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FINAL REPORT ON CSAMT, SP, AND MAGNETICS DATA SULPHURDALE KGRA

for

MOTHER EARTH INDUSTRIES, INC

FINAL REPORT ON CSAMT, SP,
AND MAGNETICS SURVEYS
SULPHURDALE PROJECT
BEAVER COUNTY, UTAH
for MOTHER EARTH INDUSTRIES, INC.

INTRODUCTION

At the request of Wayne Portanova of Mother Earth Industries, Zonge Engineering and Research Organization conducted SP, Magnetics, and CSAMT surveys at the Sulphurdale KGRA in order to assist in continuing development of the site. The surveys were originally scheduled to be run in February, 1987, but weather problems delayed some of the SP and all of the CSAMT until May, 1987. The original SP and Magnetics were discussed in a final report already issued, although this report includes references to that data and its correlation to the CSAMT data.

The primary intent of the surveys was to assist in the understanding of the subsurface structure, particularly faults and fractures, and fluid properties as they may relate to the geothermal activity. Two producing wells (34-7A and the 34-7B) were in place at the time of the survey. A dry well (24-7) was located only 450 feet from one of the producers, thus lateral resolution and station density were considered of primary importance. CSAMT was chosen as the principle mapping tool because of its superior lateral resolution compared to other electrical methods. In addition, CSAMT has been used very successfully in other geothermal projects, including detailed monitoring of a geothermal reservoir during exploitation.

A 250'-by-250' grid was suggested, in light of the short distance between the dry well and the producers. The 250' grid was used for the SP and Magnetics surveys, but a 500'-by-500' grid was used for the CSAMT survey because of budget constraints. The E-field dipole size was 250 feet.

The three-person crew mobilized from Tucson, Arizona on May 17, 1987. Hank Giclas was the crew chief in charge of operations, with Jeff Wallace and Arnie Ostrander (degreed geologists) acting as field technicians. Transmitter location and permit problems delayed data acquisition until May 21, but the survey proceeded relatively smoothly after that. The original survey estimate had been for each receiver to acquire 6 stations per production day. Only one receiver was available for this job, but the crew was able to achieve 5.8 stations per day, or very nearly the original job estimate. The crew completed the CSAMT work on June 1, 1987 and returned to Tucson on June 3, 1987. On June 2, 1987, an additional crew chief was sent to Sulphurdale to finalize the SP survey, which was complete June 5, 1987.

LINE AND STATION LOCATION - Station locations were determined in the field using Brunton compasses and a chain. The main grid itself was originally located by establishing station 6 of Line 6 (the center of the grid) between the producing geothermal wells Olga and Linda. From station 6 of Line 6, Olga was due west, and Linda was at a bearing of N 85 E. From this point, stations were chained and bearings were maintained with Bruntons. Using locations of these two wells (relative to the northwest section corner of Section 7) provided by the client after the survey, it appears that the station locations are less than 40 feet off on the west side of the grid and less than 50 feet off on the east side of grid, according to landmarks described by the crew in the field notes (for example, the west section line fence of Section 7 and its intersection of Line 1 of the grid). Large discrepancies were originally suspected when the grid was plotted relative to the dry well 42-7. Based upon the legal description and location of the well provided by the client, it is now obvious that the 42-7 well is plotted incorrectly on the University of Utah's "Geologic Map of the Cove Fort-Sulphurdale KGRA", which was originally being used as a base map. The discrepancy (approximately 300 feet) accounts for the original problems in correlating field notes with known map features. All stations in the grid were marked on the ground with wood stakes during the first phase of the survey (SP and Mag).

Spider lines (Lines 12, 14, 15, 16, 17, 18, and 19) were also located using Bruntons and chains. Lines 16, 17, and 19 were along roads shown on the USGS Cove Fort 15' quadrangle. Stations 1 through 5 of lines 16 and 17 were marked on the ground with wood stakes; the remaining stations of these three lines were marked with flagging only, primarily because the field crew was told that the property was unpermitted.

Integral stations (stations 1, 2, 3, and 4) of lines 14 and 15 were marked with wood stakes; fractional stations were marked with flagging.

Line 12 was along a dirt road not shown on the USGS topo map; stations were marked with wood stakes. (Note: a road is shown on the map in the general area, although the road shown is approximately 250 feet north of the road actually used for Line 12. The map is dated 1962, however, and the road used may be more recent.)

Stations on Line 13 were marked with wood stakes, and were chained from station 8 of Line 11.

The bearing of Line 18 was due South, along the eastern perimeter of the sulphur pit. Stations 1, 2, and 3 were marked with wood stakes. Stations 13 and 23 were positioned due east and west (respectively) of station 3, and both were 500 feet from station 3. Station 4 was located due south of station 3, and was 30 feet from the thermal gradient hole. Stations 24 and

34 were due west of station 4, and were 500 and 1000 feet away, respectively. Station 5 was 500 feet due south of station 4. These stations were marked on the ground with flagging.

The orientation of the grid itself was chosen based upon the optimum transmitter location. CSAMT transmitters are best located in areas of deep basement in low resistivity ground, if possible. Two sites near the Sulphurdale project were considered to be suitable, one northwest of the target area and one to the southwest. The northwest site was used, with a transmitter orientation of N 27 E. This required that the E-field dipole also be N 27 E, and to make movement between stations as fast as possible, the main grid lines were also oriented N 27 E.

DATA PLOTS- Included in this report are pseudosections of raw Cagniard resistivity for all lines, as well as filtered, corrected resistivity for selected lines and cross-sections. The filtered data are included primarily to highlight features which are seen in the raw data, but which may be somewhat obscured by noise. The filter used was a 3-point "comb" filter on a station-by-station basis. In addition, since static offset effects are present, all the filtered data were also corrected for static offset using the phase difference data, since phase difference is not affected by static offset. All data were corrected using the same resistivity and phase normalization values (8.5 ohm-meters and 851 milliradians, respectively) at 64 Hz., effectively stripping off the upper frequencies which were strongly affected by powerline noise. These plots are labeled "CORRECTED RESISTIVITY" and include data only up to 64 Hz., as compared to the raw Cagniard resistivity plots which are labeled "CAGNIARD RESISTIVITY" and contain data up to 4096 Hz. The filtered, corrected data are an excellent method for looking a fundamental differences in resistivity curve shape. Changes in curve shape are a definite indication of resistivity changes from station-to-station. Static offsets may cause an apparent change in resistivity between stations when in fact the change results only from a small, near-surface feature which is causing a complete shift of the resistivity curve.

Also included are pseudosection plots of phase difference data for all lines, as well as resistivity vs frequency curves for all stations (plotted on a log-log scale, referred to in the report as log-log curves).

SUMMARY AND CONCLUSIONS

The region examined on the Sulphurdale project can be divided into several distinct areas based upon the electrical data. The region west of the main grid area (comprised of most of Lines 16 and 17, and all of Line 19) is characterized by high-over-low resistivities, generally higher resistivities than the main grid area, and a 2 Hz. transition zone notch. This area shows relatively uniform data, and a definite decrease in resistivity to the east. No distinctly anomalous areas are noted in this region, and the decrease in resistivity to the east is smooth and gradational. The lower frequency transition zone notch (compared to the main grid area) suggests a deeper basement in this "regime" west of the grid.

Line 14, north of the main grid, exhibits characteristics very similar the "regime" west of the grid. Stations 1 and 3 both show a distinct 2 Hz. notch, as well as higher resistivities than the main grid. In addition, several of the northeastern stations of the grid also show a 2 Hz. notch, suggesting that the region northeast of the main grid area may be similar to the region already described west of the grid, i.e., a deeper basement. With only 2 stations on Line 14 and the northeast end stations of the grid lines, there is not sufficient data to determine definitely if this is the case.

The main grid area (Lines 1, 3, 5, 7, 9, and 11) shows localized variations as well as a "regional" trend superimposed on these local variations. Contrary to the "regime" west of the main grid, data for the main grid show a gradual increase in resistivity to the northeast. Most of the stations are characterized by a generally uniform resistivity curve, rather than a distinctly high-over-low curve as seen on Lines 16, 17, and 19. Several stations within the grid show anomalously conductive values, however, similar to data gathered over other known geothermal sites. Station 5 of Line 5 and station 5 of Line 7 both exhibit anomalously conductive values in the frequency range of interest. Both stations also exhibit phase difference values which are higher than surrounding stations, and suggest a stronger high-over-low resistivity contrast than other areas of the grid. Since these two stations are near the production wells 34-7A and 34-7B, and since the data are similar to data at other known geothermal sites, these stations are taken as the "template" anomaly for the Sulphurdale site. (There are other electrical indications of potential geothermal targets of course; comparison of the "template" area to the surrounding data is intended to assist in evaluating extensions of the current production site, or areas very similar to the production site.)

Within the grid area, other anomalous stations include station 3 of Line 11 and, very weakly, station 3 of Line 9. Station 3 of Line 11 exhibits a distinct high-over-low curve shape, low resistivities in the range of interest, and high phase difference values, similar to station 5 of Lines 5 and 7.

South of the grid, on Line 18, anomalous stations are also seen at stations 4 and 5. This portion of Line 18 looks very similar to the data around the production area, exhibiting distinct high-over-low layering, low resistivity at depth, and high phase values. Without stations further to the south, however, it is not possible to determine whether the low resistivities seen at stations 4 and 5 of Line 18 are the result of an anomalously conductive area similar to the production area, or whether these are transitional stations between the grid area and another "regime" south of the grid which is similar to the areas west of the grid and north of the grid. Stations 24 and 34, which are due west of station 4 of Line 18, both show distinct high-over-low layering and a 2 Hz. notch, identical to the Line 16, 17, and 19 "regime". Thus stations 4 and 5 may be transitional, similar to station 1 of Line 17, which shows similarities to the main production area, but is interpreted to be transitional between the "regime" west of the grid and the grid itself.

A very distinctive high resistivity area is noted in the southern part of the grid, characterized by a strong low-over-high resistivity environment. This well defined area is comprised of stations 3, 2, and 1 of Line 18, and stations 1 of Lines 5 and 7. Nearby stations are similar, but the high-over-low character is not quite as strong, such as at stations 3 of Lines 3 and 5. No other stations in the grid or on the spider lines are similar to this high resistivity area, which is clearly evident in the Cagniard resistivity data, and is most obvious in the corrected resistivity for cross-sections B-B' and C-C'. This region separates the low resistivity region near the production wells from the low resistivity region on Line 18 already discussed. It should be noted that in some geothermal environments, areas of steam caps (as compared to fluids) will appear as anomalously high resistivities, compared to the normal low resistivity targets in standard geothermal exploration. This high resistivity area coincides with a north-south fault, although the high resistivities cover a fairly broad area, based upon the interpretation of stations 13 and 23 of Line 18.

Comparison of the CSAMT data with the previously gathered Magnetics data shows some interesting correlations. The high resistivity area in the southern part of the grid discussed above is well defined in the magnetics data as a magnetic low. Areas of intense hydrothermal alteration are normally characterized by magnetic lows, but it must be pointed out that the production area at the Sulphurdale site is defined by anomalously high magnetic readings.

As noted, the area surrounding the production wells is characterized by low resistivities, which would be expected for a geothermal target. These low resistivities coincide very well with a high magnetic anomaly (which is contrary to the norm, geothermal areas normally being associated with magnetic lows), both showing signs of possible extensions to the northeast, but both showing a slight decrease in response between the central production area and the possibly anomalous area on the northeast end of Lines 7 and 9. In addition, a positive SP anomaly is also well correlated with the other two data sets.

Another correlation weakly seen between the different sets of data is in the area of a small hill west of the dry hole 24-7. This area is a magnetic high (similar to the production area), a negative SP anomaly (contrary to the production area) and may be a very slight resistivity low in the CSAMT data (similar to the production area). All three data sets delineate the area as being anomalous, although the nature of the anomaly is inconsistent.

Comparison of the three data sets also serves to highlight the extreme lateral variation in the area, and the need for high density data at this site. For example, the area near the dry well 42-7 on the northeastern part of the grid is seen in the magnetics data as being very rapidly varying over a relatively short distance (less than 250 feet). In the CSAMT data at 500 foot intervals, the nearest station to the dry hole is station 11 of Line 7, a conductive station, which therefore might be interpreted to be an attractive target. Station 11 of Line 7 is also a magnetic high, again similar to the production in the center of the grid. Yet the very close spacing of the magnetic data on Line 15 near the dry hole reveals a rapid decrease in the magnetic anomaly, suggesting that the 42-7 site may be on the edge of an attractive area, but not necessarily within the anomaly. Similarly, other locations within the grid are seen to be rapidly varying in the magnetic data over very short distances, such as between station 6 of Line 2 and station 7 of Line 2 (a distance of 250 feet). The CSAMT data, at 500 foot intervals, tends to physically filter out many of these changes, making identification of small narrow features particularly difficult. Location of faults is similarly difficult in the CSAMT data at this station density.

Differences in the data sets are also evident, although this is to be expected since the SP and Magnetics are point measurements while CSAMT is a vertical sounding, thus providing depth information. For example, in the Magnetic data, the spider lines 16, 17, and 19 are not seen to be significantly different from the main grid area. In the CSAMT data, however, this region is substantially different, particularly in the deeper data. Similarly, the spider lines northeast of the main grid are not particularly different in the magnetic data relative to the main grid, but deep CSAMT data on Line 14 suggest a definite change in this area.

To summarize, a small area near the current production wells is found to be anomalous in all three data sets. This area appears to be conductive in the CSAMT, which is consistent with previous geothermal CSAMT work. Geothermal areas are normally conductive as a result of the changes in pore spaces and pore fluids due to the geothermal conditions. The area is also found to be anomalously high in the Magnetic data, although a Magnetic low is usually associated with areas of geothermal alteration. Also evident in this central production area is an SP high. Geothermal alteration areas are normally associated with SP lows, but the correlation of the SP anomaly with the Magnetic and CSAMT anomalies is extremely good. This anomalous area consists of stations 5 and 6 of Line 5, stations 5 and 6 of Line 6, and in the CSAMT data, station 5 of Line 7. The anomalous area does not extend to the west beyond Line 4, and does not extend to the south beyond station 3 of Lines 5 and 7.

An extension of this anomalous area is possible to the northeast. Conductive values are seen at stations 9 and 11 of Line 7, and at stations 9 and 11 of Line 5. Stations 9, 10, and 11 of Line 7 are also anomalously high in the Magnetics data, making this area very similar to the main production area. Lines 14 and 15 of the magnetic data do not indicate a continuation to the northeast of this extension beyond station 11 of Lines 7 and 9, however, and Line 14 of the CSAMT data suggests a change of "regime" to the northeast.

It should be noted that the region in between these two anomalous areas (the main production area and the area to the northeast) is also conductive and high magnetically, but less so than the two described anomalous zones. The fact that the two regions are separate in both data sets is encouraging as far as data consistency is concerned, but it suggests a very complicated picture with regards to attractive target sites.

A third conductive region is seen in the CSAMT data on the extreme southern end of Line 18, at stations 4 and 5. This area was not covered by the magnetic survey however. These two stations indicate conductive values and curve shapes similar to the production area, but without data surrounding the stations, it is also possible that these two stations are not anomalously low by virtue of geothermal conditions, but merely as transition stations between the high resistivities of Line 18 and a different "regime" to the south. Stations 24 and 34 of Line 18 (due west of station 4) appear to be similar to the Line 16, 17, and 19 "regime". Additional data would have to be gathered before this site could be considered an attractive target.

No other areas of conductive values are observed which would indicate the presence of geothermal targets. Magnetic data indicate a possible target associated with the small hill west of the dry hole 24-7, but the CSAMT data stations are not dense enough to verify this definitely as a low resistivity target.

DETAILED DISCUSSION OF THE DATA

Much of the interpretation of the CSAMT data is based upon the shape of the resistivity curves (resistivity vs. frequency). Since depth of investigation is frequency dependent, changes in resistivity with depth are can be seen by examining the change in resistivity with frequency. The resistivity curves at the Sulphurdale site can be divided into three general curve types, which are shown in Figure 1. Most of the curves are relatively flat, and approximately homogeneous in the frequency range of interest. The stations near the production wells and north-northeast of the production wells, as well as stations 4 and 5 of Line 18 exhibit a definite high-over-low resistivity environment in the range of interest, suggesting low resistivities at the target depth. A few stations (stations 1 and 2 of Line 18, stations 1 of Lines 5 and 7, and stations 3 of Lines 3 and 5) exhibit a definite low-over-high environment, suggesting high resistivities at the target depth. The small, limited area of high resistivities may also be of interest, depending upon the known or suspected hydrology of the reservoir. In some environments, steam has been known to produce similar high resistivities. This small area of high resistivity (comprised of only six stations oriented approximately north-south, from station 2 of Line 18 to station 3 of Lines 3 and 5) may be an indication of an area of steam, rather than liquid water.

LINE 1

Line 1 raw data are relatively uniform. At depth, resistivities gradually increase to the northeast along the line. In the shallow data, the high resistivities at stations 5 and 7 are coincident with a small hill; it should also be noted that it is possible that station 9 is lower in resistivity than normal due to the topographic low at that location. If the latter is the case, Line 1 exhibits increasingly high resistivities to the northeast, or at least a thickening of the near-surface high resistivities to the northeast.

LINE 3

Line 3 raw data are similar to Line 1 in that a general trend toward higher resistivities is seen to the northeast. Stations 5 and 7 are on the same hill as stations 5 and 7 of Line 1 (although not as high on the hill), but no shallow high resistivities are seen on this line. Station 9 of this line falls in the same drainage as station 9 of Line 1, but values at station 9 of Line 3 are not low relative to surrounding stations. Station 5 of this line is interesting in that it is

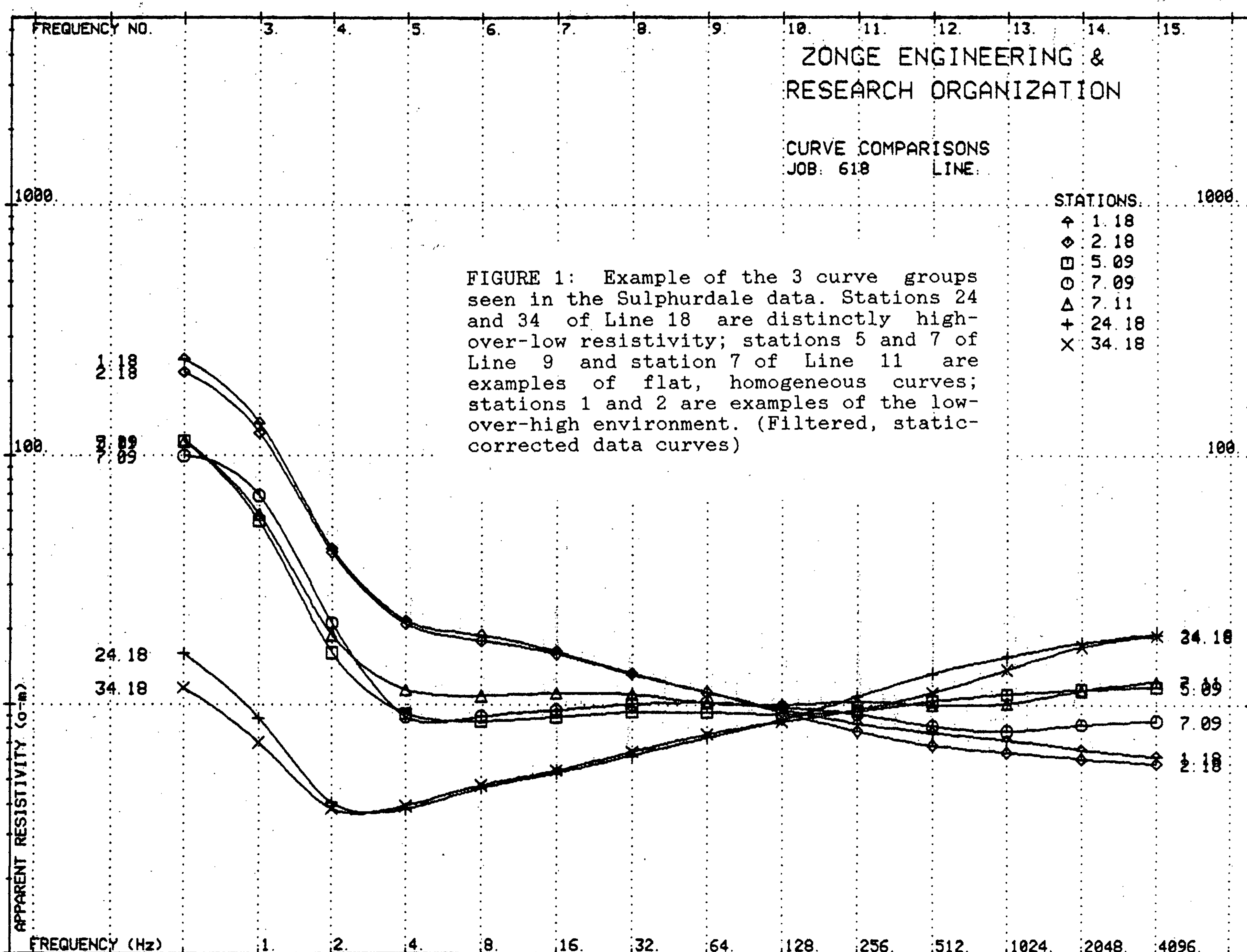

FIGURE 1: Example of the 3 curve groups seen in the Sulphurdale data. Stations 24 and 34 of Line 18 are distinctly high-over-low resistivity; stations 5 and 7 of Line 9 and station 7 of Line 11 are examples of flat, homogeneous curves; stations 1 and 2 are examples of the low-over-high environment. (Filtered, static-corrected data curves)

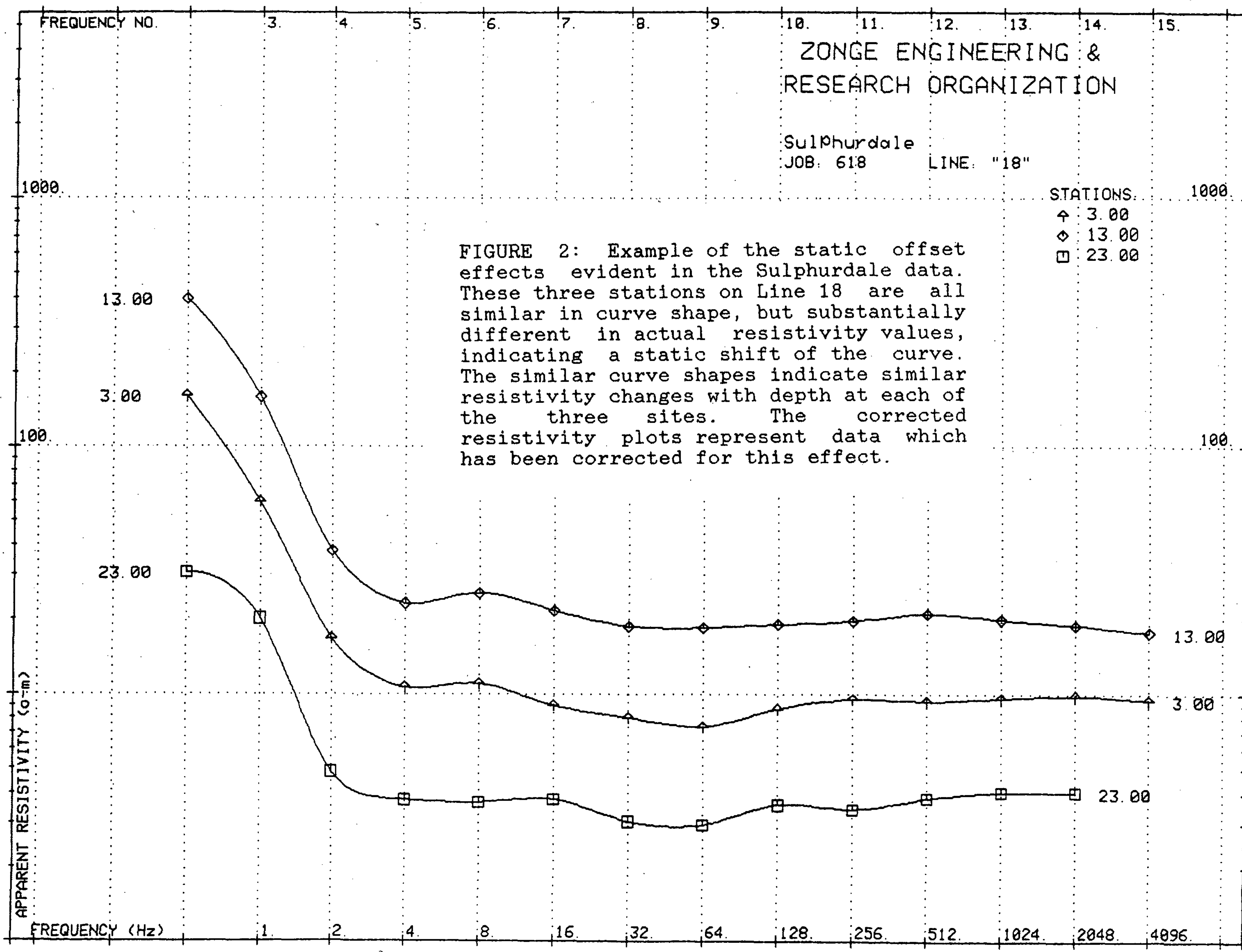

FIGURE 2: Example of the static offset effects evident in the Sulphurdale data. These three stations on Line 18 are all similar in curve shape, but substantially different in actual resistivity values, indicating a static shift of the curve. The similar curve shapes indicate similar resistivity changes with depth at each of the three sites. The corrected resistivity plots represent data which has been corrected for this effect.

slightly lower in resistivity than the other stations, although the contrast is not as great as is seen at station 5 of Line 5. Phase difference data do not show an increase in the frequency range of interest, while station 5 of Line 5 does exhibit such an increase.

LINE 5

Line 5 shows more variation in the raw data than Lines 1 and 3. The same general trend toward higher resistivities to the northeast is evident, although this trend is interrupted by anomalously low values at depth at station 5 and station 9. Station 5 is characterized by consistently high phases down to 4 Hz., and exhibits its lowest resistivity value at 4 Hz. Station 9 also has high phases, although not as consistently as station 5. (Station 11 exhibits a steep notch at 2 Hz, similar to stations on Lines 16, 17, 19, and 14.)

Station 5 of Line 5, as well as station 5 of Line 7 are seen to be anomalous at approximately the depth of interest, and are the basis for comparison in examining data at other stations with respect to possible geothermal targets. Due to the possible small size of the targets, and the absence of any immediately adjacent stations to these two anomalous stations, these two stations must be used with caution as "template" stations. If stations 4 and 6 of Lines 5 and 7 had also been acquired as CSAMT stations, a better understanding of the production area could be developed. In the absence of such data, the low resistivities at the depth of interest are consistent enough with previous geothermal work to interpret as being the result of the geothermal target.

LINE 7

Raw data for Line 7 also indicate low resistivities at station 5, very similar to station 5 of Line 5. The lowest values are at 4 Hz., and high phase values are evident (although not as consistently as on Line 5). Again, a trend toward higher resistivities to the northeast is apparent along this line. A region of high phase values is seen at station 9 and 11 at frequencies of 64 Hz. through 8 Hz.

LINES 9 and 14

Comparison of the Line 9-14 combination to cross-sections A-A' and C-C' shows similar trends in both the Cagniard Resistivity and phase difference data. The northeast end of Line 9 and both stations of Line 14 are characterized by higher resistivities than the main grid area, and the transition zone notch is at 2 Hz., as compared to the main grid area where the notch is seen at 4 Hz. Moving northeast along Lines 9-14, an increase in resistivity is seen between stations 7 and 9, and between stations 9 and 11 the notch shifts from 4 Hz. to 2 Hz. Continuing northeast, station 1 of Line 14 exhibits a very steep notch at 2 Hz,, and the data are very similar to the "regime" west of the main grid evident in the Line 16, 17, and 19 data. A similar change is seen on cross-section B-B', although the data are noisier and the change to the northeast is less well-defined on cross-section B-B'.

Station 1 of Line 9 is very similar to stations 1 and 2 of Line 18, as well as station 1 of Line 7, all of which exhibit a definite high-over-low resistivity environment. Stations 3 through 9 are relatively homogeneous, and station 11 exhibits a well-defined notch at 2 Hz. Stations 1 and 3 of Line 14 also exhibit a 2 Hz. notch, appearing very similar to the curves of Lines 16, 17, and 19.

In the filtered, corrected data, Lines 9 and 14 are very uniform, with a change in the deeper data between station 11 of Line 9 and station 1 of Line 14 which is very similar to the change seen along the A-A' cross-section. (In the filtered pseudosection, station 11 of Line 9 exhibits a notch at 4 Hz.; this is an artifact of the filtering process. The transition zone notch is at 2 Hz., as seen the Cagniard resistivity curves.)

LINE 11

Raw resistivity values for Line 11 are generally higher than the other lines; a trend towards higher resistivities to the northeast is not seen on this line, however. Station 3 of this line is anomalous compared to the other stations, showing a stronger high-over-low contrast. All other stations show relatively little variation with depth, and phase values indicate only a very weak high-over-low environment. Station 3 shows both high phase values and a well-defined resistivity low in the 8 Hz. and 16 Hz. values. While this is not identical to the data near the production wells, it may be an indication of a low resistivity region at a slightly shallower depth (than the production area). In the filtered, corrected data, station 3 appears similar to station 3 of Line 7 (see the S-3 pseudosection), which is between the high resistivity feature and the anomalous production area. Thus, station 3 of Line 11 may be near but not directly over a potential target area. The small target size versus the station spacing does not rule out this possibility, unfortunately, and a narrow target area may exist between stations 2 and 4 of this line, but not necessarily directly beneath station 3. Conceivably, such a narrow target could extend from near station 3 of Line 11 and into the central grid area without strongly affecting the stations gathered in this survey.

CROSS-SECTION A-A' (LINE 16 and GRID STATIONS 9)

This cross-section delineates very well the two different "regimes" evident in the data. All of the stations of Line 16 (with the exception of station 1) show a well-defined transition zone notch at 2 Hz. in both the raw and filtered data. In contrast to this, all grid stations 9 (and station 1 of Line 16) do not show a steep notch at 2 Hz. Low resistivities are evident on Line 5, station 9 and Line 7, station 9, with the lowest values at 4 Hz. This region is similar to the conductive area near the production wells (see the S-5 pseudosection), although this region may also be transitional between two regimes, i.e. similar to station 2 of Line 16. Line 14, and several of the grid stations 11 show a definite notch at 2 Hz., similar to the Line 16, 17, and 19 data. Thus the conductive grid stations 9 (Line 5 and Line 7) may be only transitional stations between the main grid area and a northern "regime" similar to the regime west of the grid (i.e. Lines 16, 17, and 19).

CROSS-SECTION B-B' (LINE 18 and LINE 7)

This cross-section crosses the grid approximately north-south, and passes near the production well 34-7B and the dry hole 42-7. Stations 3, 2, and 1 of Line 18 as well as station 1 of Line 7 are seen to be substantially different in curve shape from the rest of the line. These high resistivity stations show a continuous increase in resistivity with decreasing frequency, as compared to the other stations which decrease in resistivity to 4 Hz. (the transition zone notch) and then increase in resistivity normally. These stations appear to be very near to or directly on the north-south fault mapped by the University of Utah. This area is also coincident with a topographic low. Note that the change in curve shape occurs between stations 3 and 4 of Line 18, and that stations 23 and 13 (west and east of station 3) are similar to station 3, indicating the high resistivity feature is at least 1000 feet wide. Station 13 is topographically much higher than the other high resistivity stations, however, which would seem to contradict the correlation between this high resistivity feature and the topographic low.

CROSS-SECTION C-C'

Cross-section C-C', extending along Line 17, through the grid and on to Line 12, verifies the low resistivity "regime" (characterized by the 2 Hz. notch) west of the main grid, and crosses the high resistivity area on the southern edge of the grid. No low resistivity regions similar to the production area are seen along this cross-section. The well-defined high resistivity feature centered on station 1 of Line 7 may be correlatable to the topographic low in that area, or at least to the geologic cause of the topographic low. (Normally, a topographic low such as a valley will cause a low resistivity feature.) It should be noted that the north-south fault mapped by the University of Utah would intersect this cross-section at Line 7, station 1; thus the high resistivity feature may be related to this north-south fault. (It should be noted that the high resistivity feature does not extend through the grid, but terminates somewhere in the central portion of the grid, possibly west of the production region.)

RECOMMENDATIONS

The results of the survey are extremely encouraging, particularly in light of the drilling costs in this area. Any future CSAMT work should be done with a tighter station density, however, since the 500 foot interval appears to smooth (and possibly miss entirely) many of the changes that occur over very short distances. Despite this problem, several areas at the site have been identified as being interesting, potential targets, and many other areas can be safely ruled out as target areas. Magnetics and SP may be developed into useful reconnaissance tools, but the variations with depth evident in the CSAMT data suggest that these tools probably should be used as extra verification tools rather than primary exploration methods.

Correlation of the data with known geology and drill hole information should be the next priority, in order to allow differentiation of the various changes in the data. Resistivity lows may be created by geothermal fluids and changes; changes in mineralization, rock types, and near surface groundwater may also be causing some of the changes seen in the data. Thus it is not sufficient to simply identify resistivity lows; it is necessary to identify resistivity lows at appropriate depths and in the appropriate environment. The data gathered is more than sufficient to suggest that this is possible in this environment, and several attractive targets have already been identified. To fully utilize the data gathered, however, correlation with other geological data should done.

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CSAMT THEORY

Data Acquisition

Controlled source audio-frequency magnetotellurics (CSAMT) is an electromagnetic sounding technique similar to natural source magnetotellurics (MT). While MT surveys rely on magnetospheric stimulation of earth-telluric currents as a signal source, CSAMT surveys use a long grounded dipole driven by a constant current squarewave transmitter as a controlled source of electromagnetic radiation. The transmitter is located approximately from 3-6 miles from the survey sites.

During the survey, electric and magnetic field components of the transmitted waveform are measured and recorded by a microprocessor-controlled two-channel Geophysical Data Processor (GDP), designed and built by Zonge Engineering. The horizontal electric field parallel to the transmitter dipole is sensed as a potential difference across a dipole of appropriate length, terminated at both ends by porous pot electrodes in contact with the ground. The horizontal magnetic field perpendicular to the dipole is detected by a sensitive ferrite core coil positioned near the center of the receiver dipole. When data of sufficient accuracy have been acquired, the GDP microprocessor performs a Fast Fourier transform on both waveforms to extract the fundamental magnitude and phase of each channel. The apparent resistivity is calculated from the ratio of the electric and magnetic field magnitudes according to the derivations of Goldstein and Strangway (1975). The resistivity, along with the raw component magnitude and phases, are recorded on minicassette tapes and printed on paper strips for later processing, or recorded in solid state memory on a data recorder for later transfer to a computer.

The field survey is usually accomplished by a 3 person crew. One person operates the transmitter, one person operates the receiver, and the third person works the field setup. Data is gathered across a frequency spectrum of 4 Hz. to 4096 Hz. Measurements are taken at discrete binary increments (i.e. 4 Hz, 8 Hz, 16 Hz, etc.).

Data Processing

The data was edited, processed and then plotted in two formats. On a station-by-station basis, log-magnitude versus log-frequency plots are made where the log-magnitude of the electric field (E-field), magnetic field (H-field), or apparent resistivity is plotted as a function of log-frequency (these are called "log-log" plots). This is necessary for a preliminary analysis of the data and may or may not be included with the final interpretation. Data are also plotted on a line-by-line basis; a sounding pseudosection is produced where station position is represented by the horizontal axis, and frequency (the sounding parameter) by the vertical axis. By modifying the vertical axis scaling to account for the frequency dependence of electromagnetic radiation penetration into homogeneous earth, a "linear depth" pseudosection can be produced.

Interpretation

A first pass at CSAMT interpretation usually involves looking at basic changes in the Cagniard resistivity and phase difference pseudosections, and in observing changes in slope on the log-log plots of resistivity and H-field intensity. The resistivity pseudosection is scrutinized for horizontal changes in resistivity (suggesting contacts), for vertical changes in resistivity (suggesting layers), and for changes in transition zone frequencies (described below) which can often represent changes in the depth to basement. The phase difference pseudosection is used with the resistivity pseudosection to help determine whether conductive features of interest are shallow or deep.

The near-field/far-field transition zone is the frequency range in all CSAMT measurements of sufficient frequency coverage where the electric and magnetic fields change from behaving mostly as plane waves to more like curved waves. This zone is usually best observed on the log-log resistivity plots. These plots are also excellent for determining changes in signature (changes in geologic conditions) along a line on an individual station basis.

Log-log H-field plots are analyzed in conjunction with the resistivity data for dimensionality (are there 1-, 2-, or 3-D effects?) of the environment along the survey line, and for interpreting through the transition zone of the resistivity plots. The H-field data are more sensitive to horizontal layering, and are relatively immune to small two- and three-dimensional features.

Interpretation of the Cagniard resistivity data for the far-field (frequency above the transition zone) is done in exactly the same manner as in natural source magnetotellurics. The transition zone and near-field interpretation is best done by analysis of log-log H-field plots. Phase difference data are proportional to the slope of the log-log resistivity curves, and as such, can be used as an aid to determine resistor/conductor type. In its simplest interpretation , phase differences greater than 785 milliradians (pi/4) indicate the data at that point are in a high-over-low resistivity environment. Similarly, data less than 785 mr indicate a low-over-high resistivity environment.

Interpretation of CSAMT data typically utilizes many different types of data which may accentuate certain desirable features or simply help out when dealing with certain environments. We often use first and second derivative plots of the E- and H-field magnitudes, the apparent resistivities, and phase difference, as well as several filtering techniques. Various normalization techniques are also used to remove pervasive and unwanted background responses, to strip off layering effects, or to remove an overwhelming transition zone response.

CULTURAL CONSIDERATIONS

Culture at the Sulphurdale project site was extensive, and included fences, pipelines, well-casings, varying sizes of powerlines, and the power plant itself. These cultural features influenced the data in two ways: as active noise sources (such as the powerlines) and as conductors (such as fences) which distort the electric and magnetic fields being measured. In the past, CSAMT has proven to be very useful near culture, since it is substantially less influenced by culture than are most other electrical methods, particularly the very near-field methods such as dipole-dipole resistivity. Although very little influence from fences, well-casings, and pipelines was seen in the data at the Sulphurdale site, noise generated by the powerlines and the power plant was obvious, despite the 60 Hz notch filter in the receiver. Fortunately, the primary influence was on the higher frequency data, particularly the data at 512 Hz and above. This is attributed to the changing loads on the powerlines, and has been observed at several other locations also. Since the primary area of interest was well below the 512 Hz depth of investigation, the noise had relatively little effect on the project as a whole, other than to slow down the actual data acquisition rate.

As can be seen in the log-log curves, the area most strongly affected by culture was Line 7 where the line runs very near and parallel to a powerline. This orientation (in which the E-field dipole is parallel to the powerline) maximizes the coupling between the E-field dipole and powerline, and is therefore the worst configuration. The log-log curves for Line 7 are very erratic and inconsistent compared to the curves for the other lines.

In the pseudosection plots of the Cagniard Resistivity and Phase Difference data, noisy or questionable values are shown in brackets [], and the contours are drawn as if there were no reading at that point. On the log-log plots of the data, all data are shown, whether the values are considered noisy or not. For the Corrected Resistivity pseudosections, only data at 64 Hz and below are shown. This produces a plot which is in the approximate range of interest, and eliminates any possibility that the noise is influencing the static correction process (since the correction was done using values normalized to 64 Hz data, which is well below the frequencies affected by the powerline noise).

In the interpretation process, the position and orientation of the various cultural features is taken into account, and the data are examined in plan view for any correlations between the cultural features and trends in the data.

Line "01"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

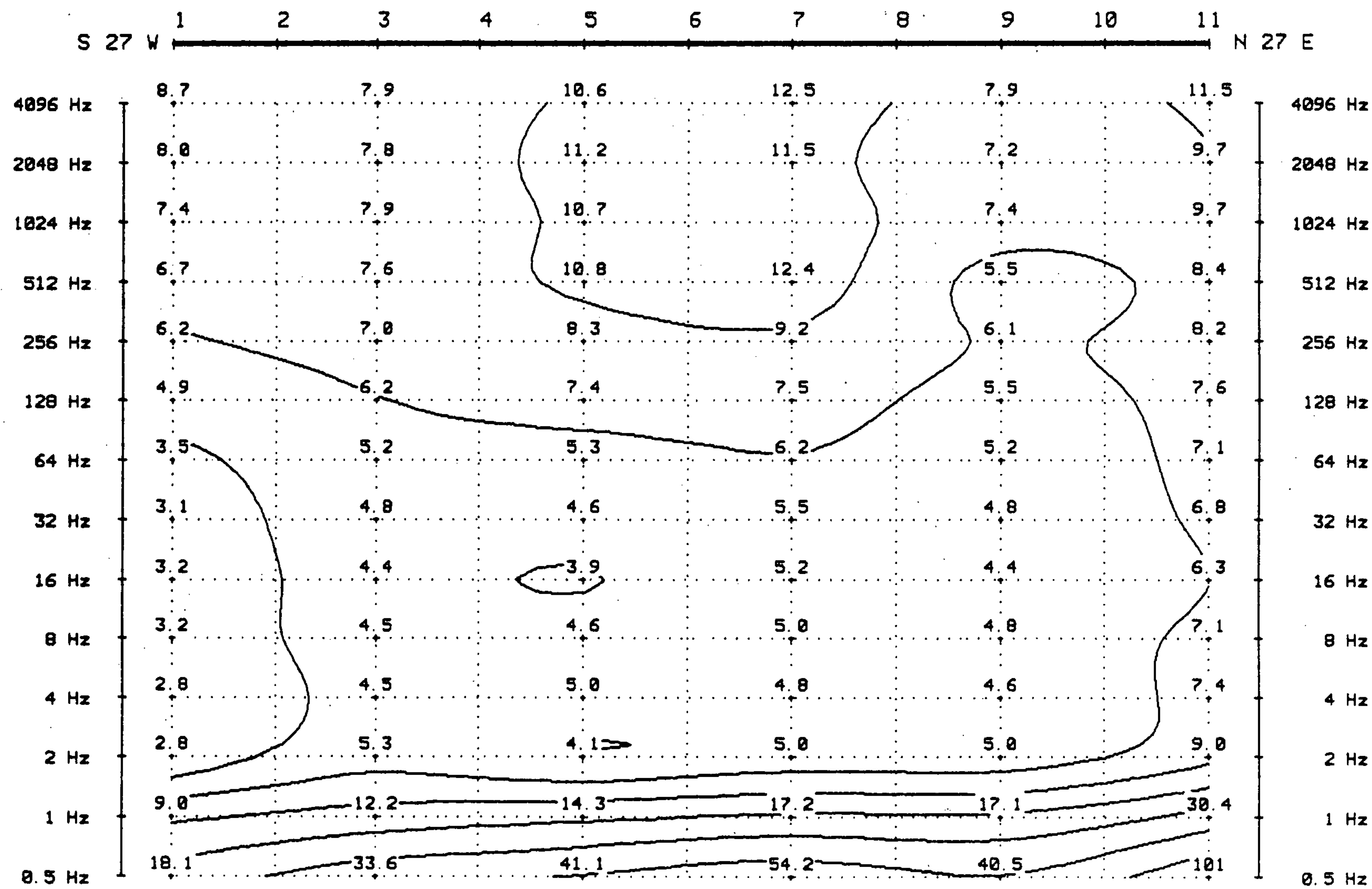
values in ohm-meters
<RHO-C

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



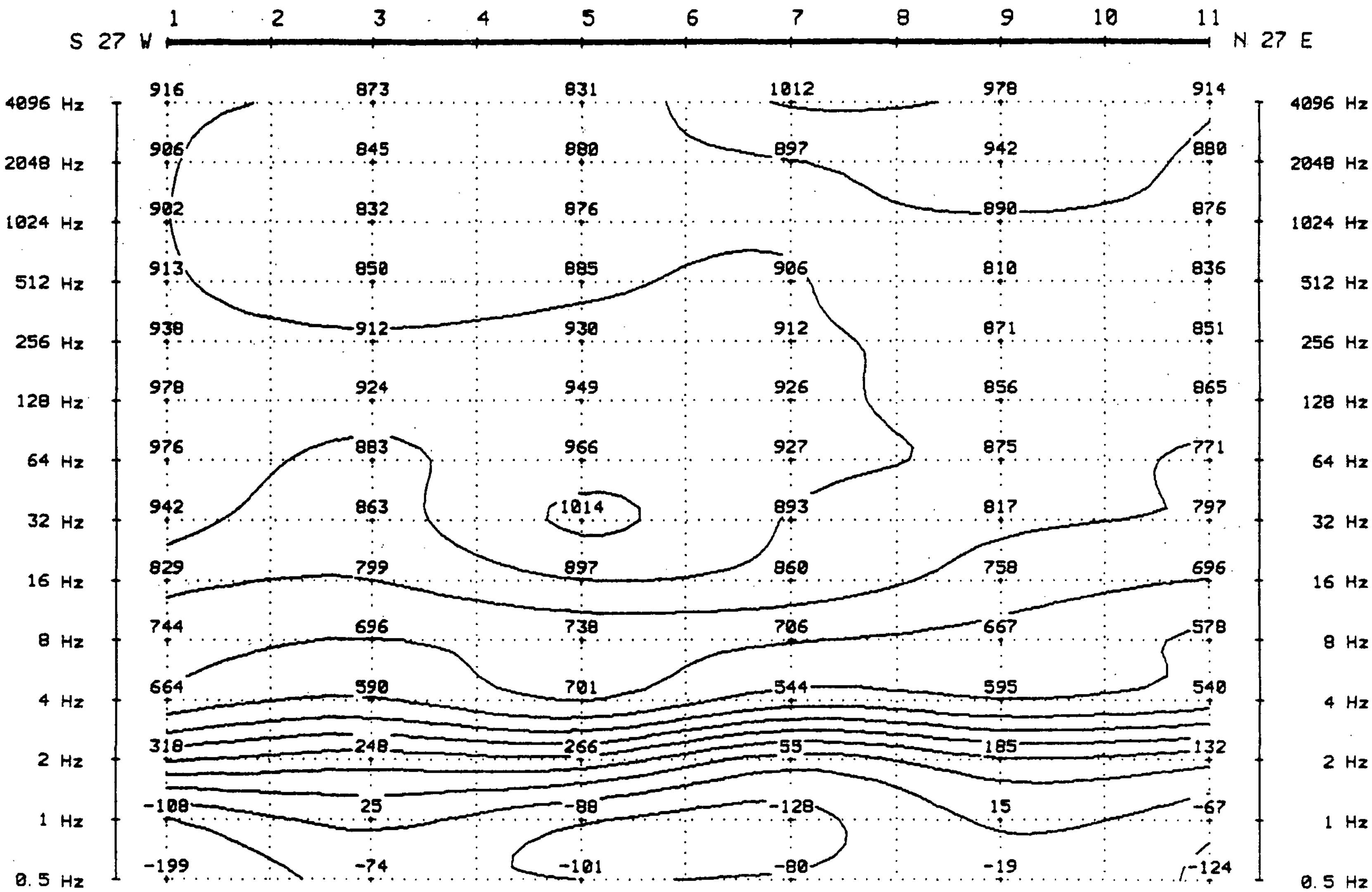
Line "01"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

values in milli-radians
<PDIFF

RECEIVER DATA		TRANSMITTER DATA
Length : 250. ft	Line : N 27 E	Length : 5280ft
Spacing: 250. ft	DiPole: N 27 E	Orient. : N 27 E
		Distance: 5.0 mi
Surveyed: MAY 87		Rx to Tx: N-W



Line "03"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

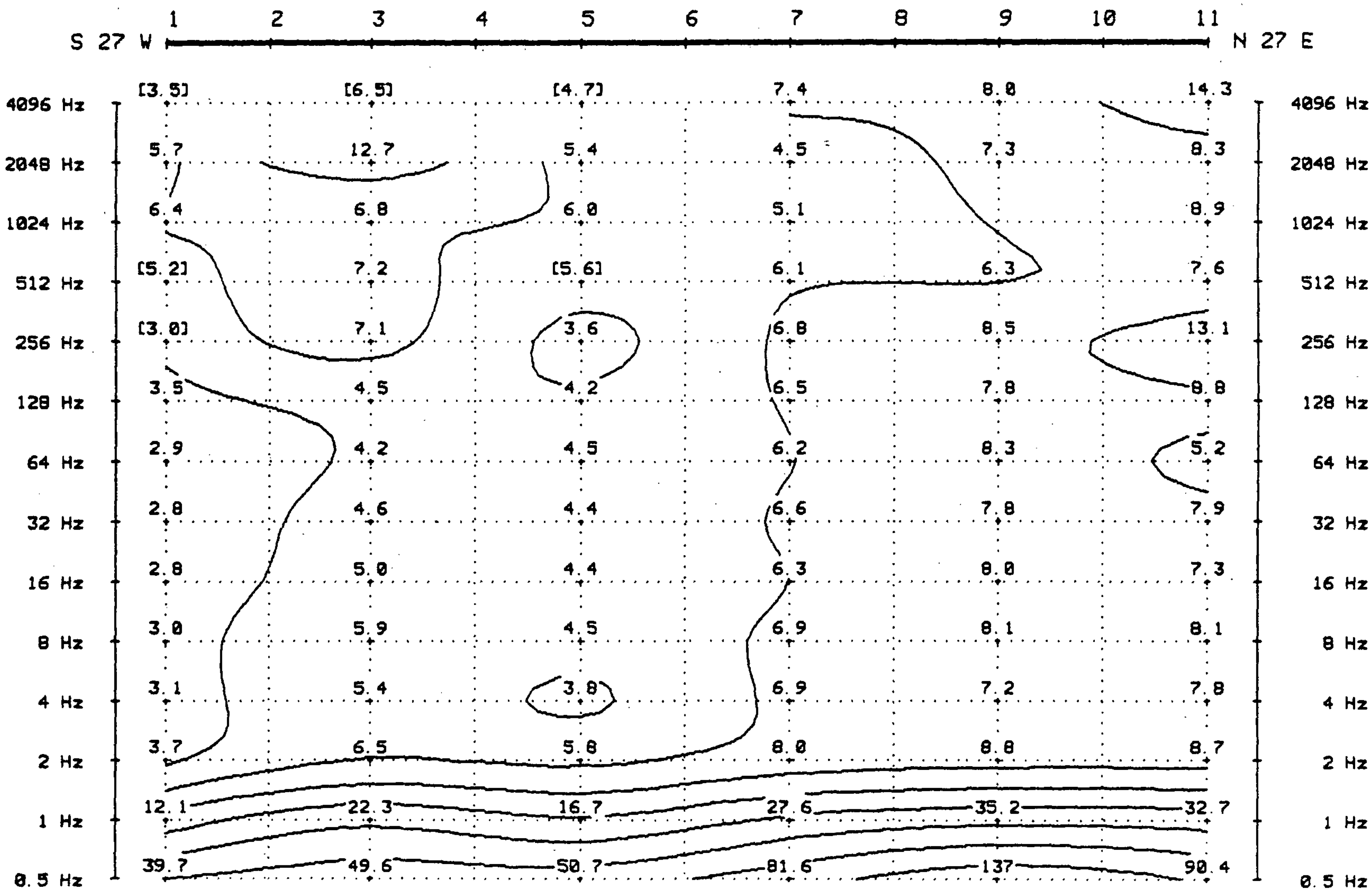
CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "03"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

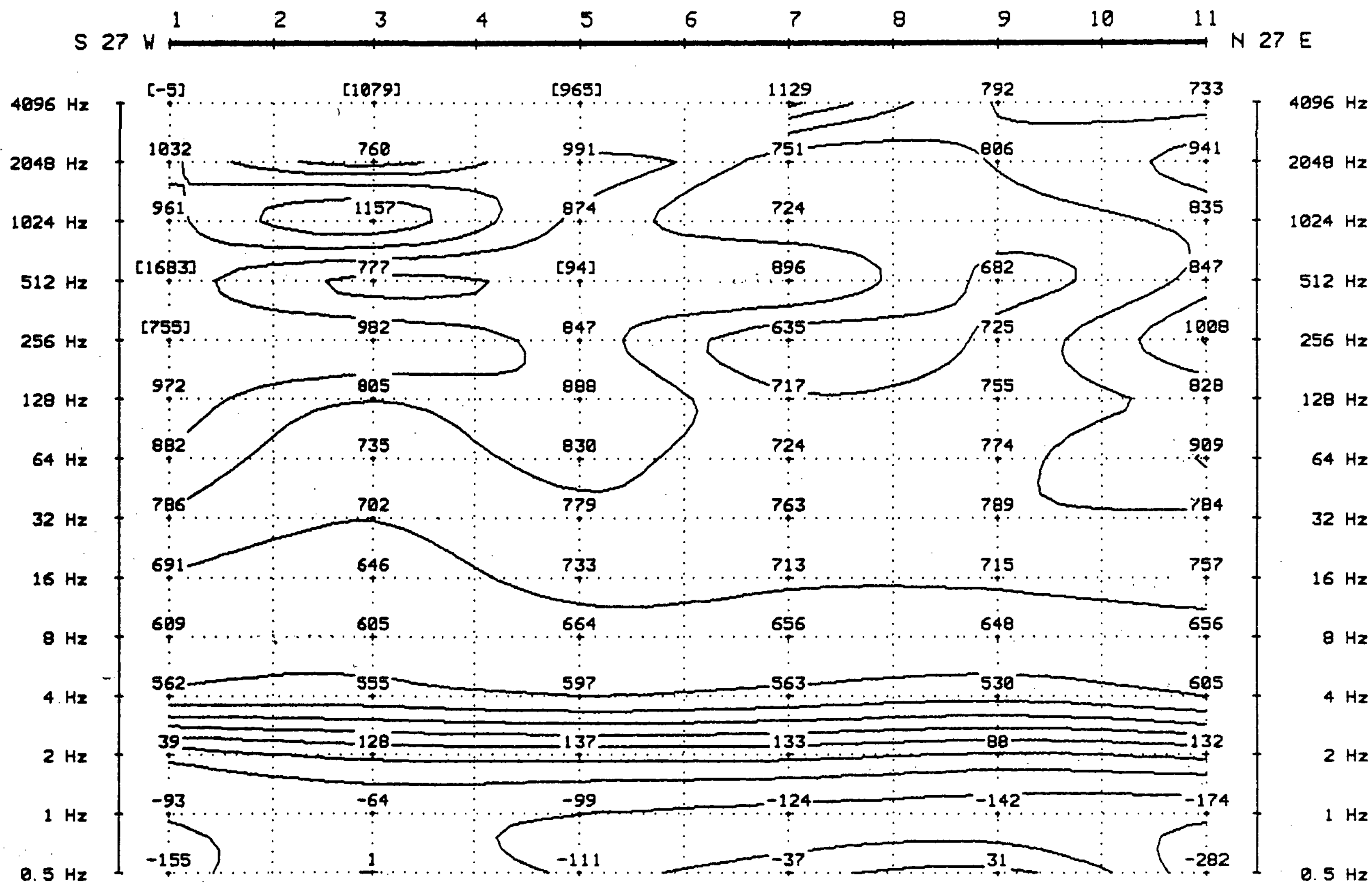
values in milli-radians
<PDIFF

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "05"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

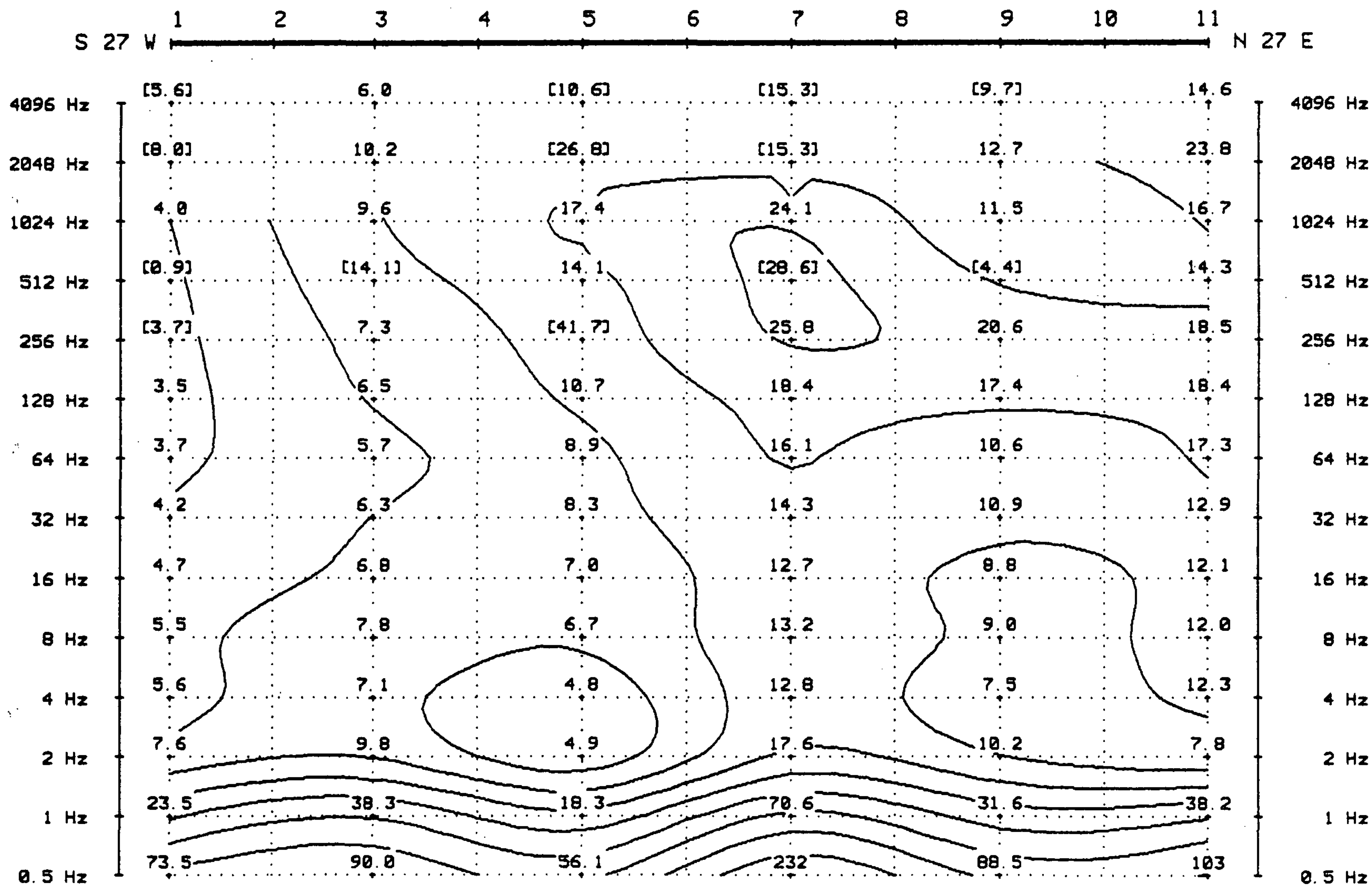
CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "05"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

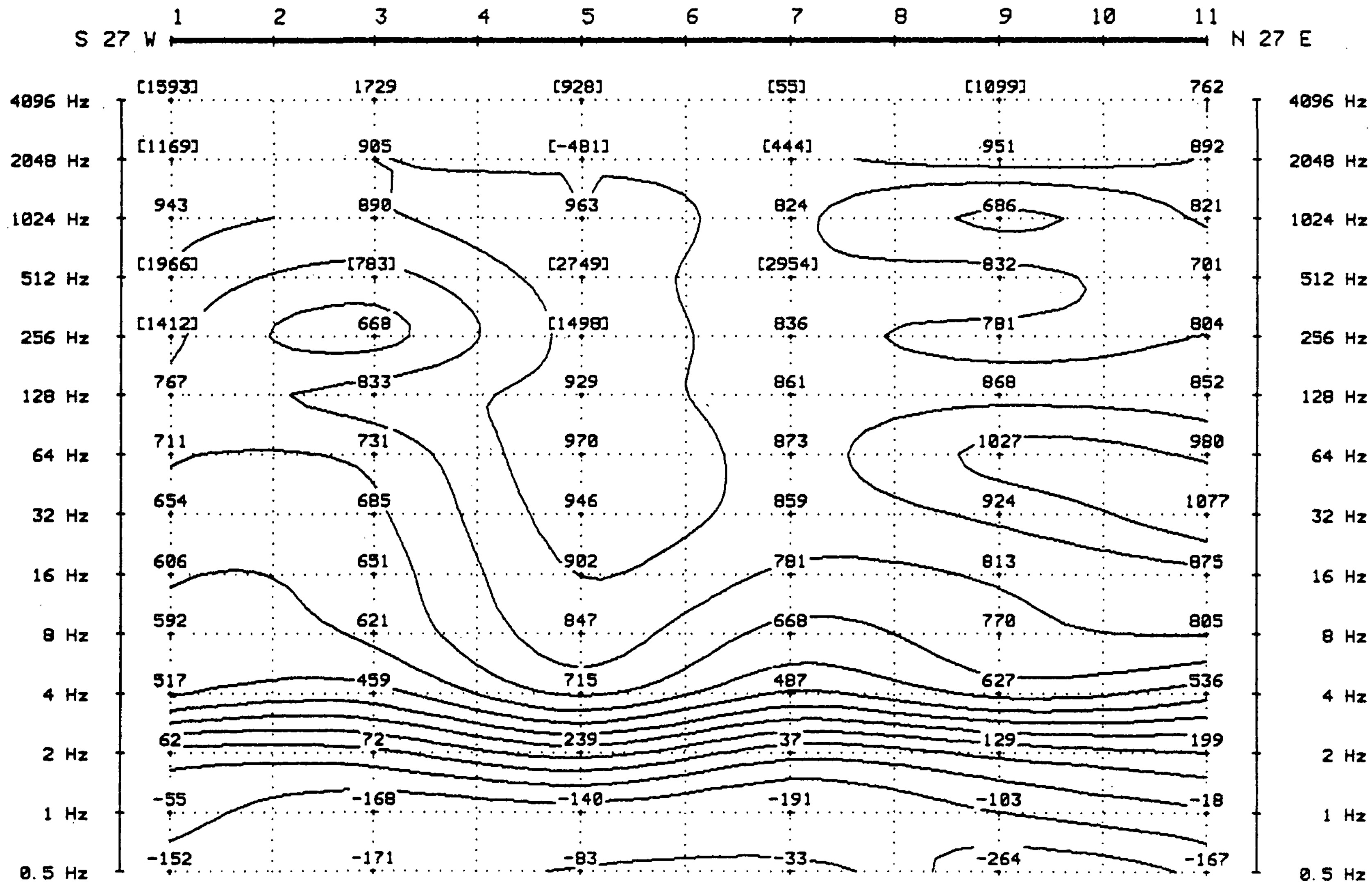
values in milli-radians
<PDIFF

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "07"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

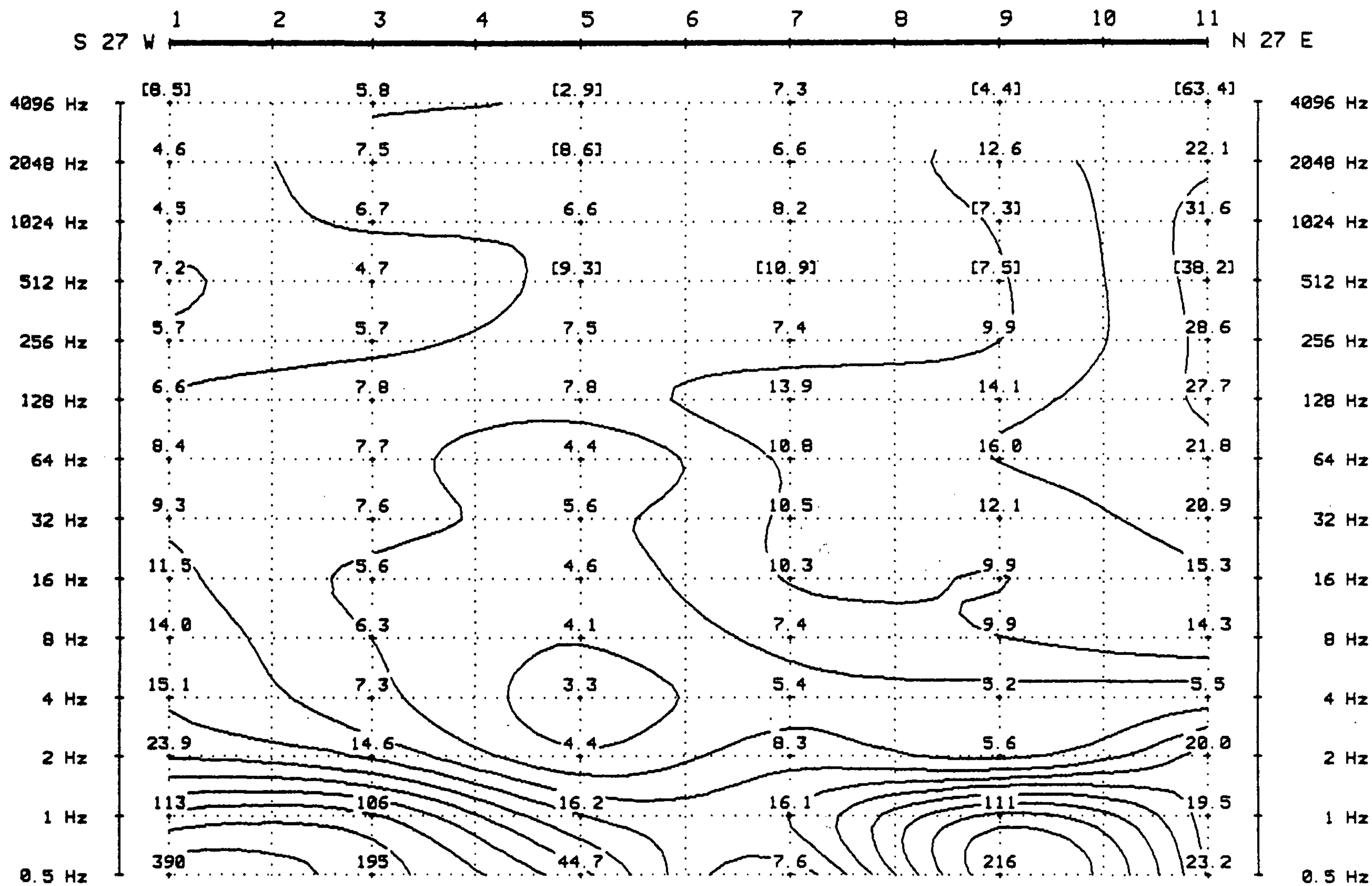
CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "07"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

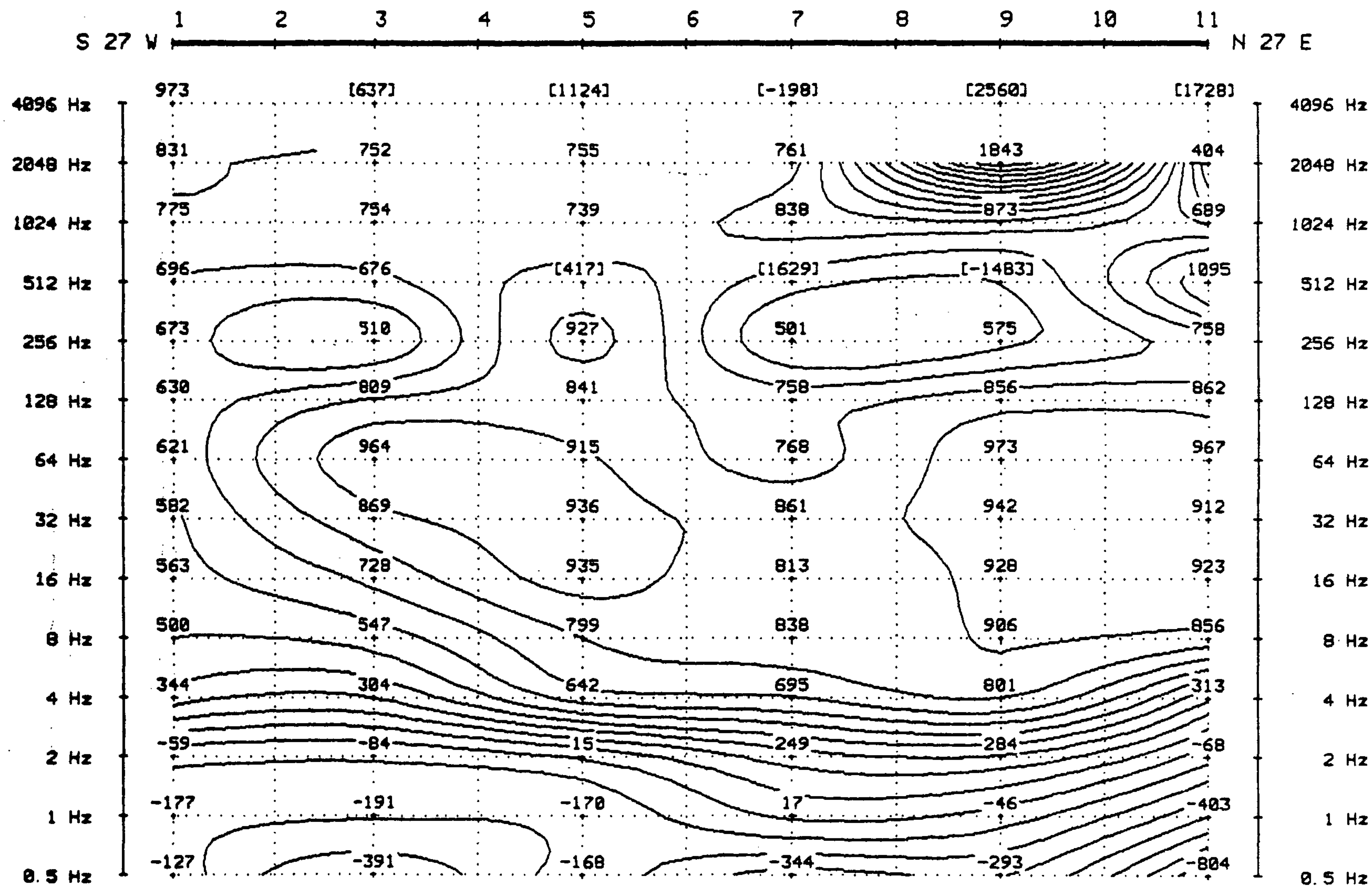
ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)
values in milli-radians
<PDIFF

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "09"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

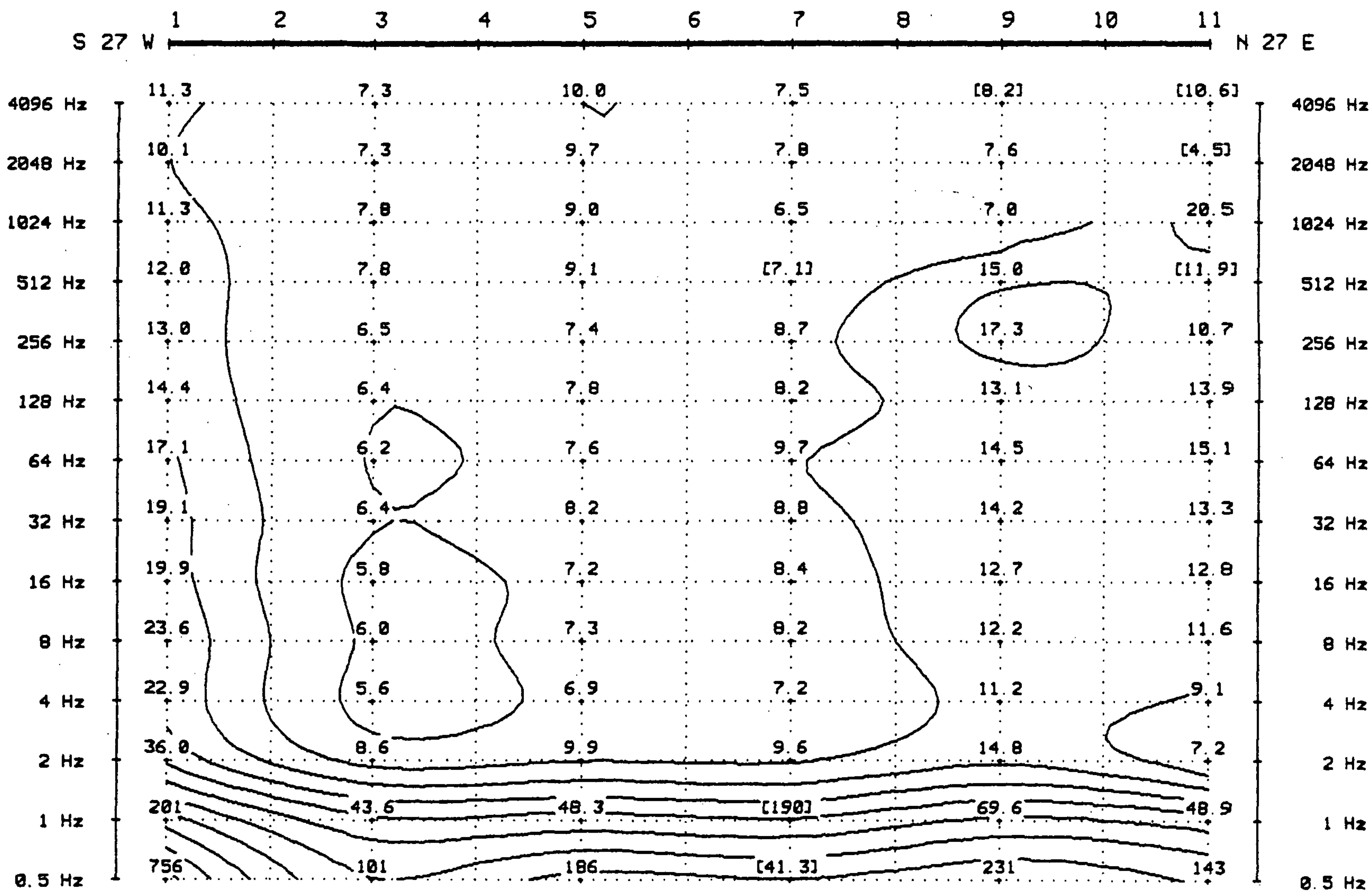
CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



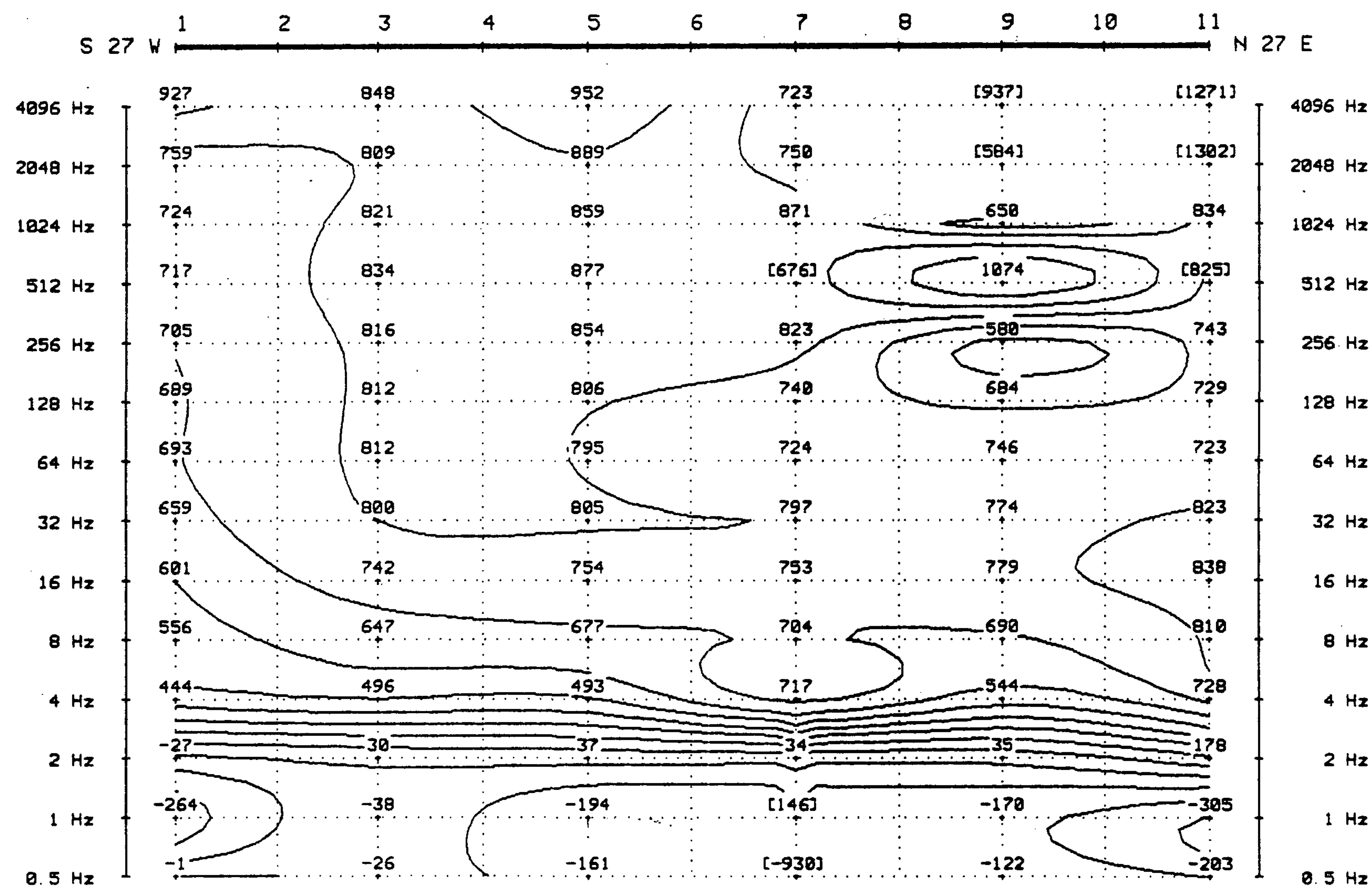
Line "09"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)
values in milli-radians
<PDIFF

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E
Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "11"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

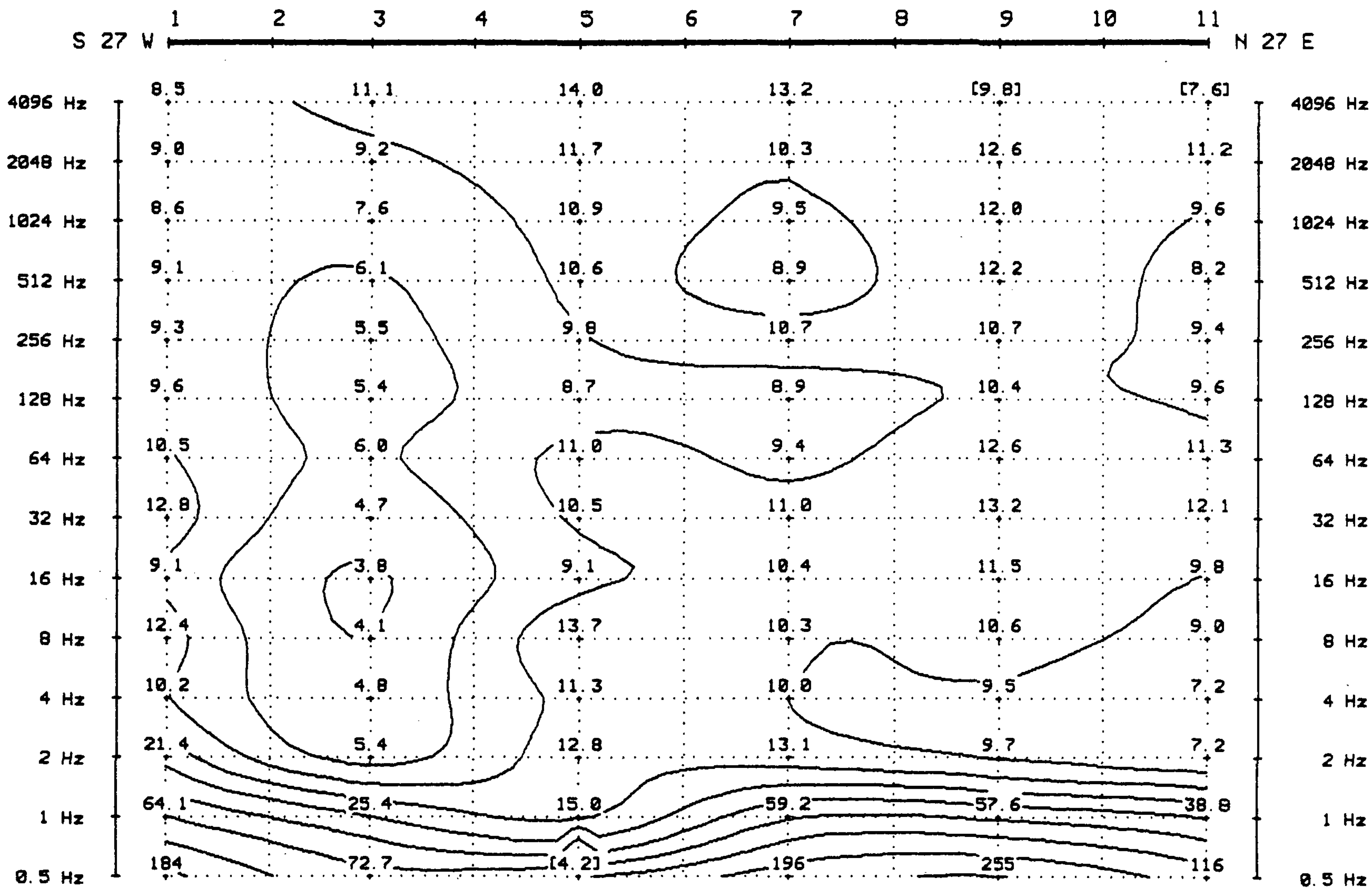
values in ohm-meters
<RHO-C

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "11"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

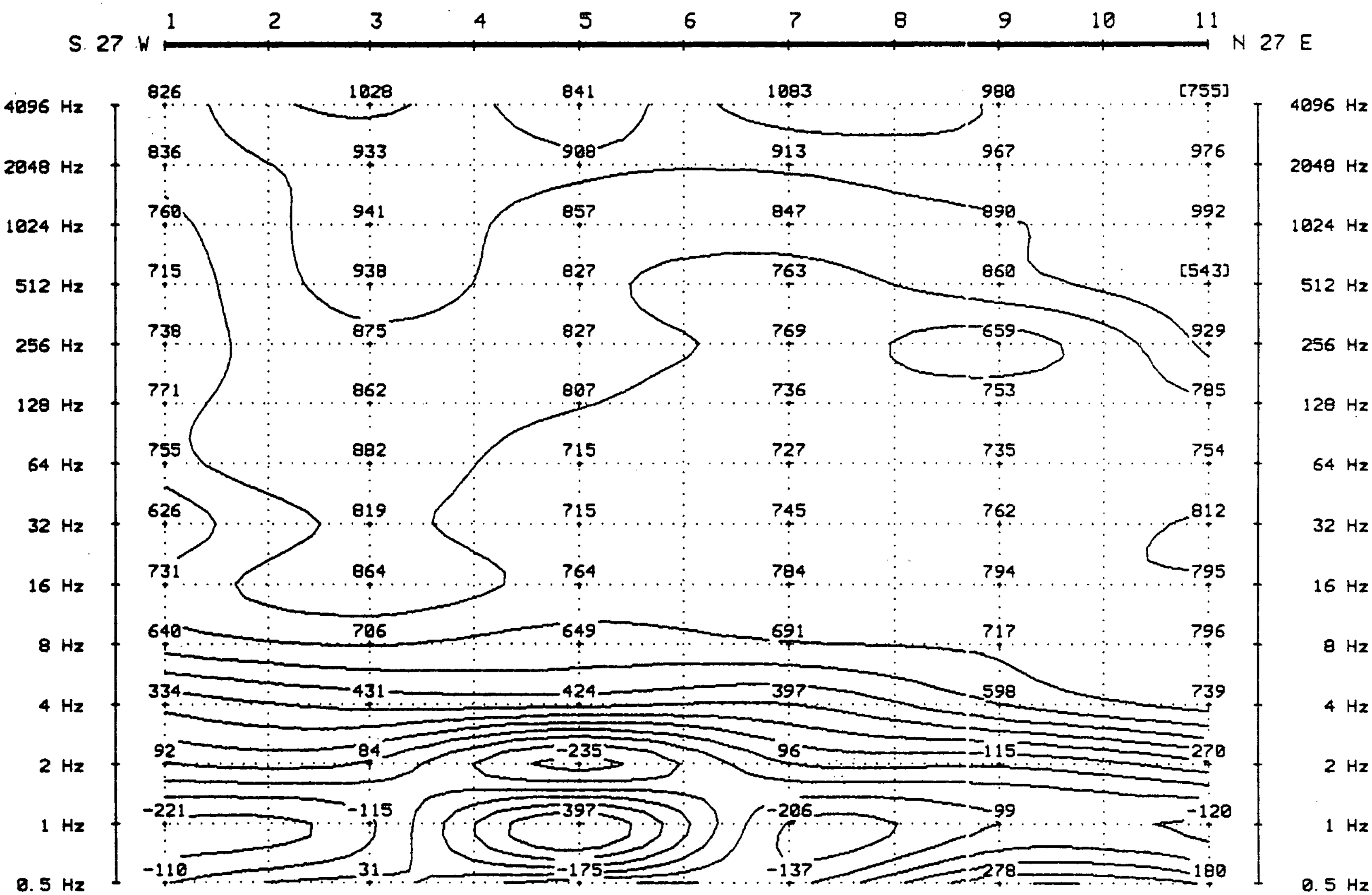
ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 28 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)
values in milli-radians
<PDIFF

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "18"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

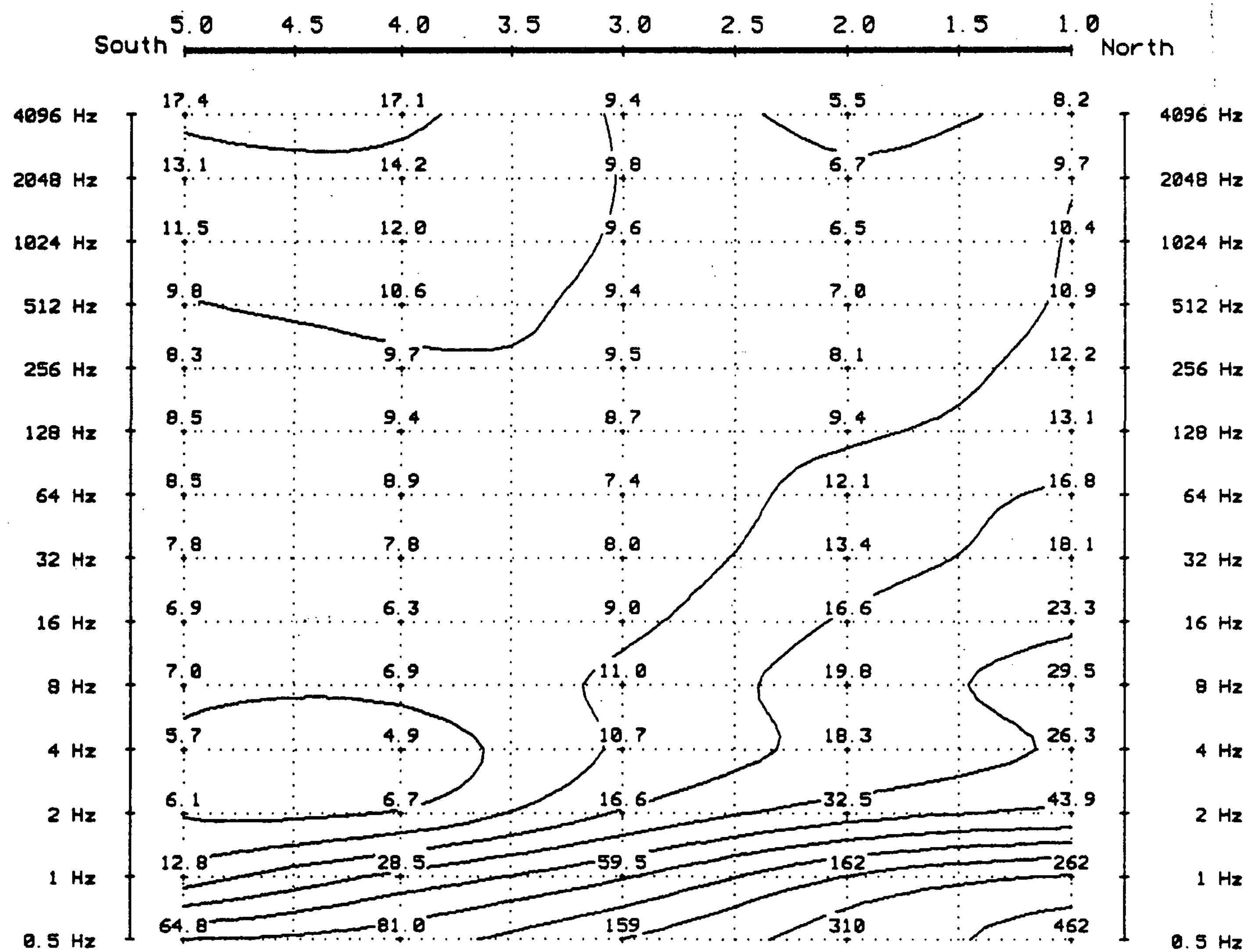
CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "18"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

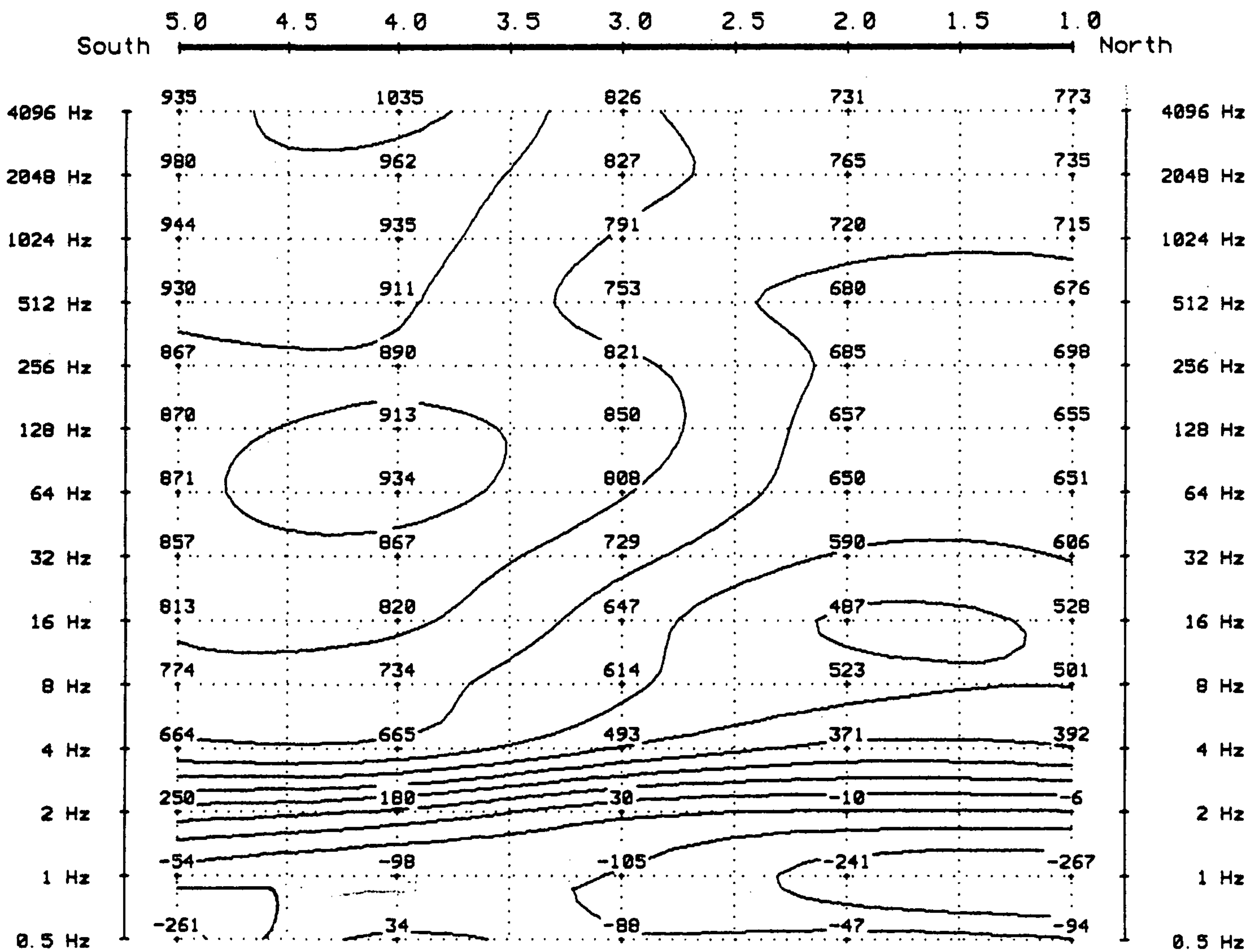
CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

values in milli-radians
<PDIFF

RECEIVER DATA
Length : 250. ft Line : North
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line "19"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 29 Sep 87

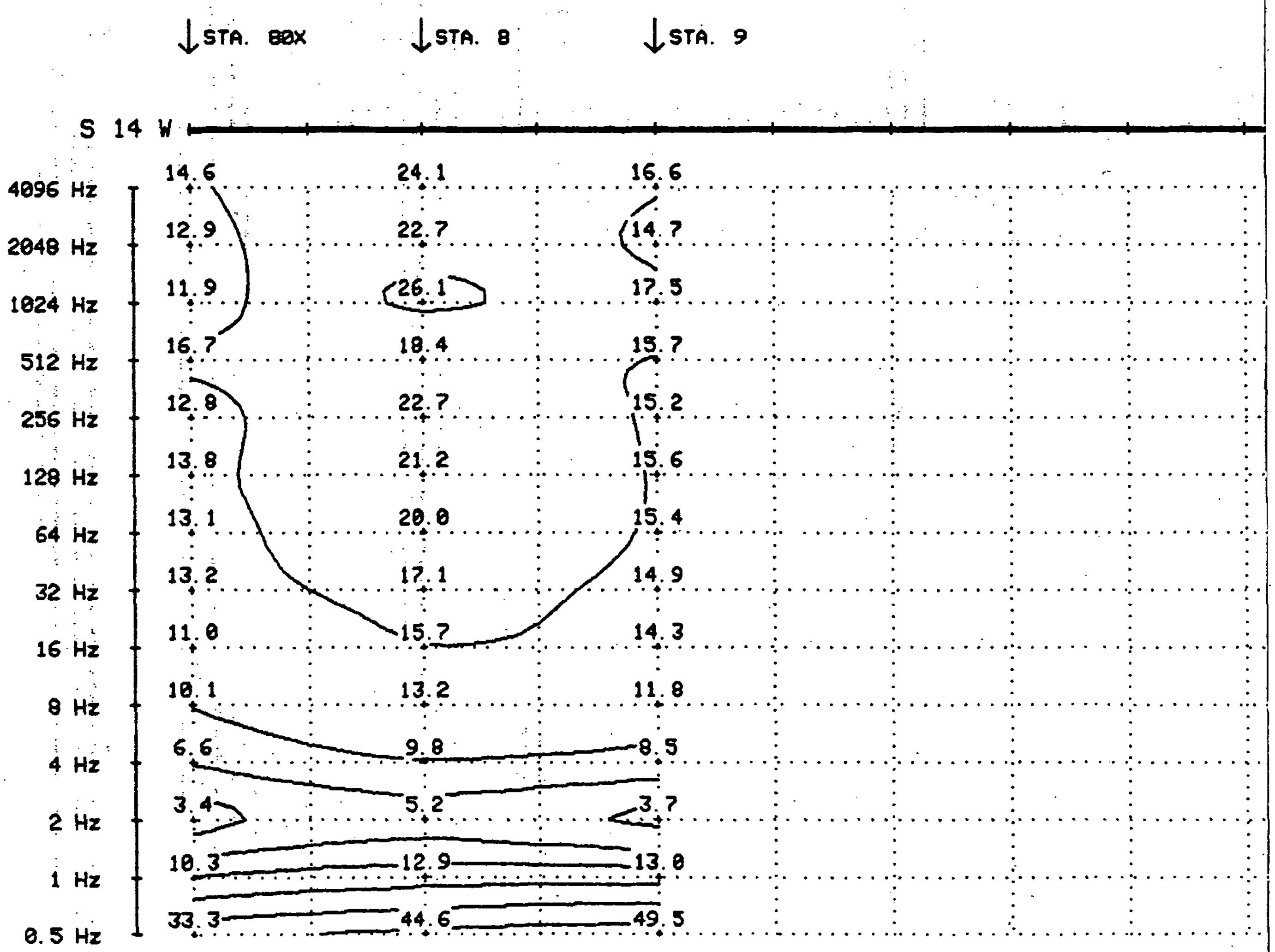
CSAMT SURVEY DATA
CAGNIARD RESISTIVIT

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 14 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTE
Length
Orient.
Distance:
Rx to Tx:



Line "19"
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

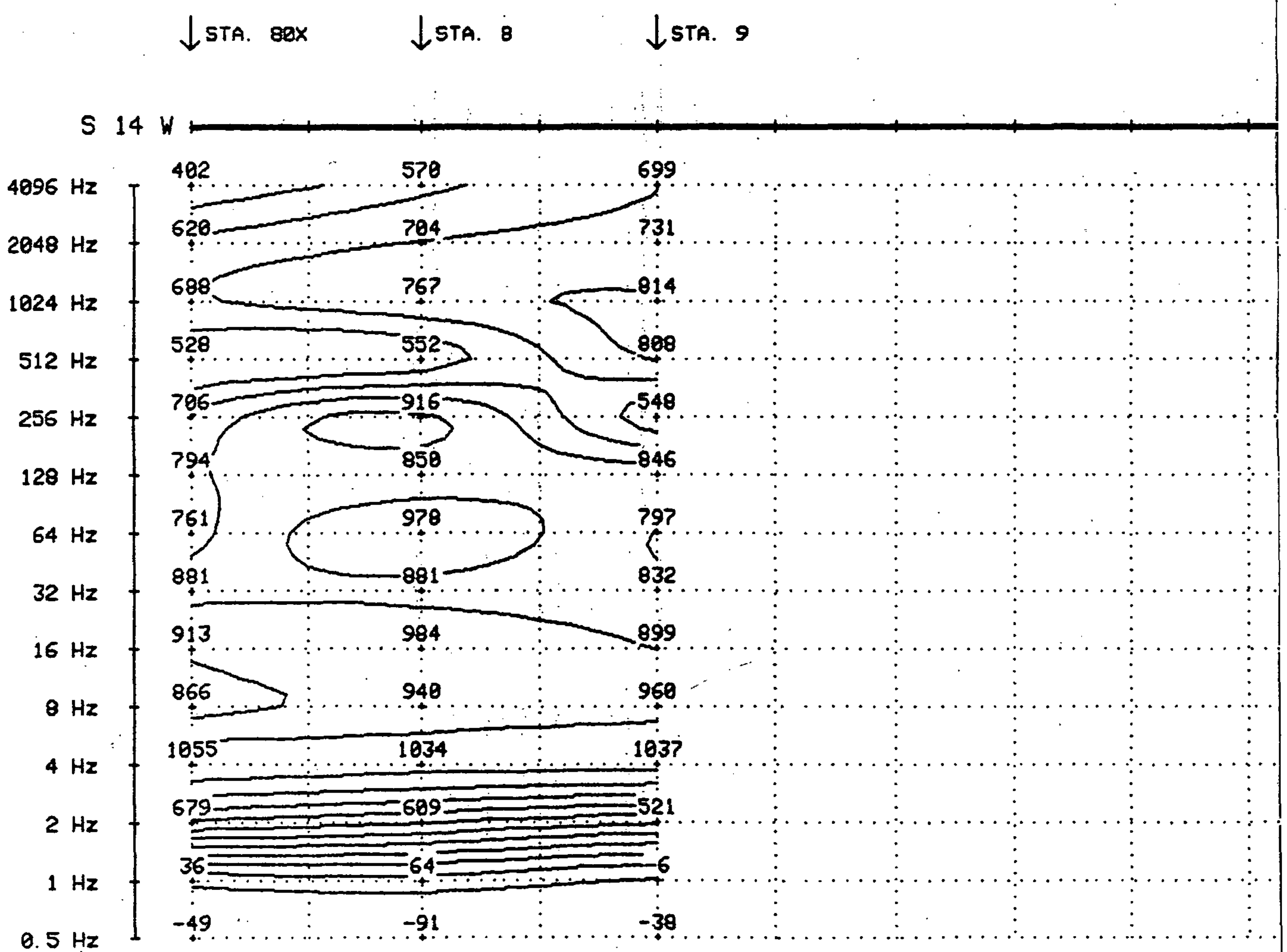
ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 29 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E -
values in milli-radians
<PDIFF

RECEIVER DATA
Length : 250. ft Line : N 14 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTE
Length :
Orient. :
Distance:
Rx to Tx:



Line S-1
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

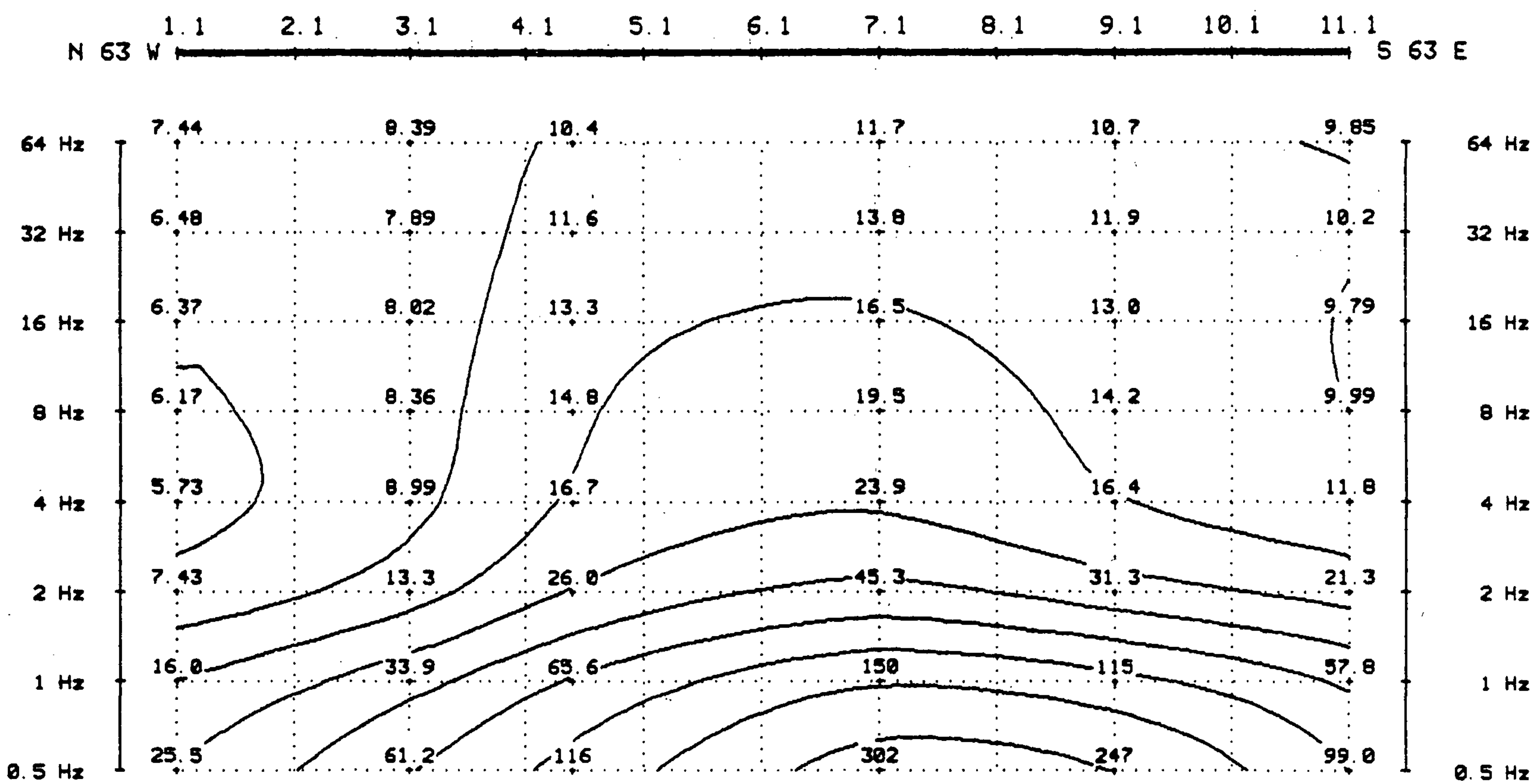
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 15 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: May 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line S-3
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 24 Sep 87

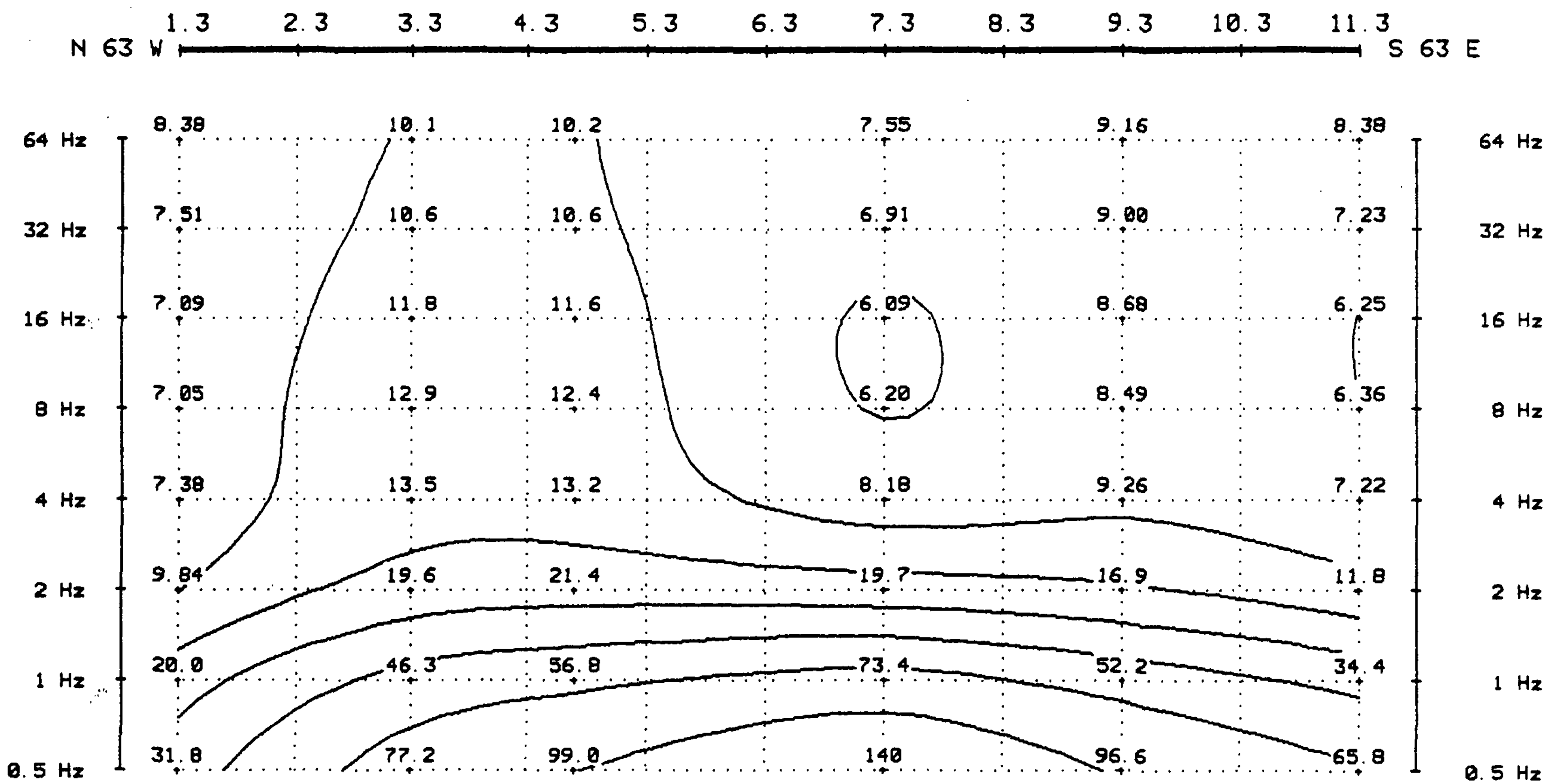
CSAMT SURVEY DATA
CORRECTED RESISTIVITY

RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line S-5
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 15 Sep 87

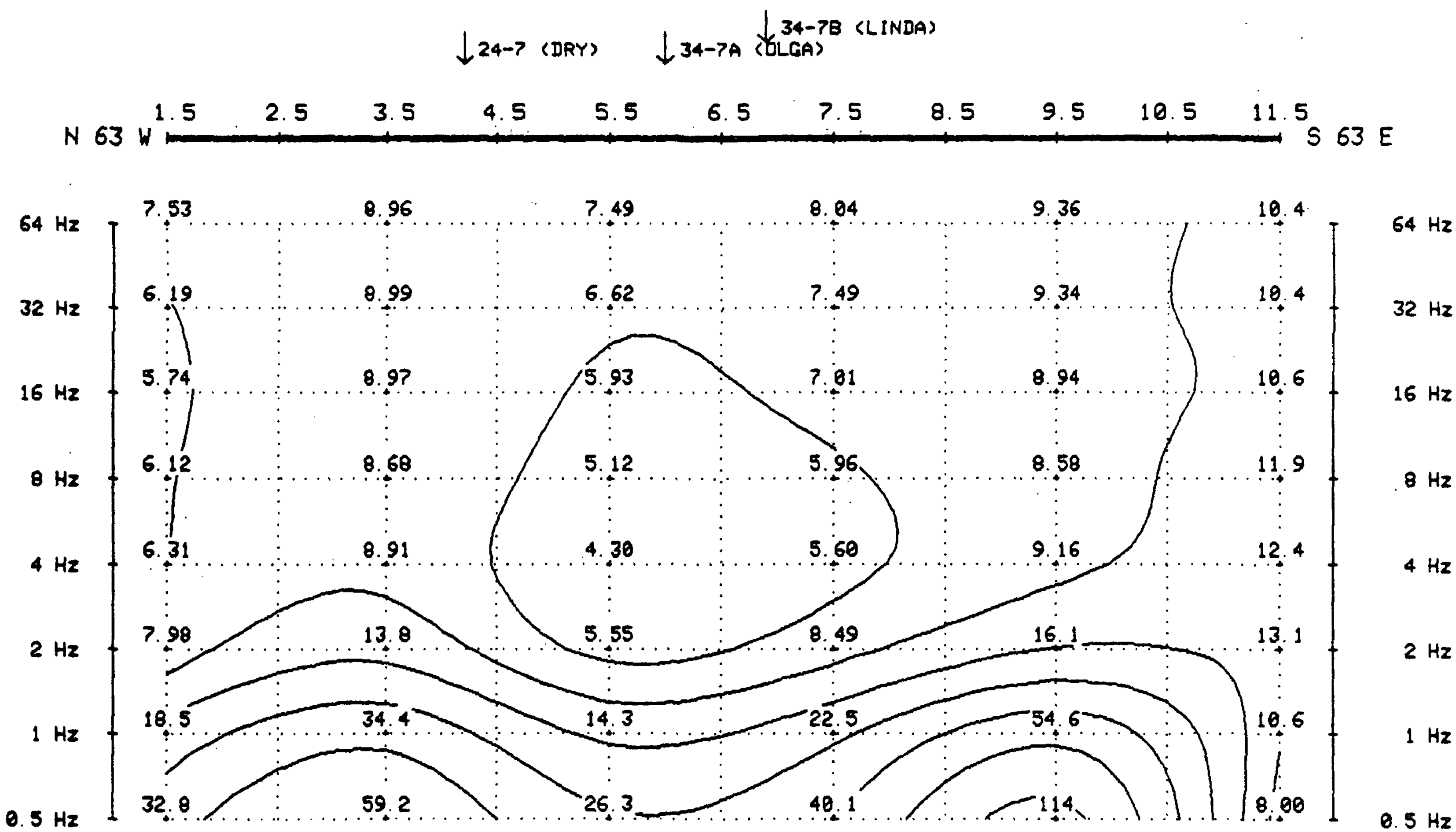
CSAMT SURVEY DATA
CORRECTED RESISTIVITY

RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: May 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line S-7
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

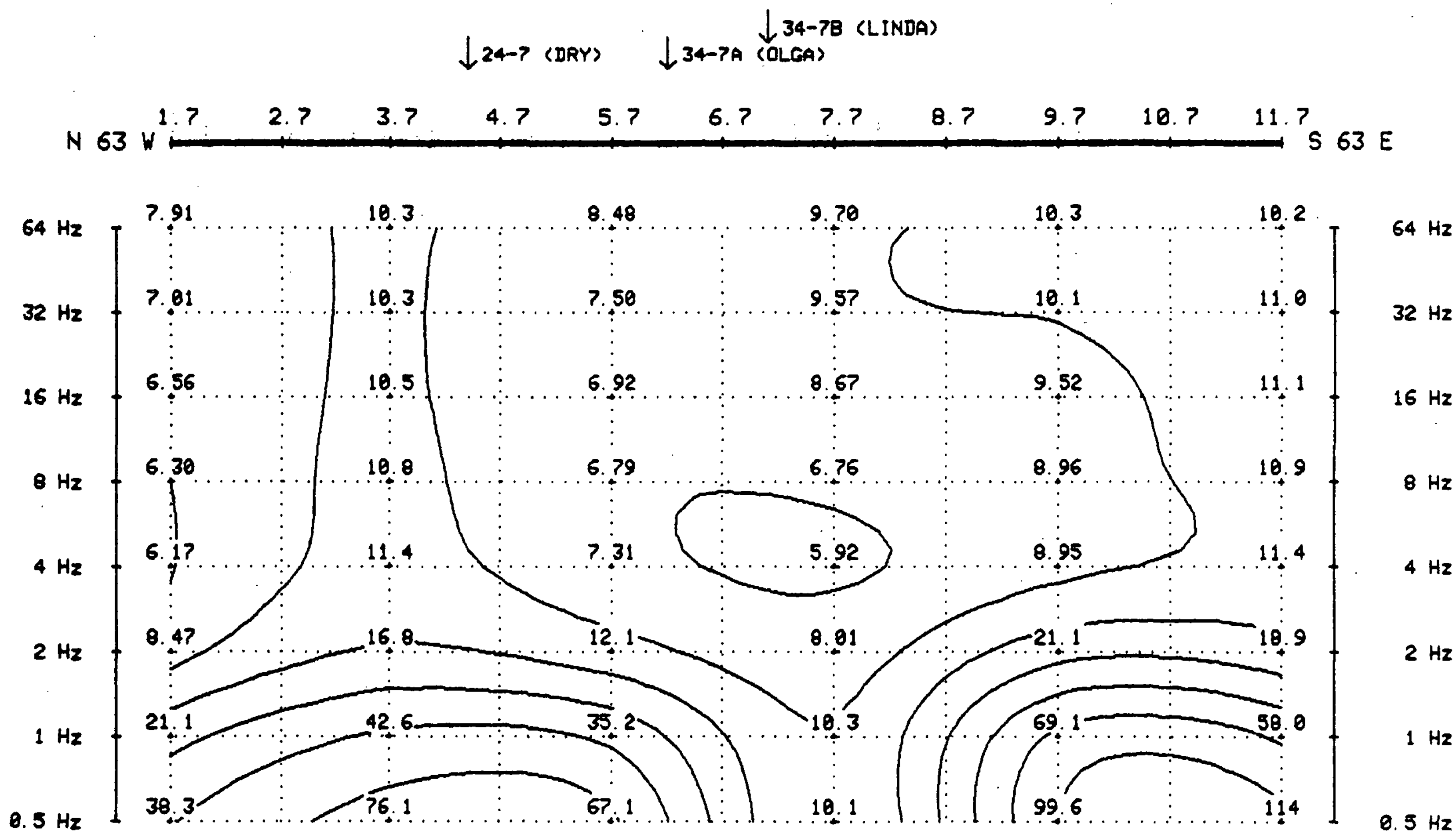
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 16 Sep 87

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: May 87

TRANSMITTER DATA
Length : 5280 ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



Line S-11
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 15 Sep 87

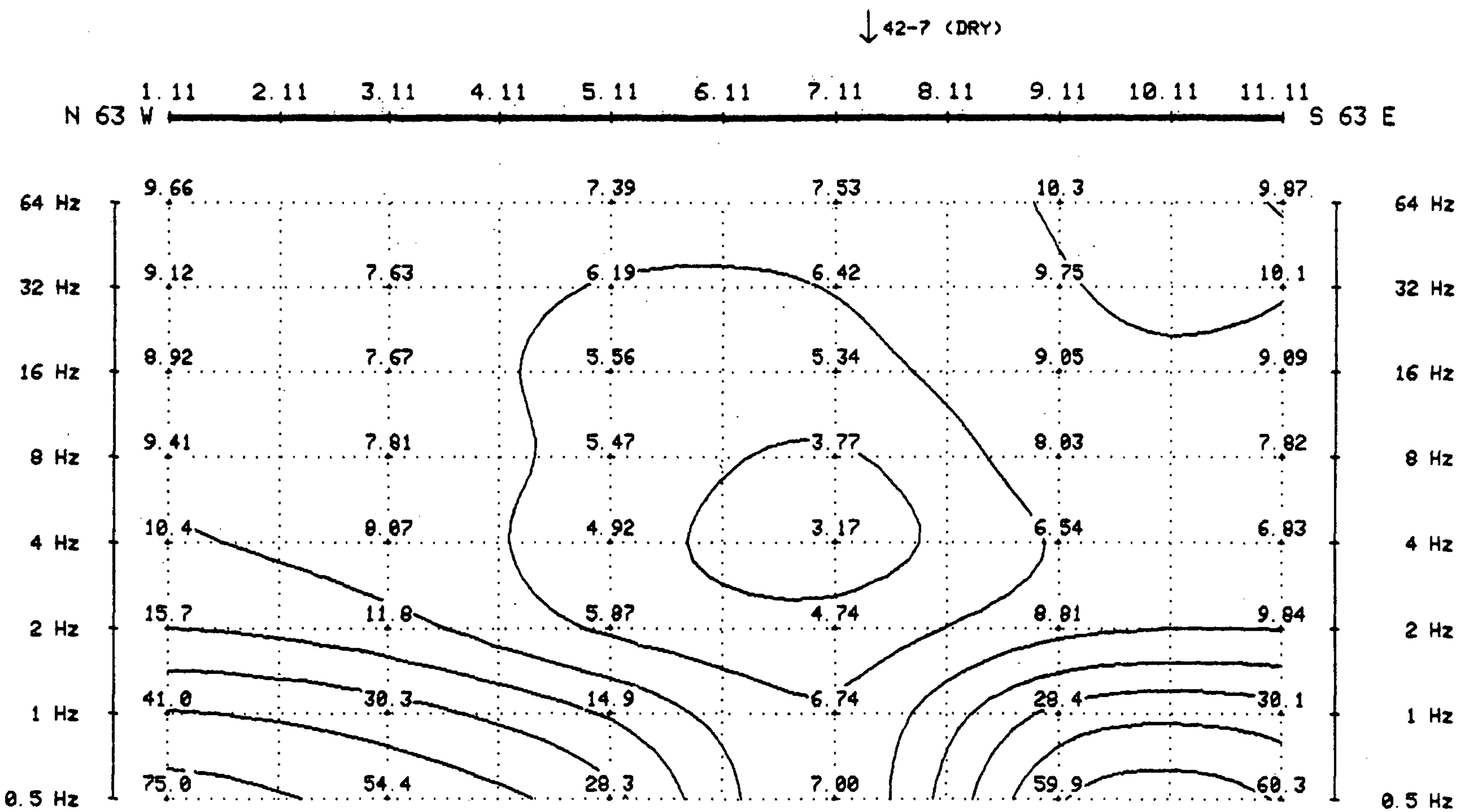
CSAMT SURVEY DATA
CORRECTED RESISTIVITY

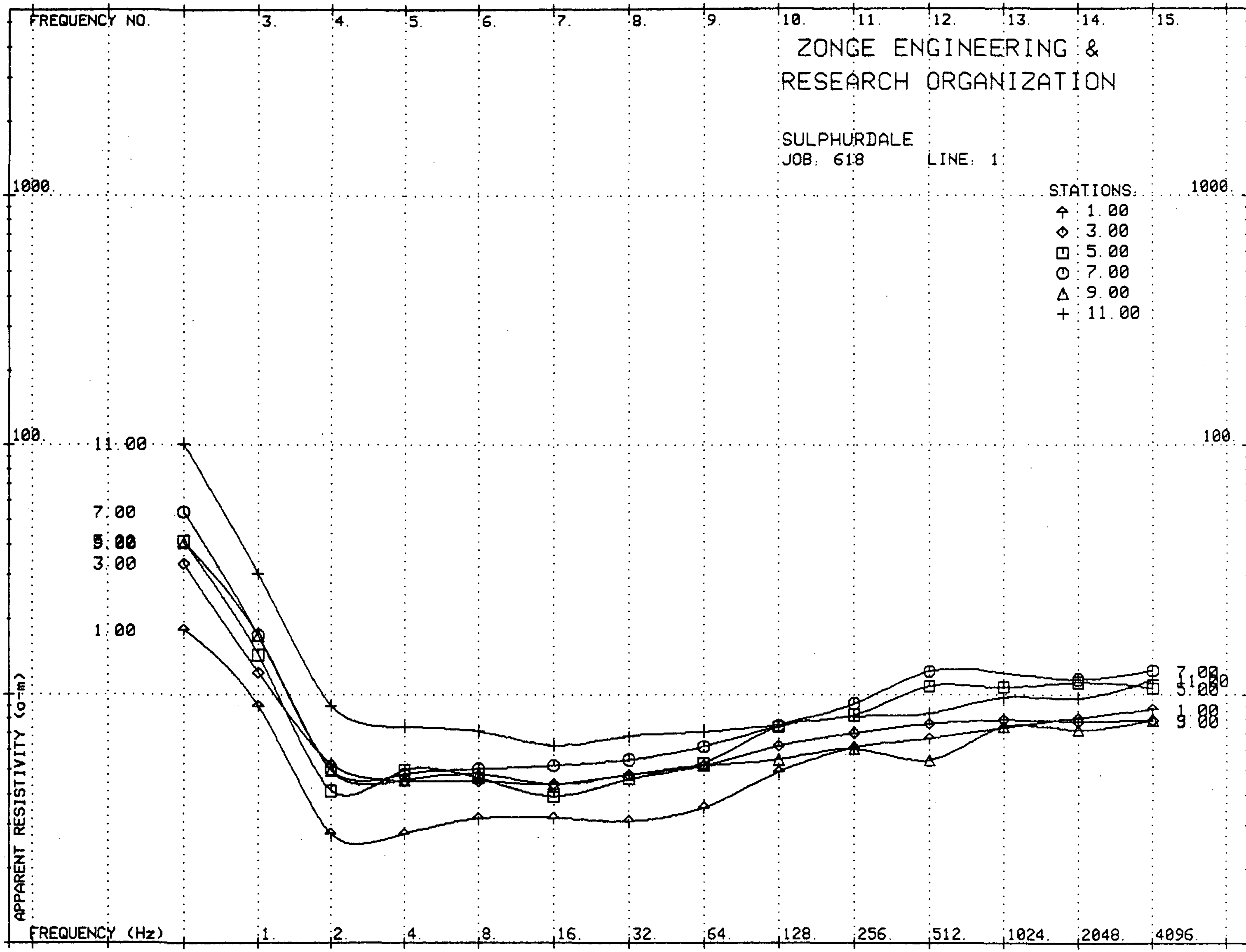
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

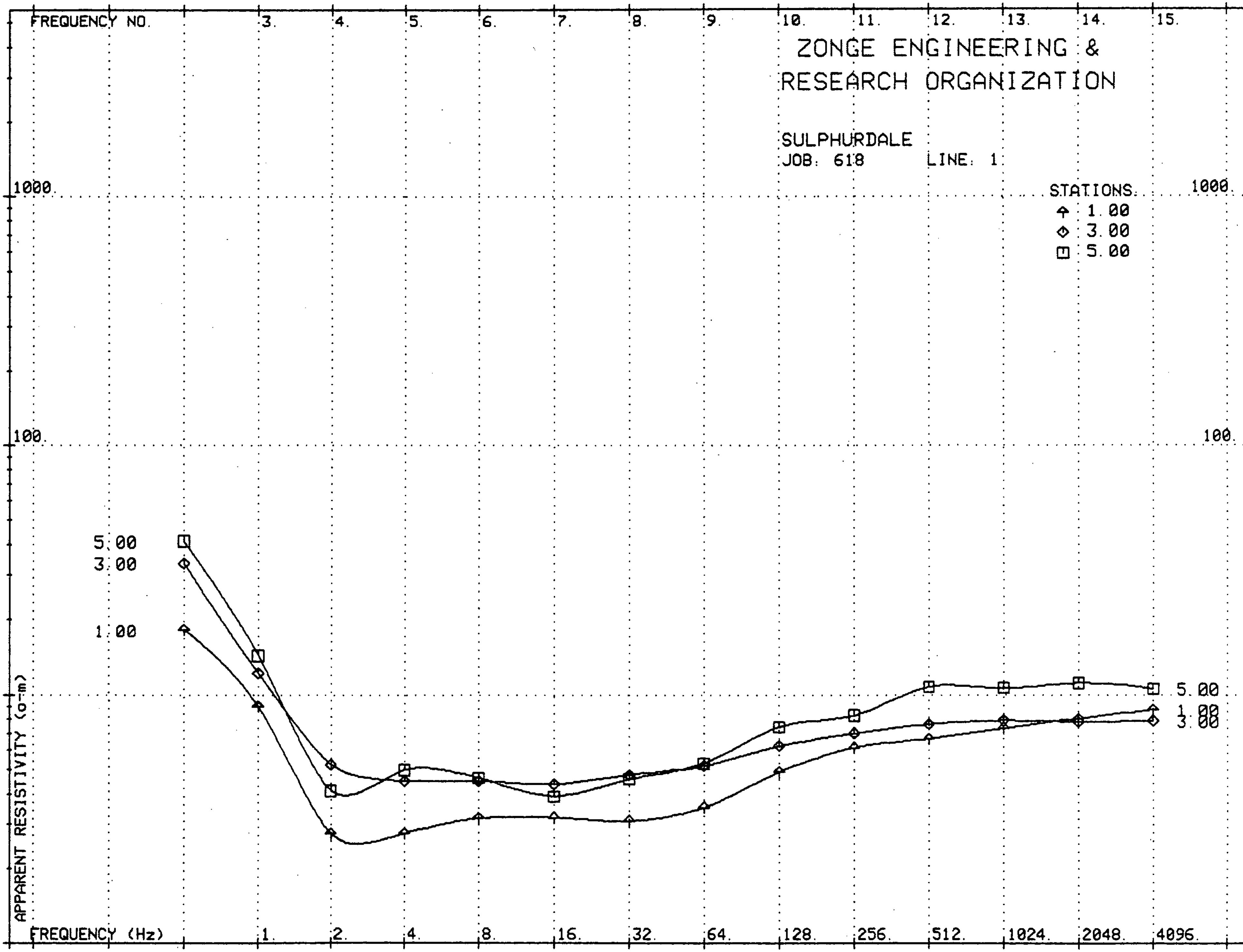
Surveyed: May 87

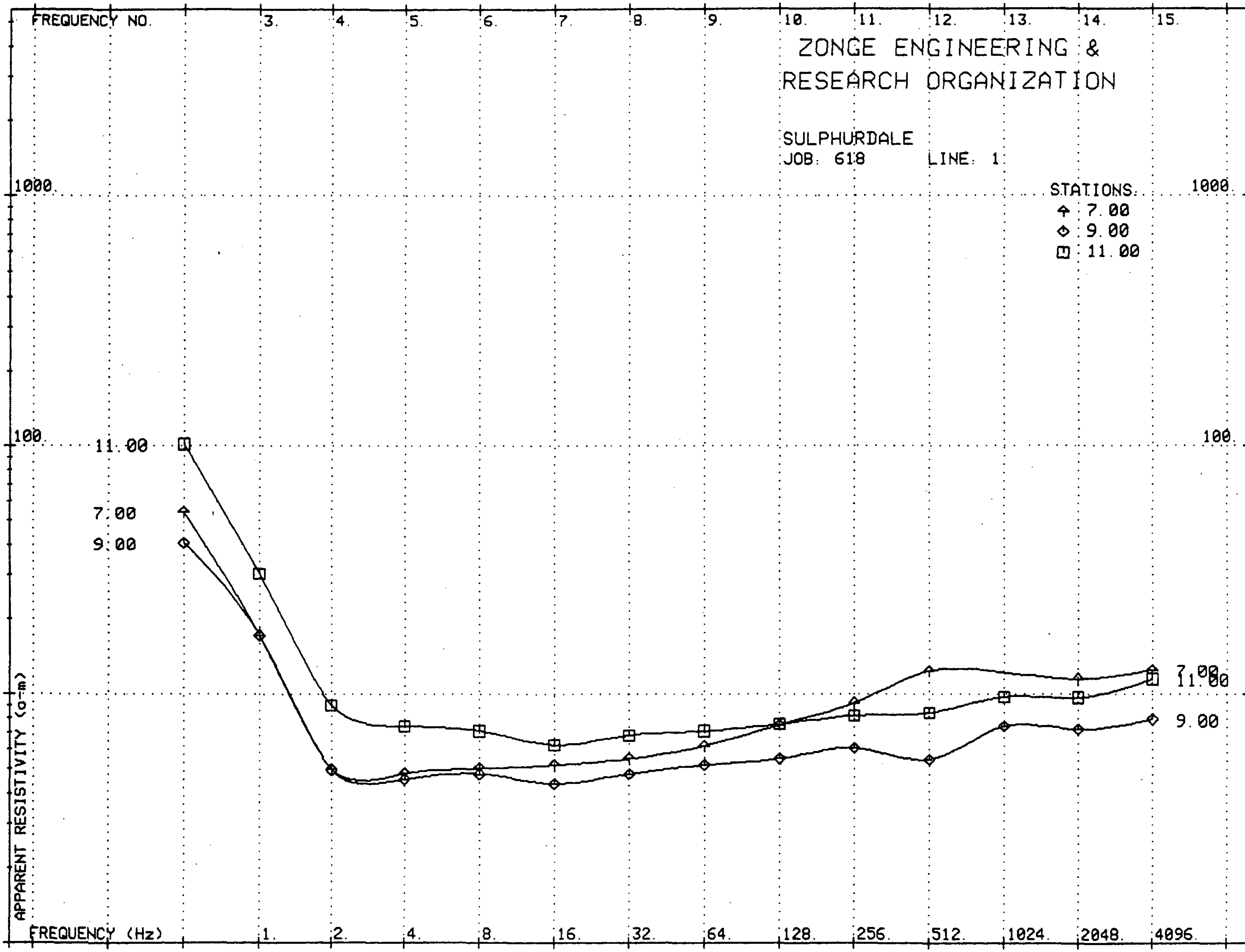
TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W



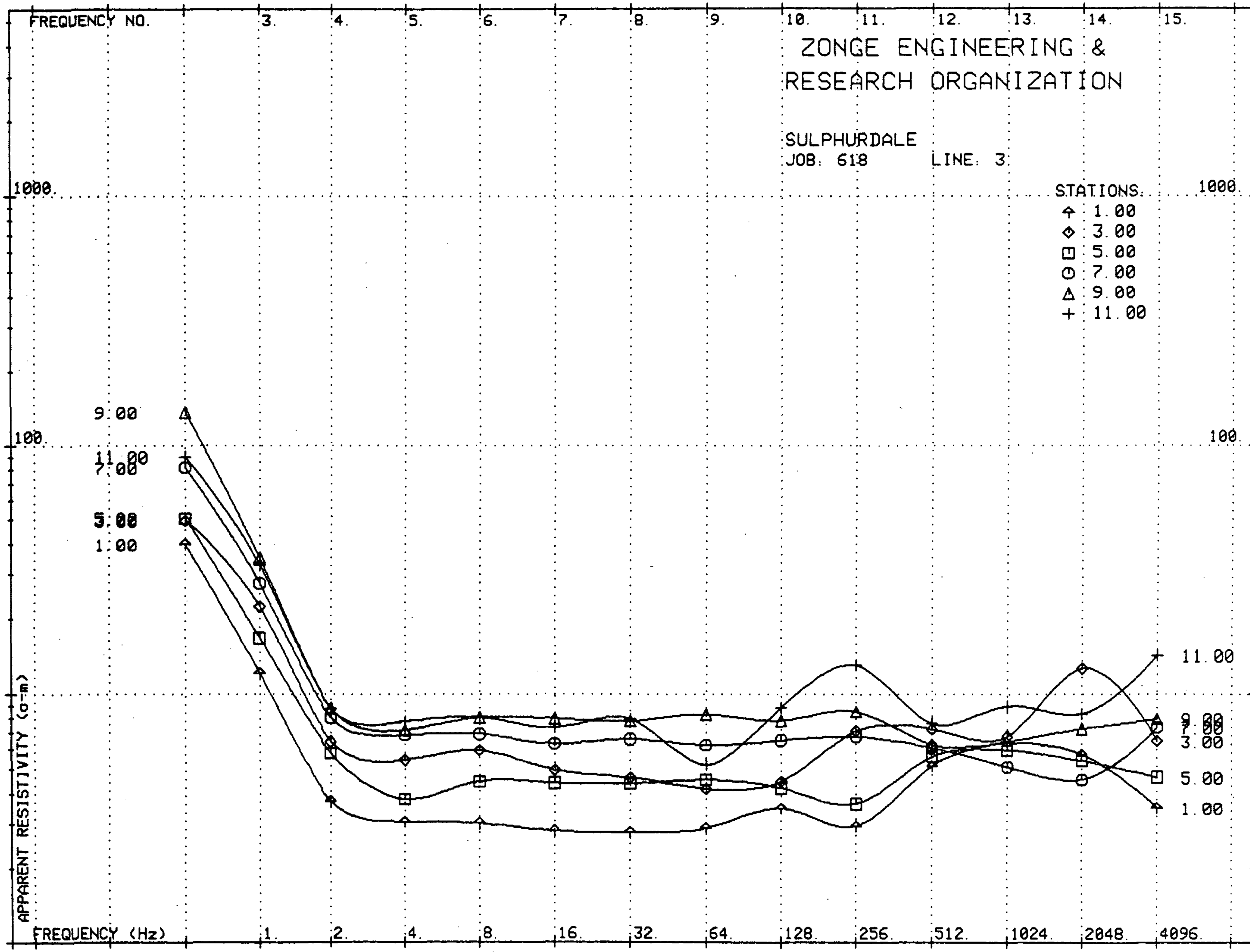


ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 1
STATIONS:
1.00
3.00
5.00
7.00
9.00
11.00
FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
1000.
100.
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
1. 2. 4. 8. 16. 32. 64. 128. 256. 512. 1024. 2048. 4096.
AMTPLT 1.31

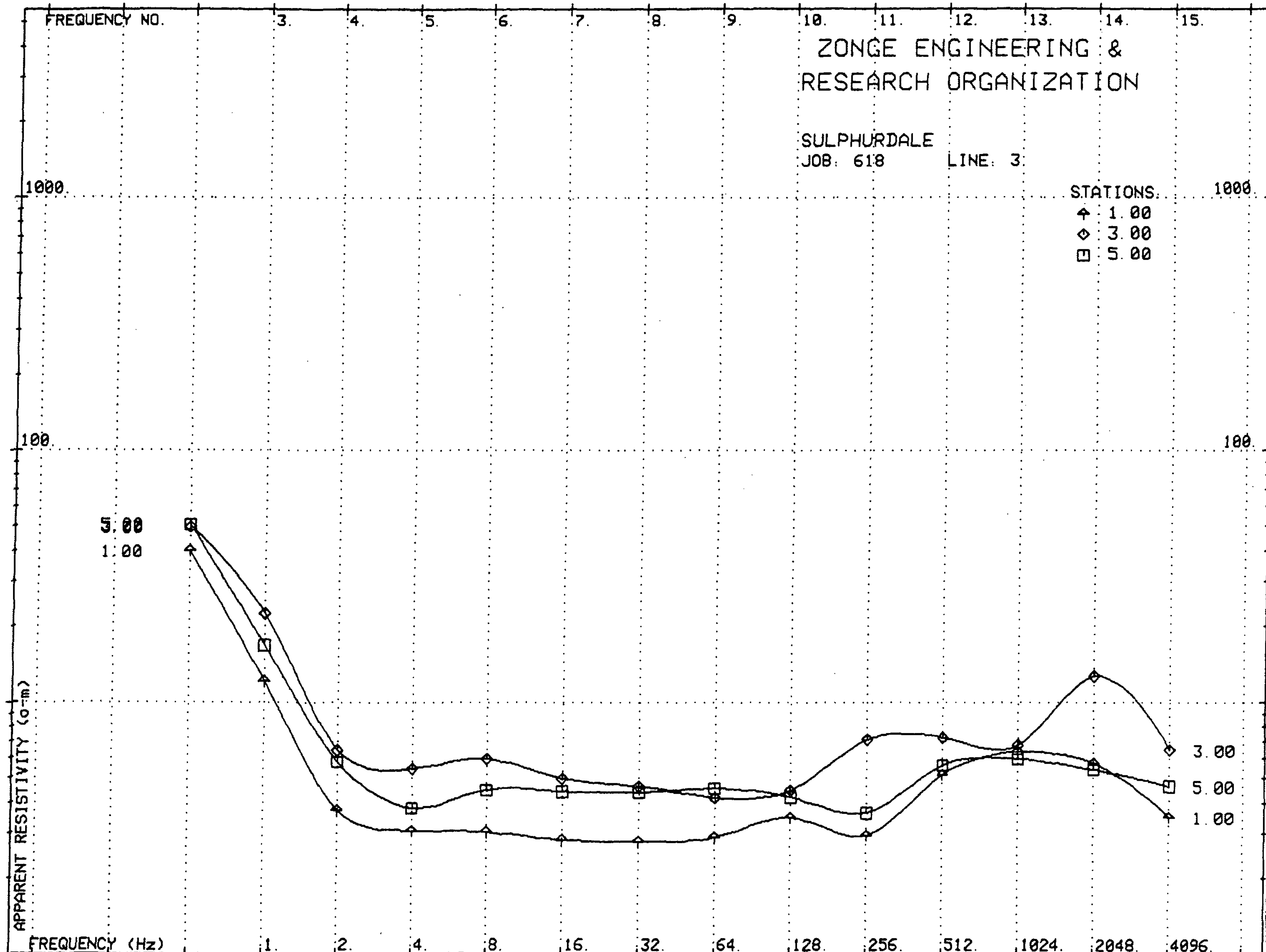

FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 1
STATIONS:
1.00
3.00
5.00
1000.
100.
5.00
3.00
1.00
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
1. 2. 4. 8. 16. 32. 64. 128. 256. 512. 1024. 2048. 4096.
AMTPLT 1.31



FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618
LINE: 1
STATIONS:
7.00
9.00
11.00
1000.
100.
11.00
7.00
9.00
7.00
11.00
9.00
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
1. 2. 4. 8. 16. 32. 64. 128. 256. 512. 1024. 2048. 4096.
AMTPLT 1.31



FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 3
STATIONS:
1.00
3.00
5.00
7.00
9.00
11.00
1000.
100.
9.00
11.00
7.00
5.00
3.00
1.00
APPARENT RESISTIVITY (Ω-m)
FREQUENCY (Hz)
1. 2. 4. 8. 16. 32. 64. 128. 256. 512. 1024. 2048. 4096.
AMTPLT 1.31


FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 3
STATIONS:
1.00
3.00
5.00
1000.
100.
5.00
1.00
3.00
5.00
1.00
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FREQUENCY (Hz)
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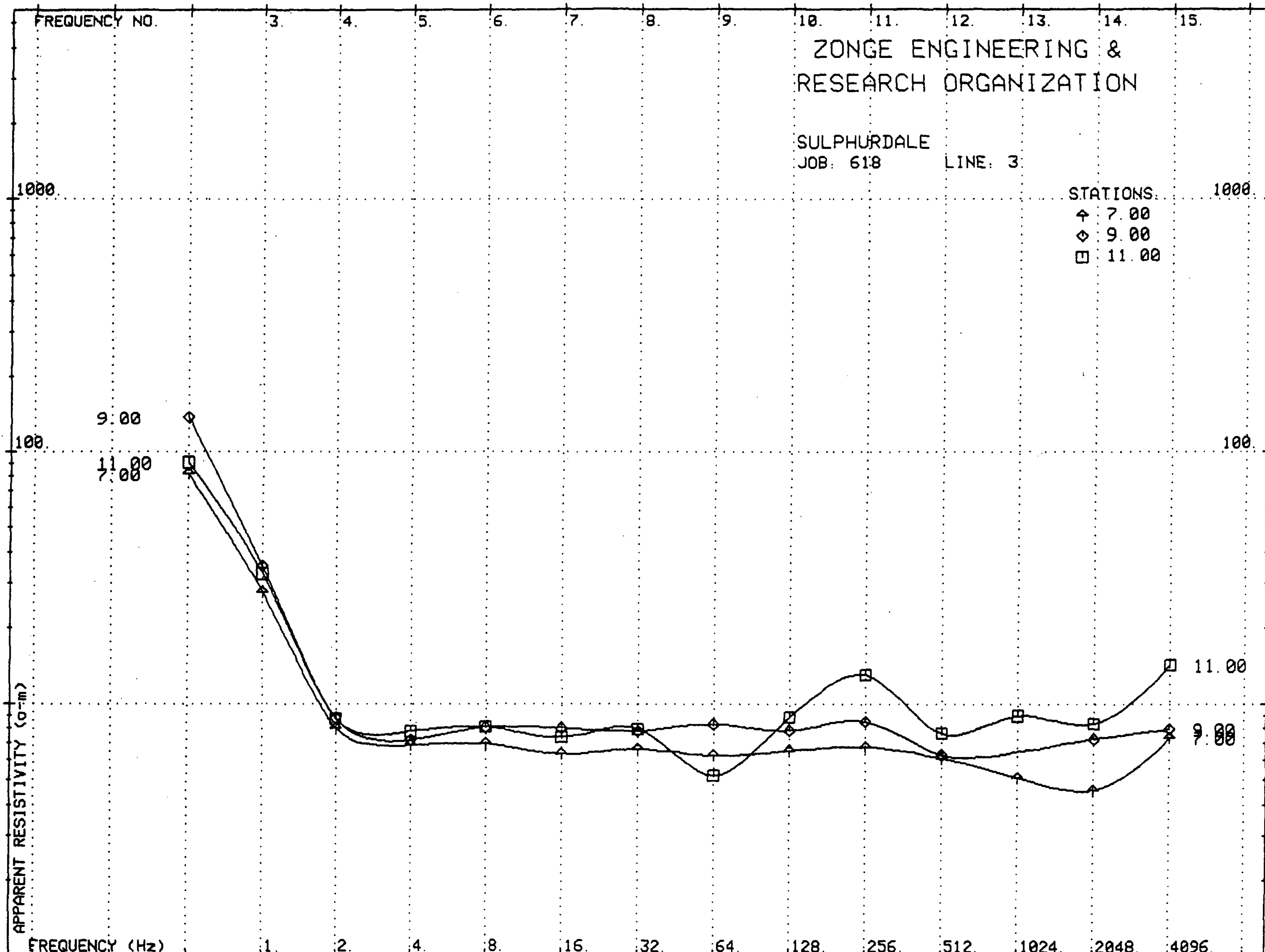
AMTPLT 1.31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RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 3
STATIONS:
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9.00
11.00
FREQUENCY NO.
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9.00
11.00
7.00
11.00
9.00
7.00
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FREQUENCY (Hz)
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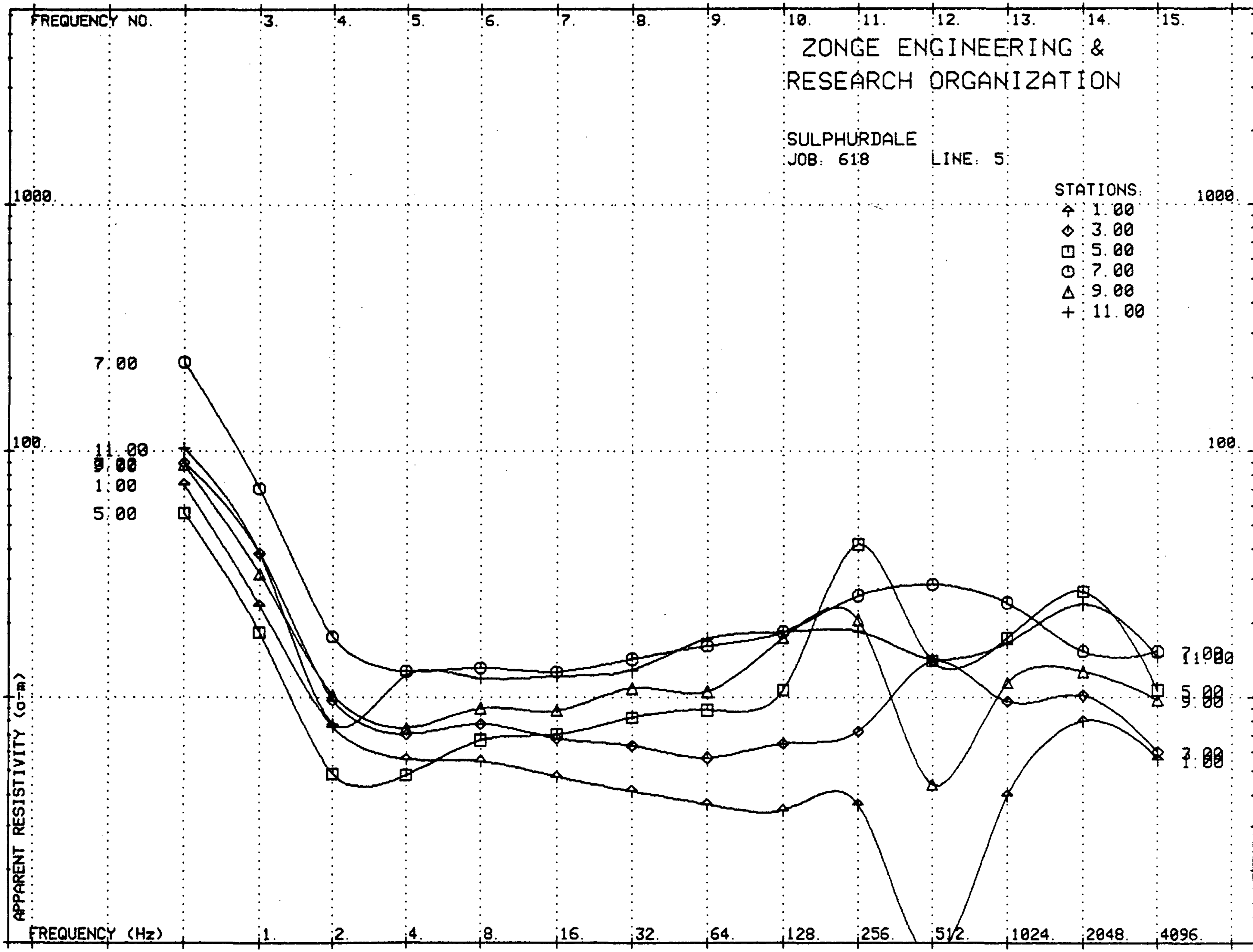
AMTPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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1.00
5.00
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FREQUENCY (Hz)
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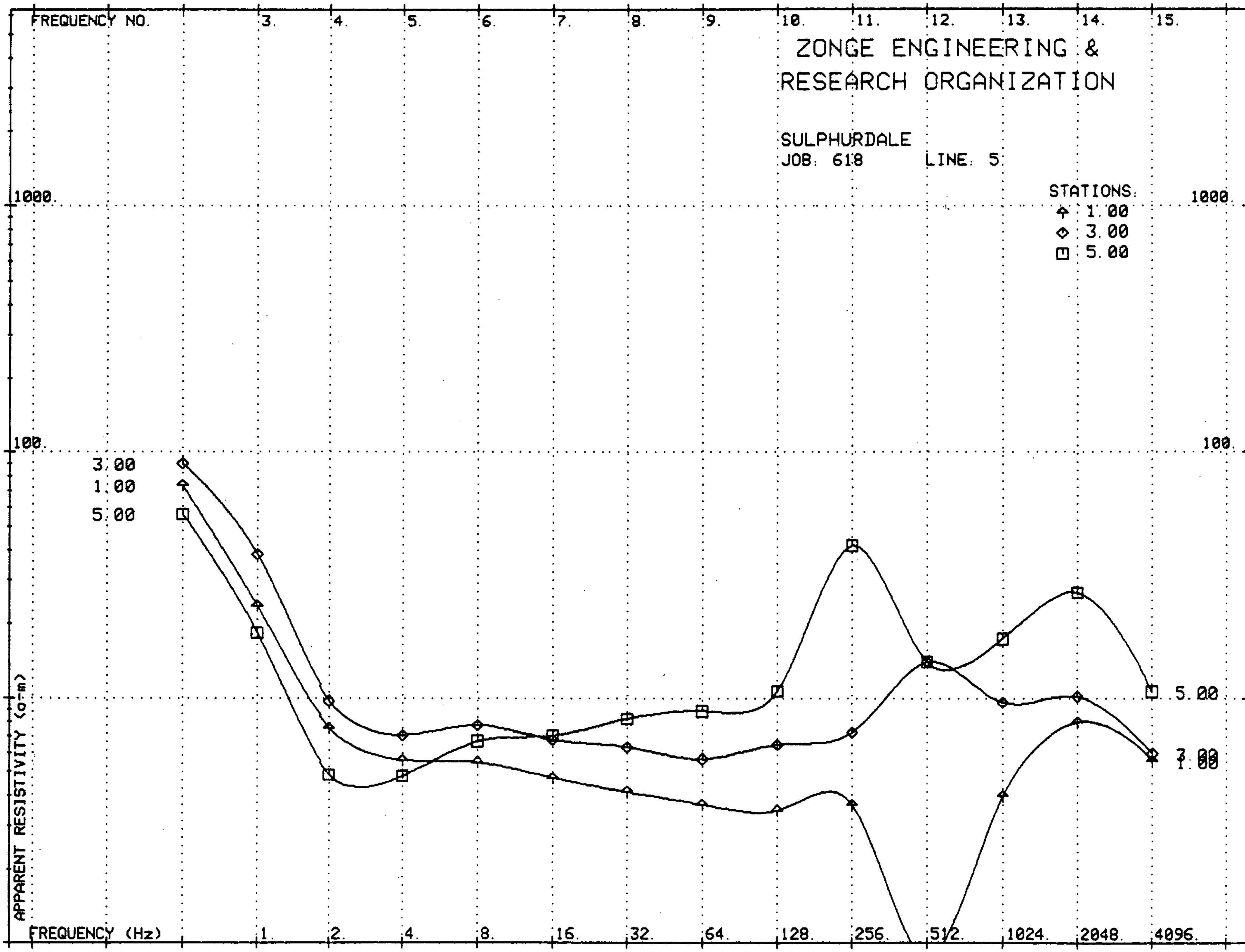
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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FREQUENCY (Hz)
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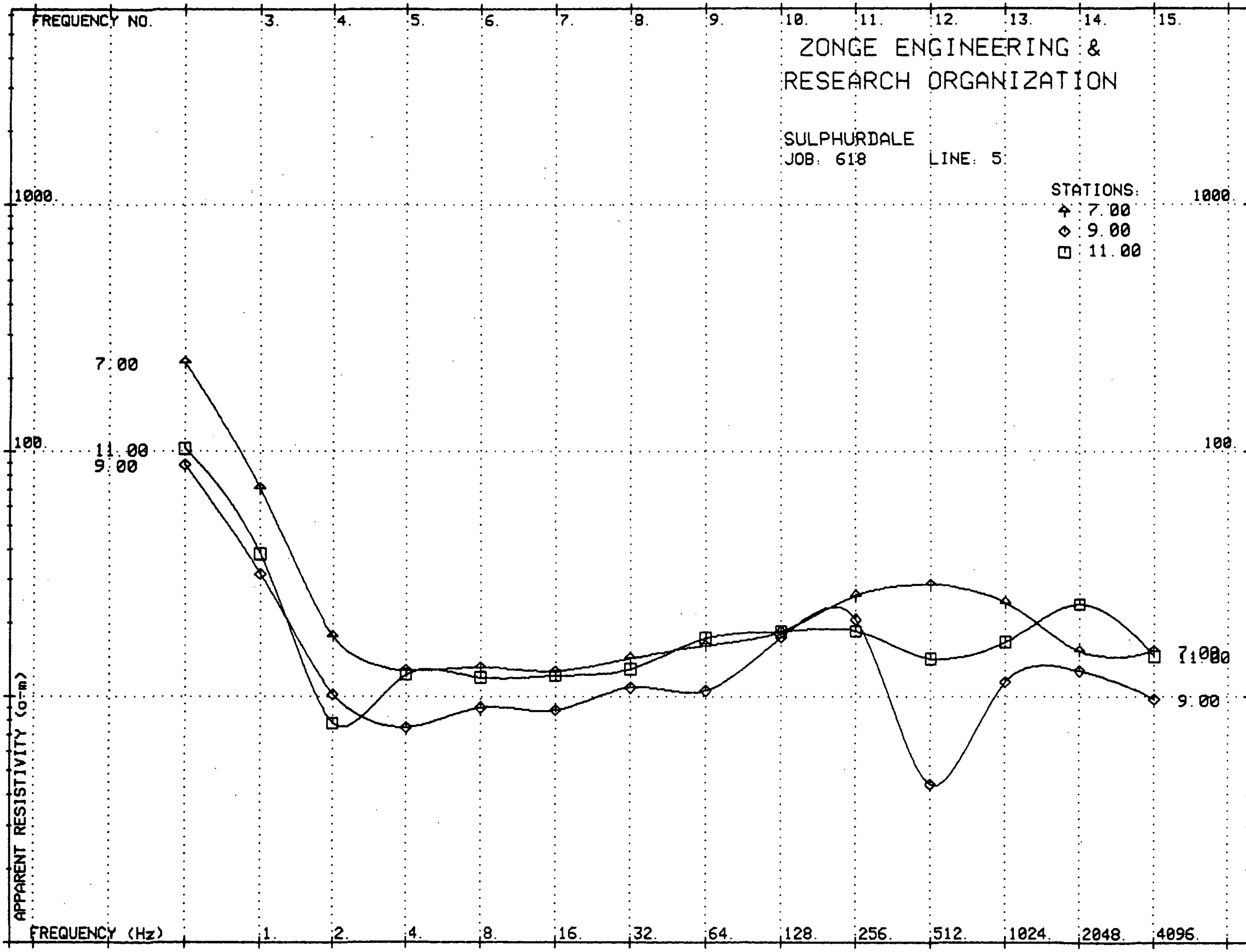

FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 5
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9.00
APPARENT RESISTIVITY (Ω-m)
FREQUENCY (Hz)
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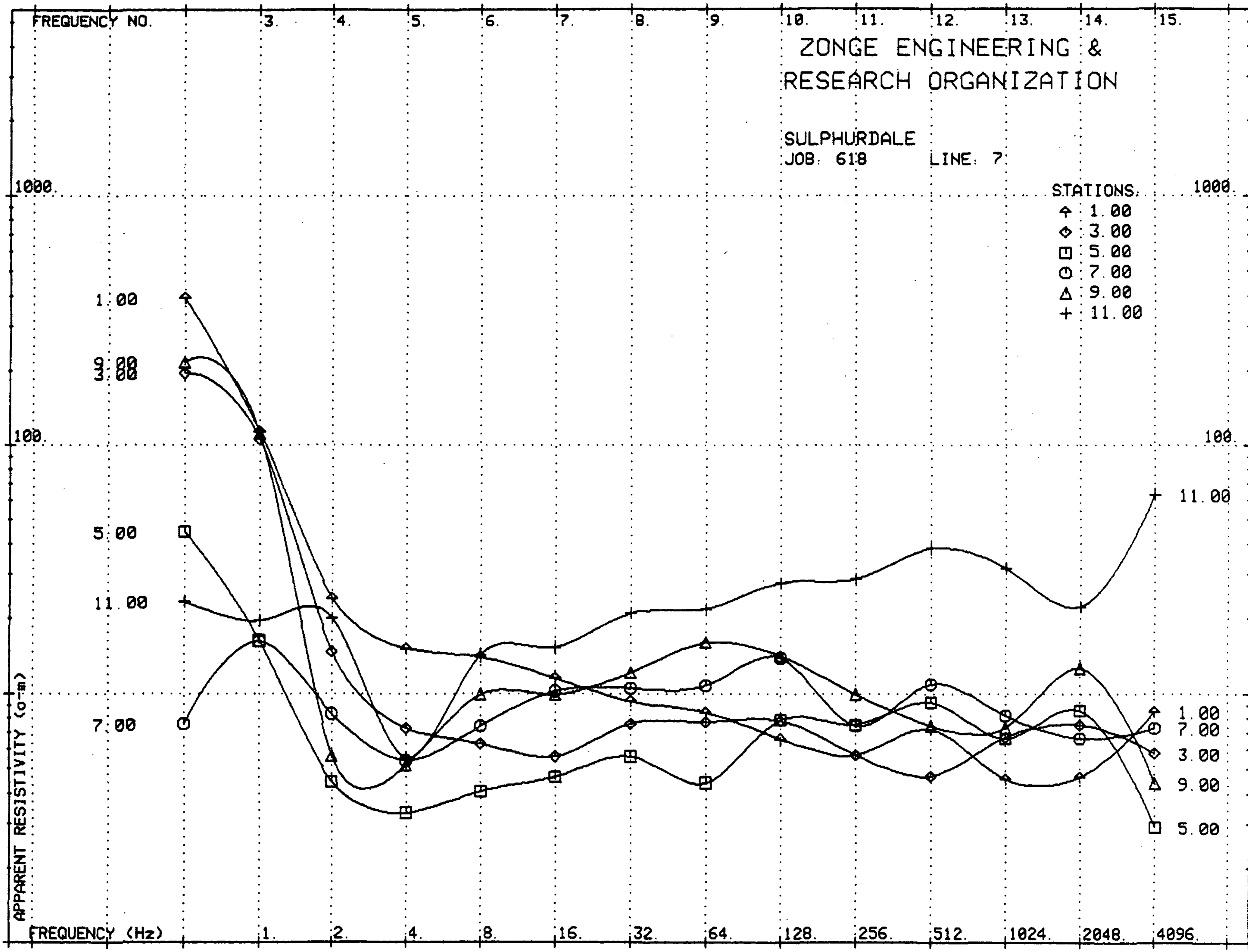
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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STATIONS.
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FREQUENCY (Hz)
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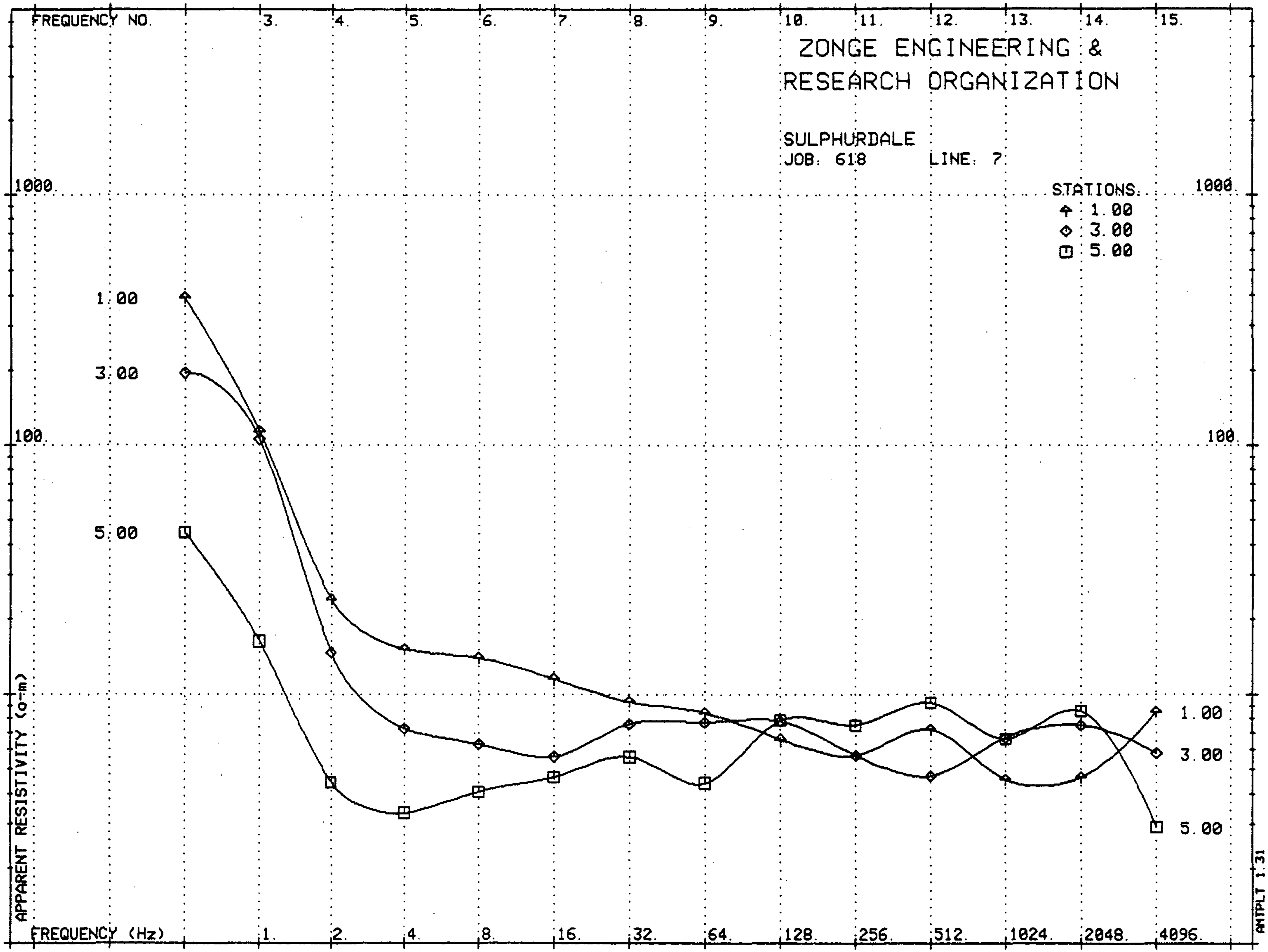

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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 7
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3.00
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FREQUENCY (Hz)
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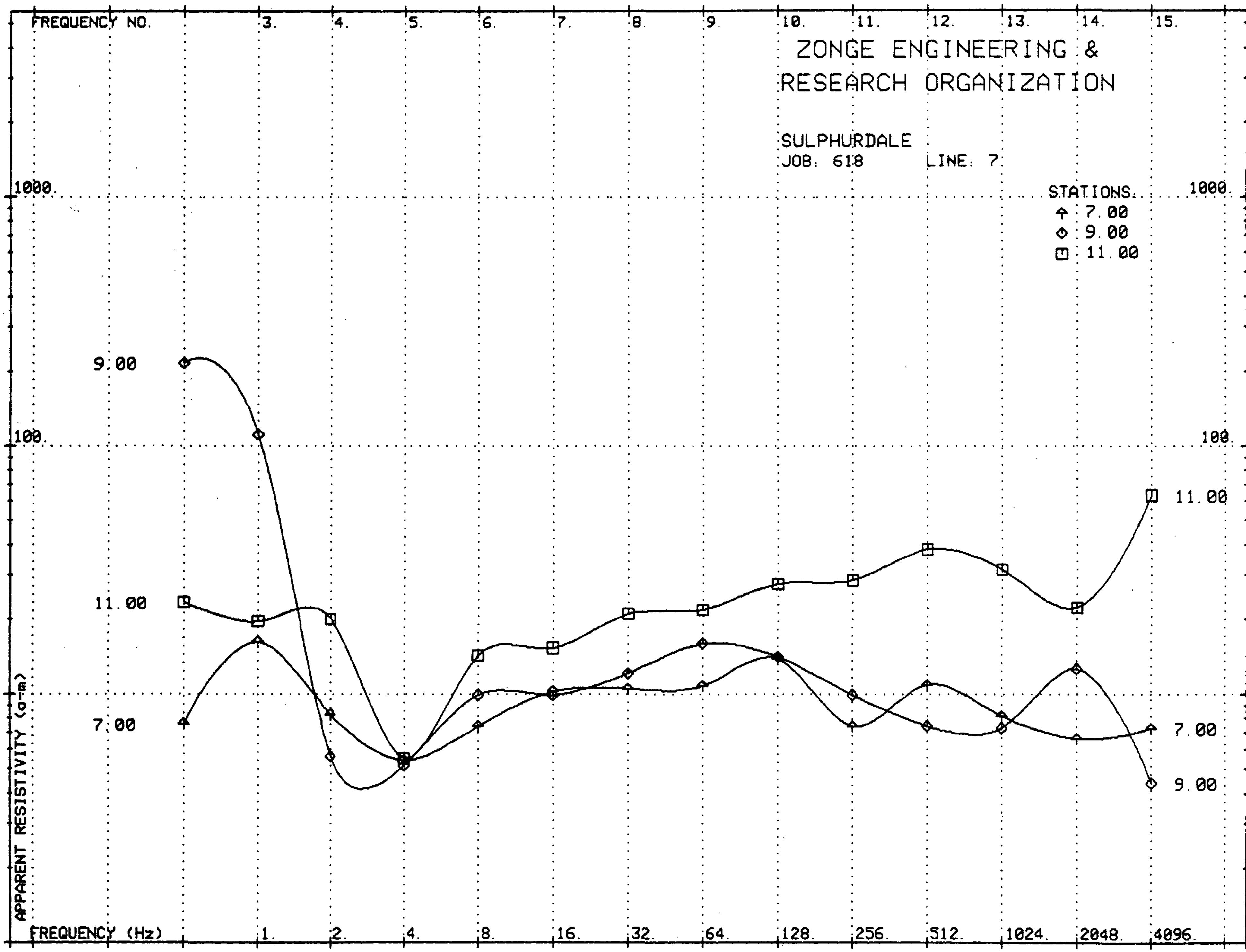

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RESEARCH ORGANIZATION
SULPHURDALE
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STATIONS:
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FREQUENCY NO.
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FREQUENCY (Hz)
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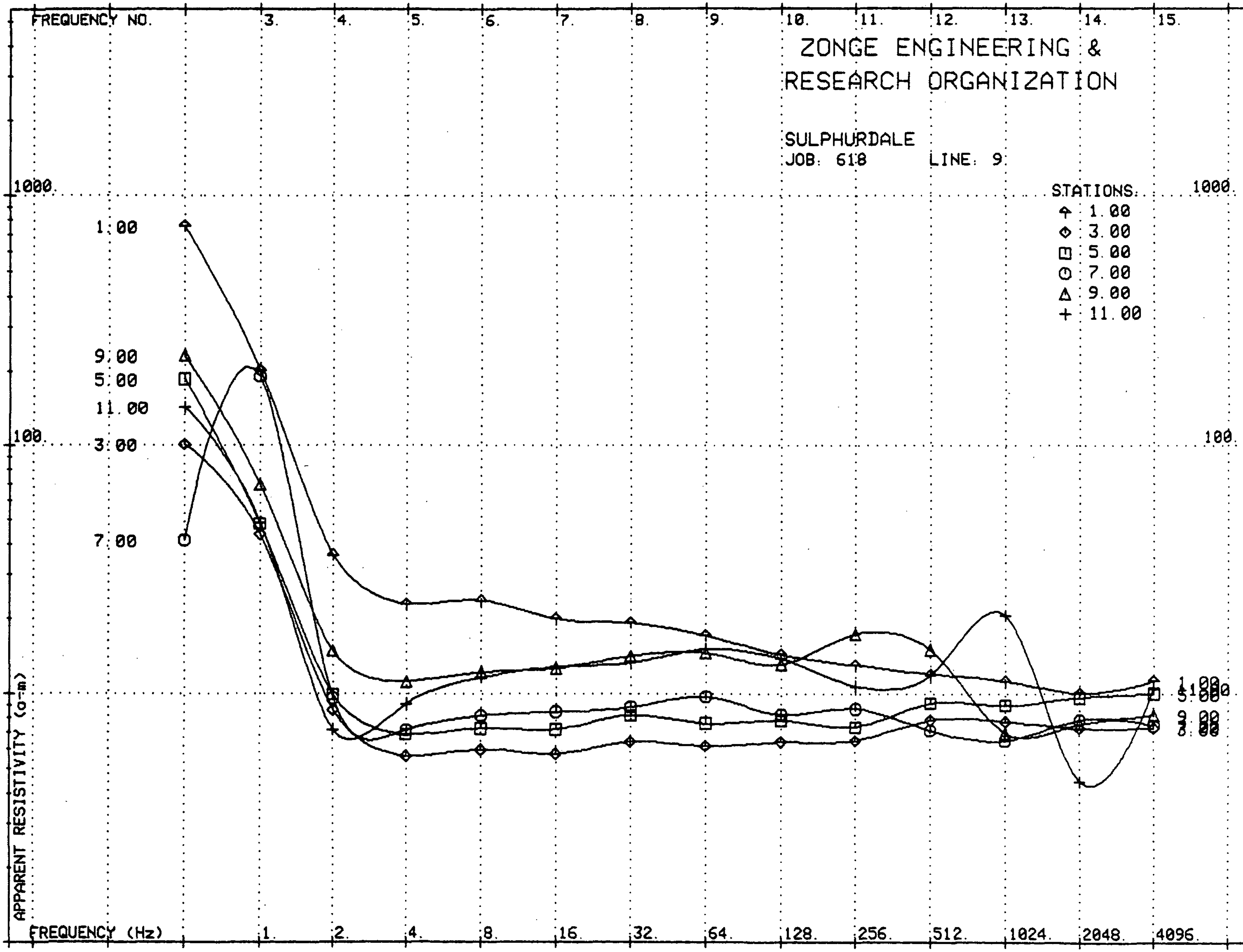
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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FREQUENCY (Hz)
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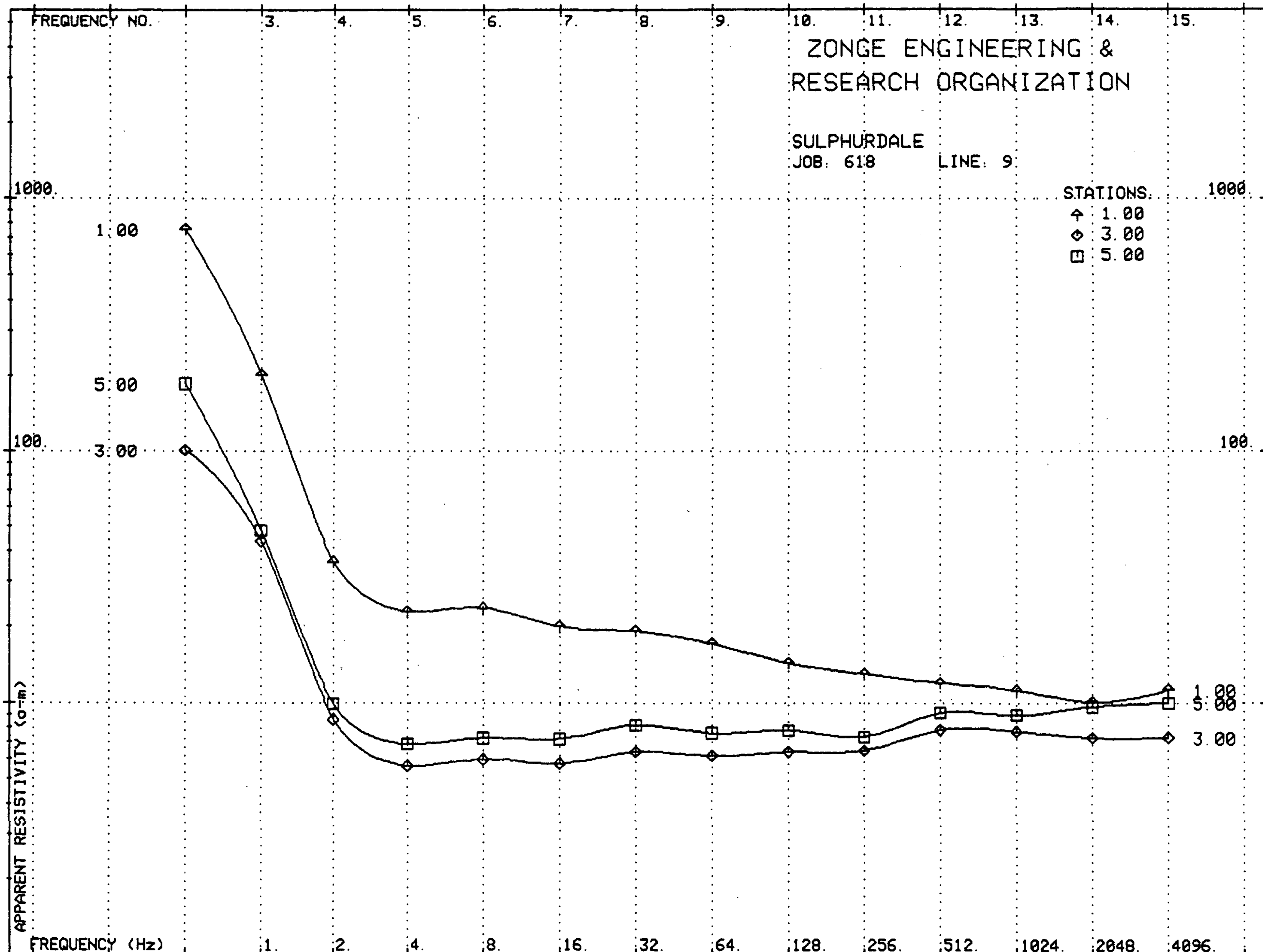
ANTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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STATIONS.
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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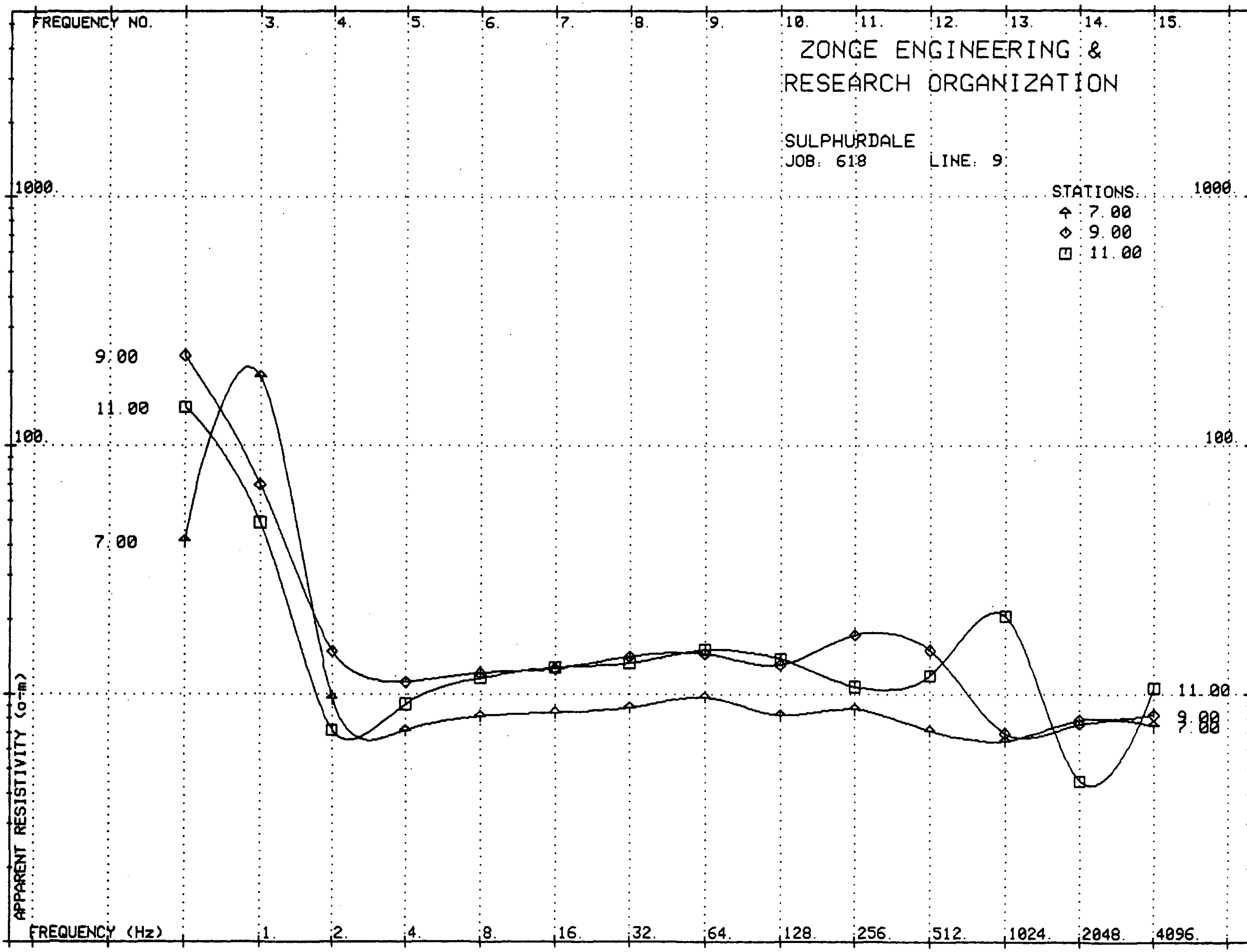

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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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FREQUENCY (Hz)
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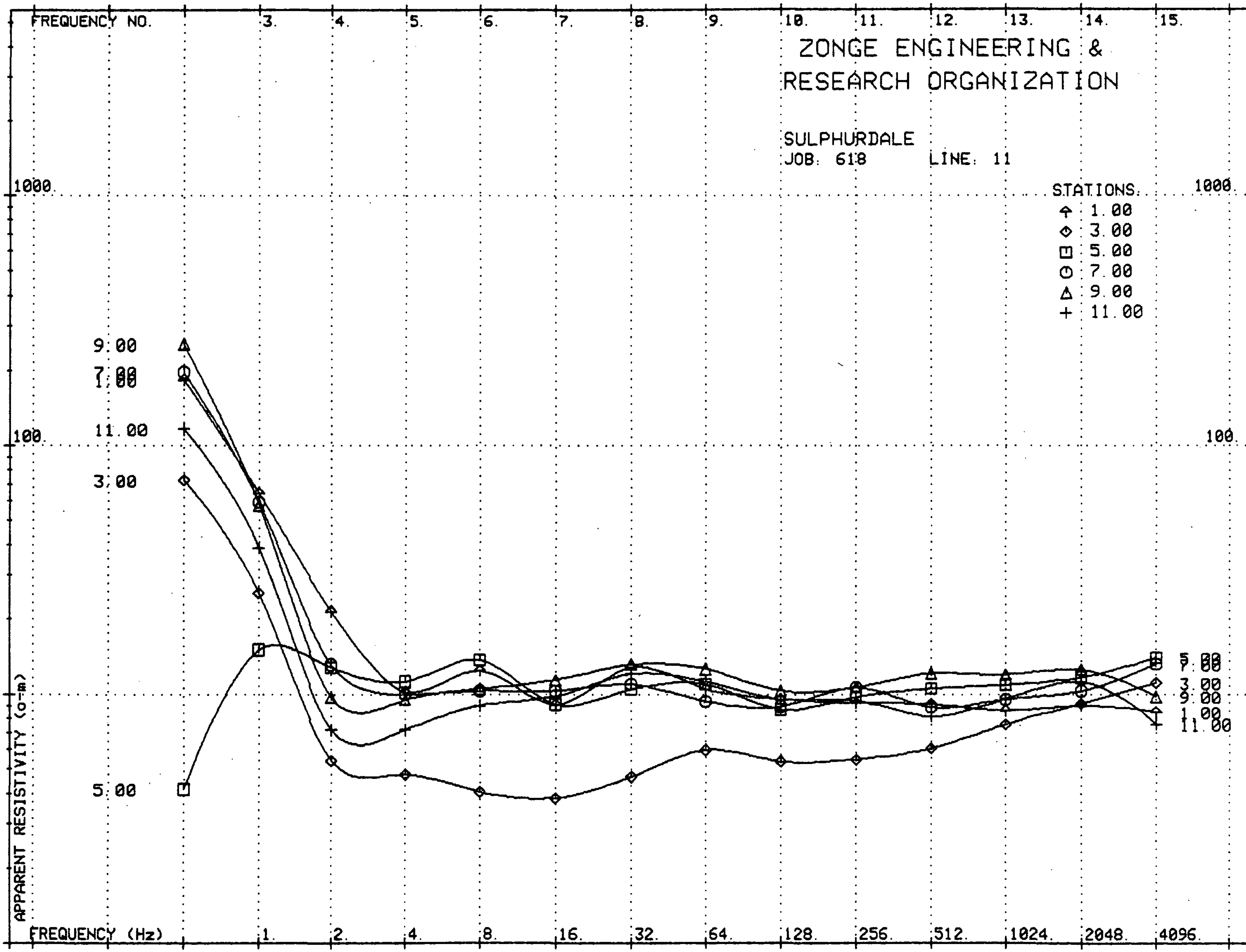
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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JOB: 618 LINE: 11
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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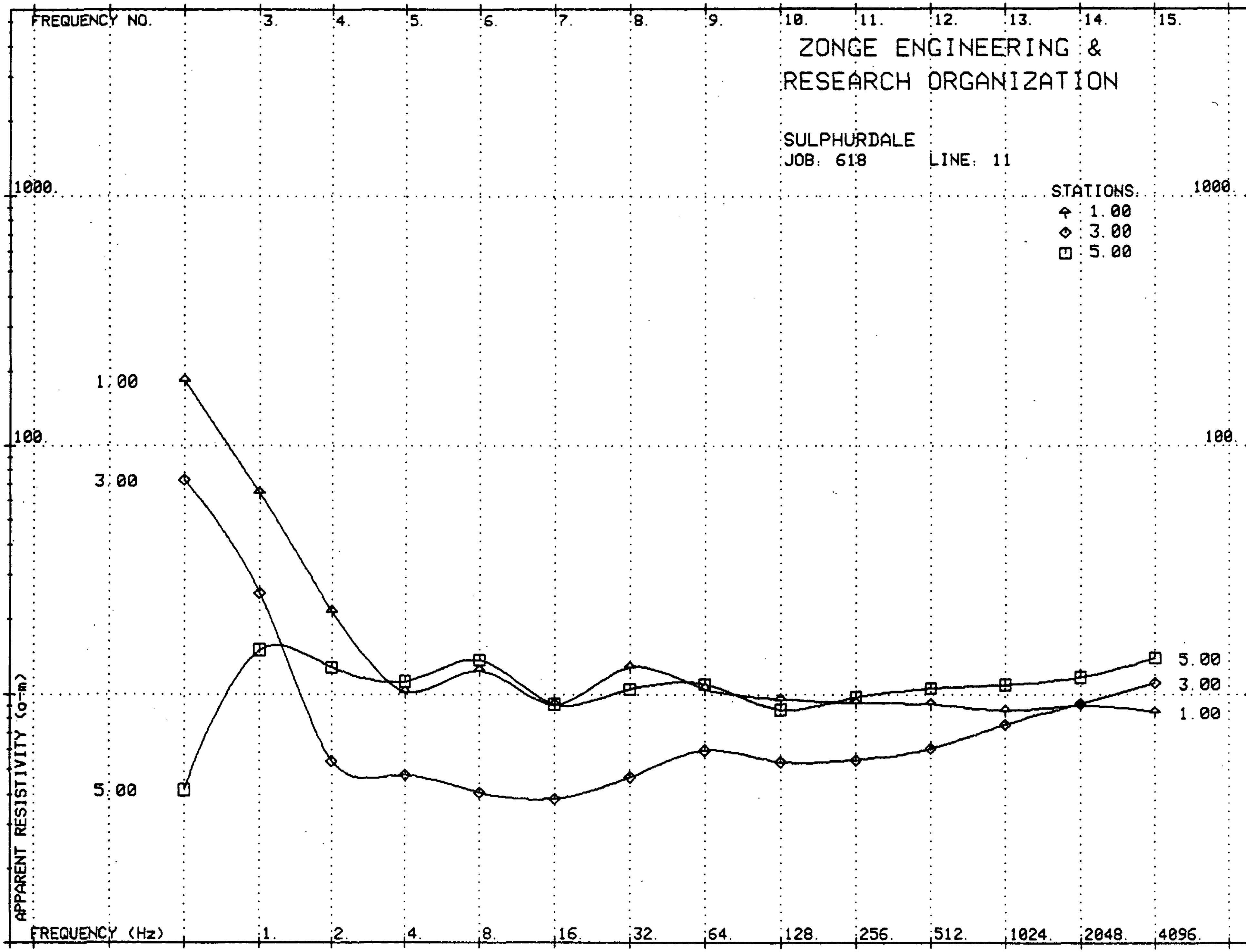
AMTPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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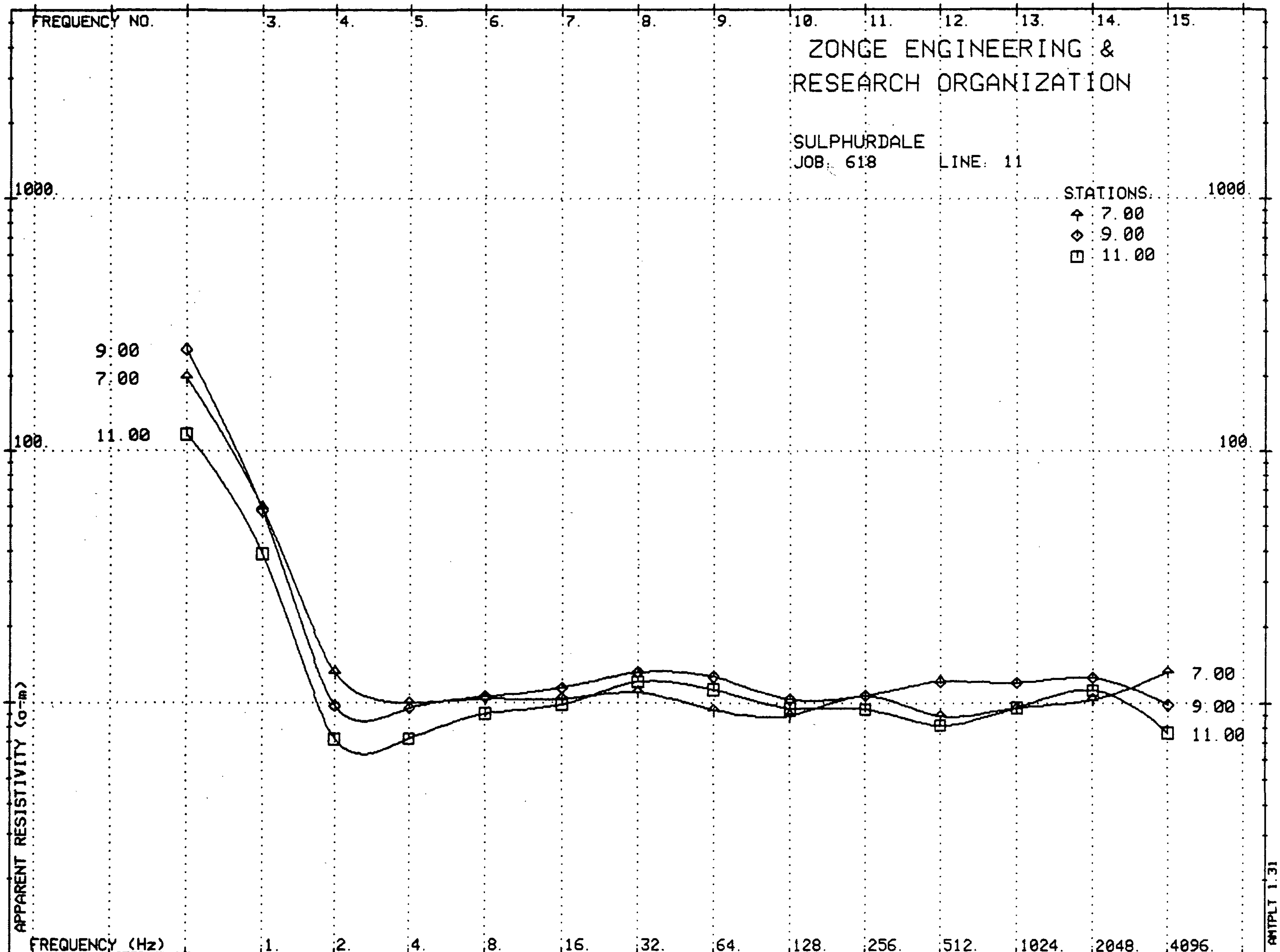
ANTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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JOB: 618 LINE: 11
STATIONS:
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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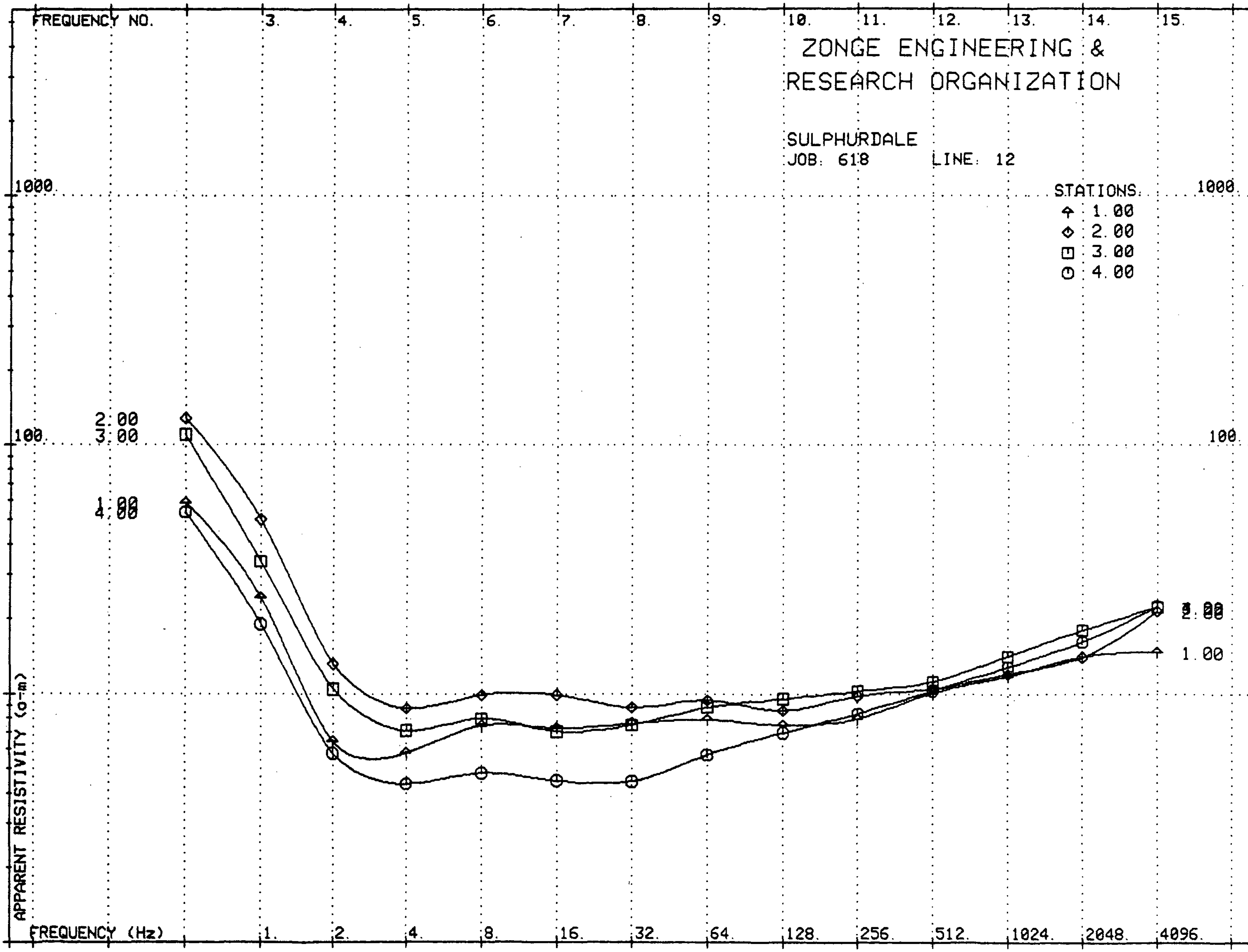
AMPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 12
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2.00
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4.00
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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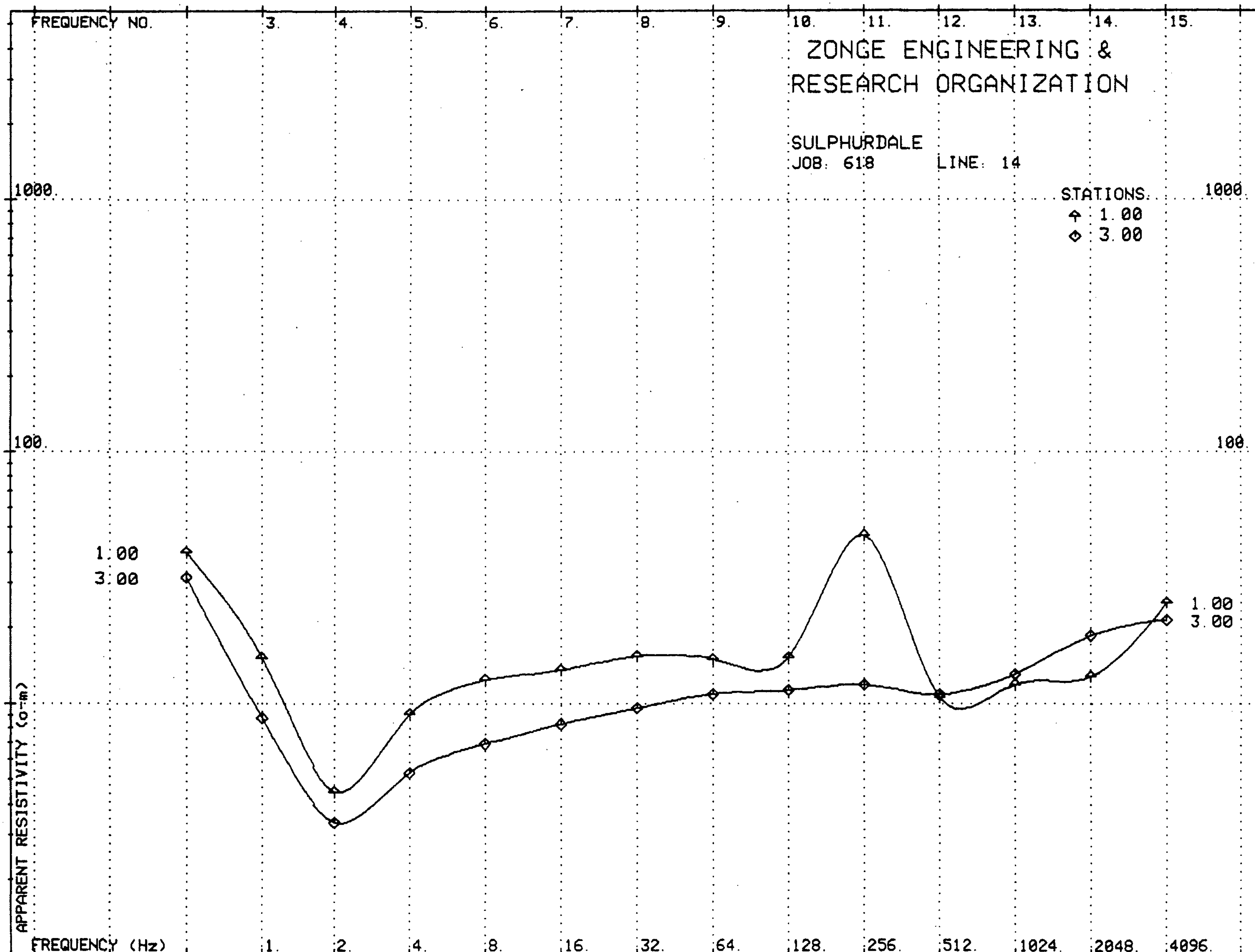
AMTPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 14
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FREQUENCY (Hz)
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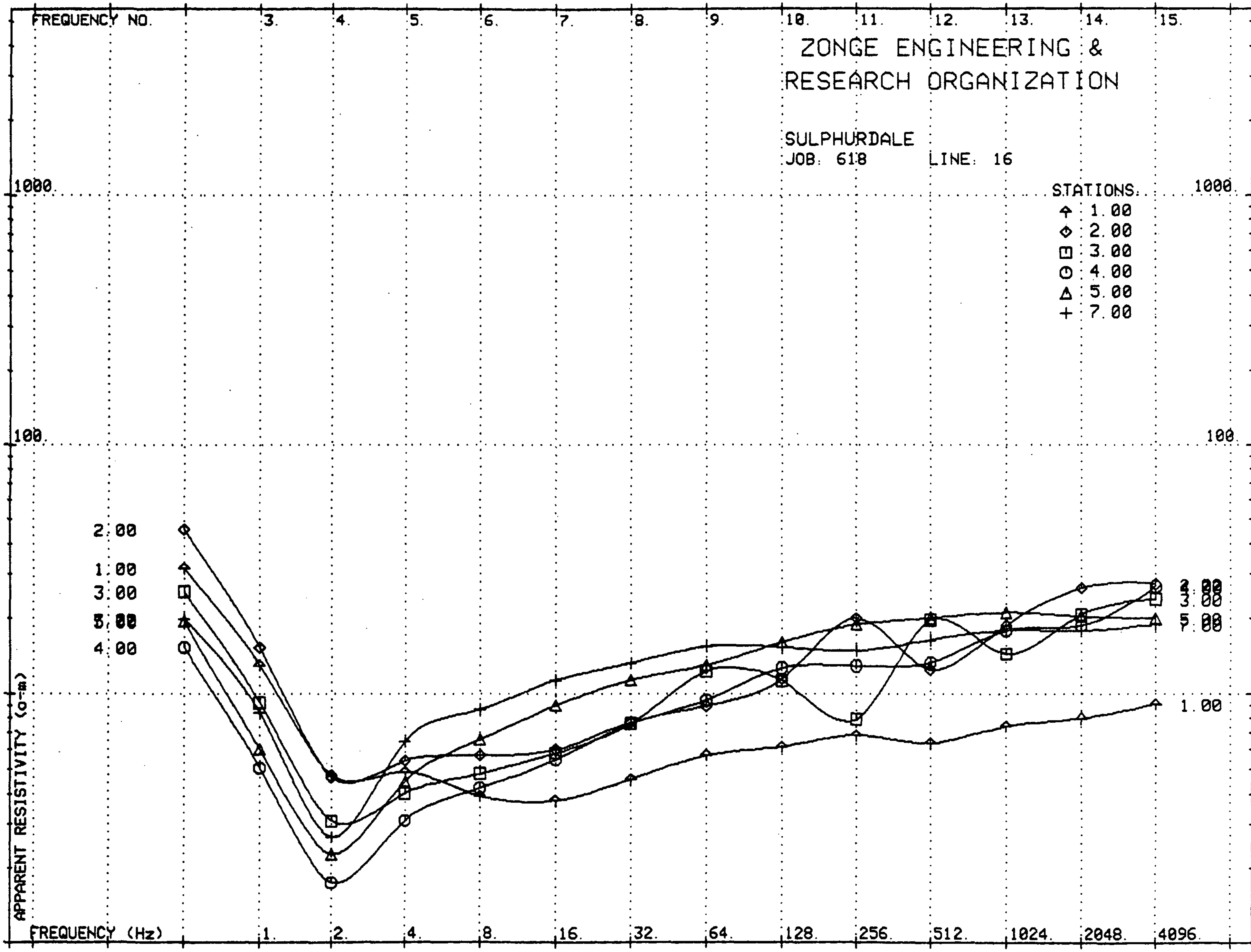
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 16
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FREQUENCY (Hz)
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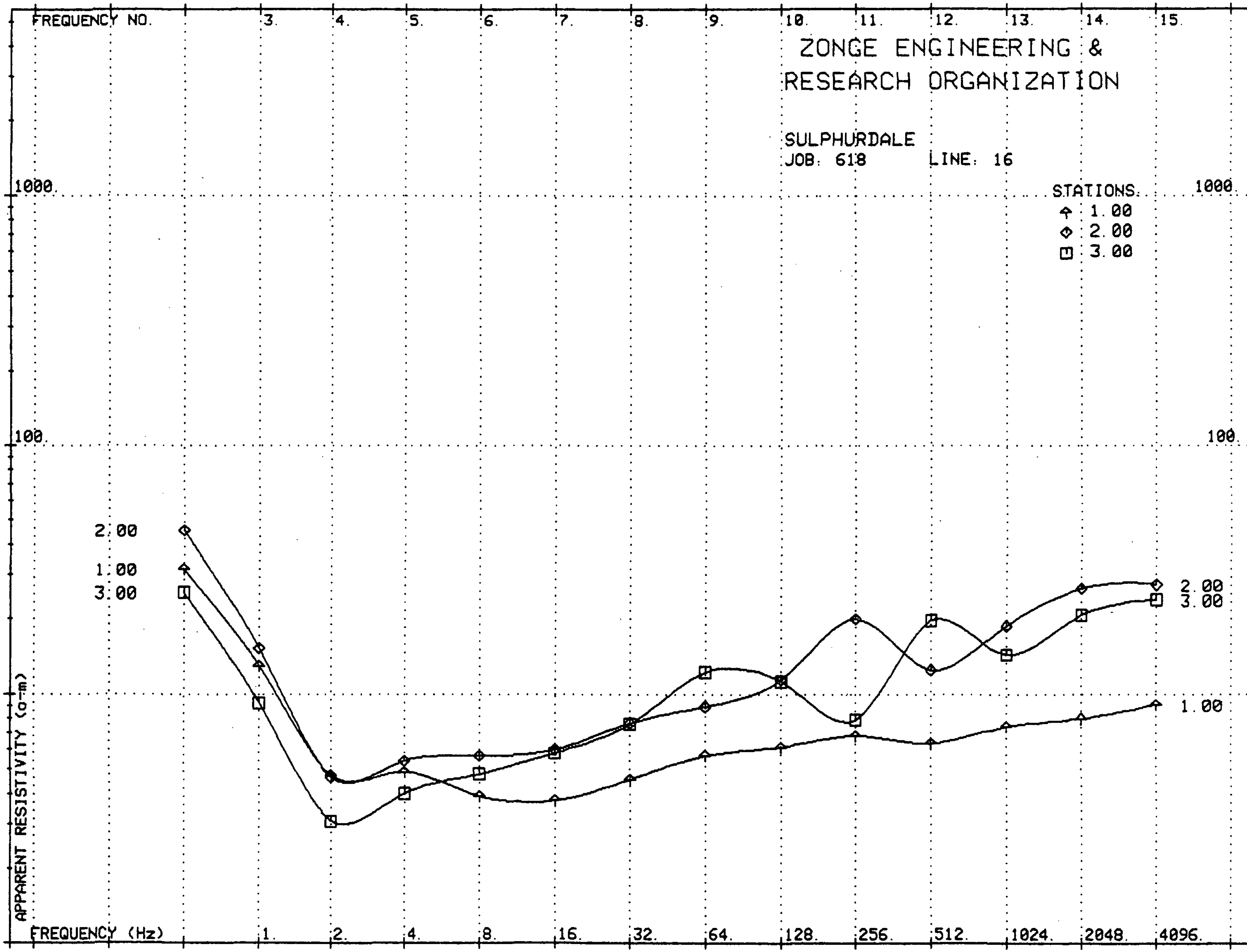
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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FREQUENCY (Hz)
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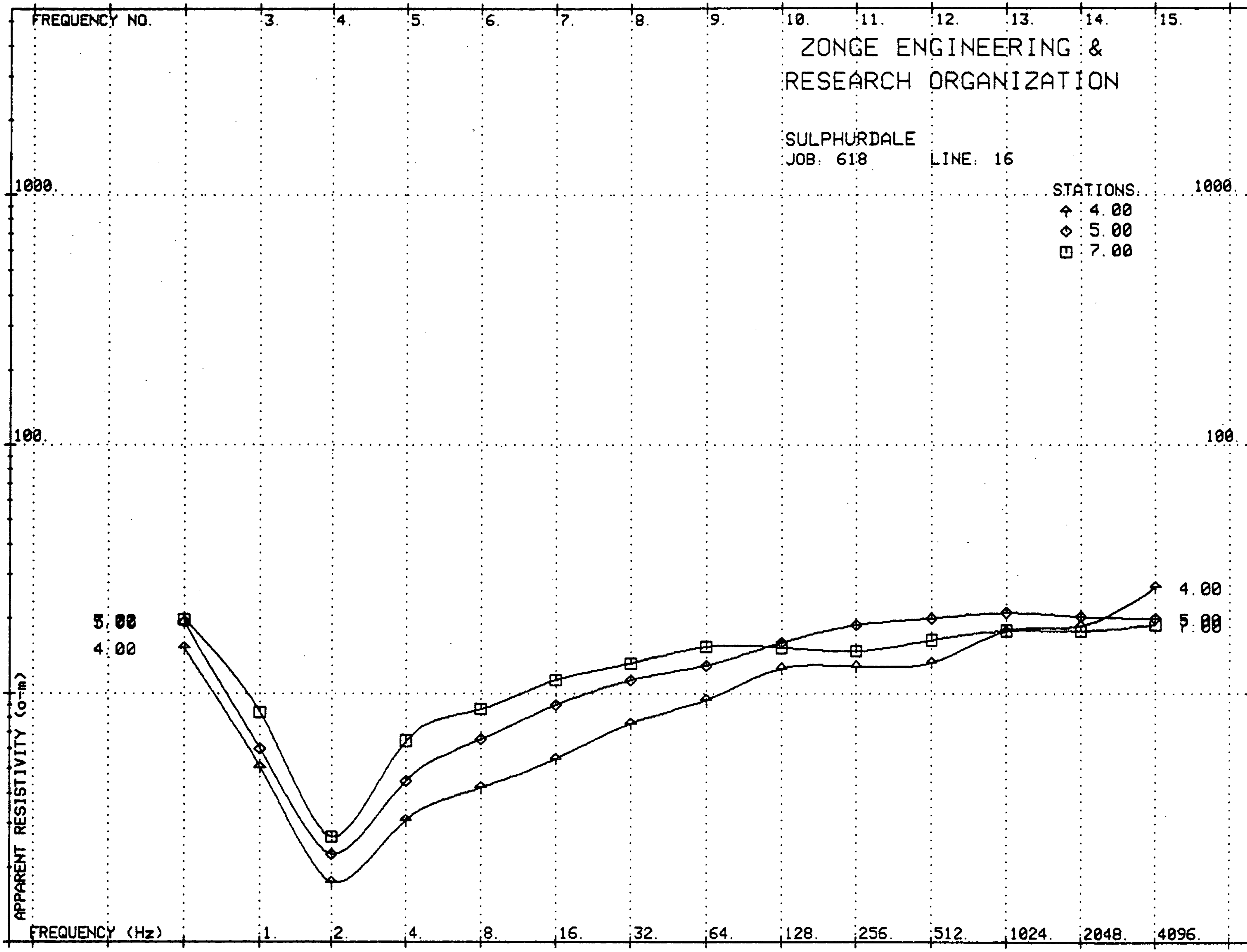

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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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FREQUENCY (Hz)
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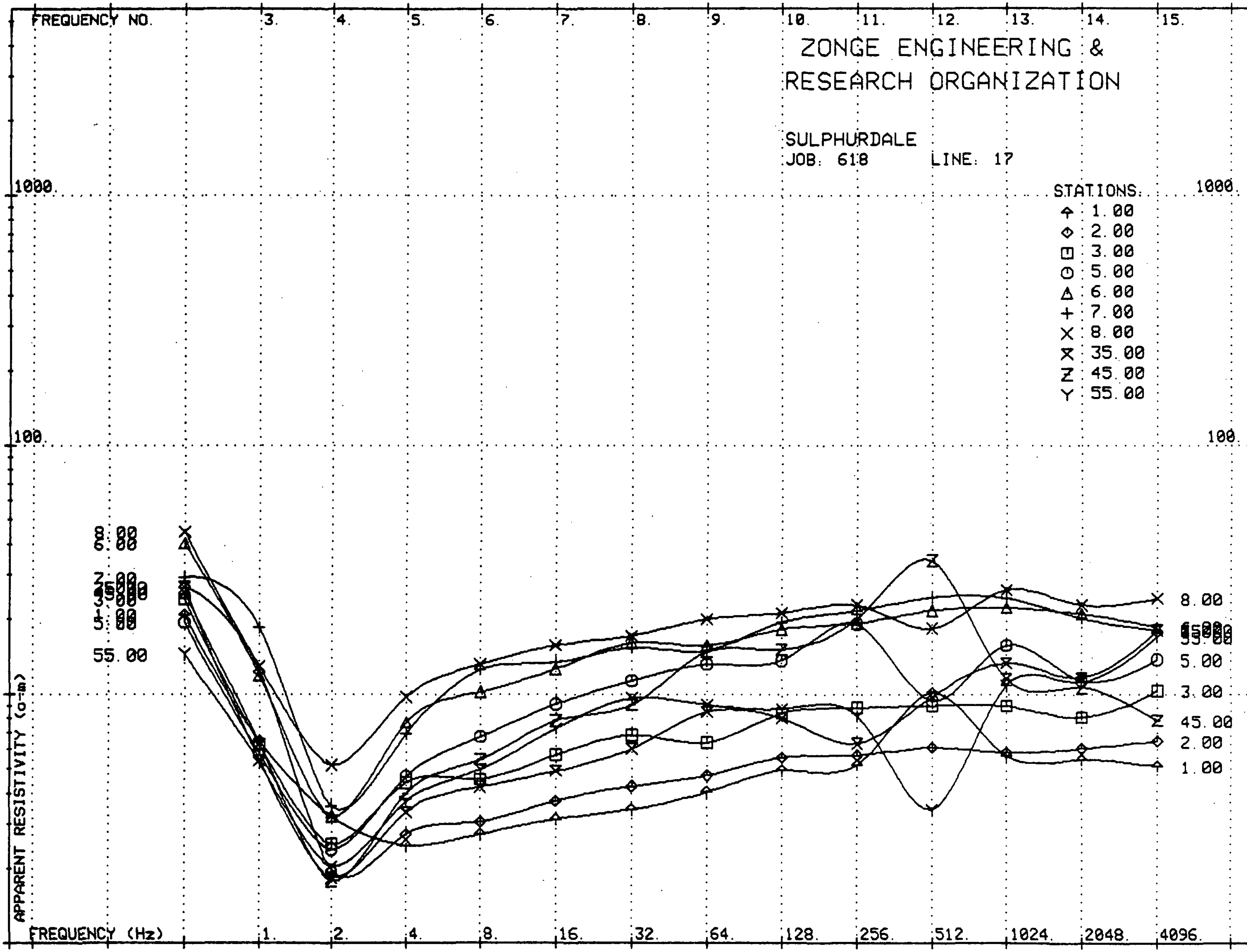
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
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8.00
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FREQUENCY (Hz)
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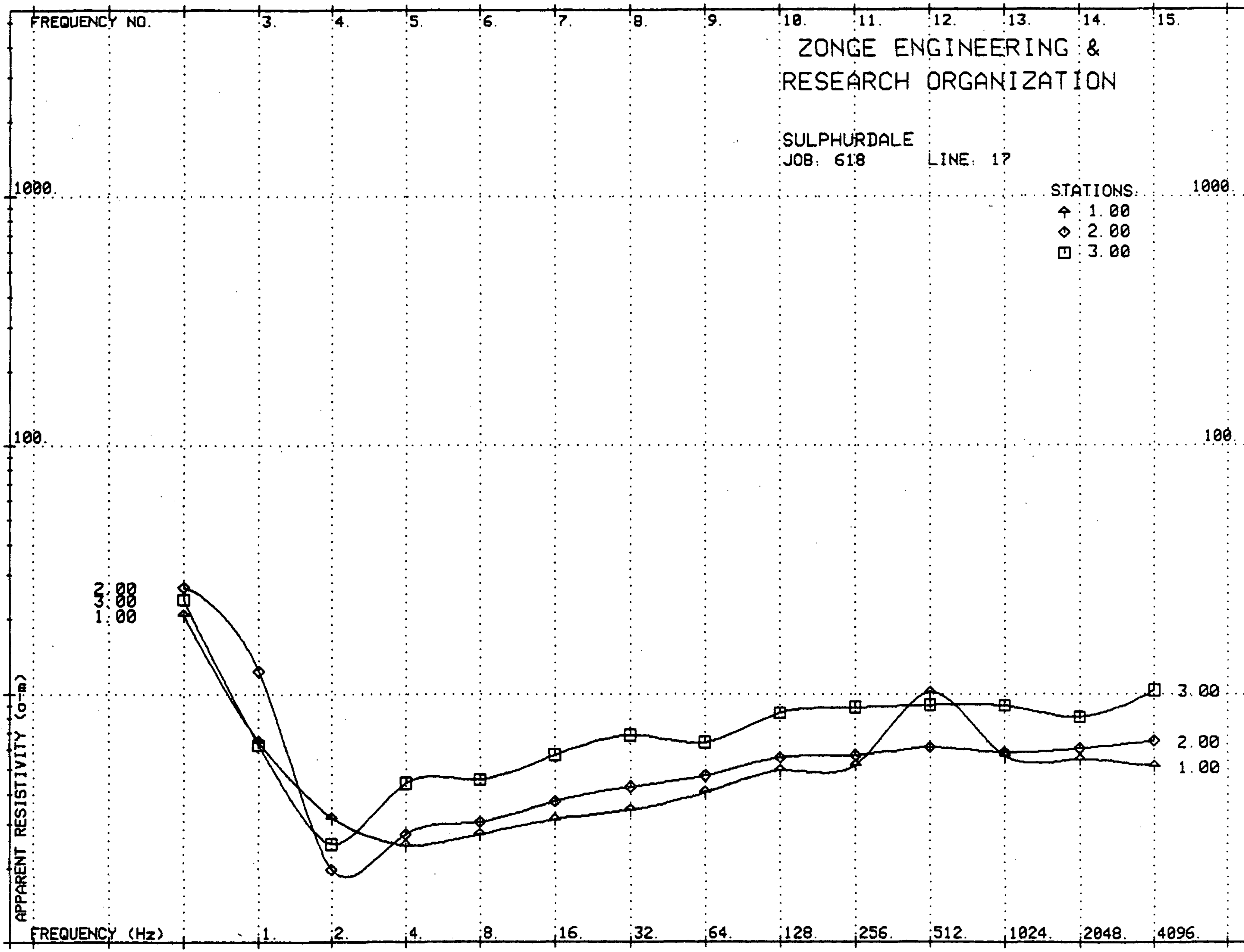
AMTPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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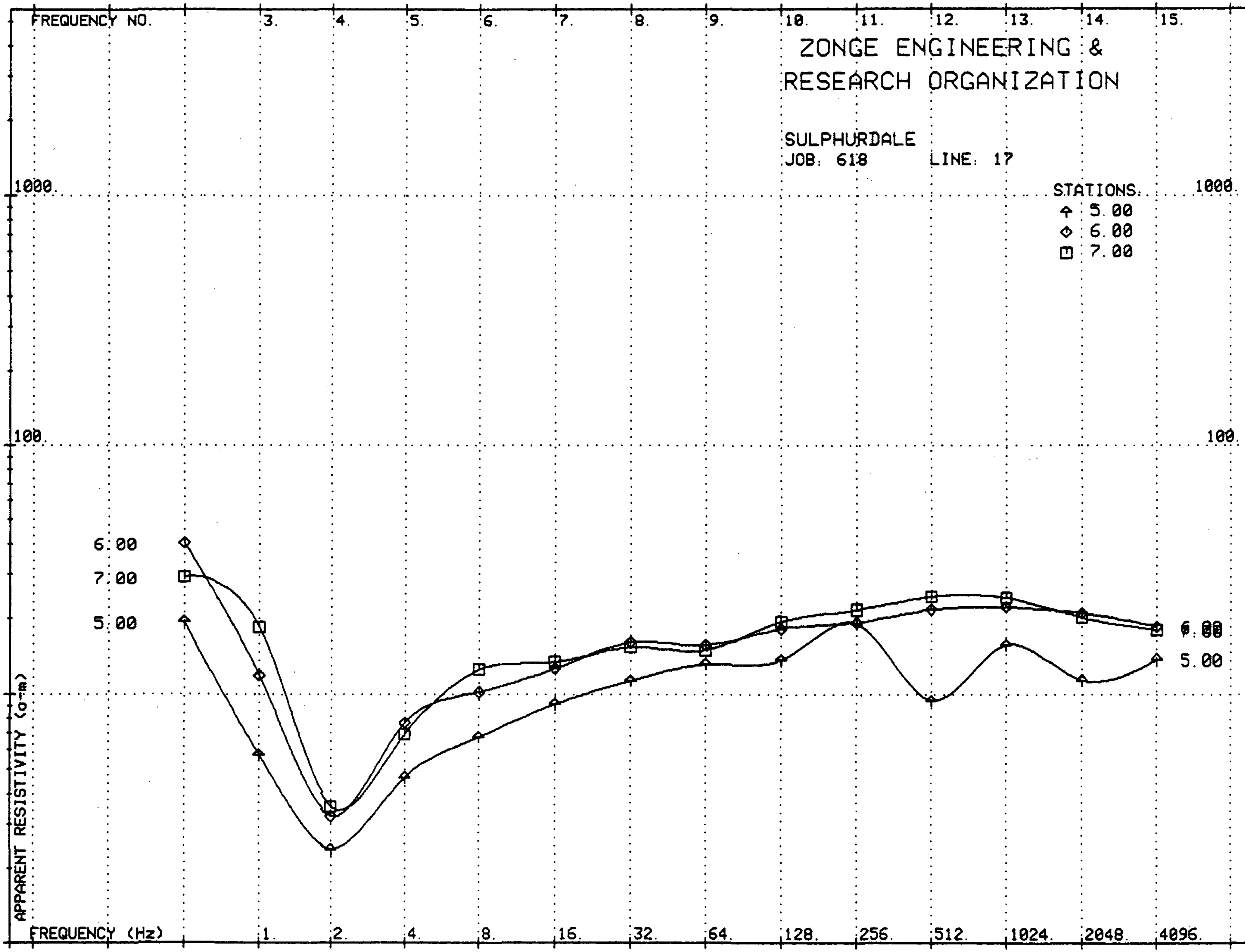
ANTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 17
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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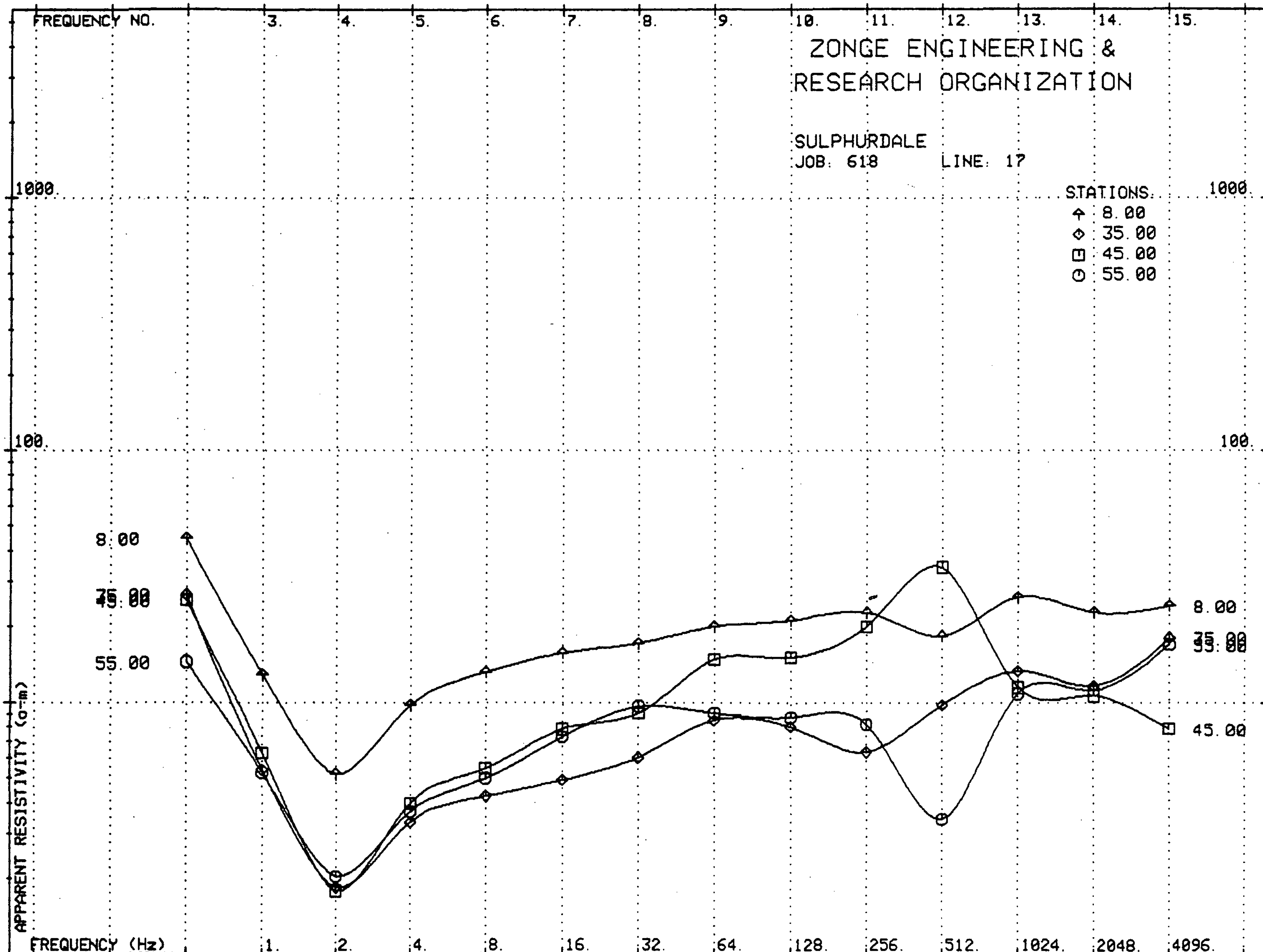
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618
LINE: 17
STATIONS.
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FREQUENCY (Hz)
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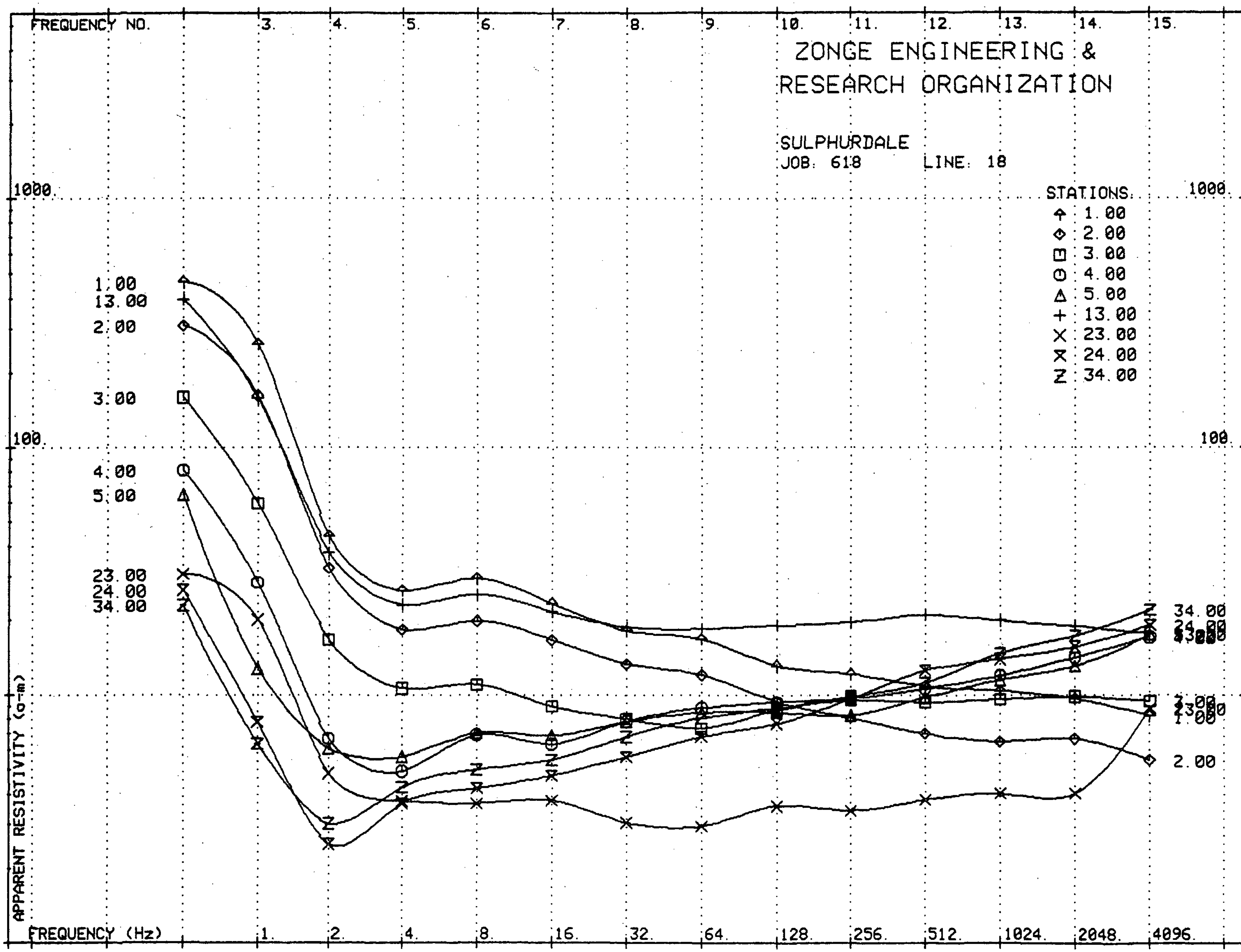
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 18
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APPARENT RESISTIVITY (Ω-m)
FREQUENCY (Hz)
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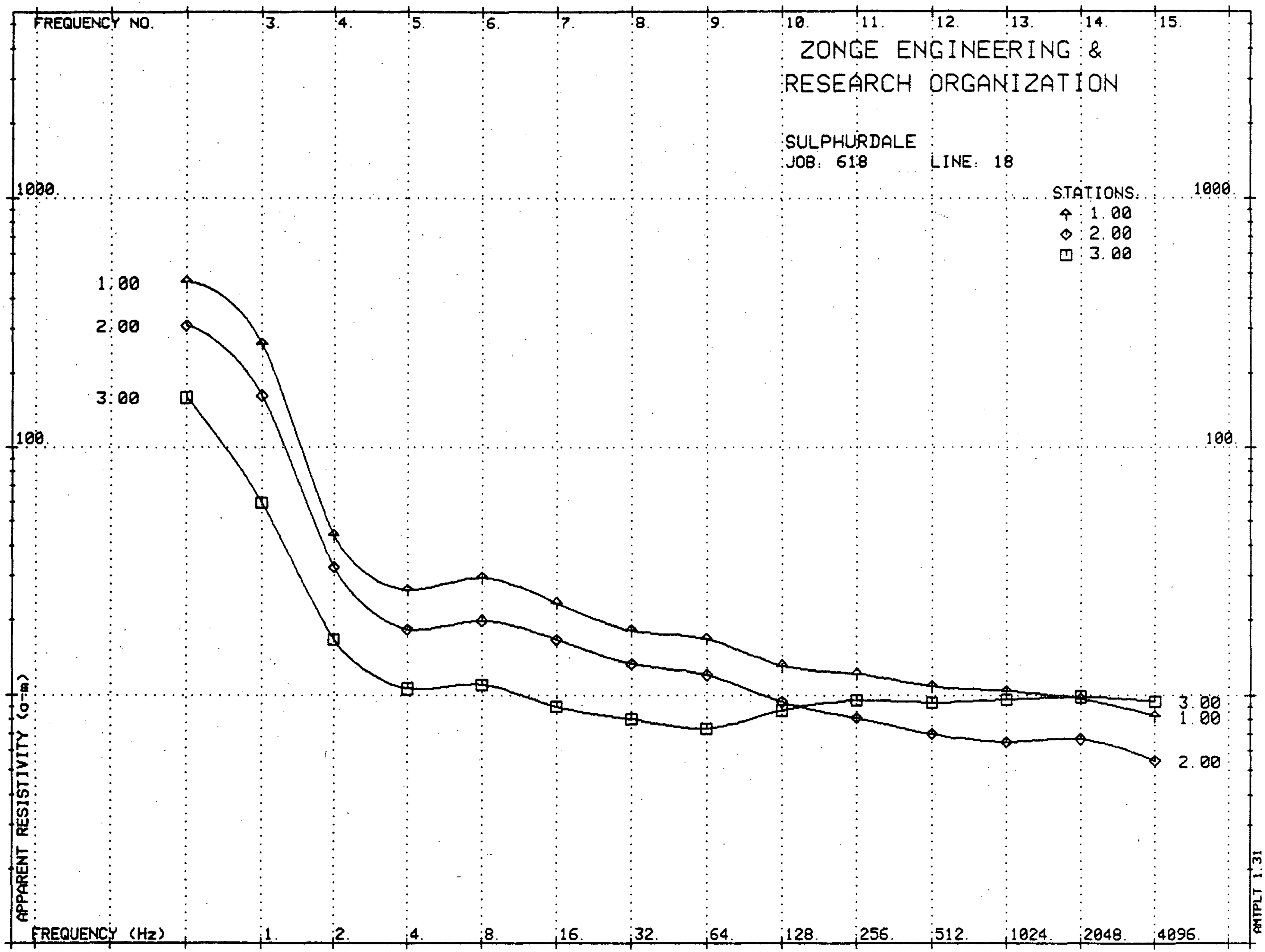
AMTPLT 1.31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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 18
STATIONS:
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2.00
3.00
1000.
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APPARENT RESISTIVITY (Ω-m)
FREQUENCY (Hz)
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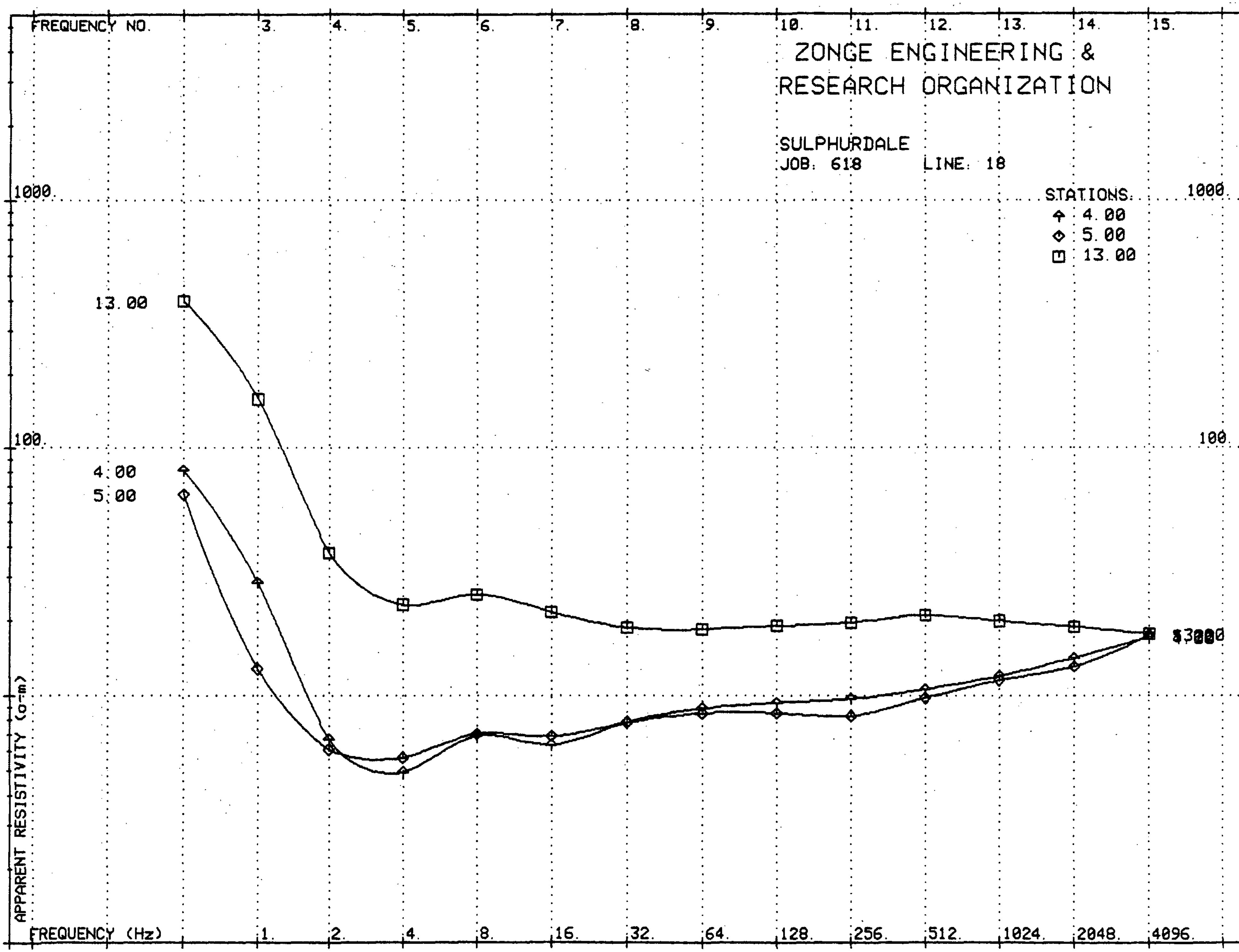
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 18
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4.00
5.00
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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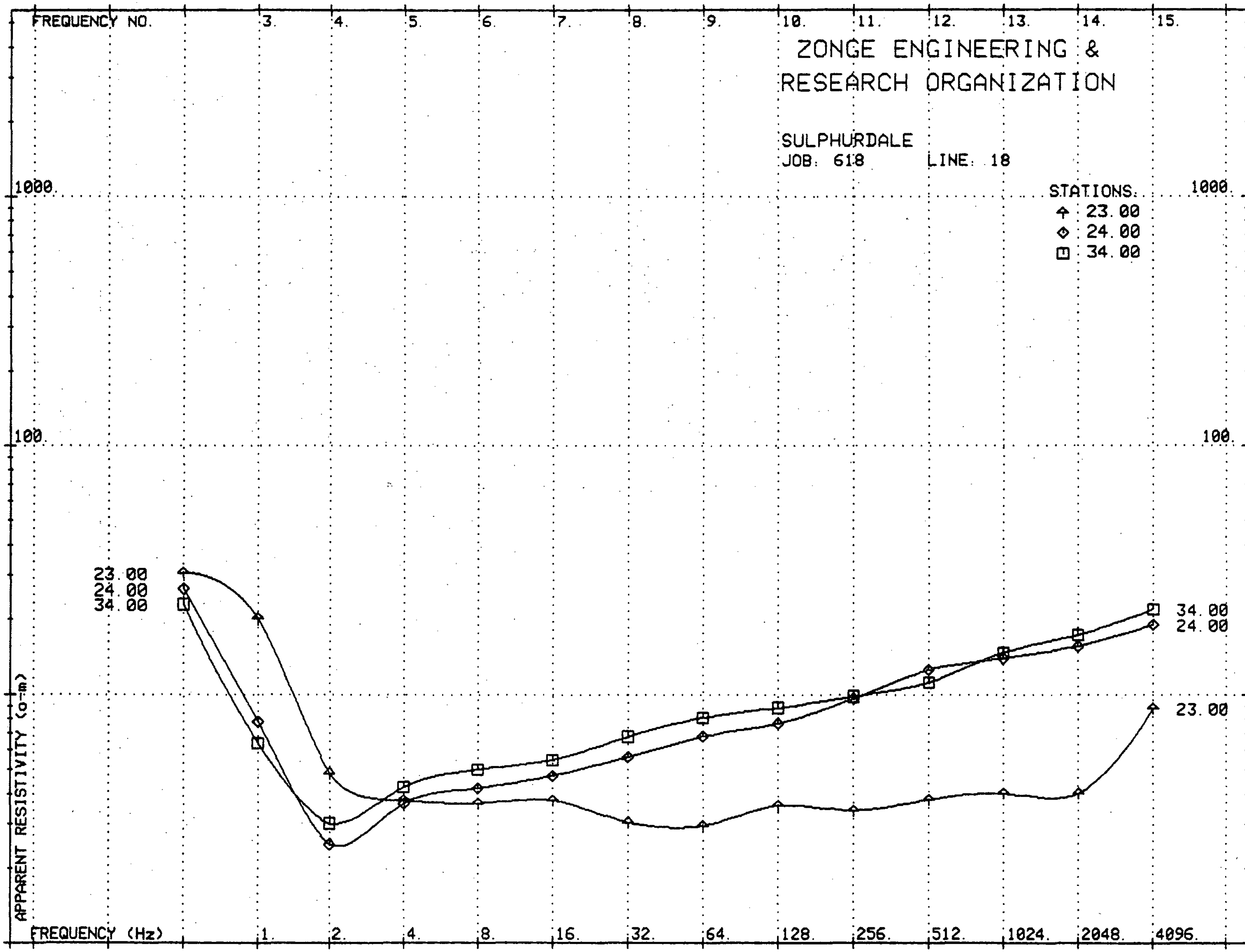
AMPLT 1.31


FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
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24.00
34.00
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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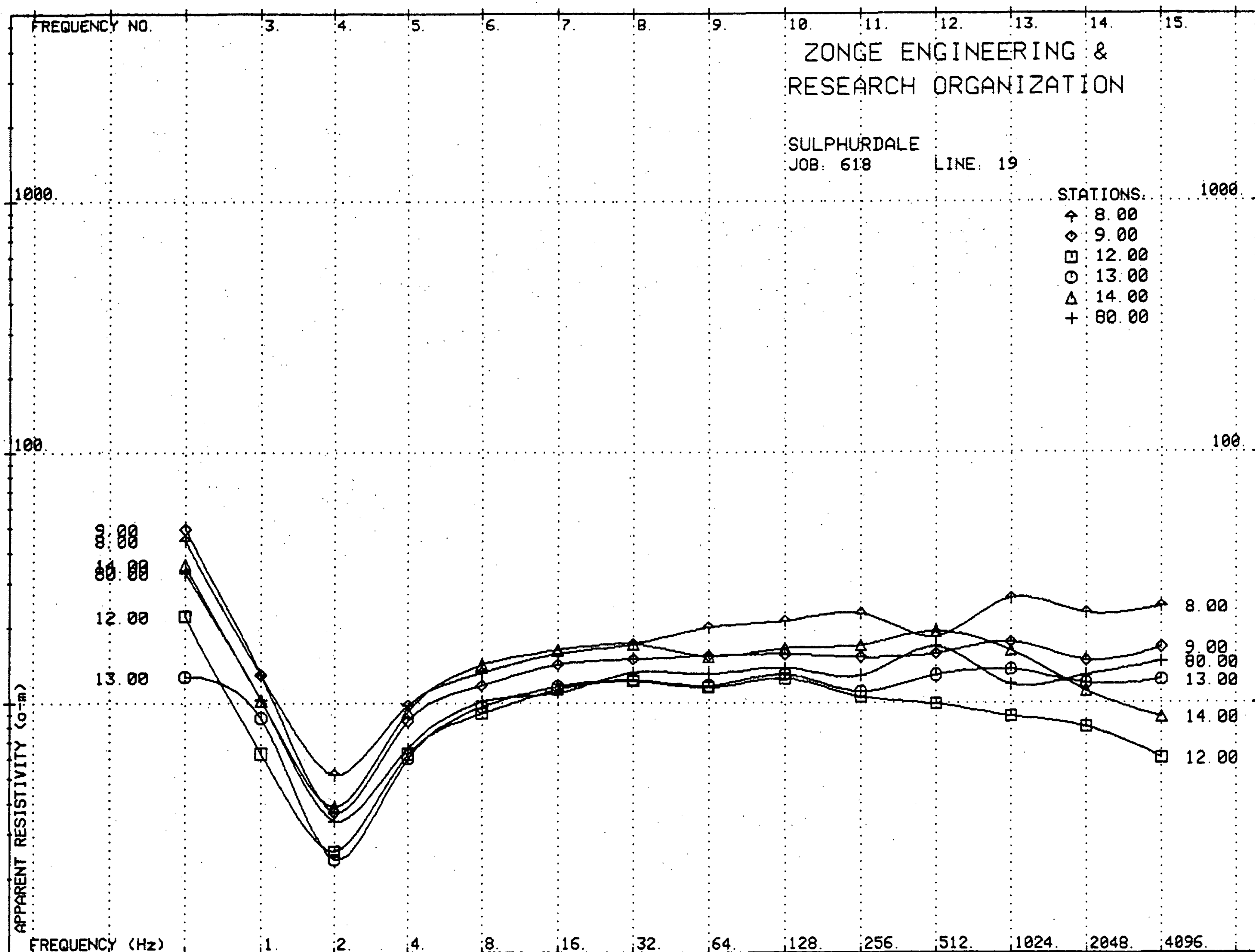
AMTPLT 1.31



FREQUENCY NO.
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ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 19
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APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
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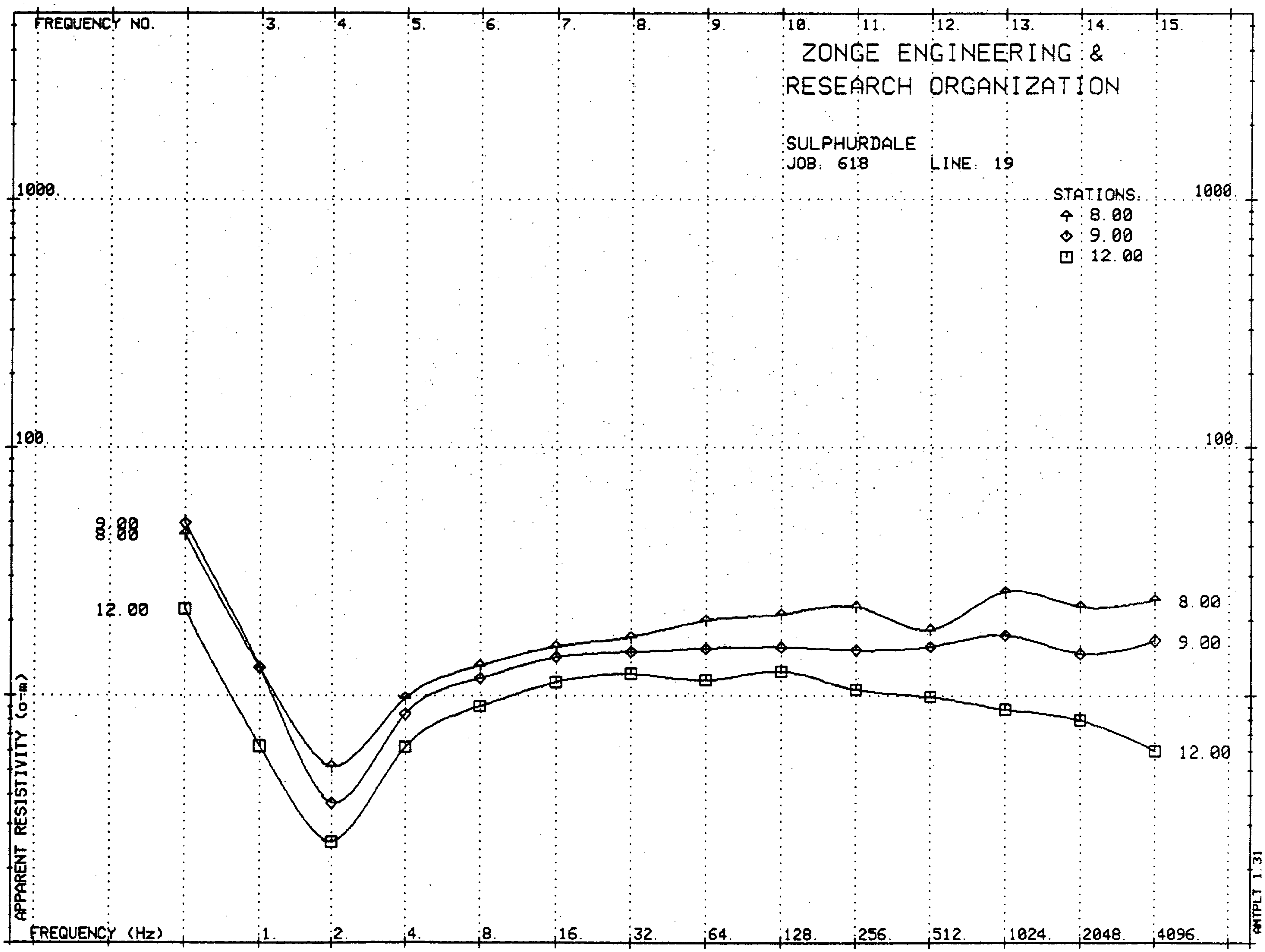
AMTPLT 1.31



FREQUENCY NO.
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.
ZONGE ENGINEERING &
RESEARCH ORGANIZATION
SULPHURDALE
JOB: 618 LINE: 19
STATIONS:
8.00
9.00
12.00
1000.
100.
APPARENT RESISTIVITY (o-m)
FREQUENCY (Hz)
1. 2. 4. 8. 16. 32. 64. 128. 256. 512. 1024. 2048. 4096.
AMTPLT 1.31

Line A-A'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

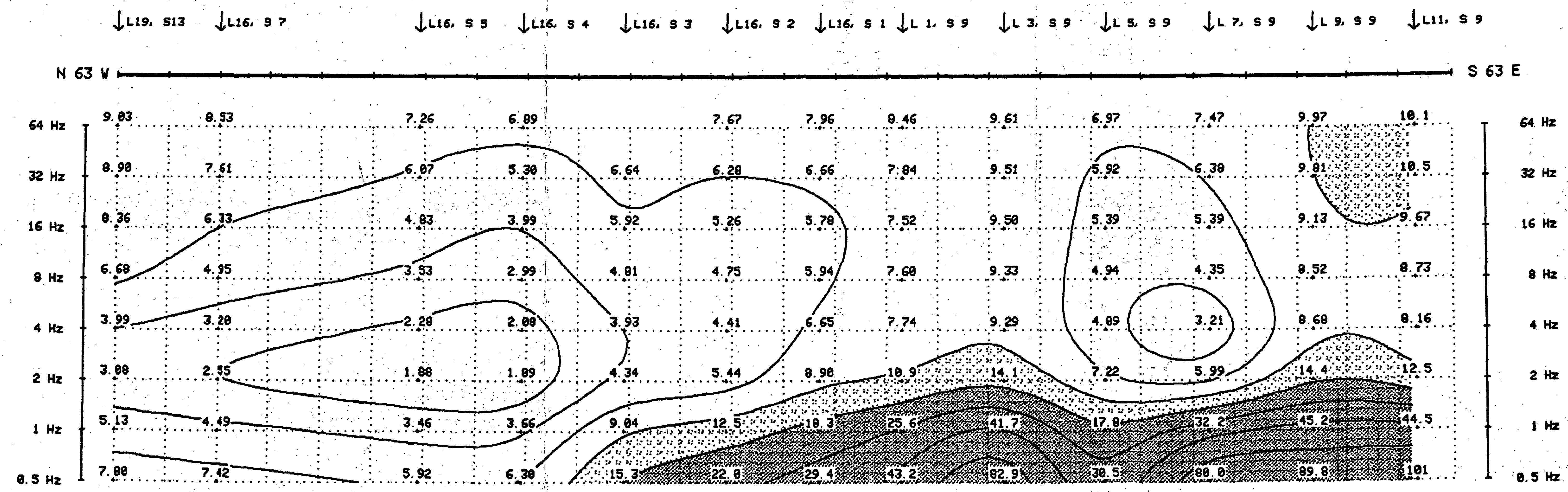
RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)
[1.70] 2.51 3.98 6.31 10.0 15.8
25.1 39.8 63.1 100 [101]



Line A-A'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 29 Sep 87

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

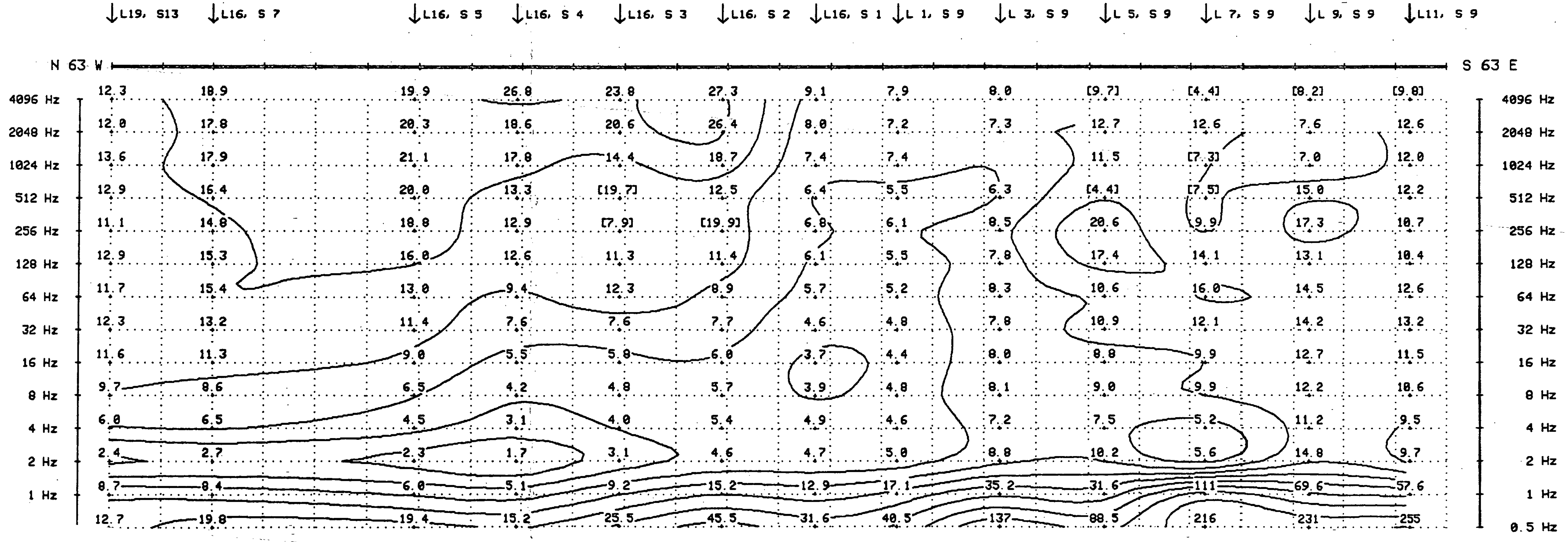
RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-V

[Plot limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)

[255]	15.8
251	10.0
158	6.31
100	3.98
63.1	2.51
39.8	[1.73]
25.1	



Line A-A'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 30 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

values in milli-radians
<PDIFF

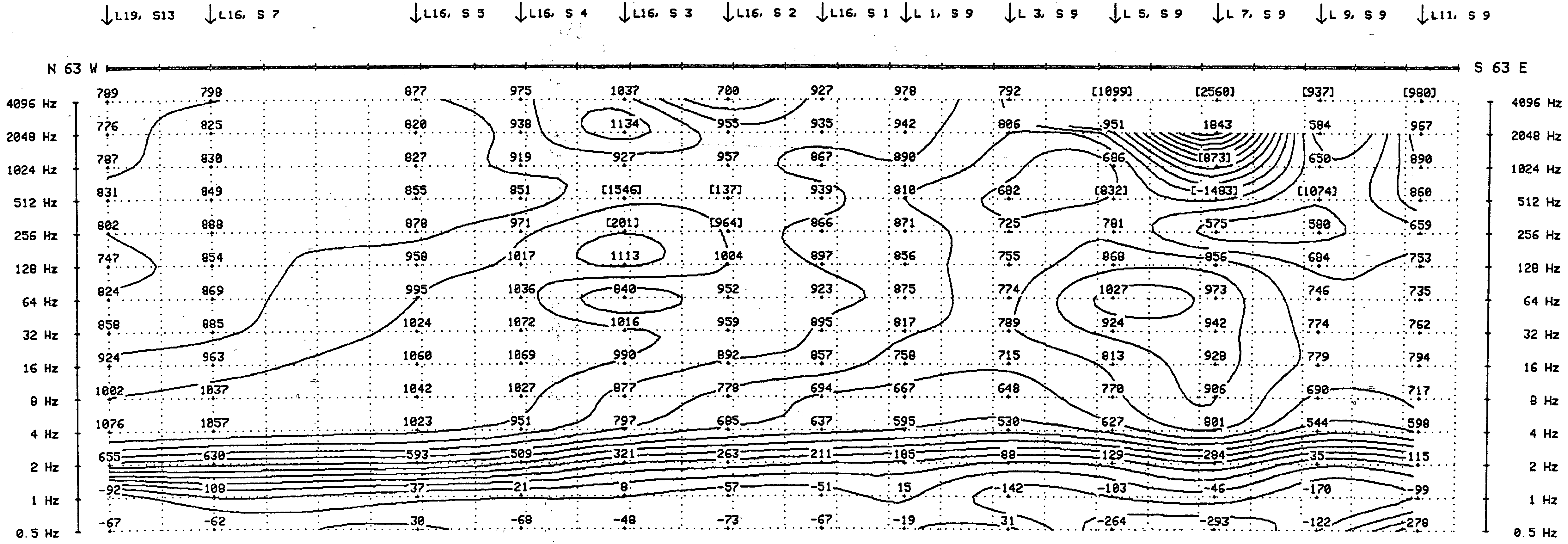
RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Plot limits] and ARITHMETIC CONTOURS
(Interval: 100.00)

[1843]	1100	300
1800	1000	200
1700	900	100
1600	800	0.00
1500	700	-100
1400	600	-200
1300	500	-300
1200	400	[-310]



Line B-B'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

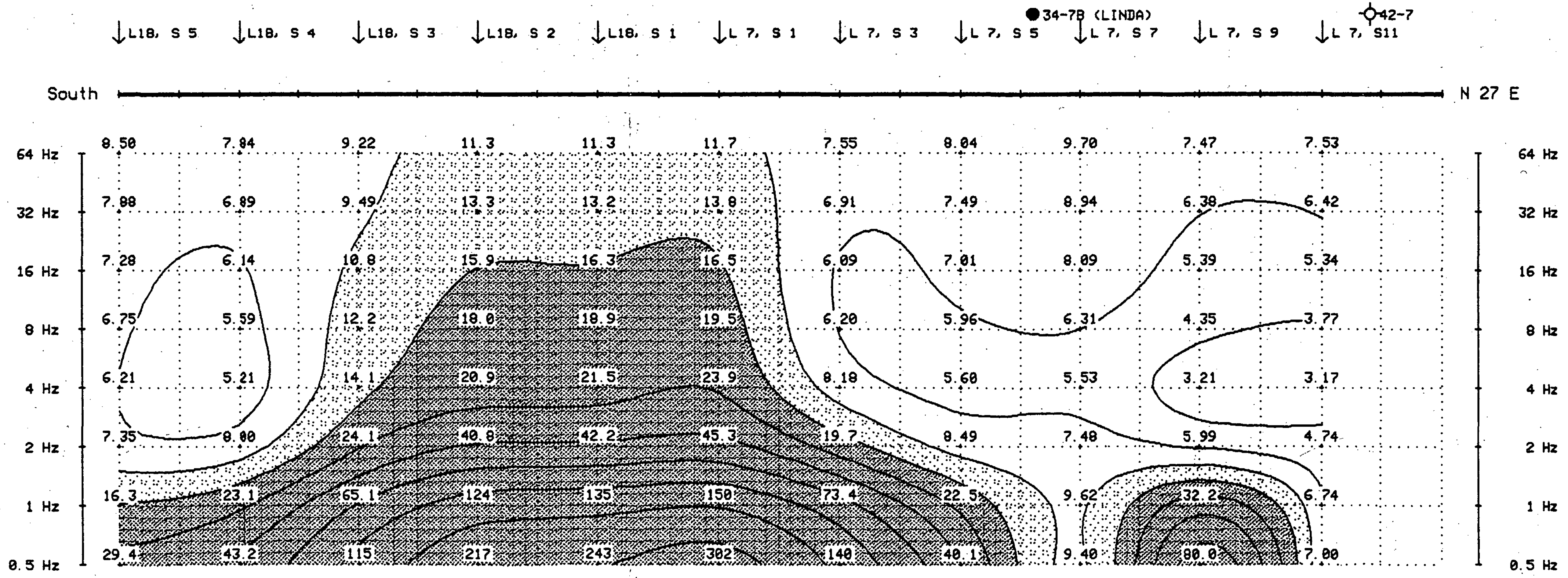
Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)

[2.99]	39.8
3.98	63.1
6.31	100
10.0	158
15.8	251
25.1	[306]

CULTURE SYMBOL LEGEND
● Well
Dry Hole
↓ Note locator



Line B-B'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 30 Sep 87

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

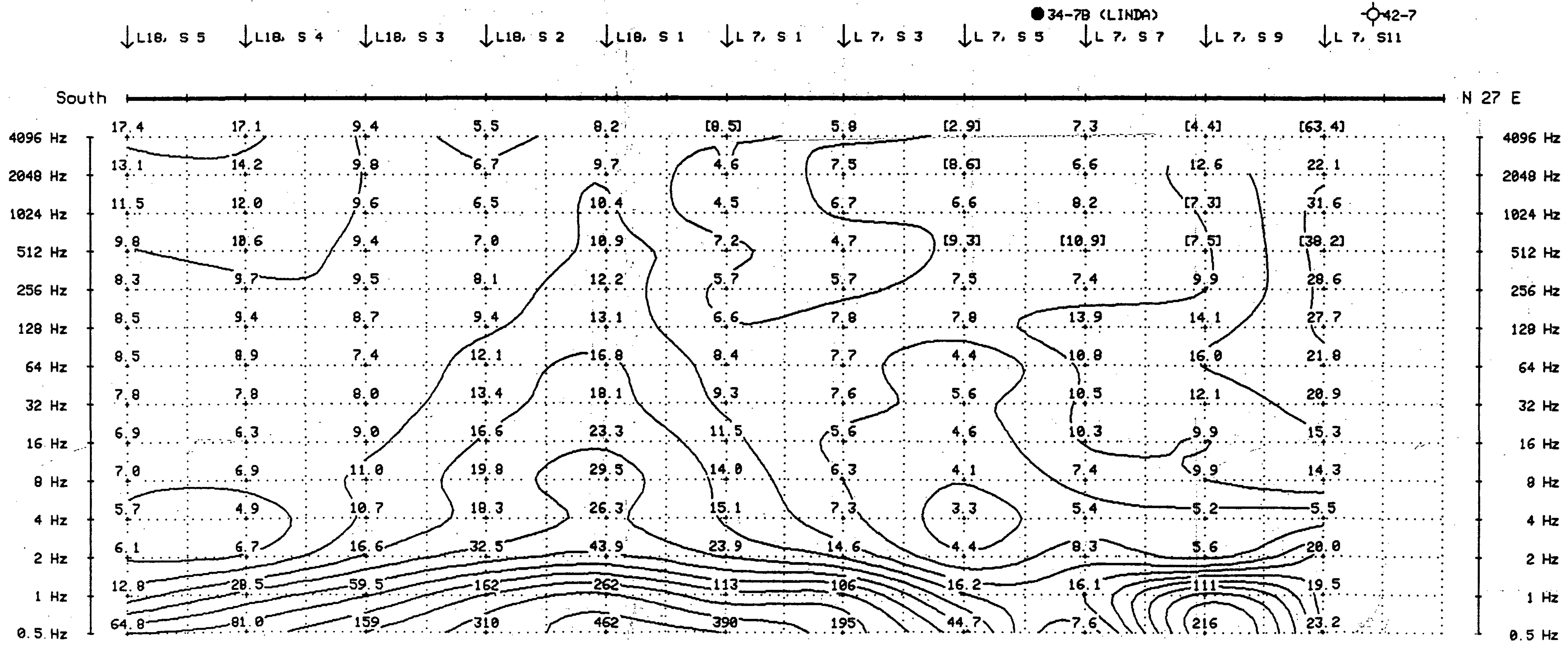
Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Plot limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)

[466]	25.1
398	15.8
251	10.0
158	6.31
100	3.98
63.1	[3.33]
39.8	

CULTURE SYMBOL LEGEND
● Well
⌖ Dry Hole
↓ Note locator



Line B-B'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 30 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

values in milli-radians
<PDIFF

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

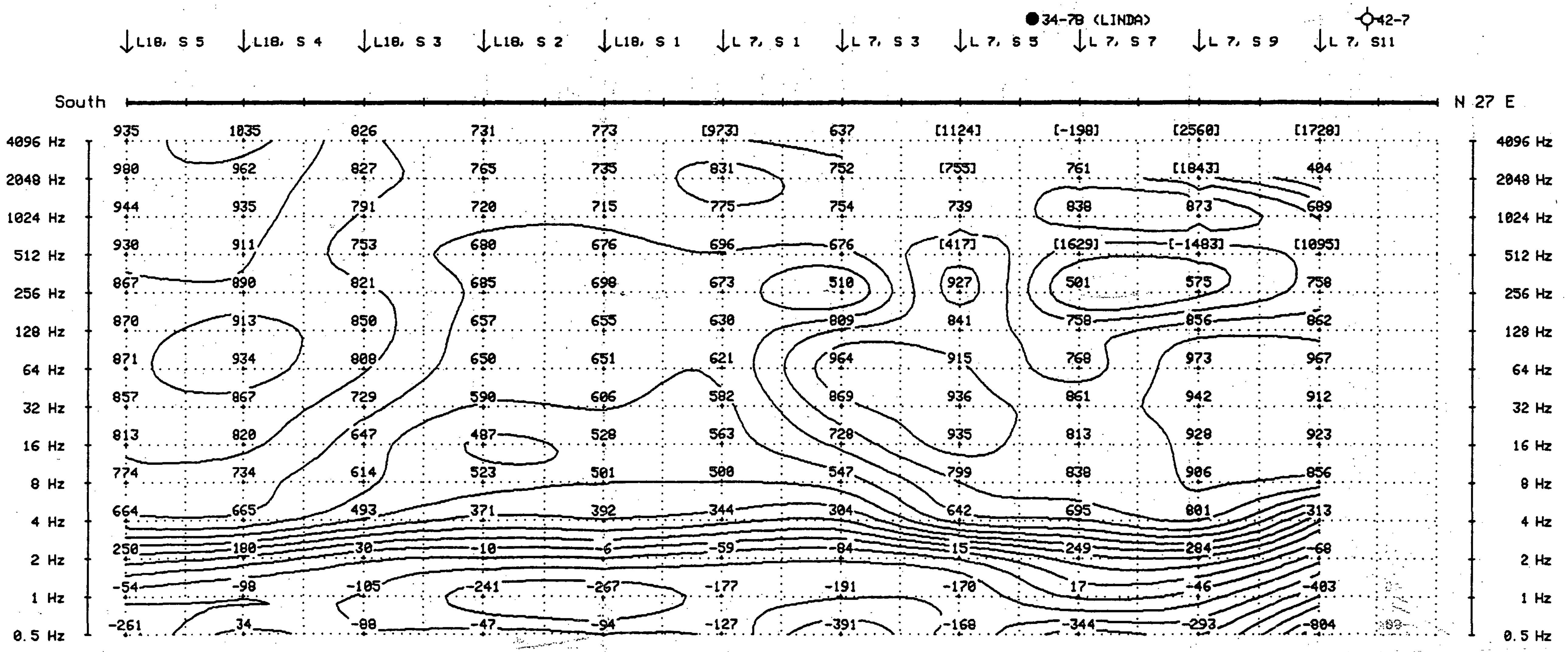
Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Plot limits] and ARITHMETIC CONTOURS
(Interval: 100.00)

[1041]	400	-300
1000	300	-400
900	200	-500
800	100	-600
700	0.00	-700
600	-100	-800
500	-200	[-804]

CULTURE SYMBOL LEGEND
● Well
⌖ Dry Hole
↓ Note locator



Line C-C'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 23 Sep 87

CSAMT SURVEY DATA
CORRECTED RESISTIVITY

RHO: 8.50, PHZ: 871., FREQ 9: 64 Hz
<RHO-C>FLTR-3>REDRHO

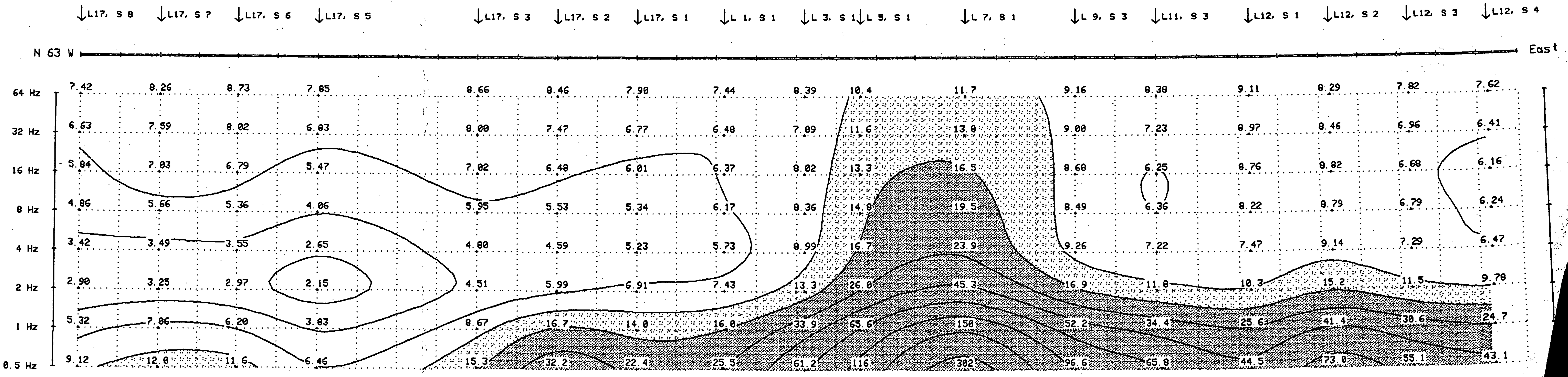
RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Shading limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)

[2.12]	39.8
2.51	63.1
3.98	100
6.31	158
10.0	251
15.8	[302]
25.1	



Line C-C'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 29 Sep 87

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

values in ohm-meters
<RHO-C

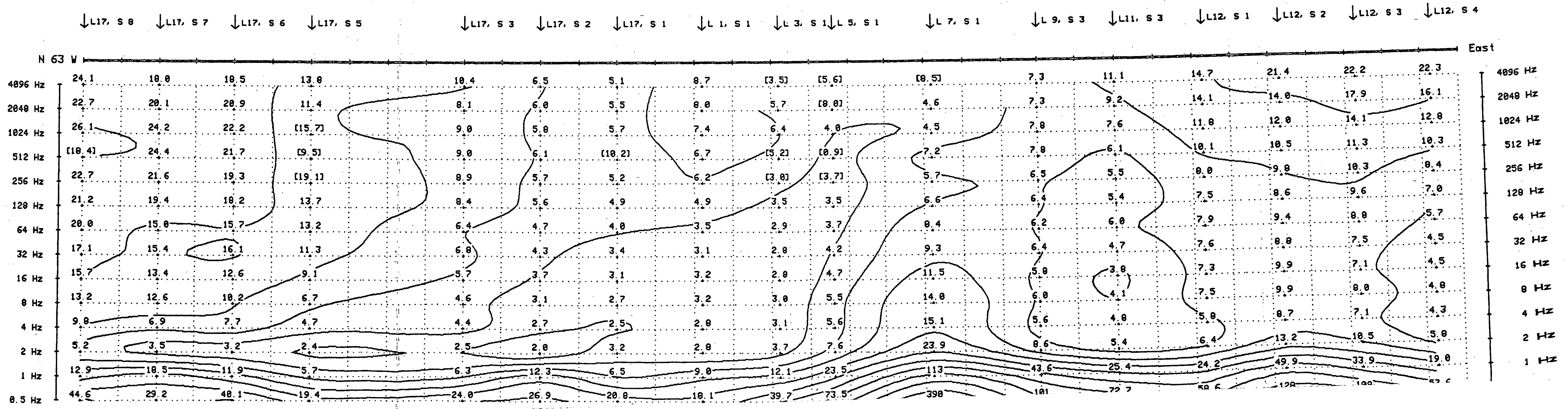
RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280 ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W

[Plot limits] and LOGARITHMIC CONTOURS
(Interval: 0.20)

[390]	15.8
251	10.0
158	6.31
100	3.98
63.1	2.51
39.8	[1.84]
25.1	



Line C-C'
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 30 Sep 87

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)

values in milli-radians
<PDIFF

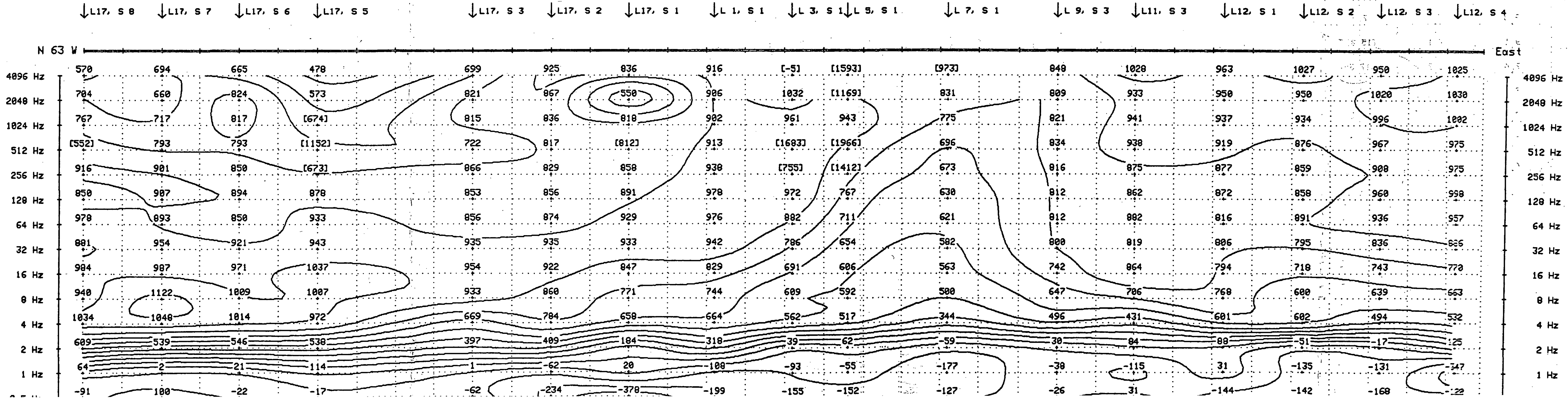
RECEIVER DATA
Length : 250. ft Line : N 63 W
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi.
Rx to Tx: N-W

[Plot limits] and ARITHMETIC CONTOURS
(Interval: 100.00)

[1131]	300
1100	200
1000	100
900	0.00
800	-100
700	-200
600	-300
500	[-378]
400	



Line 9-14
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
CAGNIARD RESISTIVITY

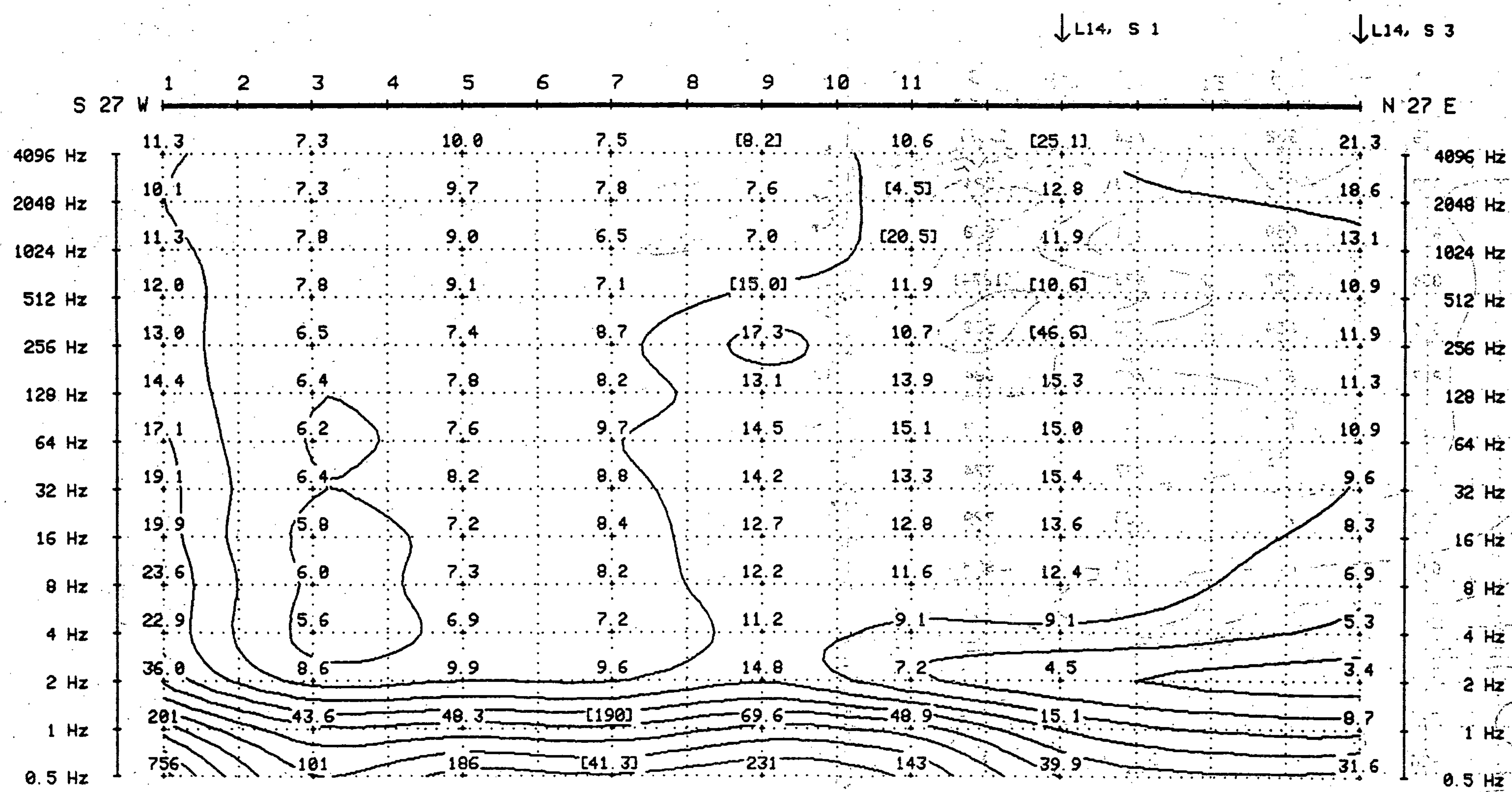
values in ohm-meters
<RHO-C

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 01 Oct 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft DiPole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-V



Line 9-14
SULPHURDALE
for
MOTHER EARTH INDUSTRIES

CSAMT SURVEY DATA
PHASE DIFFERENCE (E - H)
values in milli-radians
<PDIFF

ZONGE # 618
PLOT BY CPLOT 4.20
PLOTTED 01 Oct 87

RECEIVER DATA
Length : 250. ft Line : N 27 E
Spacing: 250. ft Dipole: N 27 E

Surveyed: MAY 87

TRANSMITTER DATA
Length : 5280ft
Orient. : N 27 E
Distance: 5.0 mi
Rx to Tx: N-W