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Geophysical Investigation of Depth to Saltwater Near the Herring River (Cape Cod National Seashore), Wellfleet, Massachusetts

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ABSTRACT

Terrain conductivity meter profiling, VLF resistivity, and transient electromagnetic sounding measurements were made near the Herring River in Wellfleet, Massachusetts to determine the depth to saltwater in the ground-water aquifer. In general, the terrain conductivity meter and VLF resistivity data are modeled with a two-layer model corresponding to the unsaturated zone and freshwater aquifer, and the saltwater saturated aquifer below. The transient sounding data suggest the presence of a transition zone between the freshwater and saltwater saturated zones. The data indicate that the aquifer thickens in the landward direction in the expected manner. Based upon limited water-well data, it is estimated that there is at least 10 m of vertical separation between the water level in wells and the saltwater zone. In some areas the separation is greater. Using a simple analysis of how tidally induced aquifer level variations would respond to increased tidal flow in the Herring River, it is estimated that completely opening the tidal and sluice gates at the mouth of the river would have no effect on water wells in the highlands to the east of the river because the mean river level would be unchanged and the small tidally driven aquifer fluctuations are estimated to persist only a few tens of meters from the river's edge. Wells near the flood plain of the Herring River might be affected by increased tidal flow, but more information on well locations and water depths is needed to make a determination. It is recommended that additional well data be collected, and observation wells be installed and geophysically logged in order that the geophysical interpretation be confirmed and refined.

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1. INTRODUCTION

The Herring River, located near the Cape Cod National Seashore, forms part of a salt marsh-estuarine ecosystem. In the early 1900's a dike was built across the mouth of the river for the purposes of mosquito control, land reclamation, wildlife habitat enhancement, and flood protection. As a result of the restricted tidal flow in the river, major hydrological and biological changes have taken place, many of a detrimental nature including stream acidification, episodes of stream anoxia, fish kills, and mosquito control problems (Roman and others, 1987). In an attempt to rehabilitate the Herring River ecosystem the National Park Service has undertaken studies to evaluate different management alternatives and effects associated with them. In a comprehensive report, Roman and others (1987) suggest that increased tidal flow into the Herring River by manipulation of the sluice-tide-gate structure located near the mouth of the river (Figure 1) would have beneficial effects on the ecosystem. The report goes on to state that additional study is required to determine what effect increased tidal flow would have on domestic water wells in the area. Increased development in the area has resulted in numerous domestic water wells being drilled in the highlands east of the river.

In order to investigate any possible effect on water wells the following approach was formulated. First, well data would be gathered from home owners in the area to determine the water-table level and total well depths. These data are to be collected by National Park Service (NPS) personnel. Second, a geophysical survey of the area would be made to determine the depth of the freshwater-saltwater interface (FWSWI). Third, a series of observation wells would be drilled, water samples collected, and induction logs run. These data will be used to confirm and refine the geophysical interpretation. Finally, an assessment of the effect of the estimated increased tidal flow on the wells would be made using the geophysical and hydrologic data.

Roman and others (1987, p. 36) estimate that removal of all the dike gates (tidal and sluice) would increase high tide levels by less than 0.5 m throughout the entire Herring River system up to High Toss Road. The mean river level would be unaffected by these changes. Thus it is postulated that if the elevation difference between the water table and the FWSWI were large, say 10 m, compared to the increase in tidally induced aquifer level changes then it is unlikely that the change in tidal surge would adversely affect the wells provided none are set near the top of the transition zone. If, on the other hand, the depth interval between the water table and the FWSWI were only a few meters, then a more detailed hydrologic analysis might be needed to determine the effect on wells in the area.

This report describes the geophysical data collected to locate the FWSWI, their interpretation, and recommendations for further work.

2. GEOLOGY AND HYDROLOGY OF THE AREA

Cape Cod was formed through the action of Wisconsin age glaciers that left a complex of terminal moraines and outwash plains (Strahler, 1966). These deposits consist of unconsolidated sand, gravel, silt, clay, and till. The Pleistocene and Holocene age deposits overlie an irregular and unexposed crystalline bedrock surface (Oldale, 1968). Based on seismic measurements, the bedrock surface ranges from 24 m below sea level near the Cape Cod Canal to more than 275 m below sea level near Provincetown (Oldale, 1969).

In the area of Wellfleet stratified glacial drift covers most of the area (Oldale, 1968). The drift is composed primarily of gravelly sand with minor amounts of clay, silt, and gravel. There is evidence of only a single episode of glaciation in this area.

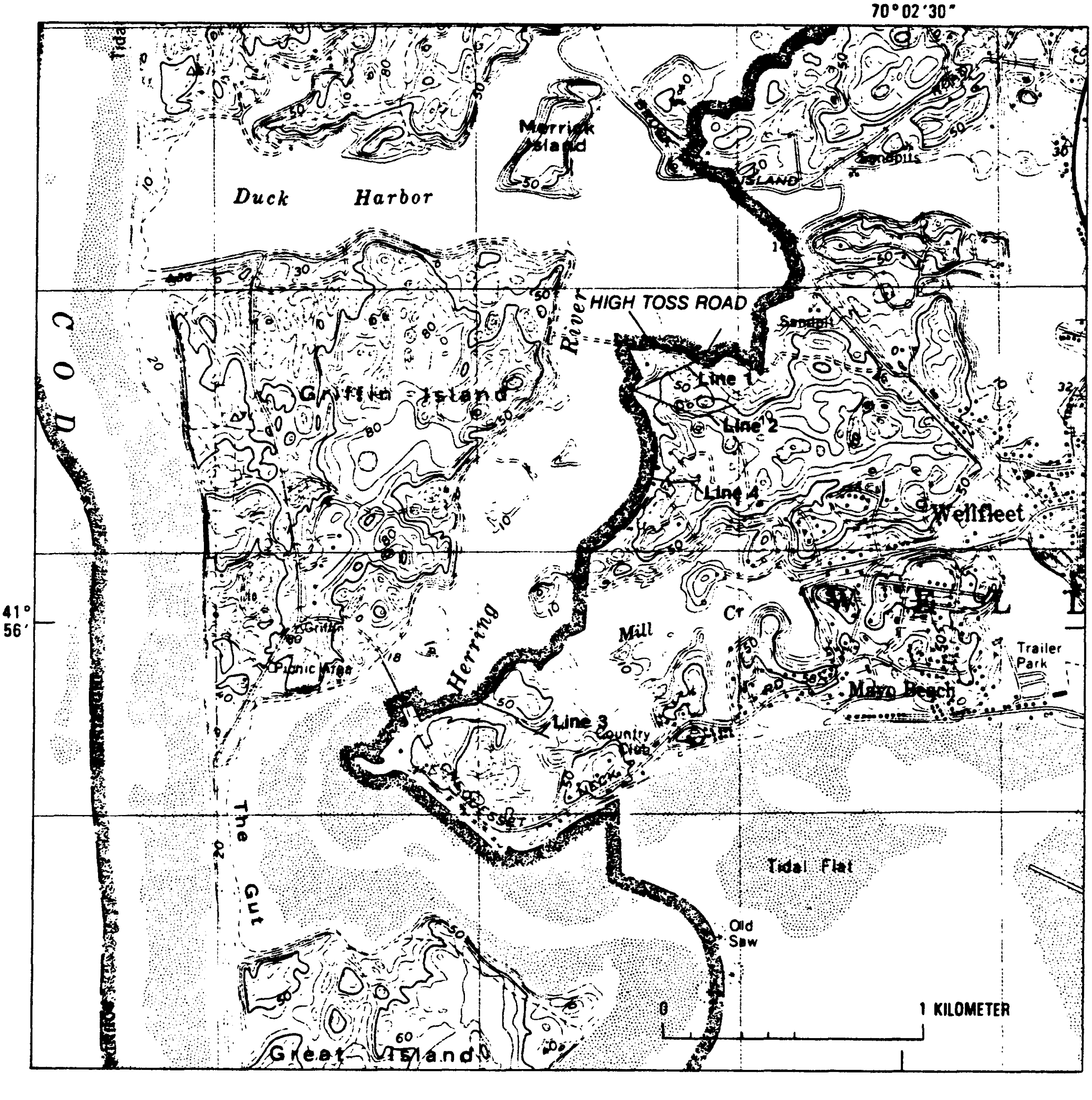

Figure 1 Map of the Herring River study area Wellfleet, Massachusetts. The locations of the four geophysical traverses are indicated.

Near the geophysical traverses described in this report, Older Wellfleet outwash plain deposits, consisting mostly of gravelly, fine to very coarse sand, cover the area (Oldale, 1968). Gravel, very fine sand, and clayey silt commonly occur in beds and lenses. The clayey silt is generally thin bedded and may be highly deformed and discontinuous. Well logs confirm this pattern with medium to very coarse sand being the primary material with lesser amounts of interbedded sand, silty clay, and clay present (LeBlanc and others, 1986). Boulders as large as 3 m in diameter are scattered throughout the drift. The depth to bedrock is about 125 m near Wellfleet based on seismic measurements (Oldale, 1969).

The abundant clay-free sand and gravel deposits form a very good freshwater aquifer. The upper surface of the aquifer is the water table, which in Wellfleet is less than 2 m above sea level (Guswa and LeBlanc, 1985: LeBlanc and others, 1986). The lower surface of the aquifer is the low hydraulic conductivity crystalline bedrock that acts as an impermeable boundary. Between the water table and the bottom of the aquifer is a transition between the freshwater saturated zone above and the saltwater saturated zone below. Guswa and LeBlanc (1985) have developed numerical models for different regions of the Cape Cod aquifer system. These models are very useful for predicting the location of the FWSWI for regional studies, however, they are much too coarse for use in small, localized studies such as this one.

3. DESCRIPTION OF GEOPHYSICAL METHODS USED

Three types of electromagnetic geophysical measurements were made in the study area to determine the depth to the saltwater layer. A brief description of the field methods and data analysis is given below.

3.1 Terrain Conductivity Profiling

Frequency-domain electromagnetic (FEM) measurements use a small transmitter coil through which is passed a sinusoidally varying current that induces eddy currents in the ground. A receiver coil located tens of meters from the transmitter records the voltage induced in it by the time varying magnetic fields produced by the currents in the transmitter loop and the ground. Separation of the effect of these two current systems is possible because they are typically 90° out of phase with respect to each other.

There are several possible orientations of the receiver and transmitter coils. Those often used are horizontal coplanar (HCP) coils or vertical coplanar (VCP) coils. These orientations are also referred to by the direction of the magnetic dipole (perpendicular to the plane of the coil) associated with the coils. Using this nomenclature, the two previously mentioned orientations are called vertical dipoles (VDP) and horizontal dipoles (HDP) respectively. In this report the dipole orientation nomenclature will be used.

The characteristics of FEM systems depends upon the frequency of the transmitter current f, the intercoil spacing s, and the conductivity σ of the ground below the coils. The dimensionless parameter $B=s/\delta$, called the induction number, defines the behavior of the electromagnetic field where $\delta=(2/\mu\omega\sigma)^{1/2}$ is the skin depth, $\omega=2\pi f$ is the angular frequency, and μ is the magnetic permeability ($4\pi \cdot 10^{-7}$ H/m). By selecting the operating frequency and spacing, an instrument can be designed to work in the low induction number region ($B<1$), thereby giving an instrument that reads ground conductivity directly (McNeill, 1980). Such an instrument is called a terrain conductivity meter (TCM). A commercially available system, the Geonics EM34, was used for this survey. This instrument is used at intercoil spacings of 10, 20, and 40 m with frequencies of 6400, 1600, and

400 Hz respectively. Choosing the parameters such that the frequency decreases by a factor of four for a two-fold increase in intercoil spacing results in all the measurements being made at the same induction number for a homogeneous earth.

The depth of exploration of TCM's is controlled by two factors: the intercoil spacing and the coil orientation (McNeill, 1980). Increasing the intercoil spacing increases the depth of exploration. For the same spacing, the vertical dipole orientation sounds deeper than the horizontal dipole orientation.

The TCM is used primarily as a profiling instrument with the measurements used to locate lateral variations of ground conductivity. However, by making measurements at all three spacings and two orientations at each measurement point, the data can be used to make soundings. The data are interpreted at each point as layered earth models which are pieced together to form cross sections. The layered earth interpretations were made using a recently developed interactive interpretation program (unpublished program EMCOND, Fitterman, 1989) based on previous work by Anderson (1979).

TCM measurements have been successfully used to map the FWSWI in coastal aquifers (Stewart, 1982) and for numerous ground-water and pollution studies (McNeill, 1988).

3.2 Transient Electromagnetic Soundings

Transient electromagnetic (TEM) soundings use a large transmitter loop (in this study a square measuring 38 m on a side) through which a continuous current is passed (Fitterman and Stewart, 1986). This current produces a primary magnetic field. At regular intervals the current is abruptly turned off causing the primary magnetic field to decay. In an attempt to maintain the magnetic field that existed before current turnoff, eddy currents are induced in the ground below the transmitter loop. The current forms closed horizontal loops that diffuse outward and downward with time. These currents have a secondary magnetic field associated with them. The diffusion of these smoke-ring-like currents is controlled by the conductivity structure of the ground. By measuring the transient voltage induced by the decaying secondary magnetic field in a receiver coil at the center of the transmitter loop, the conductivity structure can be determined.

The measured voltage transients are converted to late stage apparent resistivity to allow comparison of soundings from different locations (Fitterman, 1985; Spies and Eggers, 1986). The apparent resistivity soundings are interpreted as layered earth models using an inversion program (Anderson, 1982a, 1982b).

The TEM method has been used for a wide variety of ground-water exploration problems (Fitterman and Hoekstra 1984; Fitterman, 1986, 1987). It is particularly well suited for locating zones of saltwater intrusion because of its high lateral and vertical resolution (Stewart and Gay, 1986; Fitterman and Stewart, 1986).

TEM soundings were made at selected points along the profiles using a Geonics EM47 transient system to compare with the EM34 data.

3.3 VLF Resistivity Profiling

VLF resistivity makes use of continuously transmitted signals in the very low frequency (VLF) range (3-30 kHz) used to send messages to submarines. These electromagnetic waves consist of orthogonal magnetic and electric fields that vary in amplitude and phase relative to each other as a function of the ground resistivity (Wright, 1988). The VLF instrument (Geonics EM16R) converts the measured field quantities to apparent resistivity and phase. The apparent resistivity reflects the resistivity value of the ground, and the phase indicates if the ground resistivity increases or decreases with depth. In general, the phase will be 45° for a homogeneous half-space, greater than 45° for resistivity decreasing with depth, and less than 45° for resistivity increasing with depth.

Usually, the data cannot be modeled with a homogeneous earth, and a two-layer model is the simplest geometry that can be used. Data interpretation, even for this simple model, is highly nonunique as the model has three parameters (two layer resistivities, ρ_1 and ρ_2, and one layer thickness, h_1), whereas only two quantities are measured. To deal with the problem, a constant resistivity value has been chosen for the second-layer resistivity. Then ρ_1 and h_1 can be determined algebraically or by using an interpretation chart (Hjelt and others, 1985). A value of 2.5 ohm-m was used for ρ_2, based upon values determined from the other EM measurements. The VLF measurements were of limited value compared to the terrain conductivity meter and transient EM measurements due to the greater uncertainty in the data and the necessity of assuming a value for ρ_2. However, the VLF results show general agreement with the other data sets.

4. GEOPHYSICAL DATA AND THEIR INTERPRETATION

Measurements were made at three sites along the eastern edge of the Herring River shown in Figure 1. The sites are from north to south: Great Pastures (Lines 1 and 2), Newcomb Heights (Line 4), and Chequesset Neck (Line 3). The individual traverses are discussed below.

4.1 Great Pasture Traverses

Two lines of TCM and VLF measurements and three TEM soundings were made from the Herring River through the Great Pasture subdivision (Figure 2) The TCM data and interpretation for Line 1 are shown in Figures 3 and 4. The figures include the VDP (open symbols) and HDP (filled symbols) data for the three intercoil spacings, as well as the computed response (solid line for VDP and dashed line for HDP data, respectively) for the model shown in the cross section at the bottom of the figure. The cross section shows the ground surface, the layer resistivities in ohm-meters, and the interfaces between layers.

TCM data were collected at three spacings for the first 210 m. Because of the consistency of the readings only the 40 m spacing data were collected along the rest of the line. Reasonable fits of the 10 and 40 m spacing data were obtained, however, it was not possible to fit all three spacings. Attempts to fit only the 10 and 20 m spacing or the 20 and 40 m spacing data resulted in cross sections similar to the one shown here. The inability to fit the data at all three spacings is attributed to noise in the data from the response of man made conductors (buried telephone lines, pipes, etc.) and geometrical problems (coils not in the same plane due to irregular topography). It is not possible to say exactly how large these noise sources are, but confidence in the interpretation is based upon the lateral continuity of the model and the robustness of the model when fitting to different spacing data.

The data are essentially fit with a two-layer model. The upper layer resistivity ranges from 90 to 3000 ohm-m, and the lower layer has a resistivity of 2.5-4.0 ohm-m. A transitional layer between these two layers could be introduced, however no attempt was made to do so as the data are not sufficient to resolve it at most locations. At the west end of the line, the interpreted interface depth is about 19 m and deepens to about 54 m near station 220. The interpreted depths of the interface based upon the VLF data are shown by the small v's in the cross section. In general, there is pretty good agreement between the TCM and VLF models from station 0 to station 240, however, the VLF determined interface is considerably deeper from station 250 to 400, possibly because the assumed value for ρ_2 is incorrect.

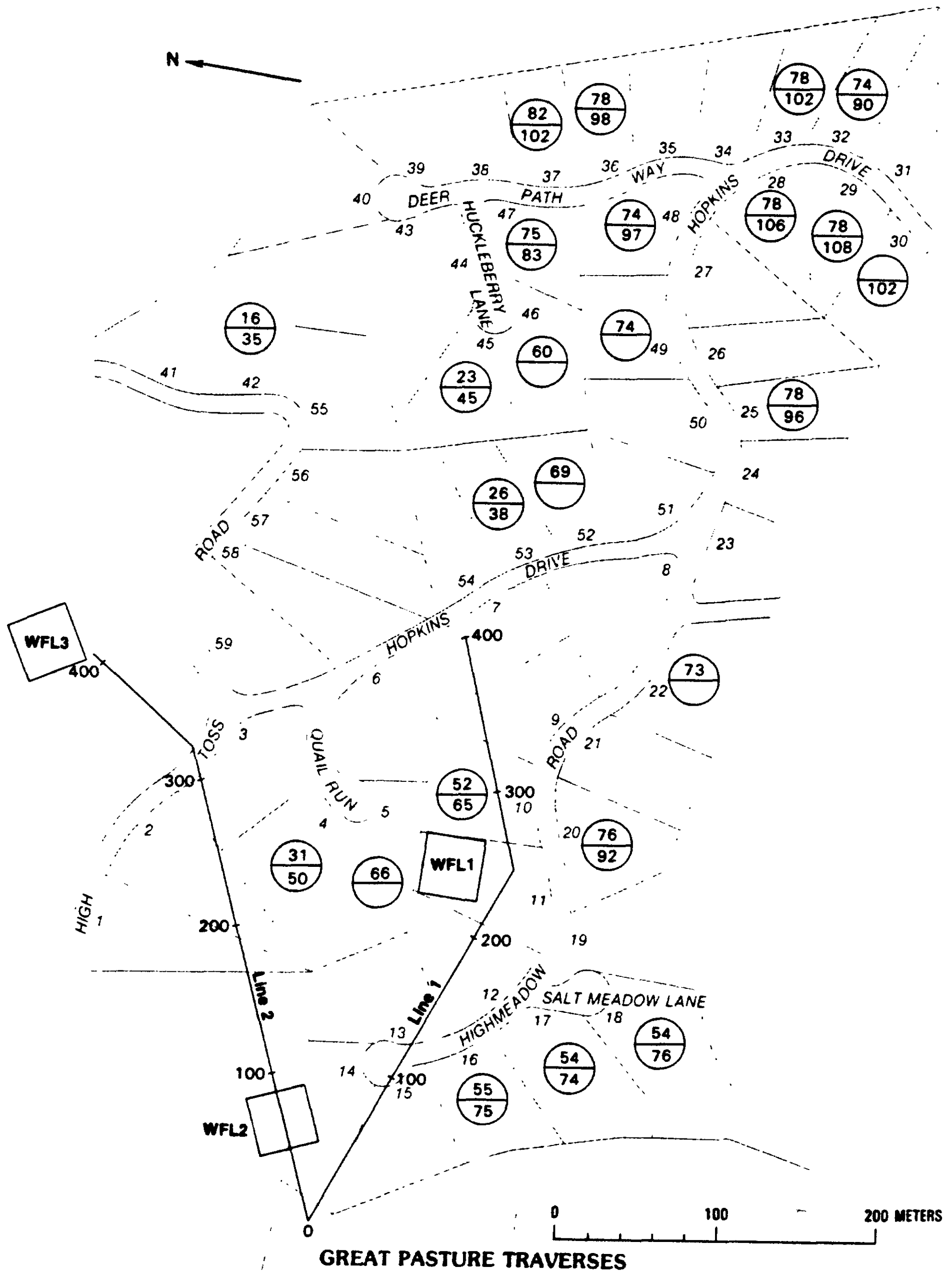

Figure 2 Location of survey lines and the TEM sounding loops at the Great Pasture traverse. The circled numbers are the depths (upper number) to the water table (upper number) and total well depth (lower number) in feet. The gray numbers and lines are lot numbers and property boundaries respectively. Exact location of the wells inside the property boundaries is not known. The numbers along the geophysical lines are the station numbers in meters.

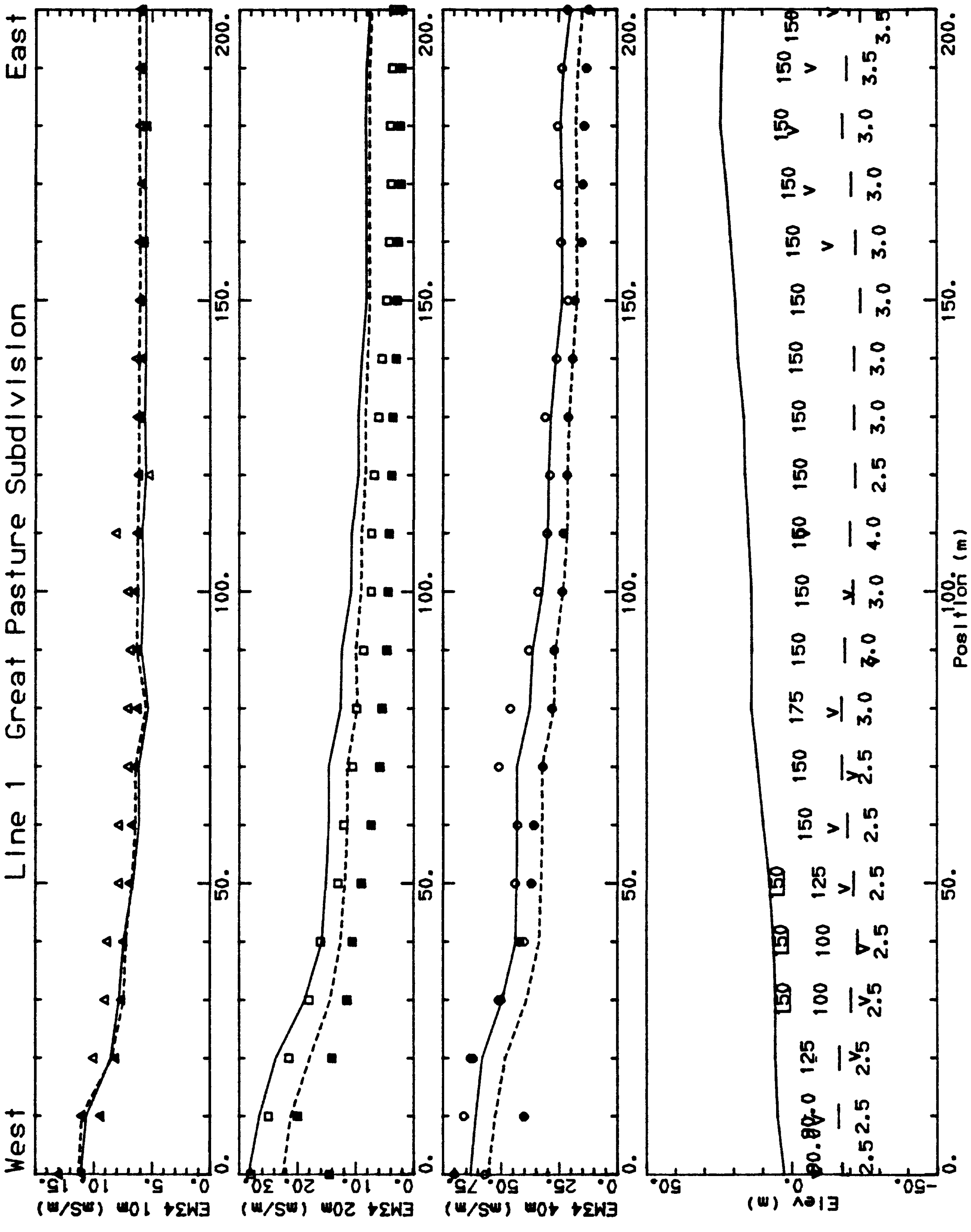

Figure 3 Terrain conductivity meter data and interpreted cross section for Line 1, Great Pasture Subdivision, x=0-200 m. The open symbols (△□○)and solid lines are the observed and computed VDP data respectively. The filled symbols (▲■●) and dashed lines are the observed and computed HDP data respectively. The v's represent the top of the conductive second layer determined from VLF measurements.

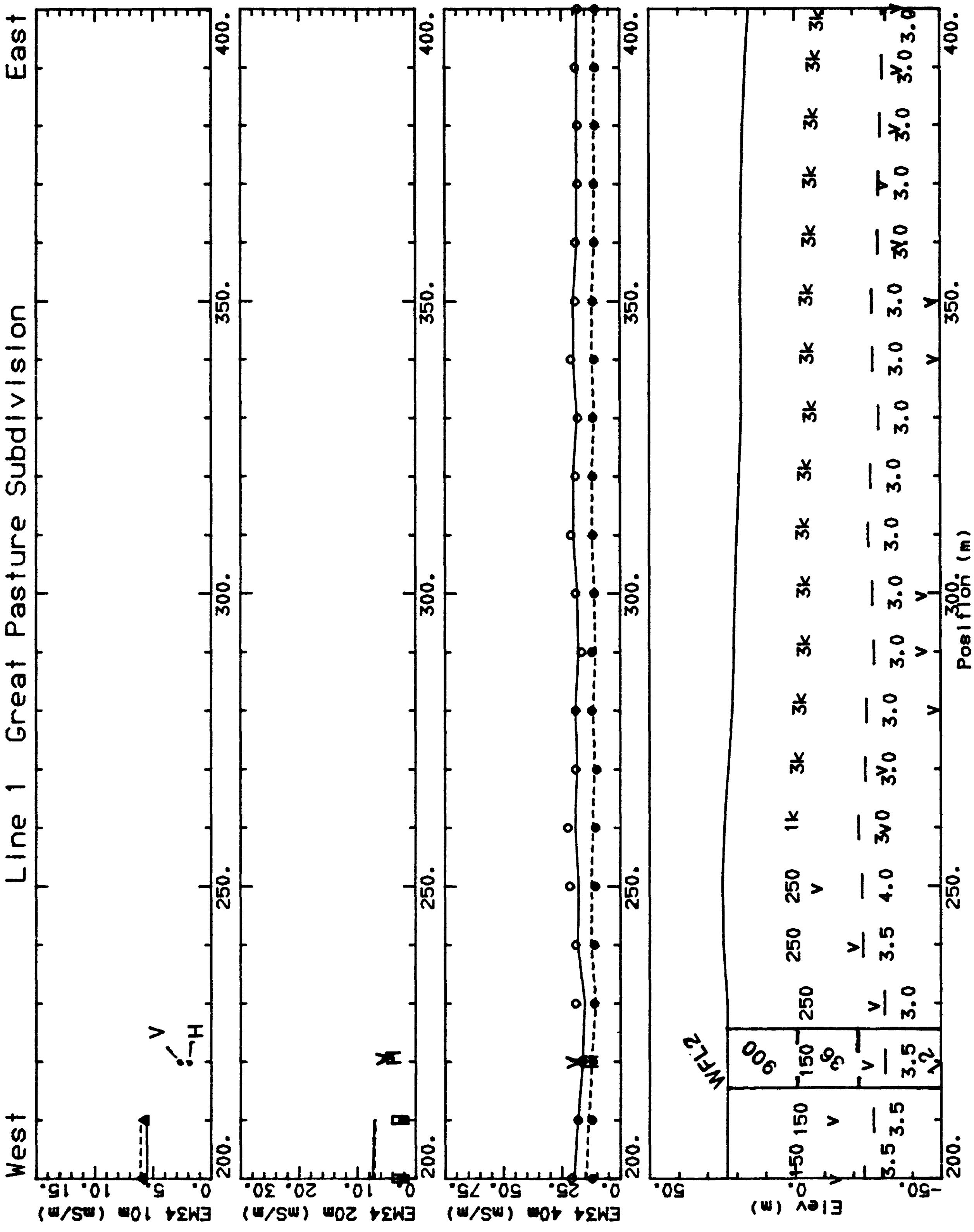

Figure 4 Terrain conductivity meter data and interpreted cross section for Line 1, Great Pasture Subdivision, x=200-400 m. Tilted numbers near station 220 are the interpreted layer resistivities from TEM sounding WFL 2. The V's and H's on the TCM plots at station 220 are the computed response based upon the interpreted model from TEM sounding WFL 2.

The results of TEM sounding WFL 2 show that the apparent resistivity decreases with time after current turnoff (Figure 5). This behavior indicates a decrease in layer resistivity with depth (Figure 6). The data are fit with a three-layer model. The first layer, which was constrained to be 900 ohm-m because it was not well resolved by the inversion, is 26 m thick. The second layer has a resistivity of 36 ohm-m and a thickness of 21 m. The last layer is very conductive with a resistivity of 1.2 ohm-m.

Comparing the TCM and TEM models near station 220 (Figure 4), we see that the base of the second layer from the TEM model corresponds to the interface level determined from the TCM data. As a further comparison of the results, the TCM response for the TEM determined model was computed and plotted at station 220 on Figure 4. (The upper case V's and H's correspond to the computed vertical and horizontal dipole conductivities respectively.) There is reasonable agreement with the 40 m spacing data. No data exist for the other spacings, but comparison with stations to the west of station 220 indicates general agreement with the 20 m spacing data, and lower values than observed at the 10 m spacing.

The first 300 m of Line 2 is similar to the results of Line 1 (Figures 7 and 8). A two-layer model with parameters similar to those of Line 1 adequately fits the data. The first-layer resistivities are in the range of 200-5000 ohm-m from the west end of the line to station 290, and the second-layer resistivity is relatively constant (4-6 ohm-m). The interface depth increases from 20 m on the west end of the line to a maximum depth of about 32 m near station 130. The interface depth decreases eastward, in part, mirroring the decrease in elevation as High Toss Road is approached. The line crosses High Toss Road near station 310 and shows the influence of a buried pipe with drastically reduced and negative values of conductivity for the VDP data (Figure 9). Judging from the way the pipe's effect continues into the salt marsh on the north side of High Toss Road, it is likely that the pipes are part of a drainage system that continues into the marsh. The model interpretation was held constant from station 320 to the end of the line as the data quality does not permit further interpretation.

The VLF determined interface position agrees with the TCM interpretation in a general way, with significant departures between stations 160 and 190, and east of station 250. These differences may be due to the assumptions on ρ_2 used in the modeling and possible terrain effects.

A TEM sounding (WFL 1) was made near station 60 (Figure 10). A three-layer model fits the data quite well (Figure 11). Comparison of the sounding and the TCM results near station 60 shows the correspondence between the first and second layer of each model. The TEM sounding also indicates a deeper, more conductive third layer. The 8.3 ohm-m second layer of the TEM sounding is conductive enough to be considered to be saltwater saturated. The computed TCM response based upon the TEM model at station 60 is in reasonable agreement with the observations (Figure 7).

TEM sounding WFL 3 shows a very different behavior from all other soundings made in this study (Figure 12). The data indicate a conductive first layer (1.8 ohm-m), a resistive second layer (180 ohm-m), and a conductive third layer(2.4 ohm-m) (Figure 13). Initially it was thought that the conductive first layer was caused by relict marine deposits in the marsh peat (J. Portnoy, written commun., 1989). However, in view of the suspected pipe detected by the TCM data the conductive surface layer may be an interpretational artifact. Without additional data in the salt marsh, these data are considered suspect and will not be discussed further.

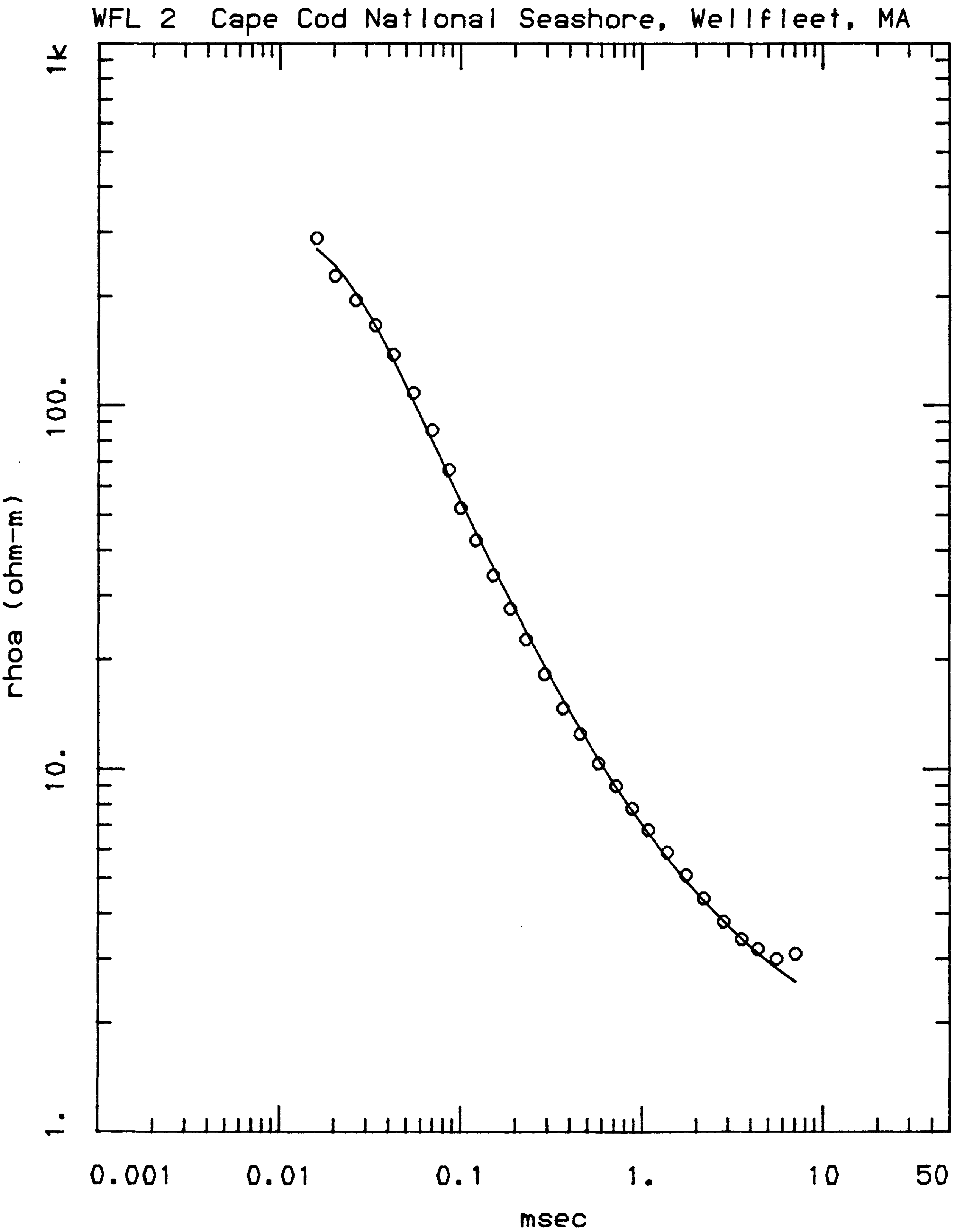

Figure 5 Apparent resistivity-time plot for TEM sounding WFL 2, Great Pasture Subdivision. The circles are the measured values, and the line is the computed response using the best fit model shown in Figure 6.

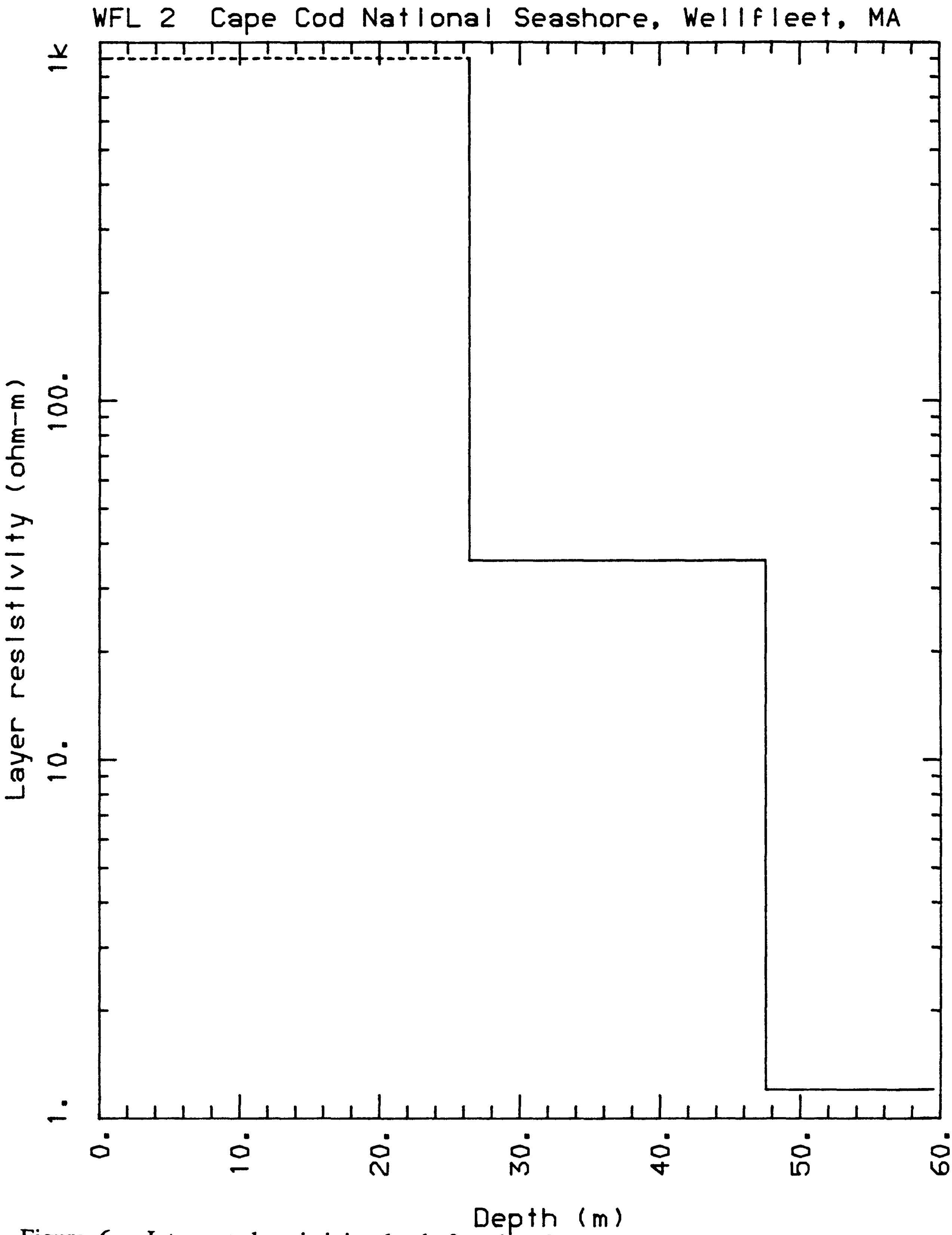

Figure 6 Interpreted resistivity-depth function for TEM sounding WFL 2, Great Pasture Subdivision. The dashed line represents a layer resistivity that was fixed during the inversion.

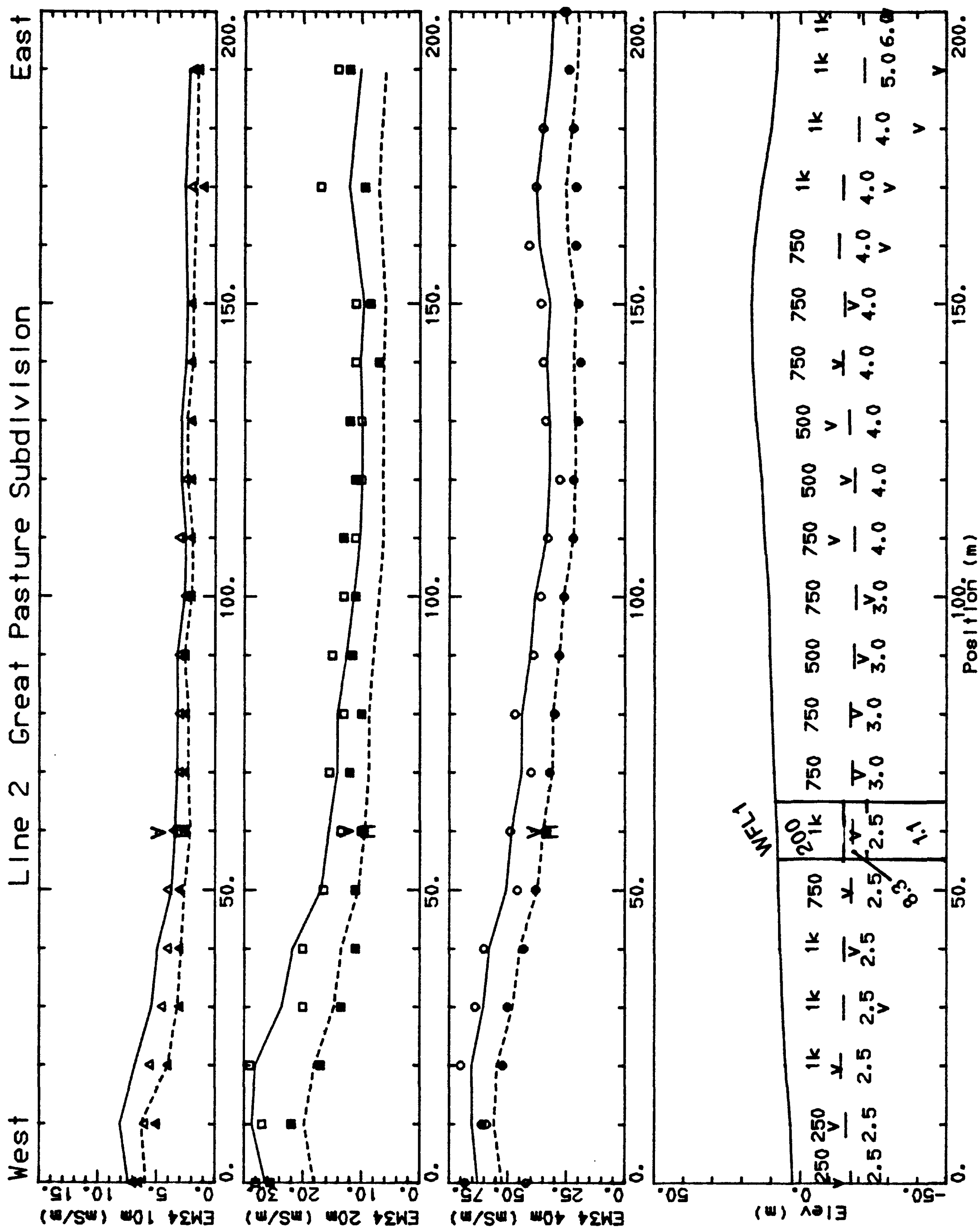

Figure 7 Terrain conductivity meter data and interpreted cross section for Line 2, Great Pasture Subdivision, x=0-200 m. Tilted numbers near station 60 are the interpreted layer resistivities from TEM sounding WFL 1. The V's and H's on the TCM plots are the computed response based upon the interpreted model from TEM sounding WFL 1.

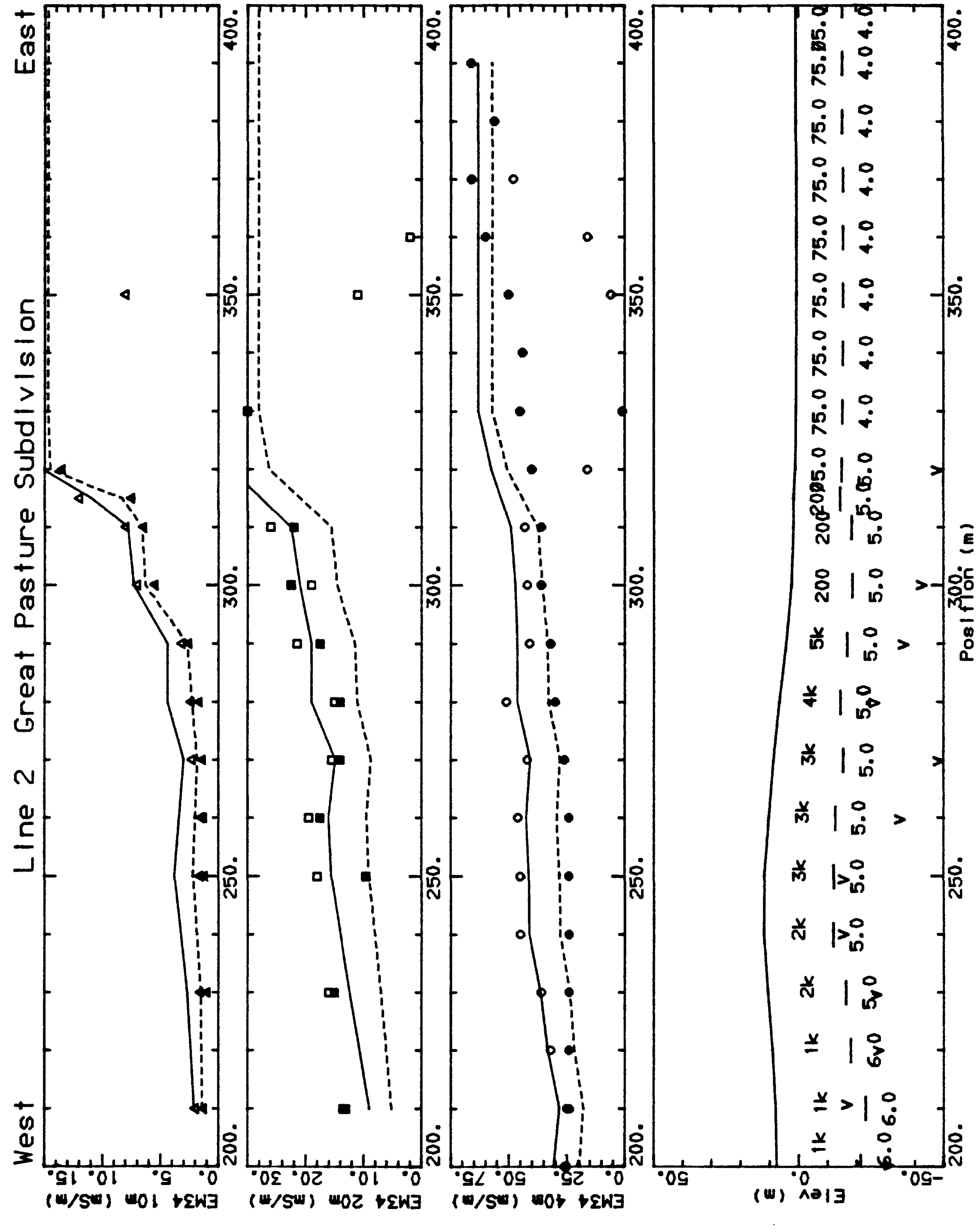

Figure 8 Terrain conductivity meter data and interpreted cross section for Line 2, Great Pasture Subdivision, x=200-400 m.

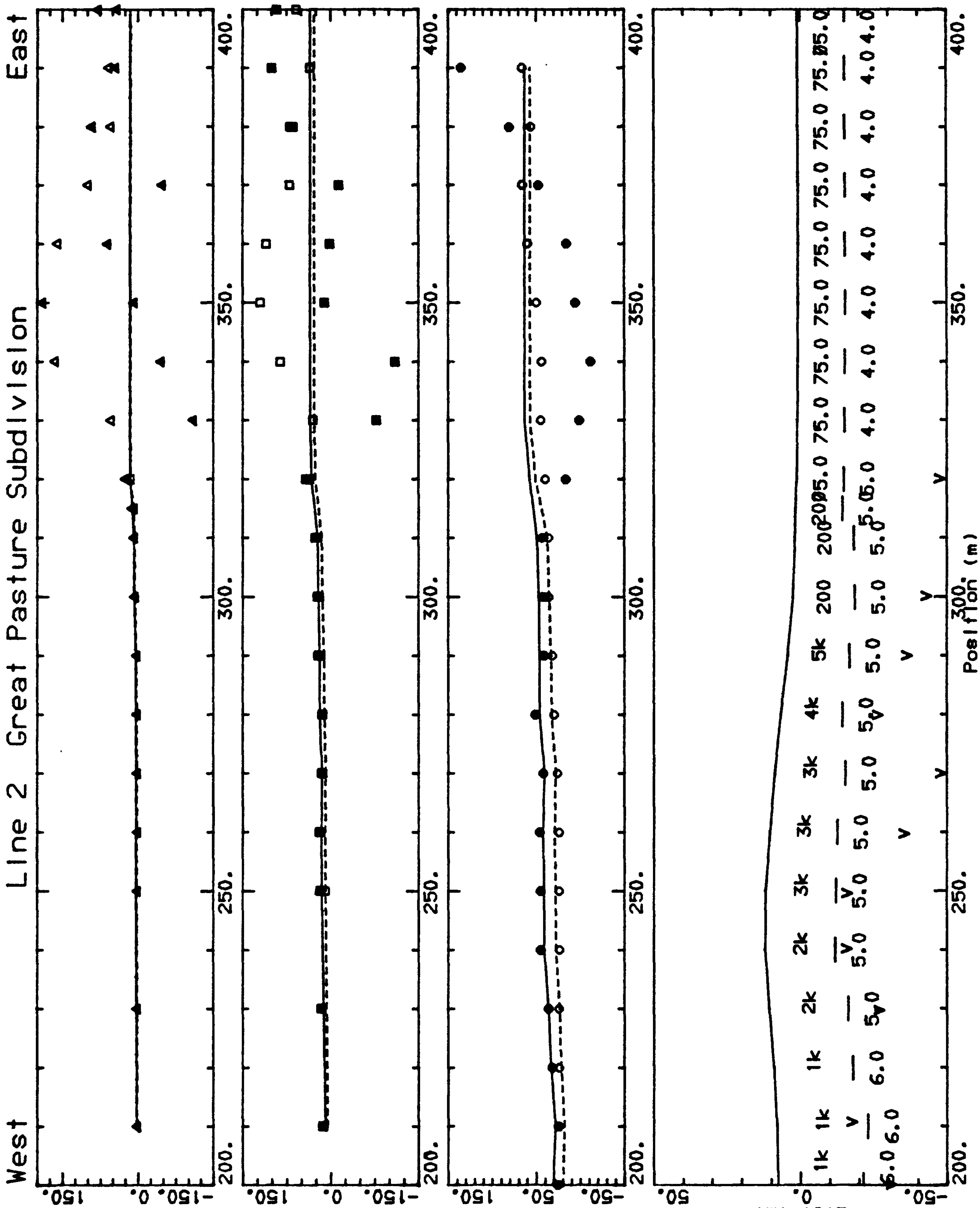

Figure 9 Terrain conductivity meter data and interpreted cross section for Line 2, Great Pasture Subdivision, x=200-400 m at expanded scale to show effect of buried pipe.

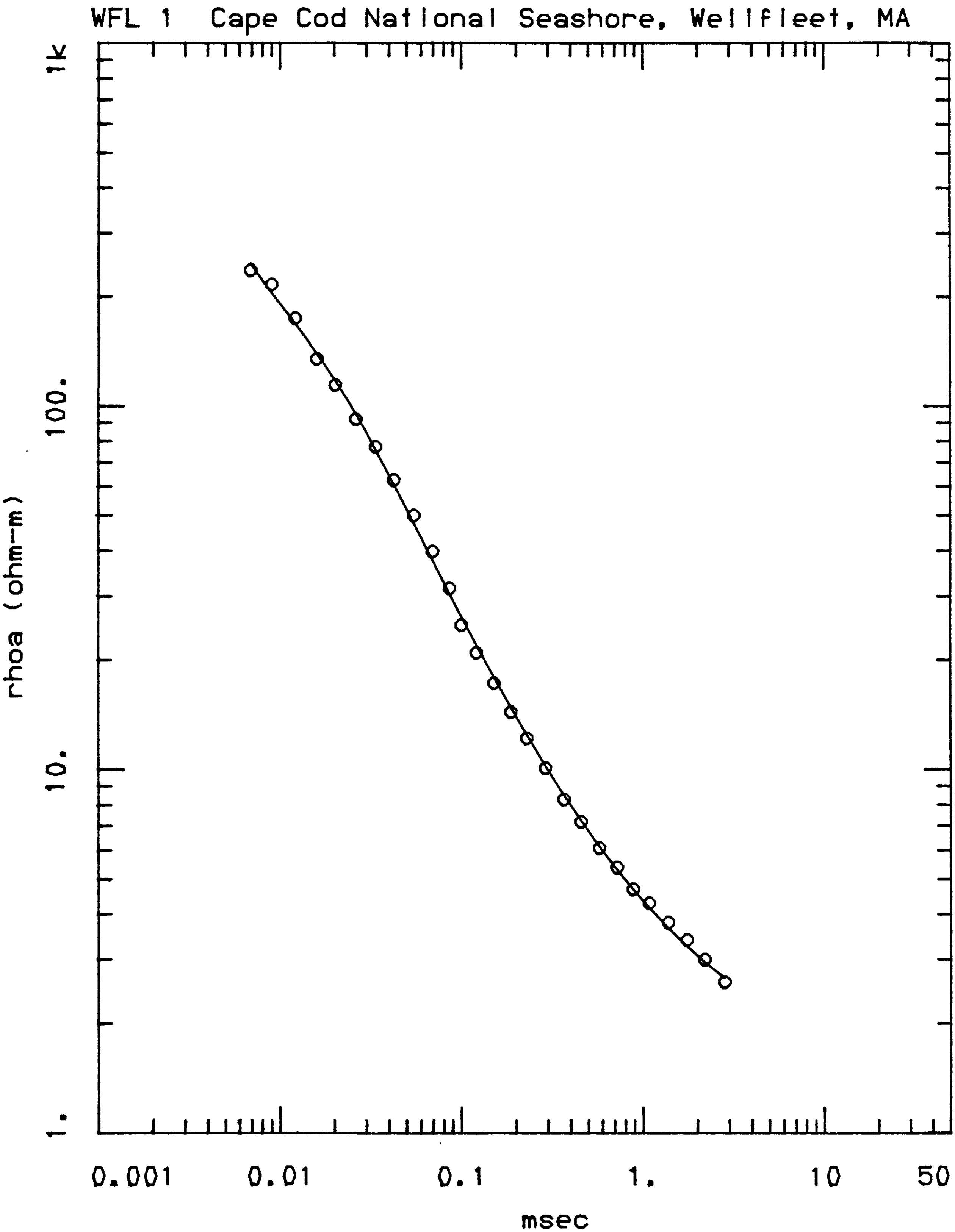

Figure 10 Apparent resistivity-time plot for TEM sounding WFL 1, Great Pasture Subdivision.

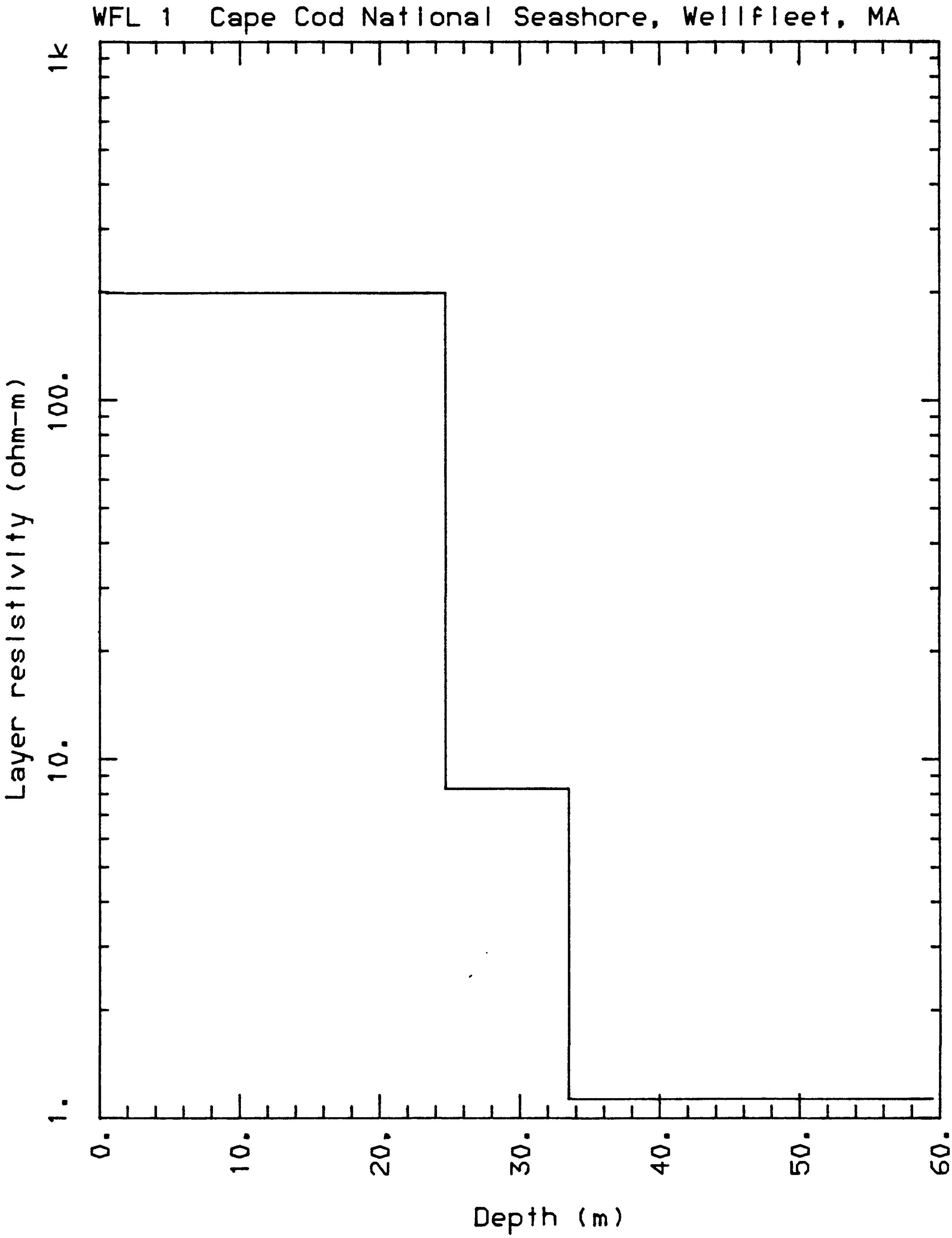

Figure 11 Interpreted resistivity-depth function for TEM sounding WFL 1, Great Pasture Subdivision.

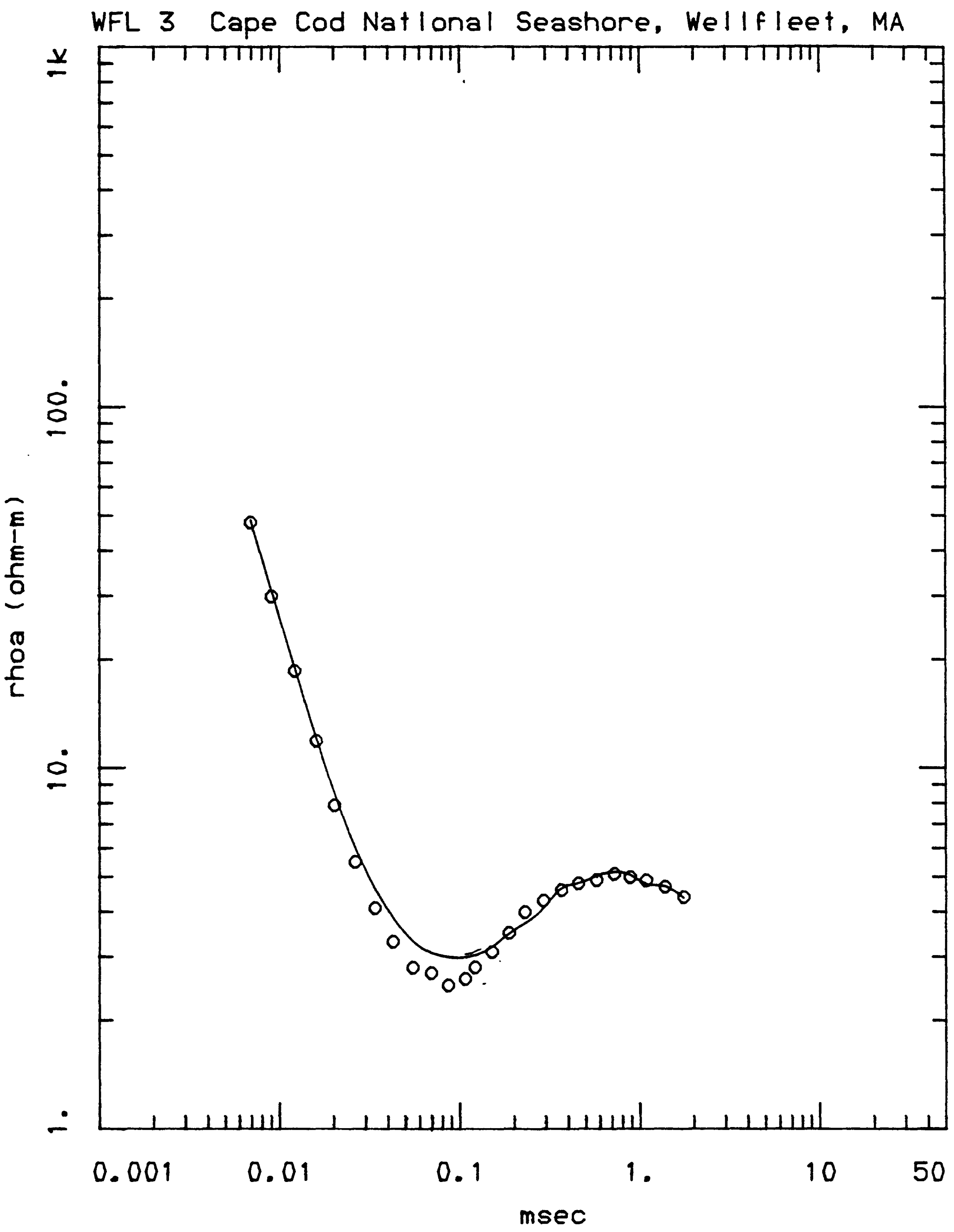

Figure 12 Apparent resistivity-time plot for TEM sounding WFL 3, Great Pasture Subdivision.

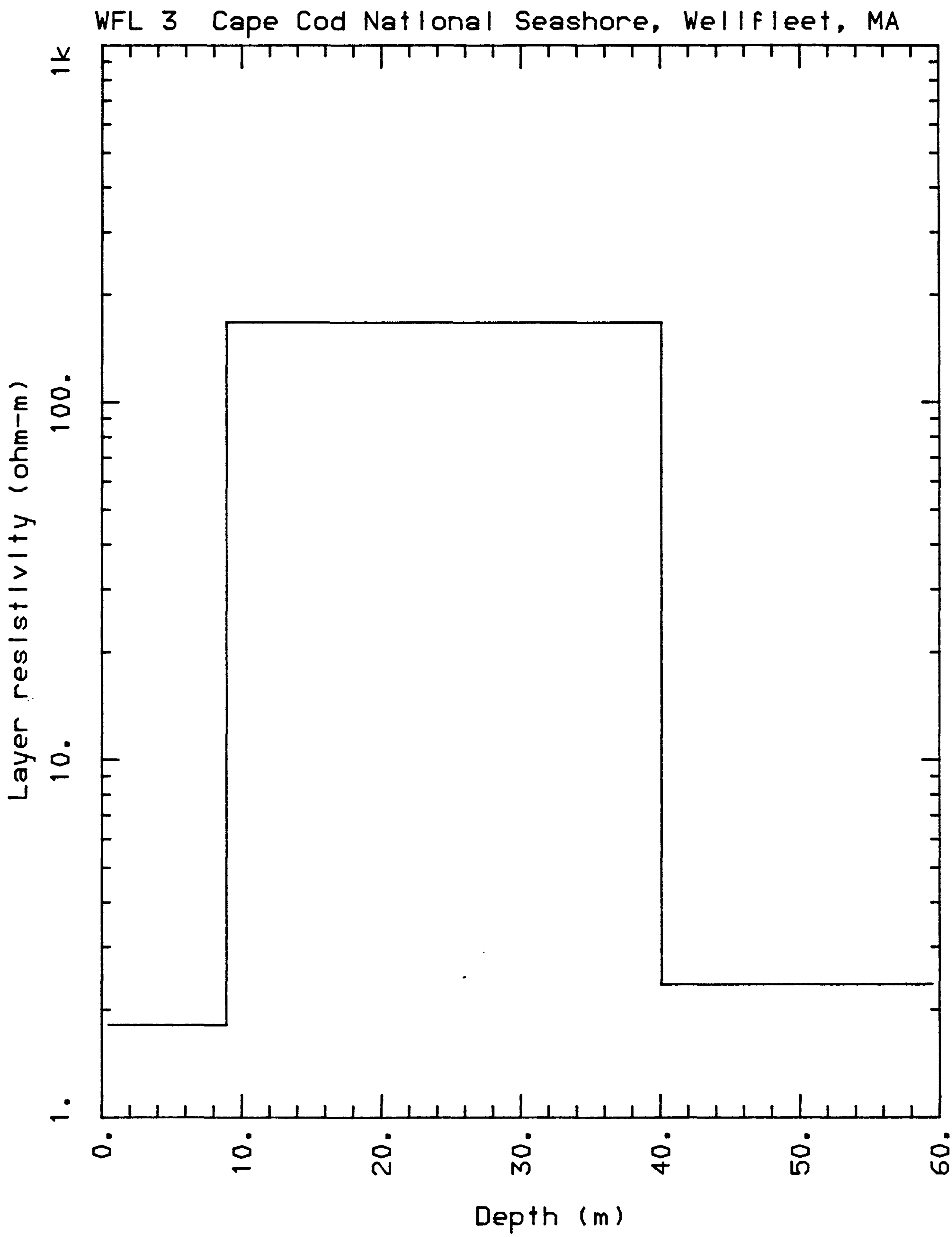

Figure 13 Interpreted resistivity-depth function for TEM sounding WFL 3, Great Pasture Subdivision.

4.2 Newcomb Heights Traverse

The central site goes from the Herring River through a portion of the Newcomb Heights subdivision (Figure 14). The TCM data (Figure 15) show some effects due to interference from a buried conductor (wires or pipes) near station 120, but are otherwise fit with a two-layer model. The first-layer resistivity is in the range of 200-500 ohm-m, and the first layer thickens from 20 m near the Herring River to over 40 m at the east end of the line. The VLF data agree with the TCM data only at the west end of the line.

One TEM sounding (WFL 7) was made near station 130 (Figure 16). The sounding shows a decrease in resistivity with depth. Buried pipes caused data to be lost between 20 and 100 µs. The interpreted resistivity-depth function (Figure 17) is compared to the TCM data in Figure 15. As with sounding WFL 1 (Line 1) it appears that a transition zone is present. The interface determined by the TCM data corresponds to the bottom of this transition zone.

4.3 Chequesset Neck Traverse

Line 3 was run about 200 m upstream of the tidal control structure near the mouth of the Herring River (Figure 18). A rather good two-layer fit was obtained for the data (Figures 19 and 20). A very limited amount of VLF data were collected because frozen ground prevented implanting the electric field sensing electrodes. In general,, where VLF readings were obtained, the interface depths are not in very good agreement with the TCM derived interface.

Because this site is undeveloped there was more freedom in positioning the transmitter loop for the TEM soundings, and it was possible to obtain three TEM soundings (Figure 21). The soundings have similar three-layer interpretations (Figure 22), however, the surface layer becomes more resistive moving away from the river to the southeast. The second-layer interpreted resistivities are low enough (4.1-5.6 ohm-m) to be due to saltwater saturated sediments. The low third-layer resistivity is definitely caused by saltwater saturated material.

Comparison of the TEM and TCM data show that the TCM determined interface falls within the second layer of the TEM models (Figure 19) suggesting that the TCM data might be modeled with a three-layer model. No attempt was made to do this as determining a five parameter model with only six observations is difficult considering the normal uncertainties in TCM data. The calculated TCM responses based on the TEM interpretation interfaces at stations 85, 130, and 165 are in good agreement with the TCM observations (Figure 19).

5. DISCUSSION

A conceptual geophysical model for the aquifer from surface to depth would include the following layers: 1) very high resistivity (>5k ohm-m) partially saturated zone above the water table, 2) high resistivity (100-2000 ohm-m), freshwater saturated aquifer, 3) intermediate resistivity (20-50 ohm-m) , transition zone between the freshwater aquifer and the saltwater saturated zone, and 4) low resistivity (<10 ohm-m) saltwater saturated zone. Differentiation between the zone above the water table and the freshwater saturated aquifer would be difficult with electromagnetic methods because of their small response due to the high resistivities. Detection of a freshwater to saltwater transition zone would depend upon the thickness of the transition and the resolution of the method used (Fitterman and others, 1988). The TEM soundings have the best chance of seeing the transition due to its greater resolving power, whereas the TCM data might allow, but not define, such a zone. The thinner the transition zone, the more difficult it would be to detect.

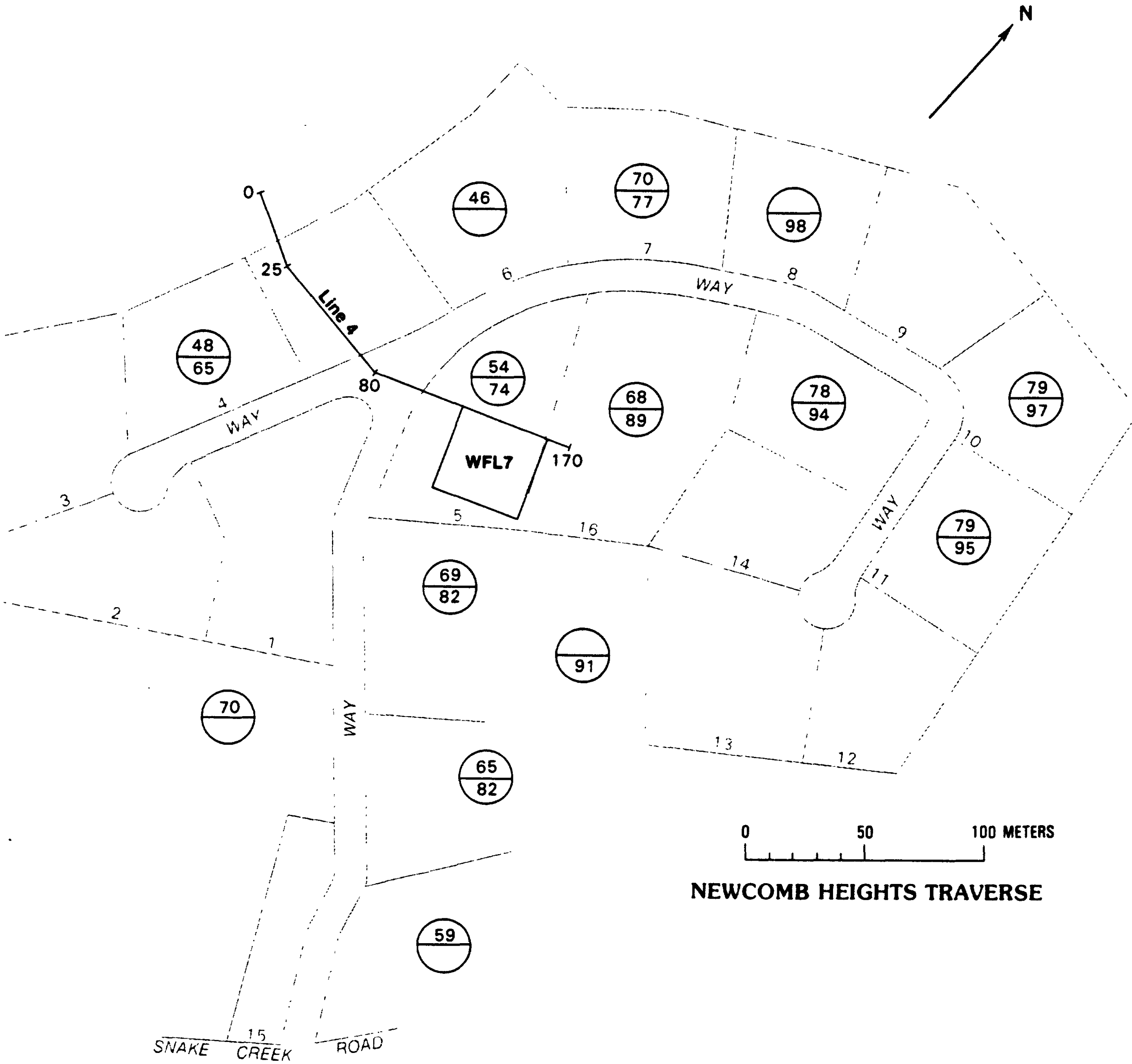

Figure 14 Location of survey line and TEM sounding loop at the Newcomb Heights traverse. The circled numbers are the depths to the water table (upper number) and total well depth (lower number) in feet. The gray numbers and lines are lot numbers and property boundaries respectively. Exact location of the wells inside the property boundaries is not known. The numbers along the geophysical line are the station numbers in meters.

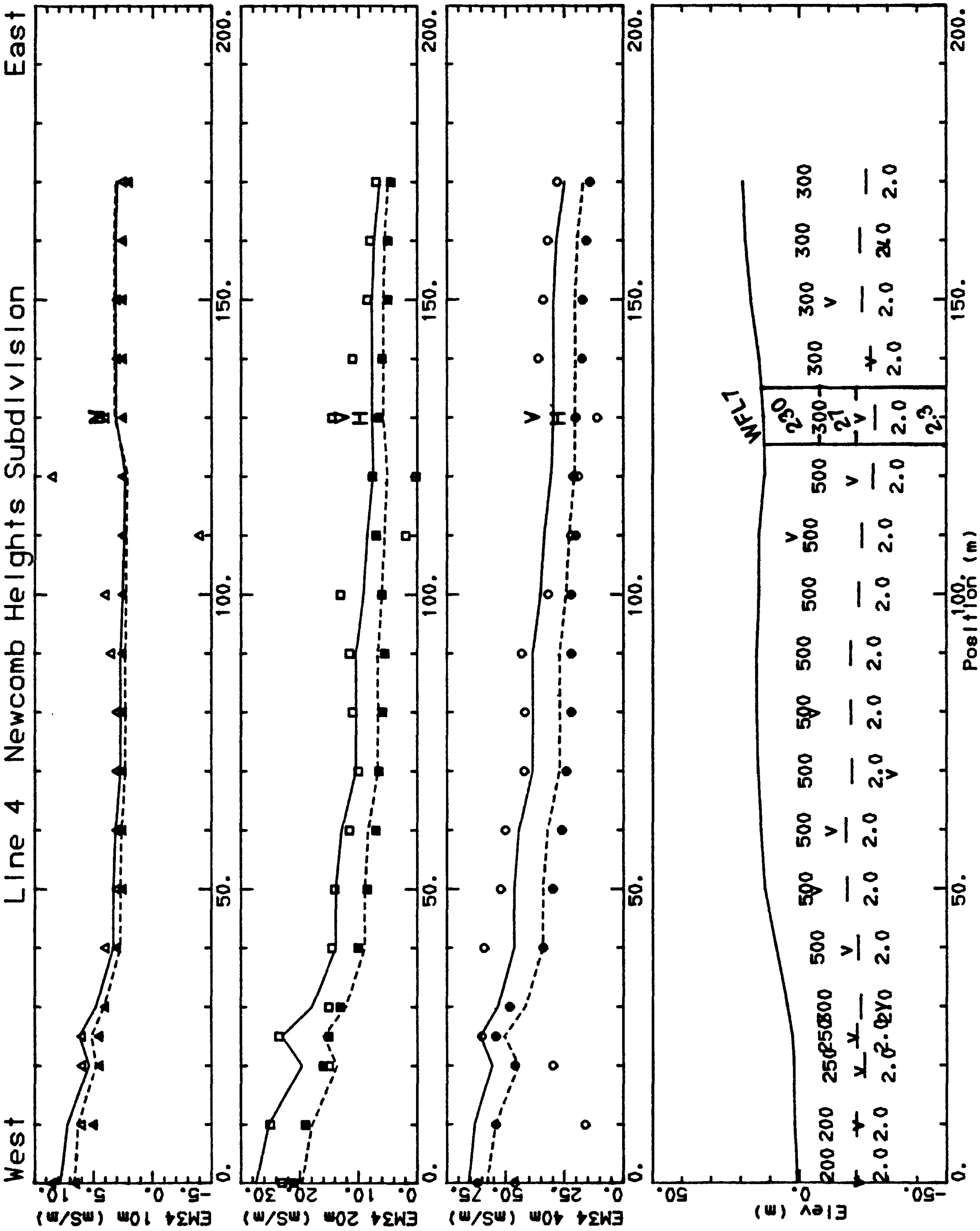

Figure 15 Terrain conductivity meter data and interpreted cross section for Line 4, Newcomb Heights Subdivision, x=0-170 m. Tilted numbers near station 130 are the interpreted layer resistivities from TEM sounding WFL 7. The V's and H's on the TCM plots are the computed response based upon the interpreted model from TEM sounding WFL 7.

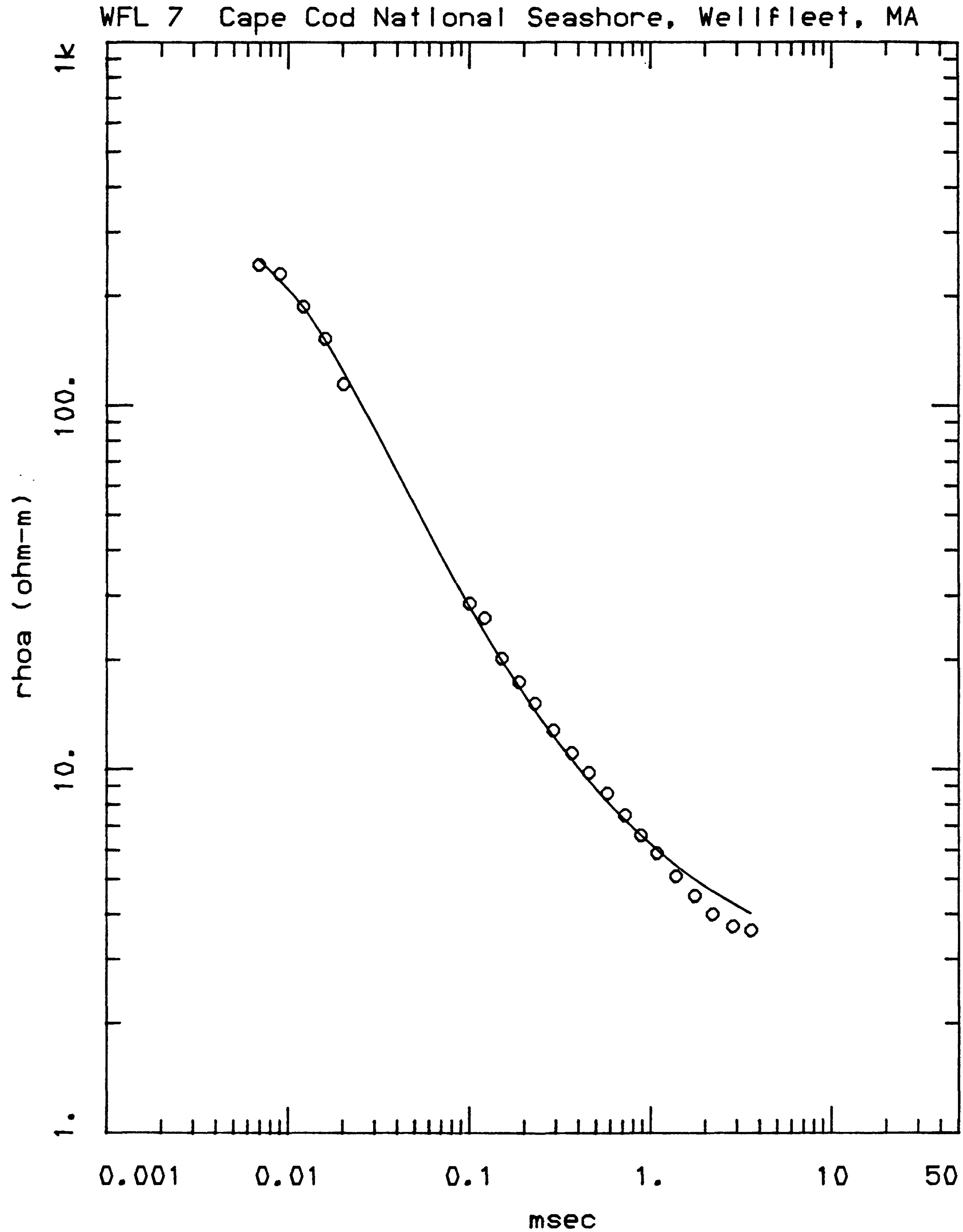

Figure 16 Apparent resistivity-time plots for TEM sounding WFL 7, Newcomb Heights Subdivision.

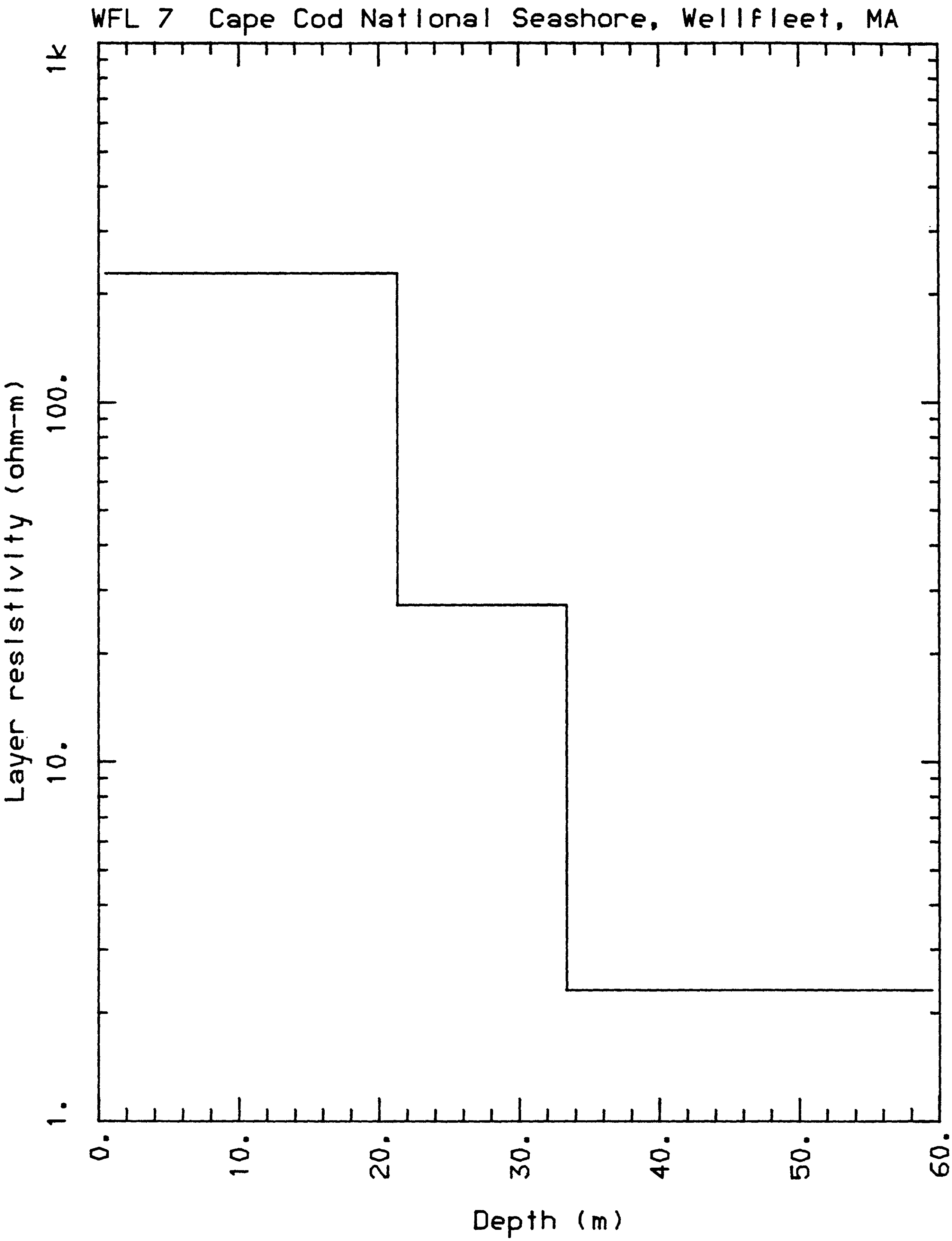

Figure 17 Interpreted resistivity-depth function for TEM sounding WFL 7, Newcomb Heights Subdivision.

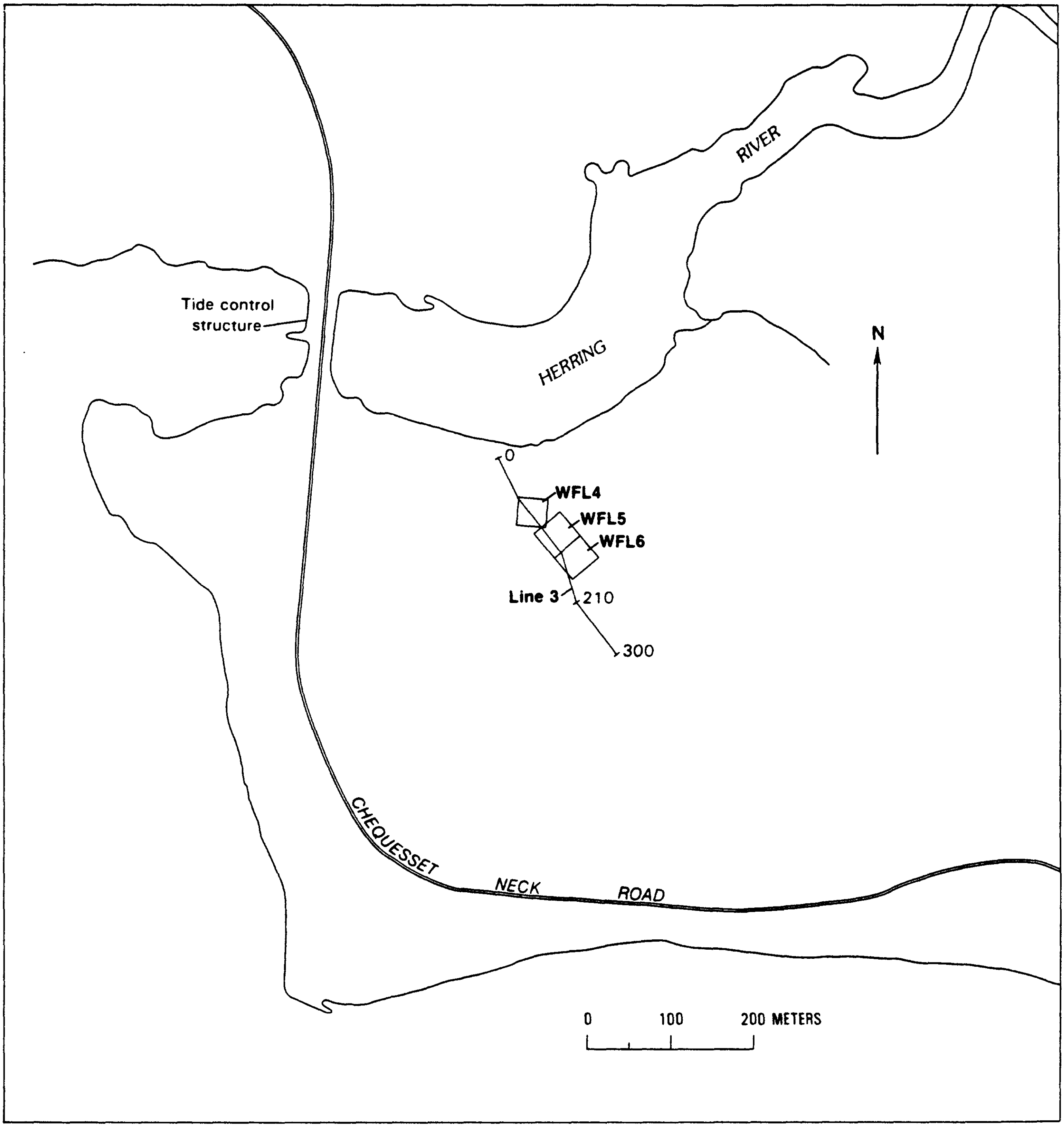

Figure 18 Location of survey line and TEM sounding loops at the Chequesset Neck traverse. The numbers along the geophysical line are the station numbers in meters..

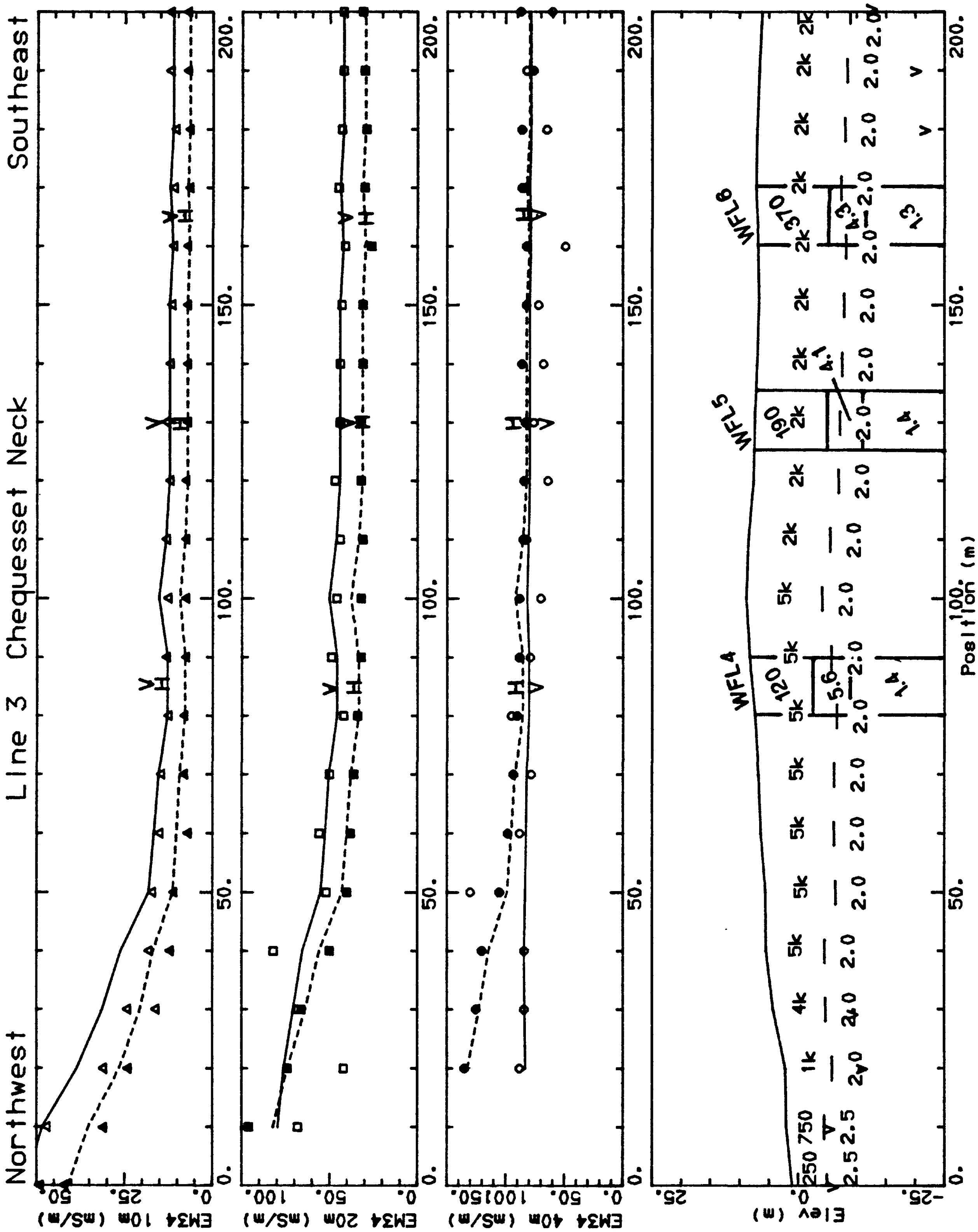

Figure 19 Terrain conductivity meter data and interpreted cross sections for Line 3, Chequesset Neck traverse, x=0-200 m. Tilted numbers near stations 85, 130, and 165 are the interpreted layer resistivities from TEM soundings WFL 4, WFL 5, and WFL 6 respectively. The V's and H's on the TCM plots are the computed response based upon the interpreted model from TEM sounding near that station.

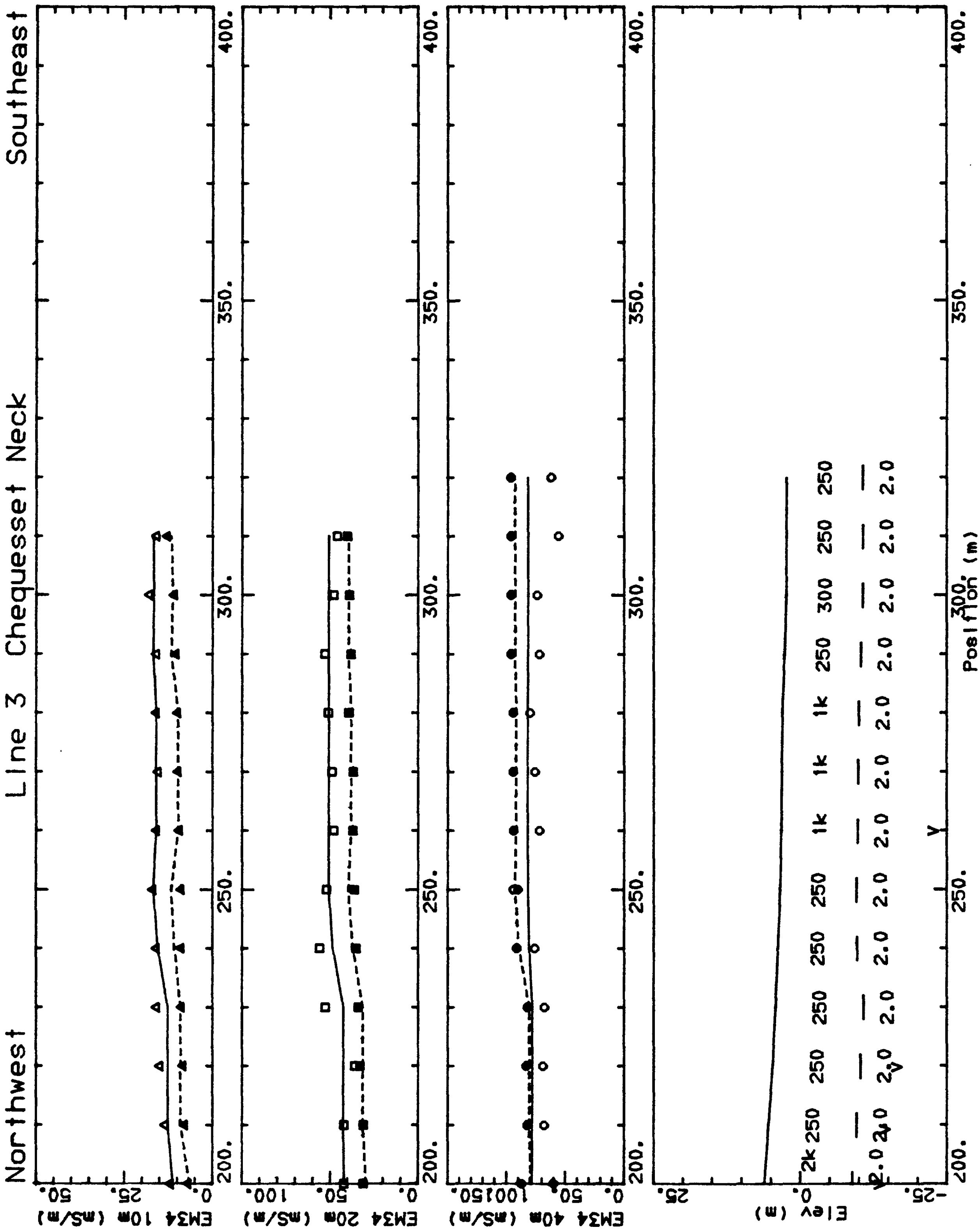

Figure 20 Terrain conductivity meter data and interpreted cross sections for Line 3, Chequesset Neck traverse, x=200-320 m.

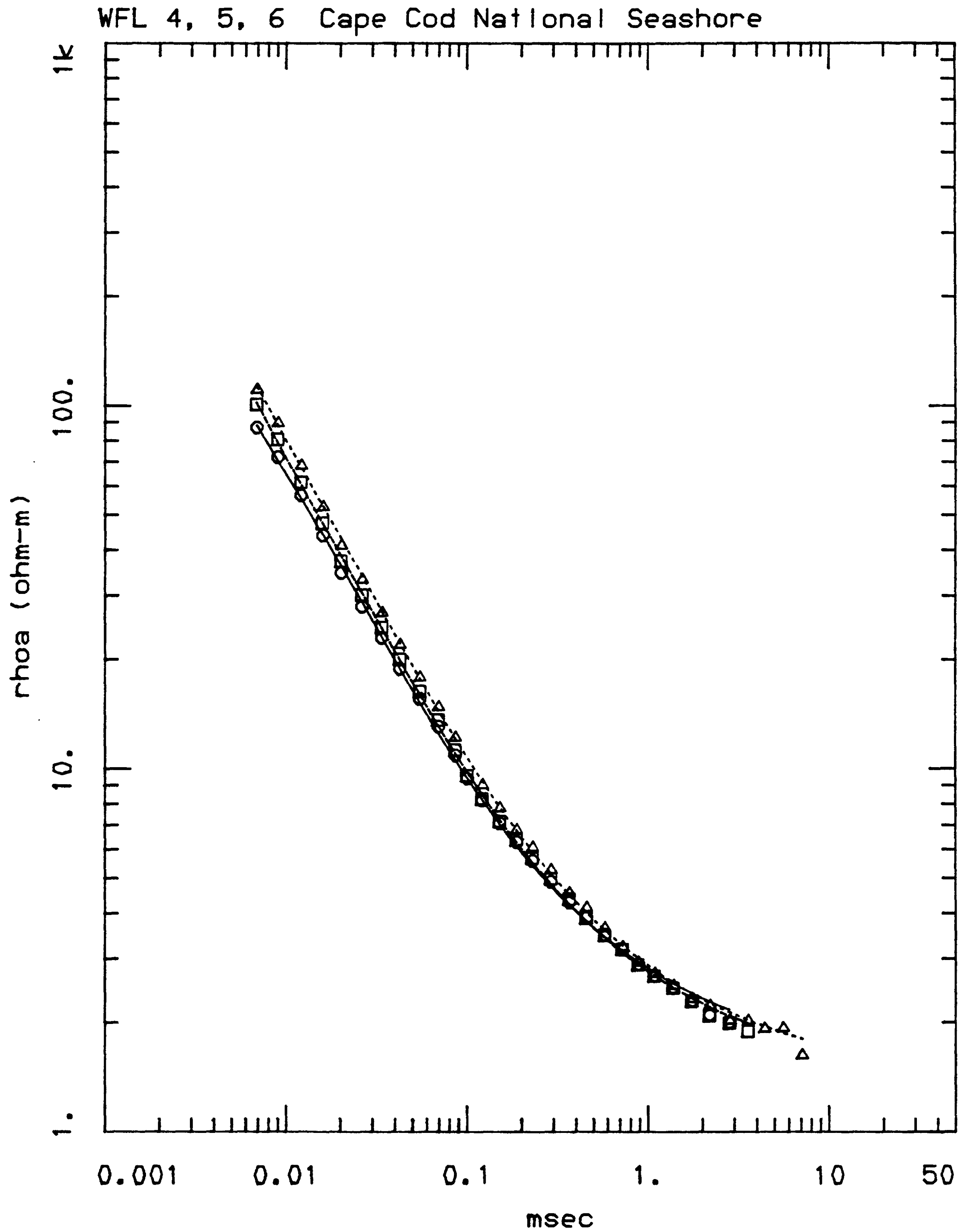

Figure 21 Apparent resistivity-time plots for TEM soundings WFL 4, WFL 5, and WFL 6, Chequesset Neck traverse. The symbols for the soundings are: ○ WFL 4, □ WFL 5, and △ WFL 6.

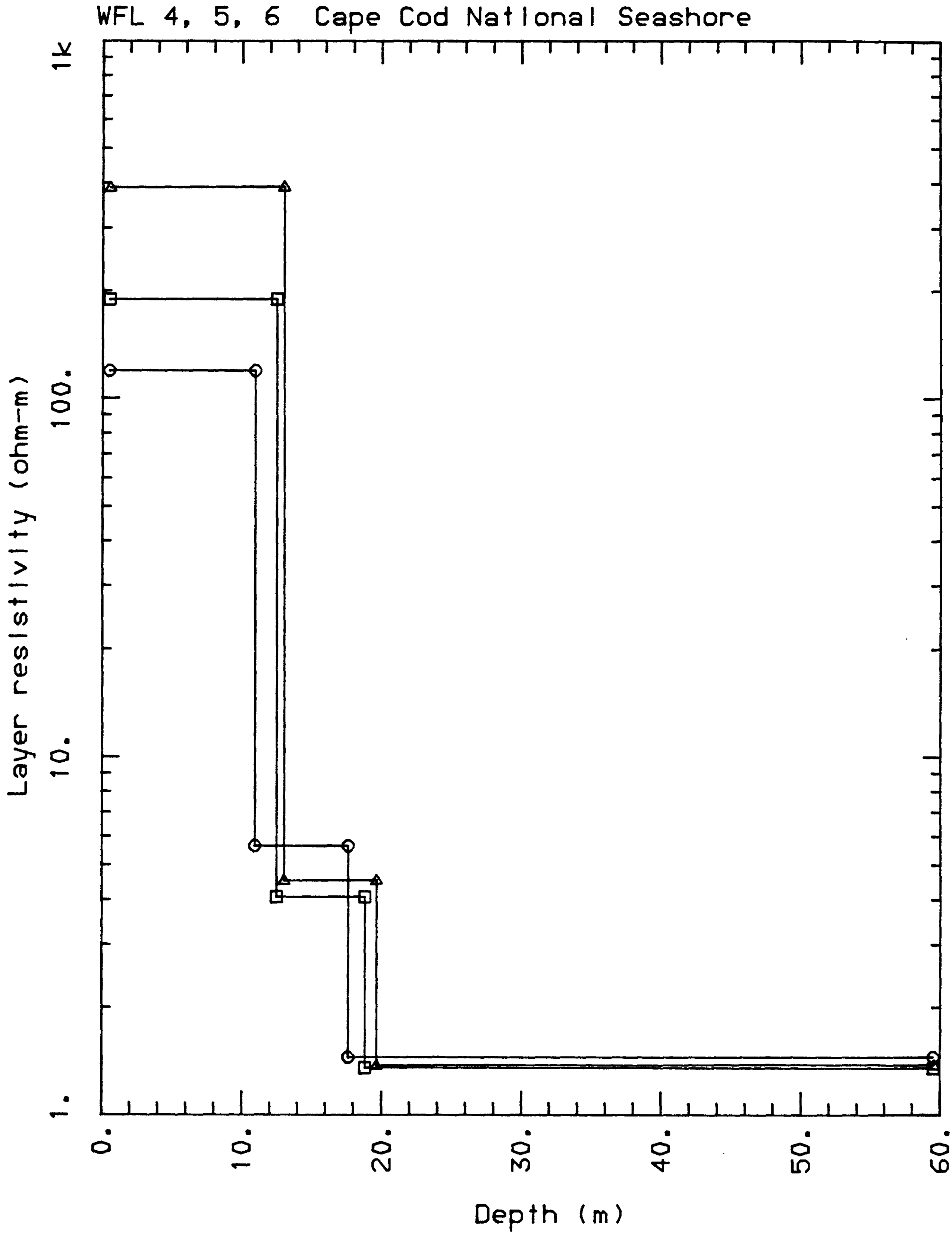

Figure 22 Interpreted resistivity-depth function for TEM soundings WFL 4, WFL 5, and WFL 6, Chequesset Neck traverse. The symbols are the same as in Figure 21.

Using only the TCM data discussed in the previous section, the location of the FWSWI would be put at the interface between the first and second layer. The TEM data, however, having greater resolution, indicate the presence of a transition zone of intermediate resistivity on the east end of Line 1 (WFL 2, near station 220) and the east end of Line 4 (WFL 7, near station 130). On the west end of Line 2 (WFL 1, near station 60) the TCM determined interface corresponds with the top of the TEM determined transition zone. On Line 3 the TCM determined interface is in the middle of the second layer for the TEM model, which is conductive enough to be saltwater saturated.

Chloride concentration data from wells near Duck Harbor (Well WNW 80-83), sampled in 1976, and on Great Island (Well WNW 50), sampled in 1965, show a transition zone thickness of as much as 8 m and 3 m respectively (LeBlanc and others, 1986). These thicknesses are similar to the second-layer thickness of the TEM soundings, where the top of the transition corresponds with the TCM interface. LeBlanc and others (1986) present data showing much larger transition zones at wells in Truro (20 m at wells TSW 200 and TSW 234), that are farther from the coast. It is not clear if the thicker transition zone at these wells is due to greater seasonal water-level changes or the the presence of local silt and clay zones (LeBlanc and others, 1986); however, this increase corresponds to the pattern seen in the TEM data where the transition zone appears to thicken in the landward direction (i.e., away from the Herring River). Such an increase cannot be explained by water velocity increases, as they are expected to be greater at the coast line where tidally induced fluctuations are larger and more frequent compared to slower long-term and seasonal ground-water fluctuations that occur inland.

In general, it appears that the TCM determined interface corresponds to the bottom of the transition zone (or top of the saltwater saturated zone). Ideally, what is needed for the purposes of this study is the depth to the bottom of the freshwater zone (or top of the transition zone). It appears that this information is not directly available from these data. Induction logs made in wells drilled to the saltwater layer would give information on the thickness and resistivity of the transition zone. These data will allow a refinement of the geophysical interpretation and enable better estimates of the location of the bottom of the freshwater aquifer to be made.

Some water-well-depth information is given in Figures 2 and 14 that can be compared to the interpreted cross sections (Figures 3, 4, 7, 8, and 15). The well depths were reported inside the property boundaries on the subdivision plat maps so the exact location and well elevation is not known. Along Line 1 well depths of 16.8 m (55 ft) and 15.9 m (52 ft) are reported about 65 m from station 120 and 24 m from station 320 respectively (see Figures 2, 3, and 4). These correspond to vertical separations of about 21 and 29 m respectively between the saltwater saturated zone and the well level. On Line 2 a well depth of 9.5 m (31 ft) is reported about 30 m from station 230, corresponding to a vertical separation of about 17 m (see Figures 2, 7, and 8). On Line 4 there are three reported wells with depths of 14.6, 16.5, and 20.7 m (48, 54, and 68 ft) at distances of 37, 15, and 25 m from stations 40, 120, and 170 respectively (see Figures 14 and 15). These give vertical separations of 13, 20, and 21 m respectively. Based upon these limited data it appears that there is more than 10 m separation between water-well levels and the saltwater saturated zone, and that this separation increases significantly in the landward direction.

The effect of tidal fluctuations on a coastal aquifers can be approximated using a simple model that allows only horizontal fluid flow (Ferris, 1951; Todd, 1960, p. 163; Ferris and others, 1962; Urish and Ozbilgin, 1989). For a confined aquifer with a tidal fluctuation range that is small compared to the aquifer thickness, the water height fluctuation in the aquifer is given by

$$h = h_0 \exp[-x(\pi S / t_0 T)^{1/2}] \sin[(2\pi t / t_0 T)^{1/2} - x(\pi S / t_0 T)^{1/2}] \quad (1)$$

where $2h_0$ is the tidal range, x is the distance landward, S is the aquifer storativity, T is the aquifer transmissivity, and t_0 is the tidal period. This equation can be used to determine the distance landward that tidal fluctuations are important. At one diffusion distance, $(t_0T/\pi S)^{1/2}$, the tidal fluctuation is 37 percent of h_0, and at three times this distance it is only 5 percent of h_0.

For the Herring River sluice-tide-gate structure in its current configuration with one sluice gate open 61 cm and two tide gates, the tidal range behind the structure ($2h_0$) is 0.55 m for the semidiurnal tide (t_0=12.42 h) with a tidal range of 2.38 m downstream of the dike (Roman and others, p. 37-40, 1987). Because the aquifer in question is unconfined, the quantity T/S is approximated by K/S_y where K is the hydraulic conductivity and S_y is the specific yield of the unconfined aquifer (Freeze and Cherry, 1979). Assuming a value of 0.35 for S_y and taking values of 100-400 ft/day ($3.5\text{-}14 \cdot 10^{-4}$ m/s) from Guswa and LeBlanc's (1985) Wellfleet aquifer model, equation (1) gives a diffusion distance of only 4-8 m. Thus the semidiurnal tidal fluctuation damps out very quickly in the landward direction. At one diffusion length the water height range ($2h_0$) is expected to be 20 cm, and only 3 cm at three diffusion lengths. Furthermore, the expected increase in $2h_0$ of 3 cm, if the sluice-tide gates were completely removed, represents only a 5 percent increase from its current value. The maximum water height range inside the aquifer will increase by the same proportion of its present value, resulting in an increase of only 1 cm at one diffusion length. Thus the increased tidally driven fluctuation of aquifer height is not expected to be significant. It should be noted, however, that the presence of impermeable layers in the aquifer, such as clay lenses, could cause local increases in these estimated fluctuations.

It is important to note that modifying the sluice-tide-gate configuration results only in changes in the tidal fluctuation and not the average water level behind the dike (Roman and others, 1987). As such, changes in the tidal amplitude have no net effect on the position of the FWSWI, but rather act as a source of motion that promotes mixing of the freshwater and saltwater. Increased motion is expected to widen the transition zone between the freshwater and saltwater.

The diffusion attenuation effect makes the small increase in tidal fluctuation rather insignificant compared to the more than 10 m between the known well depths and the top of the saltwater saturated zone. Of far greater danger to water wells in the area in view of the possibility for their being much larger are: 1) water-table drawdown and upconing of saltwater through over pumping, 2) drought conditions that result in a reduction of the water-table level, 3) long term variations in rainfall that alternately raise and lower the water table causing broadening of the freshwater-saltwater transition zone, and 4) rises in ocean level due to global warming that can cause extensive saltwater incursion and flooding of low lying property. The first danger can be easily estimated by standard hydrologic methods (Reilly and others, 1987) and controlled through modest water usage, whereas the other dangers are driven by long term climatic effects that are beyond human control.

6. RECOMMENDATIONS

Based upon the analysis of these data it appears that increased tidal surge in the Herring River due to manipulation of the sluice-tide-gate structure at the mouth of river will have no significant effect on wells in the uplands east of the river. Wells adjacent to the river's flood plain may be affected, but this is not certain as detailed well data for these properties has not been collected. To further support this conclusion the following recommendations are made:

1. Well data for all domestic water wells in the study area should be collected. This includes well location and elevation, depth to water table, and total well depth. These data will be compared against the geophysical interpretation to assess the vertical clearance between the water table and the saltwater intruded zone.

2. Observation wells along the east bank of the Herring River and in the highlands should be drilled to confirm the geophysical interpretation. The wells should be drilled deep enough to penetrate into the saltwater intruded zone. The wells should be cased with PVC pipe and logged with an induction logger. Water samples should be collected and their electrical conductivity measured. These data will establish the thickness of the transition zone and the depth to the saltwater intruded zone.

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APPENDIX A TERRAIN CONDUCTIVITY DATA AND MODELING RESULTS

The following tables contain the observed and calculated TCM data along with the interpreted model. For each station the location and elevation in meters is given. All elevations are with respect to mean sea level. The left-hand side of the data display gives the model layer resistivities and thicknesses. The right-hand side of the data display contains the observations and calculated response for the layered earth model. Indicated are the instrument type, coil pair orientation, intercoil separation, operating frequency, and the observed and calculated conductivities in millisiemens/meter.

Line 1 EM34 Data Great Pasture Subdivision, Wellfleet, Massachusetts

x= 0.0 elev= 2.6

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	90.0	20.0	1	em34	hdp	10.0	6400.	13.0	11.3
2	2.5		2	em34	hdp	20.0	1600.	14.5	22.5
			3	em34	hdp	40.0	400.	70.0	55.6
			4	em34	vdp	10.0	6400.	11.0	11.1
			5	em34	vdp	20.0	1600.	28.0	28.4
			6	em34	vdp	40.0	400.	57.0	63.2

x= 10.0 elev= 4.9

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	90.0	21.0	1	em34	hdp	10.0	6400.	9.4	11.0
2	2.5		2	em34	hdp	20.0	1600.	20.0	21.1
			3	em34	hdp	40.0	400.	40.0	52.5
			4	em34	vdp	10.0	6400.	11.0	10.6
			5	em34	vdp	20.0	1600.	25.0	26.5
			6	em34	vdp	40.0	400.	66.0	60.8

x= 20.0 elev= 5.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	125.0	22.0	1	em34	hdp	10.0	6400.	8.1	8.4
2	2.5		2	em34	hdp	20.0	1600.	14.0	17.9
			3	em34	hdp	40.0	400.	63.0	48.2
			4	em34	vdp	10.0	6400.	10.0	8.5
			5	em34	vdp	20.0	1600.	21.5	23.7
			6	em34	vdp	40.0	400.	62.0	58.1

x= 30.0 elev= 5.6

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	5.0	1	em34	hdp	10.0	6400.	7.6	7.4
2	100.0	21.0	2	em34	hdp	20.0	1600.	11.5	14.3
3	2.5		3	em34	hdp	40.0	400.	50.0	39.0
			4	em34	vdp	10.0	6400.	9.0	7.8
			5	em34	vdp	20.0	1600.	18.0	18.7
			6	em34	vdp	40.0	400.	51.0	49.5

x= 40.0 elev= 6.3

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	5.0	1	em34	hdp	10.0	6400.	7.4	7.2
2	100.0	24.0	2	em34	hdp	20.0	1600.	10.5	12.5
3	2.5		3	em34	hdp	40.0	400.	42.0	33.6
			4	em34	vdp	10.0	6400.	8.8	7.4
			5	em34	vdp	20.0	1600.	16.0	15.8
			6	em34	vdp	40.0	400.	40.0	43.7

x= 50.0 elev= 7.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	5.0	1	em34	hdp	10.0	6400.	6.9	6.7
2	125.0	24.0	2	em34	hdp	20.0	1600.	9.0	11.8
3	2.5		3	em34	hdp	40.0	400.	37.0	32.9
			4	em34	vdp	10.0	6400.	7.8	6.6
			5	em34	vdp	20.0	1600.	13.0	15.1
			6	em34	vdp	40.0	400.	44.0	43.3

Line 1 EM34 Data Great Pasture Subdivision, Wellfleet, Massachusetts

x= 60.0 elev= 9.9

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	29.0	1	em34	hdp	10.0	6400.	6.7	6.4
2	2.5		2	em34	hdp	20.0	1600.	7.3	11.4
			3	em34	hdp	40.0	400.	36.0	32.4
			4	em34	vdp	10.0	6400.	7.8	6.1
			5	em34	vdp	20.0	1600.	12.0	14.6
			6	em34	vdp	40.0	400.	43.0	43.1

x= 70.0 elev= 11.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	29.0	1	em34	hdp	10.0	6400.	6.4	6.4
2	2.5		2	em34	hdp	20.0	1600.	5.8	11.4
			3	em34	hdp	40.0	400.	32.0	32.4
			4	em34	vdp	10.0	6400.	7.0	6.1
			5	em34	vdp	20.0	1600.	10.5	14.6
			6	em34	vdp	40.0	400.	51.0	43.1

x= 80.0 elev= 13.9

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	175.0	31.0	1	em34	hdp	10.0	6400.	6.2	5.5
2	3.0		2	em34	hdp	20.0	1600.	5.4	9.7
			3	em34	hdp	40.0	400.	28.0	27.2
			4	em34	vdp	10.0	6400.	7.0	5.3
			5	em34	vdp	20.0	1600.	9.8	12.5
			6	em34	vdp	40.0	400.	46.0	37.6

x= 90.0 elev= 13.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	32.0	1	em34	hdp	10.0	6400.	6.2	6.3
2	3.0		2	em34	hdp	20.0	1600.	4.6	9.9
			3	em34	hdp	40.0	400.	27.0	26.5
			4	em34	vdp	10.0	6400.	6.8	5.9
			5	em34	vdp	20.0	1600.	8.6	12.3
			6	em34	vdp	40.0	400.	38.0	36.3

x= 100.0 elev= 13.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	35.0	1	em34	hdp	10.0	6400.	6.4	6.2
2	3.0		2	em34	hdp	20.0	1600.	4.4	9.0
			3	em34	hdp	40.0	400.	23.5	23.2
			4	em34	vdp	10.0	6400.	7.0	5.7
			5	em34	vdp	20.0	1600.	7.3	10.7
			6	em34	vdp	40.0	400.	34.0	32.1

x= 110.0 elev= 14.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	35.0	1	em34	hdp	10.0	6400.	6.2	6.2
2	4.0		2	em34	hdp	20.0	1600.	4.2	8.9
			3	em34	hdp	40.0	400.	23.0	21.3
			4	em34	vdp	10.0	6400.	8.0	5.8
			5	em34	vdp	20.0	1600.	7.2	10.6
			6	em34	vdp	40.0	400.	30.0	29.8

Line 1 EM34 Data Great Pasture Subdivision, Wellfleet, Massachusetts

x= 120.0 elev= 16.1

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	38.0	1	em34	hdp	10.0	6400.	6.1	6.1
2	2.5		2	em34	hdp	20.0	1600.	3.8	8.3
			3	em34	hdp	40.0	400.	21.5	21.4
			4	em34	vdp	10.0	6400.	5.2	5.5
			5	em34	vdp	20.0	1600.	6.8	9.5
			6	em34	vdp	40.0	400.	29.0	29.5

x= 130.0 elev= 16.5

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	38.0	1	em34	hdp	10.0	6400.	6.0	6.1
2	3.0		2	em34	hdp	20.0	1600.	3.6	8.3
			3	em34	hdp	40.0	400.	21.0	20.5
			4	em34	vdp	10.0	6400.	6.2	5.6
			5	em34	vdp	20.0	1600.	6.0	9.5
			6	em34	vdp	40.0	400.	31.0	28.5

x= 140.0 elev= 18.5

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	40.0	1	em34	hdp	10.0	6400.	5.8	6.1
2	3.0		2	em34	hdp	20.0	1600.	3.0	7.9
			3	em34	hdp	40.0	400.	19.0	19.0
			4	em34	vdp	10.0	6400.	6.3	5.5
			5	em34	vdp	20.0	1600.	5.4	8.9
			6	em34	vdp	40.0	400.	26.0	26.3

x= 150.0 elev= 19.4

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	43.0	1	em34	hdp	10.0	6400.	6.0	6.0
2	3.0		2	em34	hdp	20.0	1600.	2.8	7.5
			3	em34	hdp	40.0	400.	18.0	17.1
			4	em34	vdp	10.0	6400.	6.0	5.5
			5	em34	vdp	20.0	1600.	4.6	8.1
			6	em34	vdp	40.0	400.	21.0	23.5

x= 160.0 elev= 20.9

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	43.0	1	em34	hdp	10.0	6400.	5.6	6.0
2	3.0		2	em34	hdp	20.0	1600.	2.6	7.5
			3	em34	hdp	40.0	400.	15.0	17.1
			4	em34	vdp	10.0	6400.	6.0	5.5
			5	em34	vdp	20.0	1600.	4.1	8.1
			6	em34	vdp	40.0	400.	24.0	23.5

x= 170.0 elev= 22.4

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	150.0	43.0	1	em34	hdp	10.0	6400.	5.8	6.0
2	3.0		2	em34	hdp	20.0	1600.	2.2	7.5
			3	em34	hdp	40.0	400.	14.5	17.1
			4	em34	vdp	10.0	6400.	5.8	5.5
			5	em34	vdp	20.0	1600.	3.8	8.1
			6	em34	vdp	40.0	400.	25.0	23.5

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x= 180.0	elev=	24.5			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	150.0	42.0	1	em34	hdp	10.0	6400.	5.4	6.1
2	3.0		2	em34	hdp	20.0	1600.	2.3	7.6
			3	em34	hdp	40.0	400.	14.0	17.7
			4	em34	vdp	10.0	6400.	6.0	5.5
			5	em34	vdp	20.0	1600.	4.0	8.3
			6	em34	vdp	40.0	400.	25.5	24.4

x= 190.0	elev=	24.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	150.0	43.0	1	em34	hdp	10.0	6400.	5.8	6.1
2	3.5		2	em34	hdp	20.0	1600.	2.0	7.5
			3	em34	hdp	40.0	400.	13.0	16.6
			4	em34	vdp	10.0	6400.	6.0	5.5
			5	em34	vdp	20.0	1600.	3.6	8.1
			6	em34	vdp	40.0	400.	23.5	22.9

x= 200.0	elev=	23.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	150.0	47.0	1	em34	hdp	10.0	6400.	5.8	6.1
2	3.5		2	em34	hdp	20.0	1600.	1.9	7.1
			3	em34	hdp	40.0	400.	12.0	14.6
			4	em34	vdp	10.0	6400.	6.0	5.5
			5	em34	vdp	20.0	1600.	3.4	7.4
			6	em34	vdp	40.0	400.	21.0	19.9

x= 210.0	elev=	23.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	150.0	50.0	1	em34	hdp	10.0	6400.	5.6	6.0
2	3.5		2	em34	hdp	20.0	1600.	1.9	6.9
			3	em34	hdp	40.0	400.	12.0	13.4
			4	em34	vdp	10.0	6400.	5.8	5.5
			5	em34	vdp	20.0	1600.	3.4	7.0
			6	em34	vdp	40.0	400.	18.0	18.0

x= 220.0	elev=	23.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	150.0	54.0	1	em34	hdp	40.0	400.	11.5	12.1
2	3.5		2	em34	vdp	40.0	400.	16.4	16.0

x= 230.0	elev=	23.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	54.0	1	em34	hdp	40.0	400.	11.0	10.5
2	3.0		2	em34	vdp	40.0	400.	19.0	15.1

x= 240.0	elev=	24.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	48.0	1	em34	hdp	40.0	400.	11.0	12.4
2	3.5		2	em34	vdp	40.0	400.	19.0	18.2

x= 250.0	elev=	24.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	48.0	1	em34	hdp	40.0	400.	10.5	12.1
2	4.0		2	em34	vdp	40.0	400.	21.5	17.7

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x= 260.0	elev= 24.2				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	46.0	1	em34	hdp	40.0	400.	10.5	11.7
2	3.0		2	em34	vdp	40.0	400.	22.5	19.3

x= 270.0	elev= 22.8				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	10.0	11.0
2	3.0		2	em34	vdp	40.0	400.	19.0	18.4

x= 280.0	elev= 21.4				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	46.0	1	em34	hdp	40.0	400.	12.0	11.5
2	3.0		2	em34	vdp	40.0	400.	19.0	19.2

x= 290.0	elev= 20.9				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	48.0	1	em34	hdp	40.0	400.	12.0	10.5
2	3.0		2	em34	vdp	40.0	400.	16.5	17.7

x= 300.0	elev= 20.5				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	11.0	11.0
2	3.0		2	em34	vdp	40.0	400.	19.0	18.4

x= 310.0	elev= 19.8				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	45.0	1	em34	hdp	40.0	400.	11.5	12.0
2	3.0		2	em34	vdp	40.0	400.	21.0	20.0

x= 320.0	elev= 19.0				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	45.0	1	em34	hdp	40.0	400.	11.5	12.0
2	3.0		2	em34	vdp	40.0	400.	19.0	20.0

x= 330.0	elev= 18.3				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	11.5	11.0
2	3.0		2	em34	vdp	40.0	400.	18.0	18.4

x= 340.0	elev= 18.3				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	45.0	1	em34	hdp	40.0	400.	11.0	12.0
2	3.0		2	em34	vdp	40.0	400.	21.0	20.0

x= 350.0	elev= 18.5				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	45.0	1	em34	hdp	40.0	400.	11.5	12.0
2	3.0		2	em34	vdp	40.0	400.	19.0	20.0

x= 360.0	elev= 18.5				coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	11.0	11.0
2	3.0		2	em34	vdp	40.0	400.	19.0	18.4

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x= 370.0	elev=	18.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	11.0	11.0
2	3.0		2	em34	vdp	40.0	400.	18.0	18.4

x= 380.0	elev=	17.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	10.5	11.0
2	3.0		2	em34	vdp	40.0	400.	18.0	18.4

x= 390.0	elev=	16.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	10.5	11.0
2	3.0		2	em34	vdp	40.0	400.	19.0	18.4

x= 400.0	elev=	15.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	47.0	1	em34	hdp	40.0	400.	10.5	11.0
2	3.0		2	em34	vdp	40.0	400.	18.0	18.4

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x=	0.0	elev= 2.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	20.0	1	em34	hdp	10.0	6400.	6.5	5.9
2	2.5		2	em34	hdp	20.0	1600.	25.5	18.1
			3	em34	hdp	40.0	400.	68.0	52.4
			4	em34	vdp	10.0	6400.	7.0	7.4
			5	em34	vdp	20.0	1600.	28.0	26.4
			6	em34	vdp	40.0	400.	42.0	62.8

x=	10.0	elev= 3.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	19.0	1	em34	hdp	10.0	6400.	5.0	6.3
2	2.5		2	em34	hdp	20.0	1600.	22.0	19.8
			3	em34	hdp	40.0	400.	61.0	55.8
			4	em34	vdp	10.0	6400.	6.0	8.1
			5	em34	vdp	20.0	1600.	27.0	28.7
			6	em34	vdp	40.0	400.	59.0	65.3

x=	20.0	elev= 5.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	19.0	1	em34	hdp	10.0	6400.	4.0	4.0
2	2.5		2	em34	hdp	20.0	1600.	17.0	18.0
			3	em34	hdp	40.0	400.	52.0	54.4
			4	em34	vdp	10.0	6400.	5.5	6.8
			5	em34	vdp	20.0	1600.	29.0	28.1
			6	em34	vdp	40.0	400.	70.0	65.5

x=	30.0	elev= 6.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	21.0	1	em34	hdp	10.0	6400.	3.0	3.2
2	2.5		2	em34	hdp	20.0	1600.	13.5	14.7
			3	em34	hdp	40.0	400.	50.0	47.8
			4	em34	vdp	10.0	6400.	4.5	5.4
			5	em34	vdp	20.0	1600.	20.0	23.6
			6	em34	vdp	40.0	400.	64.0	60.3

x=	40.0	elev= 7.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	22.0	1	em34	hdp	10.0	6400.	3.0	2.9
2	2.5		2	em34	hdp	20.0	1600.	11.0	13.4
			3	em34	hdp	40.0	400.	43.0	44.8
			4	em34	vdp	10.0	6400.	4.0	4.9
			5	em34	vdp	20.0	1600.	20.0	21.7
			6	em34	vdp	40.0	400.	60.0	57.8

x=	50.0	elev= 7.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	25.0	1	em34	hdp	10.0	6400.	3.0	2.6
2	2.5		2	em34	hdp	20.0	1600.	11.0	10.5
			3	em34	hdp	40.0	400.	38.0	37.3
			4	em34	vdp	10.0	6400.	4.0	3.7
			5	em34	vdp	20.0	1600.	16.5	16.9
			6	em34	vdp	40.0	400.	46.0	50.6

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x= 60.0	elev=	8.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	26.0	1	em34	hdp	10.0	6400.	2.5	2.1
2	2.5		2	em34	hdp	20.0	1600.	10.0	9.4
			3	em34	hdp	40.0	400.	34.0	35.0
			4	em34	vdp	10.0	6400.	3.5	3.4
			5	em34	vdp	20.0	1600.	13.5	15.6
			6	em34	vdp	40.0	400.	49.0	48.4

x= 70.0	elev=	9.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	27.0	1	em34	hdp	10.0	6400.	2.5	2.3
2	3.0		2	em34	hdp	20.0	1600.	12.0	8.7
			3	em34	hdp	40.0	400.	32.0	30.8
			4	em34	vdp	10.0	6400.	3.0	3.2
			5	em34	vdp	20.0	1600.	15.5	14.1
			6	em34	vdp	40.0	400.	40.0	44.0

x= 80.0	elev=	9.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	27.0	1	em34	hdp	10.0	6400.	2.5	2.3
2	3.0		2	em34	hdp	20.0	1600.	10.0	8.7
			3	em34	hdp	40.0	400.	30.0	30.8
			4	em34	vdp	10.0	6400.	3.0	3.2
			5	em34	vdp	20.0	1600.	13.0	14.1
			6	em34	vdp	40.0	400.	47.0	44.0

x= 90.0	elev=	10.5			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	29.0	1	em34	hdp	10.0	6400.	2.5	2.6
2	3.0		2	em34	hdp	20.0	1600.	11.5	7.9
			3	em34	hdp	40.0	400.	28.0	27.9
			4	em34	vdp	10.0	6400.	3.0	3.2
			5	em34	vdp	20.0	1600.	15.0	12.5
			6	em34	vdp	40.0	400.	39.0	40.3

x= 100.0	elev=	10.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	30.0	1	em34	hdp	10.0	6400.	2.0	2.0
2	3.0		2	em34	hdp	20.0	1600.	11.0	7.0
			3	em34	hdp	40.0	400.	26.0	26.1
			4	em34	vdp	10.0	6400.	2.5	2.6
			5	em34	vdp	20.0	1600.	13.0	11.3
			6	em34	vdp	40.0	400.	36.0	38.4

x= 110.0	elev=	12.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	31.0	1	em34	hdp	10.0	6400.	2.0	1.9
2	4.0		2	em34	hdp	20.0	1600.	13.0	6.2
			3	em34	hdp	40.0	400.	22.0	22.0
			4	em34	vdp	10.0	6400.	3.0	2.5
			5	em34	vdp	20.0	1600.	11.0	10.2
			6	em34	vdp	40.0	400.	33.0	33.5

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x= 120.0	elev=	13.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	32.0	1	em34	hdp	10.0	6400.	2.0	2.4
2	4.0		2	em34	hdp	20.0	1600.	11.0	6.3
			3	em34	hdp	40.0	400.	22.0	21.3
			4	em34	vdp	10.0	6400.	2.5	2.9
			5	em34	vdp	20.0	1600.	10.0	9.9
			6	em34	vdp	40.0	400.	28.0	32.3

x= 130.0	elev=	15.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	32.0	1	em34	hdp	10.0	6400.	2.0	2.4
2	4.0		2	em34	hdp	20.0	1600.	12.0	6.3
			3	em34	hdp	40.0	400.	20.0	21.3
			4	em34	vdp	10.0	6400.	2.0	2.9
			5	em34	vdp	20.0	1600.	10.0	9.9
			6	em34	vdp	40.0	400.	34.0	32.3

x= 140.0	elev=	16.5			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	31.0	1	em34	hdp	10.0	6400.	2.0	1.9
2	4.0		2	em34	hdp	20.0	1600.	7.0	6.2
			3	em34	hdp	40.0	400.	19.0	22.0
			4	em34	vdp	10.0	6400.	2.0	2.5
			5	em34	vdp	20.0	1600.	11.0	10.2
			6	em34	vdp	40.0	400.	35.0	33.5

x= 150.0	elev=	16.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	32.0	1	em34	hdp	10.0	6400.	2.0	1.9
2	4.0		2	em34	hdp	20.0	1600.	8.5	5.9
			3	em34	hdp	40.0	400.	20.0	20.9
			4	em34	vdp	10.0	6400.	2.0	2.4
			5	em34	vdp	20.0	1600.	11.0	9.6
			6	em34	vdp	40.0	400.	36.0	32.1

x= 160.0	elev=	15.8			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	750.0	29.0	1	em34	hdp	40.0	400.	21.0	24.4
2	4.0		2	em34	vdp	40.0	400.	41.0	36.6

x= 170.0	elev=	13.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	28.0	1	em34	hdp	10.0	6400.	1.0	1.6
2	4.0		2	em34	hdp	20.0	1600.	9.5	7.1
			3	em34	hdp	40.0	400.	21.0	25.3
			4	em34	vdp	10.0	6400.	2.0	2.6
			5	em34	vdp	20.0	1600.	17.0	12.1
			6	em34	vdp	40.0	400.	38.0	38.0

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x= 180.0	elev=	10.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	30.0	1	em34	hdp	40.0	400.	22.0	22.7
2	4.0		2	em34	vdp	40.0	400.	35.0	34.8

x= 190.0	elev=	8.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	30.0	1	em34	hdp	10.0	6400.	1.4	1.5
2	5.0		2	em34	hdp	20.0	1600.	12.0	5.8
			3	em34	hdp	40.0	400.	24.0	20.4
			4	em34	vdp	10.0	6400.	1.8	2.2
			5	em34	vdp	20.0	1600.	14.0	10.1
			6	em34	vdp	40.0	400.	24.0	31.9

x= 200.0	elev=	7.5			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	29.0	1	em34	hdp	40.0	400.	25.0	19.5
2	6.0		2	em34	vdp	40.0	400.	26.0	30.7

x= 210.0	elev=	7.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	31.0	1	em34	hdp	10.0	6400.	1.3	1.4
2	6.0		2	em34	hdp	20.0	1600.	13.0	5.2
			3	em34	hdp	40.0	400.	25.0	17.7
			4	em34	vdp	10.0	6400.	2.0	2.1
			5	em34	vdp	20.0	1600.	13.5	9.0
			6	em34	vdp	40.0	400.	24.0	28.2

x= 220.0	elev=	9.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1250.0	27.0	1	em34	hdp	40.0	400.	24.0	21.6
2	6.0		2	em34	vdp	40.0	400.	32.0	33.3

x= 230.0	elev=	10.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2000.0	27.0	1	em34	hdp	10.0	6400.	1.0	1.5
2	5.0		2	em34	hdp	20.0	1600.	15.0	7.0
			3	em34	hdp	40.0	400.	24.0	23.7
			4	em34	vdp	10.0	6400.	1.6	2.7
			5	em34	vdp	20.0	1600.	16.0	12.4
			6	em34	vdp	40.0	400.	36.0	36.3

x= 240.0	elev=	12.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2000.0	24.0	1	em34	hdp	40.0	400.	24.0	27.9
2	5.0		2	em34	vdp	40.0	400.	45.0	41.2

x= 250.0	elev=	11.8			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2500.0	24.0	1	em34	hdp	10.0	6400.	1.2	2.2
2	5.0		2	em34	hdp	20.0	1600.	9.5	9.1
			3	em34	hdp	40.0	400.	24.0	28.2
			4	em34	vdp	10.0	6400.	1.6	3.8
			5	em34	vdp	20.0	1600.	18.0	15.6
			6	em34	vdp	40.0	400.	45.0	41.4

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x= 260.0	elev=	10.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	3000.0	23.0	1	em34	hdp	10.0	6400.	1.3	2.0
2	5.0		2	em34	hdp	20.0	1600.	17.5	9.5
			3	em34	hdp	40.0	400.	24.0	29.4
			4	em34	vdp	10.0	6400.	1.5	3.4
			5	em34	vdp	20.0	1600.	19.5	16.1
			6	em34	vdp	40.0	400.	46.0	42.5

x= 270.0	elev=	8.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	3000.0	24.0	1	em34	hdp	10.0	6400.	1.4	1.8
2	5.0		2	em34	hdp	20.0	1600.	14.0	8.7
			3	em34	hdp	40.0	400.	26.0	27.8
			4	em34	vdp	10.0	6400.	2.3	3.0
			5	em34	vdp	20.0	1600.	15.5	14.9
			6	em34	vdp	40.0	400.	42.0	40.7

x= 280.0	elev=	6.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	4000.0	21.0	1	em34	hdp	10.0	6400.	1.7	2.3
2	5.0		2	em34	hdp	20.0	1600.	14.0	11.1
			3	em34	hdp	40.0	400.	30.0	32.9
			4	em34	vdp	10.0	6400.	2.4	4.4
			5	em34	vdp	20.0	1600.	15.0	19.0
			6	em34	vdp	40.0	400.	51.0	46.3

x= 290.0	elev=	4.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	5000.0	21.0	1	em34	hdp	10.0	6400.	2.6	2.7
2	5.0		2	em34	hdp	20.0	1600.	17.5	11.5
			3	em34	hdp	40.0	400.	32.0	33.3
			4	em34	vdp	10.0	6400.	3.2	4.4
			5	em34	vdp	20.0	1600.	21.5	19.0
			6	em34	vdp	40.0	400.	41.0	46.3

x= 300.0	elev=	2.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	200.0	21.0	1	em34	hdp	10.0	6400.	5.5	6.3
2	5.0		2	em34	hdp	20.0	1600.	22.5	14.6
			3	em34	hdp	40.0	400.	36.0	35.6
			4	em34	vdp	10.0	6400.	7.0	7.3
			5	em34	vdp	20.0	1600.	19.0	21.0
			6	em34	vdp	40.0	400.	42.0	47.2

x= 310.0	elev=	1.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	200.0	20.0	1	em34	hdp	10.0	6400.	6.5	6.6
2	5.0		2	em34	hdp	20.0	1600.	22.0	15.6
			3	em34	hdp	40.0	400.	36.0	37.5
			4	em34	vdp	10.0	6400.	8.0	7.8
			5	em34	vdp	20.0	1600.	26.0	22.5
			6	em34	vdp	40.0	400.	43.0	49.1

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x= 315.0 elev= 1.6

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	200.0	16.0	1	em34	hdp	10.0	6400.	7.5	8.3
2	5.0		2	em34	vdp	10.0	6400.	12.0	10.9

x= 320.0 elev= 1.1

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	13.5	14.5
2	5.0		2	em34	hdp	20.0	1600.	42.0	26.2
			3	em34	hdp	40.0	400.	40.0	50.6
			4	em34	vdp	10.0	6400.	24.0	15.1
			5	em34	vdp	20.0	1600.	36.0	32.8
			6	em34	vdp	40.0	400.	16.0	57.5

x= 330.0 elev= 0.9

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	54.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	30.0	28.1
			3	em34	hdp	40.0	400.	45.0	57.0
			4	em34	vdp	10.0	6400.	-110.0	15.3
			5	em34	vdp	20.0	1600.	-78.0	35.1
			6	em34	vdp	40.0	400.	1.0	63.1

x= 340.0 elev= 0.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	165.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	86.0	28.1
			3	em34	hdp	40.0	400.	44.0	57.0
			4	em34	vdp	10.0	6400.	-46.0	15.3
			5	em34	vdp	20.0	1600.	-110.0	35.1
			6	em34	vdp	40.0	400.	-12.0	63.1

x= 350.0 elev= 0.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	190.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	120.0	28.1
			3	em34	hdp	40.0	400.	50.0	57.0
			4	em34	vdp	10.0	6400.	8.0	15.3
			5	em34	vdp	20.0	1600.	11.0	35.1
			6	em34	vdp	40.0	400.	6.0	63.1

x= 360.0 elev= 0.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	160.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	110.0	28.1
			3	em34	hdp	40.0	400.	60.0	57.0
			4	em34	vdp	10.0	6400.	60.0	15.3
			5	em34	vdp	20.0	1600.	2.0	35.1
			6	em34	vdp	40.0	400.	16.0	63.1

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x= 370.0 elev= 0.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	100.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	70.0	28.1
			3	em34	hdp	40.0	400.	66.0	57.0
			4	em34	vdp	10.0	6400.	-48.0	15.3
			5	em34	vdp	20.0	1600.	-14.0	35.1
			6	em34	vdp	40.0	400.	48.0	63.1

x= 380.0 elev= 0.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	54.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	69.0	28.1
			3	em34	hdp	40.0	400.	56.0	57.0
			4	em34	vdp	10.0	6400.	92.0	15.3
			5	em34	vdp	20.0	1600.	64.0	35.1
			6	em34	vdp	40.0	400.	80.0	63.1

x= 390.0 elev= 0.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	58.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	35.0	28.1
			3	em34	hdp	40.0	400.	66.0	57.0
			4	em34	vdp	10.0	6400.	45.0	15.3
			5	em34	vdp	20.0	1600.	100.0	35.1
			6	em34	vdp	40.0	400.	135.0	63.1

x= 400.0 elev= 0.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	80.0	14.7
2	4.0		2	em34	hdp	20.0	1600.	59.0	28.1
			3	em34	vdp	10.0	6400.	42.0	15.3
			4	em34	vdp	20.0	1600.	92.0	35.1

x= 410.0 elev= 0.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	75.0	16.0	1	em34	hdp	10.0	6400.	109.0	14.7
2	4.0		2	em34	vdp	10.0	6400.	64.0	15.3

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x= 0.0 elev= 1.0

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	250.0	6.0	1	em34	hdp	10.0	6400.	42.0	41.0
2	2.5		2	em34	vdp	10.0	6400.	49.0	53.1

x= 10.0 elev= 2.0

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	750.0	6.5	1	em34	hdp	10.0	6400.	31.0	35.2
2	2.5		2	em34	hdp	20.0	1600.	96.0	82.2
			3	em34	vdp	10.0	6400.	47.0	48.3
			4	em34	vdp	20.0	1600.	68.0	79.5

x= 20.0 elev= 2.2

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	1000.0	8.0	1	em34	hdp	10.0	6400.	24.0	26.4
2	2.0		2	em34	hdp	20.0	1600.	74.0	74.0
			3	em34	hdp	40.0	400.	135.0	132.4
			4	em34	vdp	10.0	6400.	31.0	38.5
			5	em34	vdp	20.0	1600.	42.0	76.1
			6	em34	vdp	40.0	400.	88.0	83.1

x= 30.0 elev= 4.3

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	4000.0	9.0	1	em34	hdp	10.0	6400.	16.0	20.5
2	2.0		2	em34	hdp	20.0	1600.	66.0	63.7
			3	em34	hdp	40.0	400.	125.0	122.5
			4	em34	vdp	10.0	6400.	24.0	31.3
			5	em34	vdp	20.0	1600.	68.0	70.6
			6	em34	vdp	40.0	400.	84.0	83.9

x= 40.0 elev= 5.5

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	5000.0	10.0	1	em34	hdp	10.0	6400.	12.0	16.8
2	2.0		2	em34	hdp	20.0	1600.	50.0	55.9
			3	em34	hdp	40.0	400.	120.0	114.2
			4	em34	vdp	10.0	6400.	18.0	26.0
			5	em34	vdp	20.0	1600.	82.0	65.4
			6	em34	vdp	40.0	400.	84.0	84.3

x= 50.0 elev= 5.6

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	5000.0	12.0	1	em34	hdp	10.0	6400.	11.0	11.3
2	2.0		2	em34	hdp	20.0	1600.	40.0	42.9
			3	em34	hdp	40.0	400.	105.0	98.6
			4	em34	vdp	10.0	6400.	17.0	18.1
			5	em34	vdp	20.0	1600.	52.0	55.1
			6	em34	vdp	40.0	400.	130.0	83.1

x= 60.0 elev= 6.4

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	5000.0	12.5	1	em34	hdp	10.0	6400.	7.0	10.2
2	2.0		2	em34	hdp	20.0	1600.	38.0	40.2
			3	em34	hdp	40.0	400.	98.0	95.0
			4	em34	vdp	10.0	6400.	15.0	16.6
			5	em34	vdp	20.0	1600.	56.0	52.6
			6	em34	vdp	40.0	400.	88.0	82.5

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x= 70.0	elev=	6.8			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	5000.0	13.0	1	em34	hdp	10.0	6400.	8.0	9.3
2	2.0		2	em34	hdp	20.0	1600.	36.0	37.7
			3	em34	hdp	40.0	400.	93.0	91.6
			4	em34	vdp	10.0	6400.	14.5	15.2
			5	em34	vdp	20.0	1600.	50.0	50.3
			6	em34	vdp	40.0	400.	78.0	81.7

x= 80.0	elev=	7.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	5000.0	14.0	1	em34	hdp	10.0	6400.	8.0	7.8
2	2.0		2	em34	hdp	20.0	1600.	34.0	33.3
			3	em34	hdp	40.0	400.	90.0	85.2
			4	em34	vdp	10.0	6400.	12.5	12.8
			5	em34	vdp	20.0	1600.	42.0	45.8
			6	em34	vdp	40.0	400.	95.0	80.0

x= 90.0	elev=	8.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	5000.0	14.0	1	em34	hdp	10.0	6400.	7.5	7.8
2	2.0		2	em34	hdp	20.0	1600.	32.0	33.3
			3	em34	hdp	40.0	400.	88.0	85.2
			4	em34	vdp	10.0	6400.	13.0	12.8
			5	em34	vdp	20.0	1600.	49.0	45.8
			6	em34	vdp	40.0	400.	79.0	80.0

x= 100.0	elev=	8.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	5000.0	13.0	1	em34	hdp	10.0	6400.	7.5	9.3
2	2.0		2	em34	hdp	20.0	1600.	32.0	37.7
			3	em34	hdp	40.0	400.	88.0	91.6
			4	em34	vdp	10.0	6400.	12.5	15.2
			5	em34	vdp	20.0	1600.	46.0	50.3
			6	em34	vdp	40.0	400.	70.0	81.7

x= 110.0	elev=	8.5			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2000.0	14.0	1	em34	hdp	10.0	6400.	7.5	7.7
2	2.0		2	em34	hdp	20.0	1600.	31.0	33.2
			3	em34	hdp	40.0	400.	82.0	85.0
			4	em34	vdp	10.0	6400.	13.0	13.2
			5	em34	vdp	20.0	1600.	44.0	46.2
			6	em34	vdp	40.0	400.	85.0	80.3

x= 120.0	elev=	7.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	2000.0	14.5	1	em34	hdp	10.0	6400.	7.5	7.1
2	2.0		2	em34	hdp	20.0	1600.	32.0	31.2
			3	em34	hdp	40.0	400.	84.0	82.0
			4	em34	vdp	10.0	6400.	12.0	12.2
			5	em34	vdp	20.0	1600.	47.0	44.1
			6	em34	vdp	40.0	400.	64.0	79.3

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x= 130.0 elev= 7.4

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	14.5	1	em34	hdp	10.0	6400.	7.0	7.1
2	2.0		2	em34	hdp	20.0	1600.	32.0	31.2
			3	em34	hdp	40.0	400.	83.0	82.0
			4	em34	vdp	10.0	6400.	13.0	12.2
			5	em34	vdp	20.0	1600.	44.0	44.1
			6	em34	vdp	40.0	400.	76.0	79.3

x= 140.0 elev= 7.0

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	14.5	1	em34	hdp	10.0	6400.	7.0	7.1
2	2.0		2	em34	hdp	20.0	1600.	31.0	31.2
			3	em34	hdp	40.0	400.	86.0	82.0
			4	em34	vdp	10.0	6400.	12.0	12.2
			5	em34	vdp	20.0	1600.	44.0	44.1
			6	em34	vdp	40.0	400.	68.0	79.3

x= 150.0 elev= 6.7

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	14.5	1	em34	hdp	10.0	6400.	7.0	7.1
2	2.0		2	em34	hdp	20.0	1600.	31.0	31.2
			3	em34	hdp	40.0	400.	82.0	82.0
			4	em34	vdp	10.0	6400.	11.5	12.2
			5	em34	vdp	20.0	1600.	43.0	44.1
			6	em34	vdp	40.0	400.	72.0	79.3

x= 160.0 elev= 6.8

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	15.0	1	em34	hdp	10.0	6400.	7.0	6.5
2	2.0		2	em34	hdp	20.0	1600.	26.0	29.4
			3	em34	hdp	40.0	400.	82.0	79.1
			4	em34	vdp	10.0	6400.	11.0	11.3
			5	em34	vdp	20.0	1600.	41.0	42.0
			6	em34	vdp	40.0	400.	49.0	78.2

x= 170.0 elev= 7.2

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	14.5	1	em34	hdp	10.0	6400.	6.5	7.1
2	2.0		2	em34	hdp	20.0	1600.	30.0	31.2
			3	em34	hdp	40.0	400.	83.0	82.0
			4	em34	vdp	10.0	6400.	11.0	12.2
			5	em34	vdp	20.0	1600.	45.0	44.1
			6	em34	vdp	40.0	400.	86.0	79.3

x= 180.0 elev= 7.0

lay	rho	h	obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	2000.0	15.0	1	em34	hdp	10.0	6400.	6.5	6.5
2	2.0		2	em34	hdp	20.0	1600.	29.0	29.4
			3	em34	hdp	40.0	400.	86.0	79.1
			4	em34	vdp	10.0	6400.	10.5	11.3
			5	em34	vdp	20.0	1600.	43.0	42.0
			6	em34	vdp	40.0	400.	65.0	78.2

Line 3 EM34 Data Chequesset Neck, Wellfleet, Massachusetts

x= 190.0 elev= 6.6

lay	rho	h
1	2000.0	15.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	7.0	6.5
2	em34	hdp	20.0	1600.	30.0	29.4
3	em34	hdp	40.0	400.	76.0	79.1
4	em34	vdp	10.0	6400.	12.0	11.3
5	em34	vdp	20.0	1600.	42.0	42.0
6	em34	vdp	40.0	400.	82.0	78.2

x= 200.0 elev= 6.1

lay	rho	h
1	2000.0	15.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	7.0	6.5
2	em34	hdp	20.0	1600.	31.0	29.4
3	em34	hdp	40.0	400.	87.0	79.1
4	em34	vdp	10.0	6400.	12.0	11.3
5	em34	vdp	20.0	1600.	42.0	42.0
6	em34	vdp	40.0	400.	60.0	78.2

x= 210.0 elev= 5.4

lay	rho	h
1	250.0	15.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	8.0	9.1
2	em34	hdp	20.0	1600.	31.0	31.4
3	em34	hdp	40.0	400.	82.0	80.5
4	em34	vdp	10.0	6400.	13.5	12.7
5	em34	vdp	20.0	1600.	42.0	42.5
6	em34	vdp	40.0	400.	68.0	78.0

x= 220.0 elev= 4.7

lay	rho	h
1	250.0	15.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	8.5	9.1
2	em34	hdp	20.0	1600.	33.0	31.4
3	em34	hdp	40.0	400.	83.0	80.5
4	em34	vdp	10.0	6400.	15.0	12.7
5	em34	vdp	20.0	1600.	36.0	42.5
6	em34	vdp	40.0	400.	69.0	78.0

x= 230.0 elev= 4.2

lay	rho	h
1	250.0	15.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	9.0	9.1
2	em34	hdp	20.0	1600.	34.0	31.4
3	em34	hdp	40.0	400.	82.0	80.5
4	em34	vdp	10.0	6400.	16.0	12.7
5	em34	vdp	20.0	1600.	53.0	42.5
6	em34	vdp	40.0	400.	68.0	78.0

x= 240.0 elev= 3.8

lay	rho	h
1	250.0	13.5
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	9.0	10.9
2	em34	hdp	20.0	1600.	35.0	37.2
3	em34	hdp	40.0	400.	91.0	89.5
4	em34	vdp	10.0	6400.	16.0	15.6
5	em34	vdp	20.0	1600.	56.0	48.7
6	em34	vdp	40.0	400.	76.0	80.9

Line 3 EM34 Data Chequesset Neck, Wellfleet, Massachusetts

x= 250.0	elev=	3.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	13.0	1	em34	hdp	10.0	6400.	9.0	11.7
2	2.0		2	em34	hdp	20.0	1600.	36.0	39.5
			3	em34	hdp	40.0	400.	90.0	92.7
			4	em34	vdp	10.0	6400.	17.0	16.8
			5	em34	vdp	20.0	1600.	52.0	50.9
			6	em34	vdp	40.0	400.	94.0	81.8

x= 260.0	elev=	3.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	13.0	1	em34	hdp	10.0	6400.	9.5	9.7
2	2.0		2	em34	hdp	20.0	1600.	37.0	37.9
			3	em34	hdp	40.0	400.	94.0	91.7
			4	em34	vdp	10.0	6400.	16.0	15.9
			5	em34	vdp	20.0	1600.	48.0	50.8
			6	em34	vdp	40.0	400.	72.0	82.1

x= 270.0	elev=	3.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	13.0	1	em34	hdp	10.0	6400.	10.0	9.7
2	2.0		2	em34	hdp	20.0	1600.	37.0	37.9
			3	em34	hdp	40.0	400.	94.0	91.7
			4	em34	vdp	10.0	6400.	15.5	15.9
			5	em34	vdp	20.0	1600.	49.0	50.8
			6	em34	vdp	40.0	400.	76.0	82.1

x= 280.0	elev=	3.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	1000.0	13.0	1	em34	hdp	10.0	6400.	10.0	9.7
2	2.0		2	em34	hdp	20.0	1600.	39.0	37.9
			3	em34	hdp	40.0	400.	94.0	91.7
			4	em34	vdp	10.0	6400.	16.0	15.9
			5	em34	vdp	20.0	1600.	51.0	50.8
			6	em34	vdp	40.0	400.	80.0	82.1

x= 290.0	elev=	2.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	13.0	1	em34	hdp	10.0	6400.	10.5	11.7
2	2.0		2	em34	hdp	20.0	1600.	38.0	39.5
			3	em34	hdp	40.0	400.	96.0	92.7
			4	em34	vdp	10.0	6400.	16.0	16.8
			5	em34	vdp	20.0	1600.	53.0	50.9
			6	em34	vdp	40.0	400.	72.0	81.8

x= 300.0	elev=	2.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	13.0	1	em34	hdp	10.0	6400.	11.0	11.2
2	2.0		2	em34	hdp	20.0	1600.	39.0	39.1
			3	em34	hdp	40.0	400.	96.0	92.5
			4	em34	vdp	10.0	6400.	18.0	16.6
			5	em34	vdp	20.0	1600.	48.0	50.9
			6	em34	vdp	40.0	400.	74.0	81.8

Line 3 EM34 Data Chequesset Neck, Wellfleet, Massachusetts

x= 310.0	elev=	2.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	13.0	1	em34	hdp	10.0	6400.	13.0	11.7
2	2.0		2	em34	hdp	20.0	1600.	40.0	39.5
			3	em34	hdp	40.0	400.	96.0	92.7
			4	em34	vdp	10.0	6400.	16.0	16.8
			5	em34	vdp	20.0	1600.	46.0	50.9
			6	em34	vdp	40.0	400.	56.0	81.8

x= 320.0	elev=	2.3			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	13.0	1	em34	hdp	40.0	400.	96.0	92.7
2	2.0		2	em34	vdp	40.0	400.	62.0	81.8

Line 4 EM34 Data Newcomb Heights Subdivision, Wellfleet, Massachusetts

x=	0.0	elev= 0.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	200.0	20.0	1	em34	hdp	10.0	6400.	6.5	6.6
2	2.0		2	em34	hdp	20.0	1600.	21.0	19.6
			3	em34	hdp	40.0	400.	62.0	57.8
			4	em34	vdp	10.0	6400.	8.5	7.8
			5	em34	vdp	20.0	1600.	23.0	27.4
			6	em34	vdp	40.0	400.	46.0	65.7

x=	10.0	elev= 1.6			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	200.0	21.0	1	em34	hdp	10.0	6400.	5.0	6.3
2	2.0		2	em34	hdp	20.0	1600.	19.0	17.9
			3	em34	hdp	40.0	400.	54.0	54.2
			4	em34	vdp	10.0	6400.	6.0	7.2
			5	em34	vdp	20.0	1600.	25.0	25.2
			6	em34	vdp	40.0	400.	16.0	63.2

x=	20.0	elev= 1.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	24.0	1	em34	hdp	10.0	6400.	4.5	4.8
2	2.0		2	em34	hdp	20.0	1600.	16.0	13.6
			3	em34	hdp	40.0	400.	46.0	44.5
			4	em34	vdp	10.0	6400.	6.0	5.4
			5	em34	vdp	20.0	1600.	15.0	19.6
			6	em34	vdp	40.0	400.	30.0	55.6

x=	25.0	elev= 2.4			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	250.0	22.0	1	em34	hdp	10.0	6400.	4.5	5.2
2	2.0		2	em34	hdp	20.0	1600.	15.0	15.9
			3	em34	hdp	40.0	400.	54.0	50.5
			4	em34	vdp	10.0	6400.	6.0	6.2
			5	em34	vdp	20.0	1600.	23.5	23.0
			6	em34	vdp	40.0	400.	60.0	60.6

x=	30.0	elev= 4.1			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	25.0	1	em34	hdp	10.0	6400.	4.0	4.1
2	2.0		2	em34	hdp	20.0	1600.	13.0	12.1
			3	em34	hdp	40.0	400.	48.0	41.5
			4	em34	vdp	10.0	6400.	4.0	4.8
			5	em34	vdp	20.0	1600.	15.0	17.9
			6	em34	vdp	40.0	400.	48.0	53.2

x=	40.0	elev= 8.0			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	28.0	1	em34	hdp	10.0	6400.	3.0	2.7
2	2.0		2	em34	hdp	20.0	1600.	10.0	8.9
			3	em34	hdp	40.0	400.	34.0	34.1
			4	em34	vdp	10.0	6400.	4.0	3.3
			5	em34	vdp	20.0	1600.	14.5	13.8
			6	em34	vdp	40.0	400.	59.0	46.3

Line 4 EM34 Data Newcomb Heights Subdivision, Wellfleet, Massachusetts

x= 50.0	elev=	11.9			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	28.0	1	em34	hdp	10.0	6400.	2.5	2.7
2	2.0		2	em34	hdp	20.0	1600.	8.5	8.9
			3	em34	hdp	40.0	400.	30.0	34.1
			4	em34	vdp	10.0	6400.	3.0	3.3
			5	em34	vdp	20.0	1600.	14.0	13.8
			6	em34	vdp	40.0	400.	52.0	46.3

x= 60.0	elev=	13.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	29.0	1	em34	hdp	10.0	6400.	2.5	2.6
2	2.0		2	em34	hdp	20.0	1600.	7.0	8.3
			3	em34	hdp	40.0	400.	26.0	32.1
			4	em34	vdp	10.0	6400.	3.0	3.1
			5	em34	vdp	20.0	1600.	11.5	12.8
			6	em34	vdp	40.0	400.	50.0	44.3

x= 70.0	elev=	14.2			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	32.0	1	em34	hdp	10.0	6400.	2.5	2.3
2	2.0		2	em34	hdp	20.0	1600.	6.5	6.7
			3	em34	hdp	40.0	400.	24.0	27.0
			4	em34	vdp	10.0	6400.	3.0	2.7
			5	em34	vdp	20.0	1600.	10.0	10.4
			6	em34	vdp	40.0	400.	42.0	38.5

x= 80.0	elev=	14.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	32.0	1	em34	hdp	10.0	6400.	2.5	2.3
2	2.0		2	em34	hdp	20.0	1600.	6.0	6.7
			3	em34	hdp	40.0	400.	22.0	27.0
			4	em34	vdp	10.0	6400.	3.0	2.7
			5	em34	vdp	20.0	1600.	11.0	10.4
			6	em34	vdp	40.0	400.	42.0	38.5

x= 90.0	elev=	14.7			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	32.0	1	em34	hdp	10.0	6400.	2.5	2.3
2	2.0		2	em34	hdp	20.0	1600.	5.5	6.7
			3	em34	hdp	40.0	400.	22.0	27.0
			4	em34	vdp	10.0	6400.	3.5	2.7
			5	em34	vdp	20.0	1600.	11.5	10.4
			6	em34	vdp	40.0	400.	43.0	38.5

x= 100.0	elev=	13.8			coil	s	freq	obs	calc
lay	rho	h	obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	34.0	1	em34	hdp	10.0	6400.	2.5	2.2
2	2.0		2	em34	hdp	20.0	1600.	6.0	6.0
			3	em34	hdp	40.0	400.	22.0	24.2
			4	em34	vdp	10.0	6400.	4.0	2.5
			5	em34	vdp	20.0	1600.	13.0	9.1
			6	em34	vdp	40.0	400.	32.0	35.1

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x= 110.0	elev=	13.8				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	35.0	|	1	em34	hdp	10.0	6400.	2.5	2.2
2	2.0		|	2	em34	hdp	20.0	1600.	7.0	5.6
			|	3	em34	hdp	40.0	400.	20.0	22.9
			|	4	em34	vdp	10.0	6400.	-4.0	2.4
			|	5	em34	vdp	20.0	1600.	2.0	8.5
			|	6	em34	vdp	40.0	400.	22.0	33.6

x= 120.0	elev=	11.9				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	500.0	37.0	|	1	em34	hdp	10.0	6400.	2.5	2.1
2	2.0		|	2	em34	hdp	20.0	1600.	7.6	5.1
			|	3	em34	hdp	40.0	400.	21.0	20.6
			|	4	em34	vdp	10.0	6400.	8.5	2.3
			|	5	em34	vdp	20.0	1600.	0.2	7.5
			|	6	em34	vdp	40.0	400.	19.0	30.6

x= 130.0	elev=	12.3				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	38.0	|	1	em34	hdp	10.0	6400.	2.5	3.2
2	2.0		|	2	em34	hdp	20.0	1600.	6.5	5.8
			|	3	em34	hdp	40.0	400.	20.0	20.4
			|	4	em34	vdp	10.0	6400.	4.0	3.1
			|	5	em34	vdp	20.0	1600.	14.5	7.7
			|	6	em34	vdp	40.0	400.	11.0	29.6

x= 140.0	elev=	13.9				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	38.0	|	1	em34	hdp	10.0	6400.	2.5	3.2
2	2.0		|	2	em34	hdp	20.0	1600.	6.0	5.8
			|	3	em34	hdp	40.0	400.	17.5	20.4
			|	4	em34	vdp	10.0	6400.	3.0	3.1
			|	5	em34	vdp	20.0	1600.	11.0	7.7
			|	6	em34	vdp	40.0	400.	36.0	29.6

x= 150.0	elev=	16.7				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	38.0	|	1	em34	hdp	10.0	6400.	2.5	3.2
2	2.0		|	2	em34	hdp	20.0	1600.	5.0	5.8
			|	3	em34	hdp	40.0	400.	17.0	20.4
			|	4	em34	vdp	10.0	6400.	3.0	3.1
			|	5	em34	vdp	20.0	1600.	8.5	7.7
			|	6	em34	vdp	40.0	400.	34.0	29.6

x= 160.0	elev=	18.5				coil	s	freq	obs	calc
lay	rho	h		obs	instr	pair	(m)	(Hz)	(mS/m)	(mS/m)
1	300.0	39.0	|	1	em34	hdp	10.0	6400.	2.5	3.2
2	2.0		|	2	em34	hdp	20.0	1600.	5.0	5.5
			|	3	em34	hdp	40.0	400.	15.5	19.4
			|	4	em34	vdp	10.0	6400.	2.5	3.1
			|	5	em34	vdp	20.0	1600.	8.0	7.3
			|	6	em34	vdp	40.0	400.	32.0	28.3

Line 4 EM34 Data Newcomb Heights Subdivision, Wellfleet, Massachusetts

x= 170.0 elev= 19.4

lay	rho	h
1	300.0	42.0
2	2.0	

obs	instr	coil pair	s (m)	freq (Hz)	obs (mS/m)	calc (mS/m)
1	em34	hdp	10.0	6400.	2.0	3.1
2	em34	hdp	20.0	1600.	4.5	5.0
3	em34	hdp	40.0	400.	14.0	16.9
4	em34	vdp	10.0	6400.	2.5	3.0
5	em34	vdp	20.0	1600.	7.0	6.4
6	em34	vdp	40.0	400.	28.0	24.8

APPENDIX B VLF RESISTIVITY DATA AND MODELING RESULTS

The following tables contain the observed and calculated VLF resistivity data along with the interpreted model. All data were collected using the station at Cutler, Maine operating at a frequency of 24.0 kHz. The second layer resistivity was fixed at 2.5 ohm-m for all interpretations. The station distance along the profile is given in meters. Resistivities are in ohm-m, phase (ϕ) is in degrees, and model dimensions are in meters.

VLF Resistivity   Cutler, Maine (f=24.0 kHz)
Line 1 Great Pasture Traverse

	< observed >		< calculated >		<----- model ----->		
station	rhoa	ϕ	rhoa	ϕ	rho_1	h_1	rho_2
0	90	70	89	71	135	21	2.5
10	40	68	39	70	70	13	2.5
20	150	70	151	69	190	29	2.5
30	190	71	188	70	250	32	2.5
40	200	72	205	72	300	33	2.5
50	170	80	170	79	550	28	2.5
60	150	78	152	78	430	26.5	2.5
70	200	76	206	76	400	32	2.5
80	160	75	161	75	325	28	2.5
90	270	64	266	65	275	41	2.5
100	175	63	175	67	200	32	2.5
110	80	74	81	75	200	19	2.5
120	- no data, paved road						
130	- no data, paved road						
140	- no data, paved road						
150	- no data, paved road						
160	230	89	226	85	4000	33	2.5
170	250	90	253	85	4000	34	2.5
180	170	88	166	84	4000	27	2.5
190	210	89	214	85	4000	31	2.5
200	280	90	281	85	4000	36	2.5
210	300	90	296	85	4000	37	2.5
220	480	88	481	85	4000	48	2.5
230	500	88	500	85	4000	49	2.5
240	400	83	404	83	2000	44	2.5
250	220	88	226	85	4000	32	2.5
260	600	80	605	81	1800	55	2.5
270	600	83	597	84	3000	54	2.5
280	950	81	958	81	2500	70	2.5
290	800	81	808	81	2250	64	2.5
300	900	82	897	83	3500	67	2.5
310	1050	83	1058	83	4000	73	2.5
320	950	82	955	84	4500	69	2.5
330	1050	80	1058	83	4000	73	2.5
340	800	79	802	80	2000	64	2.5
350	850	79	847	80	2000	66	2.5
360	550	79	552	79	1250	53	2.5
370	450	79	446	80	1250	47	2.5
380	550	78	552	79	1250	53	2.5
390	600	80	604	81	1750	55	2.5
400	500	81	504	81	1500	50	2.5

VLF Resistivity   Cutler, Maine (f=24.0 kHz)
Line 2 Great Pasture Traverse

	< observed >		< calculated >		<----- model ----->		
station	rhoa	φ	rhoa	φ	rho_1	h_1	rho_2
0	60	78	60	78	275	15.5	2.5
10	60	76	62	76	200	16	2.5
20	80	73	81	73	150	19.5	2.5
30	240	74	238	74	400	35	2.5
40	150	88	150	84	4000	25.5	2.5
50	140	79	139	79	500	25	2.5
60	175	80	172	81	750	28	2.5
70	215	81	219	81	750	32	2.5
80	190	80	195	81	750	30	2.5
90	240	77	234	77	500	34	2.5
100	290	81	287	81	1000	37	2.5
110	150	82	153	82	1000	26	2.5
120	200	81	195	81	750	30	2.5
130	150	80	150	80	600	26	2.5
140	185	80	183	81	750	29	2.5
150	300	83	292	83	1750	37	2.5
160	420	82	419	82	1750	45	2.5
170	420	85	423	84	2500	45	2.5
180	580	79	598	80	1500	55	2.5
190	580	75	580	75	900	56	2.5
200	300	76	301	76	600	39	2.5
210	150	77	150	77	375	26.5	2.5
220	280	75	277	74	450	38	2.5
230	295	73	300	73	450	40	2.5
240	185	73	185	74	350	30	2.5
250	180	73	182	73	300	30.5	2.5
260	360	71	357	71	450	45	2.5
270	630	70	632	70	750	61	2.5
280	210	76	211	75	400	32.5	2.5
290	300	68	301	69	350	42	2.5
300	330	64	325	65	325	46	2.5
310	500	59	502	59	425	64	2.5
320	230	52	235	52	190	51	2.5
330	18	52	- buried pipe (?), data not modeled				
340	2	66					
350	2	56					
360	2.5	49					
370	6.3	38					
380	25	35					
390	30	34					
400	13.7	34					
410	10	30					

VLF Resistivity   Cutler, Maine (f=24.0 kHz)
Line 3 Chequesset Neck Traverse

	< observed >		< calculated >		<----- model ----->		
station	rhoa	ϕ	rhoa	ϕ	rho_1	h_1	rho_2
0	20	75	20	76	4000	7.5	2.5
10	20	74	20	74	250	7.5	2.5
20	48	73	48	74	125	14	2.5
30	48	73	48	74	125	14	2.5
|	ground frozen, no data						
180	185	77	185	76	400	30	2.5
190	155	79	158	79	500	27	2.5
200	90	79	94	79	400	20	2.5
210	95	77	92	78	300	20	2.5
220	65	63	66	63	70	20	2.5
230	150	53	151	53	125	39	2.5
240	175	54	176	54	145	42	2.5
250	200	62	200	62	190	37	2.5
260	100	61	102	62	100	26	2.5

VLF Resistivity   Cutler, Maine (f=24.0 kHz)
Line 4 Newcomb Heights Traverse

	< observed >		< calculated >		<----- model ----->		
station	rhoa	ϕ	rhoa	ϕ	rho_1	h_1	rho_2
0	107	74	103	74	200	22	2.5
10	107	76	106	76	250	22	2.5
20	120	77	121	77	325	23.5	2.5
25	100	80	103	80	500	21	2.5
30	270	77	273	77	550	37	2.5
40	140	86	145	84	5000	25	2.5
50	85	88	89	83	5000	19	2.5
60	165	90	166	85	5000	27	2.5
70	500	89	501	85	5000	49	2.5
80	110	89	106	83	5000	21	2.5
90	-no data, paved road						
100	-no data, paved road						
110	20	54	20	55	19	12	2.5
120	150	64	149	63	150	31	2.5
130	220	74	225	74	375	34	2.5
140	350	80	343	85	5000	40	2.5
150	190	90	189	85	5000	29	2.5
160	450	85	463	85	5000	47	2.5

APPENDIX C TEM DATA AND INVERSION RESULTS

This appendix contains reduced TEM data and inversion result summaries. A description of the inversion results is given below. For a more detailed description of the parameters see Anderson (1982a, 1982b).

1. Inversion program name (NLSTCI) followed by description of sounding.

2. Effective transmitter loop radius. $a = L/\pi^{1/2}$ where L is side length of the square loop.

3. Transmitter turnoff time used in computations.

4. Data matrix. This includes the measurement time, observed apparent resistivity, data weight, computed apparent resistivity, and percent error of fit for the datum.

5. RMS error in resistivity units, average percentage error of fit, and convergence criterion that stopped the inversion.

6. Correlation matrix. The entry in row *i* and column *j* gives the correlation between parameters *i* and *j*.

7. Errors in parameter estimates in parameter units (standard error), normalized units (relative error), and percentage (percent error). Because of nonlinearities in the statistics, the percentage error in not absolute, but rather should be used as a measure of the relative degree of resolvability of various model parameters.

8. Final inverse model. The resistivity, conductivity, parameter number (asterisk in column labelled P), fixed parameter flag (asterisk in column labelled F), layer thickness, and depth to top of the layer are given for each layer.

<NLSTCI>: WFL 1 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	236.5	0.00423	246.6	-4.1
2	0.0000090	216.0	0.00463	204.5	5.6
3	0.0000121	174.7	0.00572	169.1	3.3
4	0.0000160	135.0	0.00741	139.3	-3.1
5	0.0000202	114.4	0.00874	117.5	-2.6
6	0.0000263	92.1	0.01085	95.1	-3.2
7	0.0000338	77.2	0.01295	75.7	1.9
8	0.0000425	62.6	0.01596	60.8	2.9
9	0.0000547	50.0	0.01997	47.6	5.1
10	0.0000693	39.8	0.02508	37.7	5.6
11	0.0000860	31.6	0.03165	30.5	3.7
12	0.0001000	25.0	0.03987	26.4	-5.2
13	0.0001210	21.0	0.04760	22.0	-4.6
14	0.0001510	17.3	0.05770	17.9	-3.5
15	0.0001870	14.4	0.06925	14.8	-2.8
16	0.0002290	12.2	0.08183	12.4	-1.9
17	0.0002900	10.1	0.09901	10.2	-1.3
18	0.0003660	8.3	0.11990	8.5	-2.7
19	0.0004540	7.2	0.13889	7.3	-0.9
20	0.0005740	6.1	0.16234	6.2	-1.1
21	0.0007190	5.4	0.18349	5.3	1.4
22	0.0008800	4.7	0.20877	4.7	0.0
23	0.0010800	4.3	0.22779	4.2	2.9
24	0.0013800	3.8	0.25707	3.7	3.5
25	0.0017500	3.4	0.29155	3.3	4.0
26	0.0021900	3.0	0.33223	3.0	1.5
27	0.0028200	2.6	0.38314	2.7	-2.6

RMS ERROR= 3.842 AVG% ERROR= 3.0 VARIABILITY CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	0.364	1.000			
3	-0.179	0.451	1.000		
4	0.759	0.774	-0.041	1.000	
5	-0.862	-0.582	-0.026	-0.748	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.5028E-02	0.1273E-02	0.5685E-01	5.7
2	0.1208E+00	0.7303E-02	0.6633E-01	6.6
3	0.8843E+00	0.1400E-01	0.4636E-01	4.6
4	0.2469E+02	0.4821E-02	0.1343E-01	1.3
5	0.8781E+01	0.7130E-02	0.3378E-01	3.4

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	198.9	1	0.50275344E-02	4	24.7	0.0
2	8.3	2	0.12075289E+00	5	8.8	24.7
3	1.1	3	0.88427508E+00			33.5

<NLSTCI>: WFL 2 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000160	289.6	0.00345	270.0	7.3
2	0.0000202	228.1	0.00438	243.2	-6.2
3	0.0000263	195.5	0.00512	204.0	-4.2
4	0.0000338	166.7	0.00600	166.2	0.3
5	0.0000425	138.4	0.00723	133.7	3.5
6	0.0000547	108.3	0.00923	102.5	5.6
7	0.0000693	85.4	0.01170	80.2	6.5
8	0.0000860	66.7	0.01499	64.0	4.2
9	0.0001000	52.4	0.01905	54.7	-4.2
10	0.0001210	42.7	0.02340	44.9	-4.8
11	0.0001510	34.1	0.02933	35.9	-4.9
12	0.0001870	27.6	0.03623	29.0	-4.9
13	0.0002290	22.7	0.04401	23.9	-4.9
14	0.0002900	18.2	0.05488	19.2	-5.0
15	0.0003660	14.7	0.06761	15.5	-5.4
16	0.0004540	12.5	0.07974	12.9	-3.2
17	0.0005740	10.4	0.09542	10.7	-2.4
18	0.0007190	9.0	0.11025	8.9	0.7
19	0.0008800	7.8	0.12804	7.7	1.2
20	0.0010800	6.8	0.14577	6.7	1.8
21	0.0013800	5.9	0.16920	5.7	3.7
22	0.0017500	5.1	0.19531	4.9	3.5
23	0.0021900	4.4	0.22624	4.3	1.3
24	0.0028200	3.8	0.26110	3.8	-0.2
25	0.0035600	3.4	0.28986	3.4	-0.3
26	0.0043700	3.2	0.30581	3.1	2.7
27	0.0055400	3.0	0.33113	2.8	5.9
28	0.0070400	3.1	0.31847	2.6	19.4

RMS ERROR= 5.755 AVG% ERROR= 4.2 X-CONVERGENCE

CORRELATION MATRIX

	2	3	4	5
2	1.000			
3	-0.433	1.000		
4	0.979	-0.587	1.000	
5	-0.980	0.524	-0.988	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
2	0.2785E-01	0.5161E-02	0.9776E-01	9.8
3	0.8305E+00	0.1313E-01	0.4491E-01	4.5
4	0.2639E+02	0.5870E-02	0.5099E-01	5.1
5	0.2113E+02	0.6552E-02	0.6362E-01	6.4

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P	F	CONDUCTIVITY	P	F	THICKNESS	DEPTH
1	900.0	1	*	0.11111000E-02	4		26.4	0.0
2	35.9	2		0.27853768E-01	5		21.1	26.4
3	1.2	3		0.83049452E+00				47.5

<NLSTCI>: WFL 3 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	47.8	0.02089	48.5	-1.4
2	0.0000090	29.9	0.03334	31.2	-4.0
3	0.0000121	18.6	0.05350	19.1	-2.4
4	0.0000160	11.9	0.08396	12.1	-1.6
5	0.0000202	7.9	0.12642	8.5	-7.1
6	0.0000263	5.5	0.18018	6.0	-8.7
7	0.0000338	4.1	0.23981	4.6	-11.7
8	0.0000425	3.3	0.29762	3.9	-14.4
9	0.0000547	2.8	0.34722	3.3	-15.6
10	0.0000693	2.7	0.36900	3.1	-12.2
11	0.0000860	2.5	0.38910	3.0	-16.6
12	0.0001070	2.6	0.37736	3.0	-13.0
13	0.0001210	2.8	0.34843	3.0	-7.5
14	0.0001510	3.1	0.31949	3.2	-3.3
15	0.0001870	3.5	0.28011	3.5	0.1
16	0.0002290	4.0	0.24938	3.7	7.3
17	0.0002900	4.3	0.22779	4.1	4.9
18	0.0003660	4.6	0.21505	4.7	-1.6
19	0.0004540	4.8	0.20534	4.8	0.1
20	0.0005740	4.9	0.20080	5.0	-2.6
21	0.0007190	5.1	0.19531	5.2	-1.1
22	0.0008800	5.0	0.19960	5.1	-1.4
23	0.0010800	4.9	0.20325	4.8	2.7
24	0.0013800	4.7	0.21053	4.7	-0.5
25	0.0017500	4.4	0.22422	4.4	0.2

RMS ERROR=0.4787 AVG% ERROR= 5.7 VARIABILITY CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	-0.114	1.000			
3	0.080	-0.921	1.000		
4	-0.735	-0.207	0.294	1.000	
5	-0.003	-0.712	0.902	0.426	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.5520E+00	0.3569E-02	0.1505E-01	1.5
2	0.8132E-03	0.7436E-01	0.8297E+01	829.7
3	0.4130E+00	0.5713E-01	0.2792E+00	27.9
4	0.8950E+01	0.6117E-02	0.2870E-01	2.9
5	0.3027E+02	0.1906E-01	0.4769E-01	4.8

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	1.8	1	0.55197787E+00	4	9.0	0.0
2	1229.8	2	0.81315084E-03	5	30.3	9.0
3	2.4	3	0.41296348E+00			39.2

<NLSTCI>: WFL 4 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	87.2	0.01146	88.3	-1.3
2	0.0000090	72.2	0.01385	70.6	2.2
3	0.0000121	56.7	0.01761	55.6	1.9
4	0.0000160	43.9	0.02275	44.1	-0.5
5	0.0000202	34.7	0.02875	36.2	-4.1
6	0.0000263	28.0	0.03560	28.8	-2.8
7	0.0000338	23.0	0.04346	23.1	-0.5
8	0.0000425	18.9	0.05271	18.9	0.0
9	0.0000547	15.6	0.06394	15.2	2.3
10	0.0000693	13.1	0.07587	12.5	4.5
11	0.0000860	10.9	0.09158	10.6	3.2
12	0.0001000	9.4	0.10593	9.4	-0.3
13	0.0001210	8.2	0.12092	8.2	-0.1
14	0.0001510	7.1	0.13908	7.0	0.8
15	0.0001870	6.3	0.15723	6.1	2.6
16	0.0002290	5.6	0.17637	5.4	3.0
17	0.0002900	4.9	0.20121	4.8	2.9
18	0.0003660	4.3	0.22883	4.2	1.7
19	0.0004540	3.9	0.25317	3.8	2.0
20	0.0005740	3.5	0.28249	3.5	1.2
21	0.0007190	3.2	0.30864	3.2	1.1
22	0.0008800	2.9	0.33898	2.9	-1.7
23	0.0010800	2.7	0.36496	2.8	-2.1
24	0.0013800	2.5	0.39526	2.6	-2.6
25	0.0017500	2.3	0.43103	2.4	-4.7
26	0.0021900	2.1	0.45872	2.3	-8.1
27	0.0028200	2.0	0.49261	2.2	-7.9

RMS ERROR=0.6234 AVG% ERROR= 2.4 VARIABILITY CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	-0.011	1.000			
3	0.027	0.505	1.000		
4	0.178	0.965	0.437	1.000	
5	-0.472	-0.273	0.166	-0.351	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.8384E-02	0.1387E-02	0.4792E-01	4.8
2	0.1772E+00	0.8113E-02	0.6078E-01	6.1
3	0.6905E+00	0.4735E-02	0.1781E-01	1.8
4	0.1094E+02	0.4007E-02	0.1698E-01	1.7
5	0.6690E+01	0.2524E-02	0.1372E-01	1.4

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	119.3	1	0.83835060E-02	4	10.9	0.0
2	5.6	2	0.17716618E+00	5	6.7	10.9
3	1.4	3	0.69050527E+00			17.6

<NLSTCI>: WFL 5 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	101.2	0.00988	102.3	-1.1
2	0.0000090	81.0	0.01235	79.5	1.9
3	0.0000121	61.7	0.01620	60.9	1.3
4	0.0000160	47.6	0.02100	47.6	0.0
5	0.0000202	37.4	0.02668	38.8	-3.5
6	0.0000263	30.2	0.03305	30.7	-1.6
7	0.0000338	24.6	0.04057	24.6	0.2
8	0.0000425	20.1	0.04960	20.0	0.3
9	0.0000547	16.4	0.06075	16.1	1.8
10	0.0000693	13.7	0.07278	13.2	3.8
11	0.0000860	11.3	0.08826	11.1	2.0
12	0.0001000	9.6	0.10363	9.8	-2.4
13	0.0001210	8.3	0.11933	8.5	-2.7
14	0.0001510	7.2	0.13793	7.3	-1.1
15	0.0001870	6.4	0.15625	6.3	1.5
16	0.0002290	5.7	0.17513	5.6	2.6
17	0.0002900	5.0	0.19960	4.8	3.4
18	0.0003660	4.4	0.22676	4.3	3.2
19	0.0004540	3.9	0.25126	3.8	1.7
20	0.0005740	3.5	0.27933	3.4	1.5
21	0.0007190	3.2	0.30581	3.1	1.9
22	0.0008800	2.9	0.33557	2.9	-0.4
23	0.0010800	2.7	0.35971	2.7	-0.4
24	0.0013800	2.5	0.39370	2.5	-0.3
25	0.0017500	2.3	0.42553	2.3	-2.1
26	0.0021900	2.1	0.45872	2.2	-5.3
27	0.0028200	2.0	0.49020	2.1	-4.5
28	0.0035600	1.9	0.50761	2.0	-5.0

RMS ERROR=0.5464 AVG% ERROR= 2.1 VARIABILITY CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	-0.557	1.000			
3	-0.056	0.467	1.000		
4	-0.282	0.920	0.425	1.000	
5	-0.462	0.636	0.543	0.597	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.5290E-02	0.1875E-02	0.8160E-01	8.2
2	0.2460E+00	0.6784E-02	0.4307E-01	4.3
3	0.7392E+00	0.4339E-02	0.1576E-01	1.6
4	0.1247E+02	0.1953E-02	0.7738E-02	0.8
5	0.6325E+01	0.2914E-02	0.1630E-01	1.6

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	189.0	1	0.52896445E-02	4	12.5	0.0
2	4.1	2	0.24600004E+00	5	6.3	12.5
3	1.4	3	0.73917639E+00			18.8

<NLSTCI>: WFL 6 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	109.3	0.00915	111.3	-1.8
2	0.0000090	88.4	0.01130	86.5	2.3
3	0.0000121	67.5	0.01480	66.3	1.8
4	0.0000160	51.9	0.01925	51.8	0.2
5	0.0000202	40.7	0.02452	42.2	-3.5
6	0.0000263	32.8	0.03045	33.4	-1.7
7	0.0000338	26.6	0.03754	26.6	-0.1
8	0.0000425	21.7	0.04608	21.7	0.1
9	0.0000547	17.6	0.05669	17.4	1.4
10	0.0000693	14.6	0.06831	14.2	3.1
11	0.0000860	12.0	0.08319	11.8	1.4
12	0.0001210	8.9	0.11136	9.1	-1.8
13	0.0001510	7.7	0.12920	7.7	0.1
14	0.0001870	6.7	0.14771	6.6	1.0
15	0.0002290	6.0	0.16667	5.8	3.1
16	0.0002900	5.2	0.19120	5.0	3.2
17	0.0003660	4.5	0.21882	4.4	1.8
18	0.0004540	4.1	0.24390	4.0	3.6
19	0.0005740	3.6	0.27548	3.5	1.8
20	0.0007190	3.2	0.30395	3.2	-0.3
21	0.0008800	2.9	0.33557	3.0	-2.1
22	0.0010800	2.7	0.35842	2.7	-1.7
23	0.0013800	2.5	0.38760	2.5	-1.3
24	0.0017500	2.3	0.42017	2.4	-2.7
25	0.0021900	2.2	0.45045	2.2	-0.9
26	0.0028200	2.0	0.48544	2.1	-4.5
27	0.0035600	2.0	0.50000	2.0	0.5
28	0.0043700	1.9	0.50505	1.9	-0.7
29	0.0055400	1.9	0.50761	1.8	3.4
30	0.0070400	1.6	0.61350	1.8	-9.5

RMS ERROR=0.6971 AVG% ERROR= 2.0 VARIABILITY CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	-0.208	1.000			
3	-0.035	-0.045	1.000		
4	-0.050	0.933	-0.146	1.000	
5	-0.556	0.051	0.176	0.073	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.2685E-02	0.6769E-03	0.4139E-01	4.1
2	0.2313E+00	0.4613E-02	0.3021E-01	3.0
3	0.7618E+00	0.3092E-02	0.1106E-01	1.1
4	0.1296E+02	0.1739E-02	0.6759E-02	0.7
5	0.6643E+01	0.2290E-02	0.1250E-01	1.3

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	372.5	1	0.26847513E-02	4	13.0	0.0
2	4.3	2	0.23132160E+00	5	6.6	13.0
3	1.3	3	0.76184314E+00			19.6

<NLSTCI>: WFL 7 Cape Cod National Seashore, Wellfleet, MA
LOOP RADIUS= 21.5 TOFF(usec)= 2.4

I	TIME(s)	OBSERVED RESISTIVITY	DATA WEIGHT	COMPUTED RESISTIVITY	PERCENT ERROR
1	0.0000069	243.5	0.00411	251.4	-3.1
2	0.0000090	230.1	0.00435	220.3	4.5
3	0.0000121	187.1	0.00534	186.3	0.4
4	0.0000160	152.6	0.00655	150.9	1.1
5	0.0000202	114.8	0.00871	123.6	-7.1
6	0.0001000	28.6	0.03493	28.0	2.2
7	0.0001210	26.1	0.03824	23.8	9.6
8	0.0001510	20.2	0.04943	19.9	1.6
9	0.0001870	17.4	0.05741	16.9	3.2
10	0.0002290	15.2	0.06579	14.5	4.6
11	0.0002900	12.8	0.07770	12.3	3.7
12	0.0003660	11.1	0.08937	10.6	4.5
13	0.0004540	9.8	0.10183	9.3	5.1
14	0.0005740	8.6	0.11574	8.2	5.2
15	0.0007190	7.5	0.13228	7.3	3.0
16	0.0008800	6.6	0.15038	6.6	-0.1
17	0.0010800	5.9	0.16863	6.0	-2.2
18	0.0013800	5.1	0.19418	5.5	-6.6
19	0.0017500	4.5	0.21930	5.0	-10.0
20	0.0021900	4.0	0.24814	4.6	-13.7
21	0.0028200	3.7	0.26738	4.3	-13.9
22	0.0035600	3.6	0.27248	4.0	-10.5

RMS ERROR= 3.820 AVG% ERROR= 5.3 X-CONVERGENCE

CORRELATION MATRIX

	1	2	3	4	5
1	1.000				
2	-0.669	1.000			
3	-0.301	0.140	1.000		
4	-0.213	0.828	-0.169	1.000	
5	-0.450	-0.284	0.429	-0.656	1.000

	PARAMETER ESTIMATE	STANDARD ERROR	RELATIVE ERROR	PERCENT ERROR
1	0.4381E-02	0.1359E-02	0.6500E-01	6.5
2	0.3658E-01	0.5067E-02	0.8374E-01	8.4
3	0.4319E+00	0.8170E-02	0.3903E-01	3.9
4	0.2130E+02	0.6639E-02	0.1997E-01	2.0
5	0.1208E+02	0.1085E-01	0.4371E-01	4.4

FINAL INVERSION MODEL

LAYER	RESISTIVITY	P F	CONDUCTIVITY	P F	THICKNESS	DEPTH
1	228.3	1	0.43810061E-02	4	21.3	0.0
2	27.3	2	0.36584165E-01	5	12.1	21.3
3	2.3	3	0.43187523E+00			33.4