UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Electrical Studies Conducted on the Lake City Caldera, Colorado
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by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

The proposed Bureau of Land Management Red Cloud Wilderness area (#CO-030-208), located within the Lake City Caldera, was studied using audio-magnetotelluric (AMT) and telluric traverse (TT) methods. Twenty AMT stations were occupied adjacent to and across the caldera during the summer of 1984. An east-west telluric traverse was made normal to the caldera ring-fracture in Burrows Park to define the electrical signature at the caldera boundary and to help assess the potential for mineralization. The survey was performed as part of the Wilderness Act charging the U.S. Geological Survey with the responsibility of mineral appraisal. The Lake City caldera is located in southwestern Colorado on the western side of the San Juan Volcanic Field. The field is composed of large calderas formed by catastrophic ash-flow eruptions in Oligocene to Miocene time (Steven and Lipman, 1976). The Miocene Lake City caldera sits within the larger San Juan caldera complex (fig. 1).

GEOLOGY

The Lake City caldera is a deeply eroded collapse caldera that shows signs of resurgence. The intracaldera rocks are composed of the three phase Sunshine Peak Tuff, collapse breccias, and a quartz syenite intrusive (Hon, Ken et al., 1983). The ring fracture has been mapped (Lipman, 1976) on three sides: north, south, and west. The complexly block faulted, quartz latite in the Red Mountain area (fig. 2) forms a post-caldera plug that covers the eastern portion of the ring fault.

Mineralization is related to Keystone graben faults, distension fractures, and widespread hydrothermal alteration. White and others (1981) mapped the whole San Juan caldera complex as an area of known molybdenum deposits (fig. 1). The principal ores are lead, zinc, gold, and silver (Lipman and others, 1976).

The ring fault and distension fractures cutting the Sunshine Peak Tuff exhibit localized hydrothermal alteration. Faults and fractures in Burrows Park (Brown, 1926) and Alpine Gulch (Lipman and others, 1976) both produced Pb-Zn-Ag ores. The ores are probably associated with mid-Tertiary resurgence of the Lake City caldera and emplacement of the quartz syenite intrusive.

The widespread hydrothermal alteration of Red Mountain is perhaps indicative of disseminated mineralization (Steven and others, 1974). Well data on Red Mountain from Earth Sciences, Inc., shows alunitic alteration extending 3000 ft below the surface (D. Bove personal commun., 1984). Altered and mineralized rocks are good targets for electrical methods because altered rocks are more conductive than the unaltered surrounding rocks.

METHODS

The Audio-Magnetotelluric Method. Magnetotellurics (MT) is an electromagnetic sounding method that measures earth resistivity as a function of depth (Keller and Frischknecht, 1966). Soundings are obtained by measuring the surface electromagnetic fields at different frequencies. Because lower frequencies penetrate farther into the earth than higher frequencies, measuring a variety of frequencies gives information on resistivity variations with depth. The USGS AMT system measures electrical and magnetic responses at frequencies in the audio-frequency range (4.5 to 27,000 Hz). Depth of exploration can be approximated by

$$\text{Depth (m)} = 355\sqrt{\frac{\rho_a}{f}}.$$

Here ρ_a is apparent resistivity and f is the frequency (Bostick, 1977). The AMT method is discussed in detail by Strangway and others (1973), and application and details of the USGS AMT system are given by Hoover and others (1976) and Hoover and Long (1976).

The Telluric Traverse Method. The telluric traverse (TT) method employs natural earth currents (telluric currents) at various frequencies to measure changes in earth resistivity along a traverse. The TT method was used as early as 1921 (Leonardon, 1928) by C. Schlumberger, but until recently has been little used in the United States. Beyer (1977) discusses the method in some detail and presents a series of model results computed for two-dimensional structures. Beyer concludes that the method is well suited for rapid reconnaissance of several hundred square-kilometers for targets such as hydrothermal systems. The method is applicable to fossil hydrothermal systems because of the longevity of the hydrothermal alteration.

DISCUSSION OF DATA

A southwest-to-northeast AMT traverse was conducted across the Lake City caldera from American Flats to Slumgullion slide (fig. 2). Each station consists of two orthogonal soundings (north-south and east-west orientation of the electric field). The data from the two soundings are averaged and smoothed, and the resulting curve is constrained not to fall or rise more than allowed for a one-dimensional earth. The curves are inverted using an algorithm by Bostick (1977) and the apparent resistivity versus depth cross-section (fig. 4) is constructed. The inversion technique, based on a one-dimensional earth, does not take into consideration lateral effects in areas of complex geology. The result is a rough approximation of vertical resistivity beneath the sounding site.

The major patterns in the cross-section are:

1) high resistivities below stations 3 and 4
2) steeply dipping resistivity gradient between stations 3 and 2
3) low resistivity below stations 4 and 5
4) steeply dipping resistivity gradient between stations 5 and 9
5) high resistivity beneath stations 9, 10, 11, and 12
6) easterly dipping resistivity gradient (400 and 630 ohm-m contours) under stations 12 and 8
7) low near surface resistivities below stations 8, 13, and 15

The high resistivities of stations 3 and 2 near American Flats appear to be caused by the Precambrian granite. The values (2500 to 6300 ohm-m) are normal for moderately unweathered granite.

The steeply dipping resistivity gradient between stations 20 and 4 indicates the location of the ring fault. Our assumption is supported by the mapped ring fault location (Lipman, 1976) and the TT data described below.

Stations 4 and 5 are in the Burrows Park area. The anomalous low resistivities (63 to 400 ohm-m) are attributed to localized hydrothermal activity and perhaps mineralization; the lowest values are at a depth of approximately 1.5 km (fig. 4). Burrows Park has produced some base metals (Brown, 1926), however, the low resistivities could be attributed to intense alteration of the chemically different megabreccias that interfinger with the Sunshine Peak tuff. The eastern portion of the area is partially inside the proposed wilderness.

A second steeply dipping resistivity gradient between stations 5 and 9 east of Burrows Park suggests a contact between the intracaldera quartz syenite intrusive and the Sunshine Peak tuff/megabreccia. The Sunshine Peak tuff/megabreccia deposit is shown on the simplified cross-section (fig. 4). Gravity and magnetic modeling also suggests a boundary (Grauch, personal commun., 1984) at this location.

The high resistivity values beneath station, 9, 10, and 11 suggests the intracaldera quartz syenite intrusive extends down to the maximum depth of exploration.

Stations 12 and 8 show a gentle east-dipping resistivity gradient (400 and 630 ohm meter contours). The gradient appears to follow the contact between the intracaldera quartz syenite intrusive and the Sunshine Peak tuff/meggabreccia.

The near surface ($\leq$ 1000 m) low resistivities (<400 ohm-m) of stations 8, 13, and 15 are related to the widespread alunization of Red Mountain, local alteration, and mineralization near station 15. Station 13 (fig. 4) is approximately located over the conduit for the quartz latite intrusion (Lipman, 1976). Because station 13 has low near-surface resistivities, the depth of exploration is limited by electrical channeling in the conductive surface. The resistivity values do suggest a lower limit for the alteration, because the resistivities of stations 8, 13, and 15 show increasing resistivties with depth.

A telluric traverse (TT) made normal to the mapped caldera ring-fracture located the ring fault in the Burrows Park Valley fill (fig. 3). The data are presented as curves of relative telluric voltages (appendix 3). A value of 1.0V is arbitrarily assigned to one dipole on the traverse; for each frequency, the values of all other dipoles are computed relative to the assigned dipole. The voltages are then plotted on a logarithmic scale (fig. 5). The expression of the ring fault can be seen as a drop in relative TT voltage at all measured frequencies. This is in good agreement with Lipman's 1976, and Hon's more recent (written commun., 1984) mapping of the ring fault. The low voltages also suggest alteration and perhaps mineralization of rock in Burrows Park.

CONCLUSIONS

The presence of some Pb-Zn-Ag mineralization, a 0.25-1.5 Km deep conductive zone (AMT stations 4 and 5, fig. 4), low relative TT voltages (TT stations 3 to 6), a nearby hydrothermal conduit (ring fault), and a close mid-Tertiary post-caldera quartz syenite intrusive (thermal engine) suggests that the rocks beneath Burrows Park have been altered and perhaps mineralized. The suggestion of mineralization, however, must be tempered with the knowledge that the interfingered Sunshine Peak tuff and meggabreccia may only be highly altered.

Red Mountain with its widespread hydrothermal alteration and low near-surface resistivities (<1000 m), may be a target for further geologic and geophysical work.

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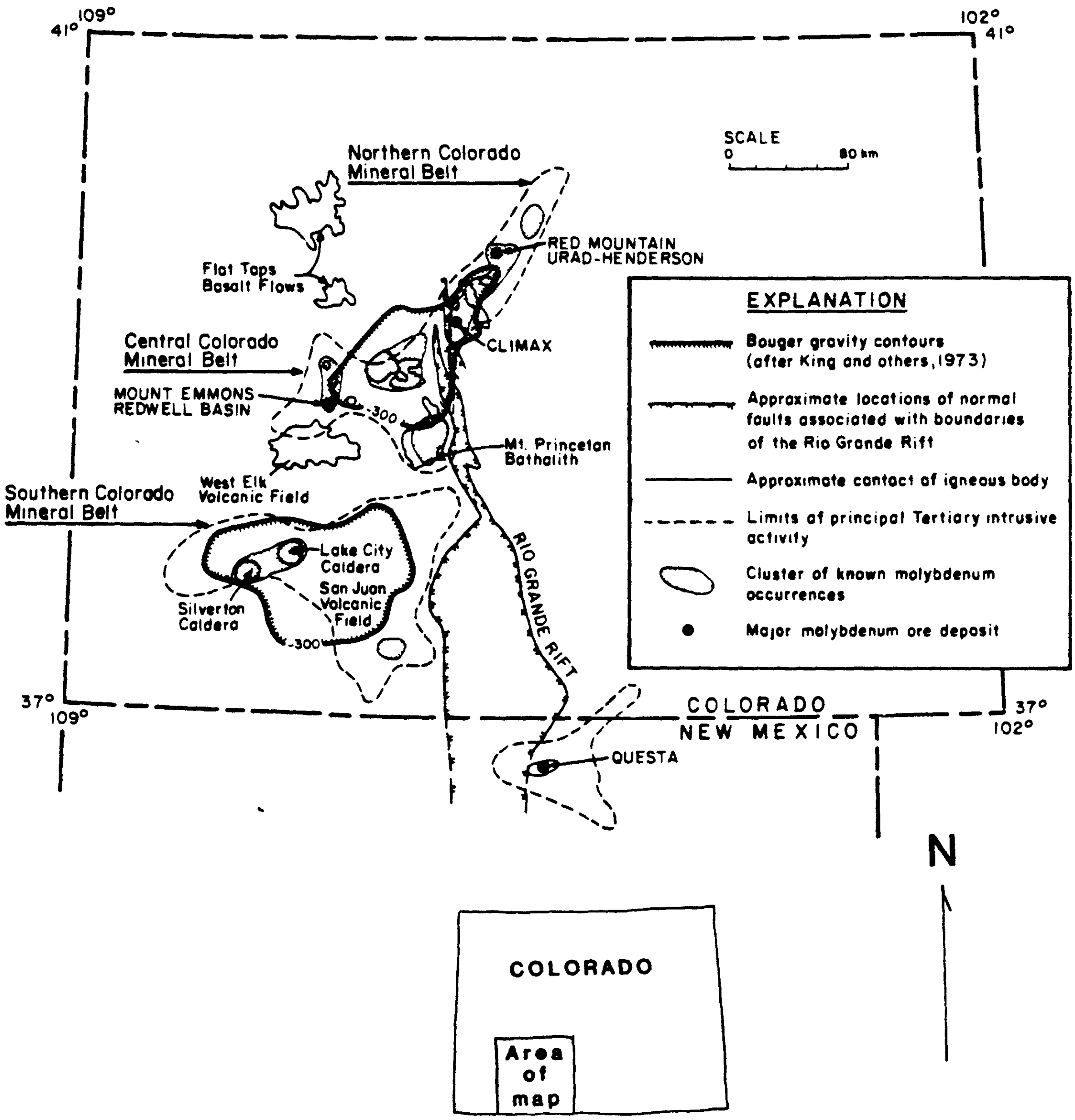


Figure 1 Location map for the Lake City caldera, southern Colorado mineral belt, northern Colorado mineral belt, and molybdenum deposits (from White et al, 1981)

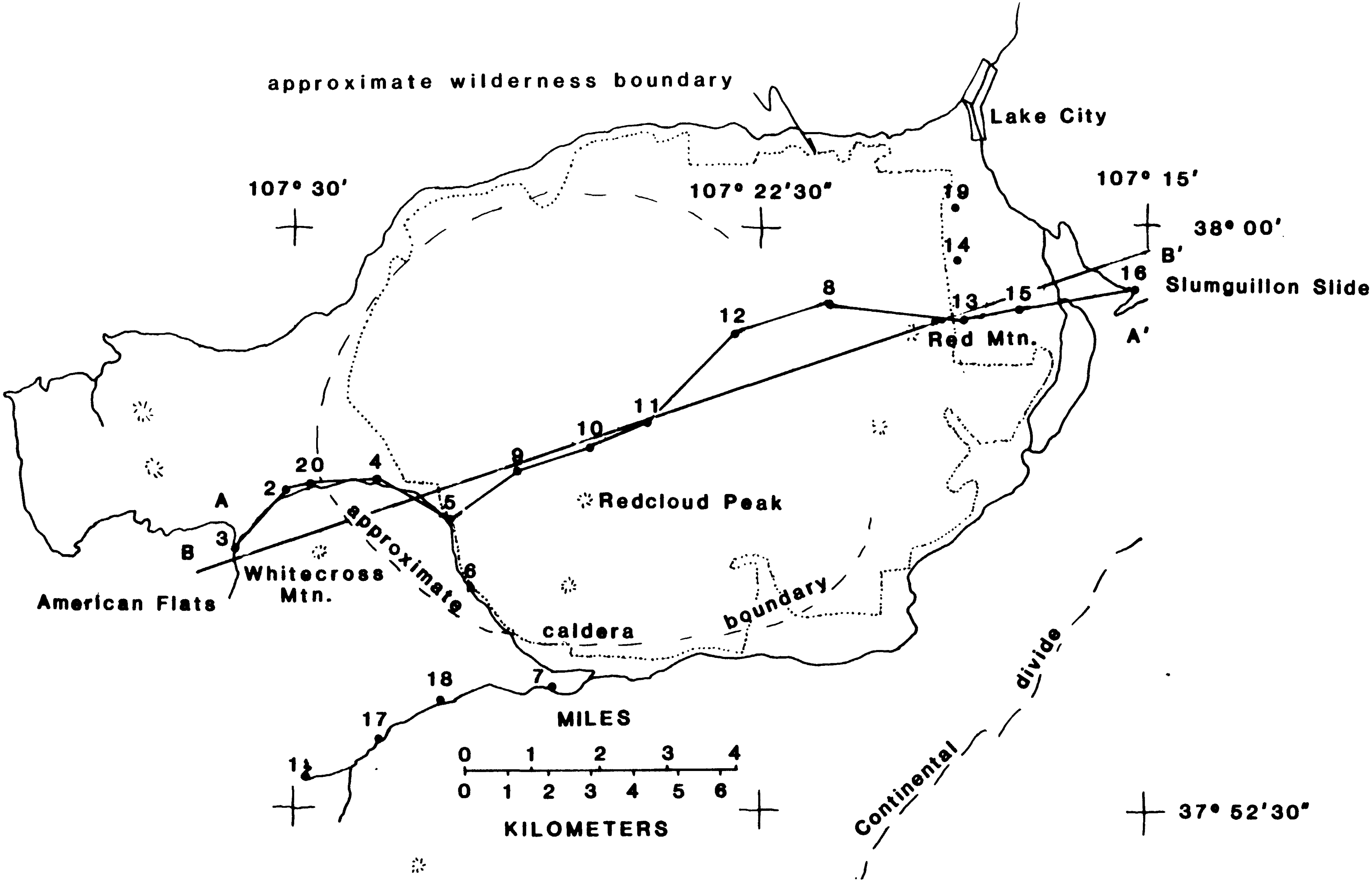


Figure 2 Audio-magnetotelluric sounding location map of Lake City area, Colorado. The mapped caldera ring fracture and proposed Red Cloud Wilderness boundary are shown. A to A′ is the location of the resistivity cross-section. B to B′ is Lipman's 1976 east-to-west cross-section location.

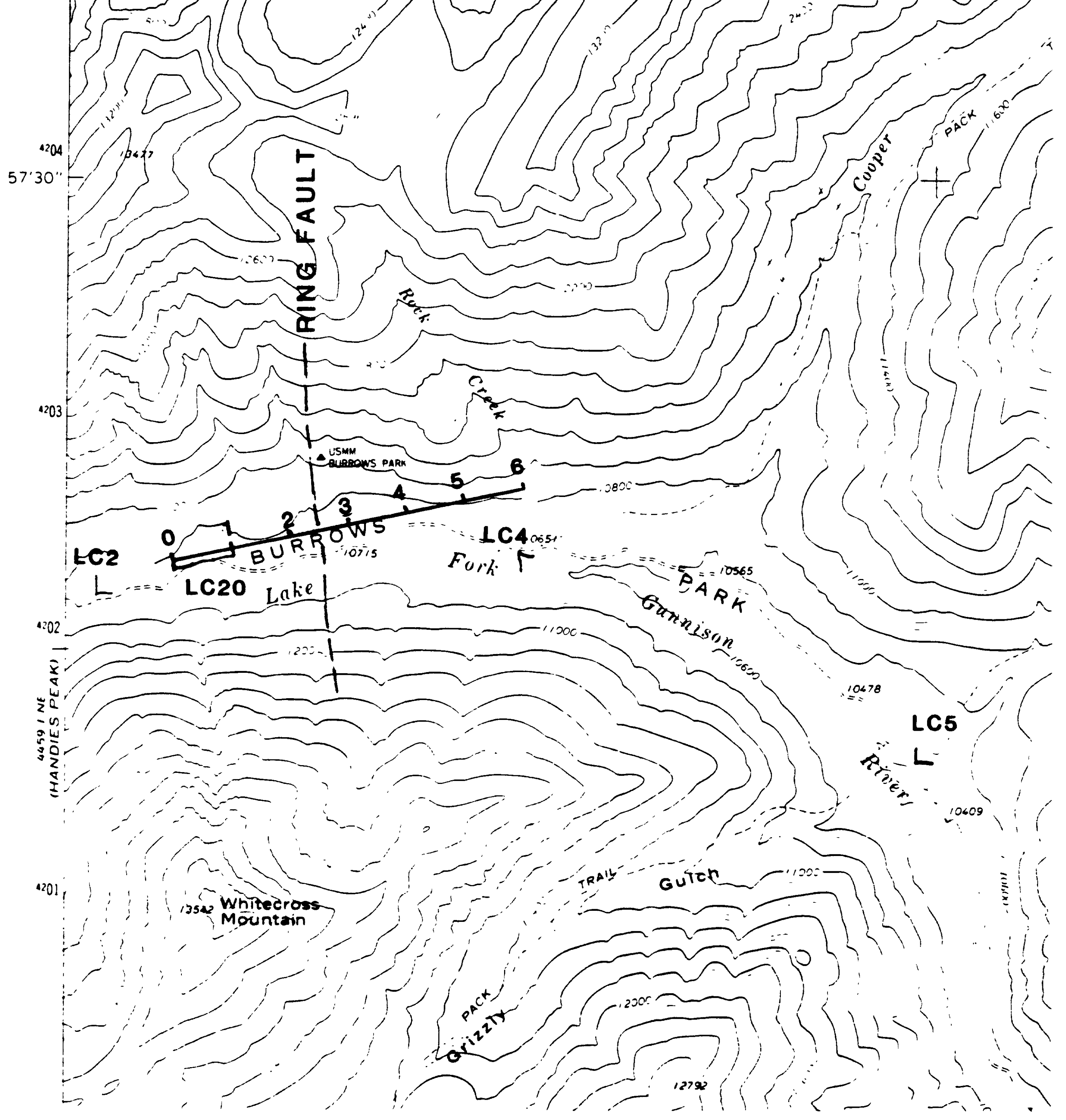


Figure 3 Telluric traverse location map from Red Cloud 7.5' Quadadrangle, Colorado. Dipoles are 250 meters long.

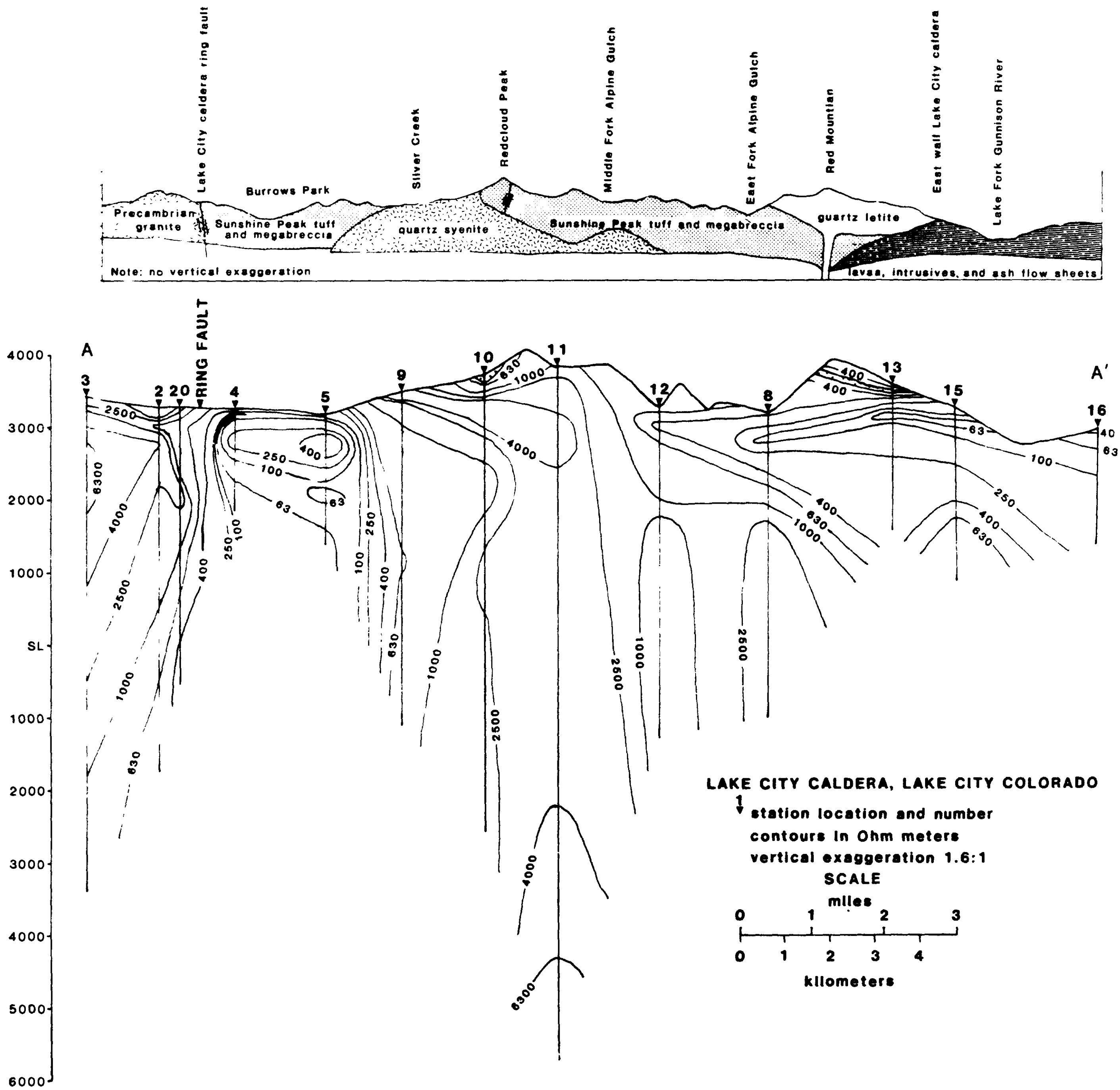


Figure 4 AMT cross-section (A to A') and simplified geologic cross-section (B to B') after Lipman, 1976. The two sections are approximately coincident.

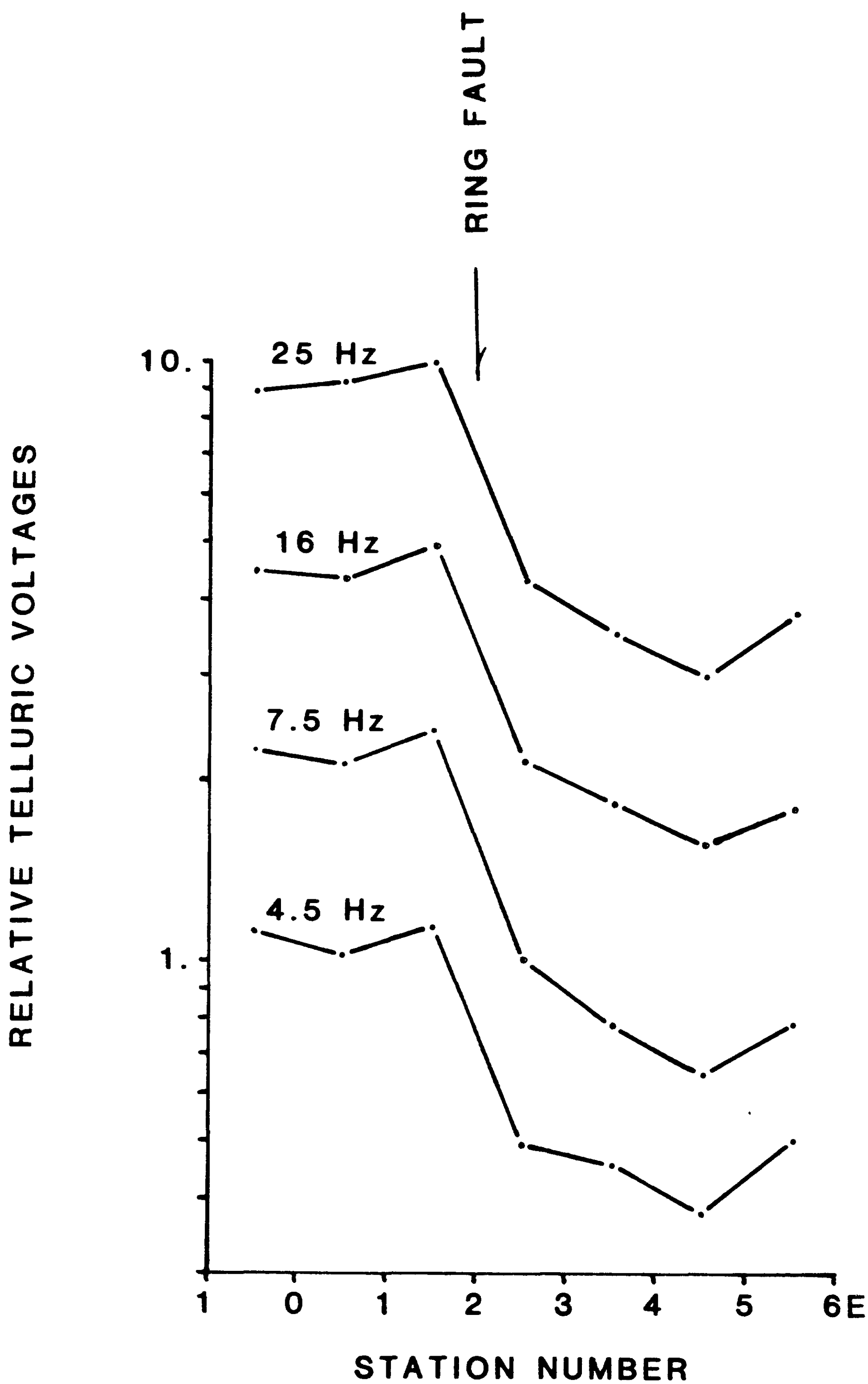
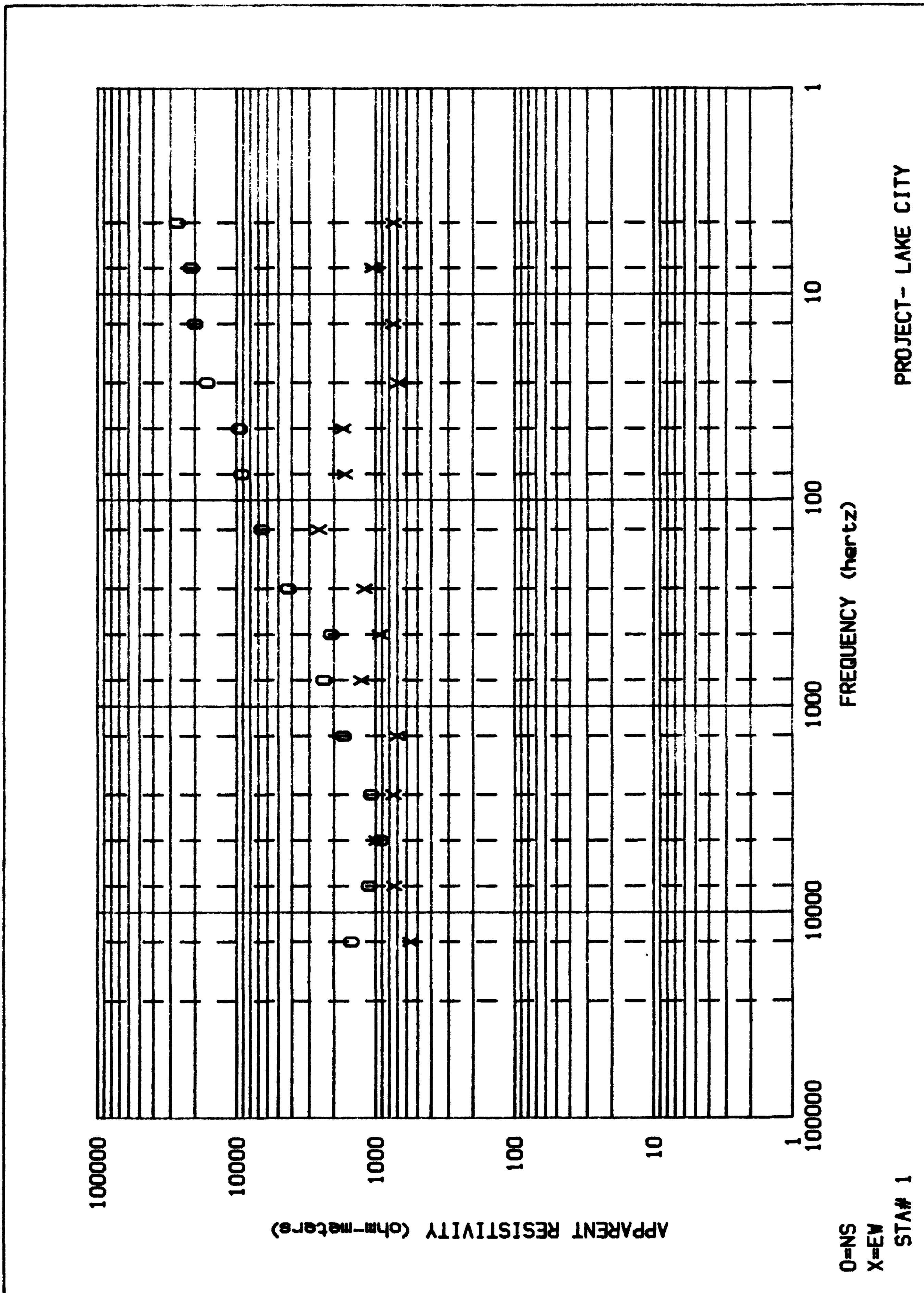


Figure 5 Telluric traverse data Burrows Peak area, Lake City, Colorado, set for the four frequencies. Dipole length is 250 meters.

Appendix 1

Plots of AMT sounding data. Each plot shows apparent resistivity versus frequency for the two scalar soundings at each location. The O (NS) is for a north-south orientation of the telluric dipole and an X is for an east-west orientation. Note that frequency decreases to the right side of the figure corresponding to increasing depth.

Sounding 20 was made on the telluric line using 250 meter dipoles.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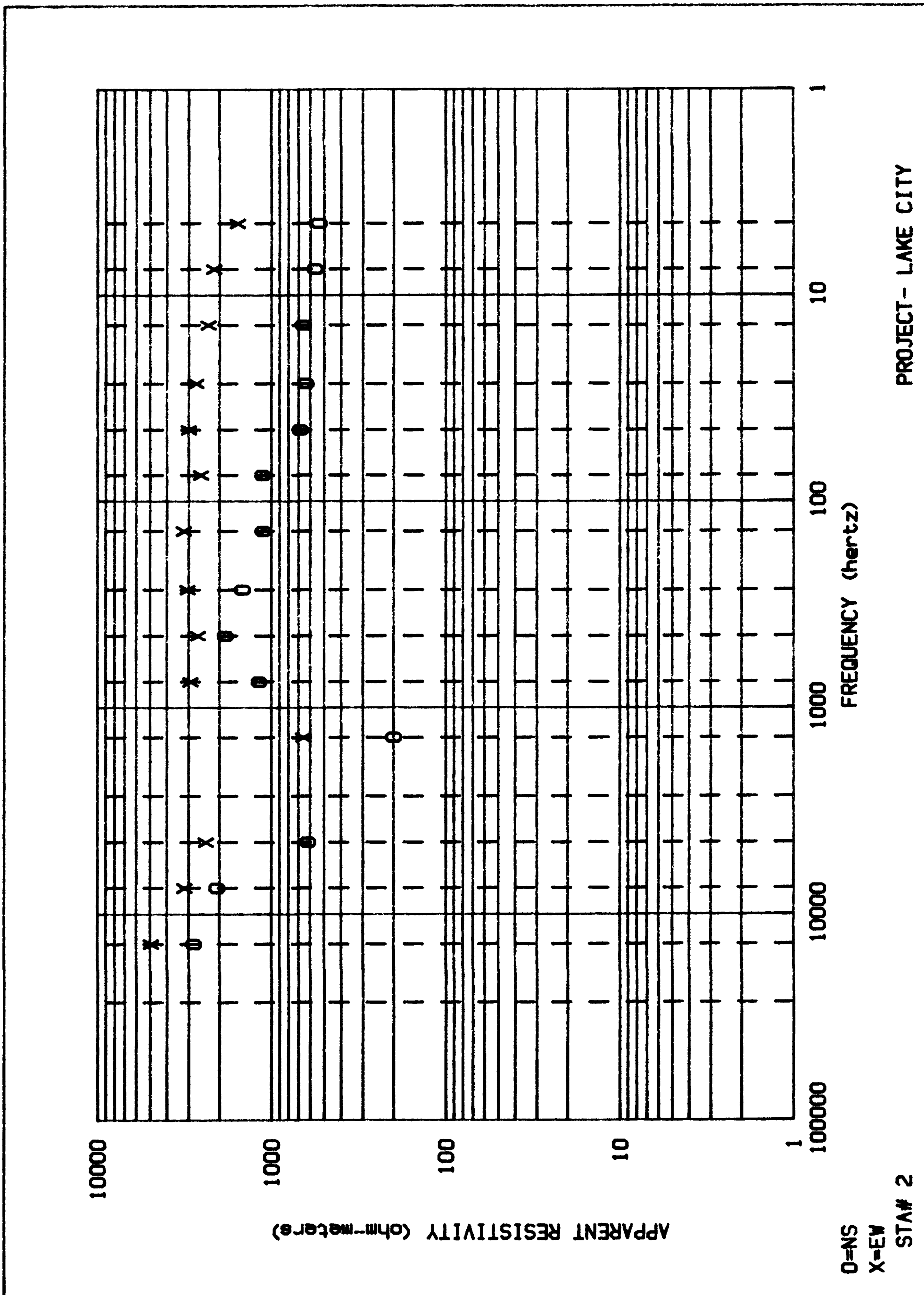
10000
1000
100
10
1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X=EW
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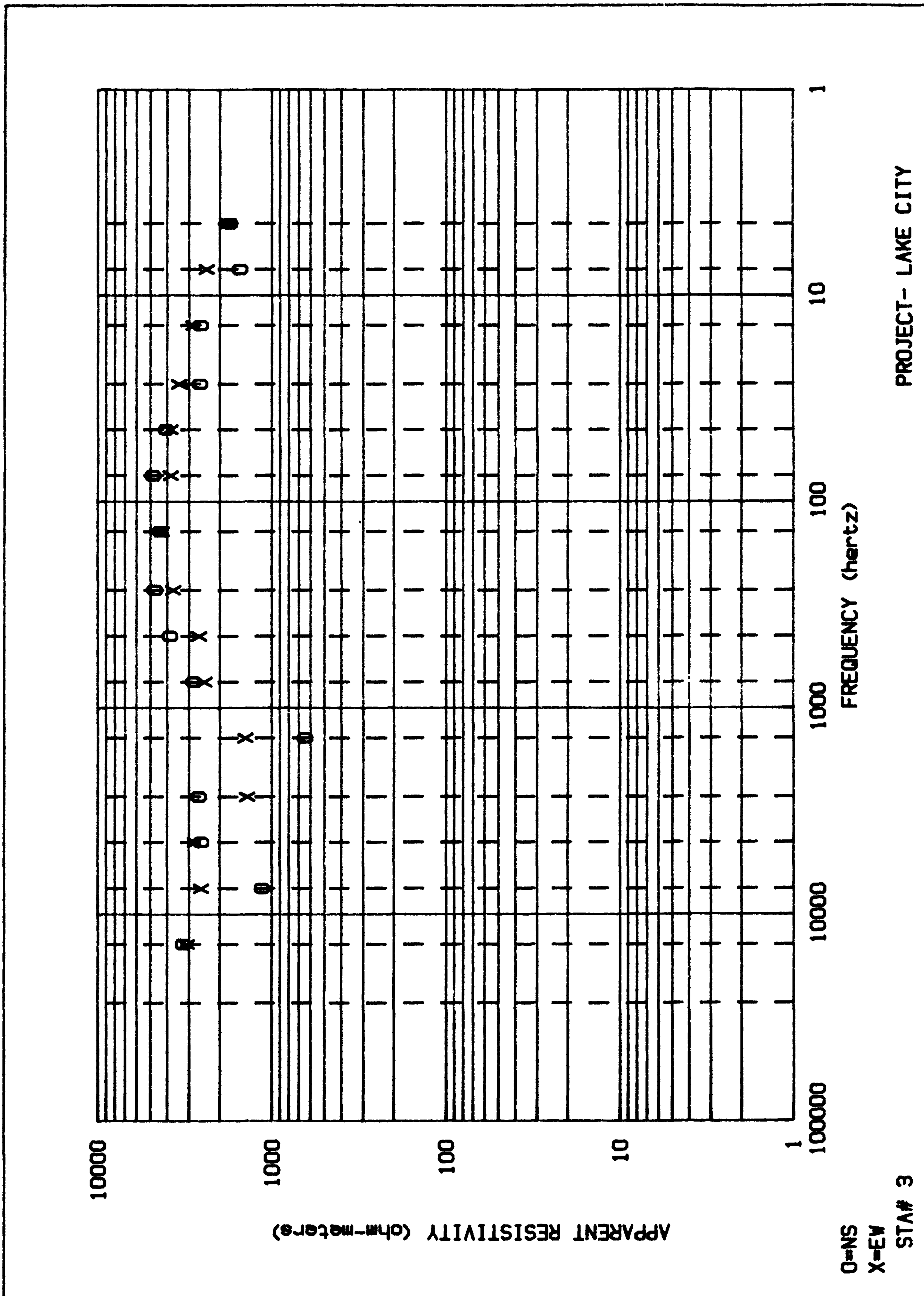
10
1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10
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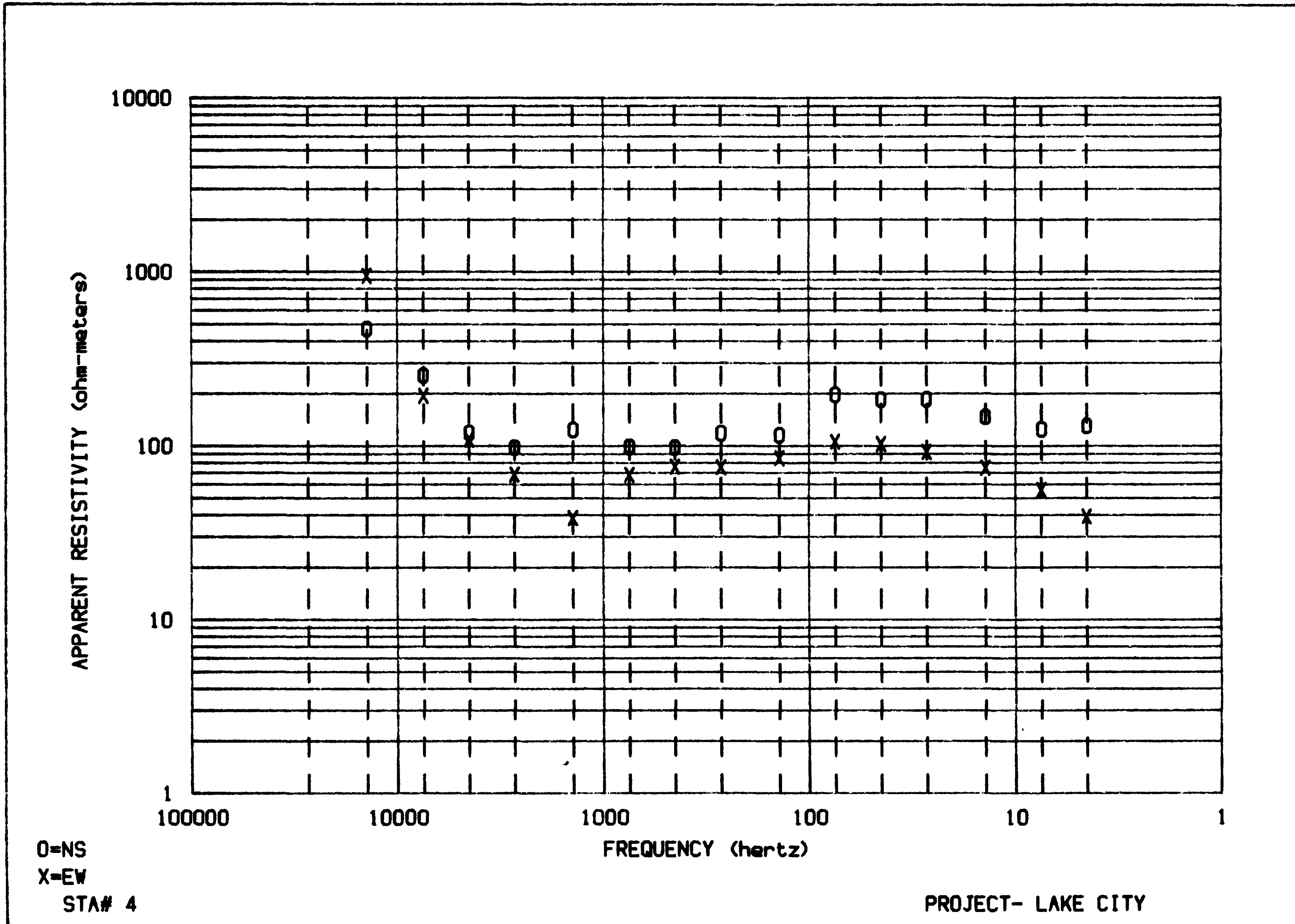
O=NS
X=EW
STA# 3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APPARENT RESISTIVITY (ohm-meters)
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10000
1000
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10
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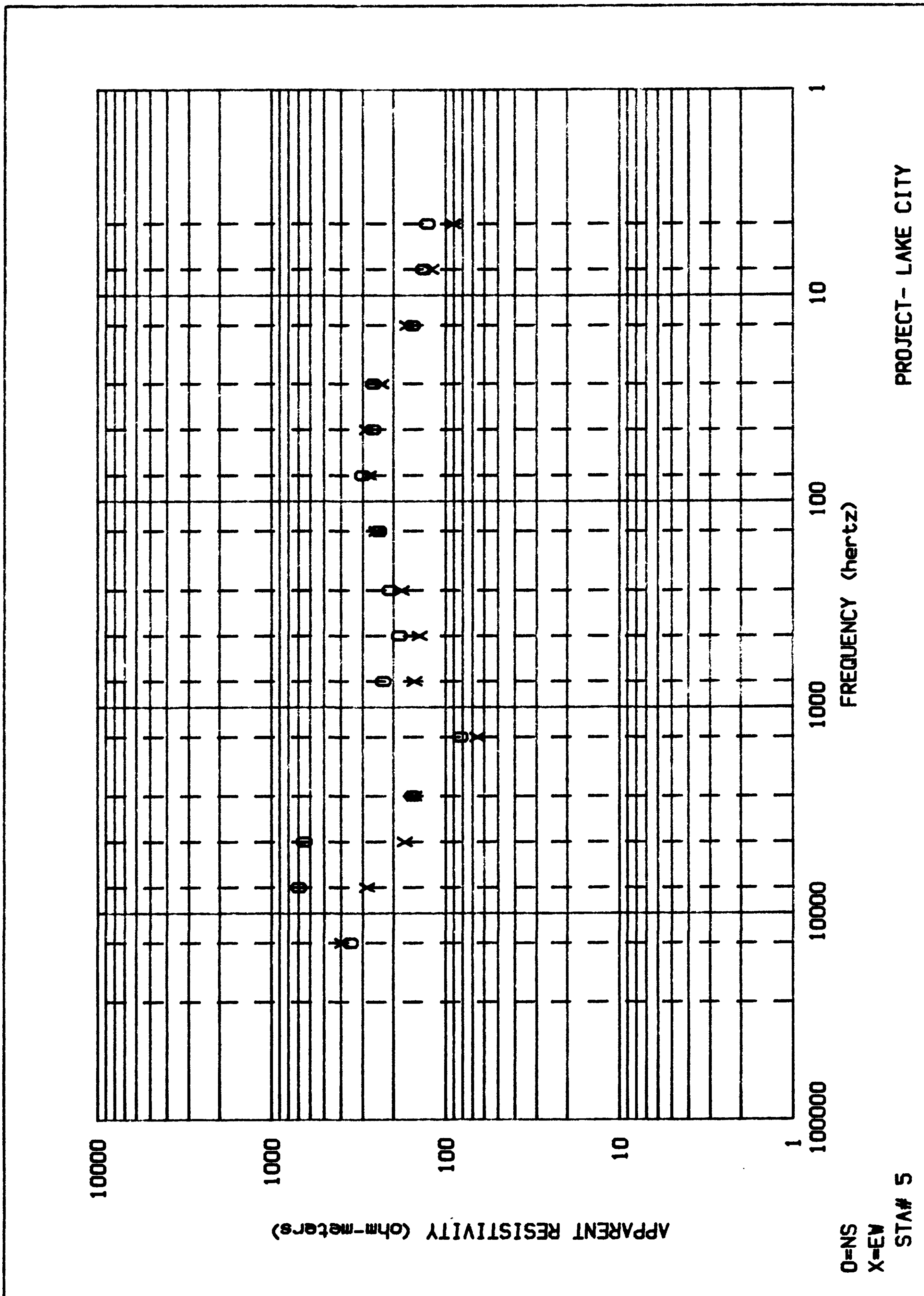
FREQUENCY (hertz)
O=NS
X=EW
STA# 4
PROJECT- LAKE CITY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APPARENT RESISTIVITY (ohm-meters)
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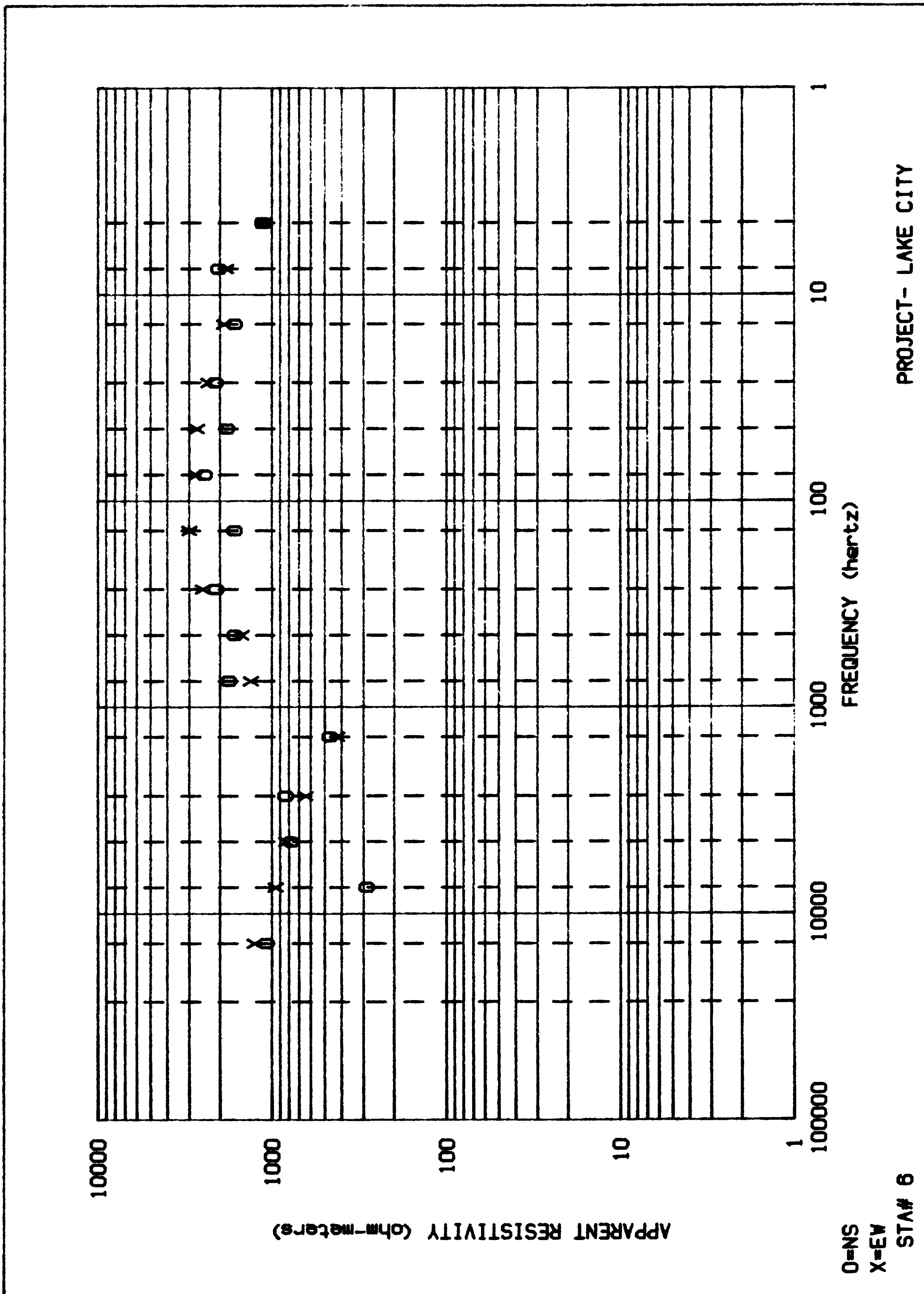
100
10
1
O=NS
X=EW
STA# 5



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10
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FREQUENCY (hertz)
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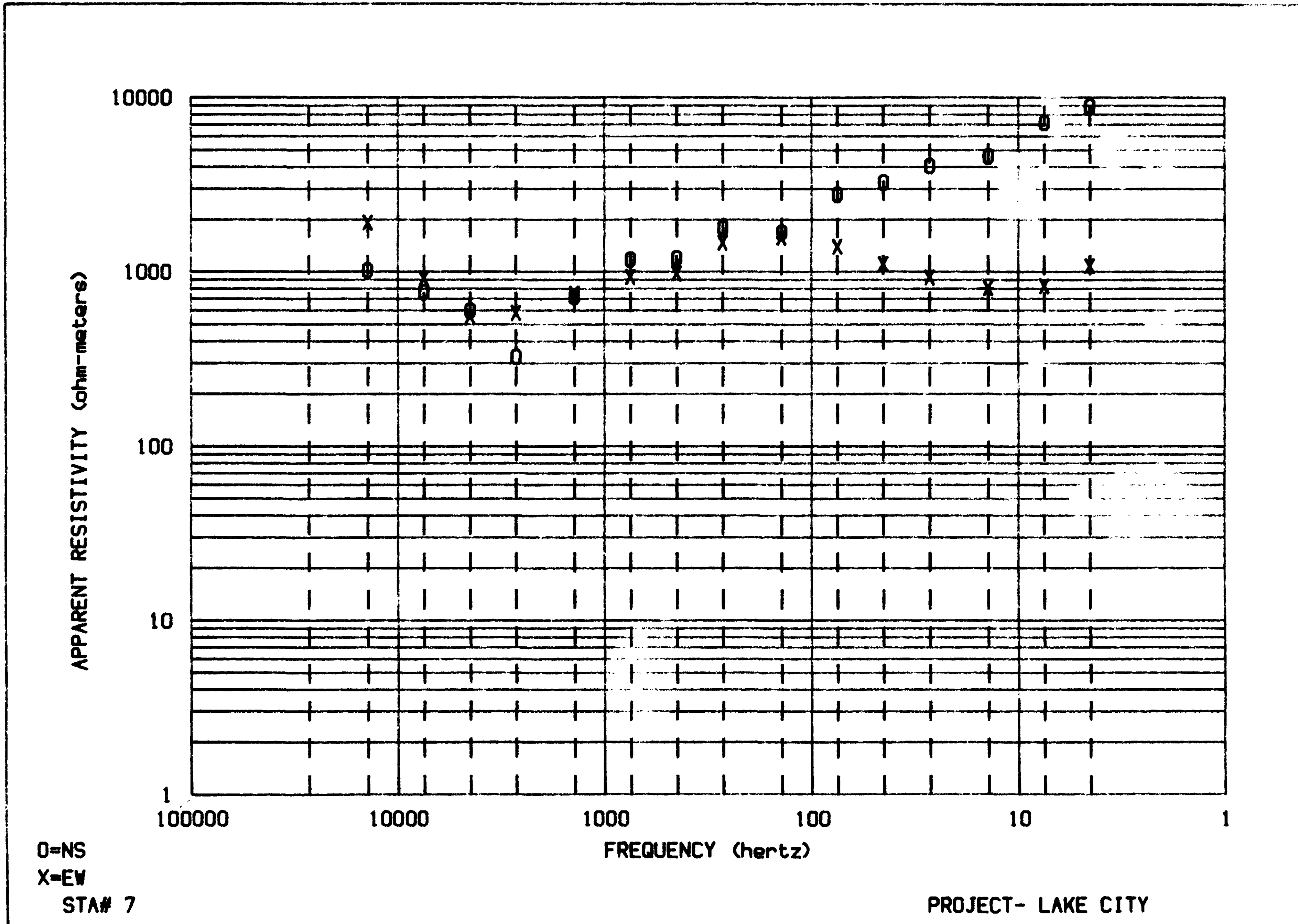
10000
1000
100
10
1
PROJECT- LAKE CITY
O=NS
X=EW
STA# 6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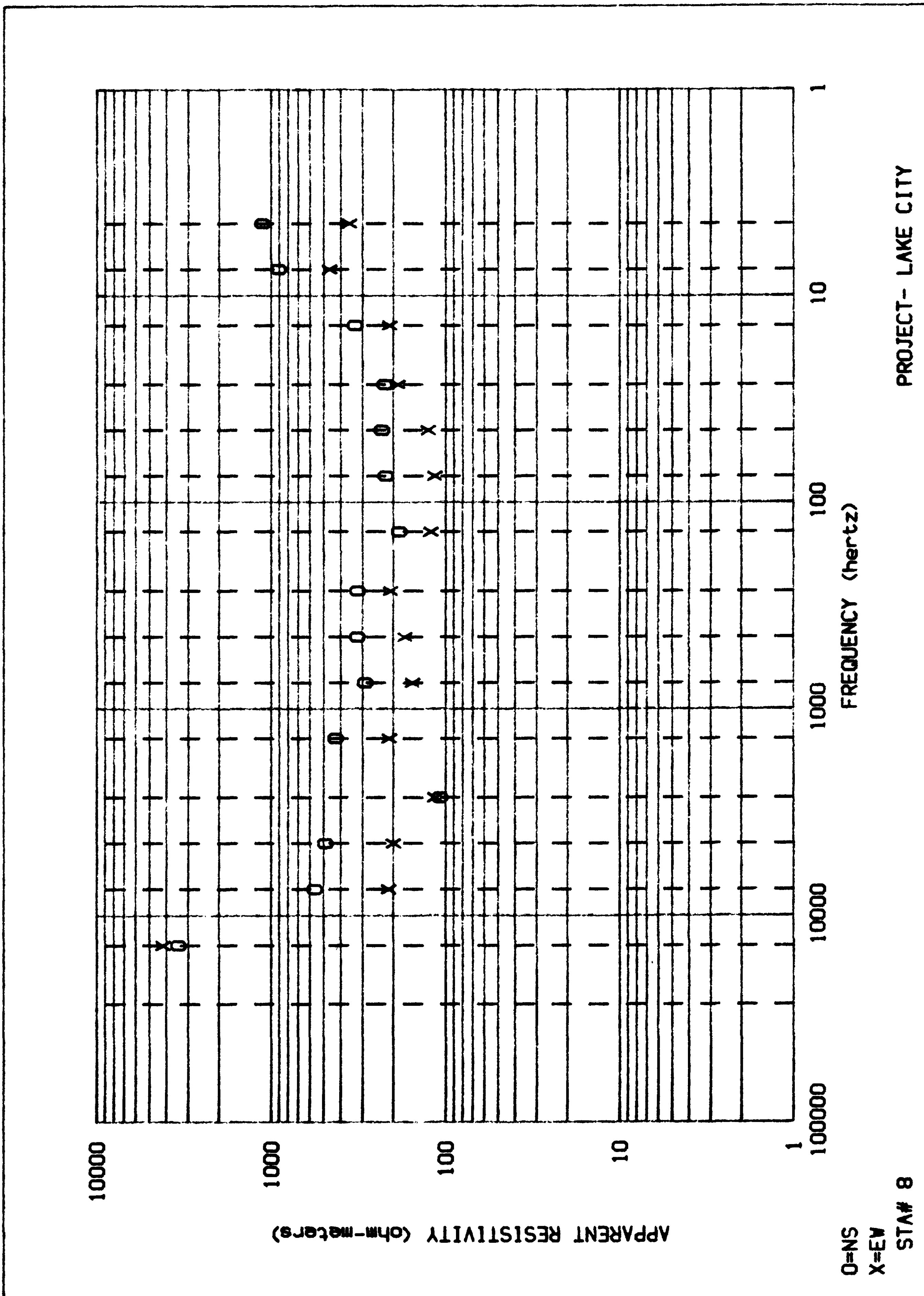
10000
1000
100
10
1
FREQUENCY (hertz)
O=NS
X=EW
STA# 7
PROJECT- LAKE CITY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10
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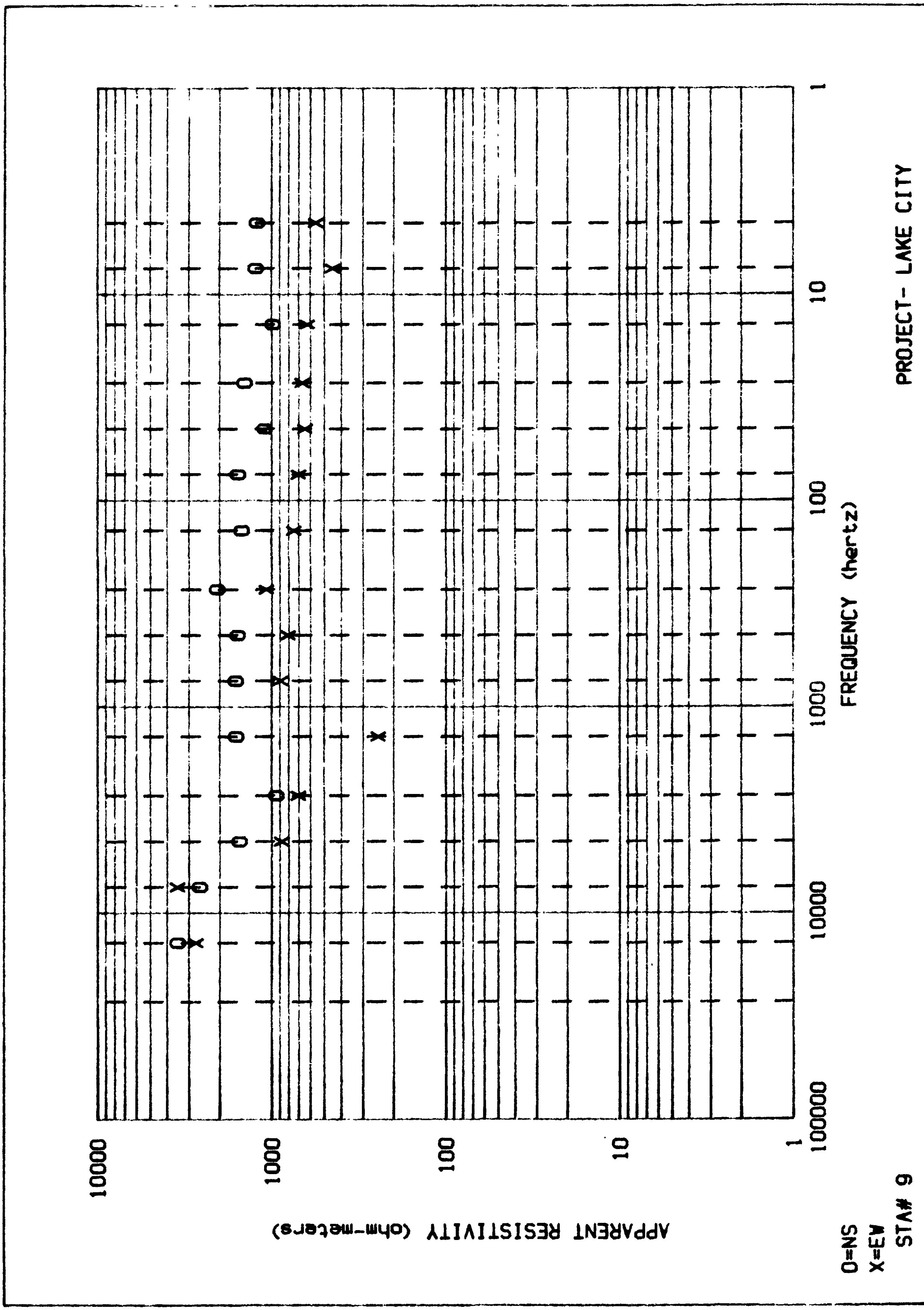
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10
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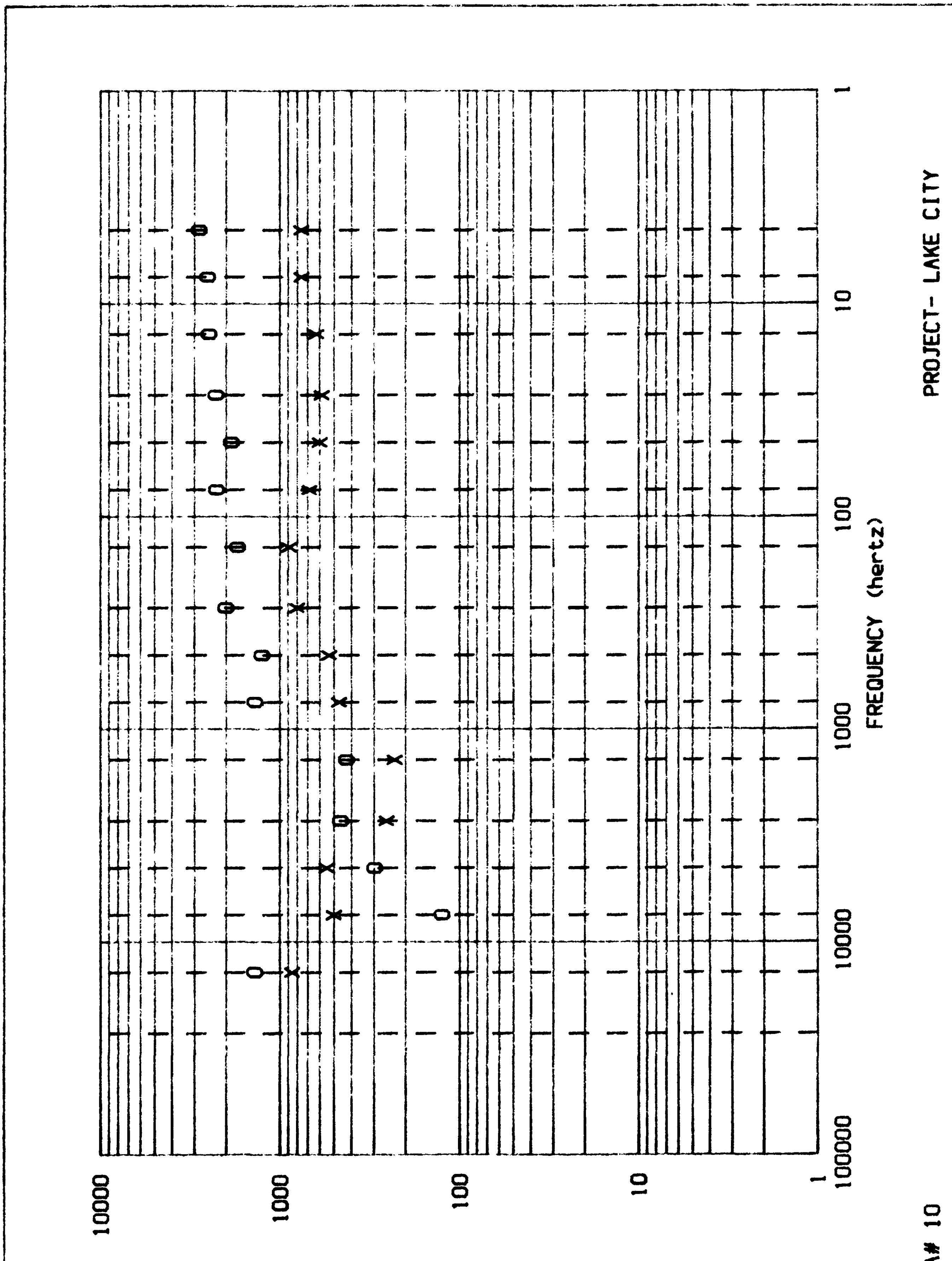

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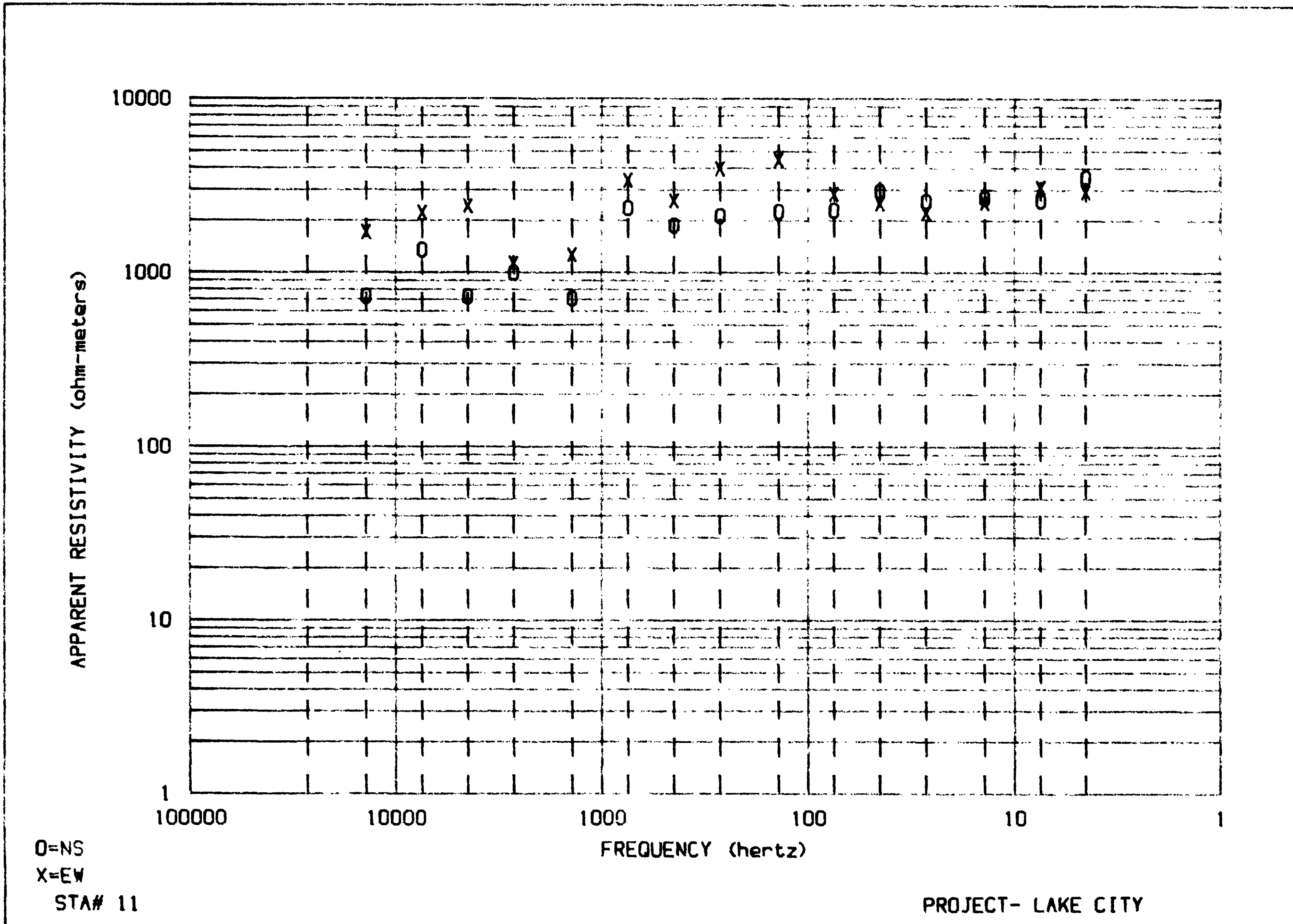
10
1



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APPARENT RESISTIVITY (ohm-meters)
FREQUENCY (hertz)
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X=EW
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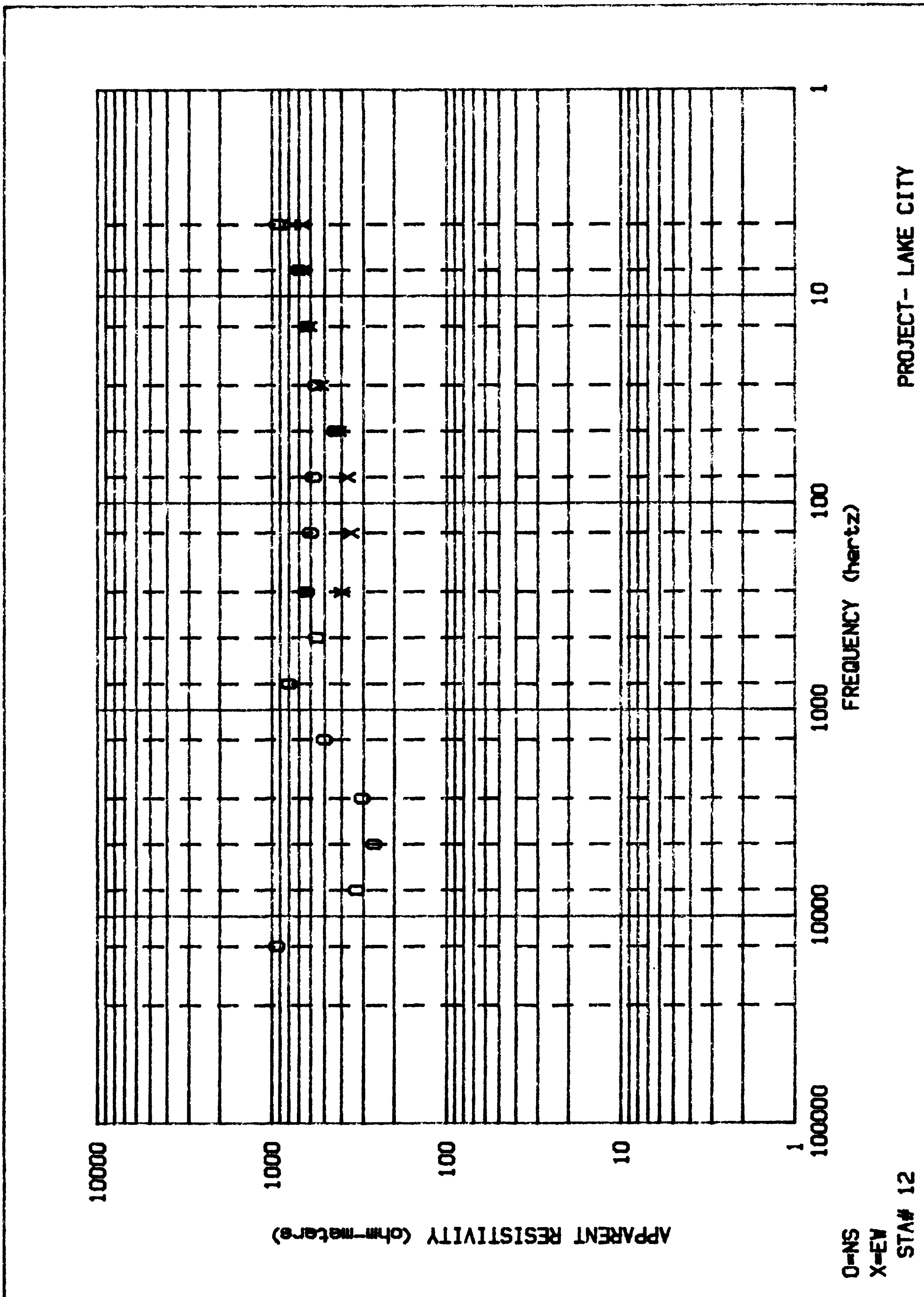
PROJECT- LAKE CITY



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FREQUENCY (hertz)
APPARENT RESISTIVITY (ohm-metre)
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10000
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10
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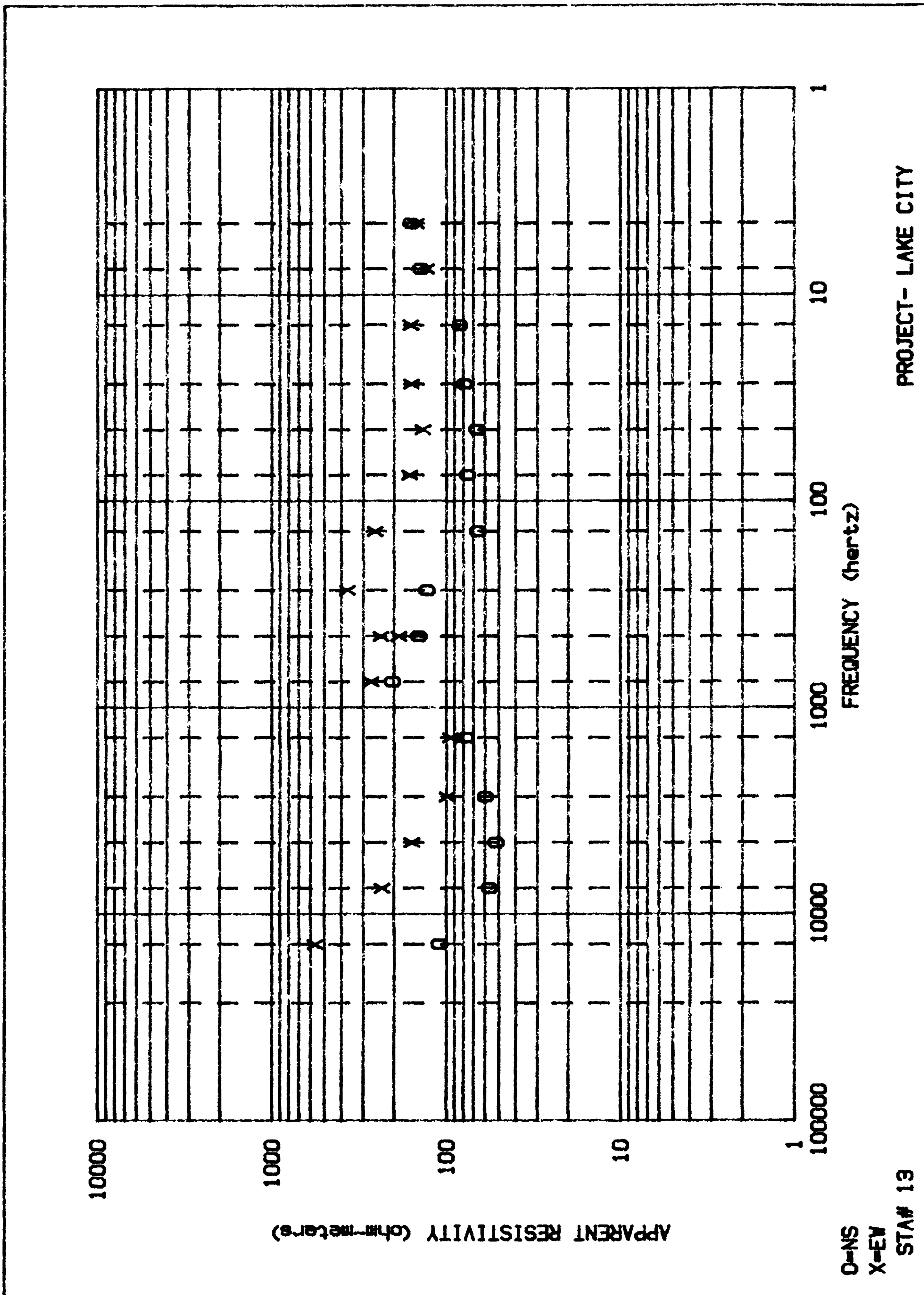

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PROJECT- LAKE CITY
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X=EW
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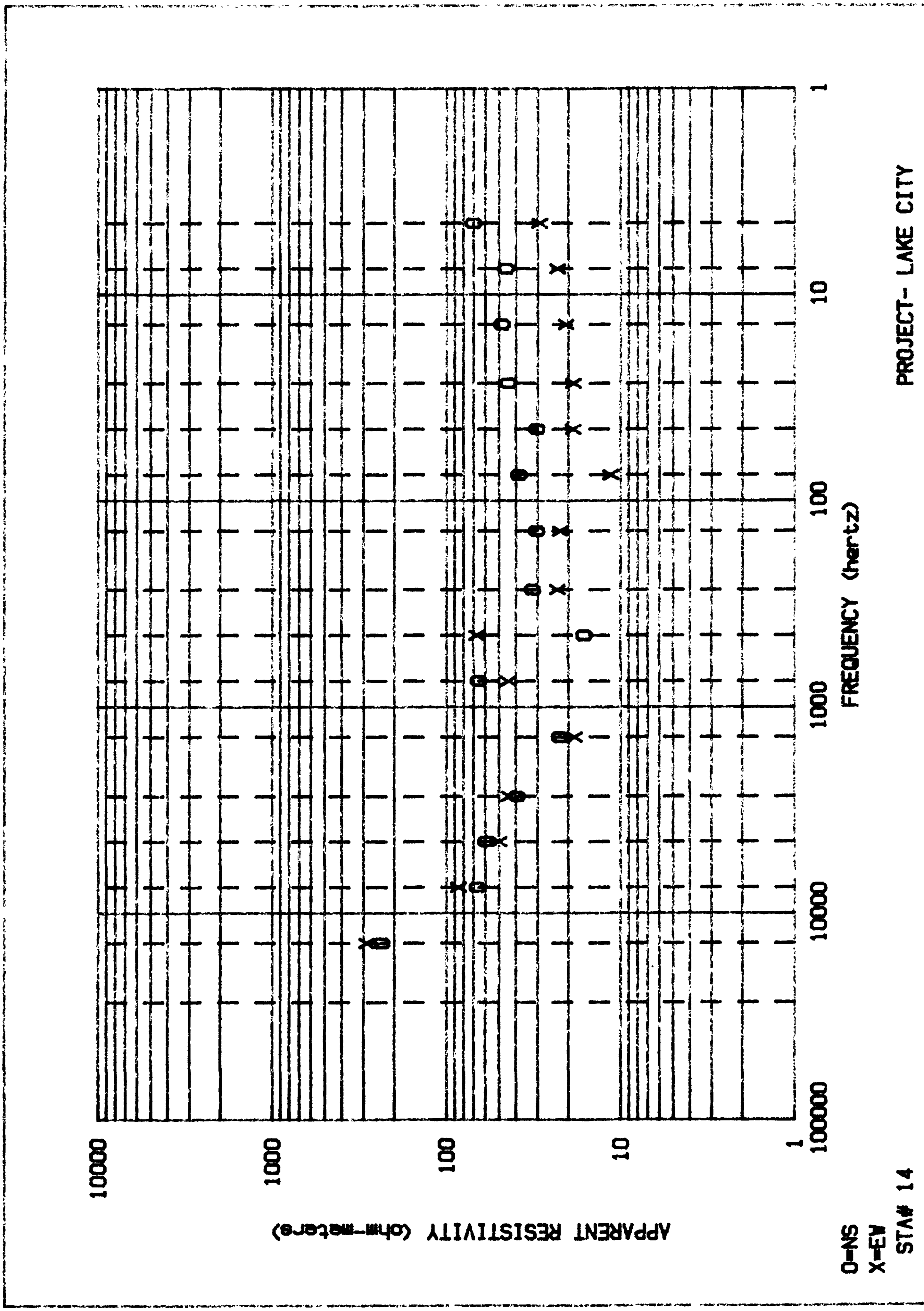
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PROJECT- LAKE CITY
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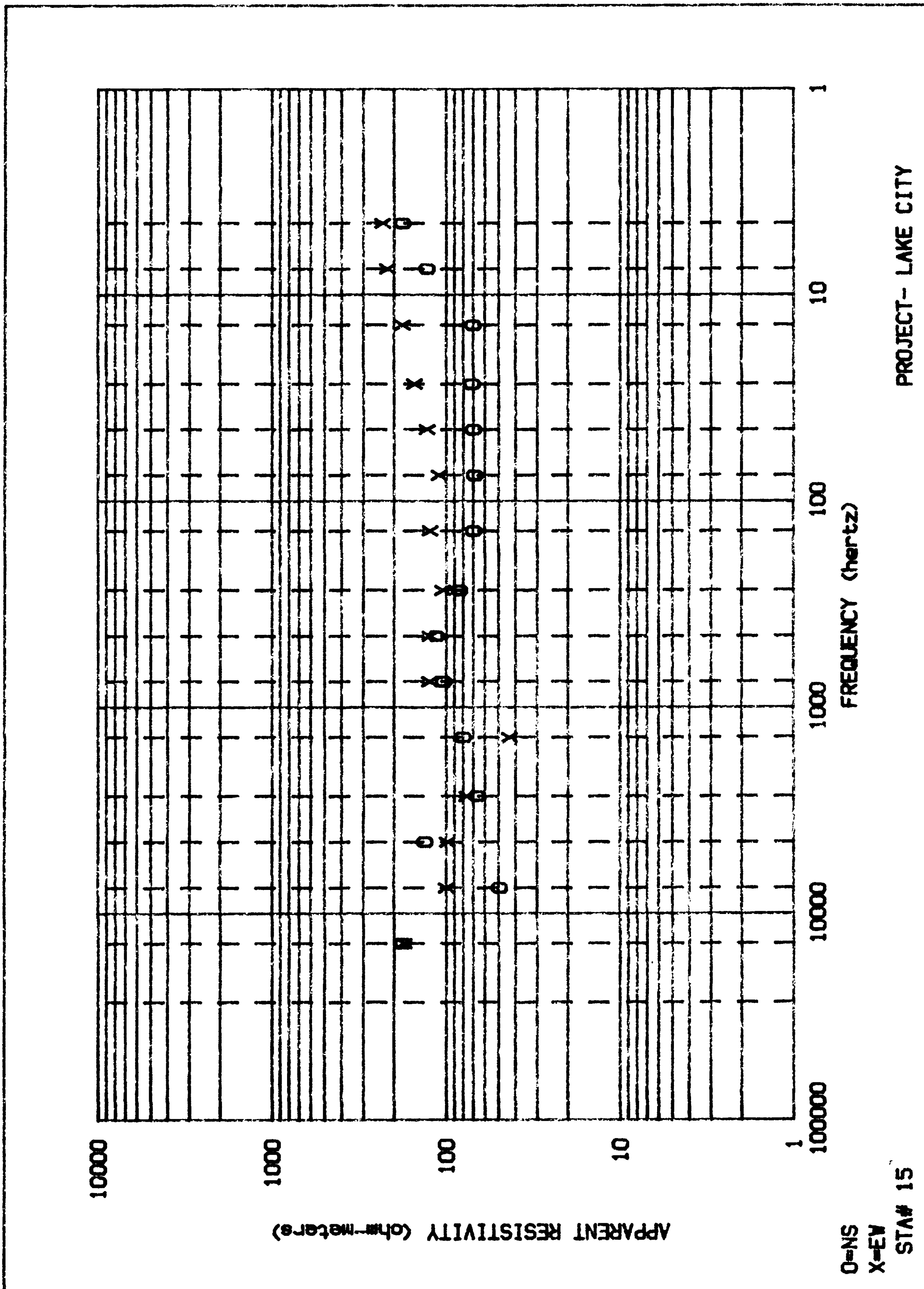
STA# 14



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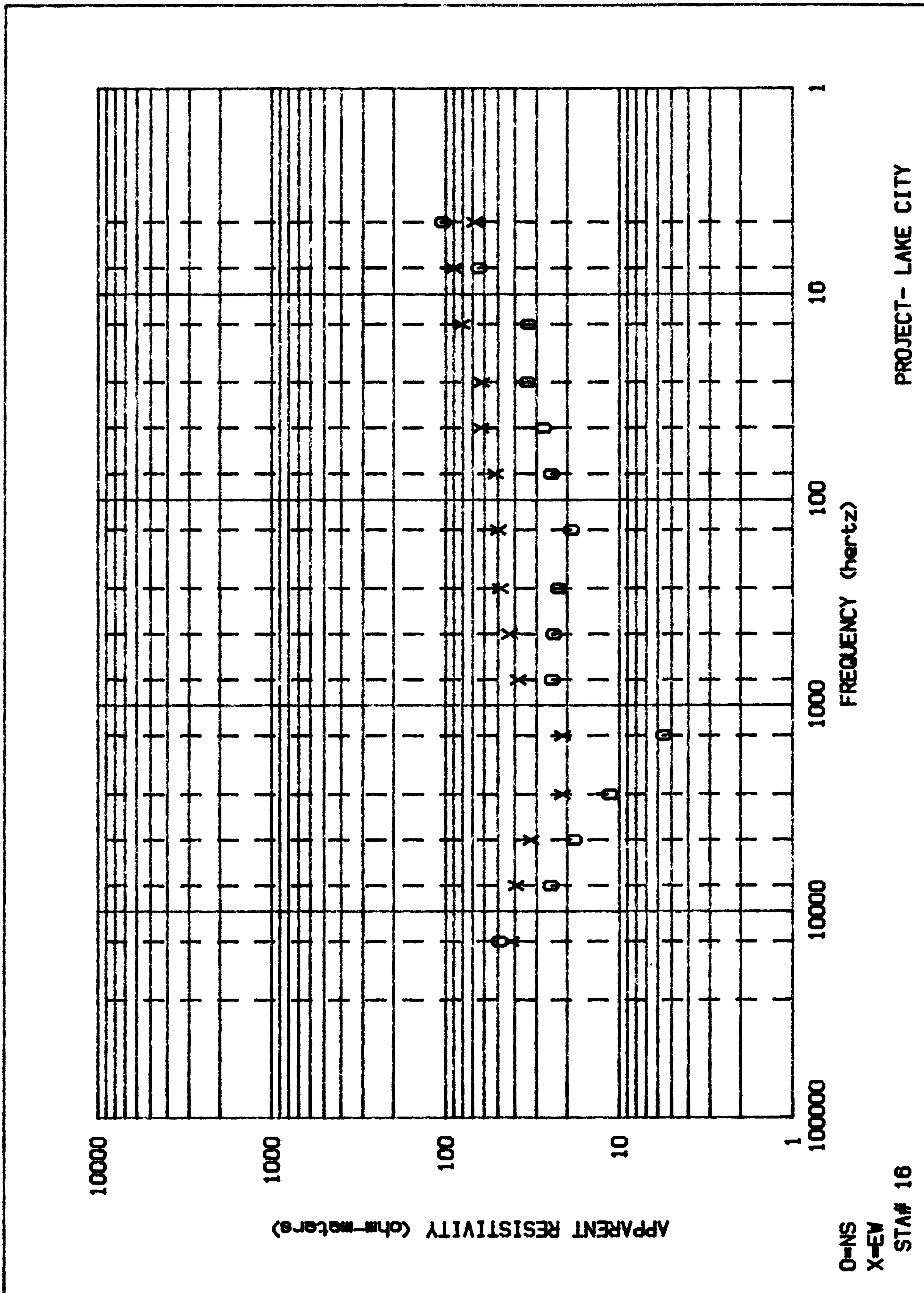

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FREQUENCY (hertz)
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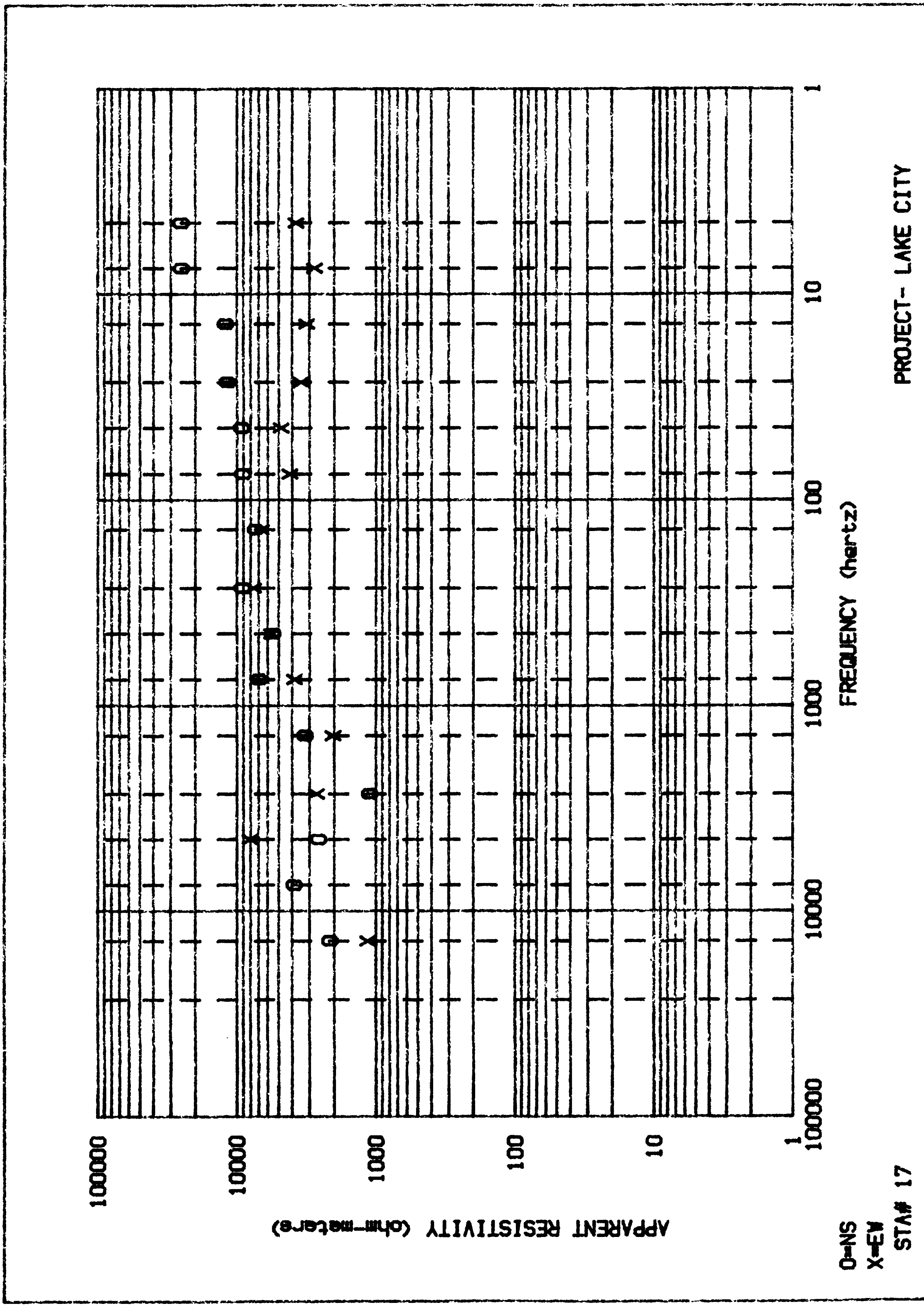
X=EW
STA# 16
PROJECT- LAKE CITY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PROJECT- LAKE CITY
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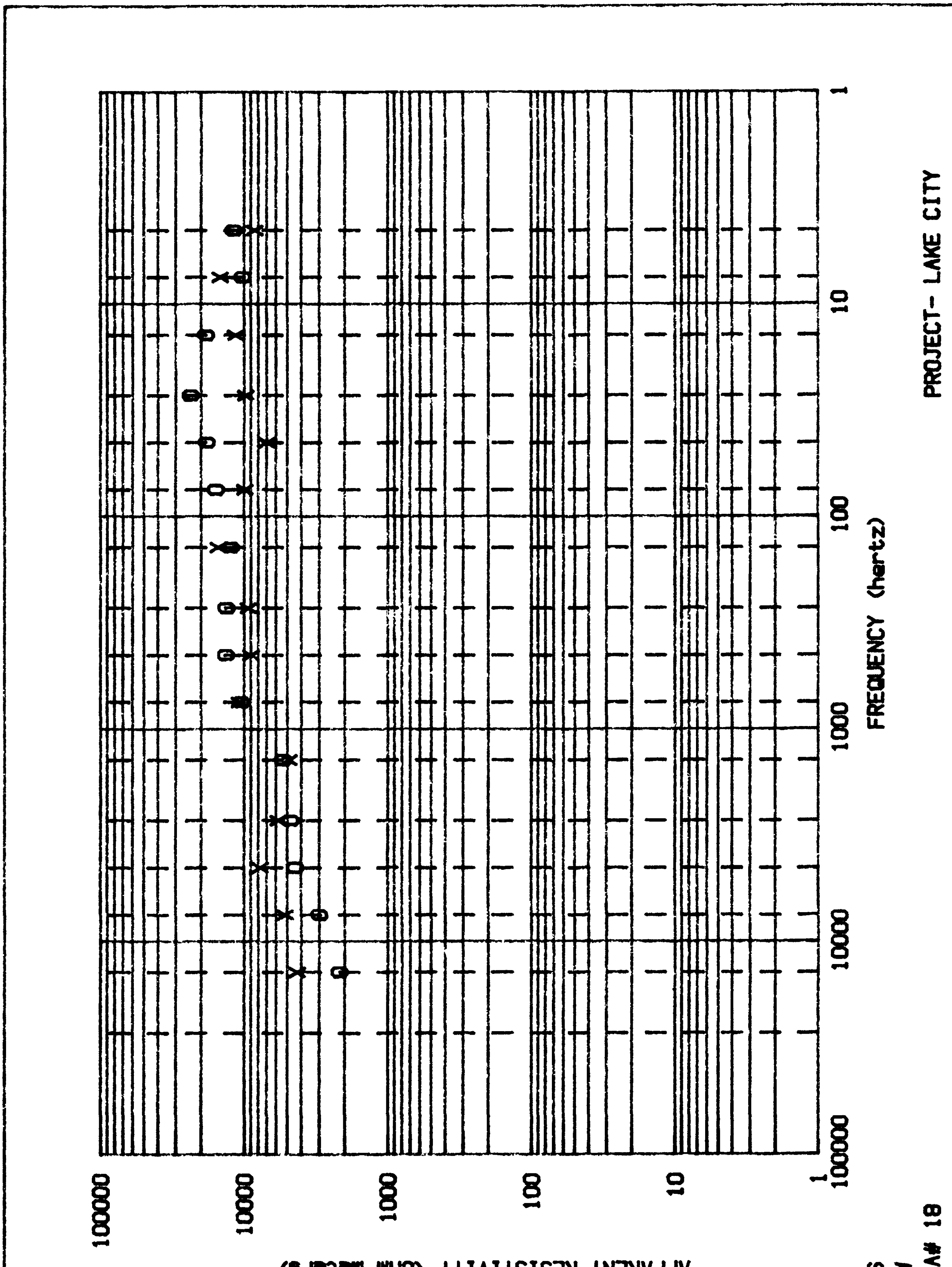
STA# 17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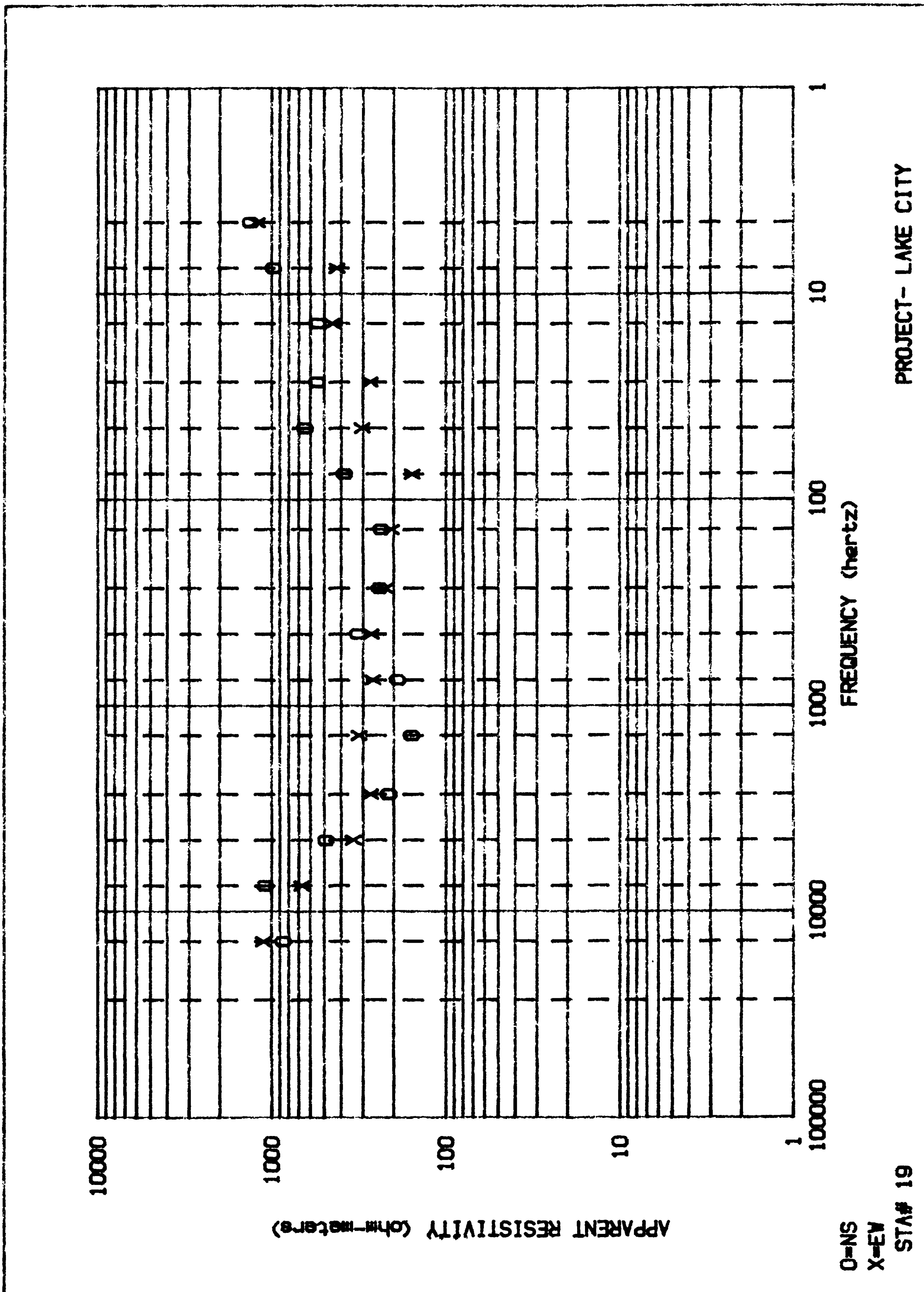
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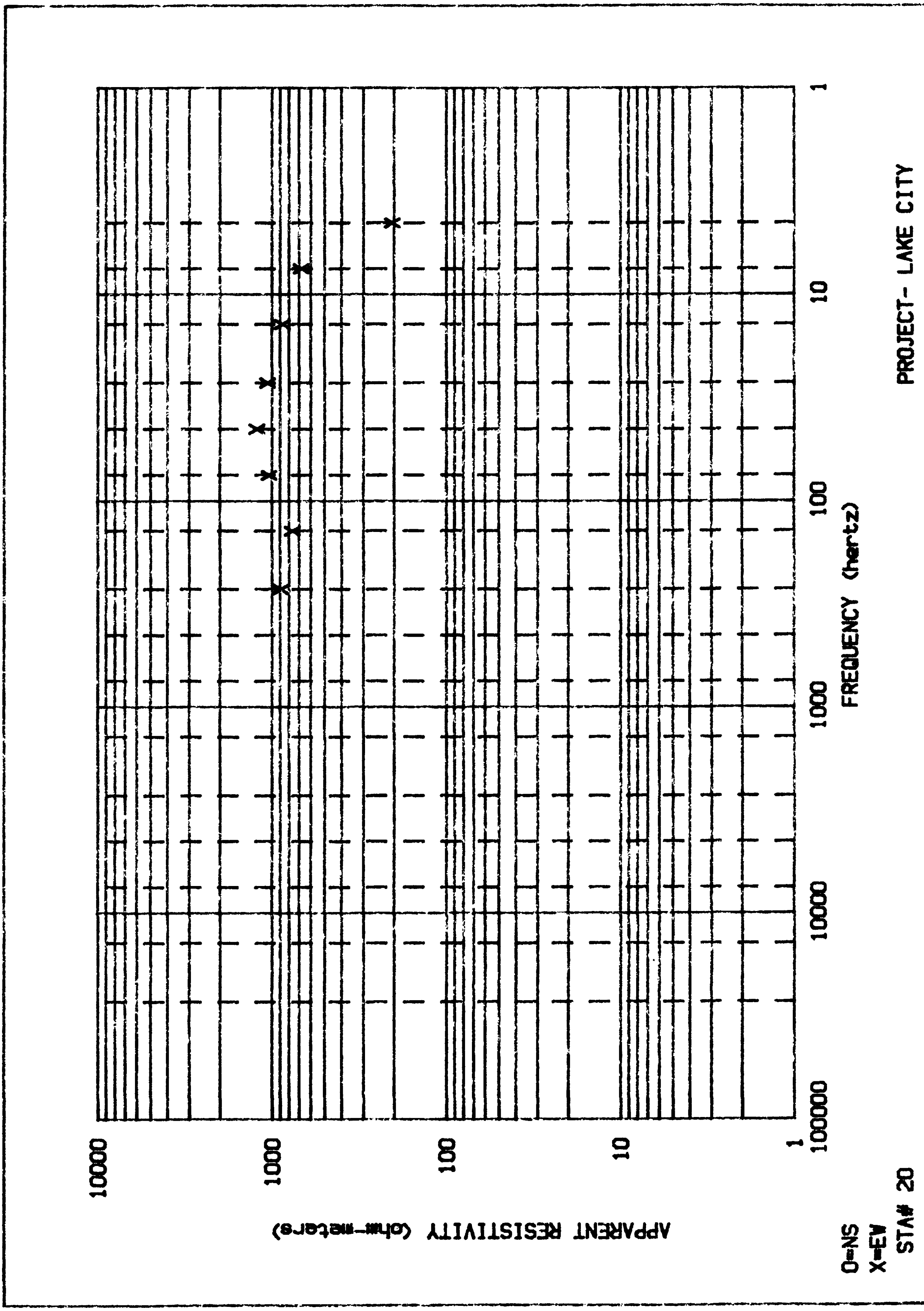
STA# 19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100
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1
PROJECT- LAKE CITY
O=NS
X=EW
STA# 20

Appendix 2

AMT data tables. At each station, two independent scalar soundings are presented. The computer printout lists the orientation of the telluric line for each sounding (NS or EW). The table gives the station number, orientation, and number of frequencies observed, followed by a line showing the frequency, apparent resistivity, number of observations used to calculate the apprent resistivity, and the standard error.

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_1 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	26673.00	13	6368.50
7.5	21260.00	10	1949.10
14.0	19921.00	13	1250.50
27.0	16313.00	14	954.40
45.0	9550.60	13	738.93
75.0	9166.40	13	443.34
140.0	6627.50	12	573.36
270.0	4222.00	13	430.00
450.0	2087.30	16	192.66
750.0	2354.70	13	280.12
1400.0	1708.90	11	283.13
2700.0	1078.80	9	142.30
4500.0	919.88	13	91.10
7500.0	1114.10	7	136.06
14000.0	1498.00	5	69.62

STATION ID_1 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	740.56	7	781.58
7.5	1057.80	11	371.38
14.0	745.16	8	261.68
27.0	683.31	10	129.45
45.0	1706.10	7	527.69
75.0	1656.20	10	581.37
140.0	2554.30	4	1260.10
270.0	1203.90	5	509.88
450.0	930.32	6	290.67
750.0	1267.80	9	463.72
1400.0	702.33	12	164.57
2700.0	745.42	11	174.49
4500.0	982.47	11	198.77
7500.0	733.09	9	52.39
14000.0	559.12	13	27.95

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_2 NS NO FREQ= 14

FREQ	AP-RES	N OBS	STD ERR
4.5	536.38	7	96.32
7.5	564.93	12	67.80
14.0	660.95	11	57.33
27.0	634.97	10	25.41
45.0	686.22	15	56.89
75.0	1130.60	11	107.16
140.0	1120.90	13	115.95
270.0	1475.60	11	93.49
450.0	1851.50	11	76.23
750.0	1179.00	13	101.63
1400.0	199.68	1	0.00
4500.0	617.73	12	72.64
7500.0	2060.70	11	276.13
14000.0	2803.50	8	357.69

STATION ID_2 EW NO FREQ= 14

FREQ	AP-RES	N OBS	STD ERR
4.5	1571.60	11	202.74
7.5	2151.40	12	136.57
14.0	2315.60	13	186.55
27.0	2710.70	13	134.16
45.0	2996.10	12	114.04
75.0	2551.30	11	228.63
140.0	3197.00	12	215.13
270.0	3045.00	13	200.70
450.0	2653.20	11	213.46
750.0	2921.30	11	302.57
1400.0	656.36	4	153.09
4500.0	2382.60	11	156.03
7500.0	3163.00	7	229.66
14000.0	4920.20	8	962.12

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_3 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1753.70	9	1127.70
7.5	1528.30	8	188.26
14.0	2579.50	9	561.19
27.0	2595.70	9	447.08
45.0	4057.50	10	666.03
75.0	4846.60	10	614.05
140.0	4377.20	11	494.32
270.0	4732.40	9	502.25
450.0	3847.90	13	380.73
750.0	2815.50	7	415.44
1400.0	644.67	5	125.72
2700.0	2633.20	4	452.04
4500.0	2548.80	10	459.38
7500.0	1142.00	6	180.47
14000.0	3237.30	12	460.91

STATION ID_3 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1779.20	9	192.02
7.5	2372.60	10	346.39
14.0	2833.40	13	220.00
27.0	3413.40	11	142.01
45.0	3826.60	13	291.58
75.0	3813.60	13	193.08
140.0	4294.80	12	215.11
270.0	3699.30	13	204.97
450.0	2620.80	10	90.87
750.0	2450.10	10	159.49
1400.0	1424.50	7	201.79
2700.0	1389.00	10	107.84
4500.0	2758.20	12	406.37
7500.0	2556.00	5	383.75
14000.0	3093.00	7	279.04

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_4 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	130.02	8	20.17
7.5	124.44	10	10.31
14.0	146.50	11	6.29
27.0	184.32	15	4.17
45.0	183.75	11	10.77
75.0	196.64	13	6.49
140.0	115.06	10	5.17
270.0	117.94	11	3.29
450.0	97.67	10	2.24
750.0	98.78	11	6.68
1400.0	123.74	10	33.08
2700.0	97.62	11	6.65
4500.0	118.62	13	10.12
7500.0	253.66	7	14.12
14000.0	469.46	11	55.59

STATION ID_4 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	39.05	12	2.76
7.5	55.62	13	3.19
14.0	74.63	15	2.44
27.0	92.11	11	2.48
45.0	102.46	11	4.89
75.0	105.62	9	6.19
140.0	85.03	11	2.57
270.0	75.18	12	3.06
450.0	75.81	10	4.08
750.0	68.13	9	3.44
1400.0	38.31	9	10.94
2700.0	68.39	9	3.85
4500.0	108.90	11	5.44
7500.0	193.99	12	17.52
14000.0	945.47	8	177.70

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_5 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	127.33	9	26.85
7.5	134.39	9	12.52
14.0	155.53	11	4.99
27.0	260.71	15	8.62
45.0	262.35	12	14.97
75.0	300.94	11	20.09
140.0	242.38	13	9.55
270.0	209.47	10	15.16
450.0	184.10	11	11.26
750.0	228.31	11	10.30
1400.0	81.85	10	10.57
2700.0	154.69	11	19.73
4500.0	649.65	10	88.69
7500.0	698.61	7	112.21
14000.0	351.30	8	24.75

STATION ID_5 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	90.72	13	5.68
7.5	121.27	12	3.18
14.0	166.87	11	6.00
27.0	234.55	11	5.51
45.0	283.58	12	13.72
75.0	276.85	7	17.18
140.0	250.07	12	6.99
270.0	179.24	14	7.17
450.0	140.91	11	4.42
750.0	150.85	13	8.93
1400.0	65.54	12	5.50
2700.0	151.66	9	5.37
4500.0	171.71	12	10.38
7500.0	283.76	10	11.26
14000.0	391.24	8	37.76

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_6 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1137.00	6	267.37
7.5	2036.50	6	1186.40
14.0	1648.30	10	252.43
27.0	2125.20	6	350.28
45.0	1824.10	11	187.64
75.0	2452.90	9	264.45
140.0	1646.10	11	147.81
270.0	2108.90	11	147.40
450.0	1646.80	13	73.46
750.0	1778.90	11	108.65
1400.0	468.38	12	83.18
2700.0	835.44	14	71.45
4500.0	780.39	12	86.77
7500.0	287.28	9	74.36
14000.0	1077.90	12	99.99

STATION ID_6 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1124.30	11	141.53
7.5	1844.30	10	484.42
14.0	1889.10	12	207.69
27.0	2326.30	11	168.69
45.0	2709.00	11	215.41
75.0	2725.20	11	352.94
140.0	2990.50	11	270.07
270.0	2509.30	10	125.74
450.0	1500.80	11	84.27
750.0	1328.00	12	61.46
1400.0	424.20	9	44.49
2700.0	641.05	12	43.20
4500.0	827.62	8	114.64
7500.0	953.25	12	76.06
14000.0	1260.20	7	221.39

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_7 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	8898.40	10	550.26
7.5	7166.90	14	327.69
14.0	4576.50	10	399.57
27.0	4049.70	14	174.99
45.0	3253.00	11	177.69
75.0	2772.40	12	109.24
140.0	1682.20	11	69.70
270.0	1796.20	11	117.39
450.0	1196.90	15	54.73
750.0	1175.50	11	92.11
1400.0	717.13	10	36.91
2700.0	325.12	10	43.29
4500.0	598.40	11	28.82
7500.0	764.16	11	50.73
14000.0	1017.40	10	70.11

STATION ID_7 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1080.40	11	77.35
7.5	826.82	11	72.50
14.0	804.37	10	73.16
27.0	924.00	11	65.41
45.0	1108.00	8	82.32
75.0	1395.90	11	83.50
140.0	1573.00	10	85.94
270.0	1468.00	12	43.34
450.0	977.13	11	87.30
750.0	931.61	13	58.12
1400.0	748.63	10	75.35
2700.0	578.16	10	56.10
4500.0	553.25	11	52.85
7500.0	914.61	10	91.72
14000.0	1919.30	9	219.11

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_8 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1124.70	10	275.15
7.5	907.68	10	84.92
14.0	331.29	11	11.97
27.0	223.51	15	12.99
45.0	231.84	11	23.76
75.0	220.88	13	18.29
140.0	184.41	11	21.60
270.0	320.52	13	11.95
450.0	320.56	12	22.65
750.0	289.71	7	16.83
1400.0	427.92	3	289.89
2700.0	107.84	8	13.60
4500.0	489.29	13	38.86
7500.0	563.07	9	46.63
14000.0	3407.20	9	473.71

STATION ID_8 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	355.71	8	283.16
7.5	464.32	11	73.93
14.0	209.36	10	38.46
27.0	188.11	5	27.97
45.0	125.62	16	14.13
75.0	115.36	11	23.48
140.0	121.07	13	10.16
270.0	206.84	9	30.05
450.0	170.62	10	12.21
750.0	154.95	12	12.73
1400.0	210.03	8	83.42
2700.0	114.85	5	10.62
4500.0	199.29	11	20.40
7500.0	211.98	9	51.68
14000.0	4178.30	8	461.71

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_9 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1218.00	8	341.54
7.5	1237.20	9	70.34
14.0	989.13	8	58.20
27.0	1439.10	12	32.96
45.0	1098.80	7	185.43
75.0	1570.00	11	125.09
140.0	1491.70	13	66.09
270.0	2069.40	12	76.69
450.0	1575.60	11	63.85
750.0	1618.80	14	98.40
1400.0	1606.30	9	282.48
2700.0	942.77	10	83.05
4500.0	1537.10	5	583.20
7500.0	2598.70	7	537.88
14000.0	3468.10	9	226.37

STATION ID_9 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	558.87	9	81.33
7.5	447.59	12	37.35
14.0	624.64	13	36.73
27.0	668.99	12	85.81
45.0	644.01	11	30.58
75.0	701.53	10	40.44
140.0	742.91	11	68.10
270.0	1078.00	11	62.43
450.0	805.95	11	62.60
750.0	891.11	11	35.67
1400.0	244.24	10	6.00
2700.0	702.24	7	83.63
4500.0	878.74	10	24.05
7500.0	3491.00	6	906.28
14000.0	2731.90	6	675.82

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_10 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	2819.20	11	263.69
7.5	2533.30	14	78.56
14.0	2485.10	13	64.69
27.0	2271.00	12	55.37
45.0	1871.40	10	58.68
75.0	2260.90	10	76.85
140.0	1727.30	10	65.90
270.0	2004.60	11	47.71
450.0	1260.50	10	99.95
750.0	1380.70	9	149.19
1400.0	426.42	11	31.44
2700.0	458.28	10	79.41
4500.0	297.47	8	39.46
7500.0	124.60	5	14.47
14000.0	1388.60	10	346.04

STATION ID_10 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	759.36	11	42.86
7.5	755.74	13	66.45
14.0	623.07	13	25.66
27.0	581.99	11	19.49
45.0	598.92	10	25.32
75.0	684.22	10	48.28
140.0	889.11	12	30.14
270.0	800.19	11	15.33
450.0	530.50	11	18.51
750.0	468.98	12	22.92
1400.0	229.25	10	14.19
2700.0	254.26	11	32.17
4500.0	547.97	8	69.66
7500.0	500.59	10	43.53
14000.0	853.19	9	41.14

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_11 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	3518.70	12	761.16
7.5	2578.70	11	287.70
14.0	2677.90	11	213.86
27.0	2572.00	14	105.02
45.0	2926.90	8	224.33
75.0	2277.00	11	131.14
140.0	2235.00	9	314.05
270.0	2114.90	10	87.15
450.0	1866.20	12	50.45
750.0	2343.30	9	161.74
1400.0	702.90	9	80.89
2700.0	990.26	8	120.88
4500.0	721.35	7	102.02
7500.0	1349.00	8	189.36
14000.0	723.97	7	119.44

STATION ID_11 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	2911.70	10	268.94
7.5	3075.00	8	257.53
14.0	2517.90	7	190.59
27.0	2203.40	10	140.60
45.0	2482.50	12	177.11
75.0	2818.50	12	179.59
140.0	4437.10	10	538.83
270.0	3949.00	11	149.67
450.0	2581.60	9	290.40
750.0	3383.20	12	266.42
1400.0	1262.40	14	104.52
2700.0	1124.00	7	163.55
4500.0	2404.80	9	329.76
7500.0	2206.70	8	531.76
14000.0	1701.40	10	176.37

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_12 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	926.52	8	49.63
7.5	702.29	10	32.63
14.0	636.22	11	22.10
27.0	559.86	12	37.82
45.0	437.82	10	24.42
75.0	580.60	10	78.12
140.0	601.77	10	22.65
270.0	635.55	11	21.62
450.0	555.96	11	23.54
750.0	799.67	10	83.92
1400.0	504.07	12	49.90
2700.0	305.68	9	30.93
4500.0	260.87	7	65.62
7500.0	329.99	7	53.66
14000.0	937.62	9	91.82

STATION ID_12 EW NO FREQ= 9

FREQ	AP-RES	N OBS	STD ERR
4.5	760.26	7	80.56
4.5	663.78	4	65.40
7.5	673.86	10	36.16
14.0	613.08	12	20.93
27.0	524.13	10	19.02
45.0	418.60	11	15.15
75.0	369.86	10	13.54
140.0	352.87	10	12.23
270.0	399.11	12	13.30

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_13 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	160.04	10	11.83
7.5	140.25	14	4.65
14.0	84.09	13	2.15
27.0	79.10	12	2.63
45.0	66.99	12	3.74
75.0	75.72	13	4.37
140.0	66.18	10	2.81
270.0	129.43	9	15.80
450.0	143.95	9	15.93
750.0	203.28	10	21.53
1400.0	76.72	9	6.90
2700.0	59.62	10	4.07
4500.0	51.74	12	5.42
7500.0	56.34	8	7.99
14000.0	110.26	6	30.82

STATION ID_13 EW NO FREQ= 16

FREQ	AP-RES	N OBS	STD ERR
4.5	148.93	13	24.46
7.5	129.65	10	7.73
14.0	159.53	10	14.87
27.0	158.74	11	16.25
45.0	135.94	8	12.37
75.0	162.08	11	15.12
140.0	255.32	11	21.44
270.0	370.54	8	25.13
450.0	236.83	9	27.64
450.0	187.21	8	30.14
750.0	269.61	13	25.64
1400.0	94.30	14	7.33
2700.0	99.04	10	17.48
4500.0	157.65	10	10.57
7500.0	233.00	11	14.52
14000.0	565.15	9	75.19

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_14 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	69.83	11	3.93
7.5	45.40	14	5.02
14.0	47.96	8	25.77
27.0	44.10	17	7.45
45.0	30.09	14	1.13
75.0	38.26	11	2.70
140.0	30.23	13	1.64
270.0	31.90	10	2.18
450.0	16.09	10	1.08
750.0	65.68	11	3.48
1400.0	22.38	13	1.06
2700.0	39.25	11	1.69
4500.0	59.27	11	8.72
7500.0	66.56	12	10.94
14000.0	234.79	7	24.78

STATION ID_14 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	29.01	10	8.57
7.5	22.98	12	4.62
14.0	20.51	8	4.30
27.0	18.55	10	4.09
45.0	18.66	11	3.02
75.0	11.36	10	2.13
140.0	22.22	9	5.73
270.0	23.02	14	2.06
450.0	66.78	8	15.02
750.0	44.07	9	8.24
1400.0	18.31	11	2.15
2700.0	43.44	10	5.24
4500.0	49.73	7	6.65
7500.0	85.33	10	8.94
14000.0	286.82	7	30.24

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_15 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	178.20	10	7.02
7.5	129.25	11	5.52
14.0	70.19	11	2.35
27.0	71.14	12	1.81
45.0	69.89	10	7.11
75.0	68.72	9	4.35
140.0	69.61	11	2.46
270.0	84.14	11	5.64
450.0	114.37	11	5.87
750.0	103.62	10	7.94
1400.0	79.93	11	5.48
2700.0	66.66	10	4.12
4500.0	132.79	7	14.71
7500.0	49.24	7	7.46
14000.0	177.82	10	9.08

STATION ID_15 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	232.49	11	19.03
7.5	218.40	14	10.60
14.0	178.42	10	5.23
27.0	152.38	10	6.96
45.0	128.89	13	6.54
75.0	109.91	10	3.41
140.0	124.08	12	4.27
270.0	104.92	10	2.03
450.0	124.59	11	2.41
750.0	124.53	9	3.10
1400.0	43.17	11	1.99
2700.0	76.27	7	5.21
4500.0	98.77	9	16.31
7500.0	99.65	6	19.47
14000.0	174.83	9	15.76

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_16 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	103.95	10	6.13
7.5	64.43	12	4.70
14.0	33.29	12	1.92
27.0	33.88	12	2.57
45.0	27.34	12	1.88
75.0	24.60	10	1.83
140.0	18.84	12	1.15
270.0	22.38	11	1.33
450.0	23.83	7	2.73
750.0	24.40	9	2.42
1400.0	5.53	6	.17
2700.0	11.31	6	1.56
4500.0	18.17	11	2.19
7500.0	24.77	5	4.10
14000.0	49.00	7	4.90

STATION ID_16 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	68.20	9	4.00
7.5	89.77	10	2.39
14.0	80.84	11	3.63
27.0	61.96	13	1.58
45.0	62.77	10	3.41
75.0	51.57	12	4.05
140.0	49.74	11	2.35
270.0	48.28	13	1.57
450.0	42.90	9	1.53
750.0	38.21	10	2.18
1400.0	21.18	7	2.18
2700.0	21.26	3	3.69
4500.0	32.21	10	10.92
7500.0	39.34	13	8.58
14000.0	42.07	7	1.72

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_17 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	25149.00	9	7413.70
7.5	25054.00	10	5459.50
14.0	12028.00	14	1218.30
27.0	11739.00	9	517.98
45.0	9288.50	10	362.92
75.0	9071.40	13	637.21
140.0	7357.40	13	263.53
270.0	9143.60	13	761.13
450.0	5475.90	12	244.64
750.0	6911.10	11	934.43
1400.0	3213.10	10	505.15
2700.0	1107.20	10	295.85
4500.0	2575.50	11	166.37
7500.0	3856.80	12	325.16
14000.0	2132.40	12	110.54

STATION ID_17 EW NO FREQ= 14

FREQ	AP-RES	N OBS	STD ERR
4.5	3744.80	11	659.86
7.5	2755.10	11	349.77
14.0	3130.80	10	340.97
27.0	3446.80	13	192.05
45.0	4796.20	14	325.41
75.0	4145.30	12	341.17
140.0	6665.00	11	2654.60
270.0	7626.10	14	884.56
450.0	5628.00	11	669.18
750.0	3830.00	11	160.66
1400.0	2029.30	11	122.61
2700.0	2659.70	13	105.59
4500.0	8027.30	10	450.06
14000.0	1144.50	10	229.07

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_18 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	11866.00	8	4374.40
7.5	10269.00	10	99.90
14.0	18468.00	7	4051.10
27.0	23623.00	13	1426.10
45.0	18213.00	13	1289.50
75.0	15730.00	11	3063.80
140.0	12434.00	12	1802.80
270.0	13301.00	10	2280.90
450.0	13416.00	12	4903.20
750.0	10496.00	11	1349.50
1400.0	5326.70	15	407.57
2700.0	4732.70	8	266.01
4500.0	4388.70	11	644.54
7500.0	2984.50	11	306.74
14000.0	2166.70	12	100.68

STATION ID_18 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	8458.70	14	1952.20
7.5	14688.00	11	2772.80
14.0	11488.00	11	1678.10
27.0	9772.70	15	887.55
45.0	6940.00	8	1187.10
75.0	9865.00	11	582.70
140.0	15151.00	13	2803.50
270.0	9318.90	12	673.60
450.0	8978.70	11	788.51
750.0	10780.00	11	1054.10
1400.0	4857.60	11	217.85
2700.0	5779.50	12	718.82
4500.0	7725.90	11	1246.50
7500.0	5120.90	9	694.80
14000.0	4255.20	10	824.71

OUTPUT FROM PRINT

PROJECT=LAKE CITY

STATION ID_19 NS NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1333.70	7	72.38
7.5	977.17	10	82.25
14.0	544.66	12	53.33
27.0	548.94	11	77.30
45.0	644.61	7	405.37
75.0	383.77	9	26.70
140.0	234.79	12	33.93
270.0	241.41	11	12.28
450.0	322.33	11	32.49
750.0	190.03	5	26.83
1400.0	157.46	15	18.91
2700.0	212.46	10	39.43
4500.0	488.96	11	75.15
7500.0	1094.90	7	318.06
14000.0	859.24	10	115.47

STATION ID_19 EW NO FREQ= 15

FREQ	AP-RES	N OBS	STD ERR
4.5	1217.50	5	665.92
7.5	422.11	9	89.93
14.0	450.72	7	44.67
27.0	272.26	10	50.18
45.0	303.27	13	59.16
75.0	156.29	10	21.00
140.0	204.78	10	28.26
270.0	223.76	14	44.14
450.0	268.58	13	41.53
750.0	262.28	12	14.93
1400.0	315.08	13	30.65
2700.0	269.90	11	21.18
4500.0	340.80	10	21.05
7500.0	670.36	10	70.67
14000.0	1119.20	14	133.29

OUTPUT FROM PRINT

PROJECT=LAKE CITY

NO DATA N-S

STATION ID_20 EW NO FREQ= 8

FREQ	AP-RES	N OBS	STD ERR
4.5	204.25	6	50.41
7.5	680.16	10	37.23
14.0	872.47	12	31.86
27.0	1064.00	12	59.75
45.0	1226.30	12	72.18
75.0	1040.50	9	53.06
140.0	761.51	6	150.23
270.0	892.15	6	87.67

Appendix 3

Telluric data tables. The tables for each station and for each frequency shows the average telluric voltage ratio between adjacent dipoles and the standard deviation of the ratio. Then, for each dipole and each frequency, the computed relative telluric voltage is referenced to the first station, which is arbitrarily set to 1 volt (the offset is 0.2 volt).

Telluric Traverse
Lake City, Line 1

Station No.	Ratio/Std. Deviation				Relative Voltage			
	25Hz	16.7Hz	7.5Hz	4.5Hz	25Hz	16.7Hz	7.5Hz	4.5Hz
					1	1	1	1
1 ÷	0.97/.00	1.03/.03	1.05/.05	1.10/.08				
					1.03	.97	.95	.91
2 x	1.12/.01	1.13/.02	1.13/.02	1.12/.03				
					1.15	1.10	1.08	1.02
3 ÷	2.39/.11	2.28/.15	2.40/.13	2.31/.13				
					.48	.48	.45	.44
4 x	0.81/.05	0.86/.04	0.79/.08	0.92/.09				
					.39	.41	.35	.41
5 ÷	1.17/.05	1.17/.05	1.21/.06	1.19/.14				
					.33	.35	.29	.34
6 x	1.26/.03	1.27/.04	1.21/.04	1.31/.02				
					.42	.45	.35	.45