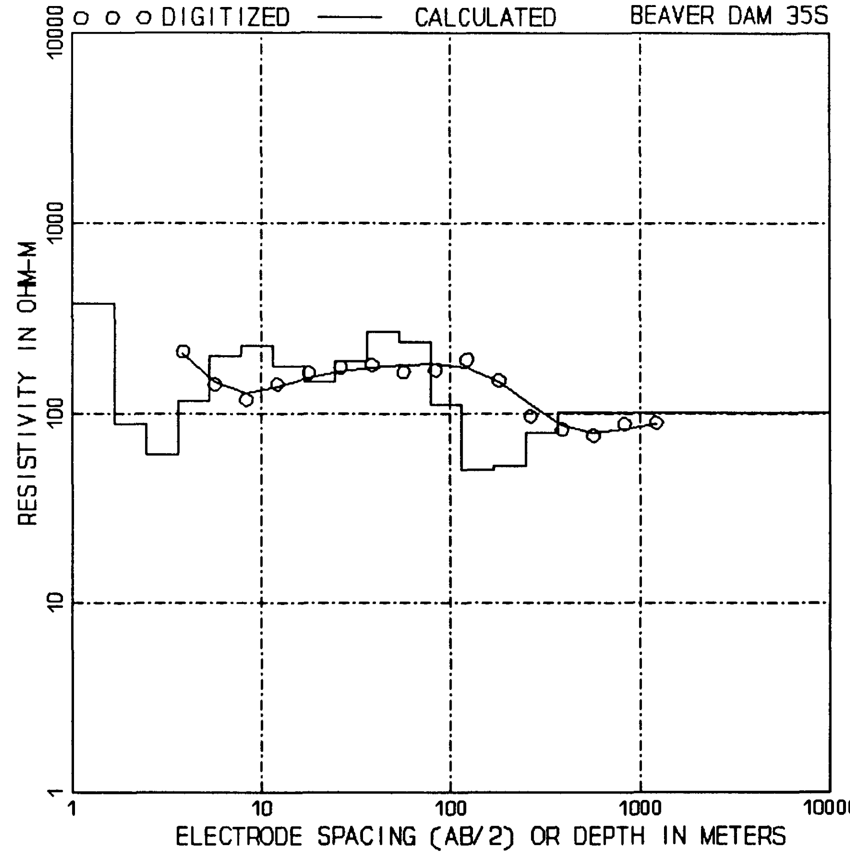


AB/2, m (ft)	App. Res.	AB/2, m (ft)	App. Res.
3.05 (10.00)	510.00	60.96 (200.00)	42.00
4.27 (14.00)	305.00	91.44 (300.00)	35.00
6.10 (20.00)	135.00	121.92 (400.00)	29.00
9.14 (30.00)	59.00	182.88 (600.00)	32.00
12.19 (40.00)	47.00	243.84 (800.00)	32.50
18.29 (60.00)	48.00	304.80 (1000.00)	35.00
24.38 (80.00)	45.00	304.80 (1000.00)	39.00
30.48 (100.00)	43.00	426.72 (1400.00)	43.00
42.67 (140.00)	39.00	609.60 (2000.00)	45.80
30.48 (100.00)	55.00	914.40 (3000.00)	43.70
42.67 (140.00)	47.00	1219.20 (4000.00)	41.70

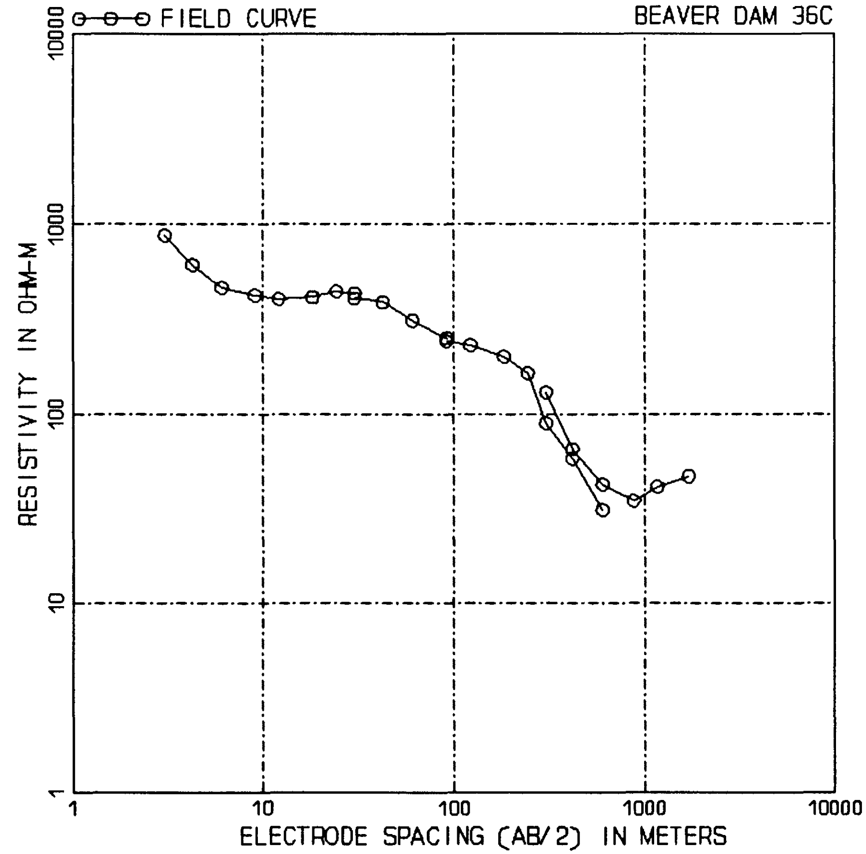
DEPTH, m (ft)	RESIS.	DEPTH, m (ft)	RESIS.
1.69 (5.53)	1152.49	36.33 (119.20)	40.20
2.48 (8.12)	230.89	53.33 (174.96)	23.54
3.63 (11.92)	45.35	78.27 (256.81)	22.94
5.33 (17.50)	42.80	114.89 (376.94)	33.11
7.83 (25.68)	58.90	168.64 (553.27)	48.35
11.49 (37.69)	66.86	247.53 (812.09)	56.84
16.86 (55.33)	72.65	363.32 (1191.99)	51.18
24.75 (81.21)	65.42	99999.00 (99999.00)	38.78



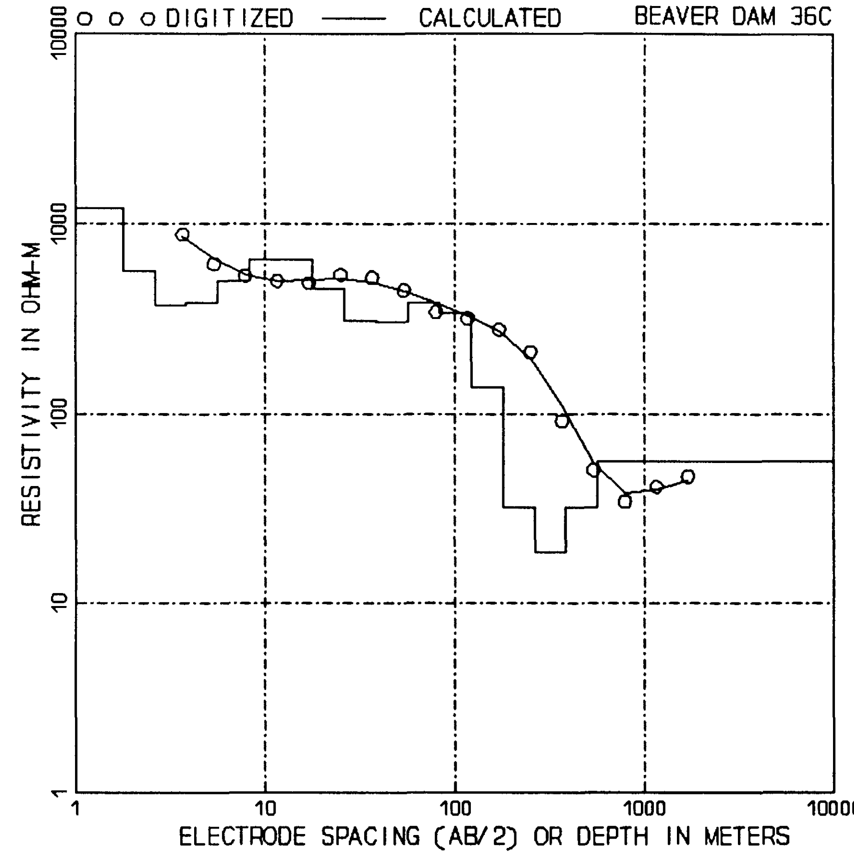
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	280.00	60.96	(200.00)	147.00
4.27	(14.00)	180.00	91.44	(300.00)	160.00
6.10	(20.00)	126.00	121.92	(400.00)	173.00
9.14	(30.00)	116.00	182.88	(600.00)	130.00
12.19	(40.00)	138.00	243.84	(800.00)	90.00
18.29	(60.00)	160.00	304.80	(1000.00)	42.50
24.38	(80.00)	168.00	304.80	(1000.00)	91.00
30.48	(100.00)	172.00	426.72	(1400.00)	78.00
30.48	(100.00)	160.00	609.60	(2000.00)	78.00
42.67	(140.00)	163.00	914.40	(3000.00)	90.50
			1219.20	(4000.00)	89.00



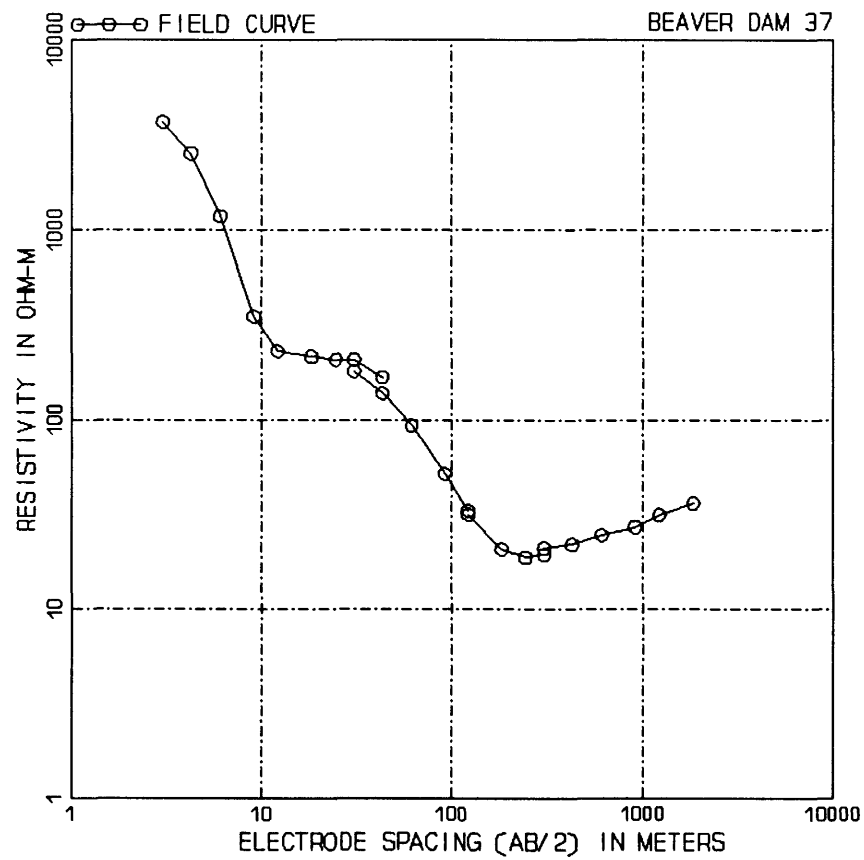
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.69	(5.53)	375.90	36.33	(119.20)	187.31
2.48	(8.12)	88.42	53.33	(174.96)	268.52
3.63	(11.92)	60.36	78.27	(256.81)	236.99
5.33	(17.50)	115.49	114.89	(376.94)	109.93
7.83	(25.68)	199.76	168.64	(553.27)	50.22
11.49	(37.69)	225.61	247.53	(812.09)	52.38
16.86	(55.33)	177.07	363.32	(1191.99)	78.71
24.75	(81.21)	146.37	99999.00	(99999.00)	100.21

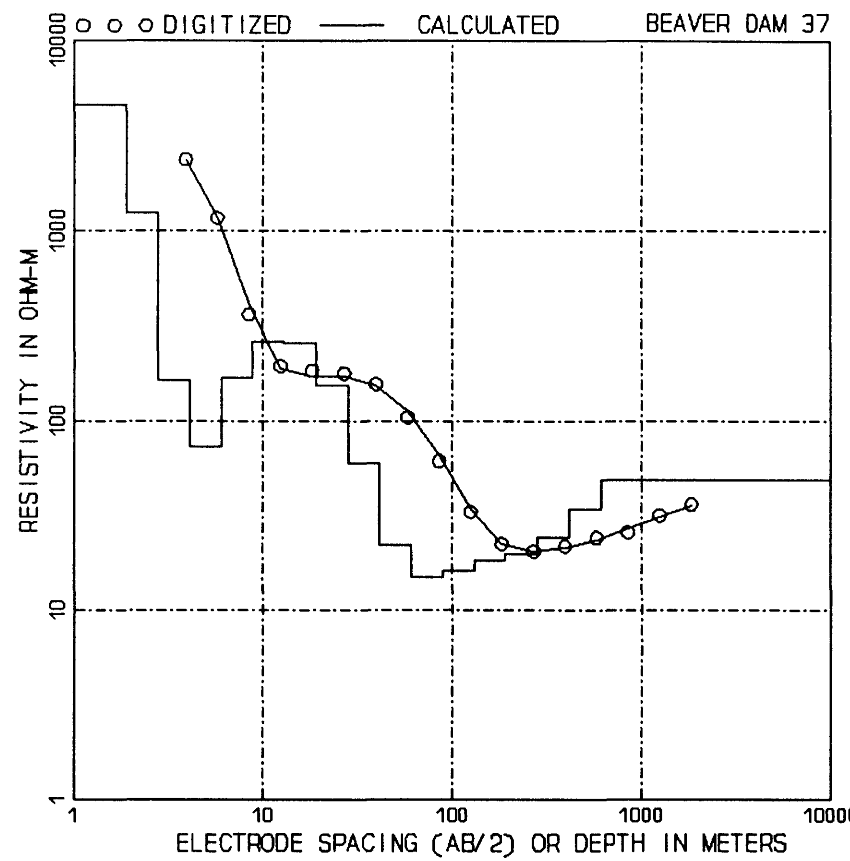


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	870.00	91.44	(300.00)	240.00
4.27	(14.00)	610.00	121.92	(400.00)	230.00
6.10	(20.00)	462.00	182.88	(600.00)	200.00
9.14	(30.00)	421.00	243.84	(800.00)	164.00
12.19	(40.00)	403.00	304.80	(1000.00)	89.00
18.29	(60.00)	412.00	418.80	(1374.00)	57.80
24.38	(80.00)	440.00	603.50	(1980.00)	31.20
30.48	(100.00)	430.00	304.80	(1000.00)	130.00
30.48	(100.00)	405.00	418.80	(1374.00)	64.90
42.67	(140.00)	387.00	603.50	(1980.00)	42.40
60.96	(200.00)	310.00	880.26	(2888.00)	34.80
91.44	(300.00)	250.00	1167.69	(3831.00)	41.20
			1705.66	(5596.00)	46.70



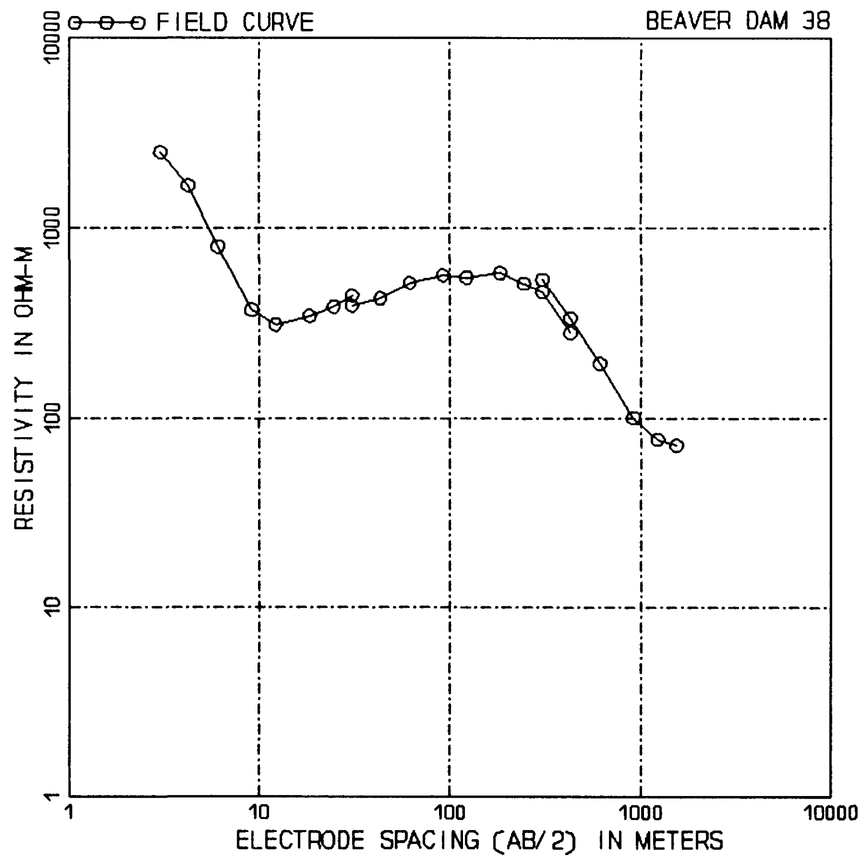
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.79	(5.86)	1200.40	38.48	(126.24)	306.13
2.62	(8.60)	562.87	56.48	(185.29)	303.40
3.85	(12.62)	369.23	82.90	(271.97)	380.59
5.65	(18.53)	380.80	121.67	(399.19)	335.64
8.29	(27.20)	499.83	178.59	(585.93)	138.40
12.17	(39.92)	651.71	262.14	(860.03)	32.04
17.86	(58.59)	647.43	384.77	(1262.35)	18.65
26.21	(86.00)	455.38	564.76	(1852.88)	32.02
			99999.00	(99999.00)	55.95

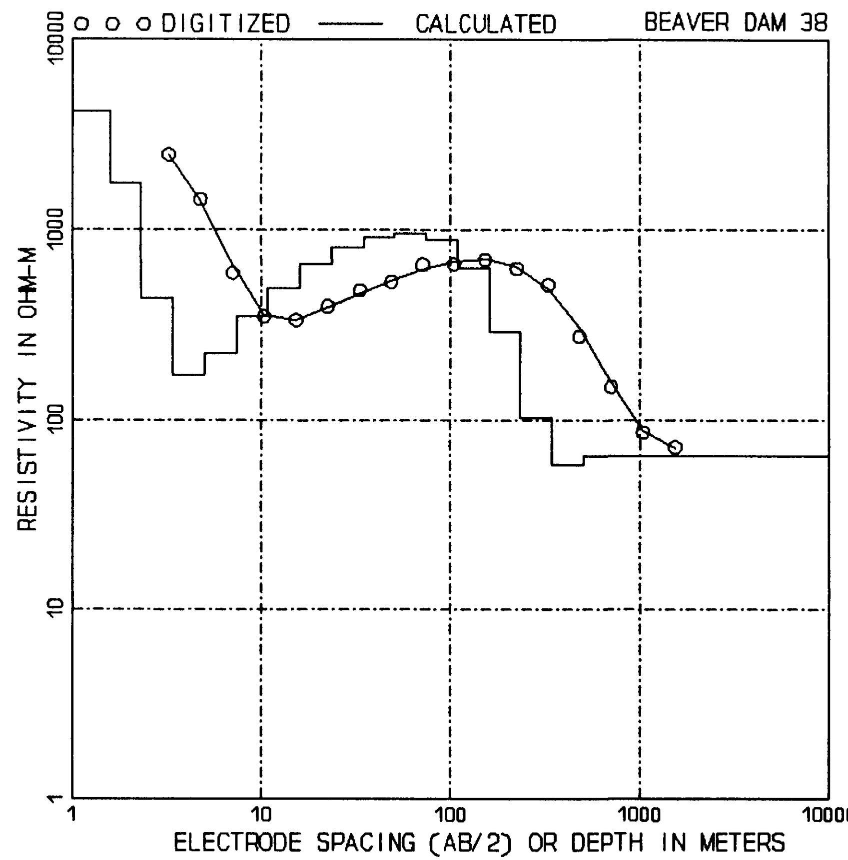




AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	3700.00	91.44 (	300.00)	52.00
4.27 (	14.00)	2520.00	121.92 (	400.00)	33.00
6.10 (	20.00)	1180.00	121.92 (	400.00)	31.50
9.14 (	30.00)	350.00	182.88 (	600.00)	20.70
12.19 (	40.00)	230.00	243.84 (	800.00)	18.80
18.29 (	60.00)	215.00	304.80 (	1000.00)	19.40
24.38 (	80.00)	207.00	304.80 (	1000.00)	21.00
30.48 (	100.00)	207.00	426.72 (	1400.00)	22.00
42.67 (	140.00)	167.00	609.60 (	2000.00)	24.70
30.48 (	100.00)	180.00	914.40 (	3000.00)	27.20
42.67 (	140.00)	138.00	1219.20 (	4000.00)	31.40
60.96 (	200.00)	93.00	1828.80 (	6000.00)	36.10

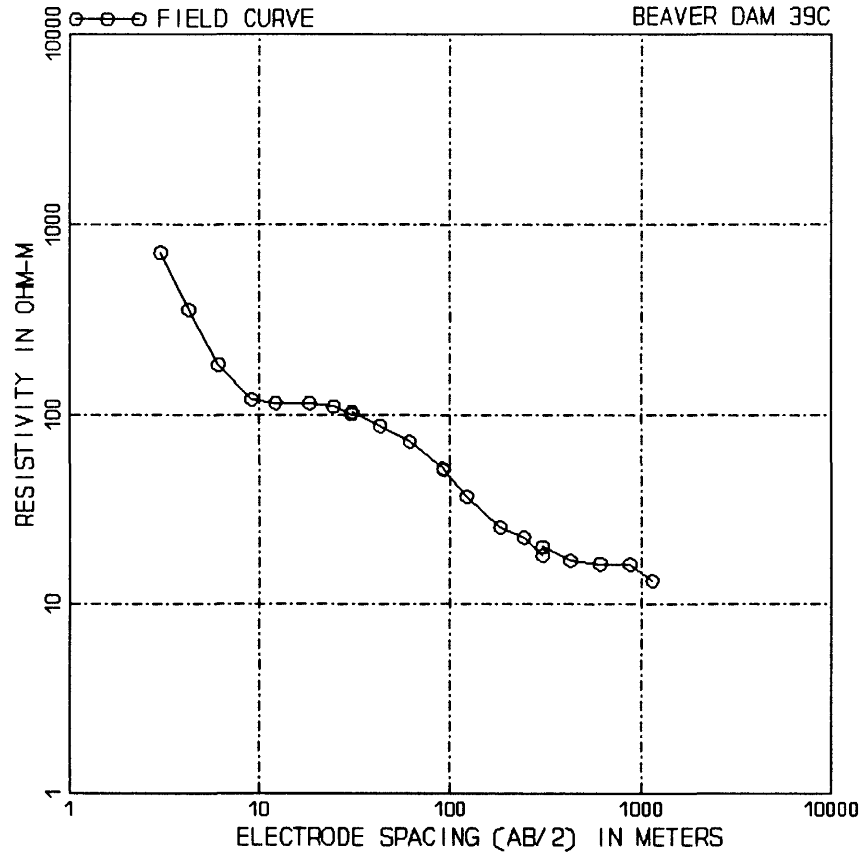
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.91 (	6.28)	4602.22	41.25 (	135.35)	59.29
2.81 (	9.22)	1235.81	60.55 (	198.66)	22.03
4.13 (	13.53)	164.21	88.88 (	291.60)	15.01
6.06 (	19.87)	73.00	130.46 (	428.01)	16.27
8.89 (	29.16)	169.16	191.49 (	628.23)	18.26
13.05 (	42.80)	261.85	281.06 (	922.12)	19.73
19.15 (	62.82)	254.20	412.54 (	1353.49)	24.09
28.11 (	92.21)	152.39	605.53 (	1986.65)	33.99
			99999.00 (	99999.00)	48.79

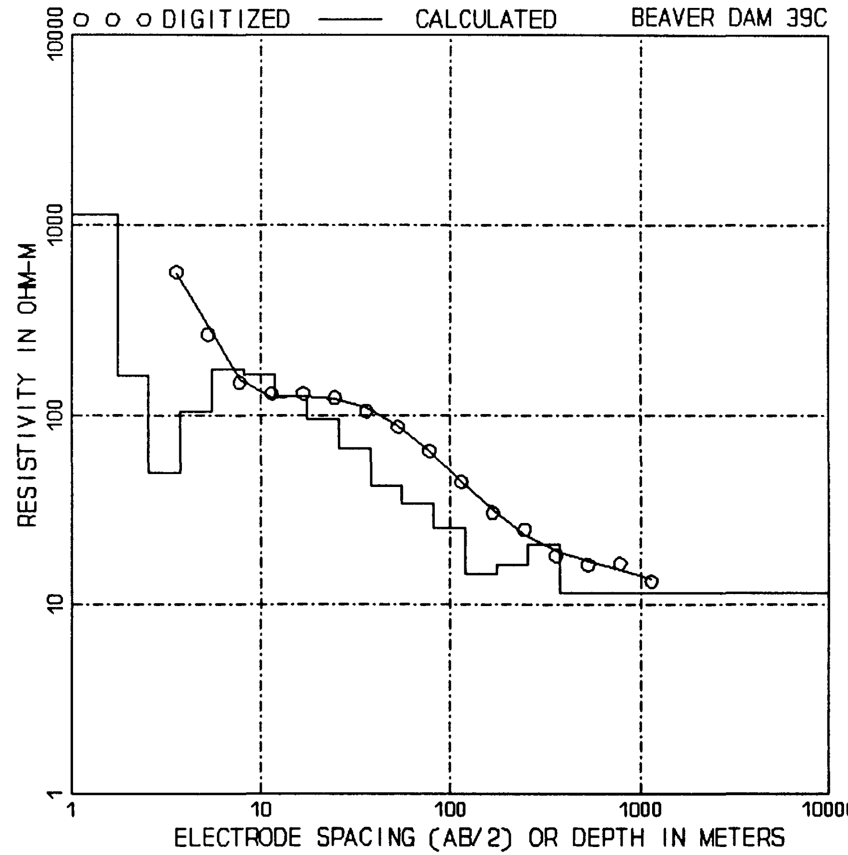




AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	2500.00	91.44	(300.00)	565.00
4.27	(14.00)	1670.00	121.92	(400.00)	550.00
6.10	(20.00)	800.00	182.88	(600.00)	580.00
9.14	(30.00)	370.00	243.84	(800.00)	510.00
12.19	(40.00)	310.00	304.80	(1000.00)	460.00
18.29	(60.00)	345.00	426.72	(1400.00)	280.00
24.38	(80.00)	385.00	304.80	(1000.00)	535.00
30.48	(100.00)	440.00	426.72	(1400.00)	335.00
30.48	(100.00)	390.00	609.60	(2000.00)	193.00
42.67	(140.00)	425.00	914.40	(3000.00)	100.00
60.96	(200.00)	515.00	1219.20	(4000.00)	77.00
			1524.00	(5000.00)	71.50

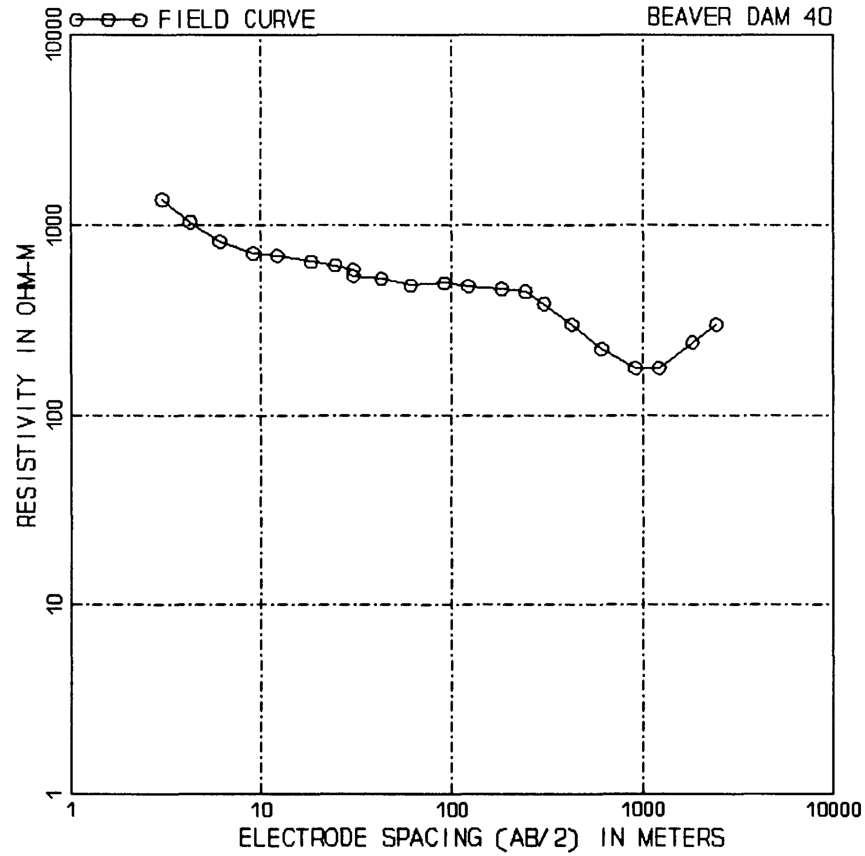
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.60	(5.24)	4208.08	34.38	(112.79)	806.11
2.34	(7.68)	1749.73	50.46	(165.55)	912.01
3.44	(11.28)	436.12	74.07	(243.00)	955.57
5.05	(16.56)	171.31	108.71	(356.68)	883.08
7.41	(24.30)	223.88	159.57	(523.53)	625.13
10.87	(35.67)	348.23	234.22	(768.43)	291.82
15.96	(52.35)	494.46	343.79	(1127.91)	102.57
23.42	(76.84)	655.69	504.61	(1655.54)	57.89
			99999.00	(99999.00)	64.84



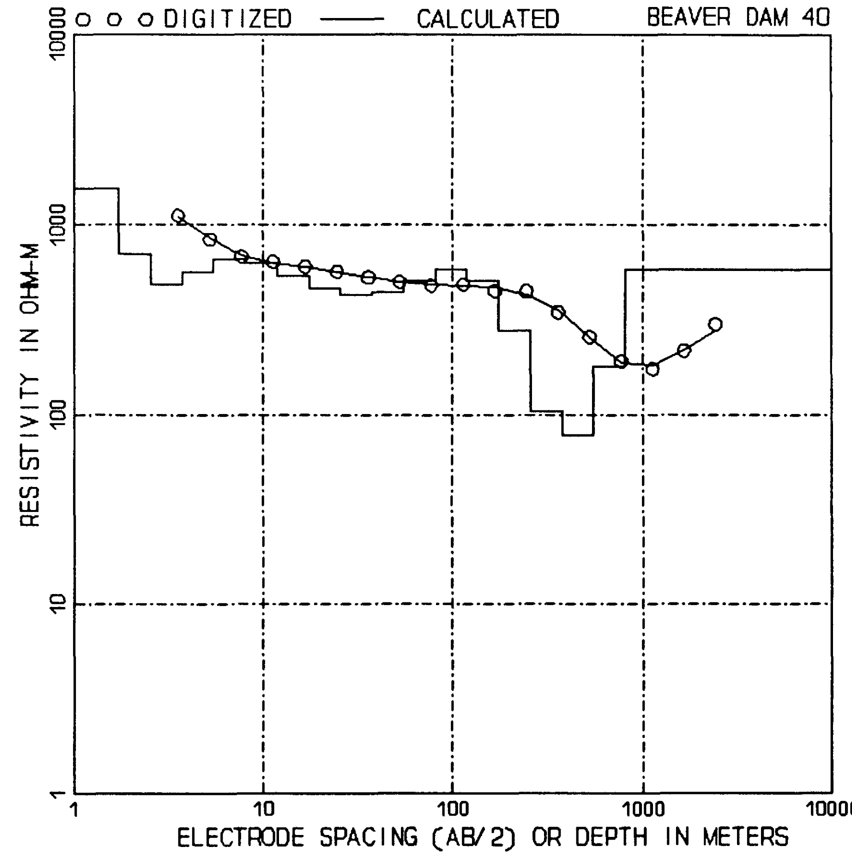


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	710.00	91.44	(300.00)	52.00
4.27	(14.00)	355.00	91.44	(300.00)	51.00
6.10	(20.00)	183.00	121.92	(400.00)	37.00
9.14	(30.00)	120.00	182.88	(600.00)	25.50
12.19	(40.00)	115.00	243.84	(800.00)	22.50
18.29	(60.00)	115.00	304.80	(1000.00)	18.00
24.38	(80.00)	110.00	304.80	(1000.00)	20.00
30.48	(100.00)	100.00	426.72	(1400.00)	17.00
30.48	(100.00)	103.00	609.60	(2000.00)	16.30
42.67	(140.00)	87.00	873.86	(2867.00)	16.20
60.96	(200.00)	72.00	1140.56	(3742.00)	13.30

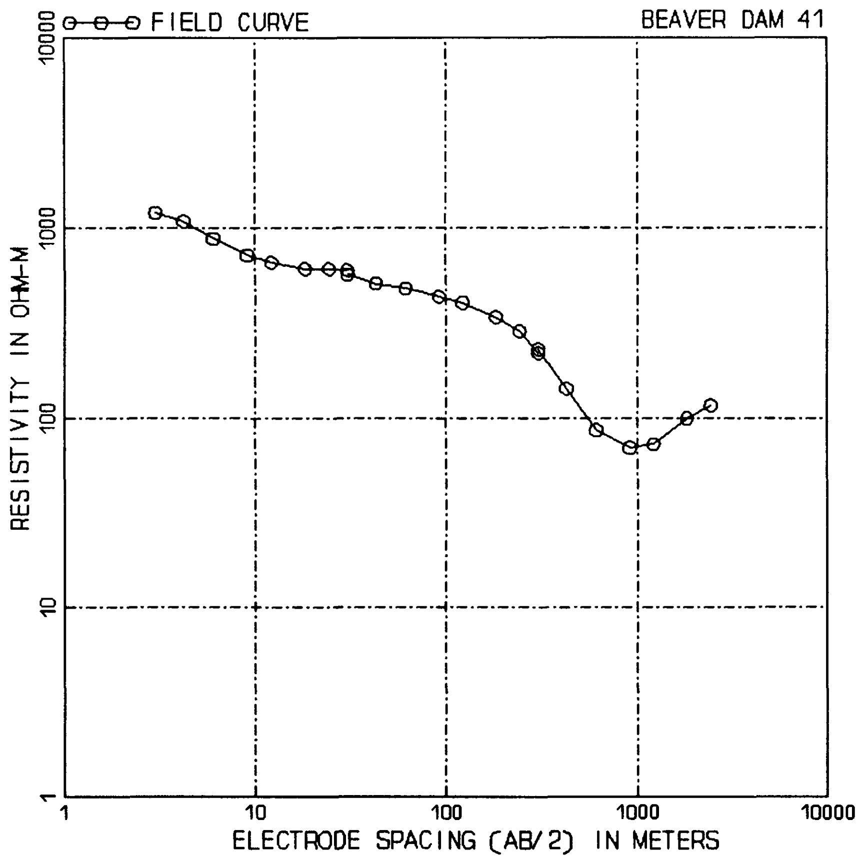
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.75	(5.75)	1129.35	37.76	(123.90)	66.70
2.57	(8.44)	160.47	55.43	(181.86)	42.55
3.78	(12.39)	49.62	81.36	(266.94)	34.12
5.54	(18.19)	104.44	119.42	(391.81)	25.45
8.14	(26.69)	172.72	175.29	(575.10)	14.54
11.94	(39.18)	164.12	257.29	(844.12)	16.24
17.53	(57.51)	126.16	377.65	(1239.01)	20.87
25.73	(84.41)	95.23	99999.00	(99999.00)	11.49



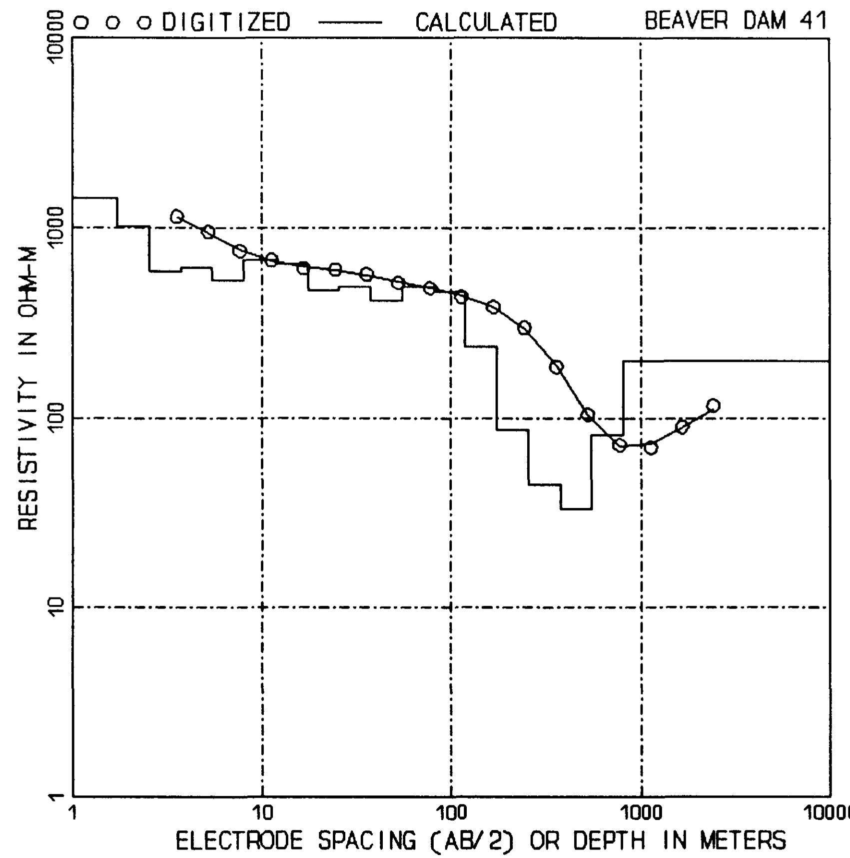
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	1360.00	91.44	(300.00)	495.00
4.27	(14.00)	1040.00	121.92	(400.00)	478.00
6.10	(20.00)	820.00	182.88	(600.00)	460.00
9.14	(30.00)	710.00	243.84	(800.00)	445.00
12.19	(40.00)	690.00	304.80	(1000.00)	385.00
18.29	(60.00)	645.00	304.80	(1000.00)	385.00
24.38	(80.00)	615.00	426.72	(1400.00)	300.00
30.48	(100.00)	585.00	609.60	(2000.00)	222.00
30.48	(100.00)	540.00	914.40	(3000.00)	177.00
42.67	(140.00)	520.00	1219.20	(4000.00)	177.00
60.96	(200.00)	480.00	1828.80	(6000.00)	240.00
			2438.40	(8000.00)	300.00



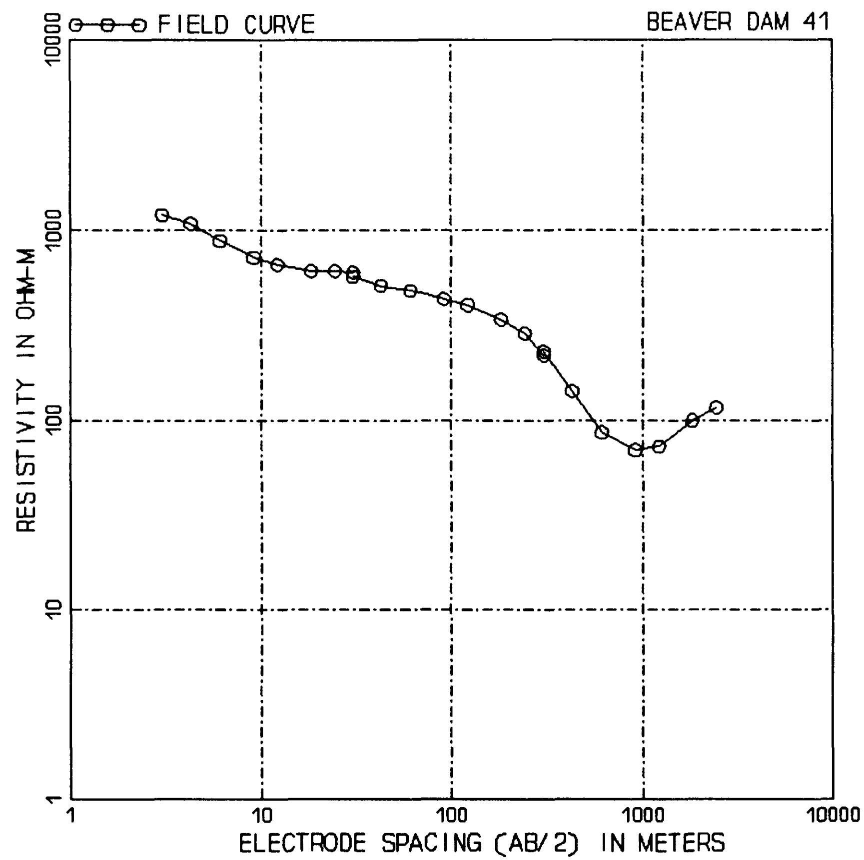
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.74	(5.71)	1560.33	55.01	(180.46)	441.51
2.55	(8.38)	696.05	80.74	(264.89)	510.79
3.75	(12.29)	480.51	118.51	(388.80)	584.98
5.50	(18.05)	567.25	173.94	(570.68)	508.15
8.07	(26.49)	660.59	255.31	(837.64)	276.29
11.85	(38.88)	626.43	374.75	(1229.49)	103.91
17.39	(57.07)	535.22	550.06	(1804.65)	77.45
25.53	(83.76)	461.59	807.37	(2648.86)	179.32
37.47	(122.95)	430.13	99999.00	(99999.00)	580.67



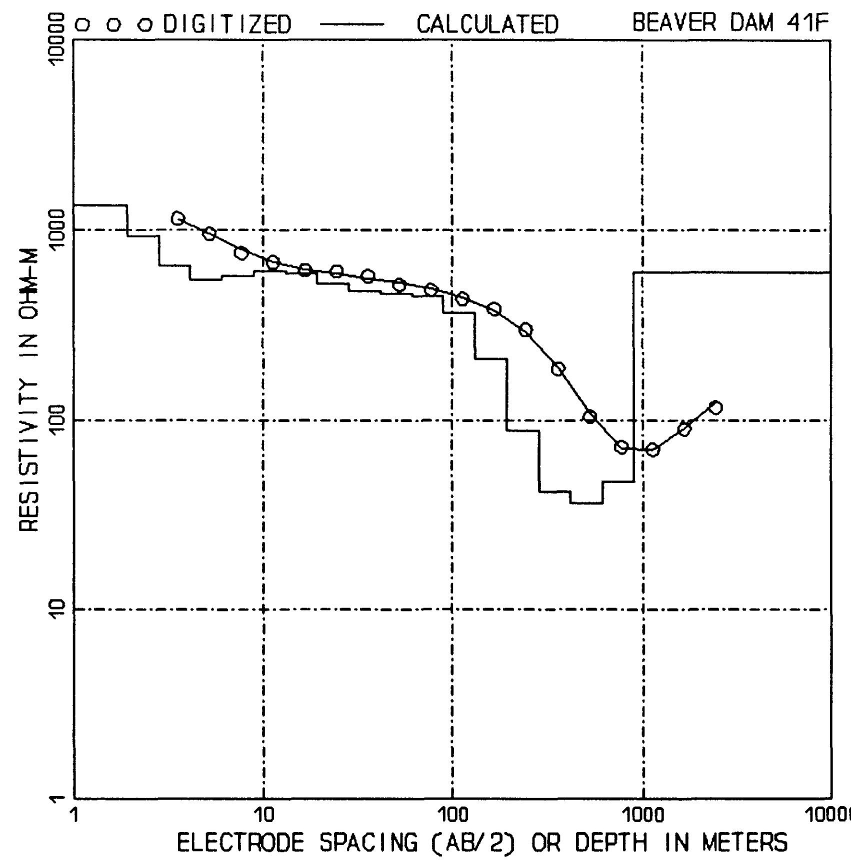
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	1200.00	91.44	(300.00)	435.00
4.27	(14.00)	1080.00	121.92	(400.00)	404.00
6.10	(20.00)	880.00	182.88	(600.00)	338.00
9.14	(30.00)	720.00	243.84	(800.00)	285.00
12.19	(40.00)	660.00	304.80	(1000.00)	220.00
18.29	(60.00)	610.00	304.80	(1000.00)	230.00
24.38	(80.00)	610.00	426.72	(1400.00)	142.00
30.48	(100.00)	600.00	609.60	(2000.00)	86.00
30.48	(100.00)	570.00	914.40	(3000.00)	69.30
42.67	(140.00)	510.00	1219.20	(4000.00)	72.50
60.96	(200.00)	480.00	1828.80	(6000.00)	99.00
			2438.40	(8000.00)	116.00



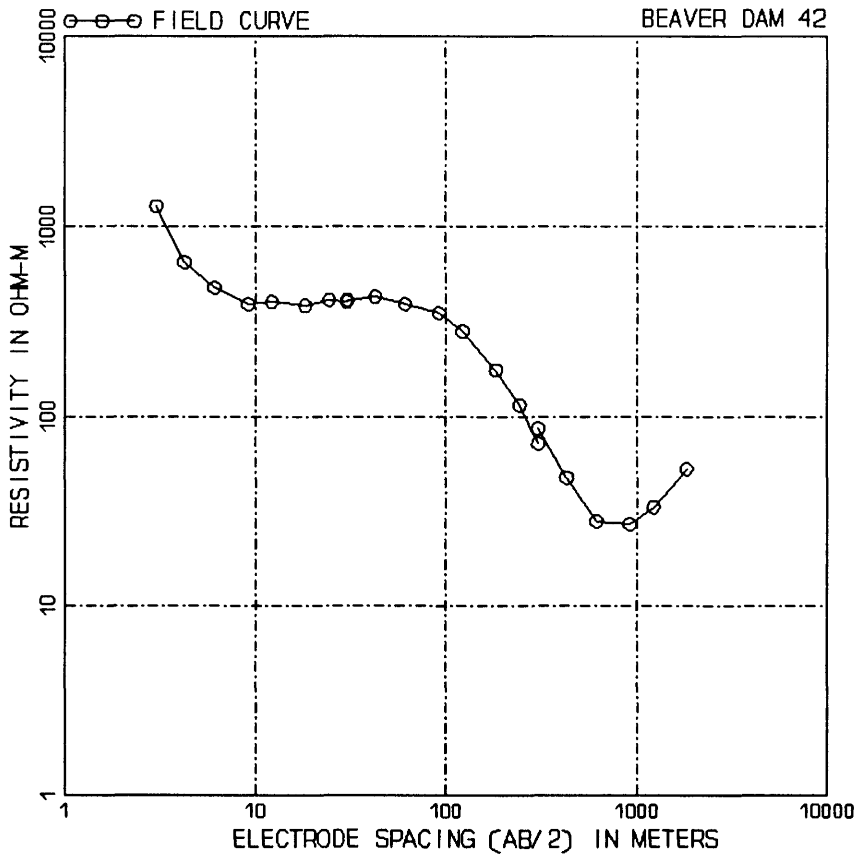
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.74	(5.71)	1430.79	55.01	(180.46)	415.37
2.55	(8.38)	1014.62	80.74	(264.89)	490.11
3.75	(12.29)	591.65	118.51	(388.80)	462.39
5.50	(18.05)	617.68	173.94	(570.68)	235.22
8.07	(26.49)	533.54	255.31	(837.64)	86.80
11.85	(38.88)	675.08	374.75	(1229.49)	44.41
17.39	(57.07)	649.82	550.06	(1804.65)	33.12
25.53	(83.76)	466.54	807.37	(2648.86)	80.96
37.47	(122.95)	492.62	99999.00	(99999.00)	200.56



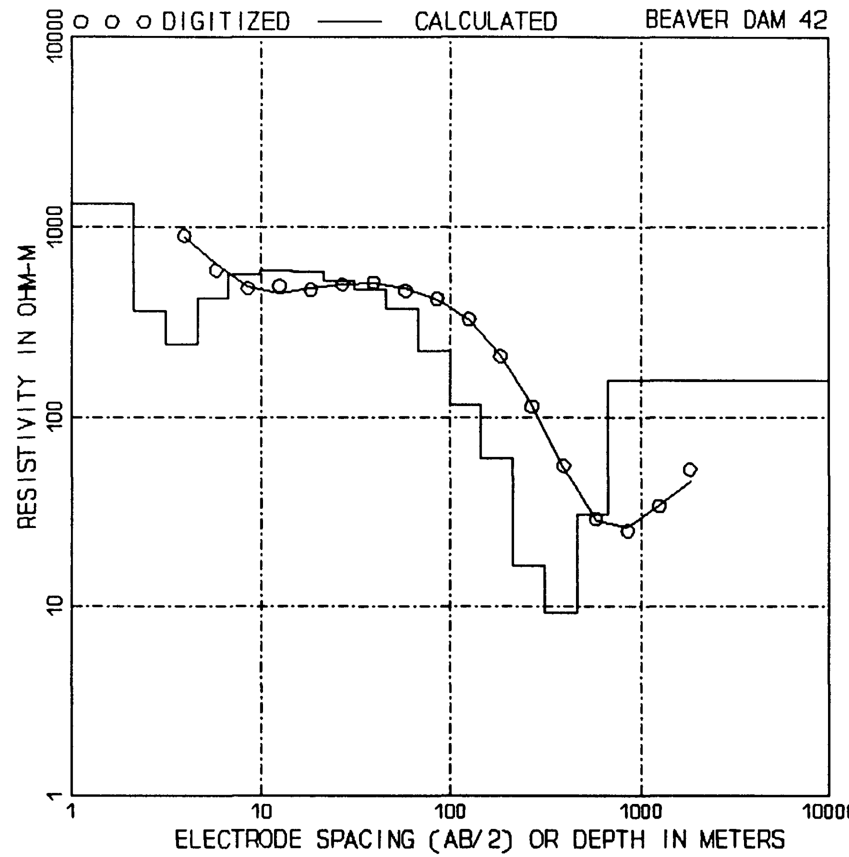
AB/2, m (	ft)	App. Res.	AB/2, m (	ft)	App. Res.
3.05 (	10.00)	1200.00	91.44 (	300.00)	435.00
4.27 (	14.00)	1080.00	121.92 (	400.00)	404.00
6.10 (	20.00)	880.00	182.88 (	600.00)	338.00
9.14 (	30.00)	720.00	243.84 (	800.00)	285.00
12.19 (	40.00)	660.00	304.80 (	1000.00)	220.00
18.29 (	60.00)	610.00	304.80 (	1000.00)	230.00
24.38 (	80.00)	610.00	426.72 (	1400.00)	142.00
30.48 (	100.00)	600.00	609.60 (	2000.00)	86.00
30.48 (	100.00)	570.00	914.40 (	3000.00)	69.30
42.67 (	140.00)	510.00	1219.20 (	4000.00)	72.50
60.96 (	200.00)	480.00	1828.80 (	6000.00)	99.00
			2438.40 (	8000.00)	116.00



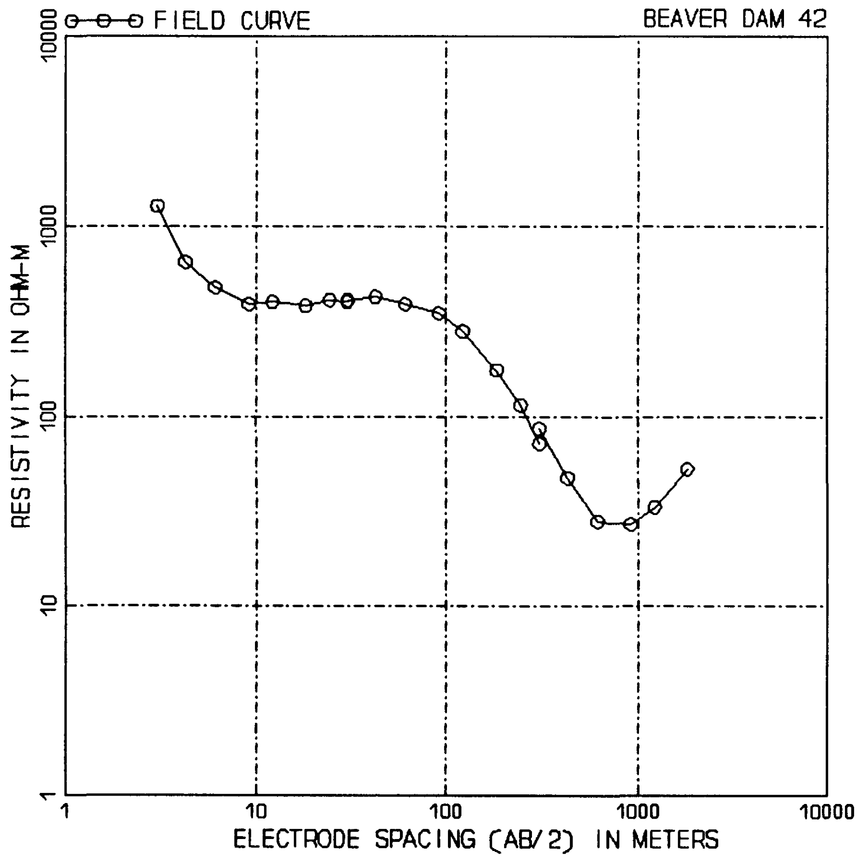
DEPTH, m (	ft)	RESIS.	DEPTH, m (	ft)	RESIS.
1.93 (	6.34)	1352.78	61.12 (	200.52)	460.50
2.84 (	9.31)	933.79	89.71 (	294.32)	446.64
4.16 (	13.66)	644.43	131.67 (	432.00)	363.32
6.11 (	20.05)	547.09	193.27 (	634.09)	209.32
8.97 (	29.43)	571.45	283.68 (	930.72)	87.19
13.17 (	43.20)	610.37	416.39 (	1366.10)	41.49
19.33 (	63.41)	588.22	611.17 (	2005.17)	36.22
28.37 (	93.07)	522.77	897.08 (	2943.18)	46.93
41.64 (	136.61)	474.01	99999.00 (	99999.00)	600.00



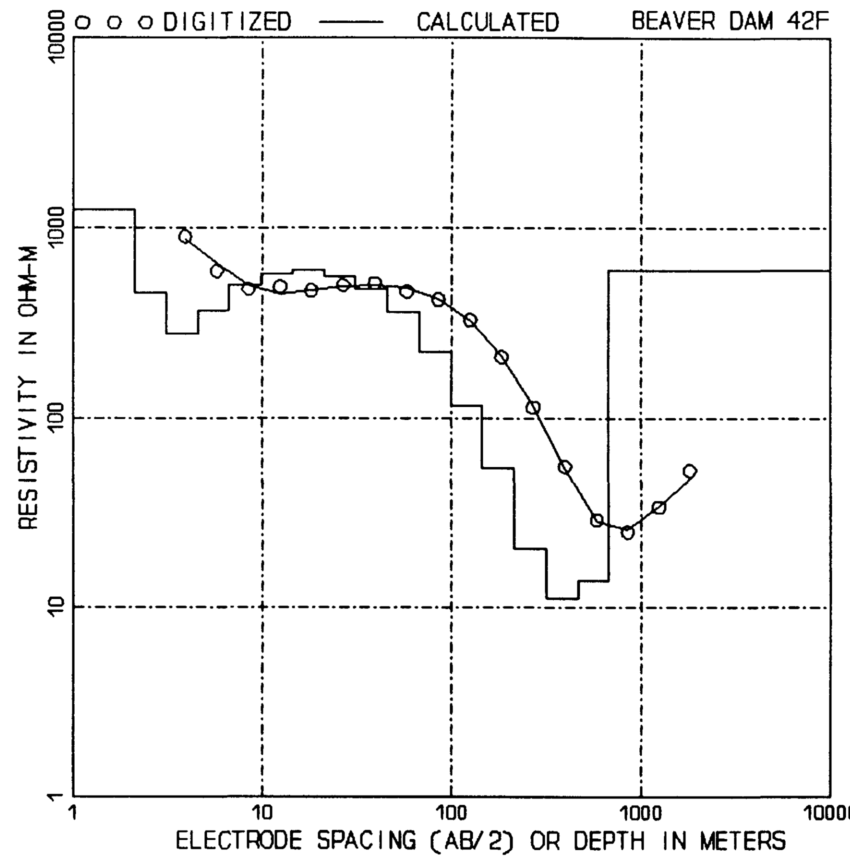
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	1275.00	91.44	(300.00)	350.00
4.27	(14.00)	650.00	121.92	(400.00)	280.00
6.10	(20.00)	475.00	182.88	(600.00)	175.00
9.14	(30.00)	390.00	243.84	(800.00)	115.00
12.19	(40.00)	400.00	304.80	(1000.00)	72.00
18.29	(60.00)	382.00	304.80	(1000.00)	86.00
24.38	(80.00)	410.00	426.72	(1400.00)	47.50
30.48	(100.00)	400.00	609.60	(2000.00)	28.00
30.48	(100.00)	410.00	914.40	(3000.00)	27.00
42.67	(140.00)	425.00	1219.20	(4000.00)	33.30
60.96	(200.00)	390.00	1828.80	(6000.00)	52.80



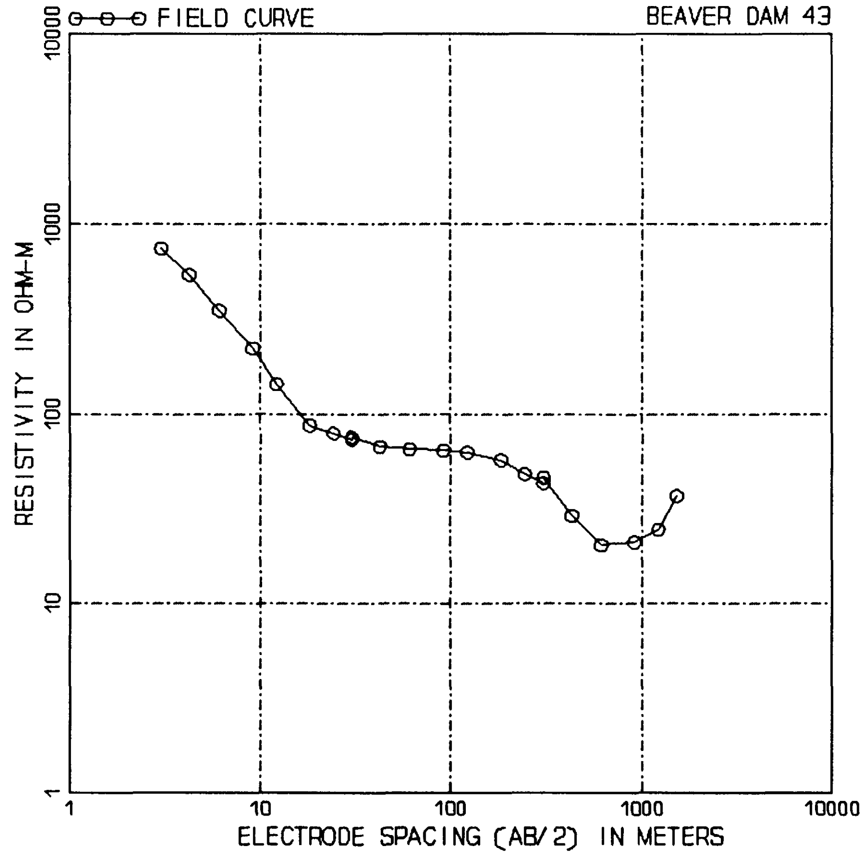
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.13	(6.98)	1322.72	45.84	(150.39)	465.98
3.12	(10.25)	359.21	67.28	(220.74)	369.39
4.58	(15.04)	239.89	98.76	(324.00)	222.89
6.73	(22.07)	419.70	144.95	(475.57)	116.18
9.88	(32.40)	560.73	212.76	(698.04)	60.15
14.50	(47.56)	590.77	312.29	(1024.58)	16.55
21.28	(69.80)	580.08	458.38	(1503.88)	9.28
31.23	(102.46)	525.84	672.81	(2207.39)	30.44
			99999.00	(99999.00)	155.09



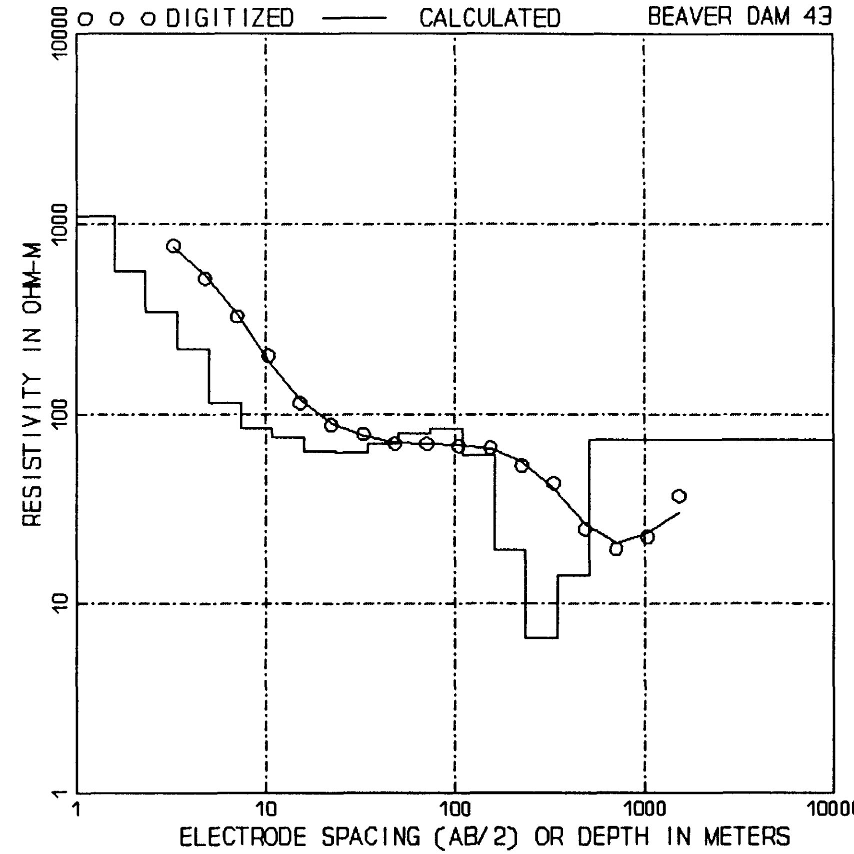
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	1275.00	91.44	(300.00)	350.00
4.27	(14.00)	650.00	121.92	(400.00)	280.00
6.10	(20.00)	475.00	182.88	(600.00)	175.00
9.14	(30.00)	390.00	243.84	(800.00)	115.00
12.19	(40.00)	400.00	304.80	(1000.00)	72.00
18.29	(60.00)	382.00	304.80	(1000.00)	86.00
24.38	(80.00)	410.00	426.72	(1400.00)	47.50
30.48	(100.00)	400.00	609.60	(2000.00)	28.00
30.48	(100.00)	410.00	914.40	(3000.00)	27.00
42.67	(140.00)	425.00	1219.20	(4000.00)	33.30
60.96	(200.00)	390.00	1828.80	(6000.00)	52.80



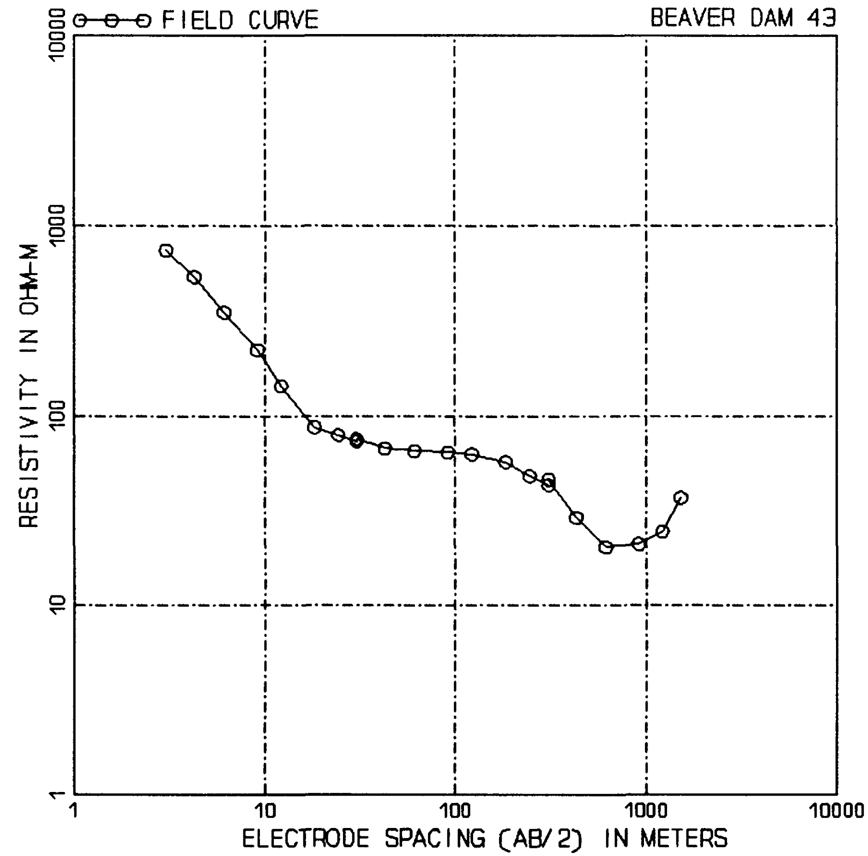
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.13	(6.98)	1242.88	45.84	(150.39)	475.95
3.12	(10.25)	453.70	67.28	(220.74)	361.58
4.58	(15.04)	274.55	98.76	(324.00)	223.02
6.73	(22.07)	363.31	144.95	(475.57)	115.90
9.88	(32.40)	497.91	212.76	(698.04)	54.63
14.50	(47.56)	577.51	312.29	(1024.58)	20.28
21.28	(69.80)	595.90	458.38	(1503.88)	11.23
31.23	(102.46)	553.23	672.81	(2207.39)	13.81
			99999.00	(99999.00)	600.00



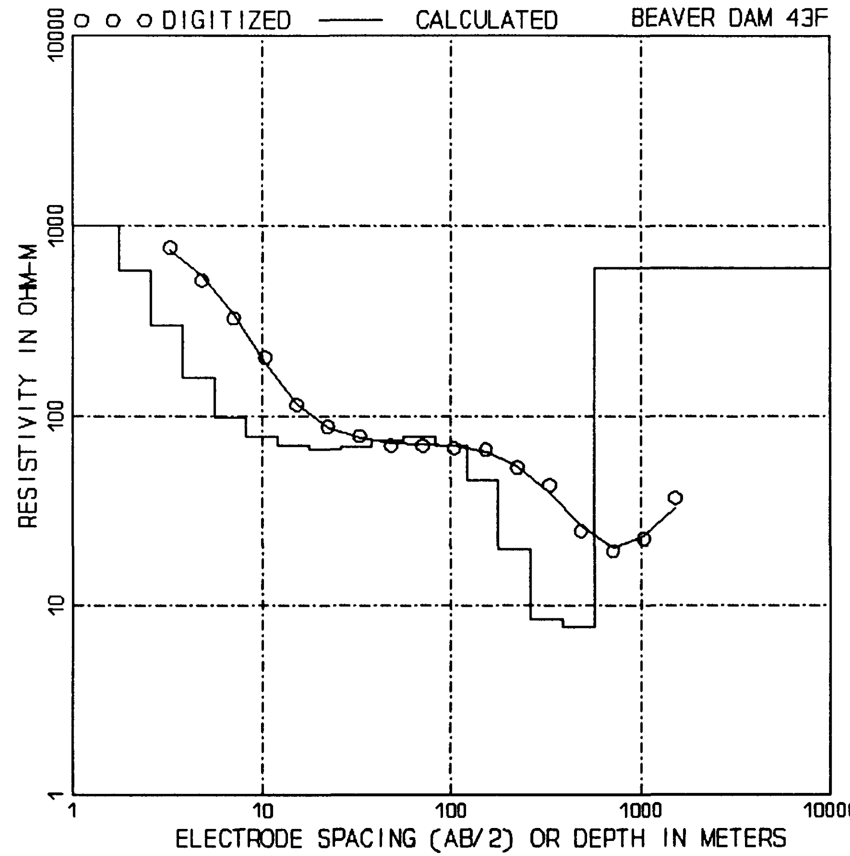
AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	742.00	91.44	(300.00)	64.00
4.27	(14.00)	541.00	121.92	(400.00)	62.50
6.10	(20.00)	350.00	182.88	(600.00)	57.00
9.14	(30.00)	221.00	243.84	(800.00)	48.00
12.19	(40.00)	143.00	304.80	(1000.00)	43.00
18.29	(60.00)	87.00	304.80	(1000.00)	46.00
24.38	(80.00)	79.00	426.72	(1400.00)	29.00
30.48	(100.00)	73.00	609.60	(2000.00)	20.30
30.48	(100.00)	75.00	914.40	(3000.00)	21.00
42.67	(140.00)	67.00	1219.20	(4000.00)	24.50
60.96	(200.00)	65.00	1524.00	(5000.00)	36.80



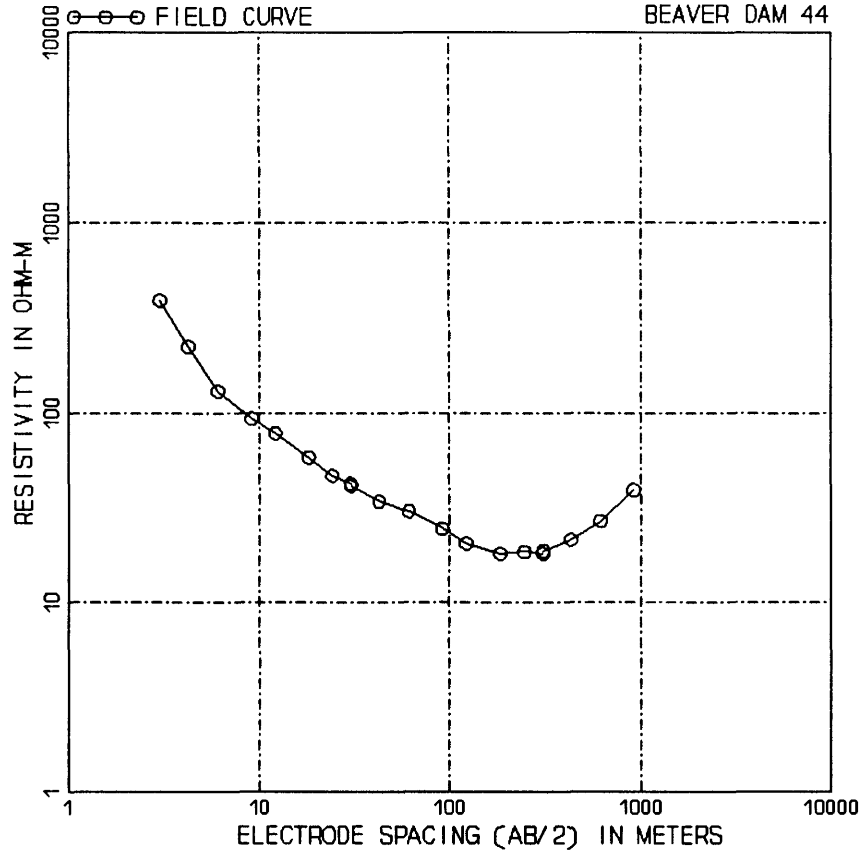
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.60	(5.24)	1099.34	34.38	(112.79)	62.22
2.34	(7.68)	568.60	50.46	(165.55)	69.13
3.44	(11.28)	344.62	74.07	(243.00)	78.98
5.05	(16.56)	219.53	108.71	(356.68)	84.10
7.41	(24.30)	114.82	159.57	(523.53)	60.67
10.87	(35.67)	84.25	234.22	(768.43)	19.11
15.96	(52.35)	74.59	343.79	(1127.91)	6.57
23.42	(76.84)	63.57	504.61	(1655.54)	14.01
			99999.00	(99999.00)	72.65

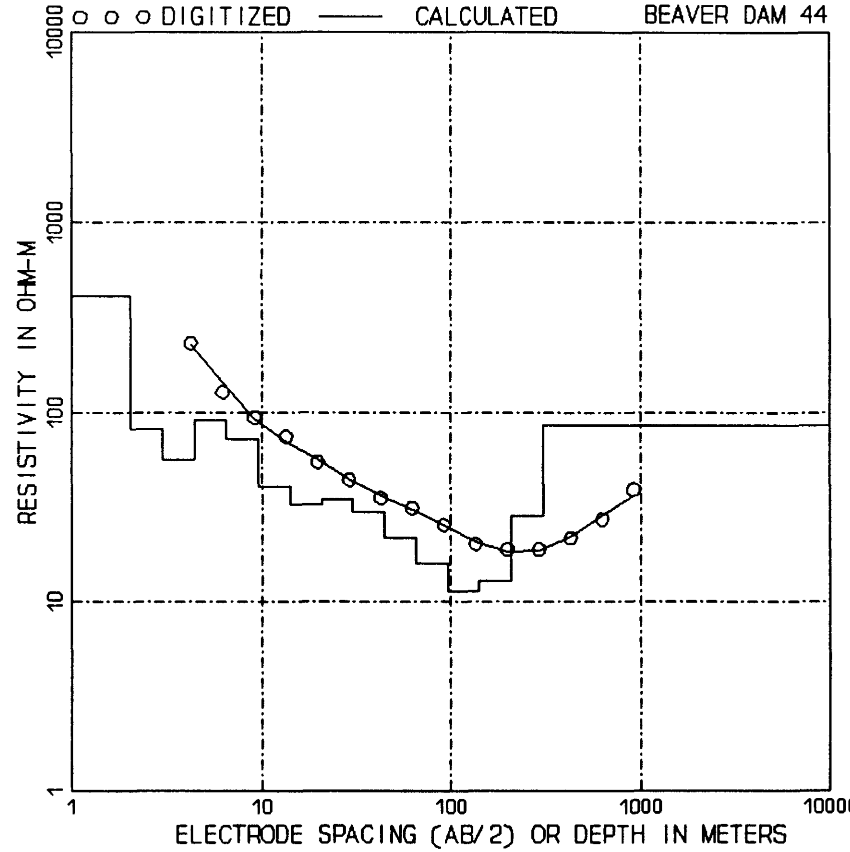


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	742.00	91.44	(300.00)	64.00
4.27	(14.00)	541.00	121.92	(400.00)	62.50
6.10	(20.00)	350.00	182.88	(600.00)	57.00
9.14	(30.00)	221.00	243.84	(800.00)	48.00
12.19	(40.00)	143.00	304.80	(1000.00)	43.00
18.29	(60.00)	87.00	304.80	(1000.00)	46.00
24.38	(80.00)	79.00	426.72	(1400.00)	29.00
30.48	(100.00)	73.00	609.60	(2000.00)	20.30
30.48	(100.00)	75.00	914.40	(3000.00)	21.00
42.67	(140.00)	67.00	1219.20	(4000.00)	24.50
60.96	(200.00)	65.00	1524.00	(5000.00)	36.80



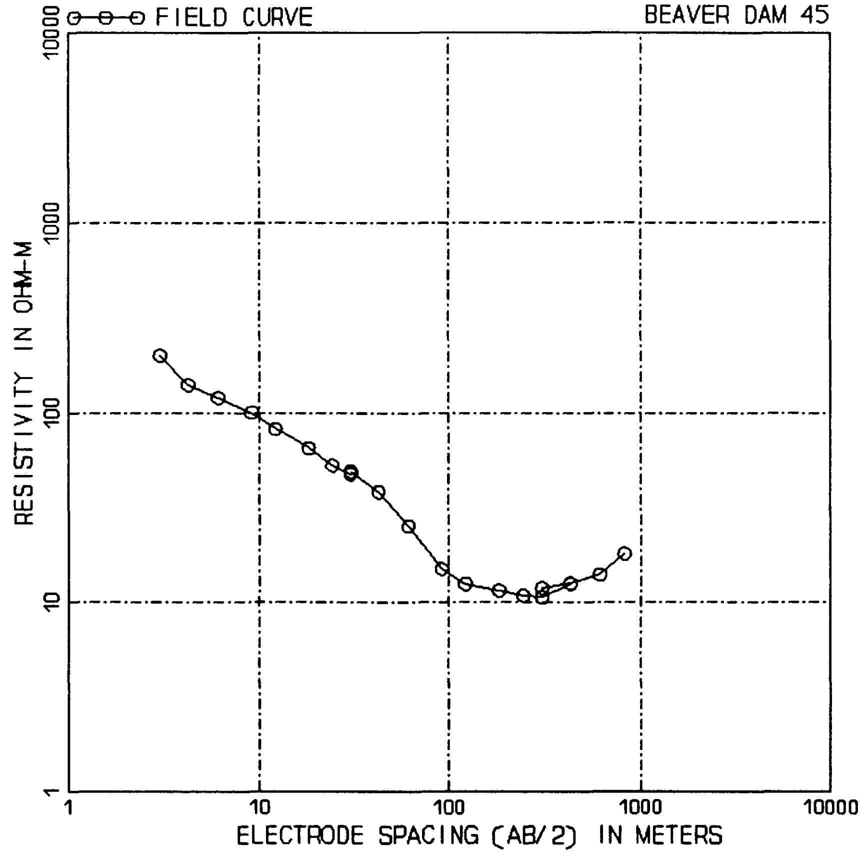
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
1.77	(5.82)	1002.63	38.20	(125.32)	68.50
2.60	(8.54)	584.56	56.07	(183.95)	74.37
3.82	(12.53)	299.60	82.30	(270.00)	77.50
5.61	(18.39)	158.78	120.79	(396.31)	69.49
8.23	(27.00)	98.49	177.30	(581.70)	45.99
12.08	(39.63)	77.07	260.24	(853.82)	19.74
17.73	(58.17)	69.40	381.98	(1253.23)	8.39
26.02	(85.38)	66.17	560.68	(1839.49)	7.65
			99999.00	(99999.00)	600.00

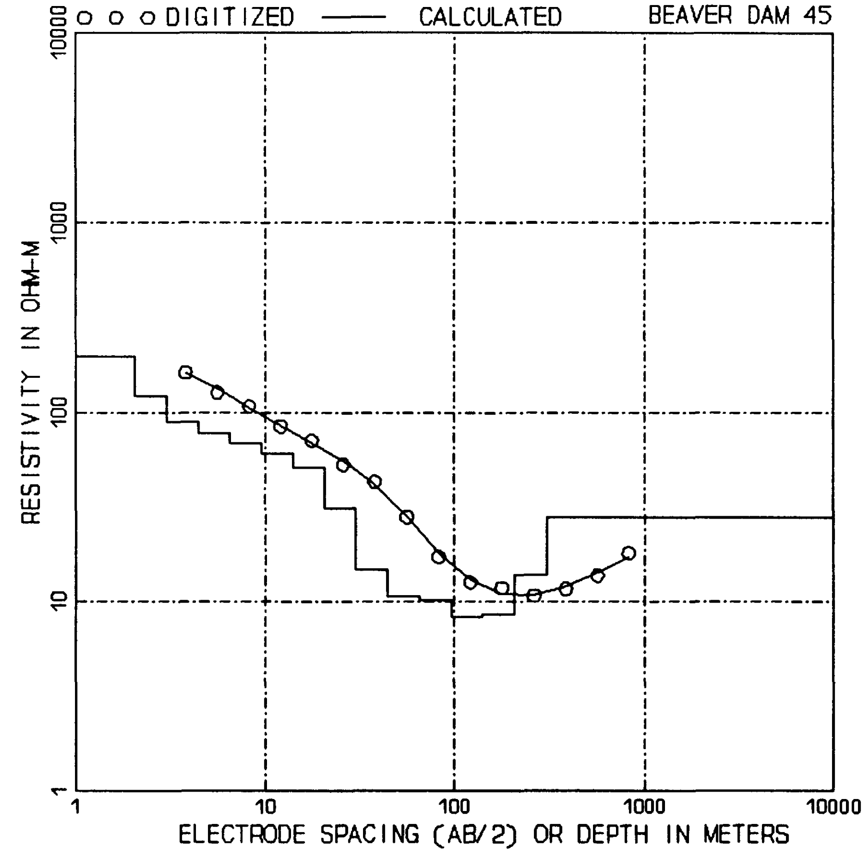




AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	390.00	60.96	(200.00)	30.30
4.27	(14.00)	222.00	91.44	(300.00)	24.50
6.10	(20.00)	130.00	121.92	(400.00)	20.50
9.14	(30.00)	93.00	182.88	(600.00)	18.00
12.19	(40.00)	78.00	243.84	(800.00)	18.50
18.29	(60.00)	58.00	304.80	(1000.00)	18.00
24.38	(80.00)	46.50	304.80	(1000.00)	18.70
30.48	(100.00)	42.20	426.72	(1400.00)	21.50
30.48	(100.00)	41.00	609.60	(2000.00)	26.80
42.67	(140.00)	34.00	914.40	(3000.00)	39.00

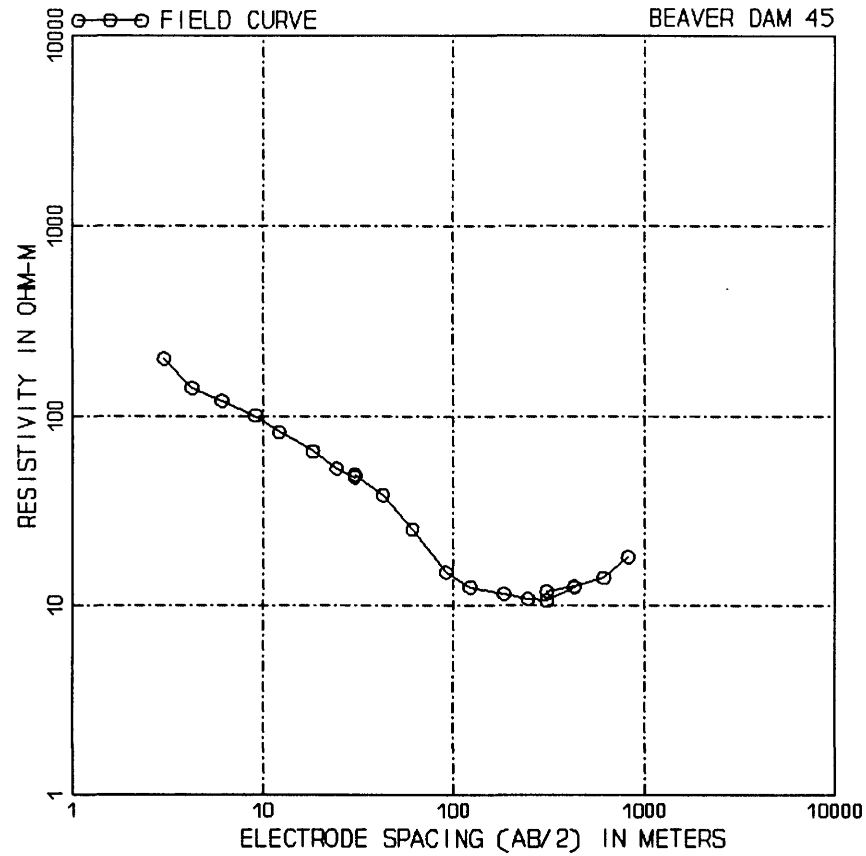
DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.06	(6.77)	404.83	30.28	(99.33)	34.66
3.03	(9.93)	81.75	44.44	(145.80)	29.64
4.44	(14.58)	55.61	65.23	(214.01)	21.86
6.52	(21.40)	90.43	95.74	(314.12)	15.97
9.57	(31.41)	72.28	140.53	(461.06)	11.30
14.05	(46.11)	40.30	206.27	(676.74)	12.78
20.63	(67.67)	32.49	302.77	(993.32)	28.22
			99999.00	(99999.00)	85.05



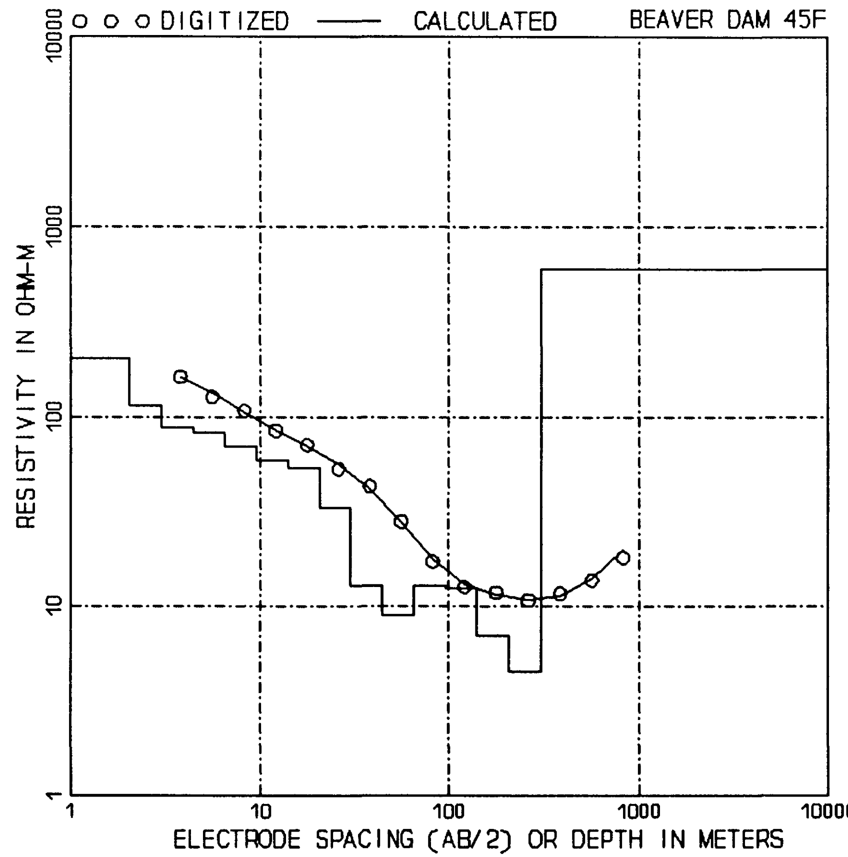


AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	200.00	60.96	(200.00)	25.20
4.27	(14.00)	140.00	91.44	(300.00)	15.00
6.10	(20.00)	120.00	121.92	(400.00)	12.50
9.14	(30.00)	100.00	182.88	(600.00)	11.50
12.19	(40.00)	82.00	243.84	(800.00)	10.80
18.29	(60.00)	65.00	304.80	(1000.00)	10.60
24.38	(80.00)	52.50	426.72	(1400.00)	12.50
30.48	(100.00)	47.50	304.80	(1000.00)	11.90
30.48	(100.00)	49.00	426.72	(1400.00)	12.60
42.67	(140.00)	38.20	609.60	(2000.00)	14.00
			822.96	(2700.00)	18.00

DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.06	(6.77)	197.22	30.28	(99.33)	31.11
3.03	(9.93)	122.53	44.44	(145.80)	14.70
4.44	(14.58)	89.16	65.23	(214.01)	10.59
6.52	(21.40)	77.71	95.74	(314.12)	10.23
9.57	(31.41)	69.05	140.53	(461.06)	8.32
14.05	(46.11)	60.79	206.27	(676.74)	8.59
20.63	(67.67)	51.06	302.77	(993.32)	13.89
			99999.00	(99999.00)	27.85



AB/2, m	(ft)	App. Res.	AB/2, m	(ft)	App. Res.
3.05	(10.00)	200.00	60.96	(200.00)	25.20
4.27	(14.00)	140.00	91.44	(300.00)	15.00
6.10	(20.00)	120.00	121.92	(400.00)	12.50
9.14	(30.00)	100.00	182.88	(600.00)	11.50
12.19	(40.00)	82.00	243.84	(800.00)	10.80
18.29	(60.00)	65.00	304.80	(1000.00)	10.60
24.38	(80.00)	52.50	426.72	(1400.00)	12.50
30.48	(100.00)	47.50	304.80	(1000.00)	11.90
30.48	(100.00)	49.00	426.72	(1400.00)	12.60
42.67	(140.00)	38.20	609.60	(2000.00)	14.00
			822.96	(2700.00)	18.00



DEPTH, m	(ft)	RESIS.	DEPTH, m	(ft)	RESIS.
2.06	(6.77)	201.49	30.28	(99.33)	33.13
3.03	(9.93)	113.80	44.44	(145.80)	12.74
4.44	(14.58)	87.32	65.23	(214.01)	8.94
6.52	(21.40)	82.01	95.74	(314.12)	12.83
9.57	(31.41)	69.70	140.53	(461.06)	12.35
14.05	(46.11)	58.48	206.27	(676.74)	6.98
20.63	(67.67)	53.13	302.77	(993.32)	4.57
			99999.00	(99999.00)	600.00

APPENDIX 3

Longitude and Latitude coordinates of sounding locations in degrees.

Sounding number	Longitude	Latitude	Sounding number	Longitude	Latitude
1	-114.00705	36.95233	24	-113.96796	37.05337
2	-114.02705	36.95415	25	-113.98012	37.04080
3	-114.04483	36.95227	26	-114.00204	37.03103
4	-114.06544	36.95575	27	-113.97234	37.08345
5	-113.91088	37.01128	28	-113.97849	37.10500
6	-113.92262	37.00494	29	-113.99918	37.11840
7	-113.93583	36.99935	30	-114.02363	37.08815
8	-113.94962	36.99375	31	-114.04626	37.08398
9	-113.96754	36.98616	32	-114.05759	37.07447
10	-113.98983	36.97799	33	-114.07083	37.06319
11	-113.96256	36.97430	34	-114.08428	37.05202
12	-113.96089	36.95833	35	-114.09670	37.04146
13	-113.92549	36.91264	36	-113.98895	37.13431
14	-113.91372	36.91822	37	-113.90515	36.88812
15	-113.89763	36.92884	38	-113.90234	36.86859
16	-113.88356	36.94173	39	-114.03401	36.95787
17	-113.95815	36.88961	40	-113.95304	37.14781
18	-113.93362	36.89969	41	-113.97009	37.14671
19	-113.95283	36.87273	42	-113.99312	37.14248
20	-113.96516	36.86012	43	-114.00612	37.13960
21	-113.97723	36.84789	44	-113.99749	37.22285
22	-113.94313	36.89650	45	-114.02406	37.14176
23	-113.93098	37.02200			

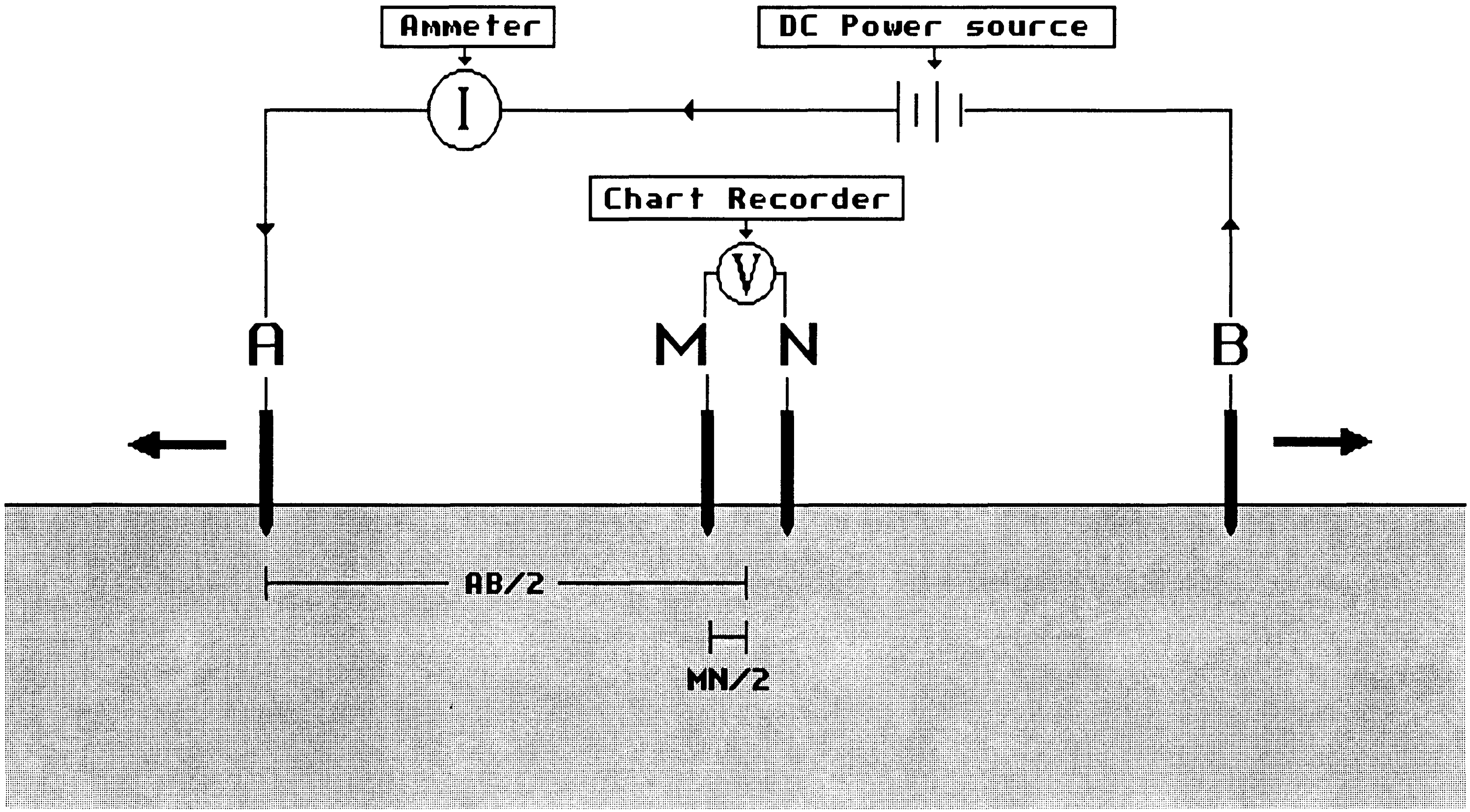


Figure 1. Schlumberger electrode array. A and B, current electrodes; M and N, potential electrodes. Arrows show direction of expansion.

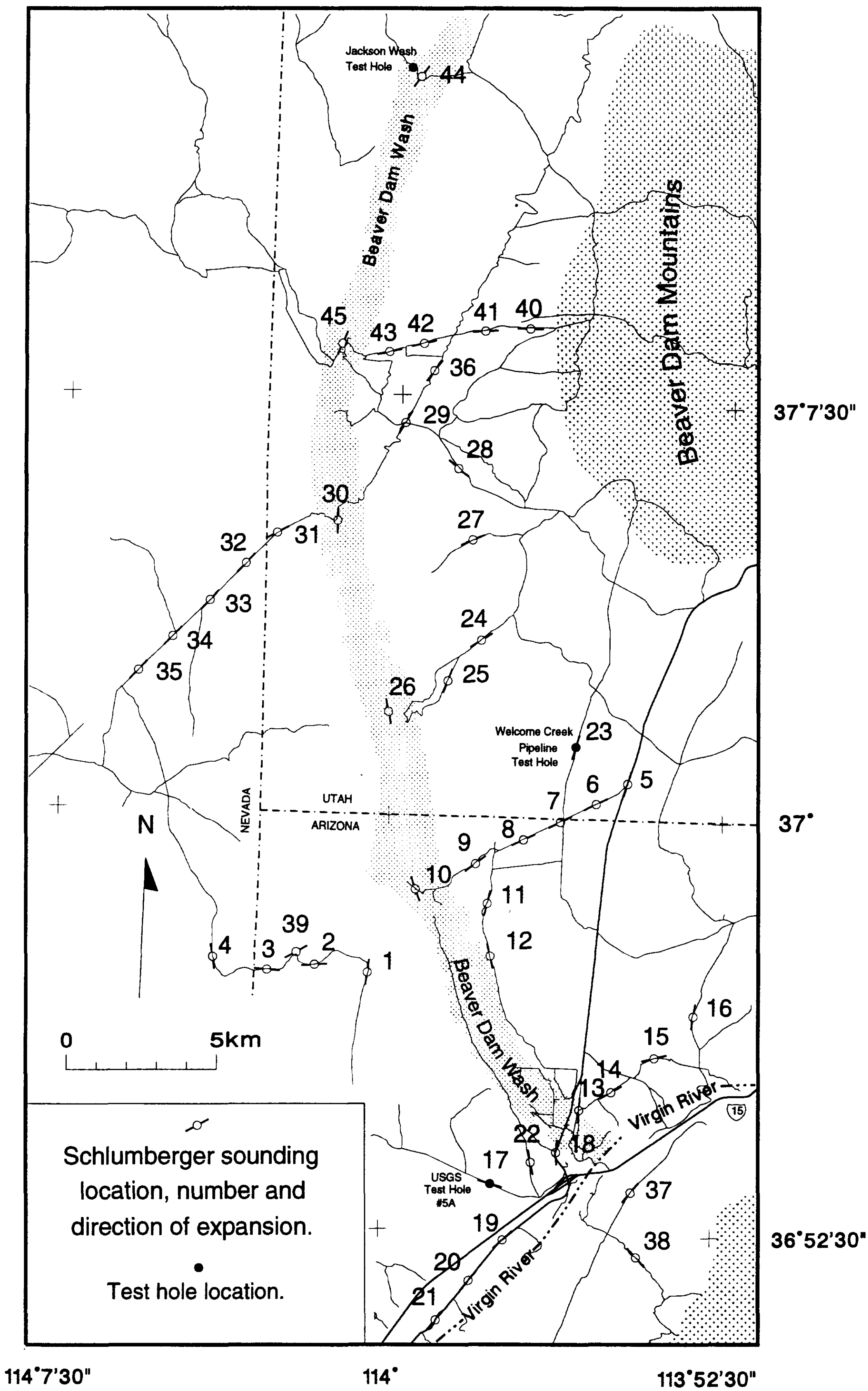


Figure 2. Map showing location of Schlumberger-sounding stations.

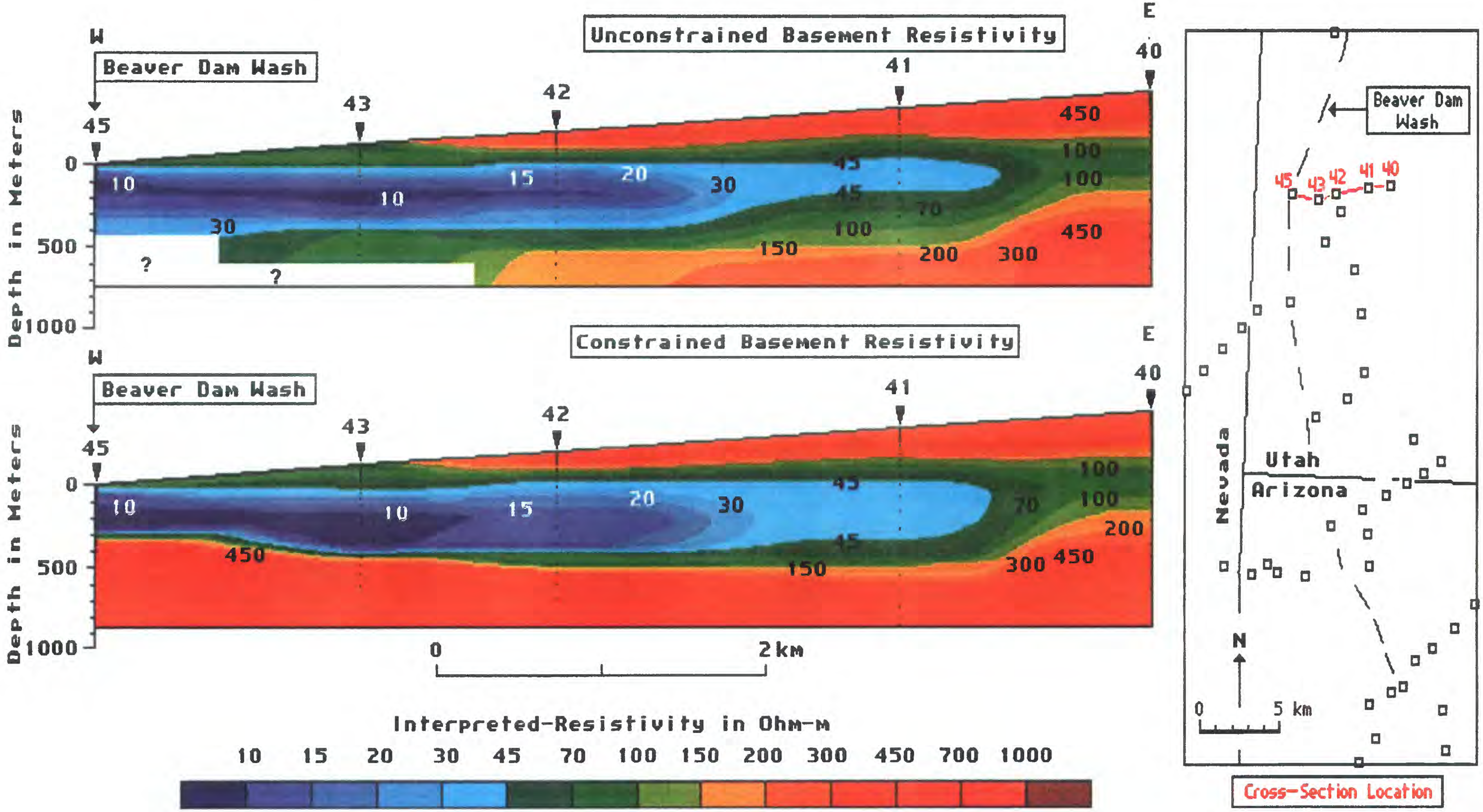


Figure 3. Two equivalent interpreted-resistivity representations of cross-section 45-40.

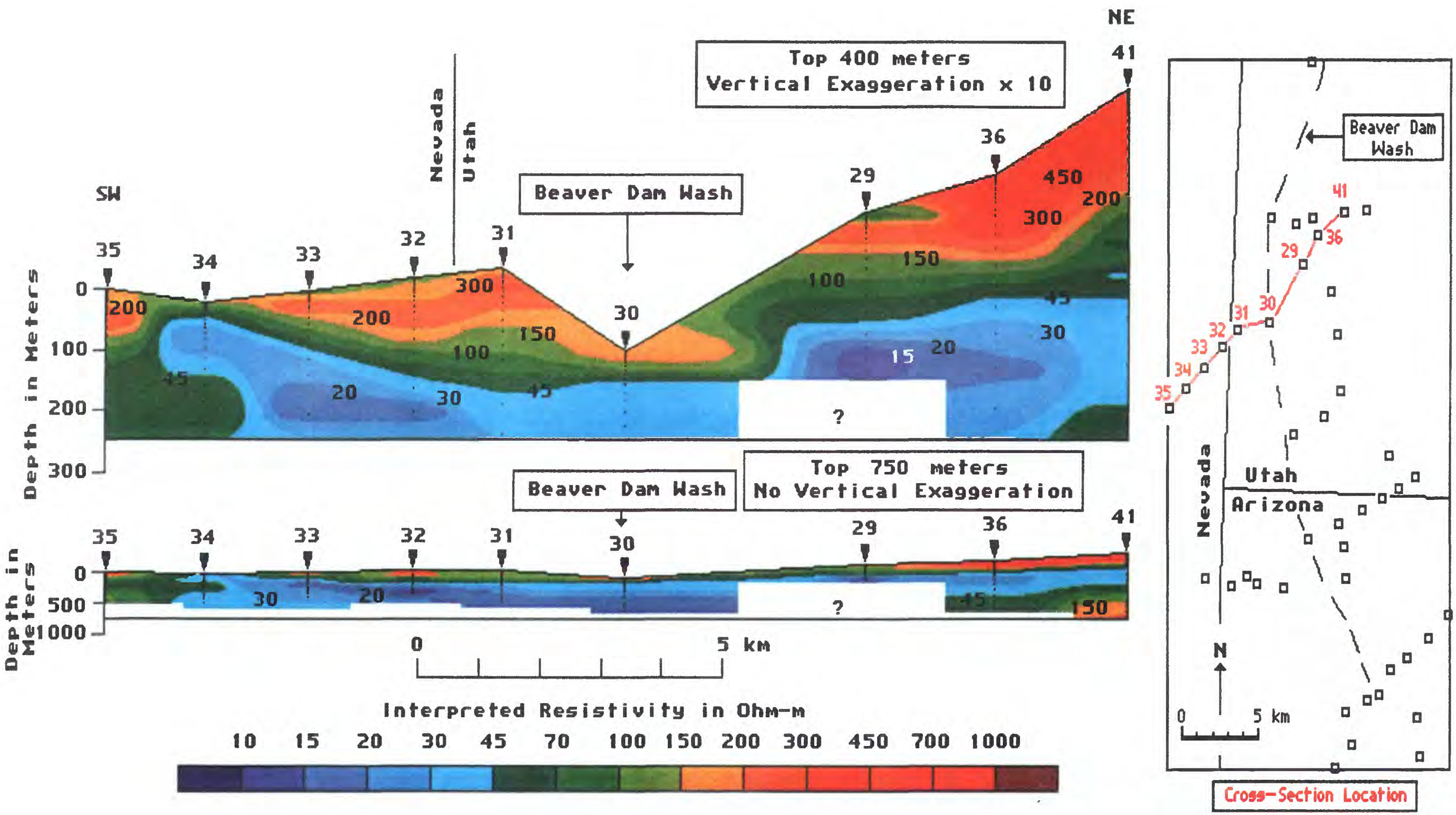


Figure 4. Interpreted resistivity cross section 35-41.

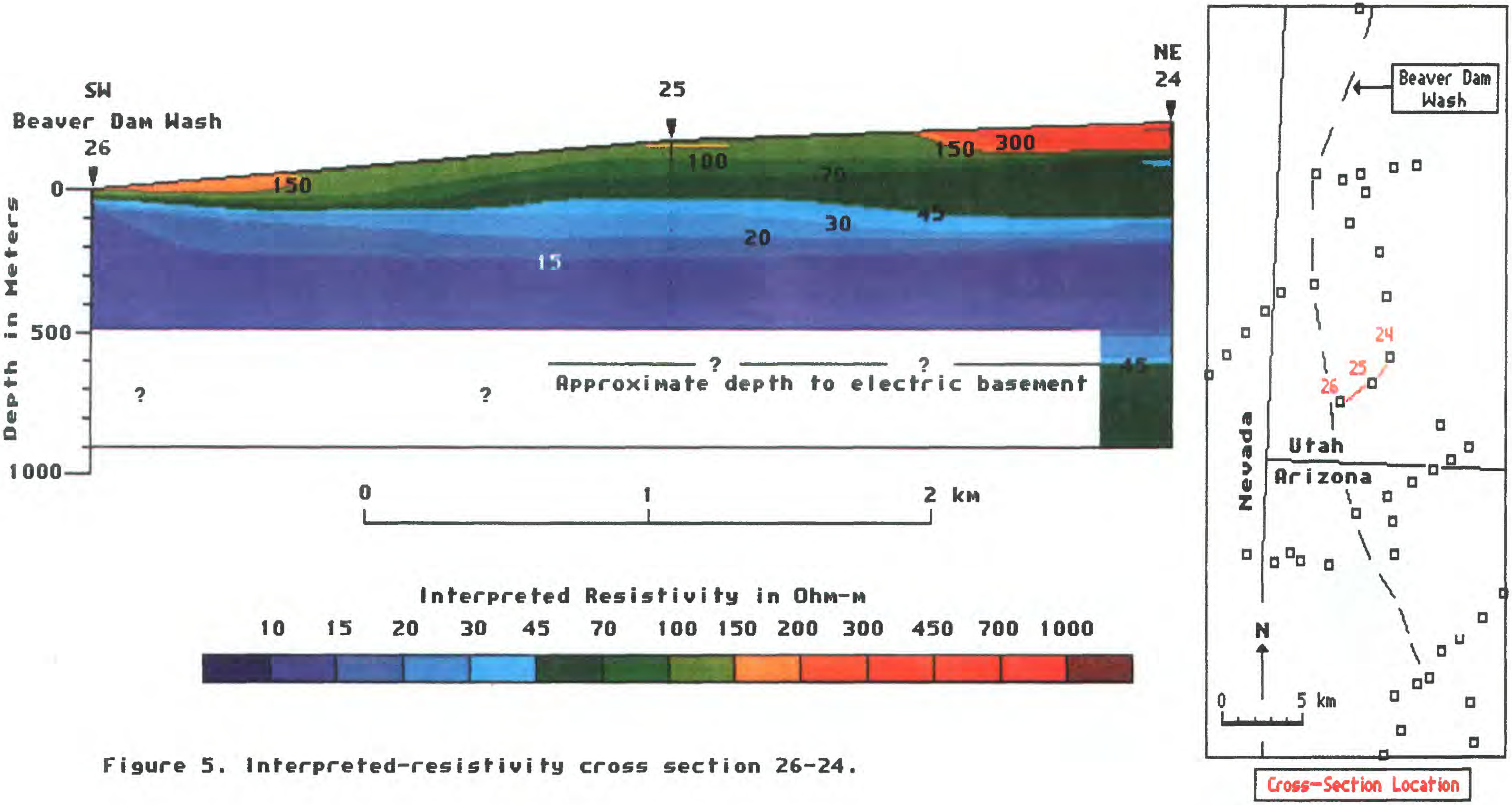


Figure 5. Interpreted-resistivity cross section 26-24.

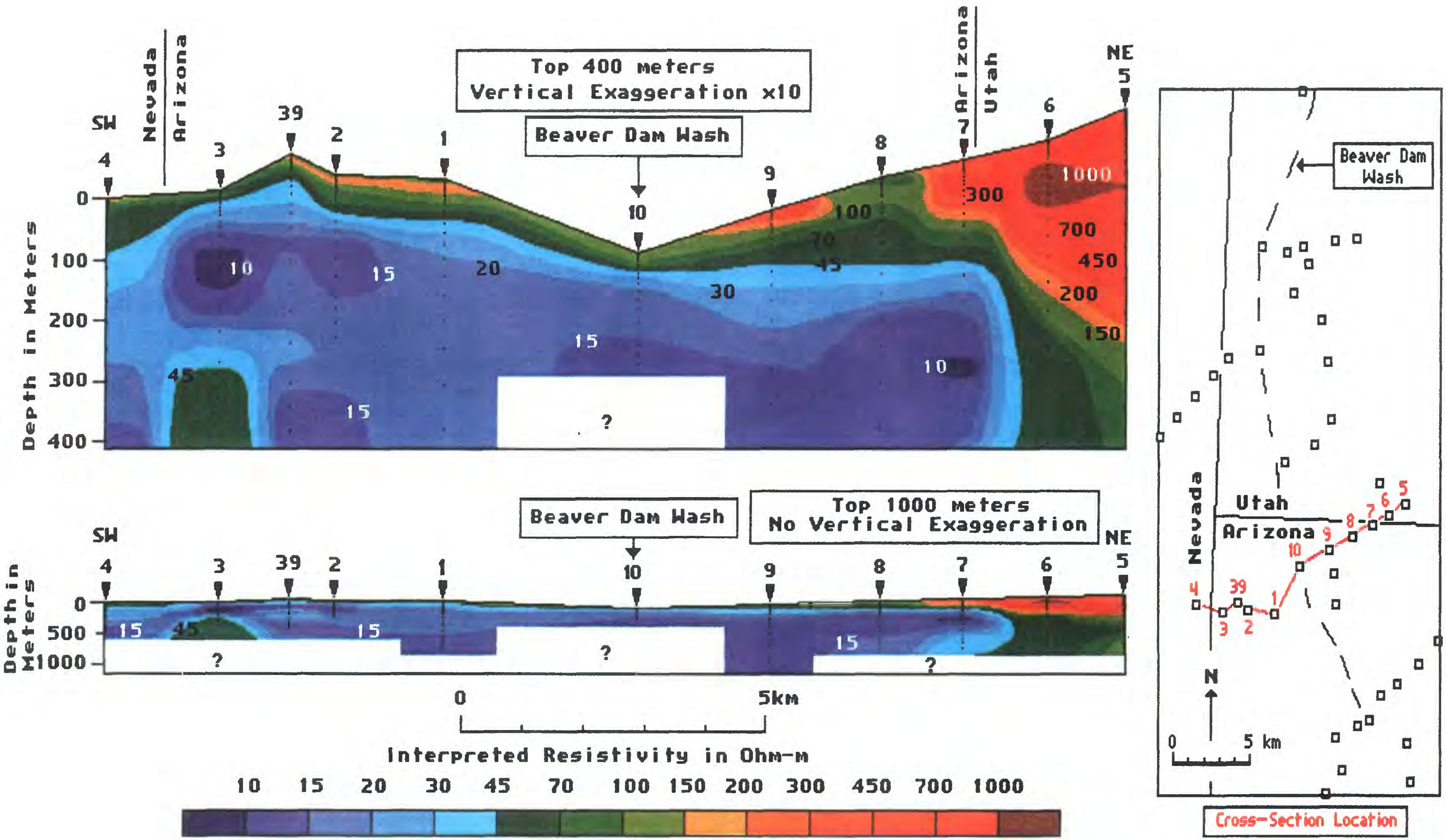


Figure 6. Interpreted-resistivity cross section 4-5.

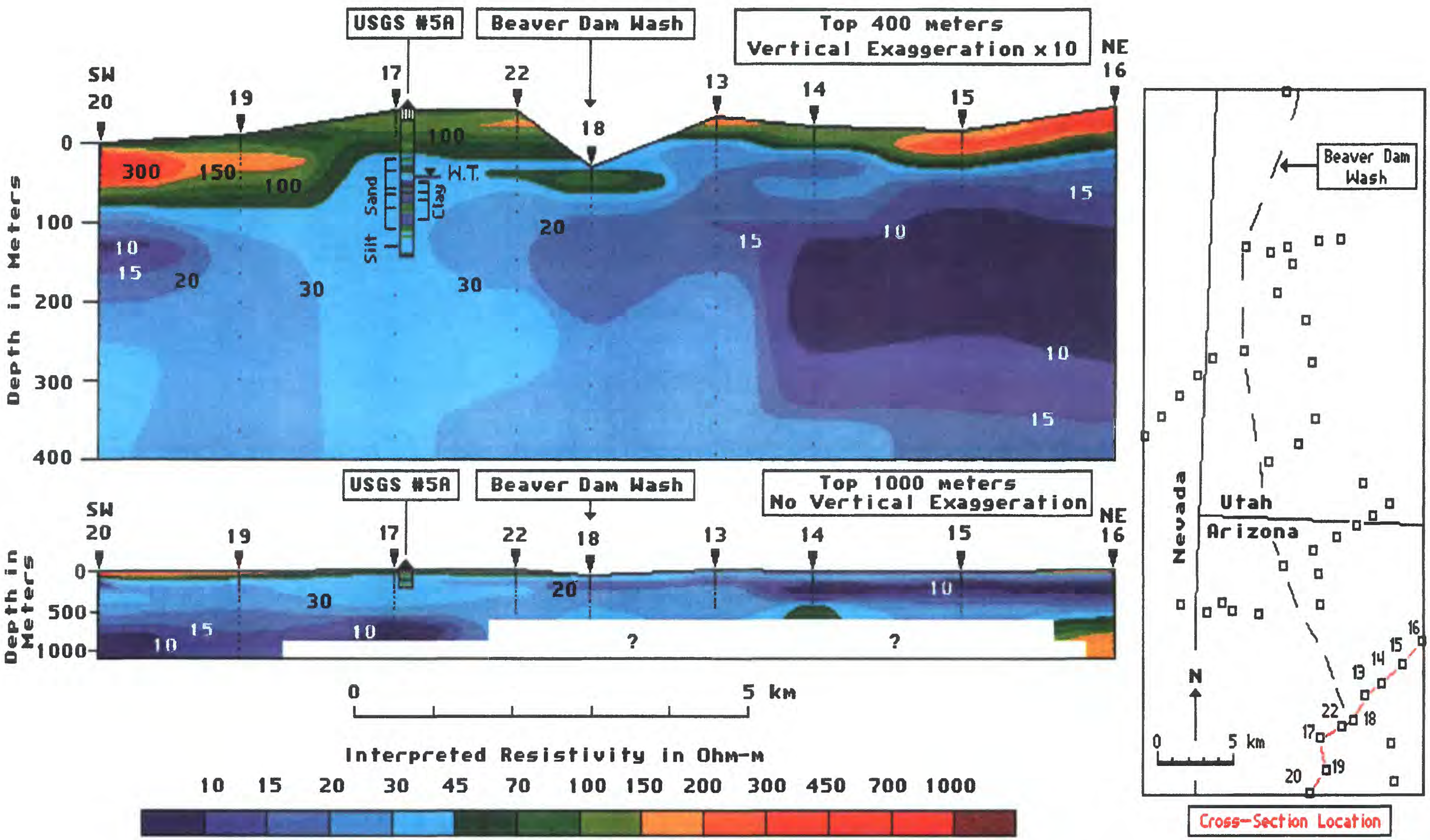


Figure 7. Interpreted resistivity cross section 20-16. Data in test-well symbol taken from electric logs.

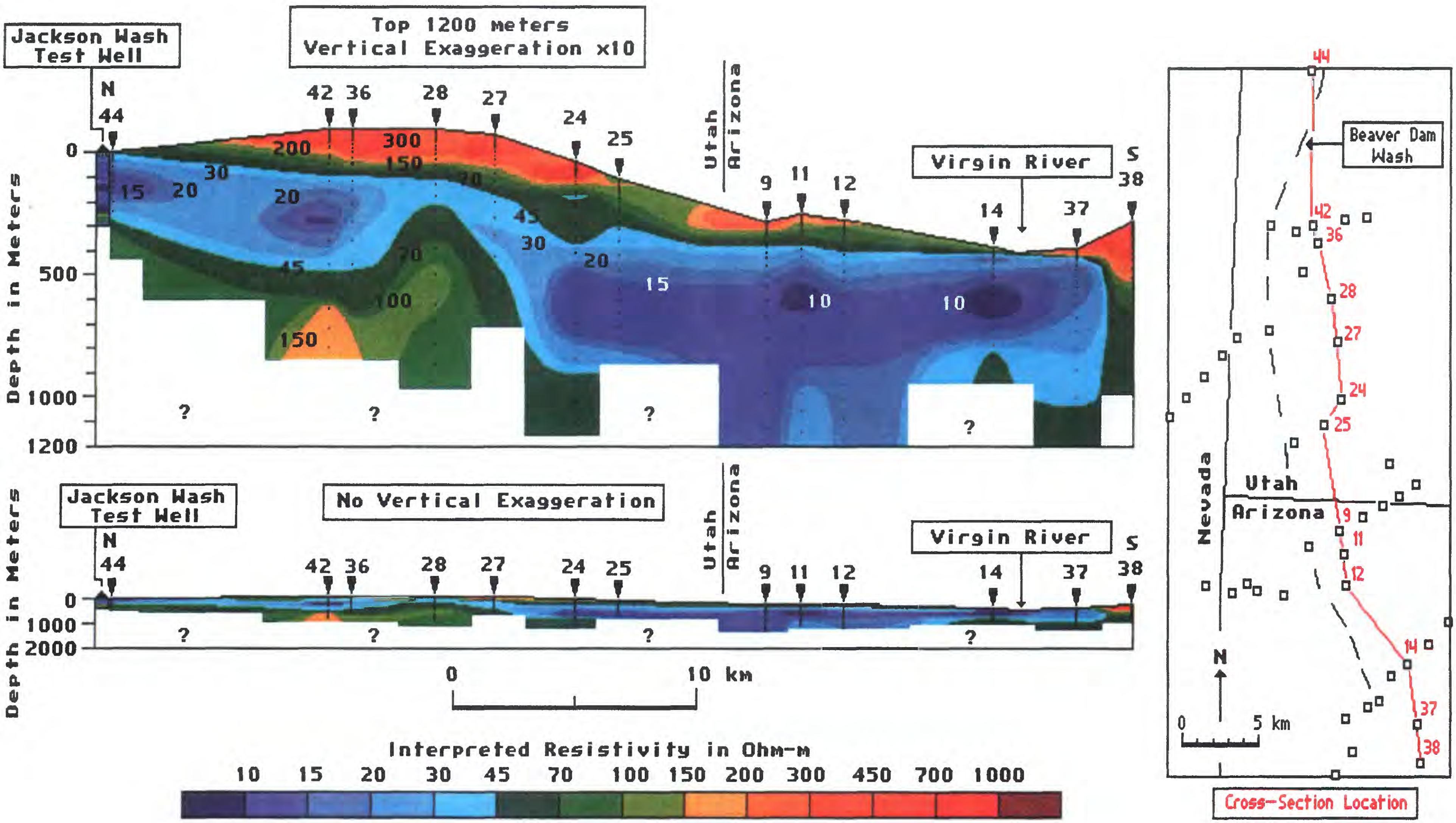


Figure 8. Interpreted resistivity cross section 44-38.

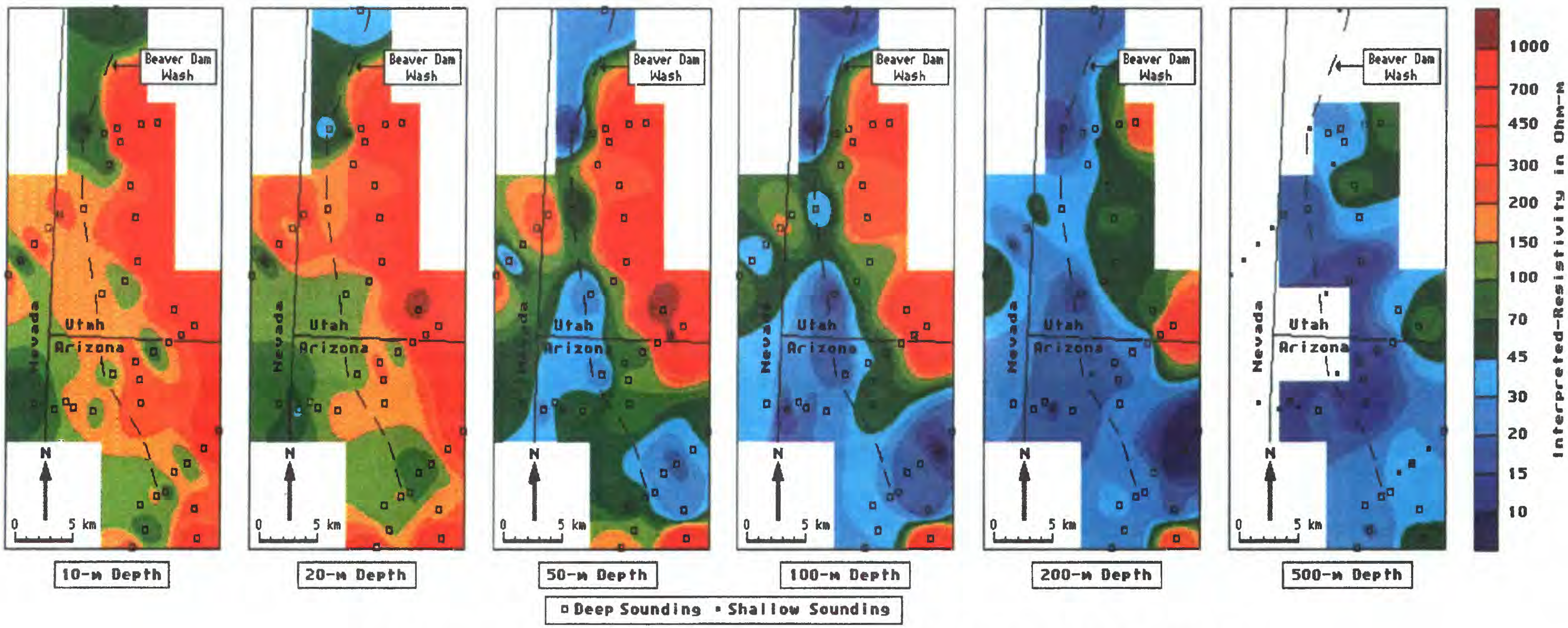


Figure 9. Interpreted-resistivity maps at depths of: 10, 20, 50, 100, 200, and 500 m.