DB. IV

GEOPHYSICAL DATA

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GEOPHYSICAL SURVEY
for
THE STUDY ON SABO AND FLOOD CONTROL
IN THE LAOAG RIVER BASIN

Ilocos Norte, Philippines

1.0 INTRODUCTION

1.1 General Consideration and Objectives

Japan International Cooperation Agency (JICA) Study Team in cooperation with the Department of Public Works and Highways (DPWH) is currently undertaking the Study on Sabo and Flood Control in the Laoag River Basin. Part of the study shall require the geotechnical investigation of the proposed sabo dams for their appropriate designing works. Thus, the Woodfields Consultants, Inc. (WCI) was contracted by the JICA Study team to carry out the investigation on the proposed sabo dams and/or within the damsites by means of geophysical exploration (Geo-resistivity Survey).

The present geo-resistivity survey was carried out to determine the geological conditions of the sabo damsites. It may also provide additional relevant information to permit the construction of sabo dams within the constraints of the prevailing geotechnical condition. The survey further hopes to achieve the following objectives:

1. Estimate depth to subsurface boundaries separating layers of different resistivities and their resistivity values.

2. Estimate depth and thickness of overburden materials (river deposits) along each proposed dam axis;

3. Estimate depth and thickness of weathered and top soil materials on both abutments along each proposed dam axis.

4. Traverse or survey areas for locations of subsurface materials with abnormally high or low resistivity compared to the surrounding; and

5. Probe and locate the existence (if there is any) of geological structures; e.g. faults and fractures within the proposed damsites.

1.2 Method of Approach

The physical features and prevailing geologic and topographic conditions of the proposed damsites suggested the method of investigation and survey of the entire area. Thus, after the requisite gathering and compilation of available geologic maps and reports in the region and upon issuance of the "Notice to Proceed" (NTP) by the JICA Study Team to WCI, actual geo-resistivity survey and fieldworks were undertaken.

During the course of the geo-resistivity survey, the rock exposure within each proposed damsite were closely examined to determine their textures, weathering/fracturing, consolidation and delineation of their geologic structures. They were later correlated with the available borehole logs (exploratory boreholes by National Irrigation Administration - NIA) in the vicinity of each proposed damsite.

Likewise, the types and characteristics of the river deposits and weathering mantle/soil cover within each proposed damsite and immediate vicinity were examined in the field. Their depositions and characteristics would serve later as calibration points for the expected resistivity values of the subsurface layers directly beneath them.

The field studies were further supplemented with the interpretation of aerial photographs (provided by JICA Study Team) for each proposed damsite to check the geologic conditions and existence of geologic structures within the subject area.

Combining the informations obtained from the geo-resistivity survey with the field geologic condition verification and use of aerial-photo interpretation, the subsurface conditions beneath each proposed damsite were derived.

The entire fieldworks and study for the geophysical investigation (Resistivity Survey) of the proposed sabo damsite lasted from January to February 1997.

1.3 Location and Physiography

The proposed sabo dams are situated on top of each river namely; Cura River, Labugaon River, Solsona River, Madongan River and Papa River that form part of the entire Laoag River Basin in Ilocos Norte in the northwestern part of the Luzon Island. They are located in the four (4) municipalities namely; Carasi, Solsona, Marcos and Nueva Era in the eastern part of the province (**see Figure 1**).

Each river head water comes from the Cordillera Central Mountain Range with elevation of about 2,000 meters above mean sea level (amsl) and flows down to the alluvial fan-forming flood plains of the

Laoag River before they all empty into the China Sea in Laoag City. Elevations around each damsite range from 110 - 140 m, amsl and topography is generally rugged and steep almost in all abutments.

The Laoag River Basin with a drainage area of about 1,350 km² covers approximately 40% of the total provincial land of Ilocos Norte consisting of Laoag City and ten (10) municipalities.

2.0 GEOLOGY

2.1 Regional Geology and Structures

The regional framework of the entire Ilocos Norte Province reflects the present landforms of the area. The eastern highlands of the province being part of the Cordillera Mountain Range were subjected to orogenic and structural movements which has resulted to the occurrence of N-S transcurrent fault systems and E-W tensional fault systems in the area.

Pre-Pliocene intrusion covers the entire eastern highland with igneous rocks, e.g. diorite. Almost simultaneous with this event, the extrusion of valcanic rocks, e.g. basalt, andesite and agglomerate covers the relatively lower flanks.

The younger formation (Plio - pleistocene) later covers the coastal hill and low lands of the province. It consists of marine and terrestrial sediments of limestone, sandstone, siltstone, conglomerate and pyroclastic flows.

2.2 Local Geology

Two (2) types of Igneous rocks may be expected entirely in the proposed sabo dams. These are; the diorite (intrusive) and volcanic rock unit consists mainly of andesite and basalt with minor agglomerates.

The diorite is generally massive on wall exposures but sometimes hydrothermally altered when exposed to river water. It is generally fractured and sheared but often times exhibits tightness due to filling of secondary minerals in the opennings. Sometimes, the diorite interfingers with the volcanics.

The volcanics are oftentimes fractured and sheeted and weathering leaves few meters of silty soil. The basalt is differentiated from the andesite by virtue of the darker color the former exhibits. Likewise, the basalt is fine-grained in textures and fresh surface often times exhibit velvety textures. In solsona damsite, the basalt occurs as dikes and sills within the diorite body.

3.0 GEO - RESISTIVITY SURVEY

3.1 Principles of Geo - resistivity Survey

The geo-resistivity survey is a geophysical method by which subsurface conditions are determined from measurements carried out from the ground surface. The arrangement of electrodes or stakes is shown in Figures 2.

Electric current is sent through the ground from electrodes A and B. For a given distance between these two (2) electrodes, the potential difference is measured over electrodes M and N. The electric current, the voltage difference between M and N and the current electrode separation are recorded. Based on these data, the apparent resistivity of the soil or rock formation is computed.

For the Schlumberger array, the potential electrode separation MN is always maintained so that MN/AB ratio is always less than 2/5 as the current electrode spread is increased. Everytime the MN distance is increased, readings at the same AB spread are repeated.

An electrical sounding consists of a succession of apparent resistivity measurements made with an increasing electrode separation, the center of the configuration and its orientation remaining fixed.

If the measured resistivity of the layer does not vary from measurement to measurement, the changes in apparent resistivity will be due mainly to the increasing penetration of the current into the earth. The distribution of the current will be influenced by the characteristics of the deeper beds.

3.2 Field Survey and Procedures

Using the profile survey lines of all the proposed Sabo Dam Axes, the locations and selection of sounding stations were based. For the lines downstream of some of the existing NIA dams, the location of soundings points were executed by means of Brunton and tape measurement thus, profiles along these lines have approximate elevations through the points.

For each profile survey line, the number of sounding stations were made according to its length, physical features and field constraints. Whenever possible, all the sounding stations were placed on depressions near river waters and relatively lower elevations where finer river deposits are accummulated for the electrodes to have good contacts of current into the grounds. On the other hand, where elevated and levee sections of each profile line are to be explored, the survey was successfully accomplished by pouring water with salt (saline solution) into the electrodes every separation until the desired depth of penetration is accomplished. The saline solution acts only as a meduim to make the electrodes in good contact deeper into the ground. In any way, it does not affect the procedure of the resistivity survey. The resistivity survey for the entire Sabo Damsites was completed with the following specifications:

Electrode Array	Schlumberger
Frequency	0.1 to 0.3 Hertz
Array Length	Minimum; AB/2 = 50 m Miximum; AB/2 = 150 m
Direction of Line Survey	Along rivers
Resistivity Instrument	ABEM TERRAMETER SAS - 300

Also, see **Table 1** for the summary of resistivity sounding stations made in the subject area.

3.3 Resistivity Results

The field results were plotted in the normal manner as measured apparent resistivity against half of the current electrode separation AB/2 on double logarithmic paper.

A smooth curve for each sounding station was drawn through the data points, adjusting for the corrections introduced by changing the MN distance. The data curves were then matched with the master curves for the Schlumberger array. Tables 2 - 13 shows the "true" resistivity values and the thickness of the resistivity layers detected beneath each Sabo Damsite.

3.4 Interpretation of Results and Evaluations

Because resistivity of rock formation varies over a wide range, depending upon the amount and chemistry of the water in the pores and interstices or openings within the formation, the prevailing geologic condition was attended and the available borehole logs near the subject area were correllated to formulate the characteristics of the subsurface layers.

3.4.1 <u>Cura Sabo Damsite</u>

a) **Figure 3** - Sta. 0 + 420 M.

The section shows a wide resistivity range of the river deposit from all the layers penetrated by the survey. Where the materials are dominated with boulders, the resistivity becomes higher.

While the river deposit consists of several layers almost through out the section, it is separated from the lower formations because of its distinct resistivity range value from the latter. The sudden drop of the resistivity range value of the next formation could indicate that this volcanic layer is weathered and altered and to some extent, sheared and probably faulted. The deep occurrence of diorite body at the center of the valley could suggest that this portion has moved down relative to both abutments. The sheared or fault lines are apparently indicated at VES - 7 on the left abutment and at VES - 1 on the right abutment having both encountered resistivity values of the formation lower than 100 ohm-m.

The resistivity range value of the diorite body in the section probably suggests that it is slightly weathered.

b) Figure 4 - NIS Intake Structure

The river deposit is thicker towards the right abutment but generally shallower in occurrence than at section 420 m. upstream of this profile. Again, the wide resistivity range value of the river deposit accounts for the sizes of the materials.

The volcanic bedrock seemed consistent of its resistivity range value through out the section thus, the deep occurrence of this bed at the center of the valley does not directly imply on extension of the sheared/faulted zone at section upstream.

3.4.1. b <u>Labugaon Sabo Damsite</u>

a) Figure 5 - Sta. 0 + 235 M.

The river deposit contains two (2) to four (4) layers of varying resistivities. It is generally shallow and almost evenly distributed within the valley. Its thickness which averages about six (6) meters is in good agreement with the thickness of river deposit along the present dam structure which is about 235 m. downstream.

The bedrock of the diorite yielded a resistivity range value from 65-208 ohm - meters. While this formation seemed to follow the surface topography, the decrease in the resistivity range value towards the left abutment could suggest that this portion of the valley is heavily weathered and altered.

The resistivity range value of more 1000 ohm-meters of the lower most formation strongly suggests that this layer is massive and fresh diorite body.

3.4.1.C Solsona Sabo Damsite

a) Figure 6 - Dam Axis

Because of its narrow river channel, the river deposit probed by VES -1 is only a little over one (1) meter in thickness. Underneath this river deposit is a weathered diorite which is about three (3) meter-thick.

At the right abutment of the section, the flatter slope consists of colluvial materials of bouldery fragments. The relatively high resistivity range value of 5,400 - 8,800 ohm - meters could indicate that this bed is relatively dry.

The walls of both abutments of the river are exposed to diorite body with dikes and intercallations of basalt dikes. While the diorite appears fractured and sheared, the basalt dikes make the rock wall strong and massive. It is probably in this manner that the resistivity of this exposure becomes greater than the diorite body encountered at the lowermost section.

b) Figure 7 - 100 M. Downstream of Existing Dam

While only two (2) sounding stations were made along this line, the resistivity profile shows the distinct attitude of the bedrock. The depth to bedrock which has a resistivity range value of 25 - 40 ohm -m is generally dipping towards the right abutment. The relative low resistivity range value of diorite may be indicated by the presence of numerous fractunes and shears and /or the bedrock is heavily weathered and to some extent hydrothermally altered.

The lower section of the profile which yielded a resistivity range value of slightly more than 100 ohm -m may indicate that this diorite bedrock is slightly altered and /or weathered.

For the river deposit, the layers encountered in this unit indirectly implies that the materials are getting finer at depth.

3.4.1 d Madongan Sabo Damsite

a) Figure 8 - Sta. 0 + 133 M.

The section shows the relatively thick occurrence of river deposit and probably, colluvial materials derived from the immediate slopes and higher elevations. Both deposits, having a variety of resistivity values through out the layers encountered have somewhat interfingered with the bedrock encountered below.

The relative thick river and colluvial deposits along this narrow section of Madongan River can be partly attributed to the intense mechanical transport of blocky and bouldery fragments of volcanics from immediate gullies and creeks of both abutments during the early development of the river. Due in part, it may also be from the intense fracturing and faulting of the bedrock which make it susceptible to inundation and truncation by mechanical weathering. The borehole logs of four (4) drill holes along the line of the present dam reveals that the bedrocks encountered at the depth of 16 meters is sheared and probably faulted. In quite good agreement with the bedrock encountered by resistivity survey, the right abutment of this section looks sheared and /or faulted. The resistivity range value of 140-325 ohm-meters is distinctly different from the one encountered at VES - 2 which is 750 ohm-meters. Hence, it appears that VES - 2 has encountered the fresh bedrock whereas the rest of the sounding stations have penetrated only the weathered and fractured volcanics.

b) Figures 9 - Sta. 0 + 60 M.

Closer to the existing dam with available borehole logs, this section has encountered a river deposit unit (composed of 2-3 layers) of about 18 meters in thickness.

The river deposit is separated below by a layer of basalt which is apparently weathered and fractured because of its relatively low resistivity range value of 200 - 330 ohm-meters compared to the one encountered at VES - 4 which yielded a resistivity value of 880 ohm-meters.

Separating the distinct difference in the resistivity values below the river deposit, a line of shearing and fracturing is shown between sounding stations VES - 2 and VES - 3 - apparently towards the unspecified inclination at VES -

4. The hachure portions represent the weathered and fractured volcanics.

c) **Figure 10** - 150 M. Downstream of Existing Dam
The behavior of river deposits seemed thicker towards the center of the valley. The bottom layer of this unit may indicate that the materials are coarser having a resistivity range value of about 1,000 ohm-m.

The volcanic bedrock is generally shallow with an average depth of about 7.0 mbgs but resistivity value which ranges from 100 to 160 ohm-m may imply that this rock unit is weathered and/or fractured. Its existence is dipping deeply towards VES-1 at depth of about 36.80 meters.

3.4.1 e **Papa Sabo Damsite**

a) **Figure 11** - Sta. 0 + 217.53 M

The thickness of the river deposit along this profile is not consistent over short intervals of the sounding stations. The thickest, at about 10 meters was probed at VES - 2 whereas the thinnest was encountered at VES - 7 with only about two (2) meters.

The resistivity range value of the river deposit does not vary in great numbers-an indication that the materials encountered are more or less of uniform sizes.

The first bedrock encountered seemed fractured and weathered because of its resistivity range value of 144 - 265. This range value is slightly lower than the next bedrock which is diorite.

b) **Figure 12** - Sta. 0 + 100 M.

The river deposit may only average about 5 meters in thickness through out the entire section. The discrepancy in the resistivity value of the layers encountered in this unit may lie on the sizes of the materials. Finer ones correspond with the lower resistivity value of the layer whereas, coarser materials yielded relatively higher values.

It is interesting to note that the first bedrock along this profile is extended in depth at VES - 2; - 3; - 4 and 5 and that another bed below of relatively low resistivity range value of 75 - 97.5 ohm - meters, and probably at VES - 4 has been detected.

While the resistivity range value of the first bedrock appears weathered and fractured, the bed below it, covering VES - 2; - 3; - 4 and - 5 further suggests that it is probably sheared and /or faulted. From the indication of the resistivity contacts, the right side of VES -2 moved down relative to the left abutment. Likewise, although the sheared / faulted zone was not detected of its occurrence at VES - 4 and - 5, it can be inferred that the left side of VES - 5 also moved down relative to the right abutment.

c) **Figure 13** - Sta. 0 + 150 M.

The depth to bedrock is deeper towards VES - 3 of this profile. The average resistivity value of about 146 ohm-m of this bed may correspond to the weathering and/or fracturing of the rock unit.

Following the behavior of the weathered diorite, the lowermost layer of diorite seemed massive and fresh. The resistivity range value of 346 - 420 ohm-meter may however, indicate some minor fracturing.

d) **Figure 14** - 150 M. Downstream of Existing Dam

The river deposit seemed regular in deposition through out the entire profile. Beneath the overburden, the resistivity range value of 45 - 75 ohm-m of the diorite may indicate heavy weathering and fracturing of this bed. Its relative thick deposition may further imply that this rock unit is quite heavily altered by hydrothermal solution.

The relatively fresh diorite having a resistivity range of 280 - 384 ohm-m was detected at stations VES - 1 and VES - 2.

TABLES

TABLE 1 : SUMMARY OF REISTIVITY SOUNDING STATIONS

River	Sabo Damsite	Number of Stations
Cura	Sta. 0 + 420.00 m.	7
	NIS Intake Structure	9
Labugaon	Sta. 0 + 235.00 m.	6
Solsona	Dam Axis no. 1	6
	100 m. Downstream of Existing Dam	2
Madongan	Sta. 0 + 133.00 m.	9
	Sta. 0 + 60.00 m.	7
	150 m. Downstream of Existing Dam	3
Papa	Sta. 0 + 217.53 m	7
	Sta. 0 + 100.00 m	8
	Sta. 0 + 150.00 m	3
	150 m Downstream of Existing Dam	3
		Total = 70

TABLE 2 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED CURA SABO DAM - STA. 0 + 420 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm - m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	180.0	0.70	0 - 0.70
	2	117.0	1.19	0.70 - 2.89
	3	250.0	3.57	2.89 - 6.46
	4	100.0	11.04	6.46 - 17.50
	5	312.0		17.50 -
VES - 2	1	2,000.0	0.62	0 - 0.62
	2	1,100.0	1.86	0.62 - 2.48
	3	400.0	5.58	2.48 - 8.06
	4	110.0	46.50	8.06 - 54.56
	5	286.0		54.56 -
VES - 3	1	380.0	1.50	0 - 1.5
	2	76.0	37.50	1.5 - 39.0
	3	247.0		39.0 -
VES - 4	1	2,200.0	3.50	0 - 3.50
	2	440.0	5.25	3.50 - 8.75
	3	90.0	39.00	8.75 - 47.75
	4	440.0		47.75 -
VES - 5	1	270.0	4.20	0 - 4.20
	2	110.0	21.00	4.20 - 25.20
	3	270.0		25.20 -
VES -6	1	260.0	0.22	0 - 0.22
	2	2,600.0	5.50	0.22 - 5.72
	3	260.0	7.00	5.72 - 12.72
	4	105.0	22.00	12.72 - 34.72
	5	260.0		34.72 -
VES - 7	1	1,800.0	1.60	0 - 1.60
	2	720.0	3.20	1.60 - 4.80
	3	180.0	9.60	4.80 - 14.40
	4	72.0	28.80	14.40 - 43.20
	5	450.0		43.20 -

TABLE 3 : TABULATED RESULTS OF GEO-RESISTIVITY SURVEY AT THE PROPOSED CURA SABO DAM - NIS INTAKE STRUCTURE

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm - m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	750.0	1.60	0 - 1.60
	2	485.0	3.20	1.60 - 4.80
	3	128.0	40.00	4.80 - 44.80
	4	250.0		44.80 -
VES - 2	1	850.0	0.86	0 - 0.86
	2	550.0	3.44	0.86 - 4.30
	3	120.0	34.40	4.30 - 38.70
	4	300.0		38.70 -
VES - 3	1	1,300.0	0.90	0 - 0.90
	2	520.0	4.50	0.90 - 5.40
	3	110.0	25.10	5.40 - 40.50
	4	295.0		40.50 -
VES - 4	1	320.0	0.60	0 - 0.60
	2	800.0	2.40	0.60 - 3.00
	3	280.0	60.00	3.00 - 63.00
	4	432.0		63.00 -
VES - 5	1	170.0	2.50	0 - 2.50
	2	425.0	3.75	2.50 - 6.25
	3	170.0	56.25	6.25 - 62.50
	4	425.0		62.50 -
VES - 6	1	220.0	0.58	0 - 0.58
	2	1,100.0	4.06	0.58 - 4.64
	3	130.0	52.78	4.64 - 57.42
	4	430.0		57.42 -
VES - 7	1	840.0	1.50	0 - 1.50
	2	336.0	6.00	1.50 - 7.50
	3	130.0	48.00	7.50 - 55.50
	4	218.0		55.50 -
VES - 8	1	200.0	1.00	0 - 1.00
	2	2,000.0	4.00	1.00 - 5.00
	3	200.0	40.00	5.00 - 45.0
	4	650.0		45.0 -
VES - 9	1	160.0	1.90	0 - 1.90
	2	1,150.0	2.30	1.90 - 4.20
	3	160.0	23.00	4.20 - 27.20
	4	400.0		27.20 -

TABLE 4 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED LABUGAON DAM - STA. 0 + 235 M.

SOUDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm -m)	THICKNESS (m)	DEPTH (mbgs)
VES -1	1	190.0	0.84	0 - 0.84
	2	110.0	0.84	0.84 - 1.68
	3	435.0	1.26	1.68 - 2.94
	4	208.0	14.28	2.94 - 17.22
	5	1,600.0		17.22 -
VES - 2	1	300.0	1.60	0 - 1.60
	2	450.0	5.2	1.60 - 6.80
	3	180.0	9.60	6.80 - 16.40
	4	1,125.0		16.40 -
VES - 3	1	240.0	1.20	0 - 1.20
	2	600.0	3.60	1.20 - 4.80
	3	120.0	18.00	4.80 - 22.80
	4	1,500.0		22.80 -
VES 4	1	210.0	1.80	0 - 1.80
	2	525.0	3.60	1.80 - 5.40
	3	105.0	14.40	5.40 - 19.80
	4	1,300.0		19.80 -
VES 5	1	460.0	0.72	0 - 0.72
	2	184.0	1.44	0.72 - 2.16
	3	575.0	2.88	2.16 - 5.04
	4	100.0	7.20	5.04 - 12.24
	5	1,250.0		12.24 -
VES - 6	1	700.0	0.70	0 - 0.70
	2	1,050.0	2.45	0.70 - 3.15
	3	65.0	7.35	3.15 - 10.50
	4	1,050.0		10.50 -

TABLE 5 : TABULATED RESULTS OF GEO-RESISTIVITY SURVEY AT THE PROPOSED SOLSONA SABO DAM - DAM AXIS NO. 1

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm - m.)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	300.0	1.30	0 - 1.30
	2	195.0	2.60	1.30 - 3.90
	3	1,950.0	3.90	3.90 - 7.80
	4	195.0		7.80 -
VES - 2	1	270.0	3.60	0 - 3.60
	2	2,700.0	5.40	3.60 - 9.00
	3	270.0		9.00 -
VES - 3	1	1,050.0	1.50	0 - 1.50
	2	310.0	3.00	1.50 - 4.50
	3	3,100.0	3.60	4.50 - 8.10
	4	310.0		8.10 -
VES - 4	1	600.0	1.00	0 - 1.00
	2	1,650.0	3.00	1.00 - 4.00
	3	430.0	5.00	4.00 - 9.00
	4	2,550.0	4.20	9.00 - 13.20
	5	330.0		13.20 -
VES - 5	1	440.0	0.28	0 - 0.28
	2	8,800.0	4.20	0.28 - 4.48
	3	220.0		4.48 -
VES - 6	1	540.0	2.10	0 - 2.10
	2	5,400.0	4.20	2.10 - 6.30
	3	108.0		6.30 -

TABLE 6 : TABULATED RESULTS OF GEO-RESISTIVITY SURVEY PROPOSED SOLSONA SABO DAM - 100 M. DOWNSTREAM OF EXISTING DAM

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	380.0	0.80	0 - 0.80
	2	152.0	0.80	0.80 - 1.60
	3	750.0	4.00	1.60 - 5.60
	4	200.0	6.40	5.60 - 12.00
	5	40.0	32.00	12.00 - 44.00
	6	130.0		44.00 -
VES - 2	1	2,000.0	0.40	0 - 0.40
	2	400.0	5.00	0.40 - 5.40
	3	100.0	12.60	5.40 - 18.00
	4	25.0	32.40	18.00 - 50.20
	5	120.0		50.00 -

TABLE 7 : TABULATED RESULTS OF GEO-RESISTIVITY SURVEY AT THE PROPOSED MADONGAN SABO DAM - STA. 0 + 133 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm - m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	780.0	0.48	0 - 0.48
	2	300.0	3.60	0.48 - 4.08
	3	675.0	18.00	4.08 - 22.08
	4	270.0		22.08 -
VES - 2	1	300.0	2.20	0 - 2.20
	2	450.0	33.00	2.20 - 35.20
	3	750.0		35.20 -
VES - 3	1	500.0	0.70	0 - 0.70
	2	325.0	10.50	0.70 - 11.20
	3	565.0	15.75	11.20 - 26.95
	4	325.0		26.95 -
VES - 4	1	180.0	1.60	0 - 1.60
	2	450.0	24.00	1.60 - 25.60
	3	900.0	12.00	25.60 - 37.60
	4	290.0		37.60 -
VES - 5	1	310.0	3.60	0 - 3.60
	2	775.0	18.00	3.60 - 21.60
	3	310.0		21.60 -
VES - 6	1	280.0	0.70	0 - 0.70
	2	420.0	17.50	0.70 - 18.20
	3	1,400.0	12.30	18.20 - 30.50
	4	210.0		30.50 -
VES - 7	1	500.0	2.20	0 - 2.20
	2	285.0	1.60	2.20 - 3.80
	3	625.0	22.00	3.80 - 25.80
	4	250.0		25.80 -
VES - 8	1	290.0	0.70	0 - 0.70
	2	435.0	2.10	0.70 - 2.80
	3	360.0	16.20	2.80 - 19.00
	4	540.0	13.00	19.00 - 29.00
	5	150.0		29.00 -
VES - 9	1	960.0	0.70	0 - 0.70
	2	624.0	0.70	0.70 - 1.40
	3	340.0	16.60	1.40 - 18.00
	4	510.0	16.60	18.00 - 34.60
	5	140.0		34.60 -

TABLE 8 : TABULATED RESULTS OF GEO - RESISTIVITY AT THE PROPOSED MADONGAN SABO DAM - STA. 0 + 60 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	250.0	3.60	0 - 3.60
	2	625.0	10.80	3.60 - 14.40
	3	250.0		14.40 -
VES - 2	1	250.0	0.30	0 - 0.30
	2	625.0	1.50	0.30 - 1.80
	3	390.0	4.50	1.80 - 6.30
	4	900.0	4.50	6.30 - 10.30
	5	320.0		10.30 -
VES - 3	1	440.0	0.52	0 - 0.52
	2	290.0	1.56	0.52 - 2.08
	3	480.0	15.60	2.08 - 17.68
	4	310.0		17.68 -
VES - 4	1	880.0	0.68	0 - 0.68
	2	180.0	5.44	0.68 - 6.12
	3	880.0		6.12 -
VES - 5	1	320.0	2.10	0 - 2.10
	2	3,200.0	6.30	2.10 - 8.40
	3	320.0		8.40 -
VES - 6	1	230.0	3.40	0 - 3.40
	2	575.0	6.80	3.40 - 10.20
	3	230.0		10.20 -
VES - 7	1	200.0	4.00	0 - 4.00
	2	500.0	20.00	4.00 - 24.00
	3	200.0		24.00 -

TABLE 9 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED MADONGAN SABO DAM - 150 M. DOWNSTREAM OF EXISTING DAM

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	420.0	1.60	0 - 1.60
	2	800.0	3.20	1.60 - 4.80
	3	160.0	32.00	4.80 - 36.80
	4	520.0		36.80 -
VES - 2	1	440.0	2.70	0 - 2.70
	2	1,000.0	5.40	2.70 - 8.10
	3	100.0	13.50	8.10 - 21.60
	4	400.0		21.60
VES - 3	1	400.0	0.80	0 - 0.80
	2	1,000.0	3.20	0.80 - 4.00
	3	160.0	20.00	4.00 - 24.00
	4	546.0		24.00 -

TABLE 10 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED PAPA SABO DAM - STA. 0 + 217.53 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	260.0	0.50	0 - 0.50
	2	390.0	2.50	0.50 - 3.00
	3	247.0	15.00	3.00 - 18.00
	4	380.0		18.00 -
VES - 2	1	230.0	1.20	0 - 1.20
	2	150.0	6.00	1.20 - 7.20
	3	375.0	3.00	7.20 - 10.20
	4	144.0	15.00	10.20 - 25.20
	5	360.0		25.20 -
VES - 3	1	130.0	0.70	0 - 0.70
	2	200.0	3.50	0.70 - 4.20
	3	160.0	3.50	4.20 - 7.70
	4	265.0	2.45	7.70 - 10.15
	5	116.0	3.50	10.15 - 13.65
	6	300.0		13.65 -
VES - 4	1	370.0	0.60	0 - 0.60
	2	180.0	3.00	0.60 - 3.60
	3	400.0	2.40	3.60 - 6.00
	4	160.0	24.00	6.00 - 30.00
	5	400.0		30.00 -
VES - 5	1	170.0	0.86	0 - 0.86
	2	330.0	2.15	0.86 - 3.01
	3	160.0	17.20	3.01 - 20.21
	4	330.0		20.21 -
VES - 6	1	180.0	0.30	0 - 0.30
	2	345.0	4.50	0.30 - 7.50
	3	168.0	15.00	7.50 - 22.50
	4	280.0		22.50 -
VES - 7	1	185.0	0.76	0 - 0.76
	2	460.0	1.52	0.76 - 2.28
	3	184.0	19.00	2.28 - 21.28
	4	460.0		21.28 -

TABLE 11 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED PAPA SABO DAM - STA. 0 + 100 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	210.0	1.70	0 - 1.70
	2	137.0	8.50	1.70 - 10.20
	3	210.0		10.20 -
VES - 2	1	180.0	7.50	0 - 7.50
	2	130.0	15.00	7.50 - 22.50
	3	300.0	12.00	22.50 - 34.50
	4	97.0		34.20 -
VES - 3	1	170.0	3.60	0 - 3.60
	2	225.0	3.60	3.60 - 7.20
	3	136.0	36.00	7.20 - 43.20
	4	75.0		43.20 -
VES - 4	1	130.0	0.48	0 - 0.48
	2	325.0	2.40	0.48 - 2.88
	3	130.0		2.88 -
VES - 5	1	130.0	0.20	0 - 0.20
	2	325.0	5.00	0.20 - 5.20
	3	130.0	15.00	5.20 - 20.20
	4	325.0		20.20 -
VES - 6	1	200.0	3.00	0 - 3.00
	2	400.0	1.50	3.00 - 4.50
	3	128.0	12.00	4.50 - 16.50
	4	208.0		16.50 -
VES - 7	1	180.0	1.00	0 - 1.00
	2	420.0	3.00	1.00 - 4.00
	3	168.0	15.00	4.00 - 19.00
	4	420.0		19.00 -
VES - 8	1	510.0	0.46	0 - 0.46
	2	204.0	1.38	0.46 - 1.84
	3	425.0	2.08	1.84 - 3.91
	4	170.0	20.70	3.91 - 24.61
	5	275.0		24.61 -

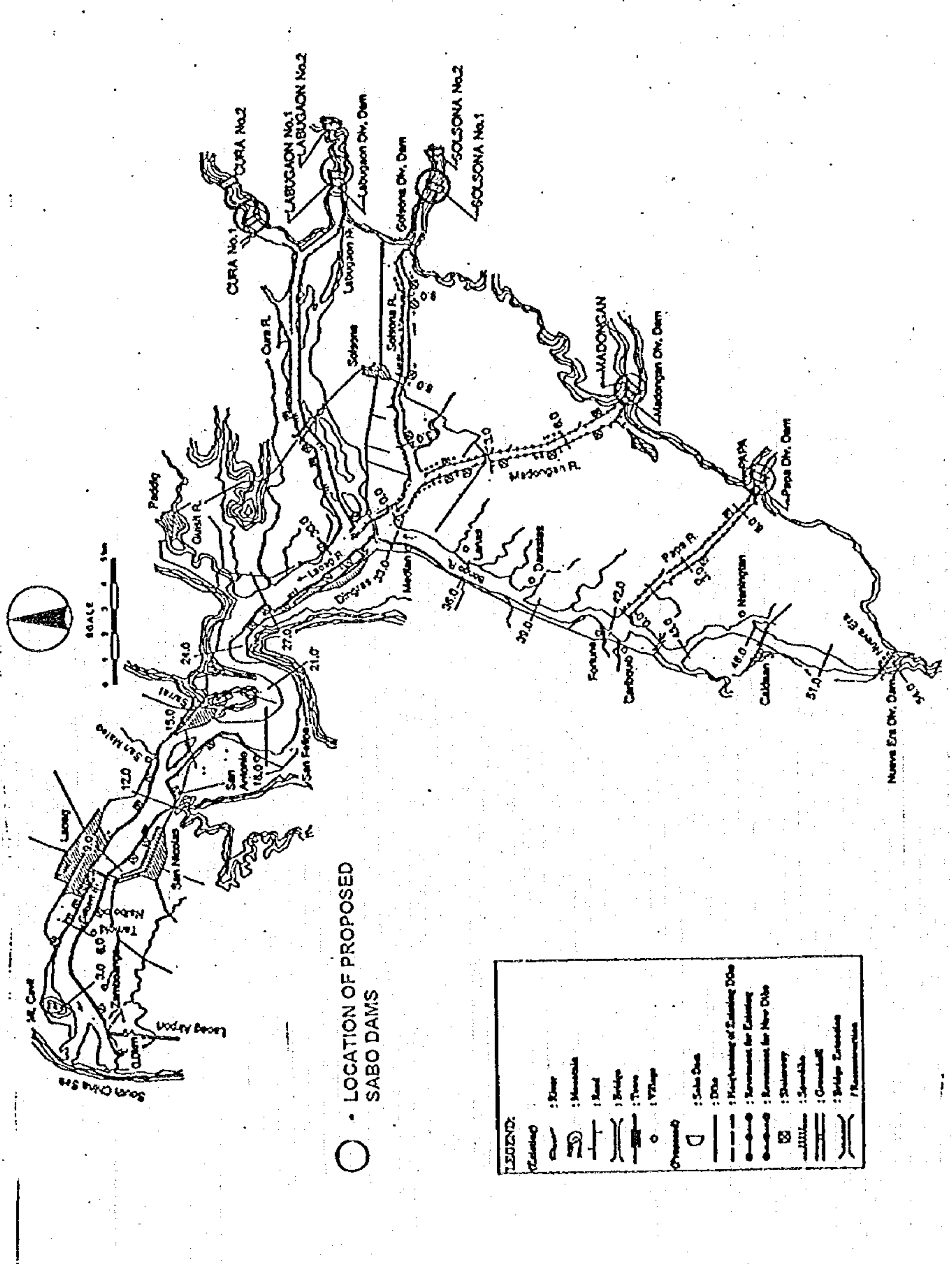
TABLE 12 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED PAPA SABO DAM - STA. 0 + 150 M.

SOUNDING STA. NO.	RESISTIVITY LAYER	REISISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	140.0	1.50	0 - 1.50
	2	560.0	2.25	1.50 - 3.75
	3	168.0	22.50	3.75 - 26.25
	4	420.0		26.25 -
VES - 2	1	150.0	1.70	0 - 1.70
	2	375.0	5.10	1.70 - 6.80
	3	150.0	25.50	6.80 - 32.30
	4	375.0		32.30 -
VES - 3	1	190.0	1.20	0 - 1.20
	2	100.0	2.40	1.20 - 3.60
	3	500.0	12.00	3.60 - 15.60
	4	120.0	18.00	15.60 - 33.60
	5	364.0		33.60 -

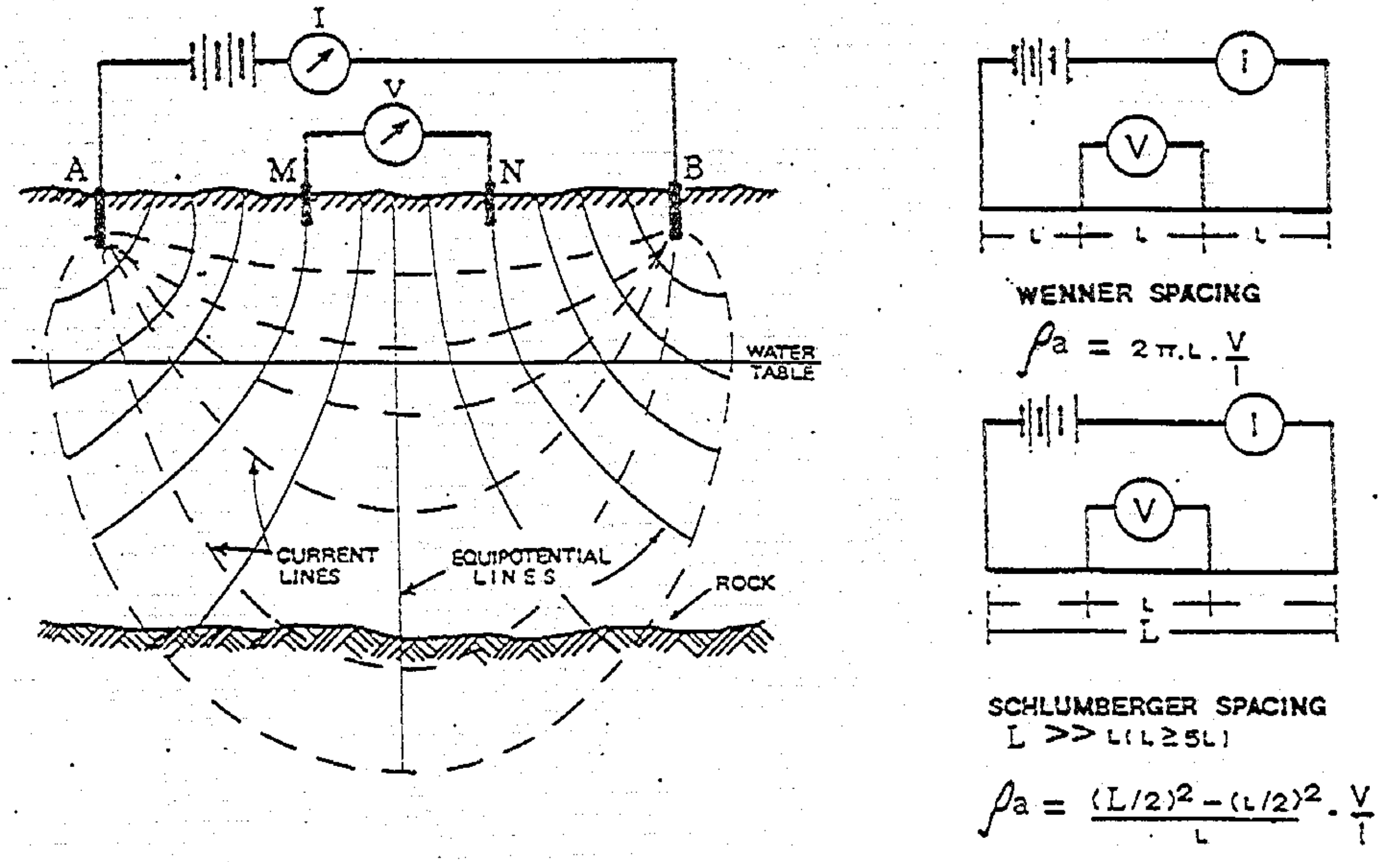
TABLE 13 : TABULATED RESULTS OF GEO - RESISTIVITY SURVEY AT THE PROPOSED PAPA SABO DAM - 150 M. DOWNSTREAM OF EXISTING DAM

SOUNDING STA. NO.	RESISTIVITY LAYER	RESISTIVITY (ohm-m)	THICKNESS (m)	DEPTH (mbgs)
VES - 1	1	1,000.0	1.70	0 - 1.70
	2	650.0	0.85	1.70 - 2.55
	3	400.0	6.65	2.55 - 9.20
	4	65.0	27.60	9.20 - 36.80
	5	280.0		36.80 -
VES - 2	1	960.0	1.30	0 - 1.30
	2	624.0	1.30	1.30 - 2.60
	3	384.0	5.00	2.60 - 7.60
	4	75.0	40.00	7.60 - 47.60
	5	384.0		47.60 -
VES - 3	1	1,300.0	2.50	0 - 2.00
	2	450.0	7.50	2.50 - 10.00
	3	45.0	30.00	10.00 - 40.00
	4	90.0		40.00 -

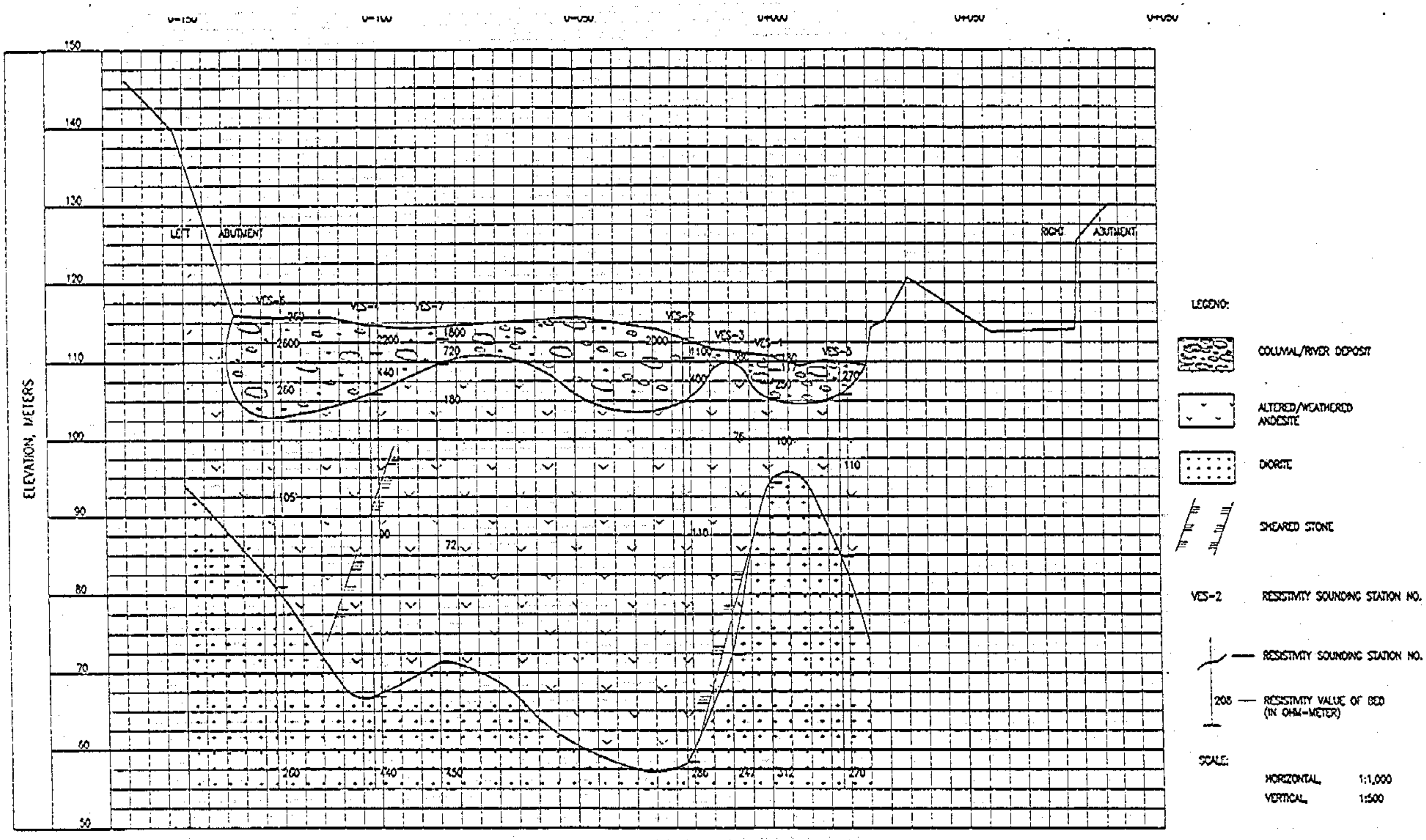
FIGURES



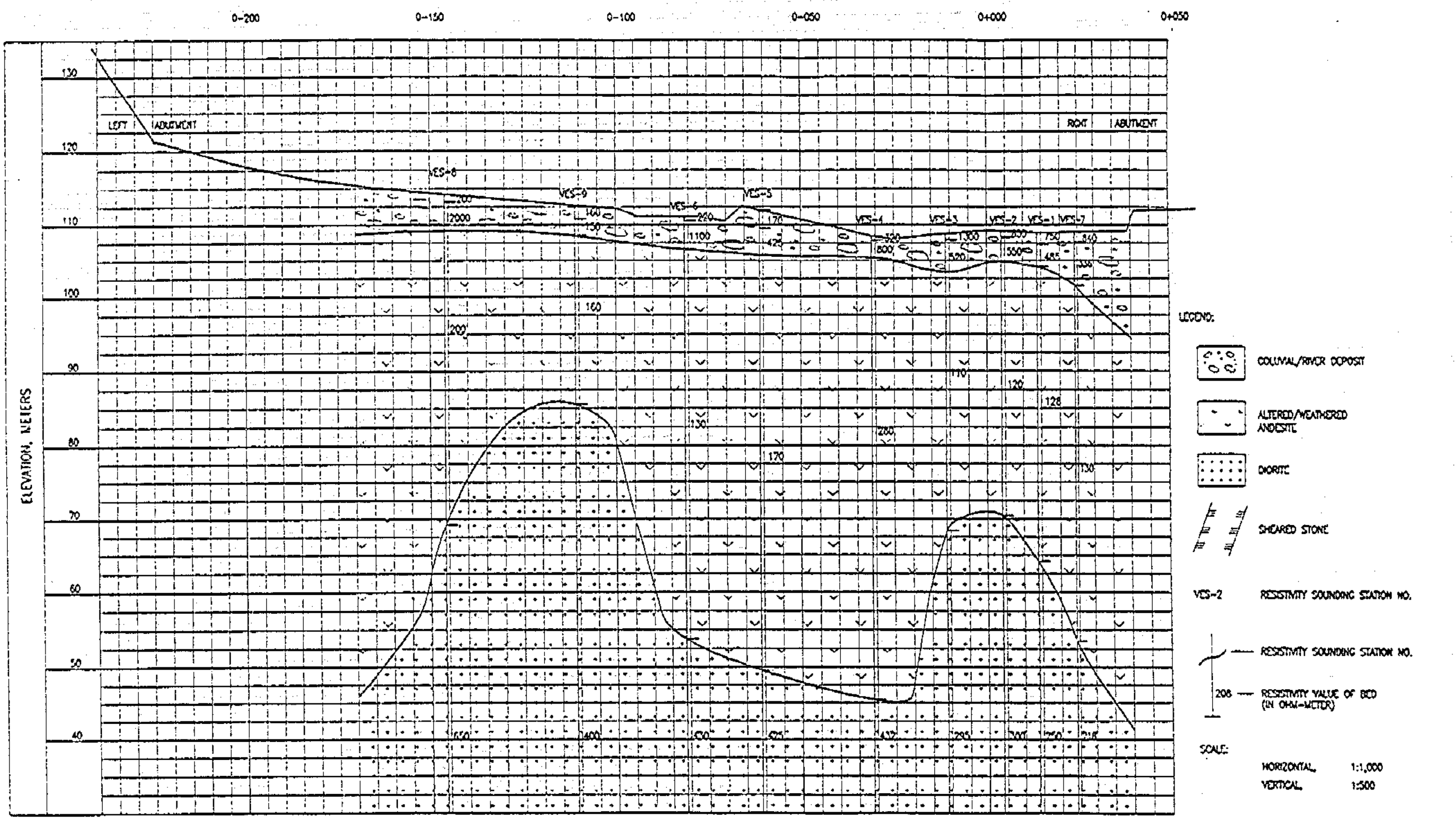
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 1 LOCATION MAP OF PROPOSED SABO DAMS IN THE LAOAG RIVER BASIN
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



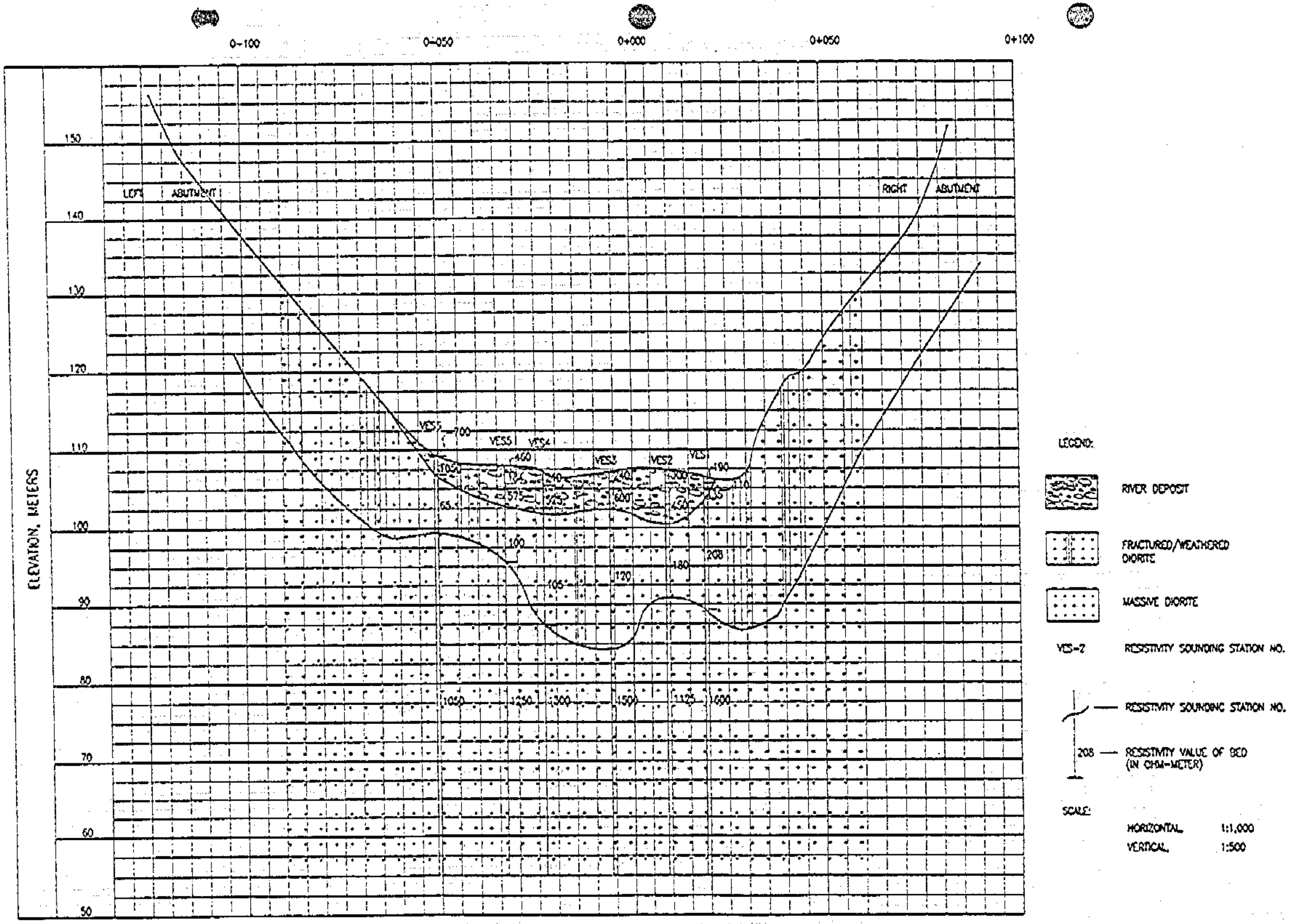
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 2 PRINCIPLES OF GEO-RESISTIVITY SURVEY
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



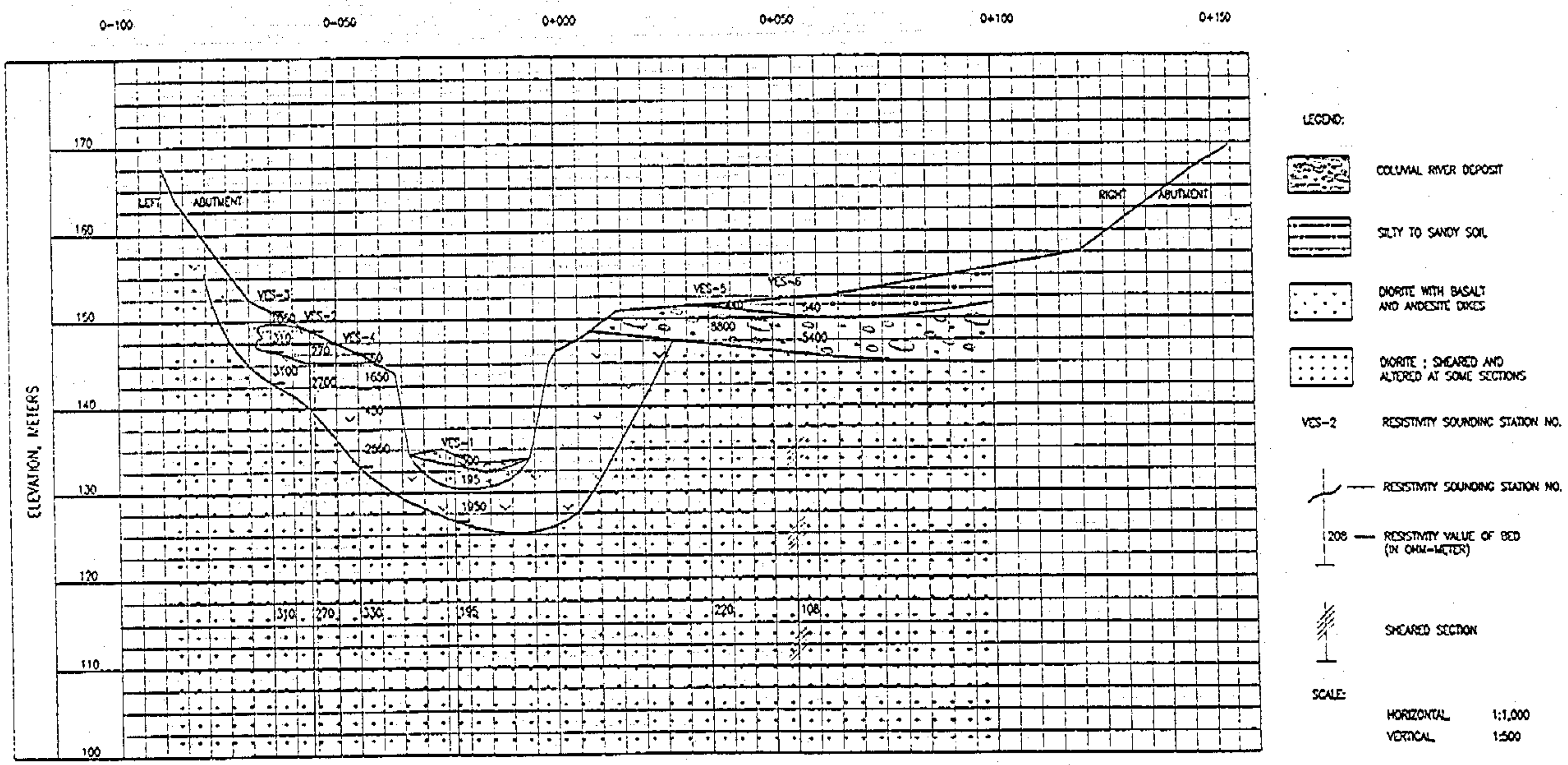
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 3 RESISTIVITY PROFILE ALONG STA. 0+420M. OF CURA SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



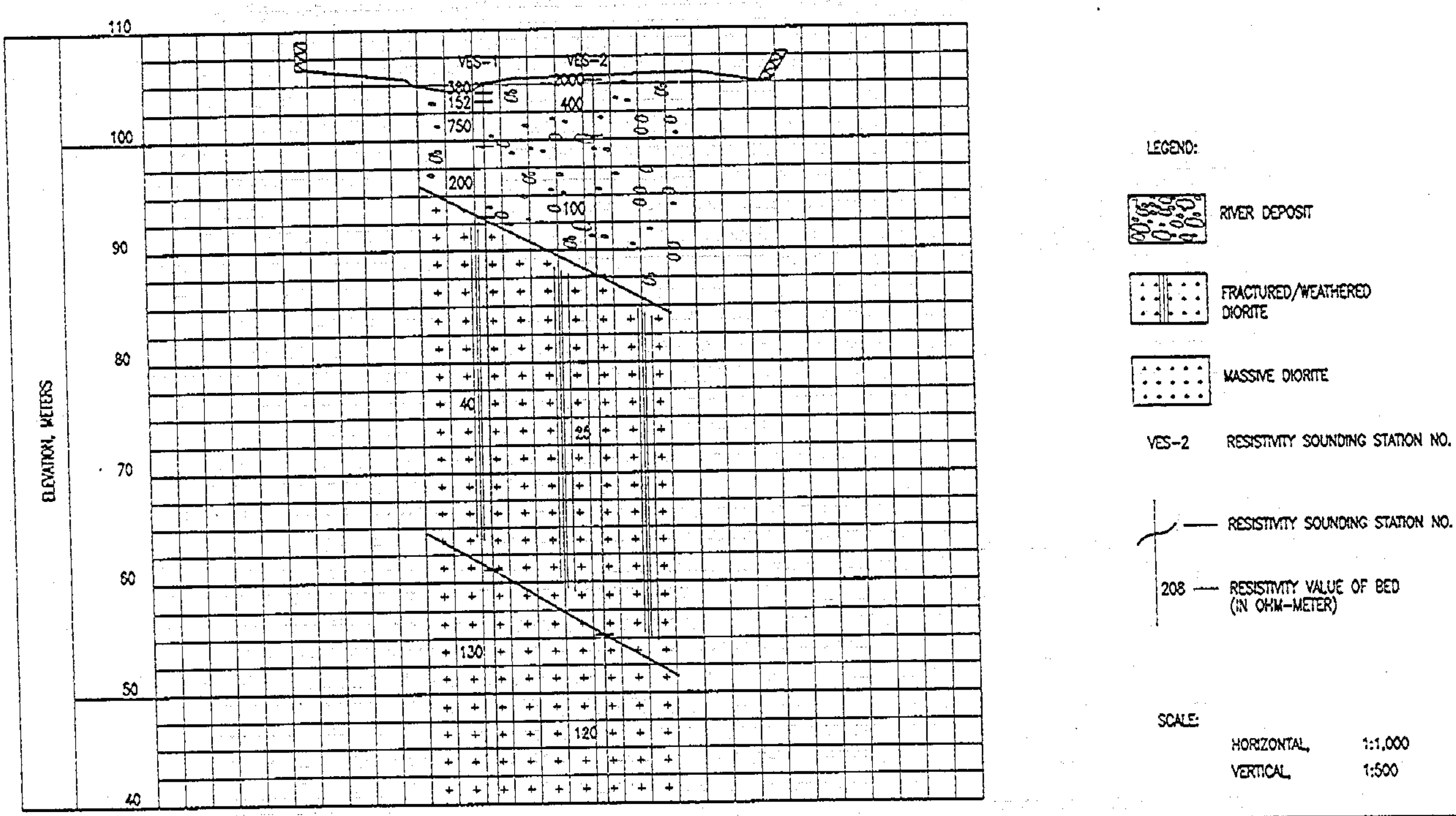
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 4 RESISTIVITY PROFILE ALONG LINE OF NIS INTAKE STRUCTURE OF CURA SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



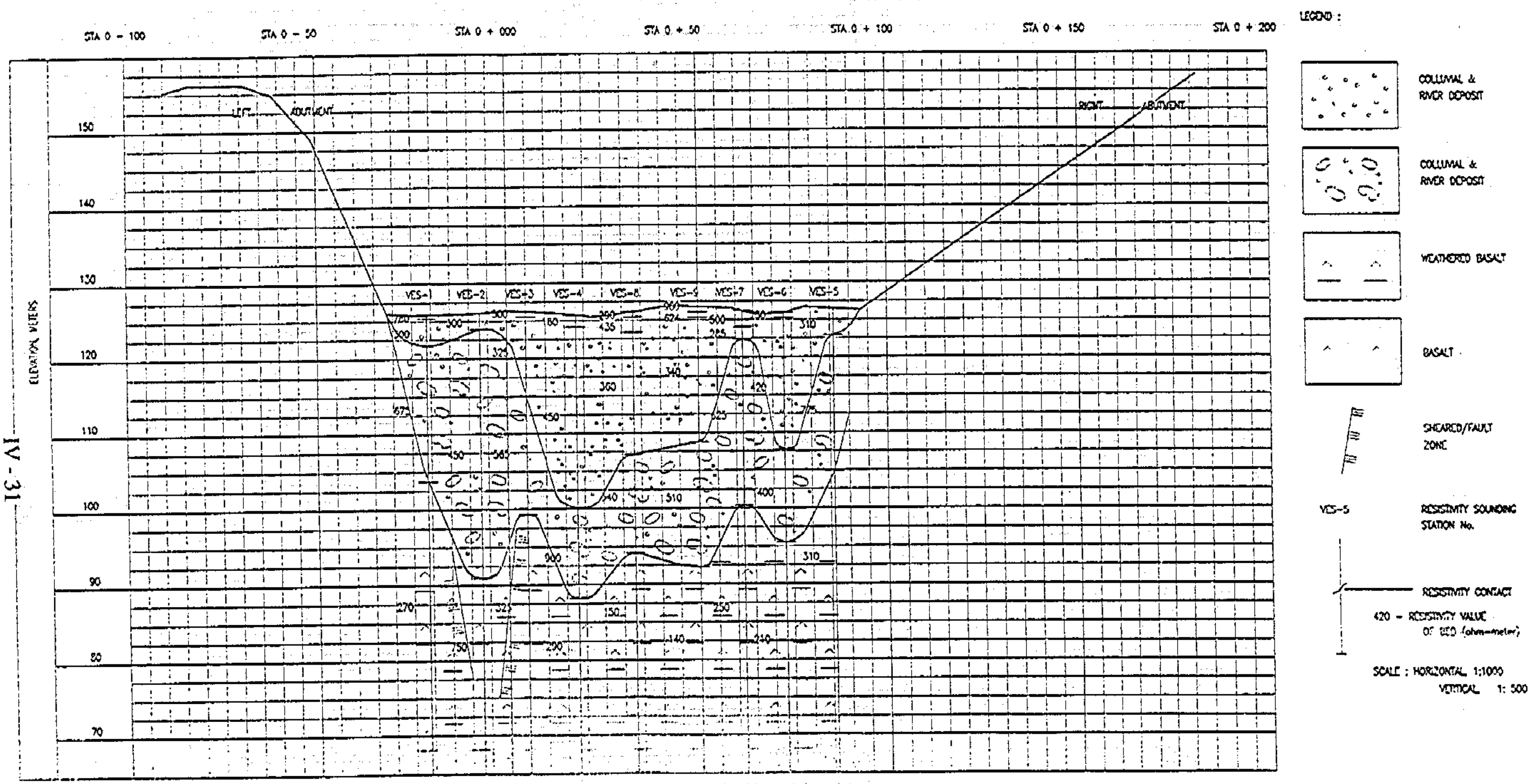
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 5 RESISTIVITY PROFILE ALONG STA. 0+235M. OF LABUGAON SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



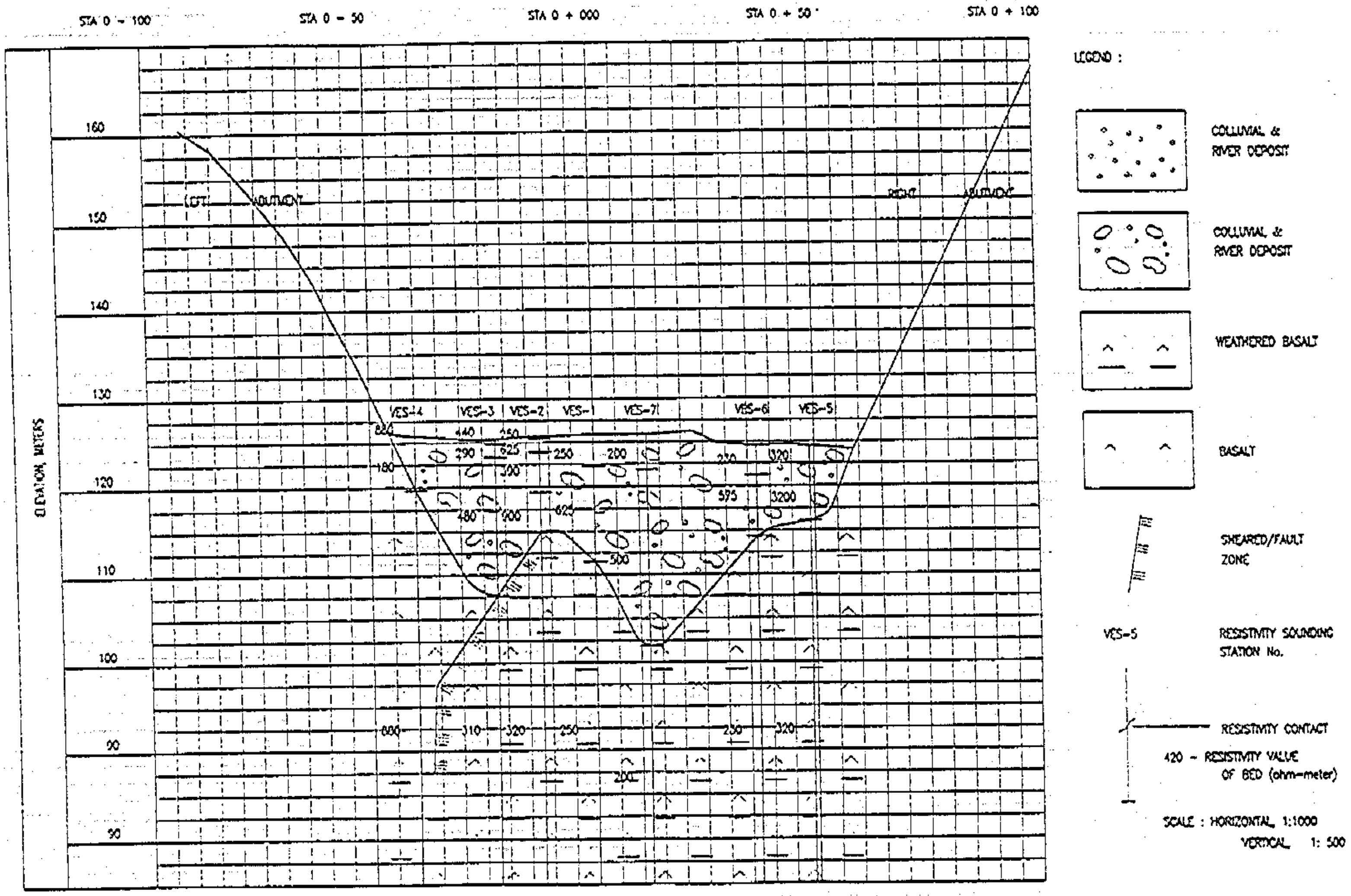
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 6 RESISTIVITY PROFILE ALONG DAM AXIS No. 1 OF SOLSONA SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 7 RESISTIVITY PROFILE ALONG LINE 100M. DOWNSTREAM OF EXISTING SOLSONA DAM
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 8 RESISTIVITY PROFILE ALONG STA. 0+133M. OF MADONGAN SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	

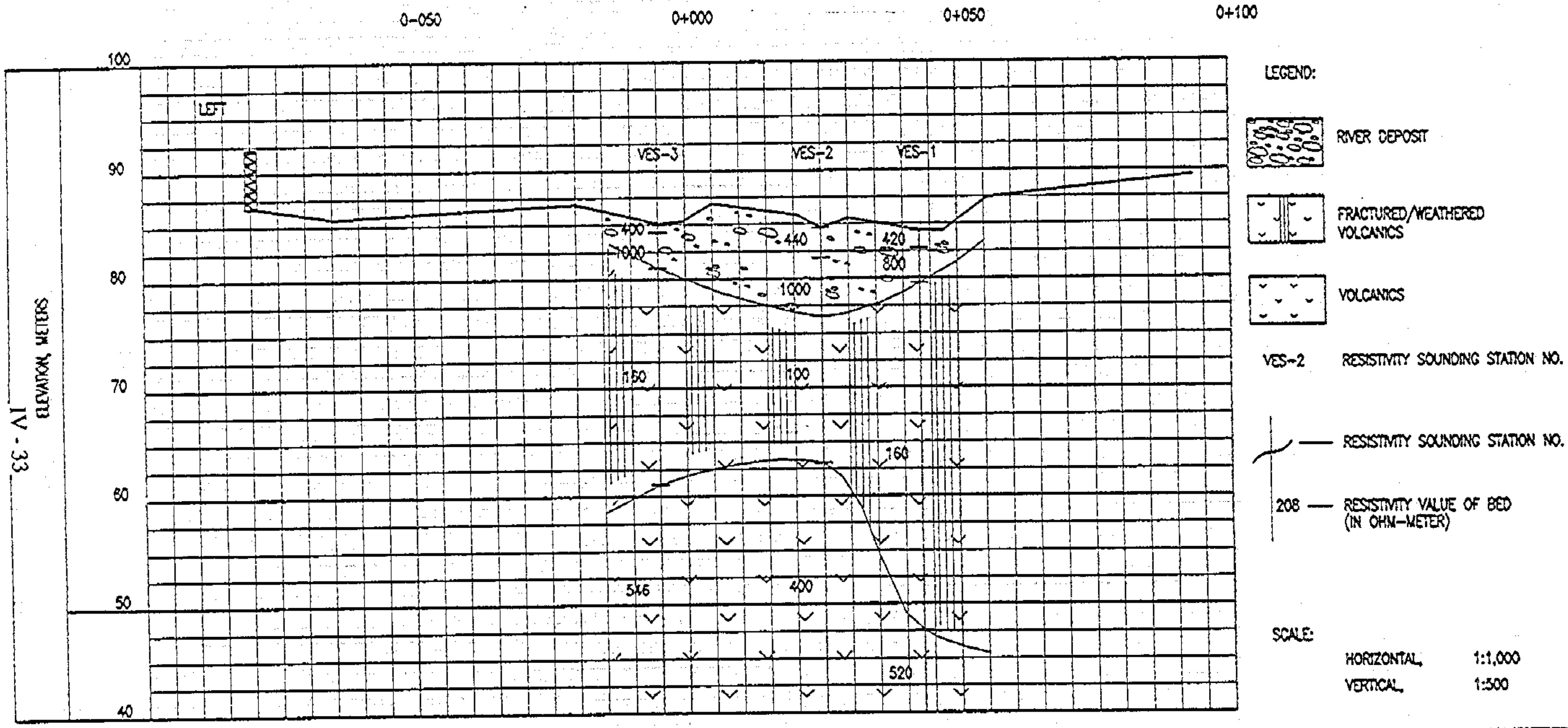


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

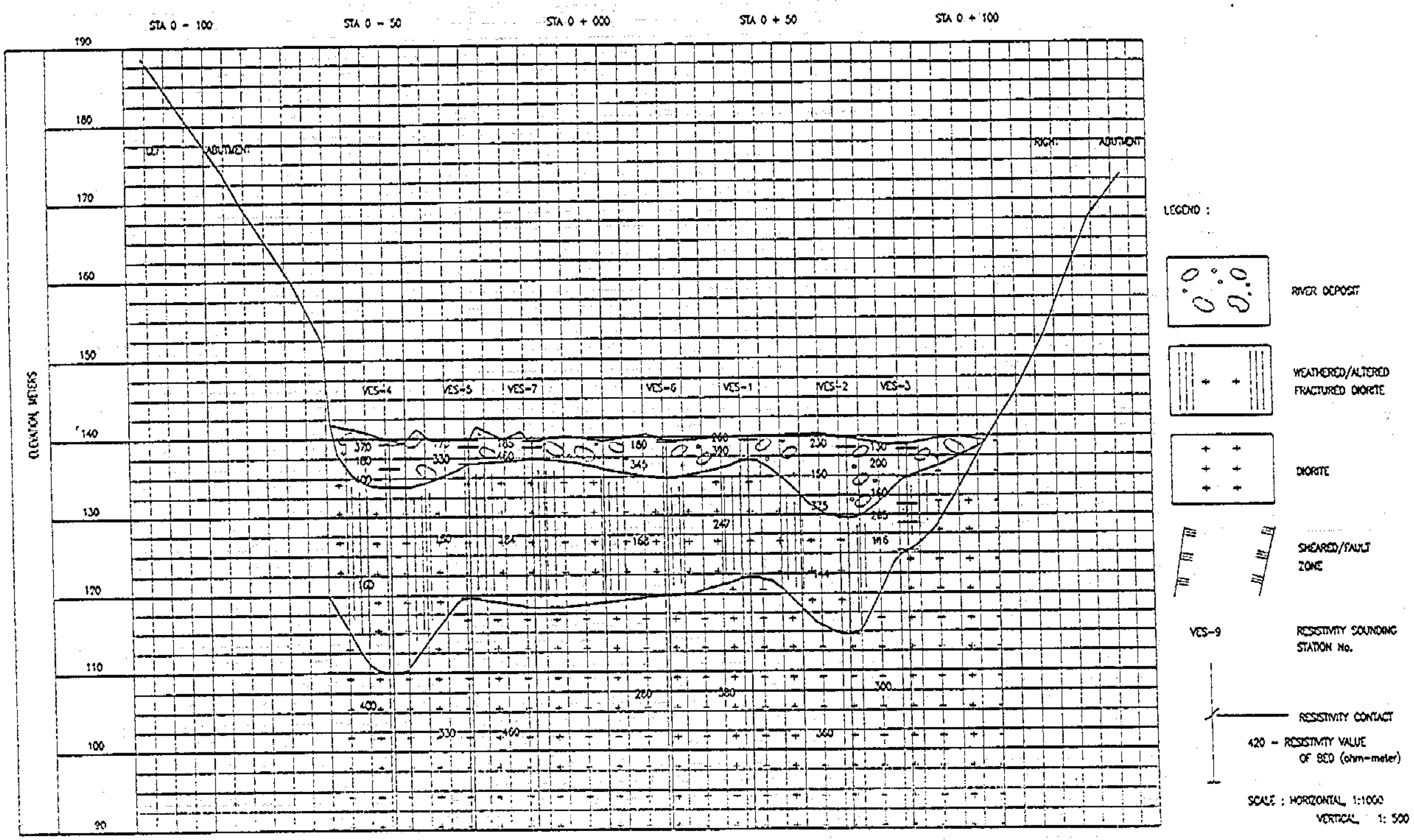
GEOPHYSICAL SURVEY

THE JICA STUDY TEAM

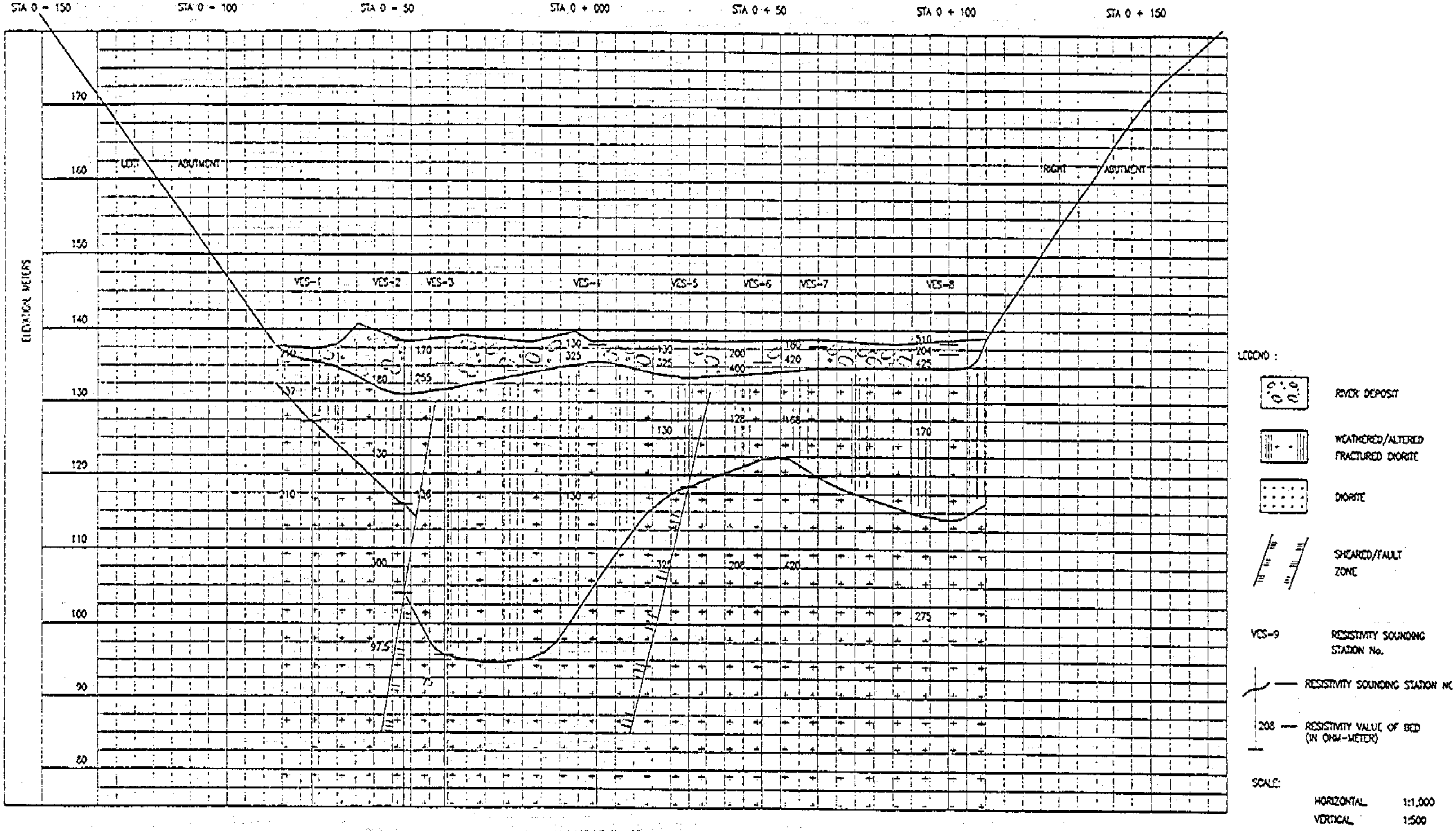
Figure No. 9 RESISTIVITY PROFILE ALONG STA. 0+60M. OF MADONGAN SABO DAMSITE



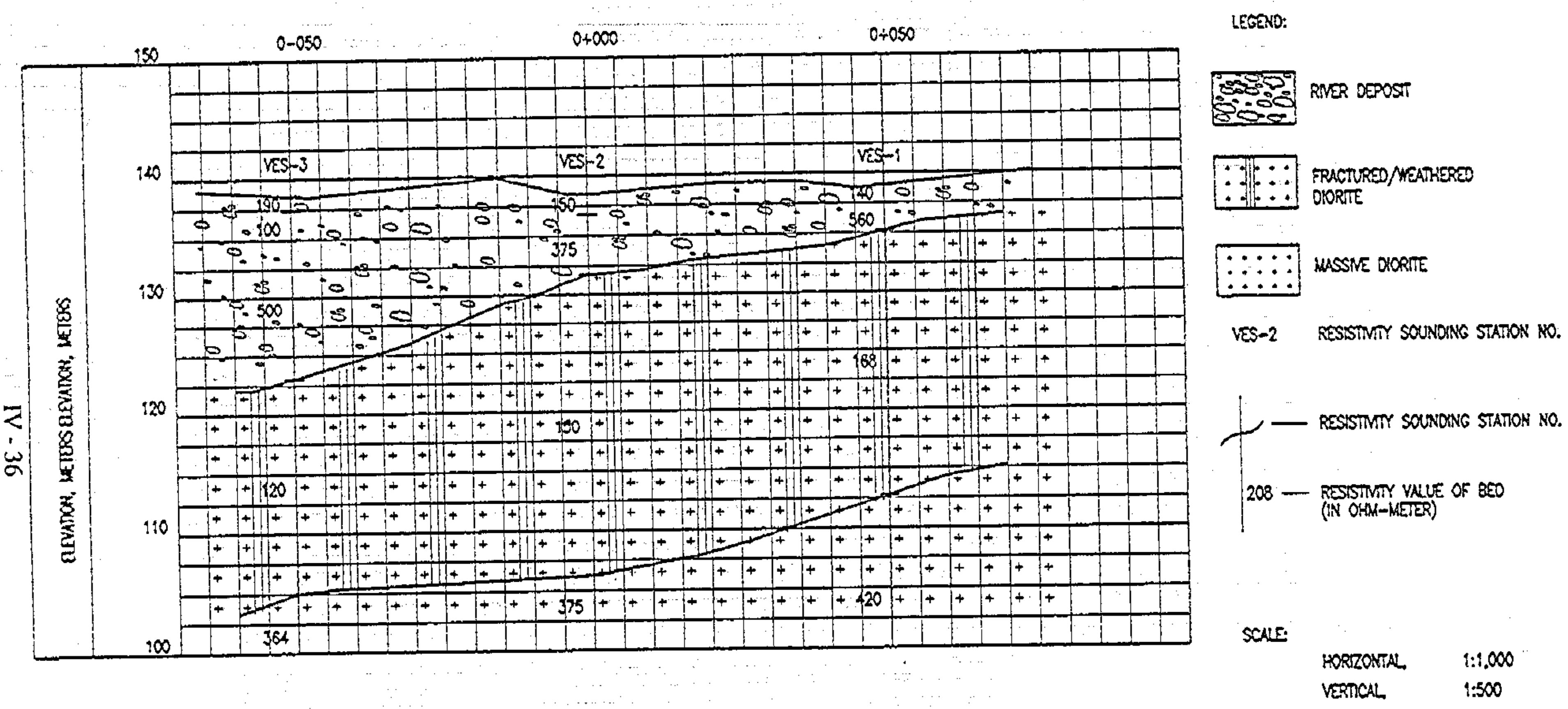
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 10 RESISTIVITY PROFILE ALONG LINE 150M. DOWNSTREAM OF EXISTING MADONGAN DAM
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



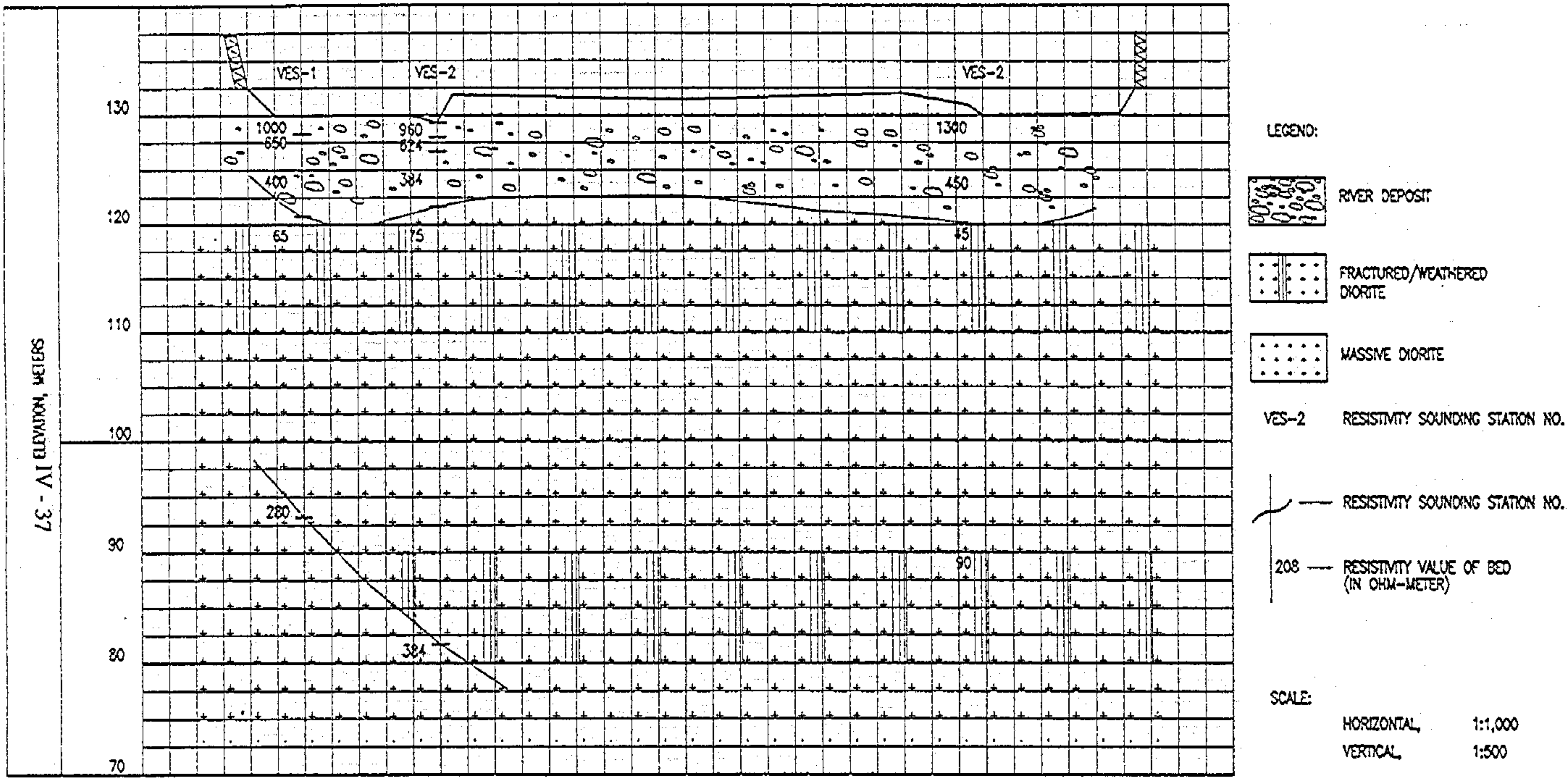
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 11 RESISTIVITY PROFILE ALONG STA. 0+217.53M. OF PAPA SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAC RIVER BASIN	Figure No. 12 RESISTIVITY PROFILE ALONG STA. 0+100M. OF PAPA SABO DAMSITE
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 13 RESISTIVITY PROFILE ALONG STA. 0+150M. DOWNSTREAM OF PAPA SABO DAM
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	

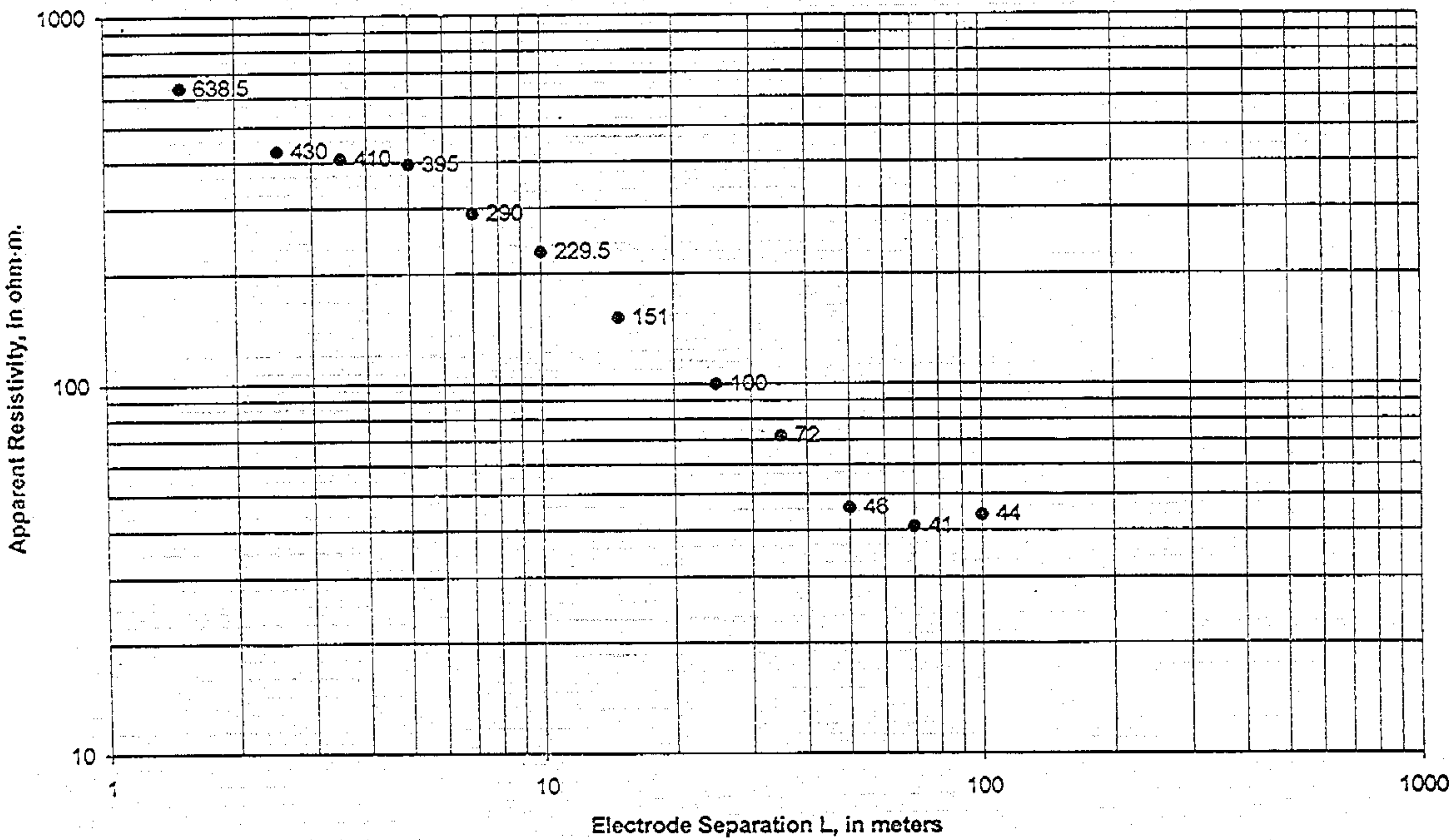


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Figure No. 14 RESISTIVITY PROFILE ALONG LINE 150M. DOWNSTREAM OF EXISTING PAPA DAM
GEOPHYSICAL SURVEY	
THE JICA STUDY TEAM	

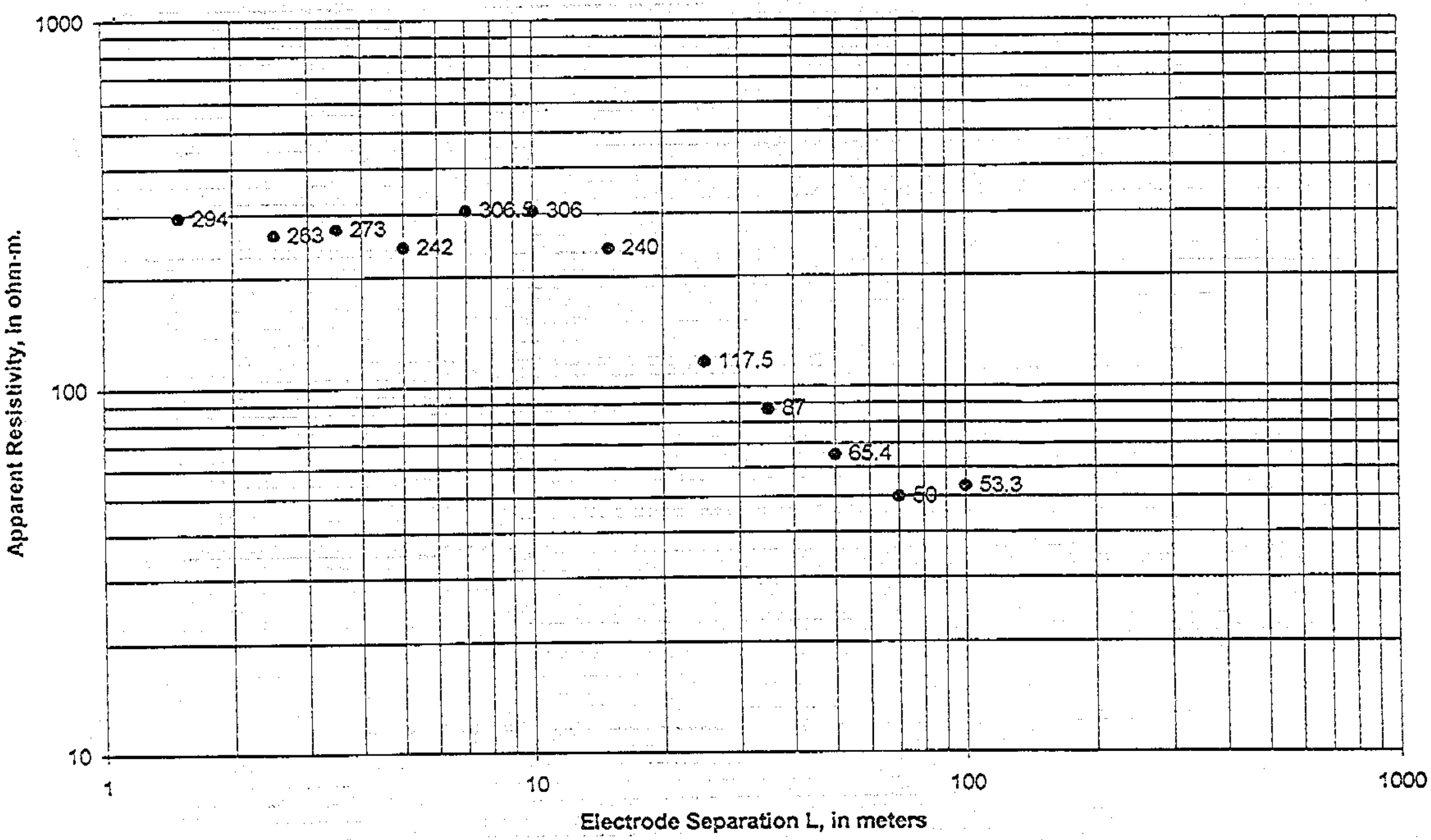
ANNEX

RESISTIVITY DATA PLOT FOR LAOAG SABO AND FLOOD CONTROL STUDY

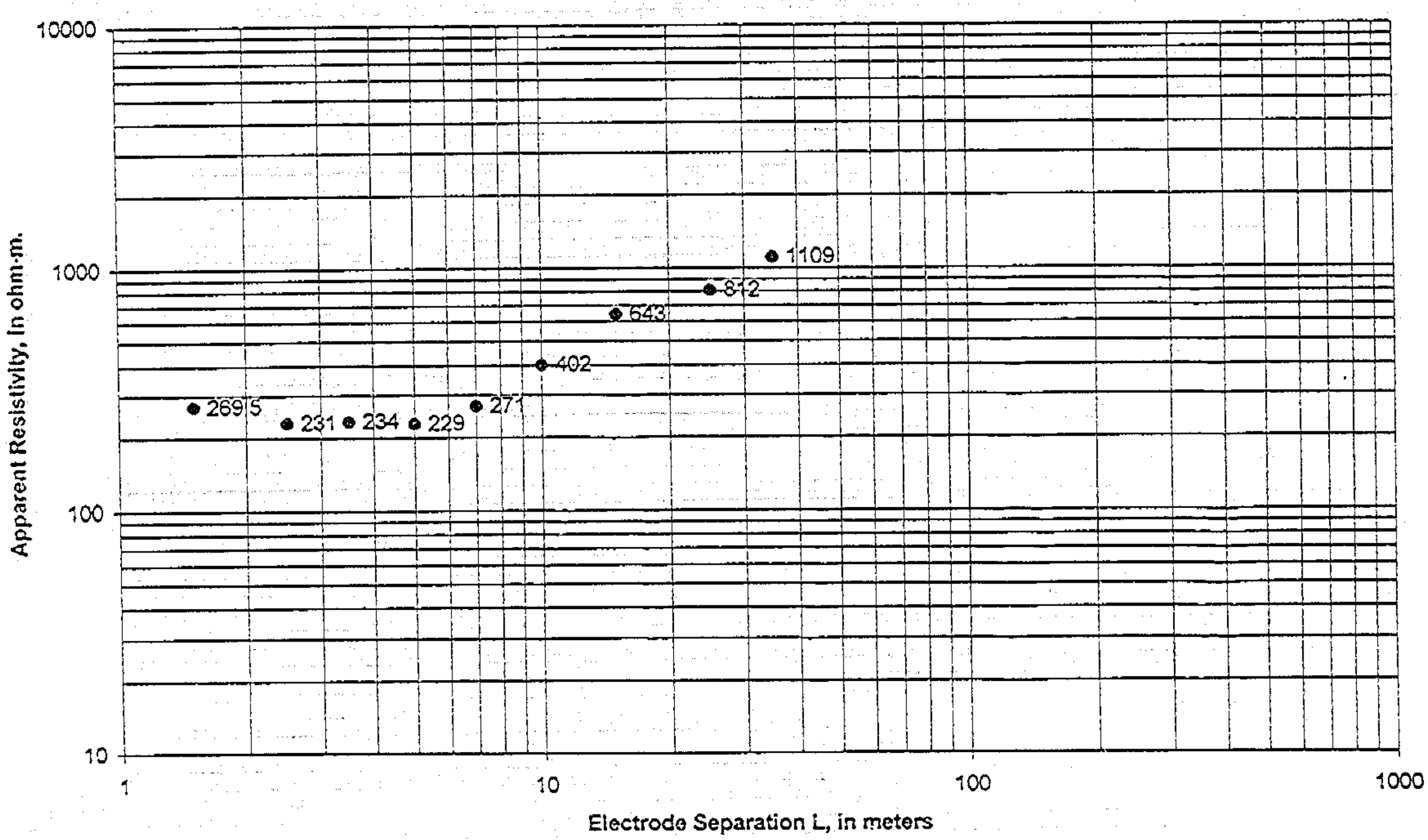
VES-1: SOLSONA DAMSITE, STA. 0 - 100 M.



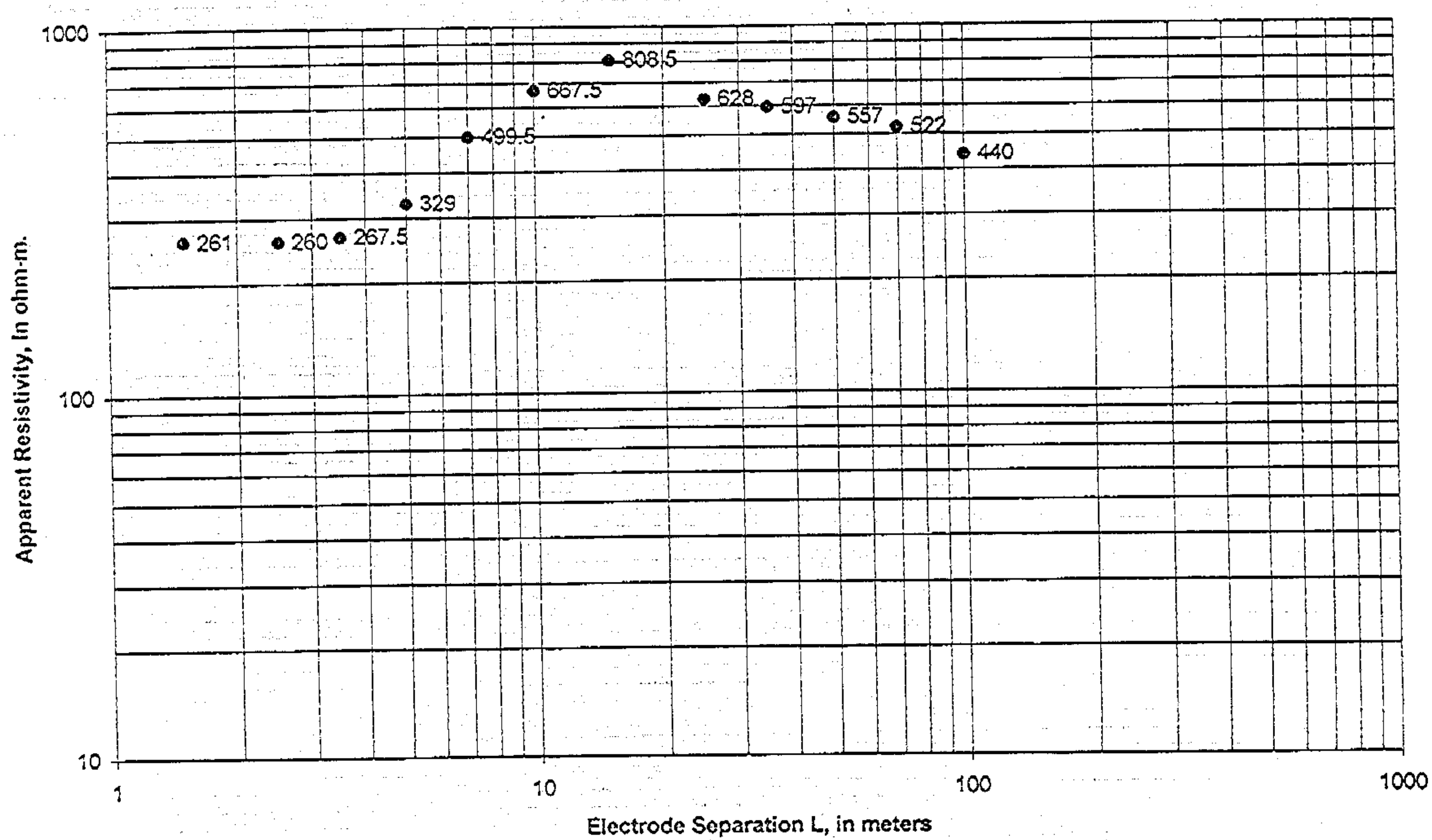
VES-2: SOLSONA DAMSITE, STA. 0 - 100 M.



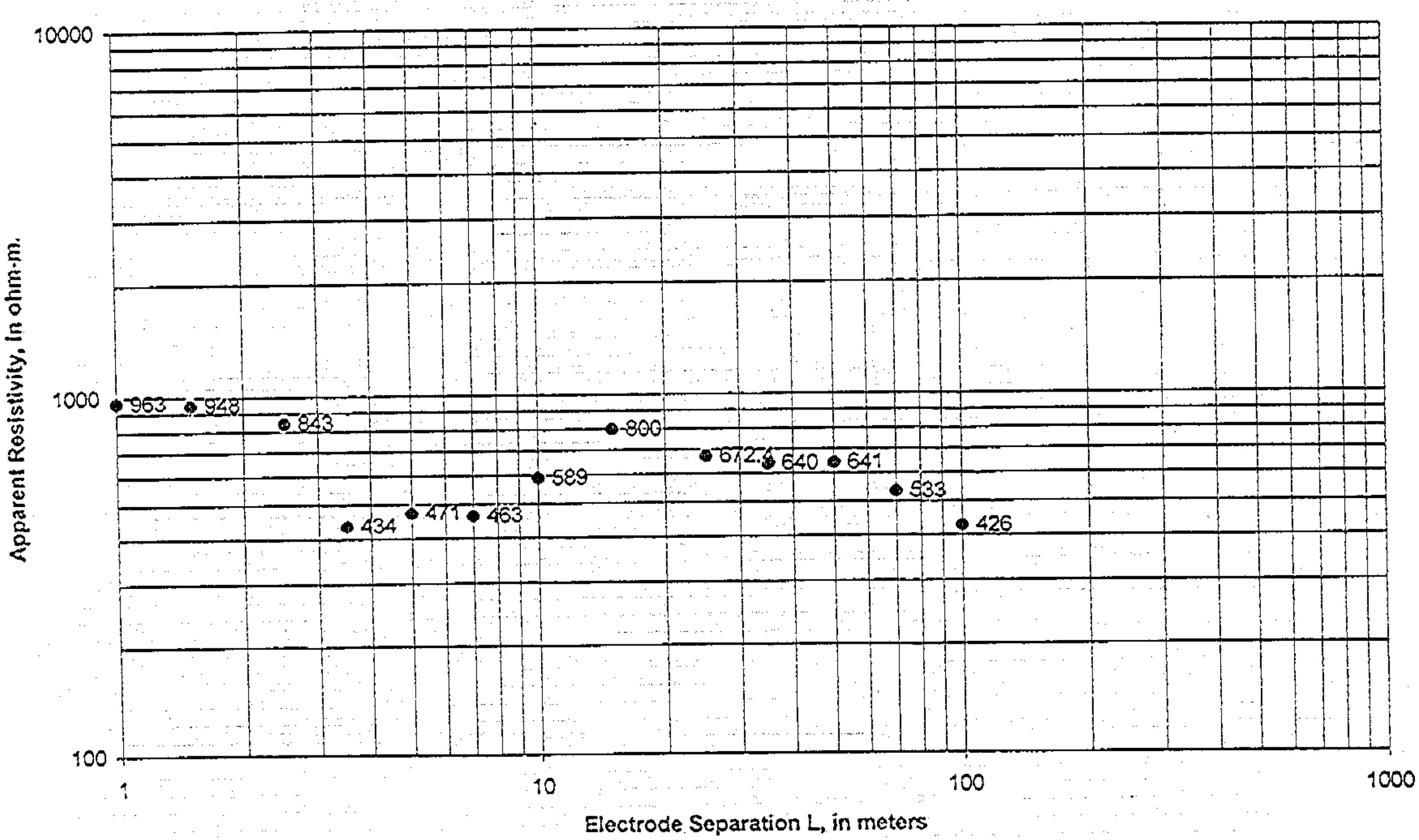
VES-1: SOLSONA DAMSITE, D - AXIS



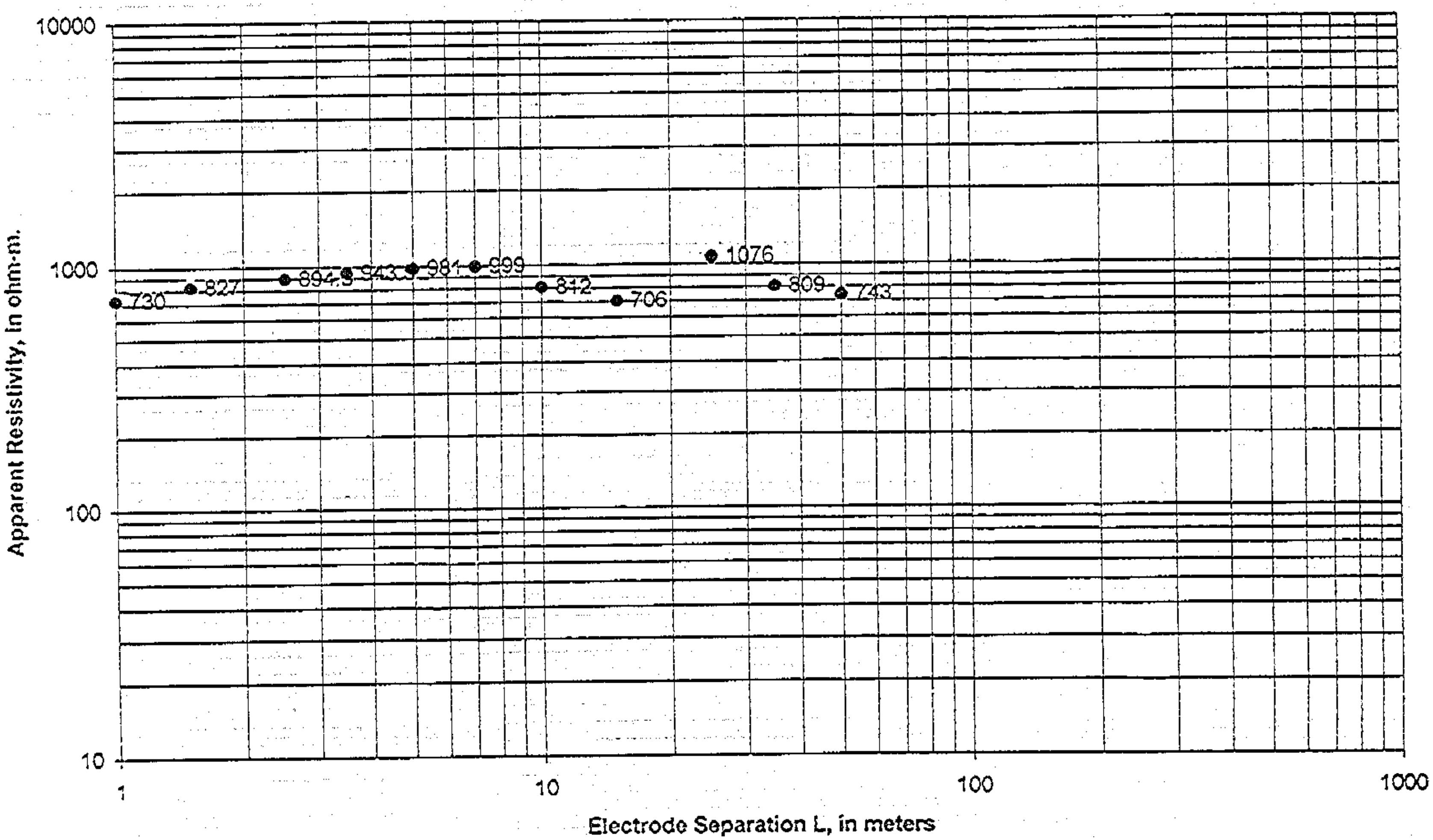
VES-2: SOLSONA DAMSITE, D - AXIS



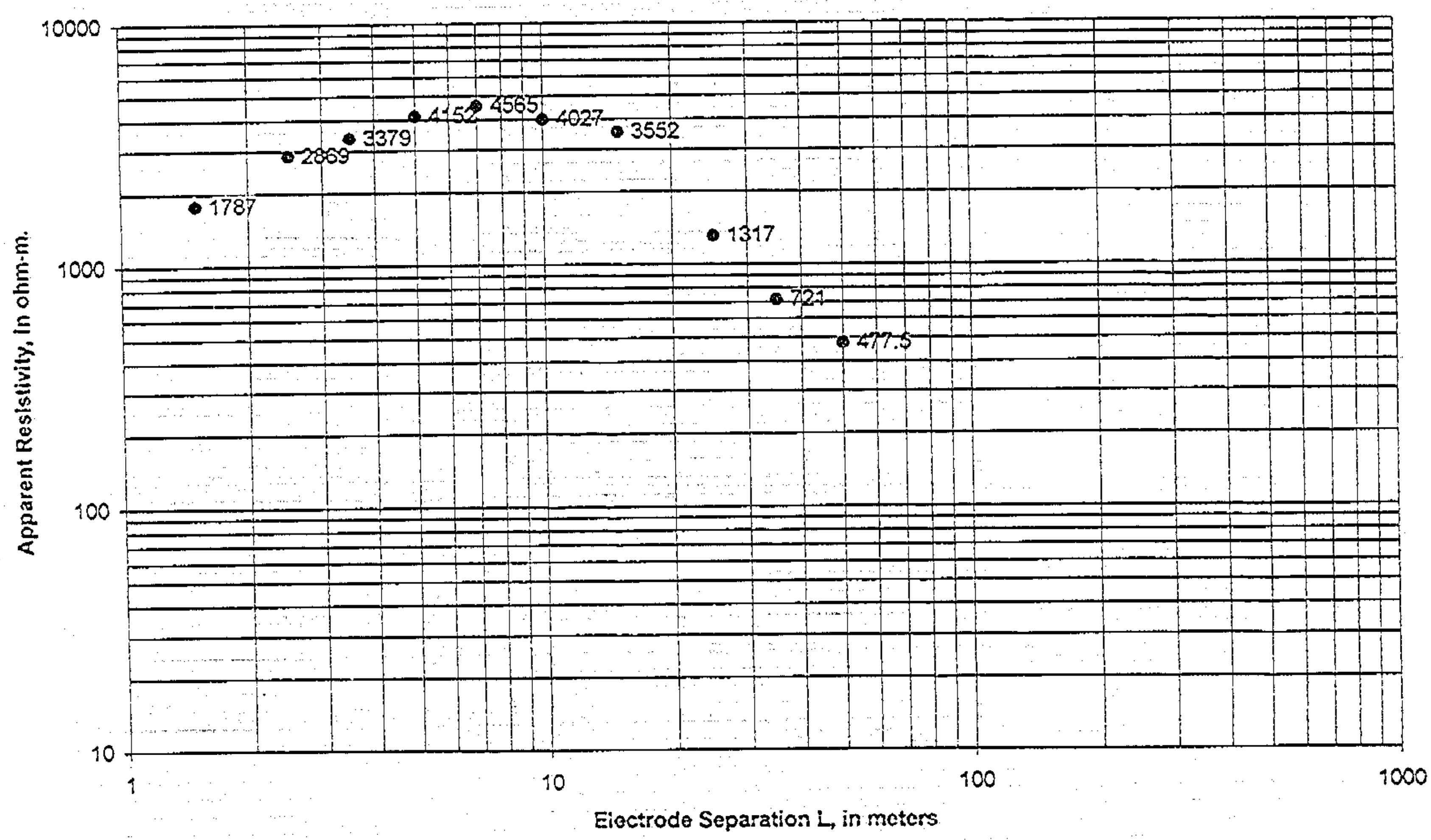
VES-3: SOLSONA DAMSITE, D - AXIS



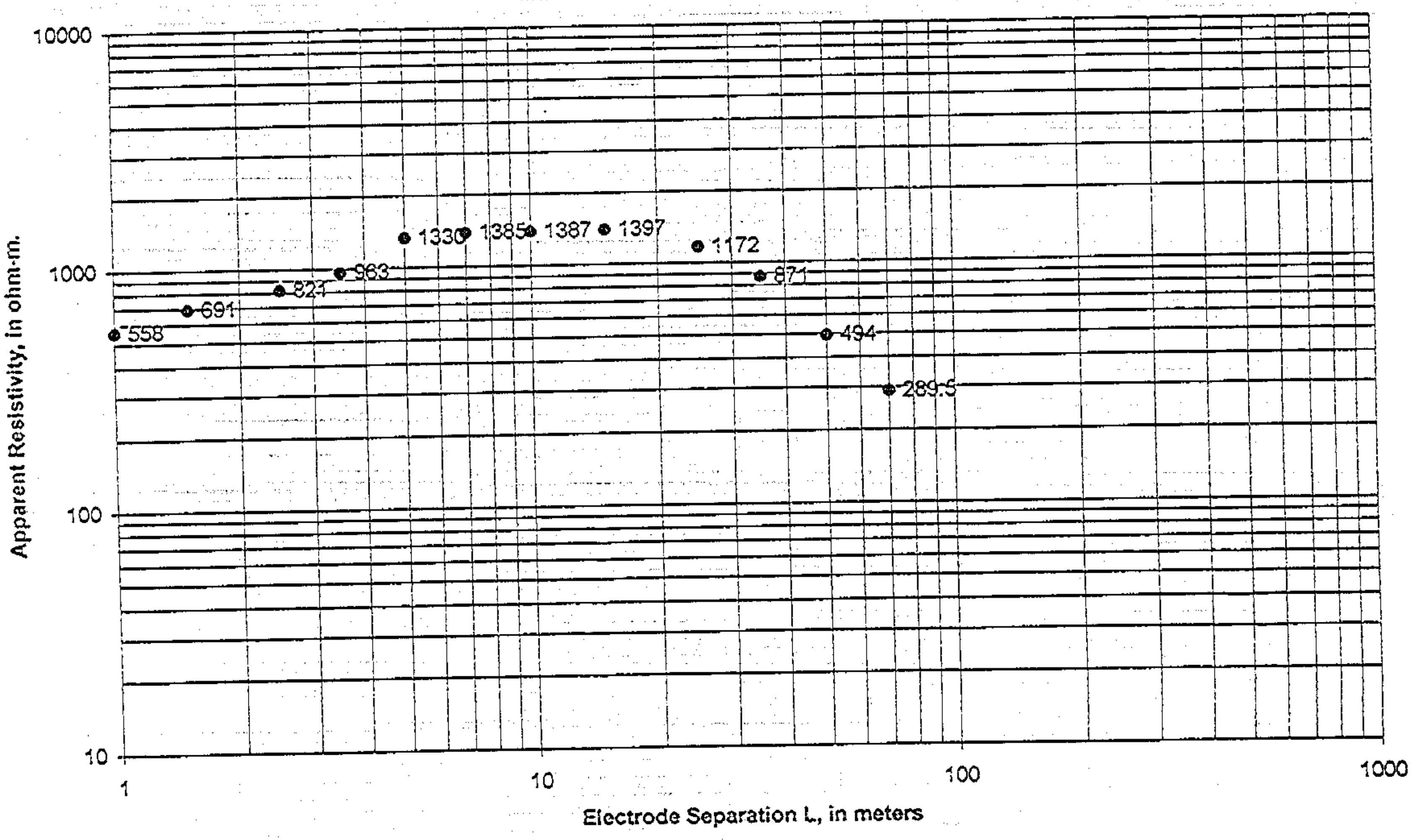
VES-4: SOLSONA DAMSITE, D - AXIS



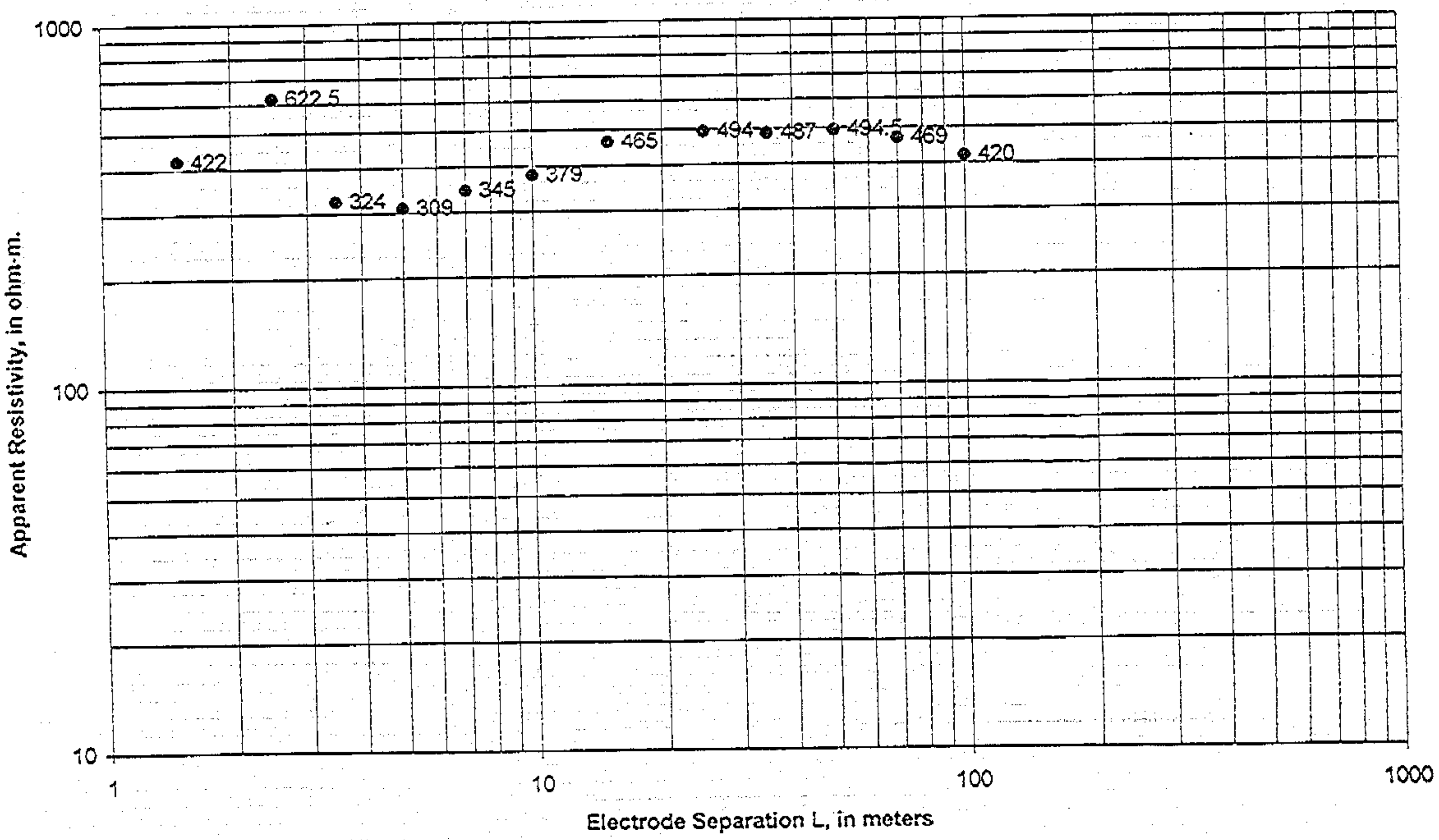
VES-5: SOLSONA DAMSITE, D - AXIS



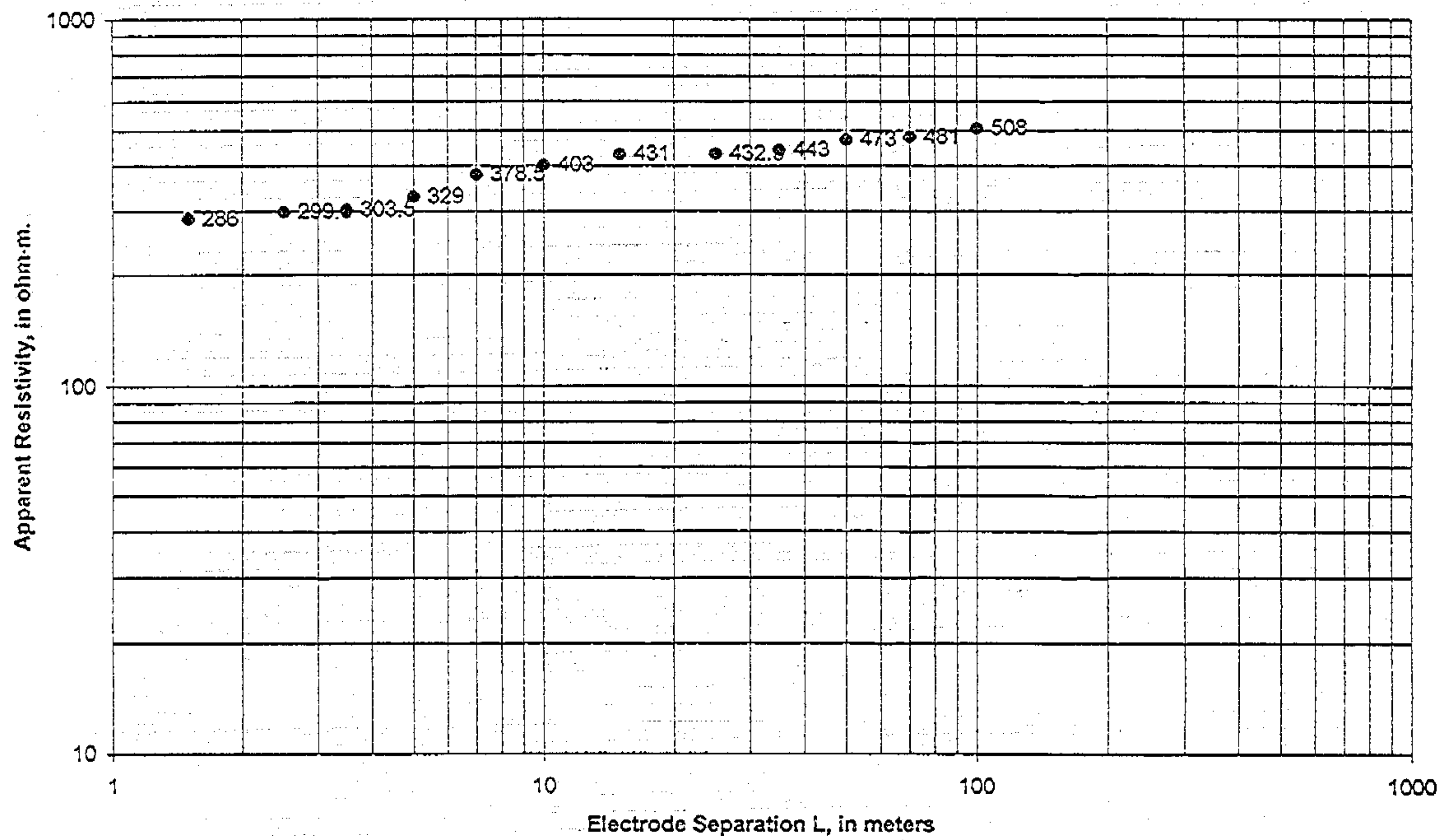
VES-6: SOLSONA DAMSITE, D - AXIS



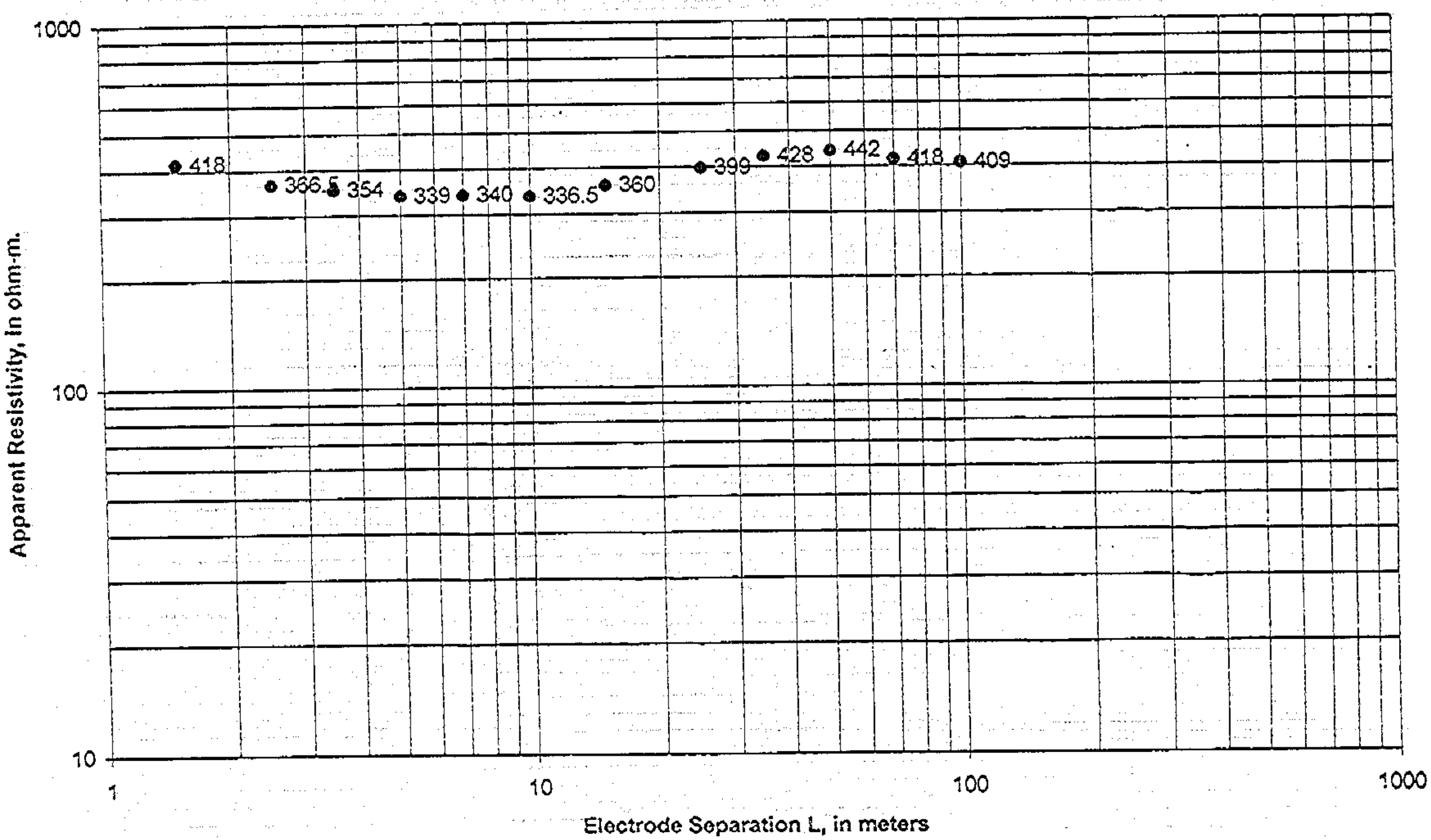
VES-1: MADONGAN DAMSITE, STA. 0 + 133 M.



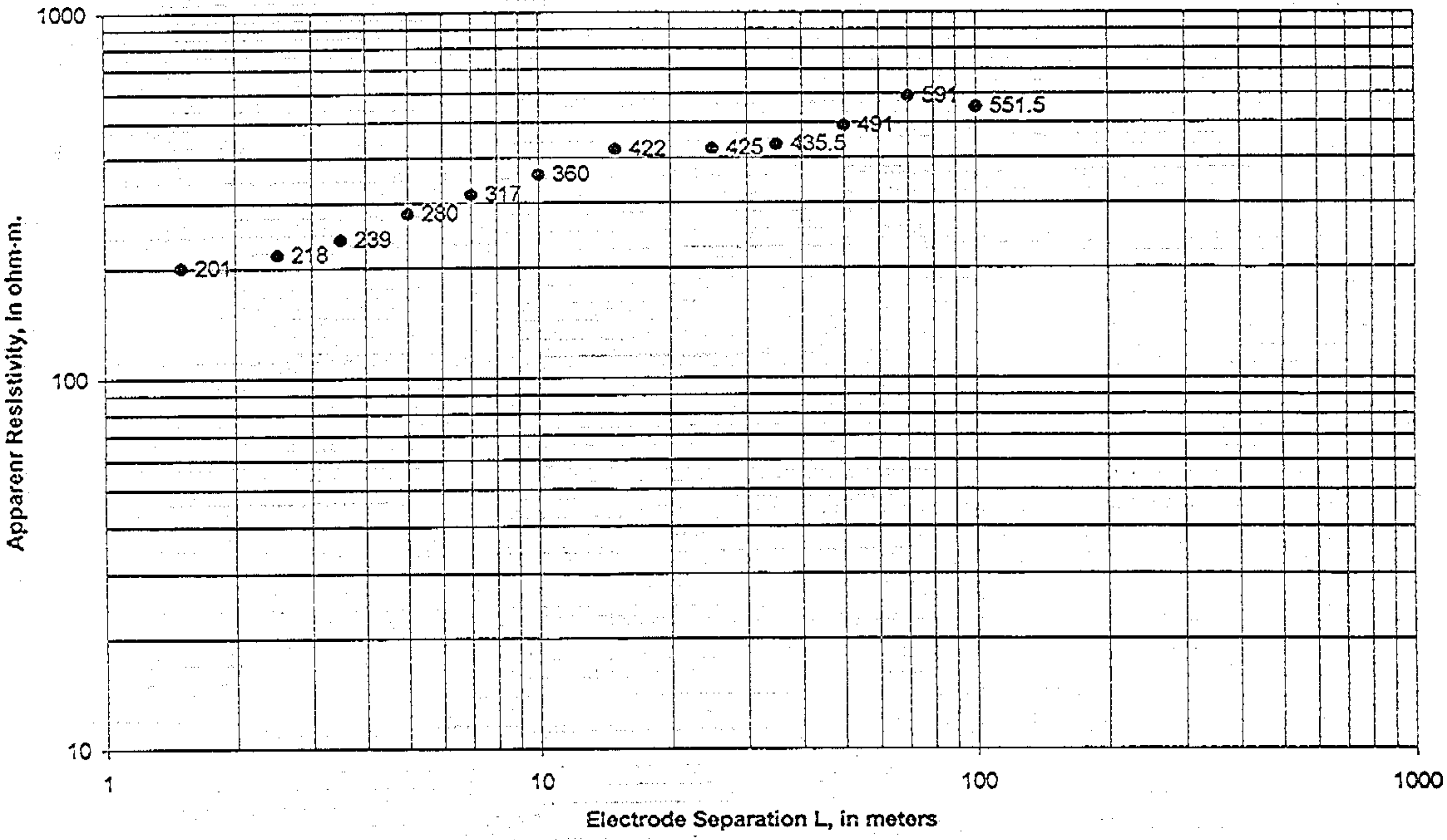
VES-2: MADONGAN DAMSITE, STA. 0 + 133 M.



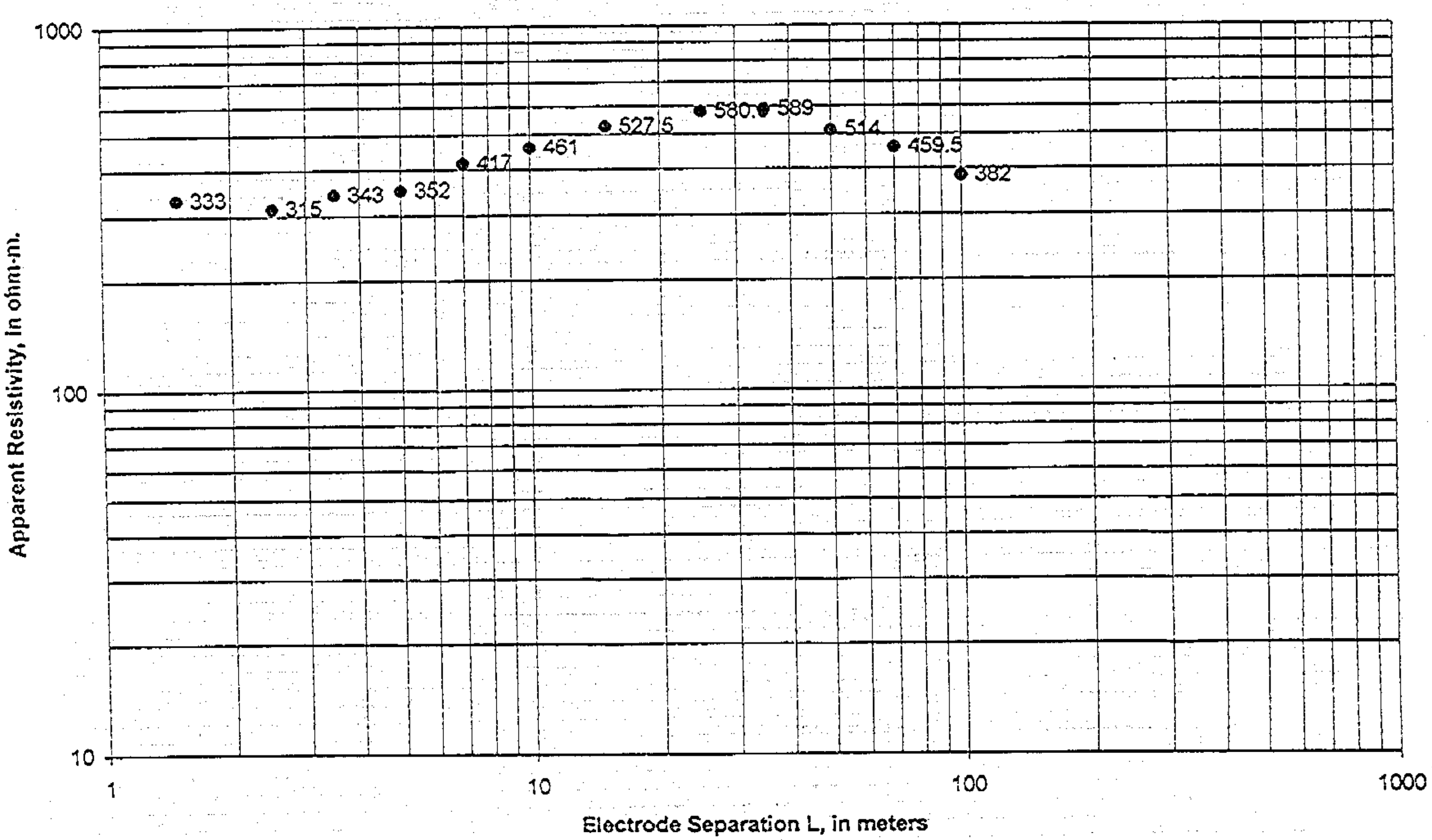
VES-3: MADONGAN DAMSITE, STA. 0 + 133 M.



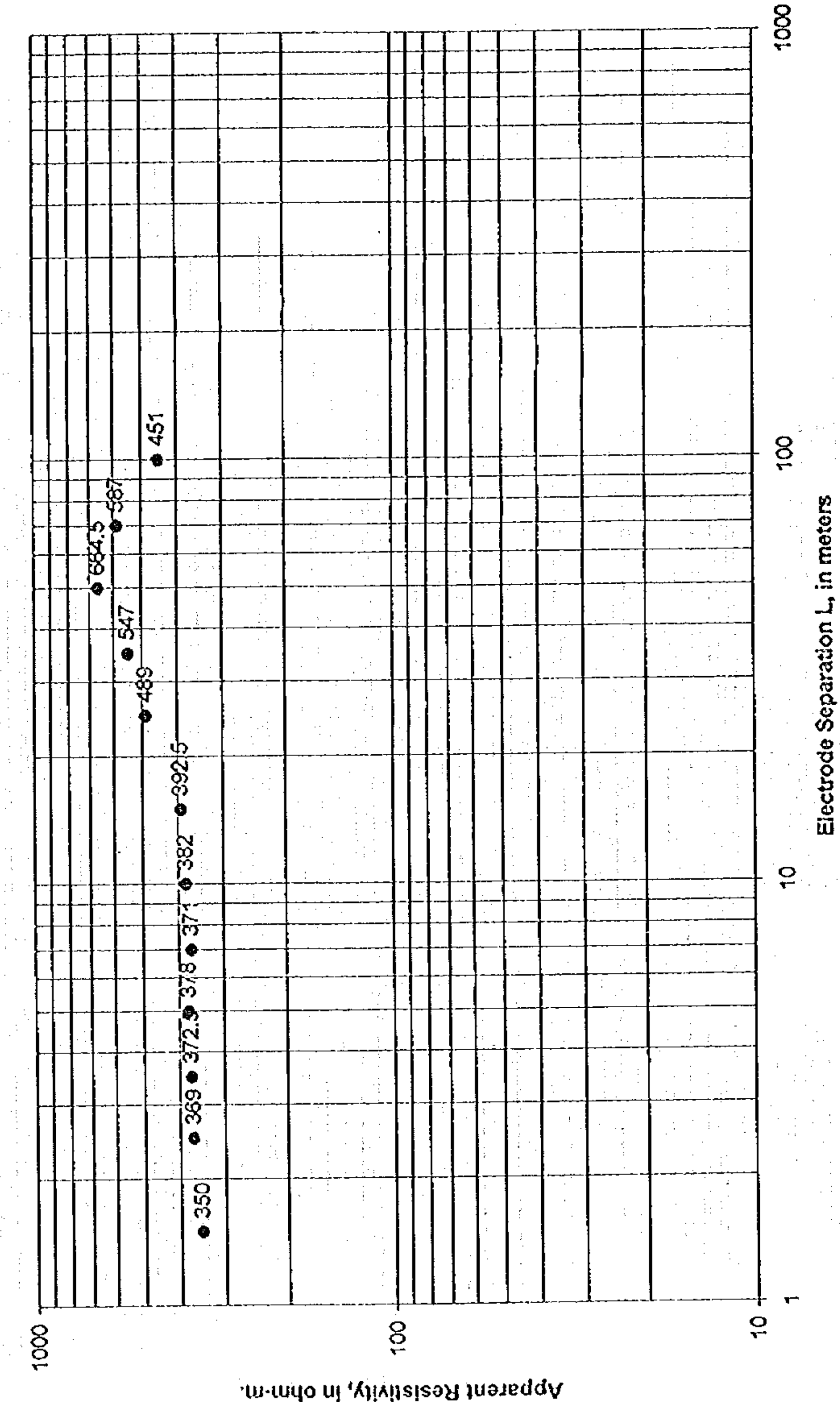
VES-4: MADONGAN DAMSITE, STA. 0 + 133 M.

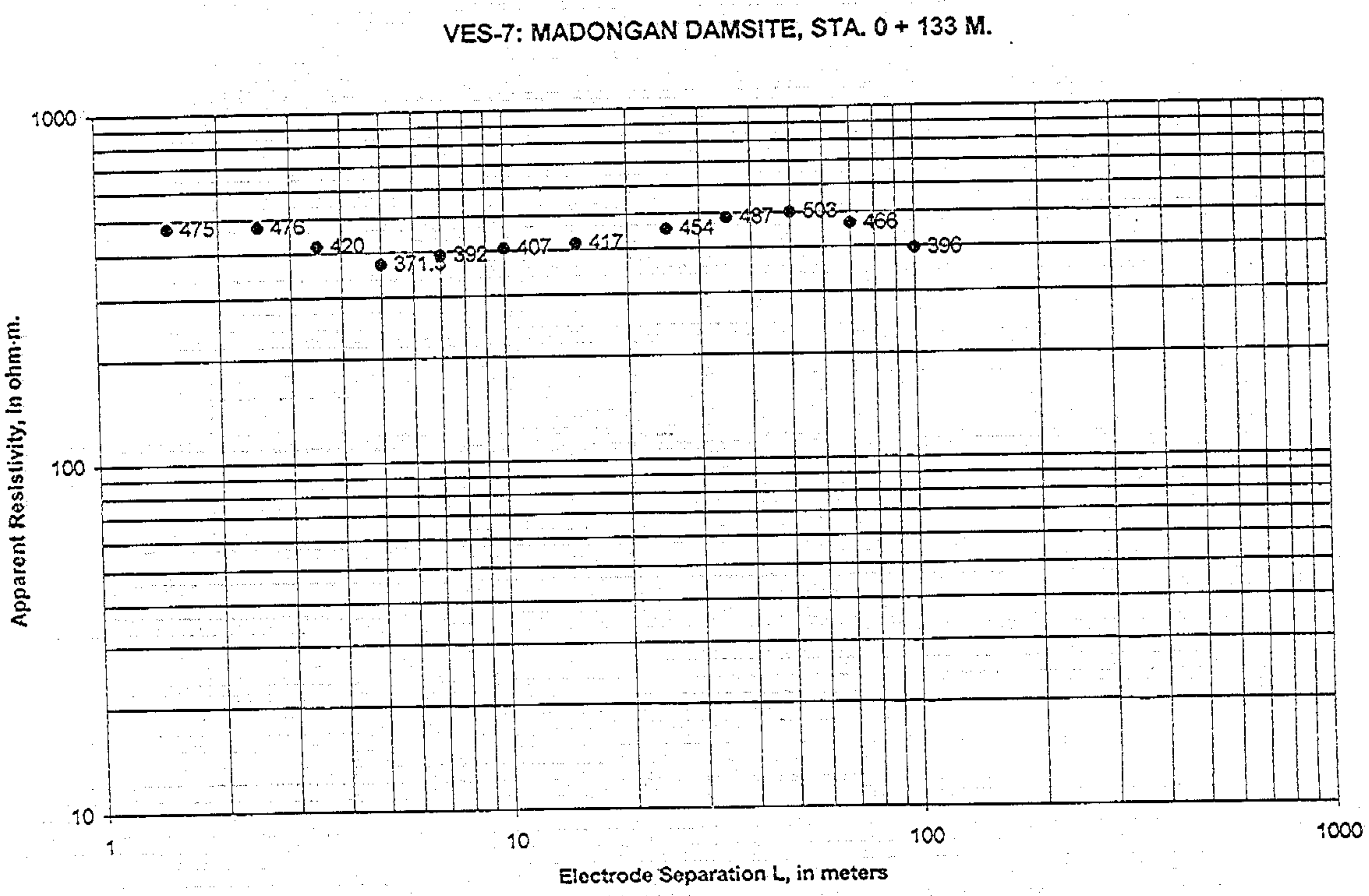


VES-5: MADONGAN FAMSITE, STA. 0 + 133 M.

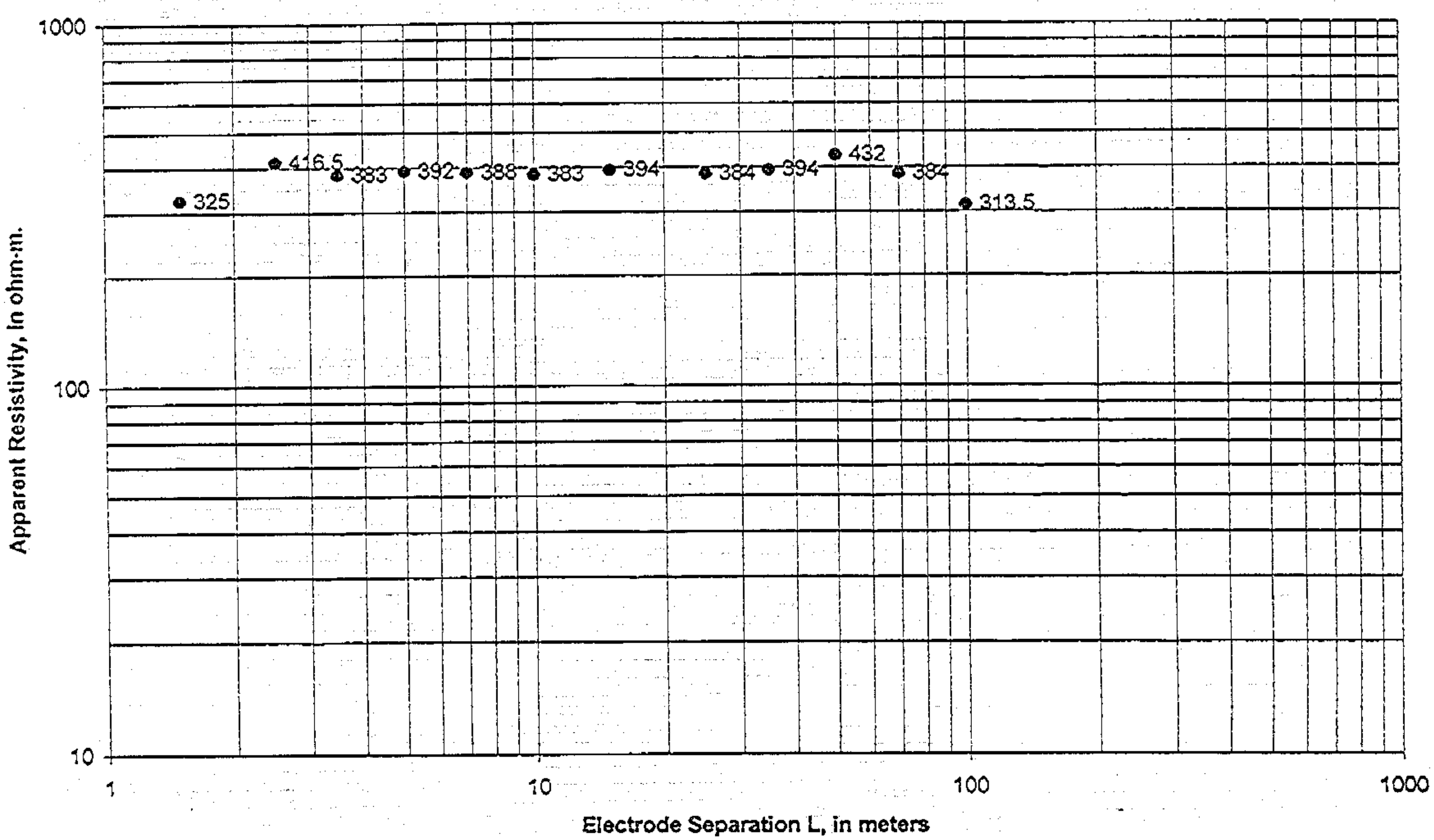


VES-6: MADONGAN DAMSITE, STA. 0 + 133 M.

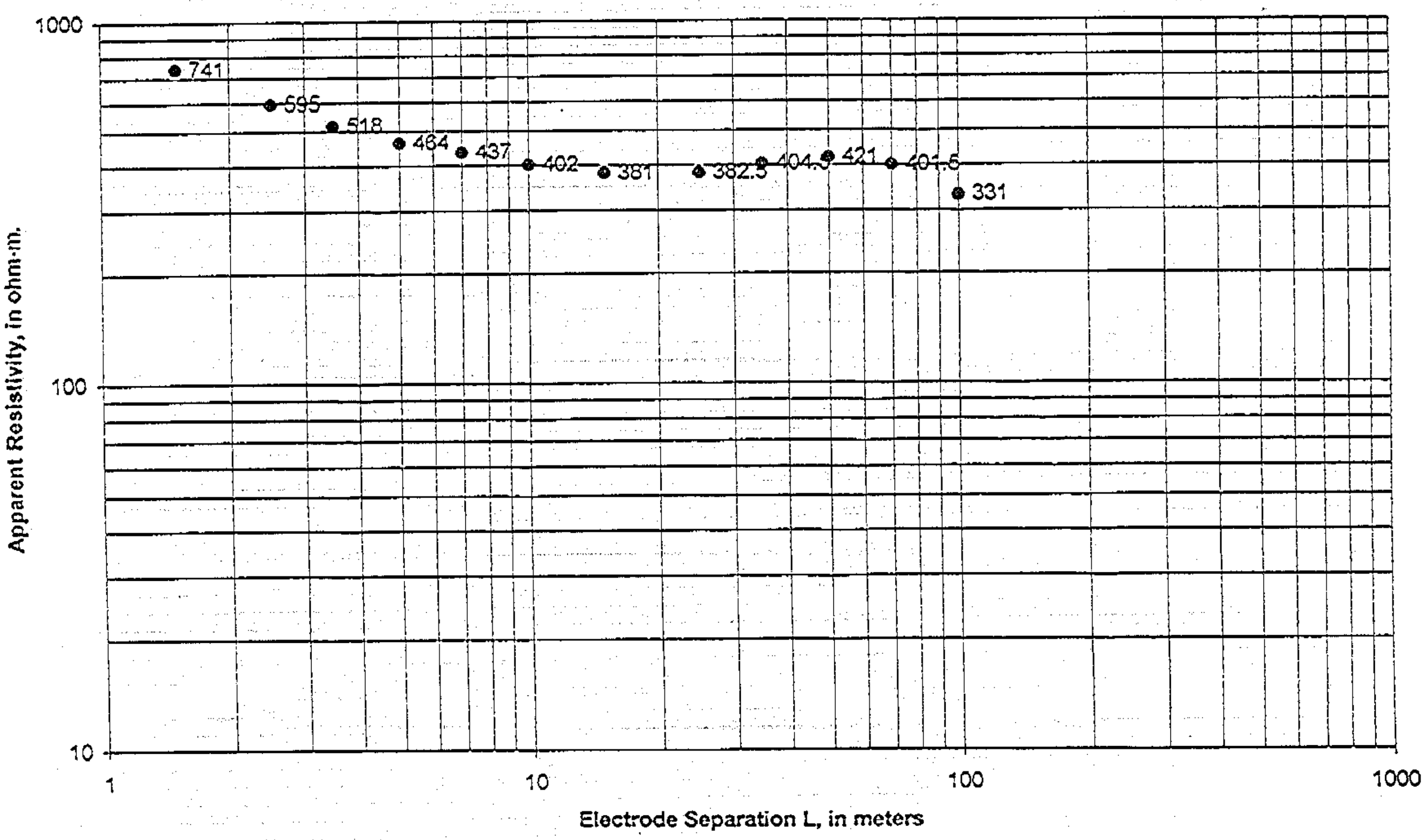



VES-7: MADONGAN DAMSITE, STA. 0 + 133 M.
475
476
420
371.5
392
407
417
454
487
503
466
396
1000
100
10
1
10
100
1000
Apparent Resistivity, in ohm-m.
Electrode Separation L, in meters

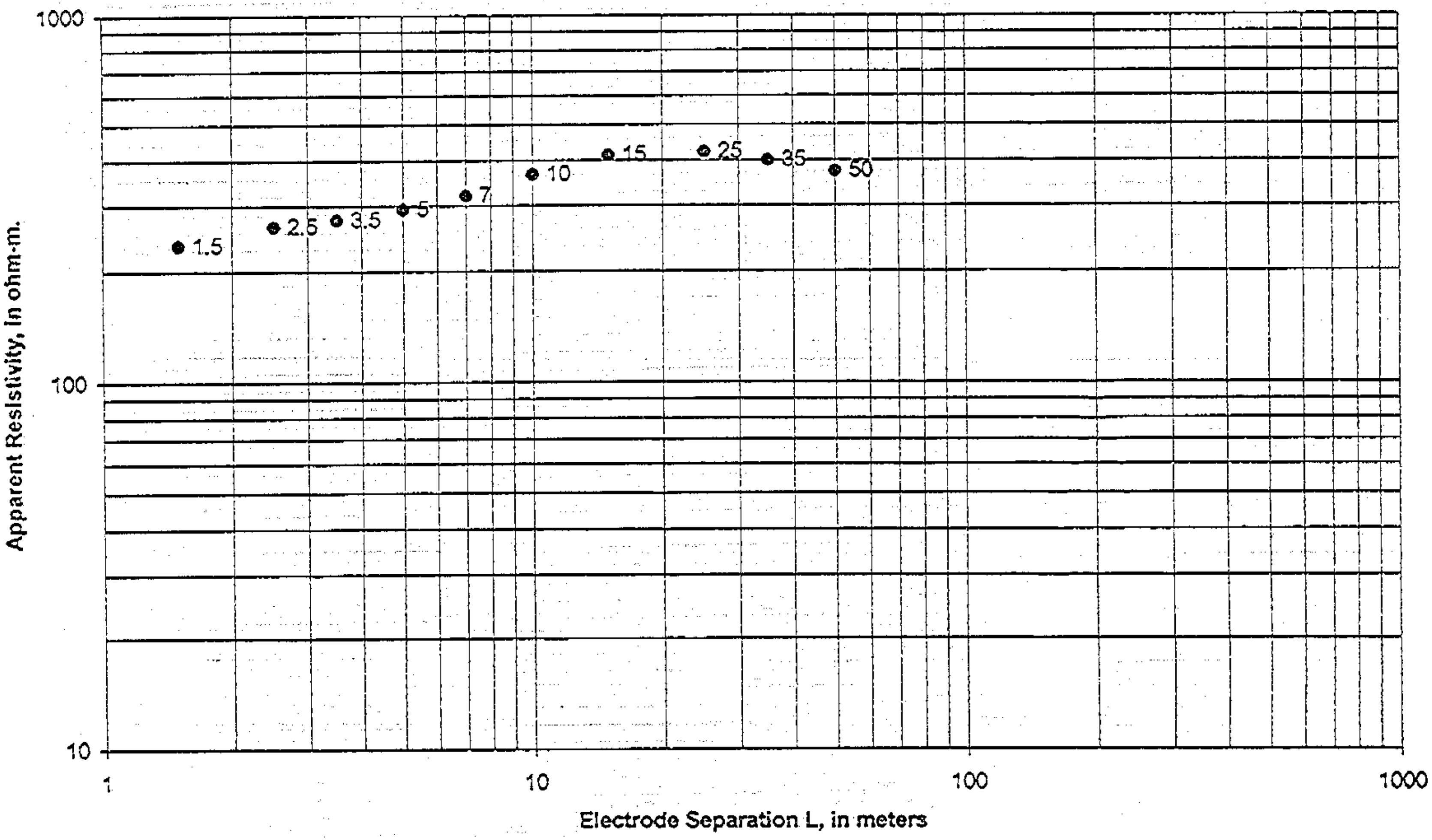
VES-8: MADONGAN DAMSITE, STA. 0 + 133 M.



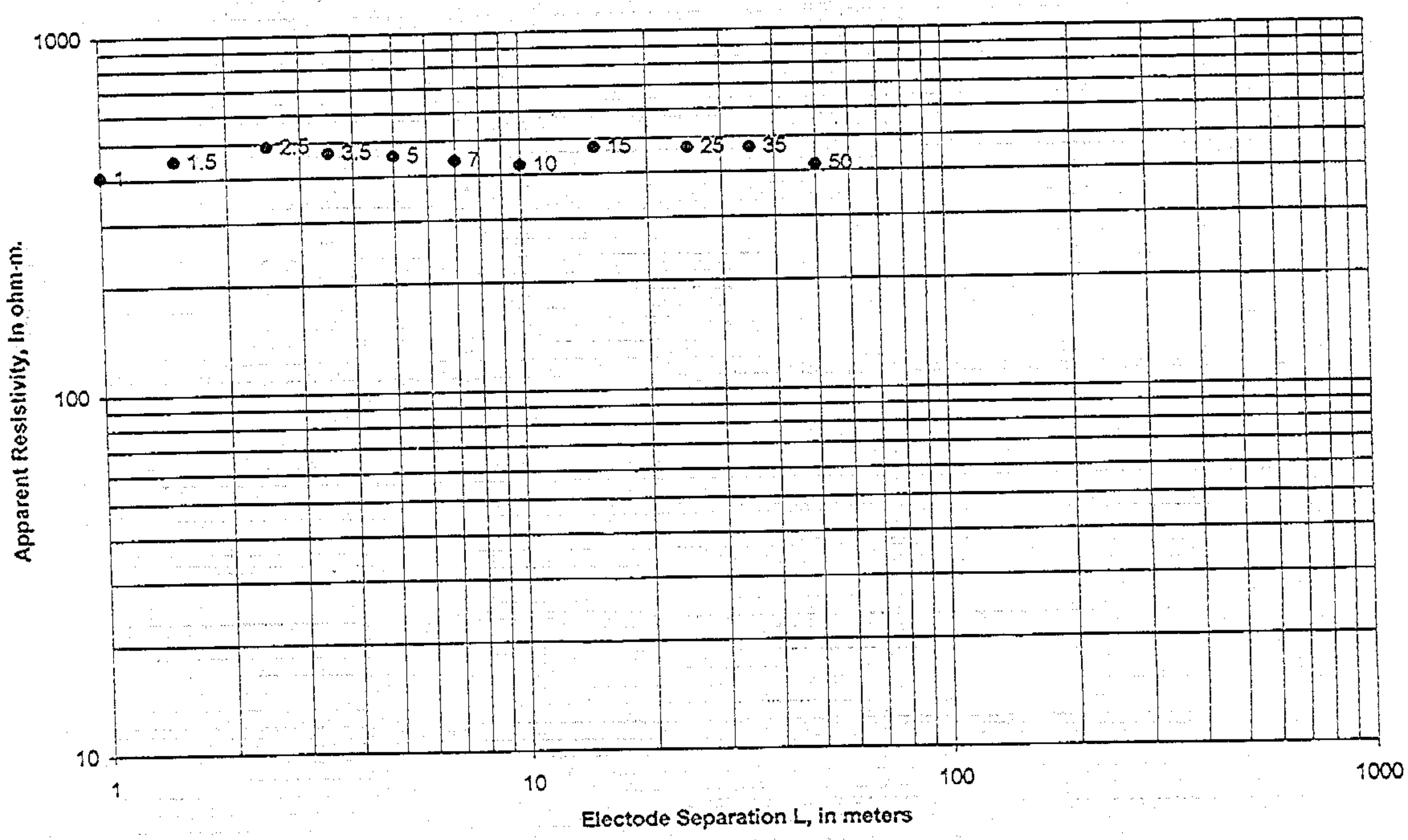
VES-9: MADONGAN DAMSITE, STA. 0 + 133 M.



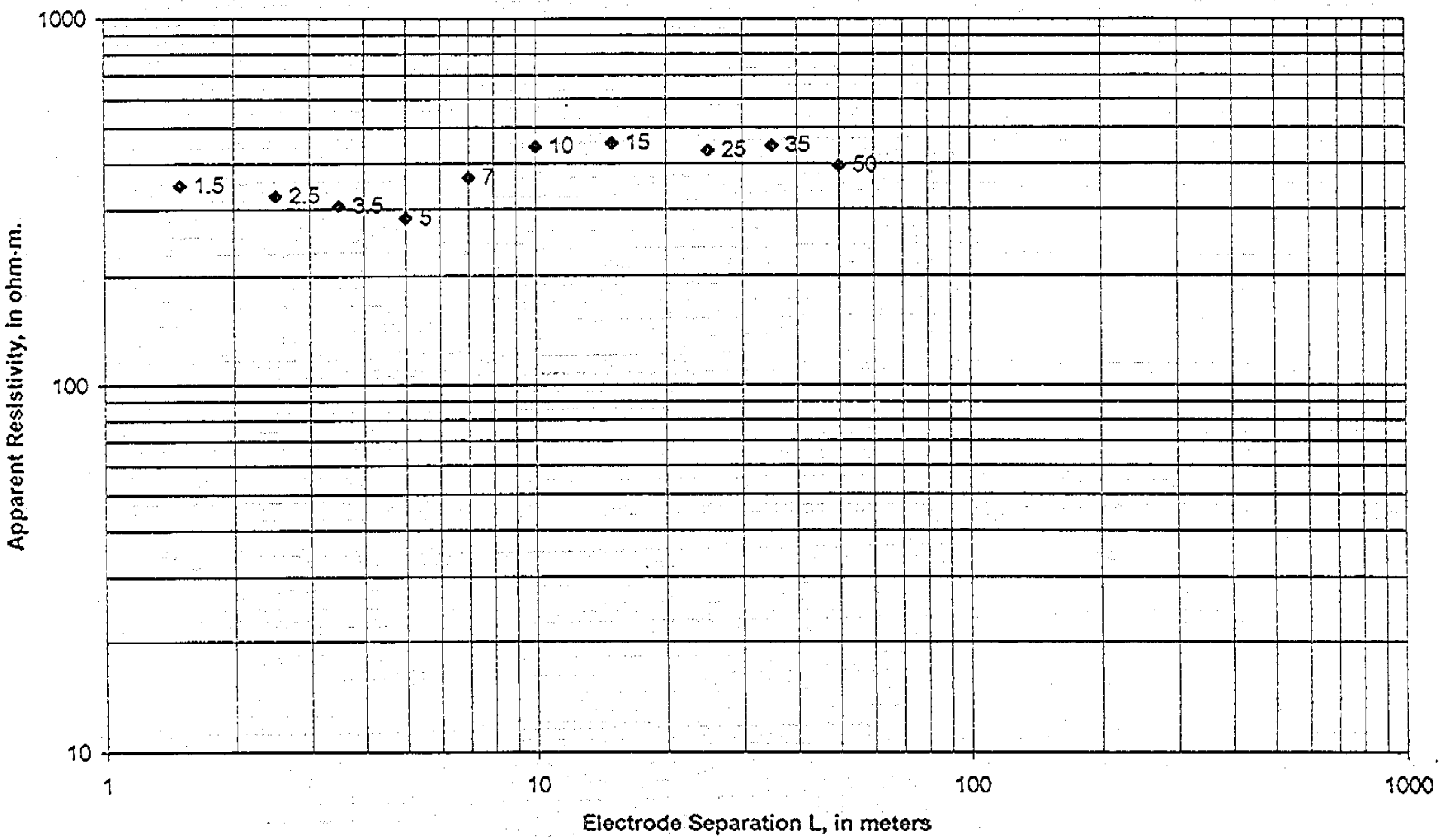
VES-1: MADONGAN DAMSITE, STA. 0 + 60 M.



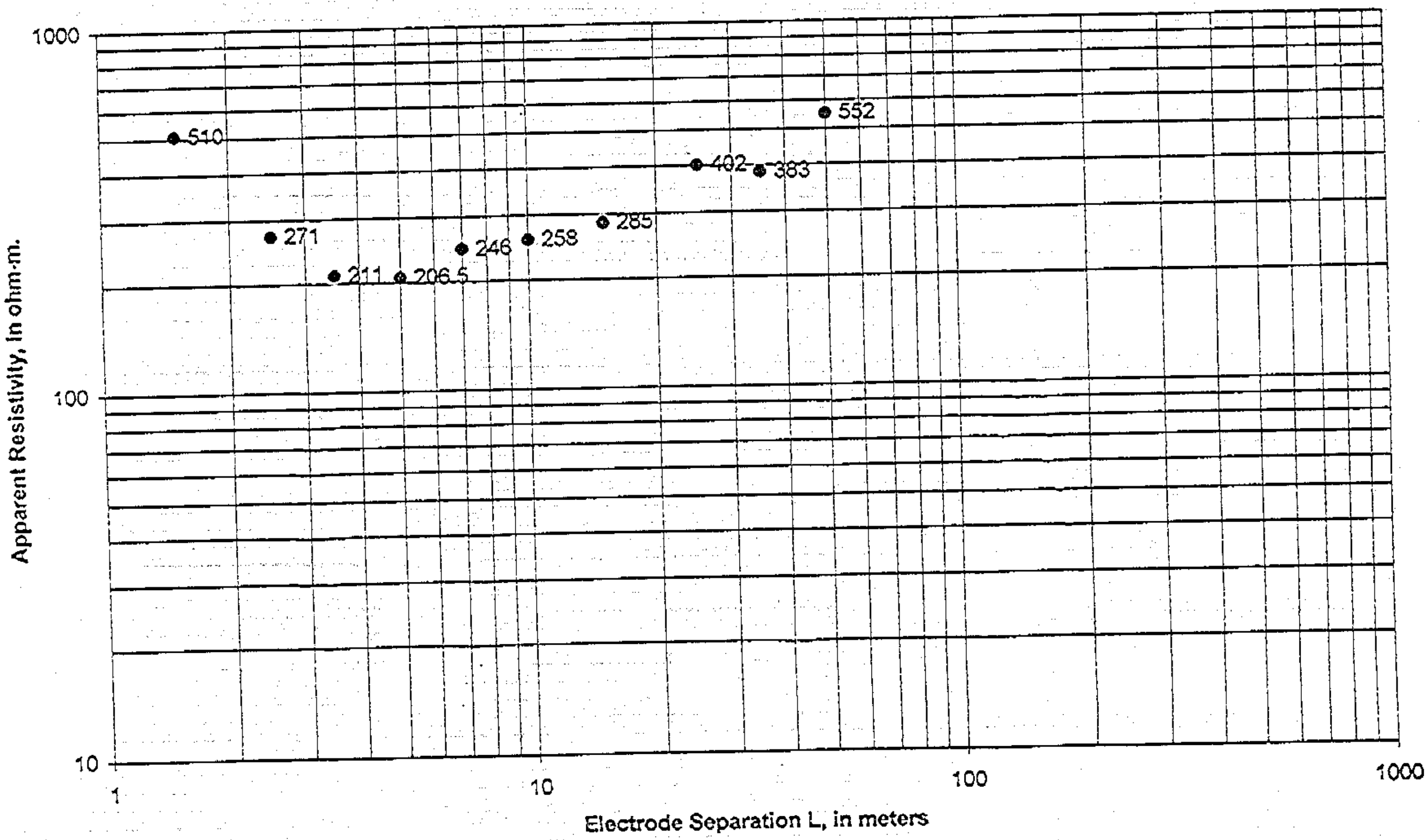
VES-1: MADONGAN DAMSITE, STA. 0 + 60 M.



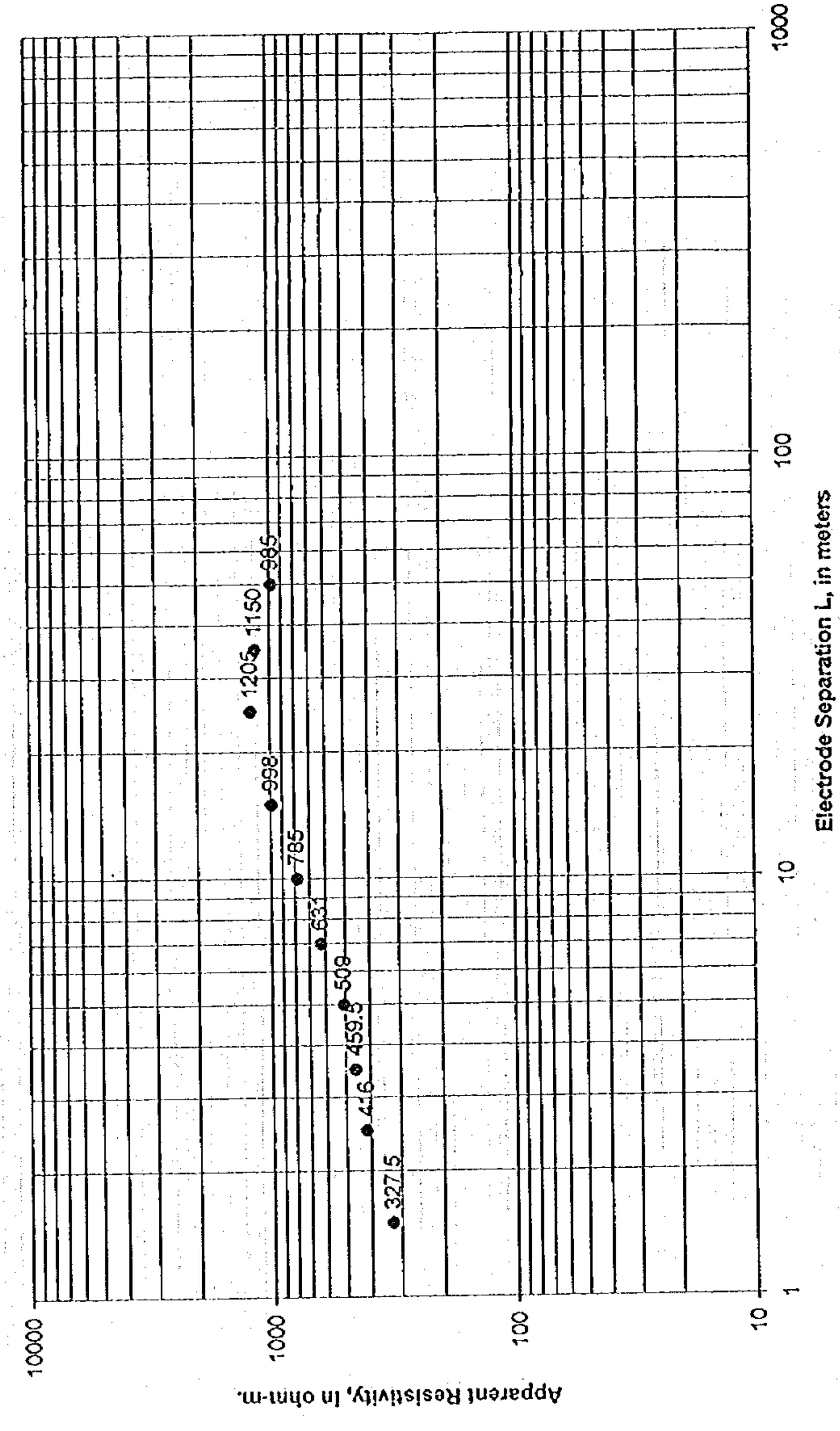
VES-3: MADONGAN DAMSITE, STA. 0 + 60 M.



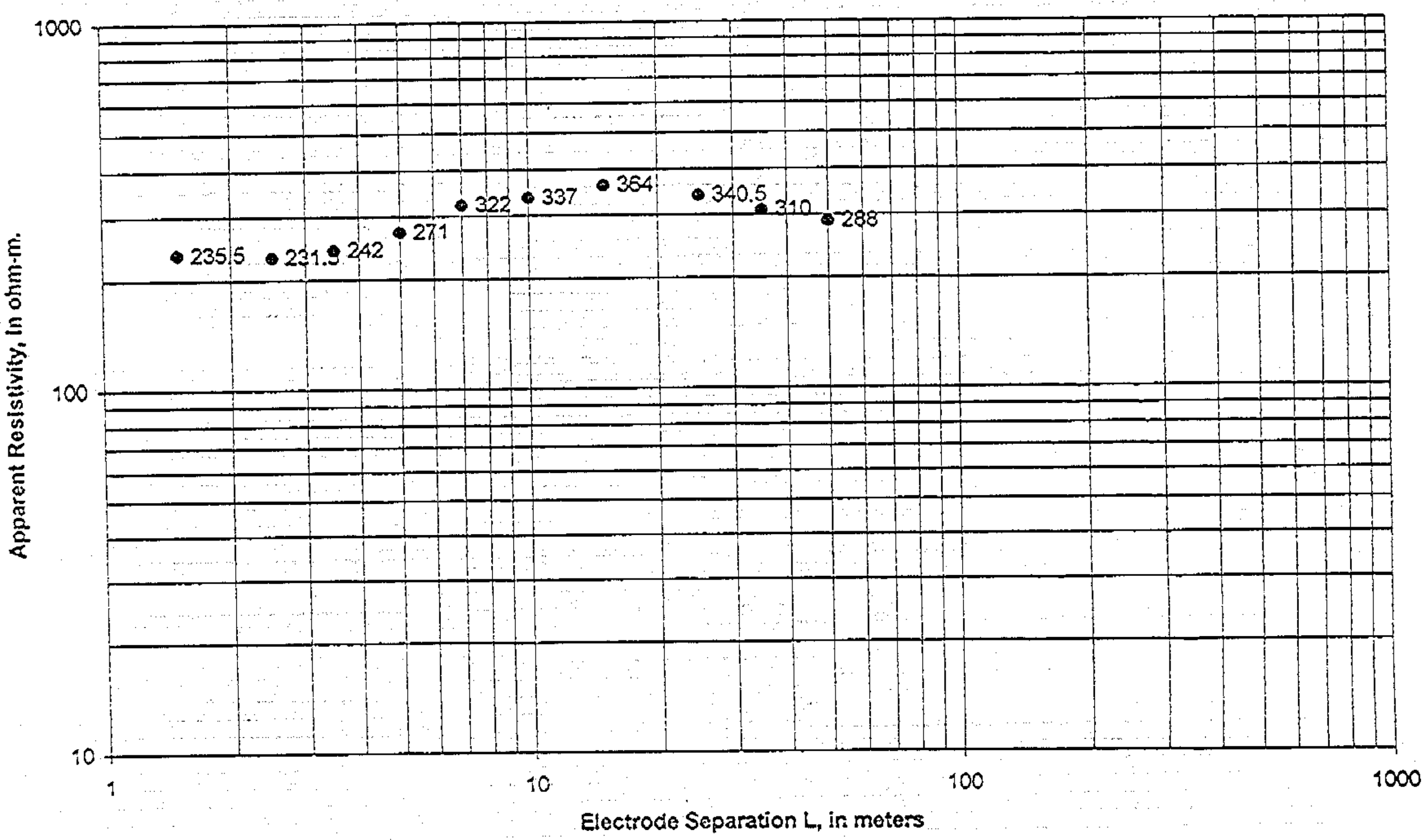
VES-4: MADONGAN DAMSITE, STA. 0 + 60 M.



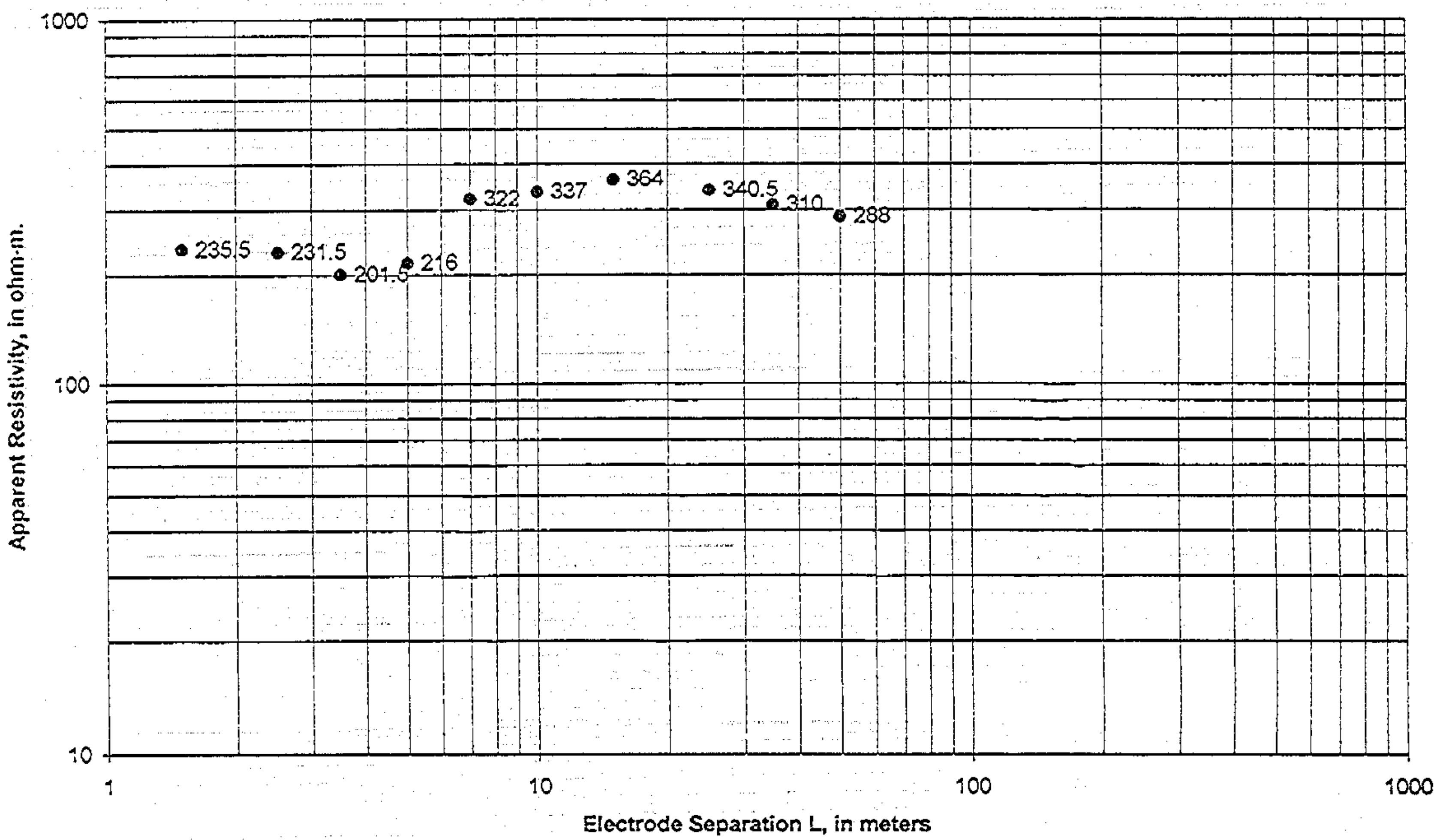
VES-5: MADONGAN DAMSITE, STA. 0 + 60 M.



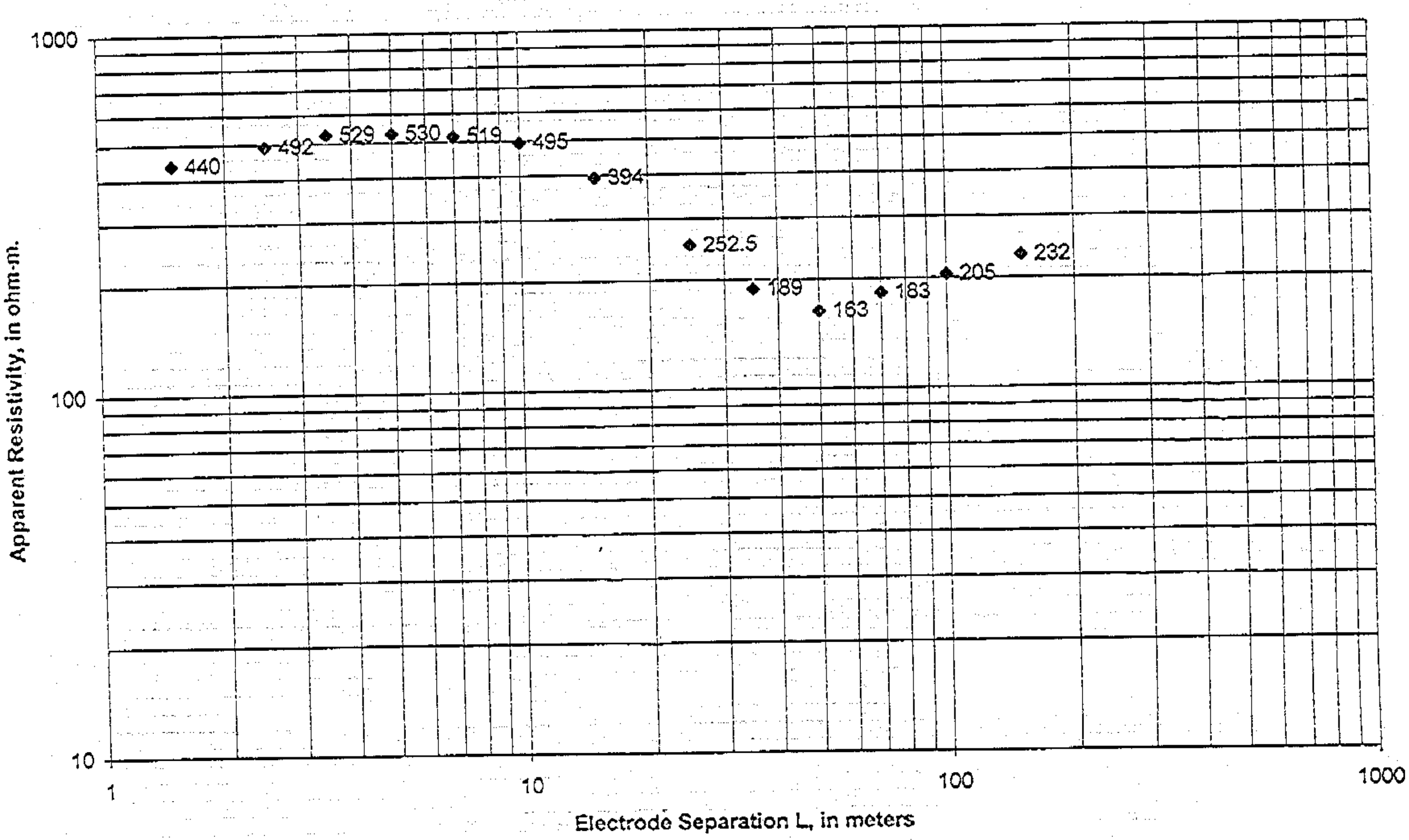
VES-6: MADONGAN DAMSITE, STA. 0 + 60 M.

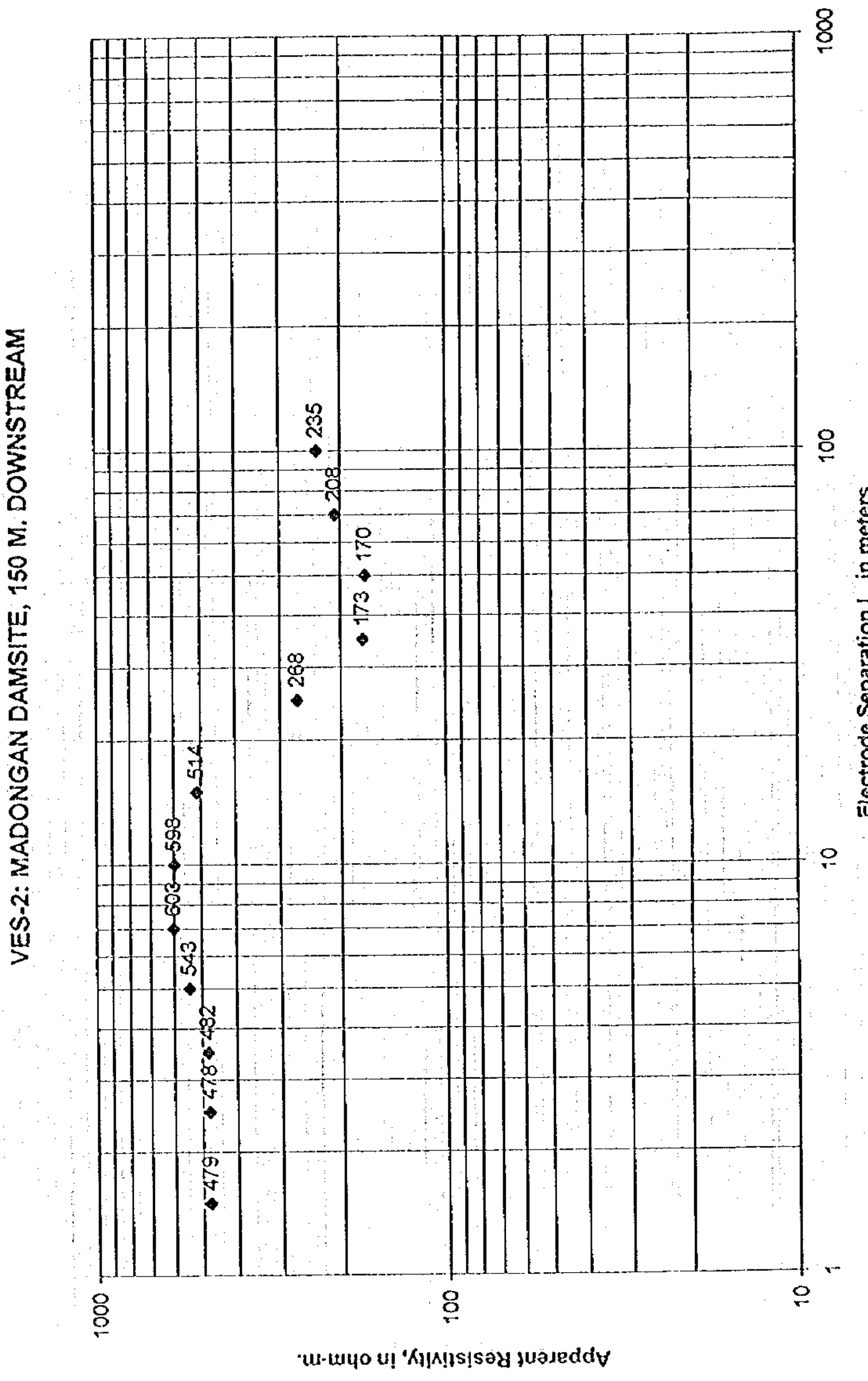


VES-7: MADONGAN DAMSITE, STA. 0 + 60 M.

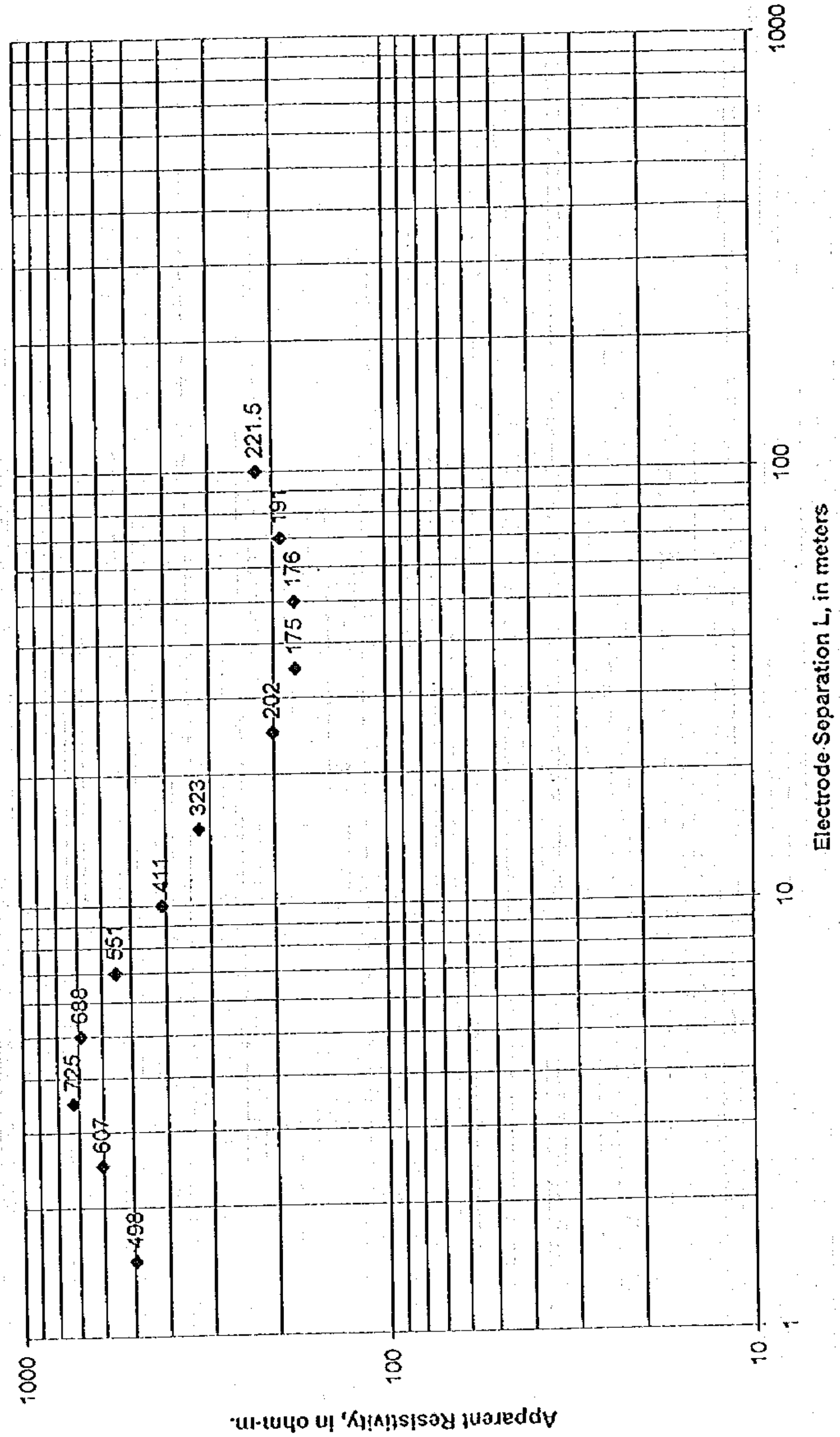


VES-1: MADONGAN DAMSITE, 150 M. DOWNSTREAM

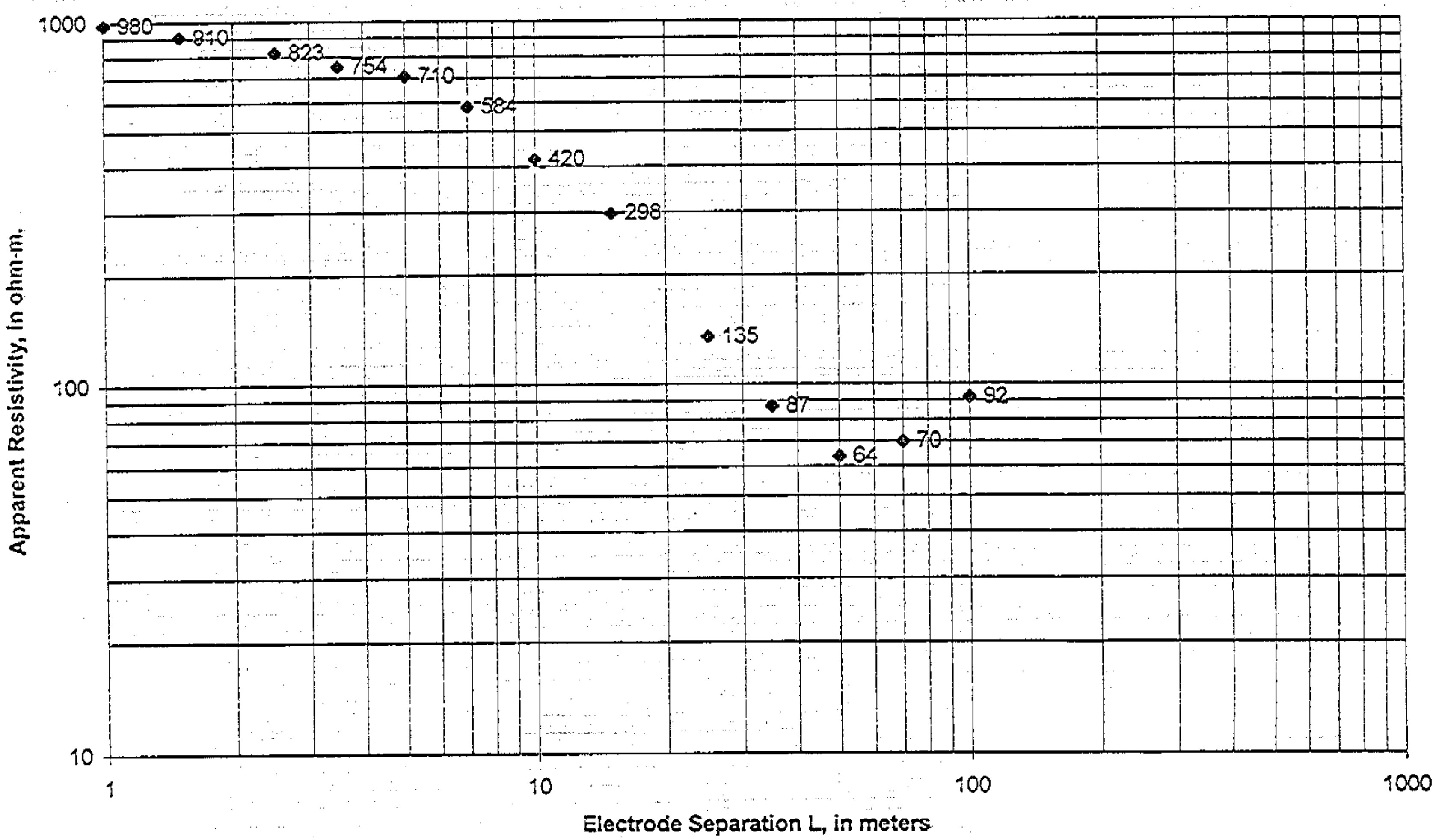



VES-2: MADONGAN DAMSITE, 150 M. DOWNSTREAM
Apparent Resistivity, in ohm-m.
Electrode Separation L, in meters
1000
100
10
1
479
478
482
543
603
598
514
268
173
170
208
235

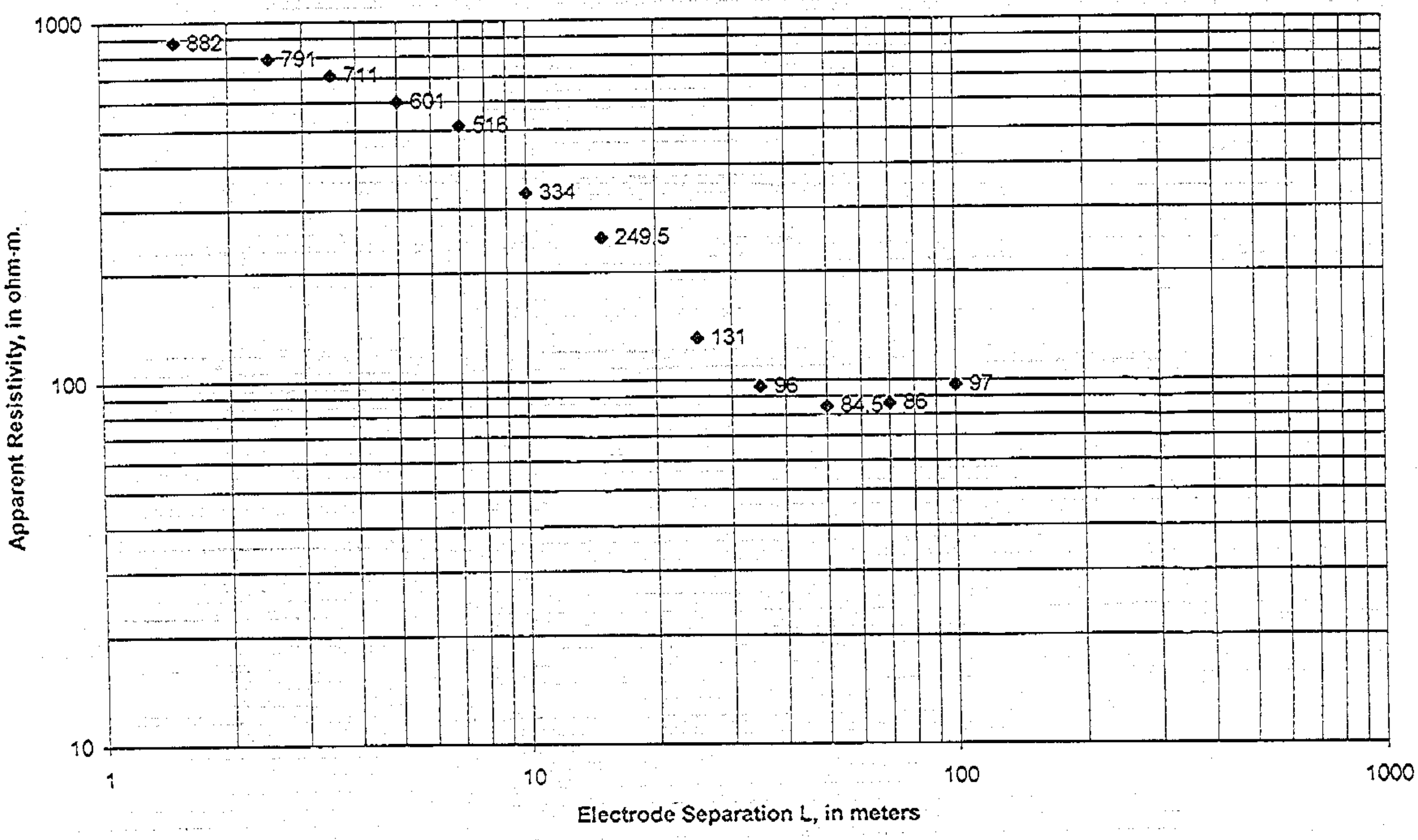
VES-3: MADONGAN DAMSITE, 150 M. DOWNSTREAM



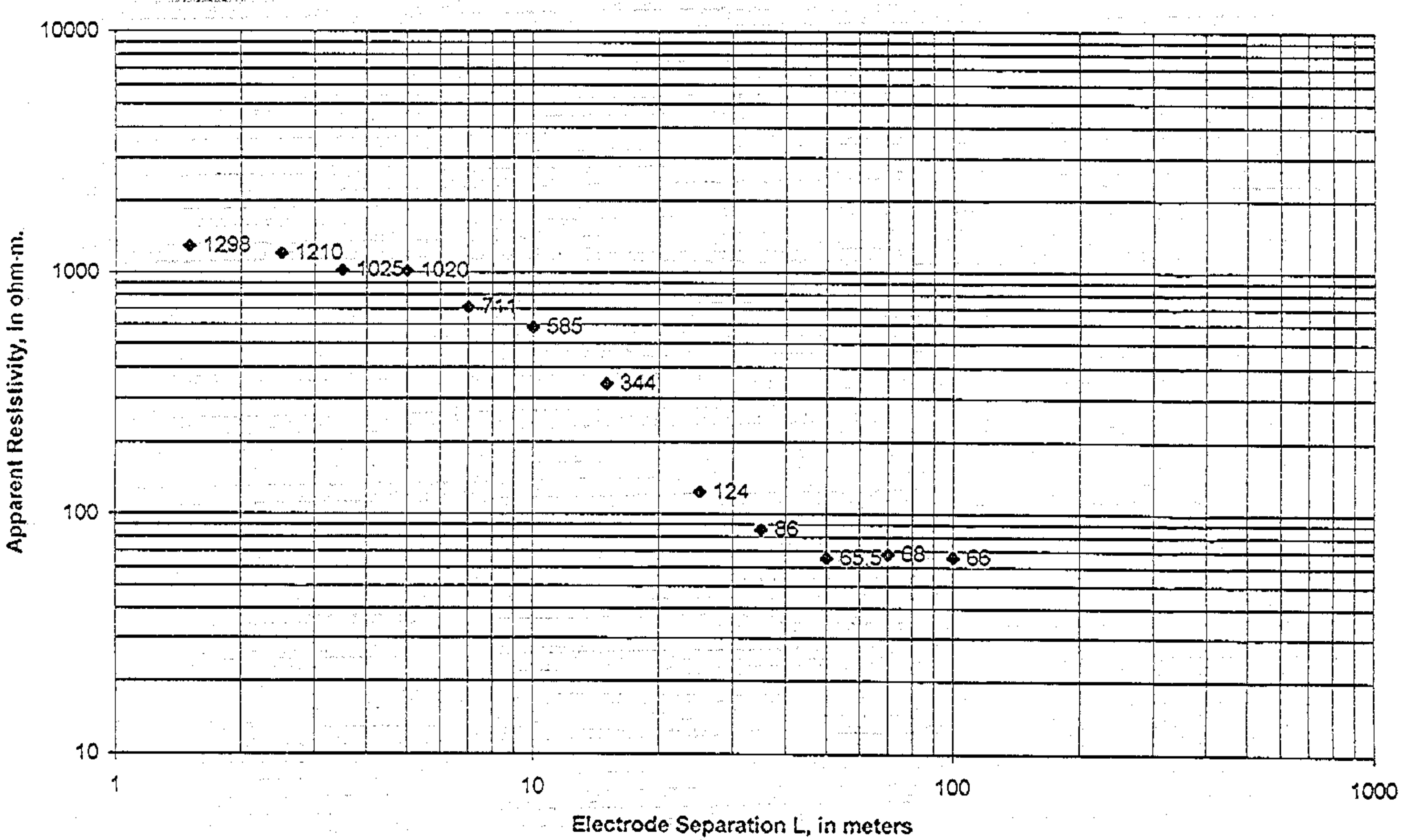
VES-1: PAPA DAMSITE, STA. 150 M. DOWNSTREAM



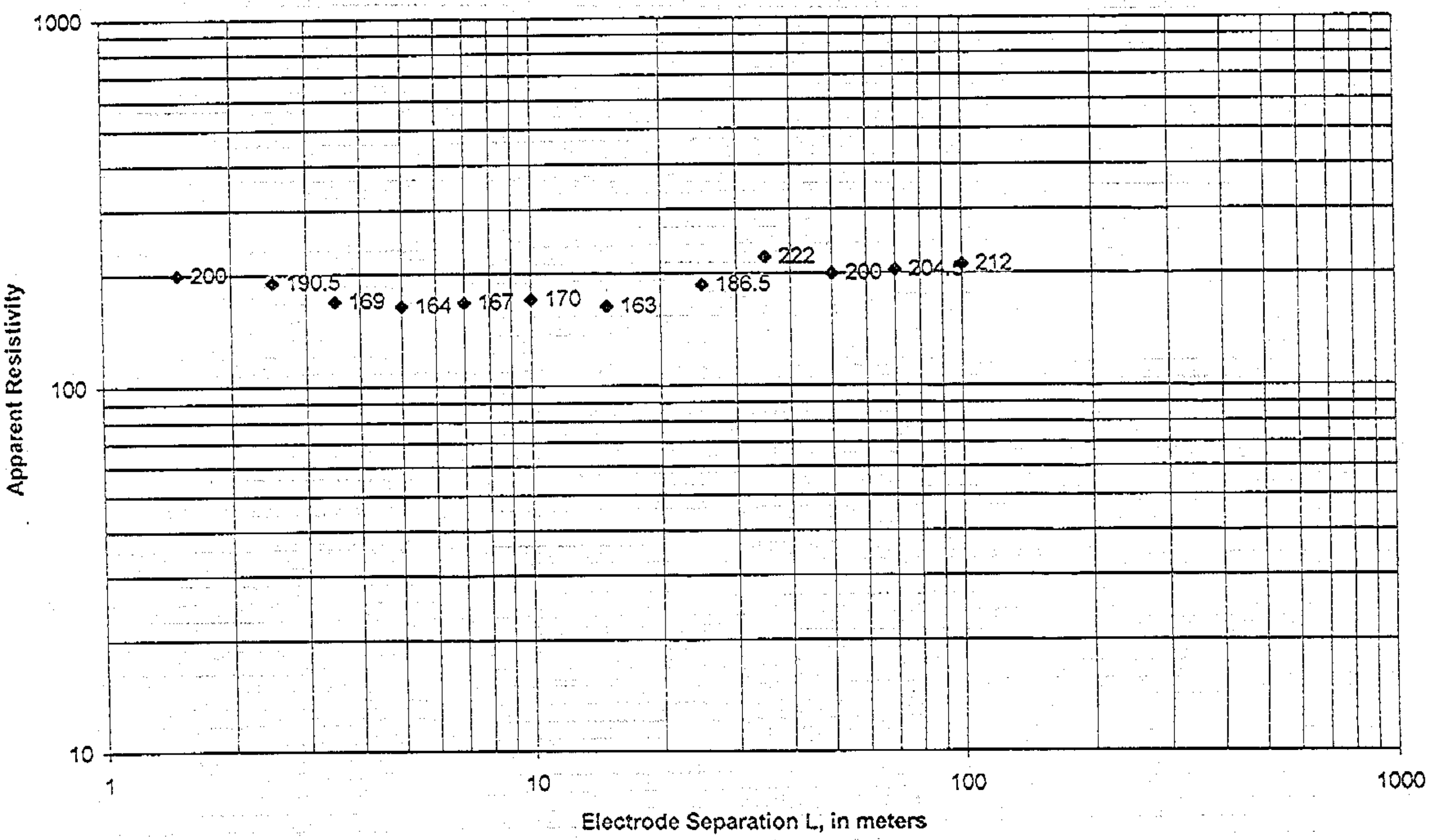
VES-2: PAPA DAMSITE, STA. 150 M. DOWNSTREAM



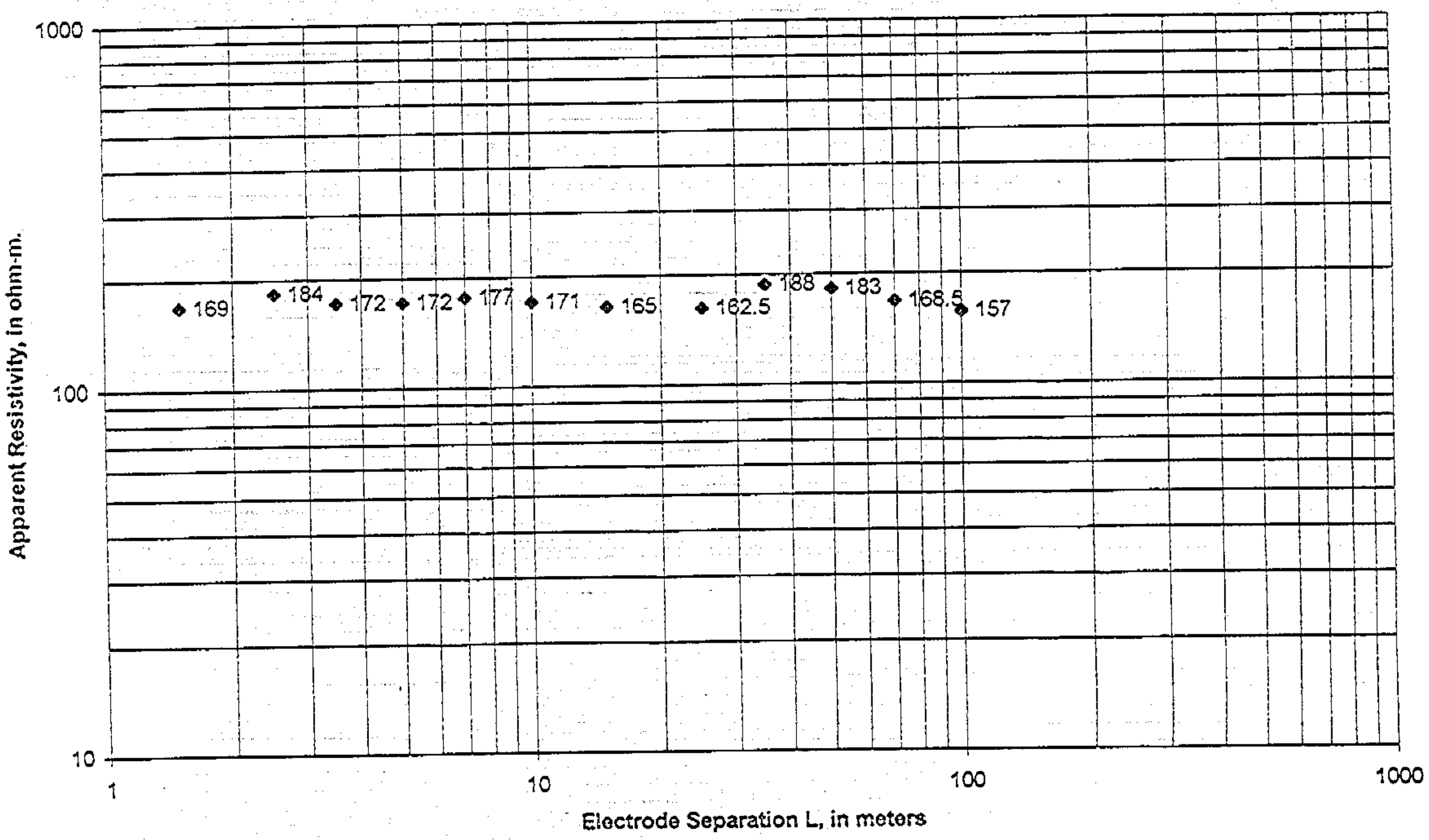
VES-3: PAPA DAMSITE, STA. 150 M. DOWNSTREAM



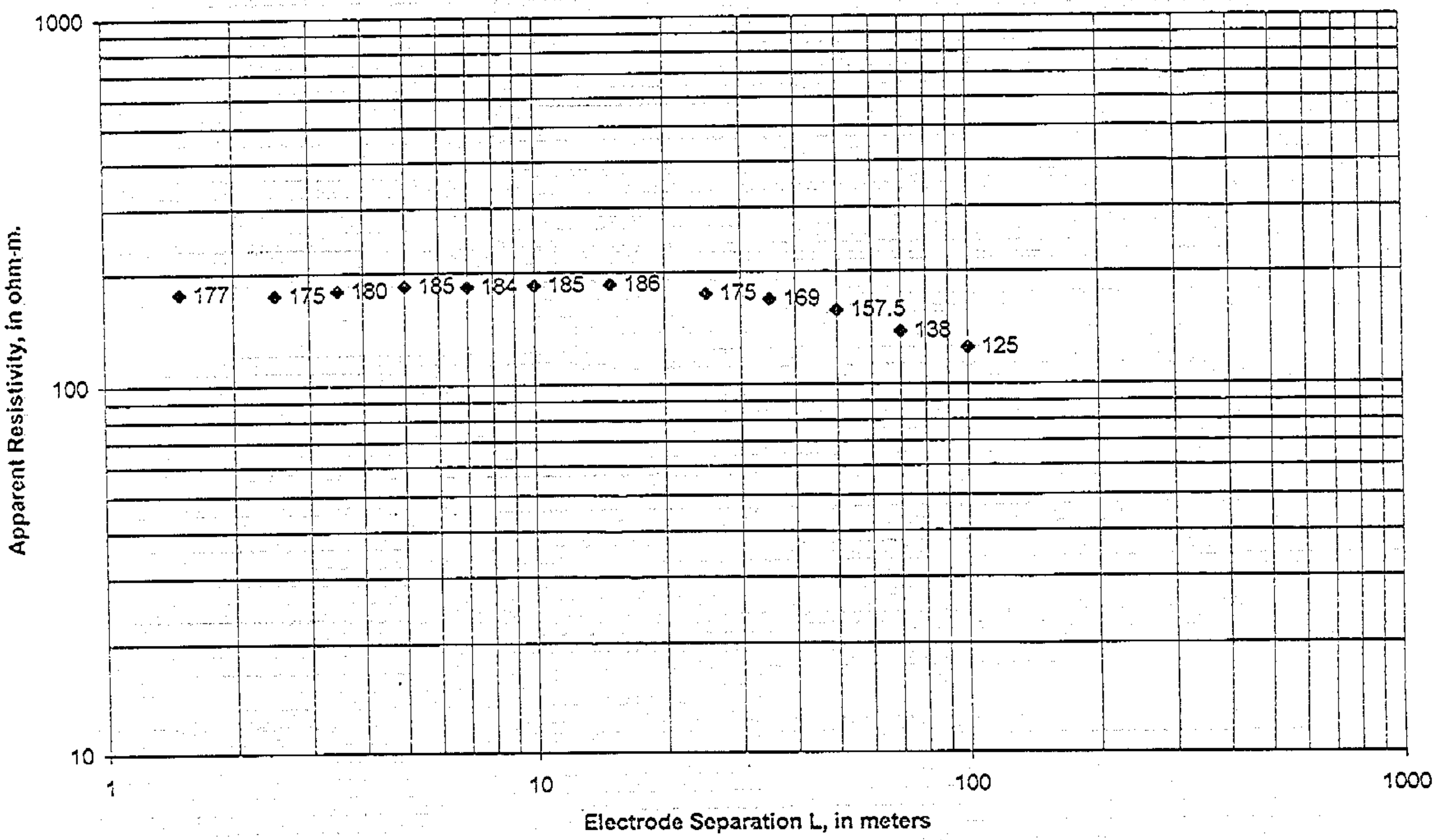
VES-1: PAPA DAMSITE, STA. 0 + 100 M.



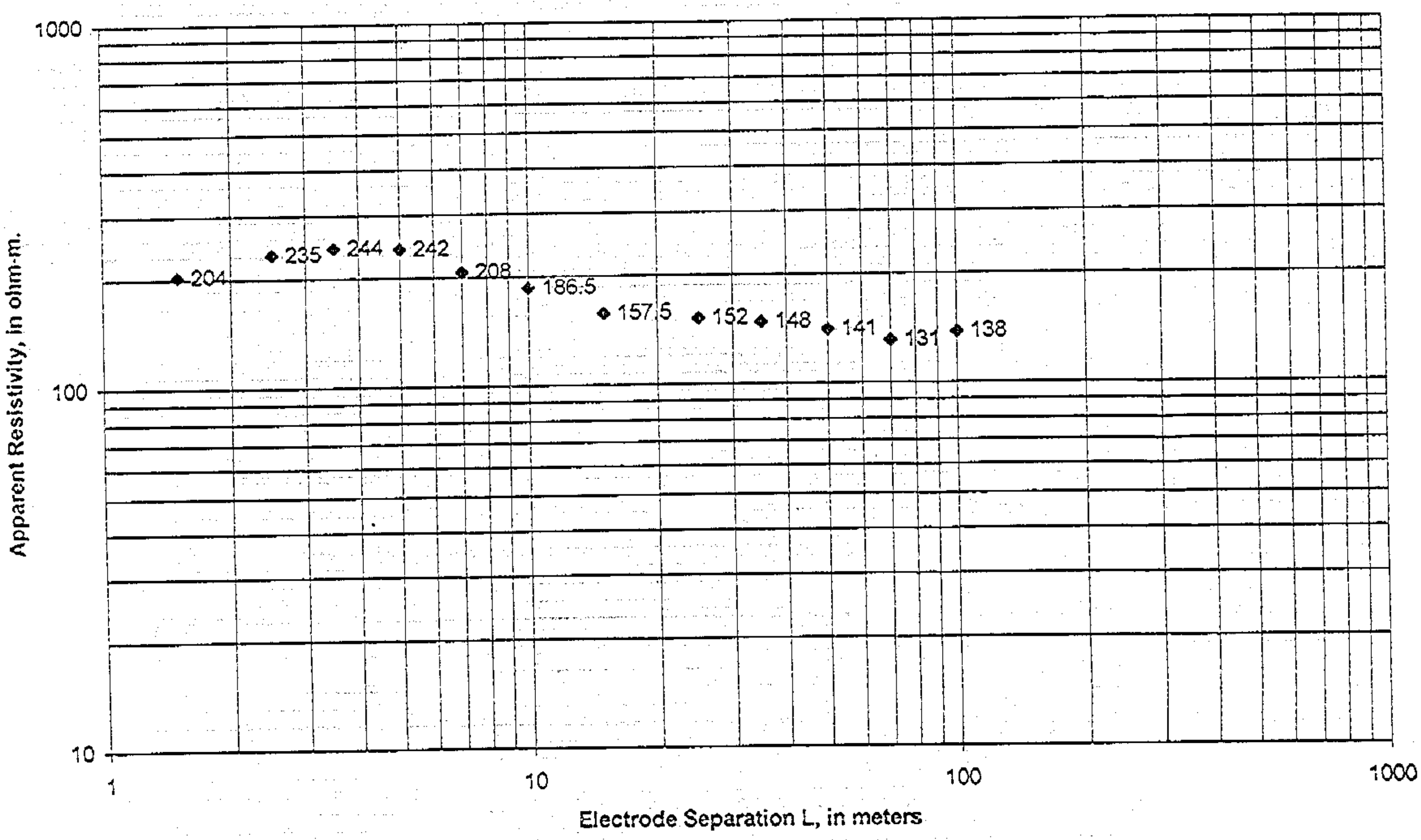
VES-2: PAPA DAMSITE, STA. 0 + 100 M.



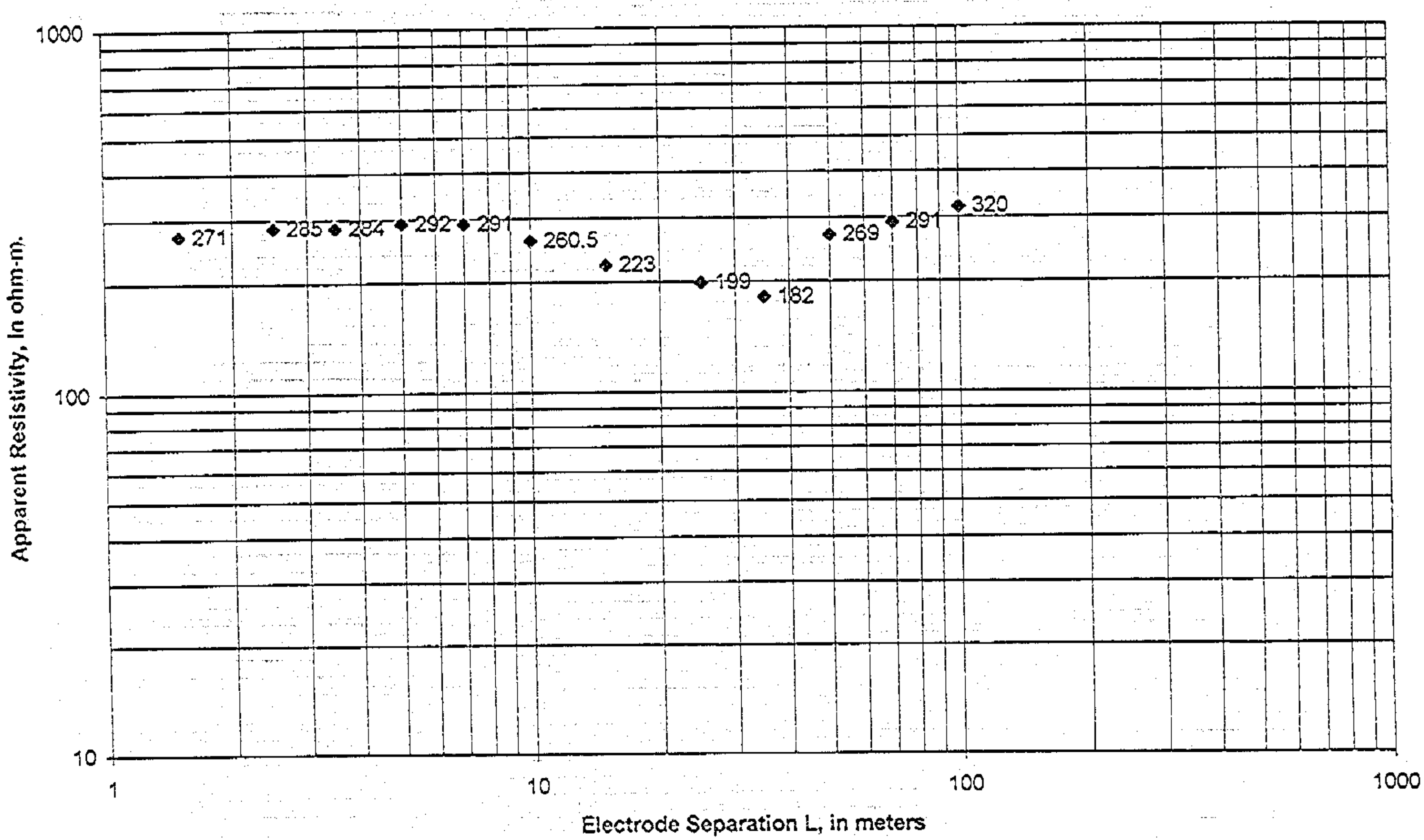
VES-3: PAPA DAMSITE, STA. 0 + 100 M.



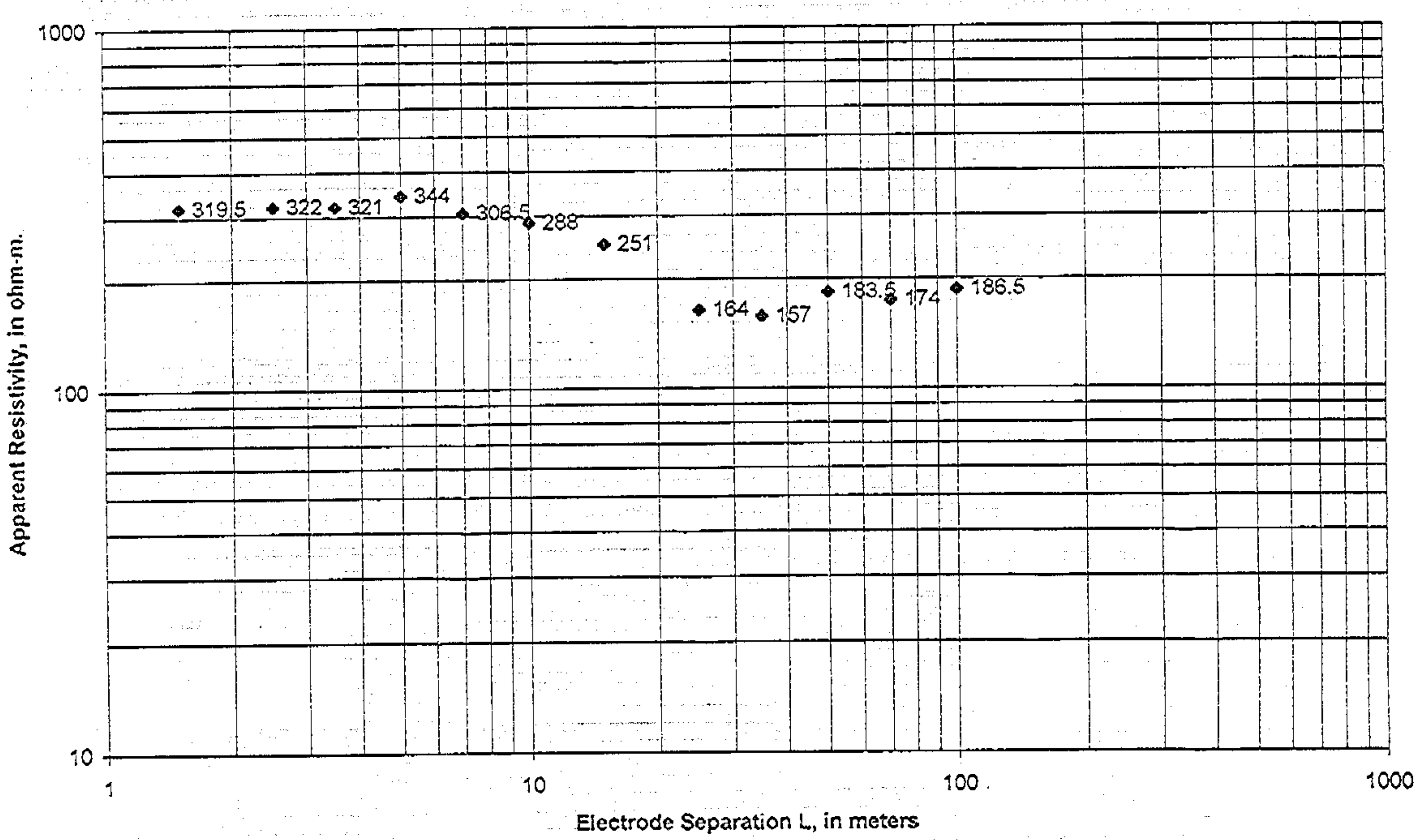
VES-4: PAPA DAMSITE, STA. 0 + 100 M.



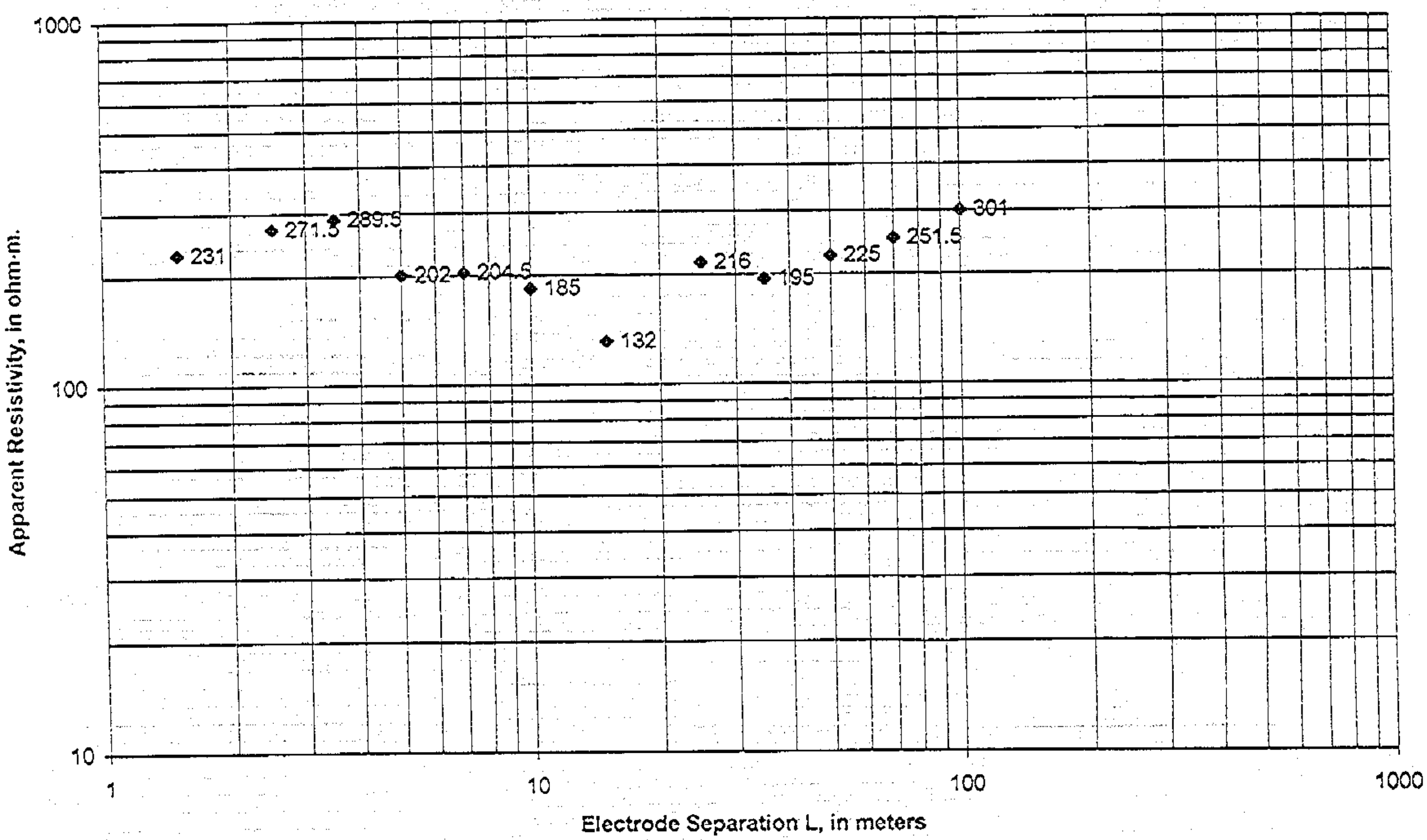
VES-5: PAPA DAMSITE, STA. O + 100 M.

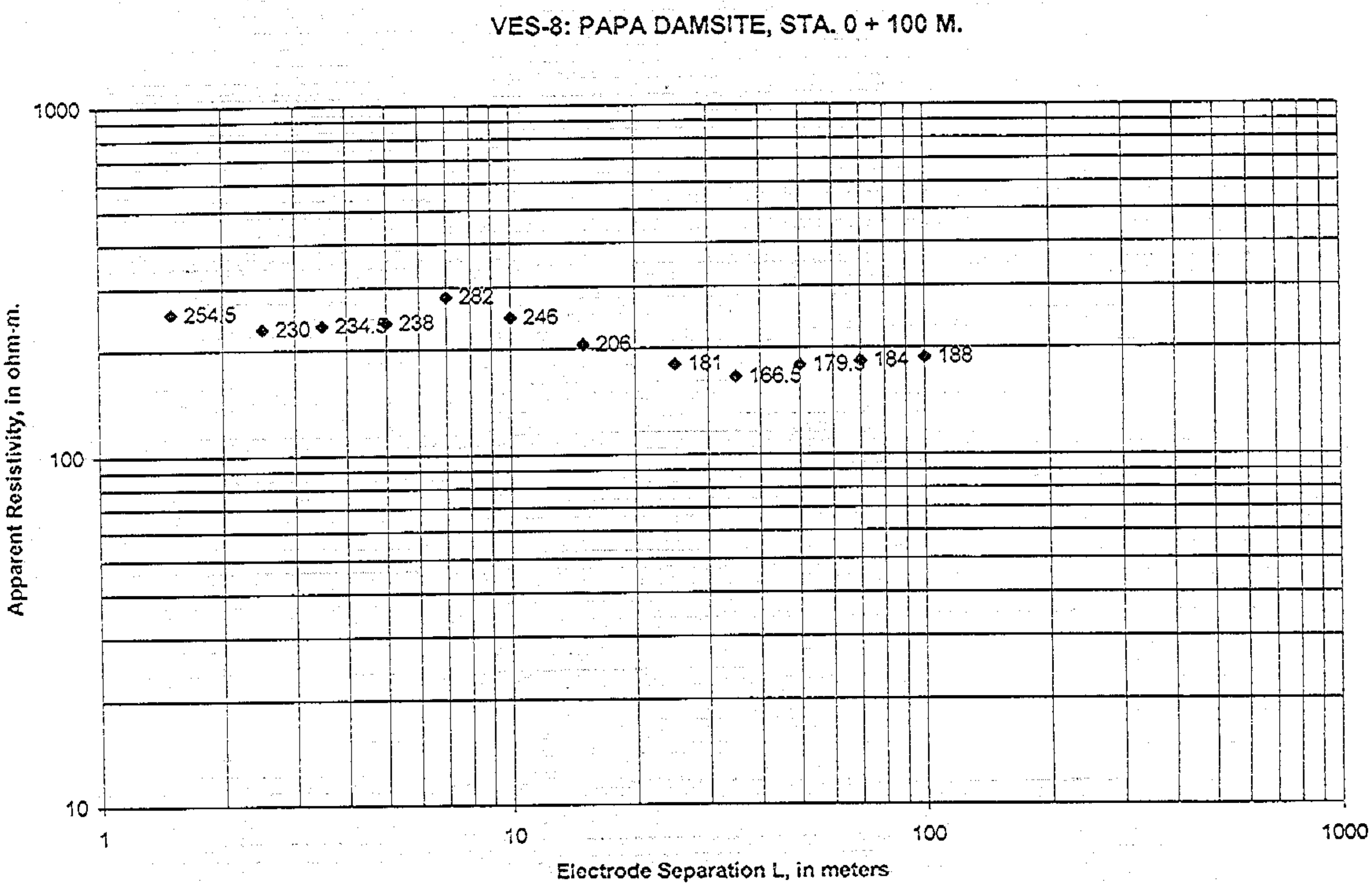


VES-6: PAPA DAMSITE, STA. 0 + 100 M.

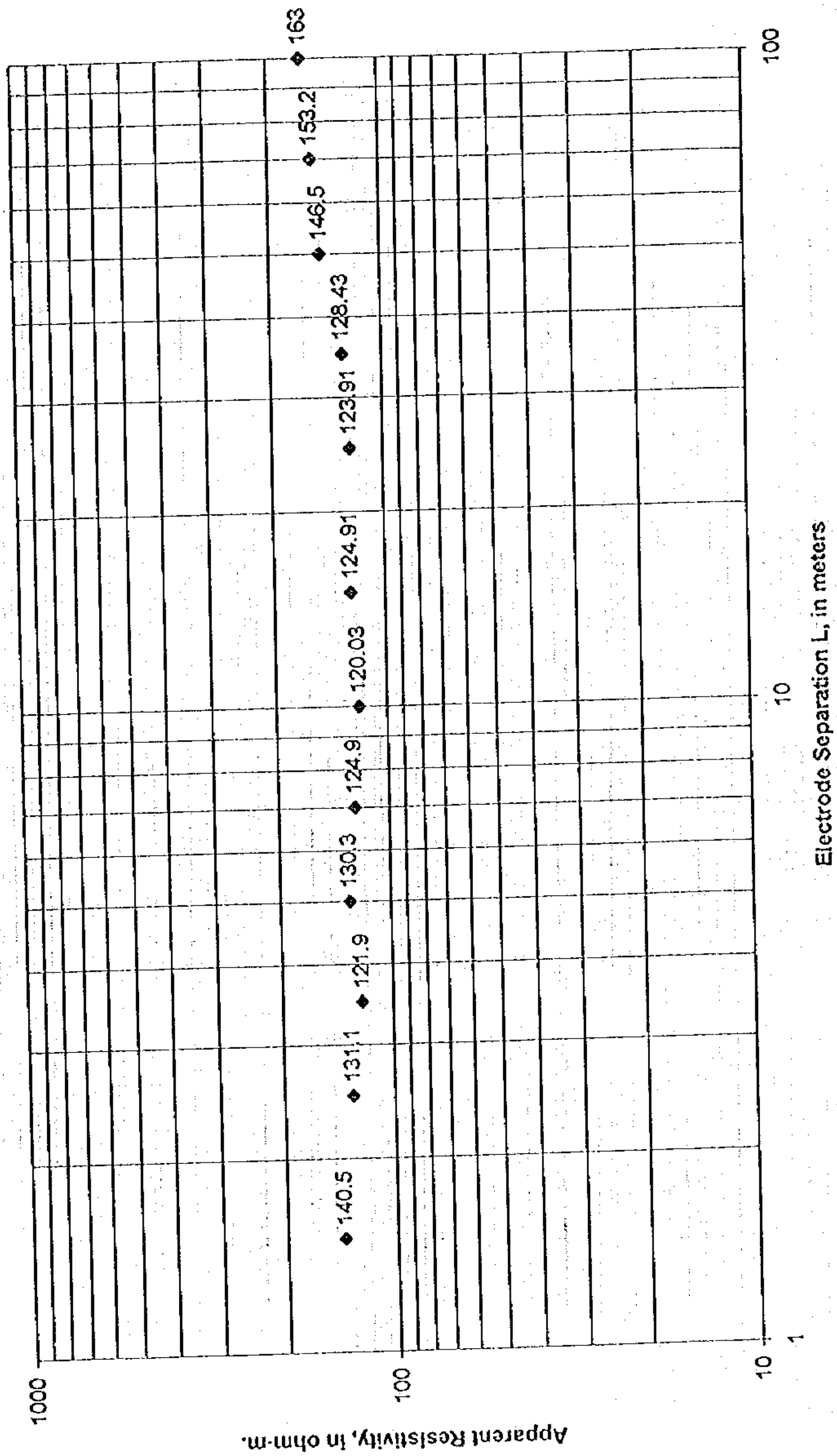


VES-7: PAPA DAMSITE, STA. 0 + 100 M.

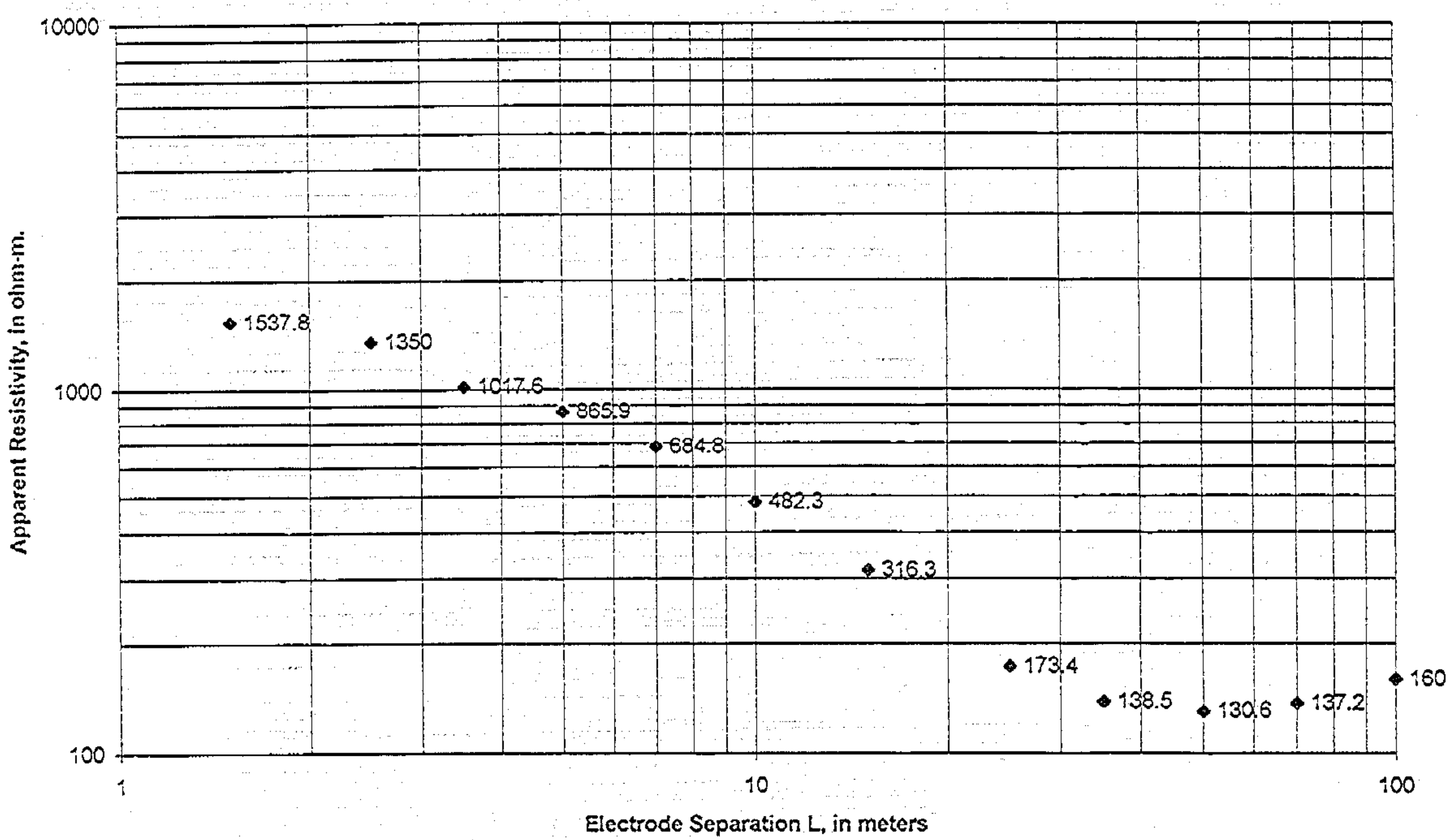



VES-8: PAPA DAMSITE, STA. 0 + 100 M.
1000
100
10
1
10
100
1000
254.5
230
234.5
238
282
246
206
181
166.5
179.5
184
188
Apparent Resistivity, in ohm-m.
Electrode Separation L, in meters

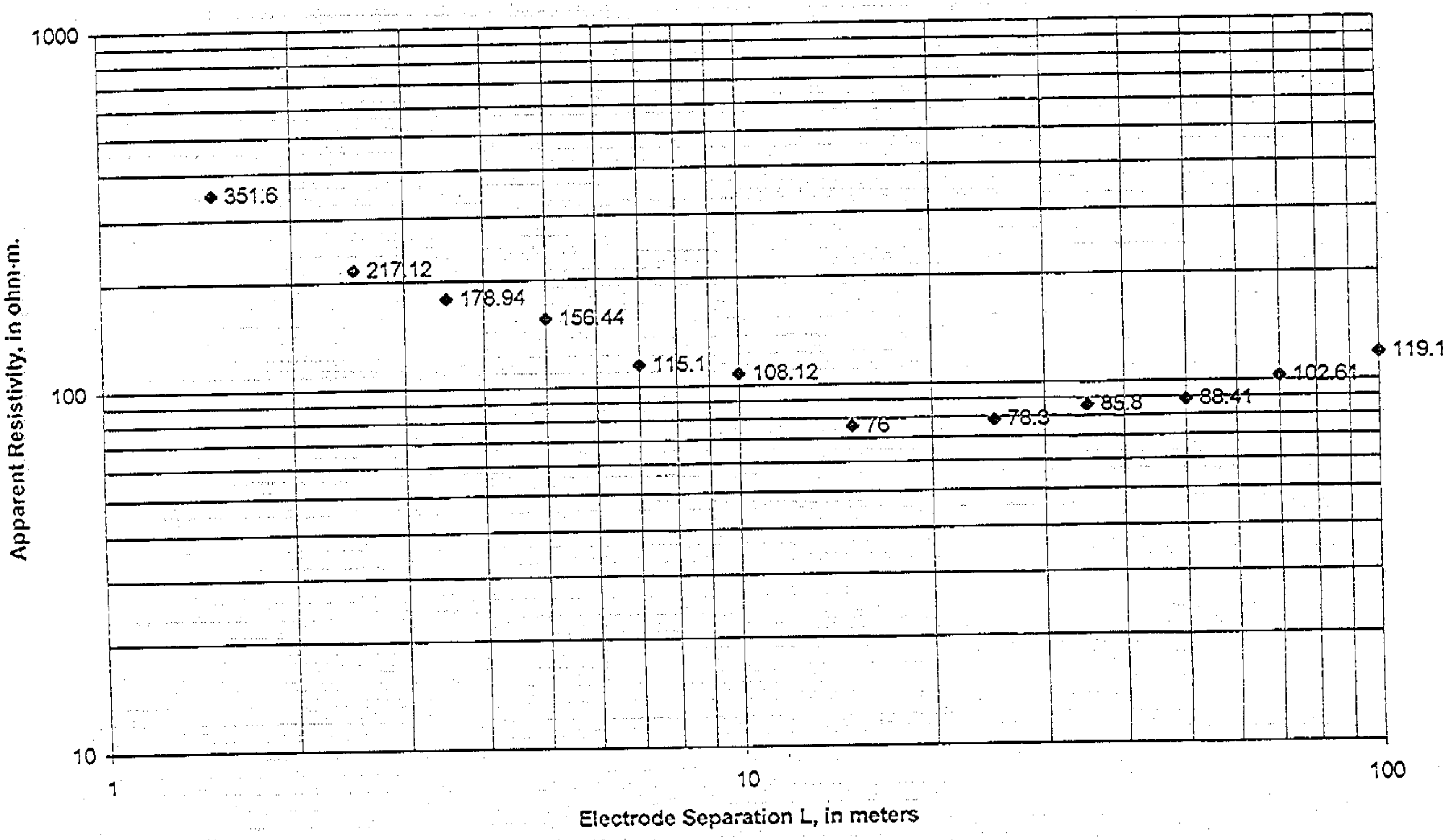
VES-1: CURA DAMSITE, STA. 0 + 420 M.



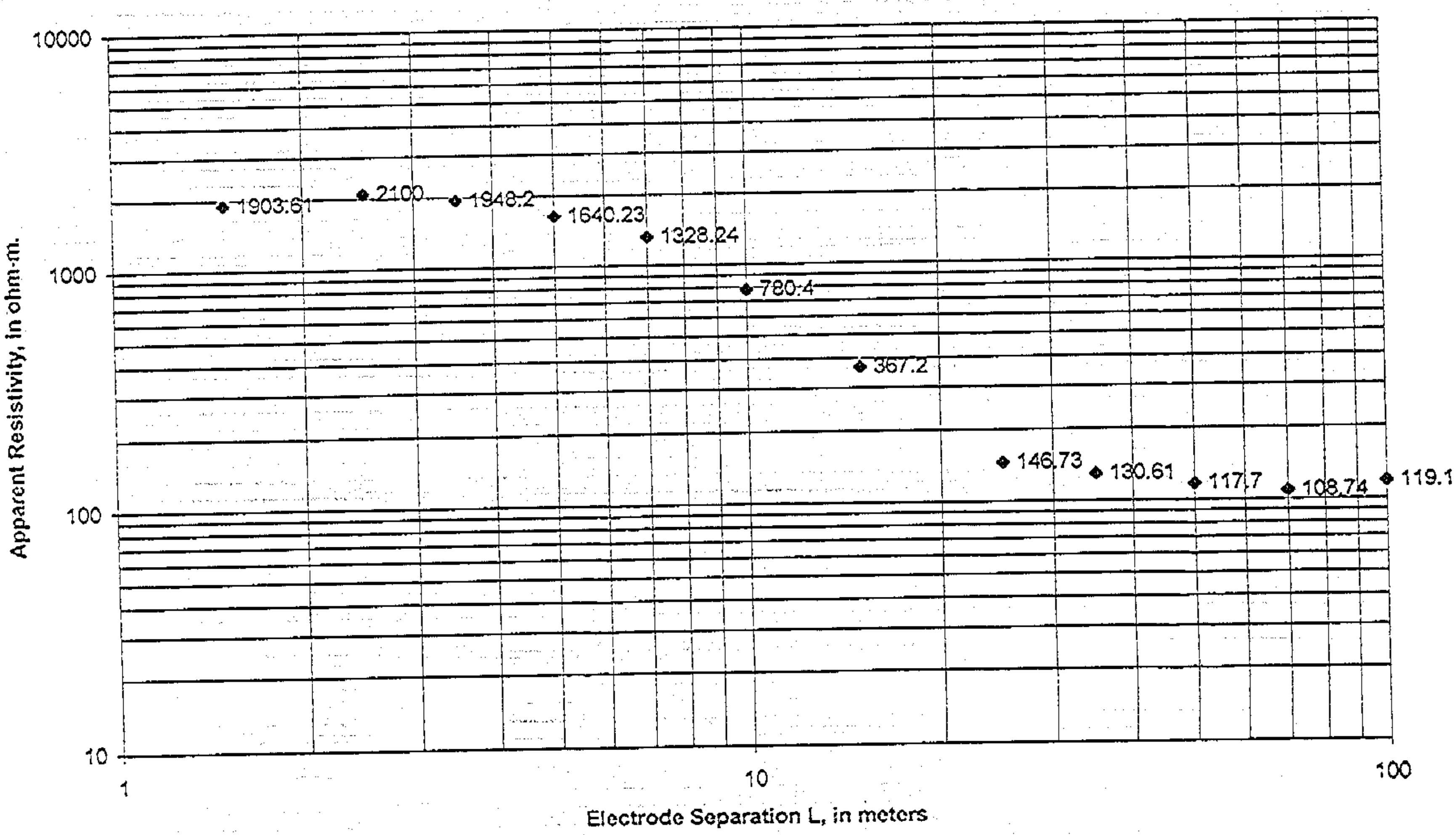
VES-2: CURA DAMSITE, STA. 0 + 420 M.



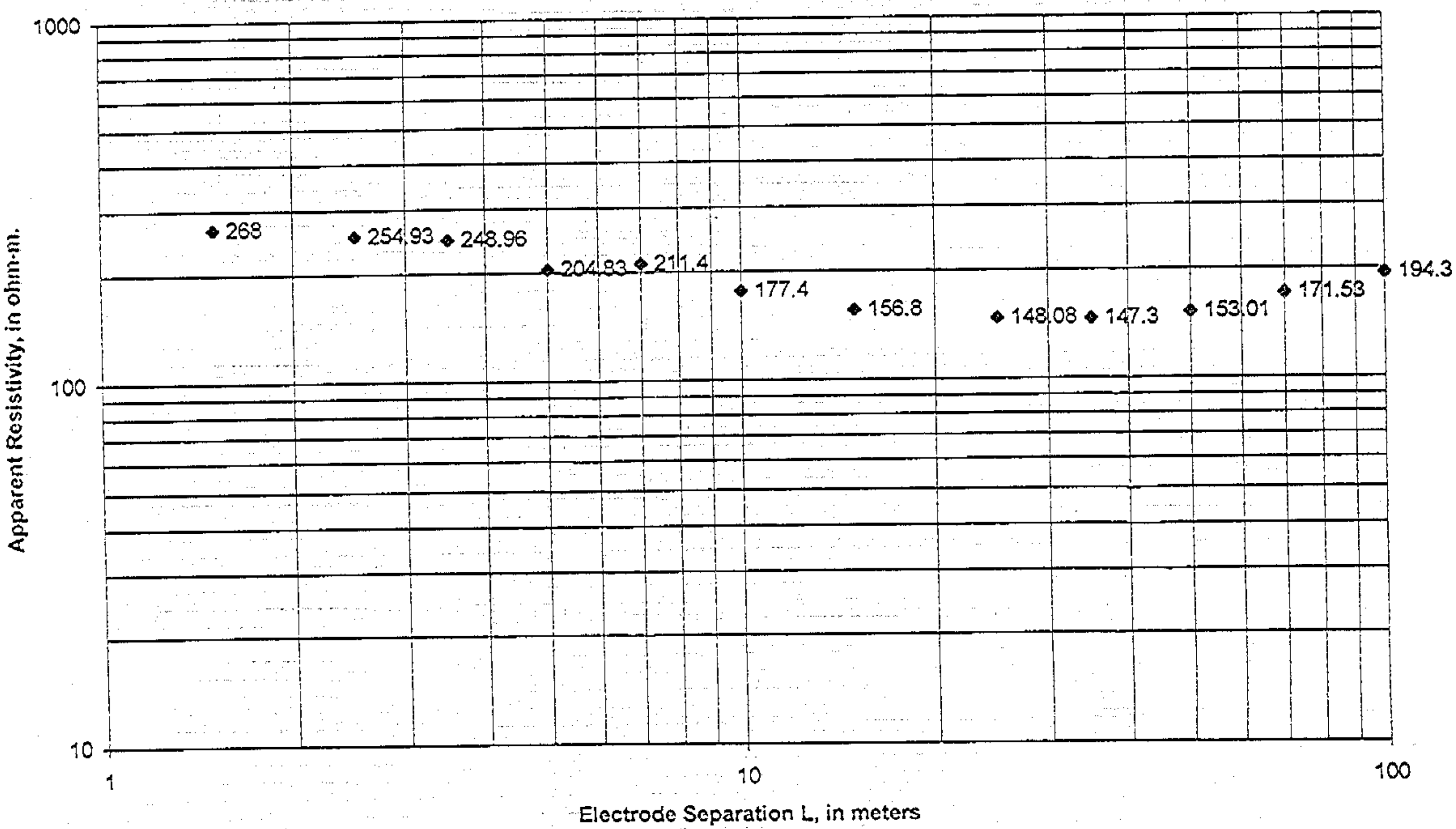
VES-3: CURA DAMSITE, STA. 0 + 420 M.



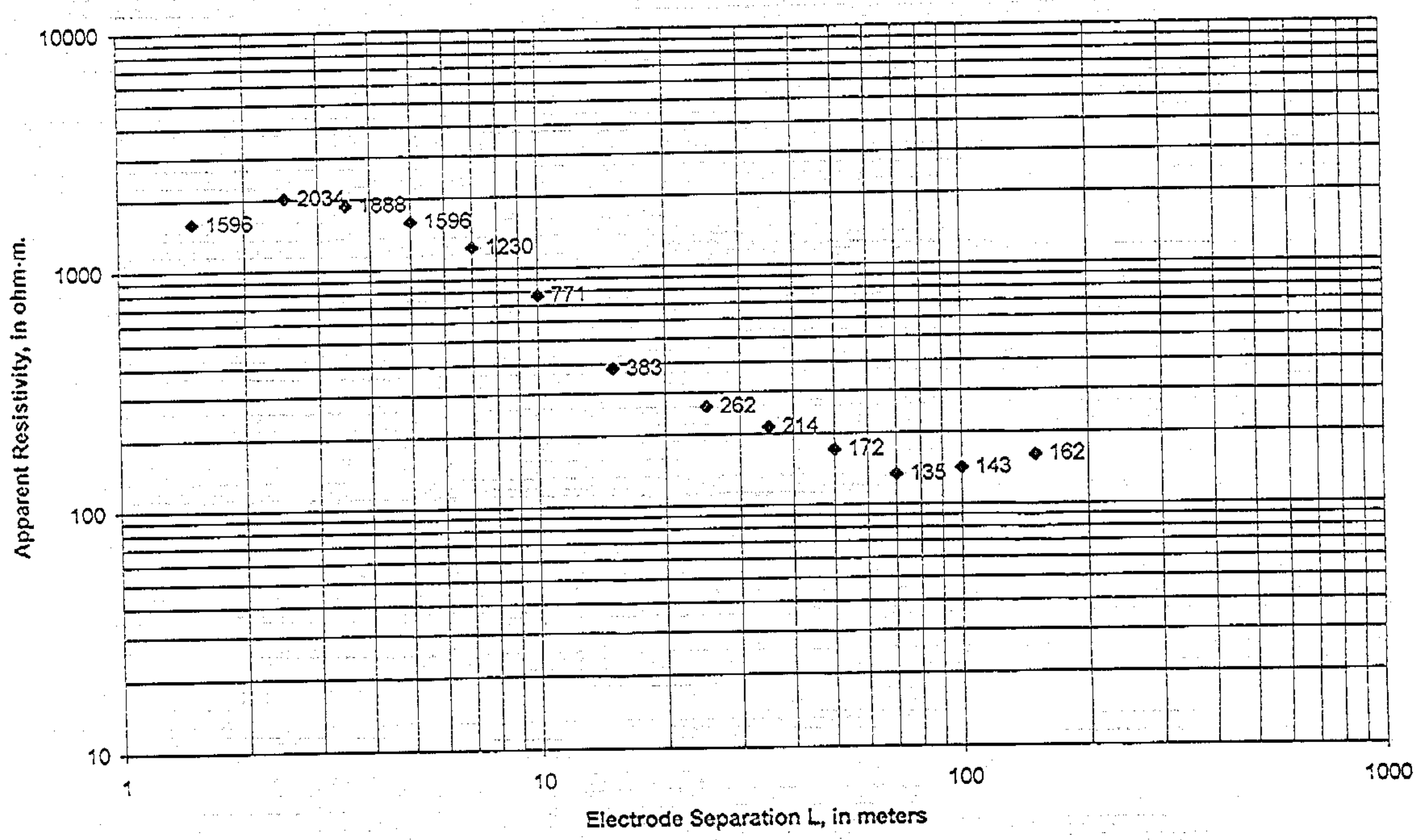
VES-4: CURA DAMSITE, STA. 0 + 420 M.



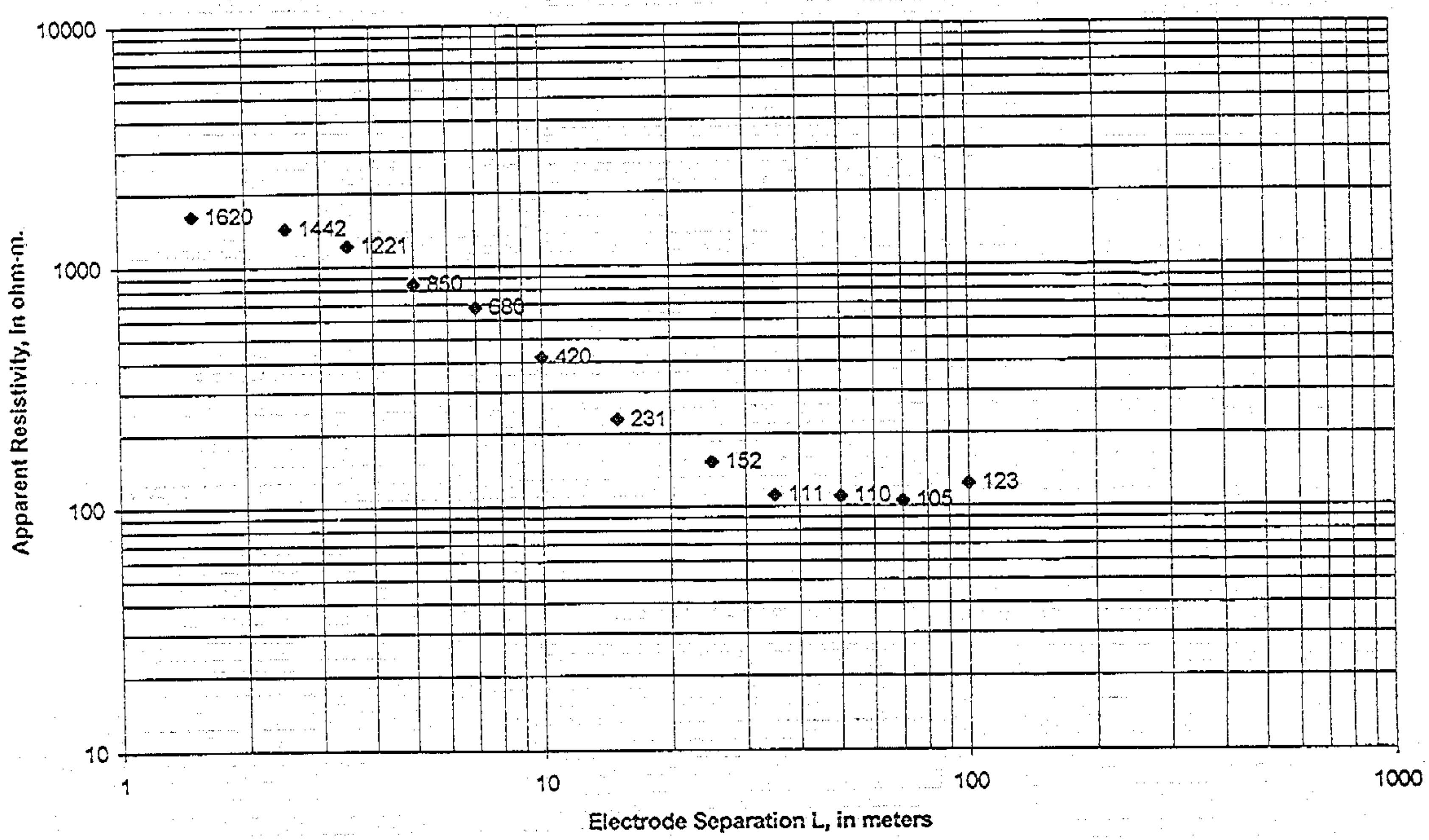
VES-5: CURA DAMSITE, STA. 0 + 420 M.



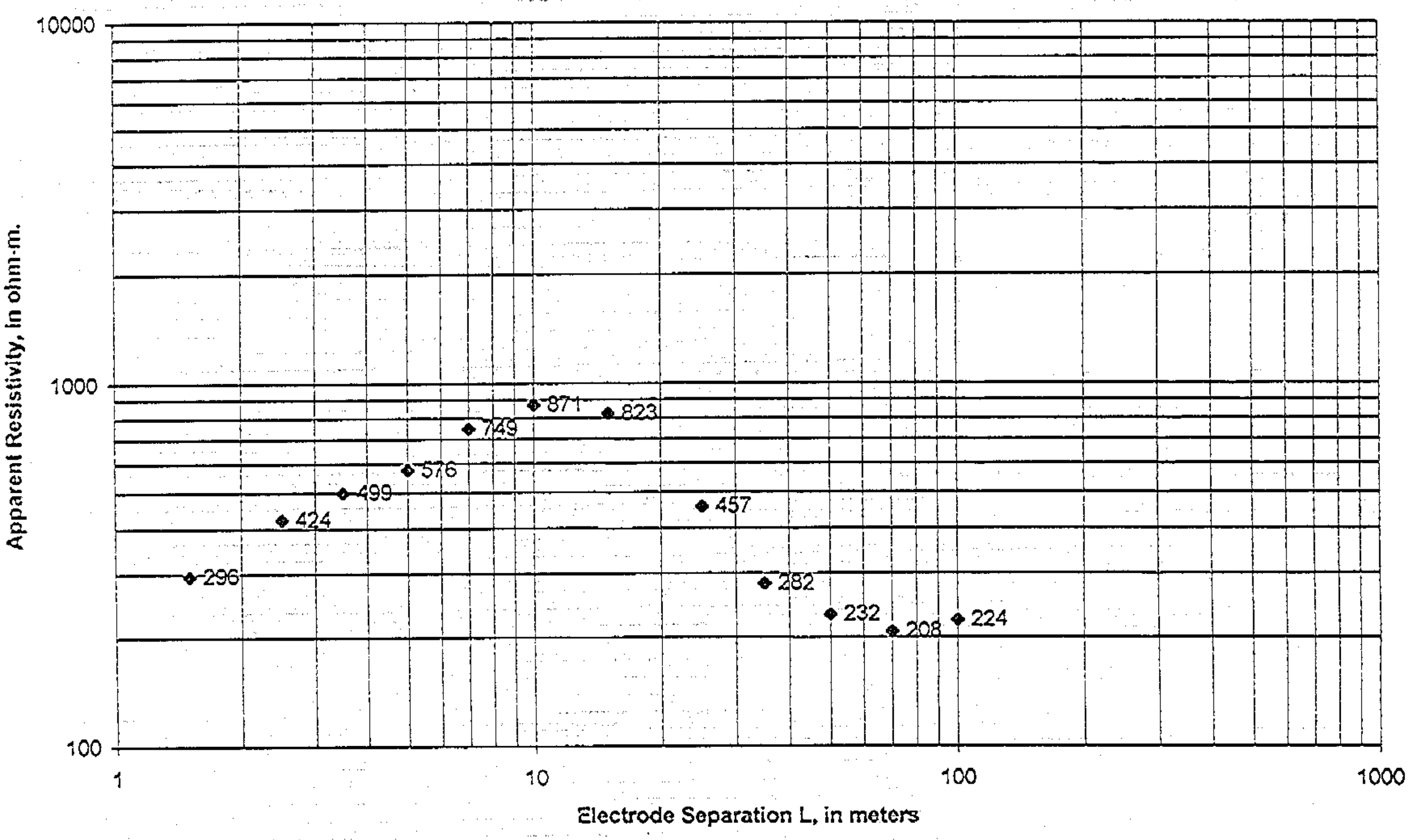
VES-6: CURA DAMSITE, STA. 0 + 420 M.



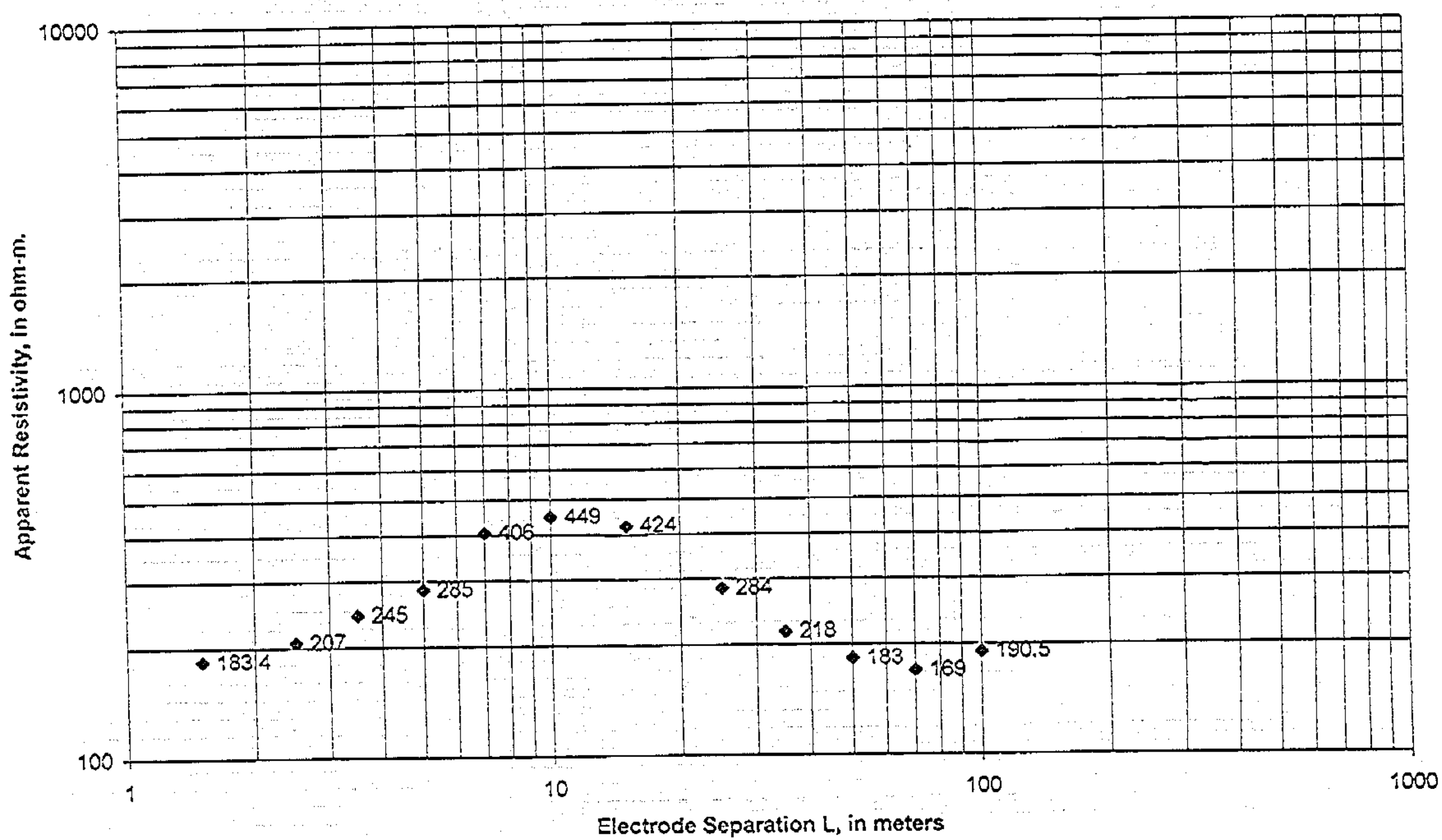
VES-7: CURA DAMSITE, STA. 0 + 420 M.



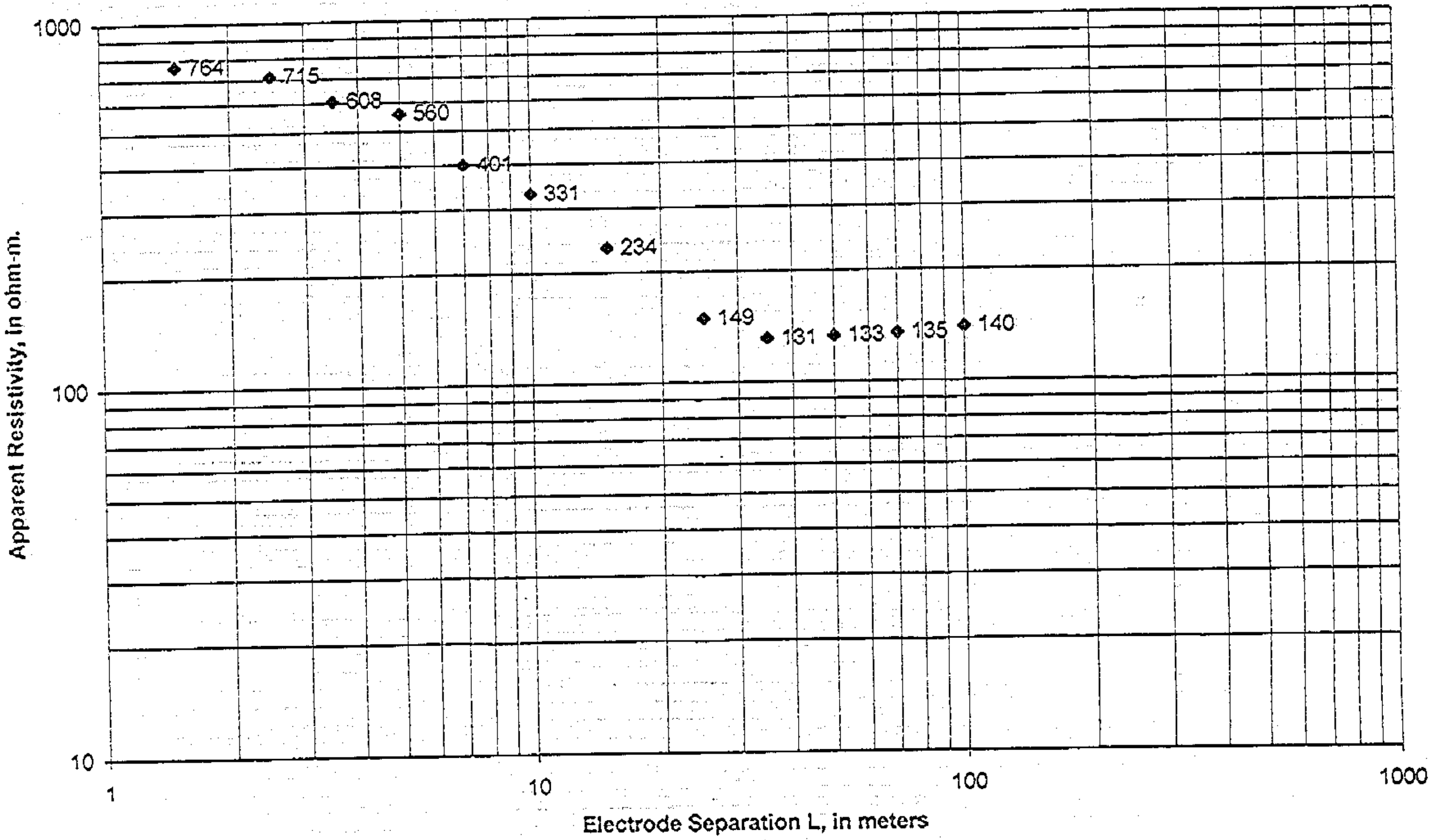
VES-8: CURA DAMSITE, STA. 0 + 420 M.



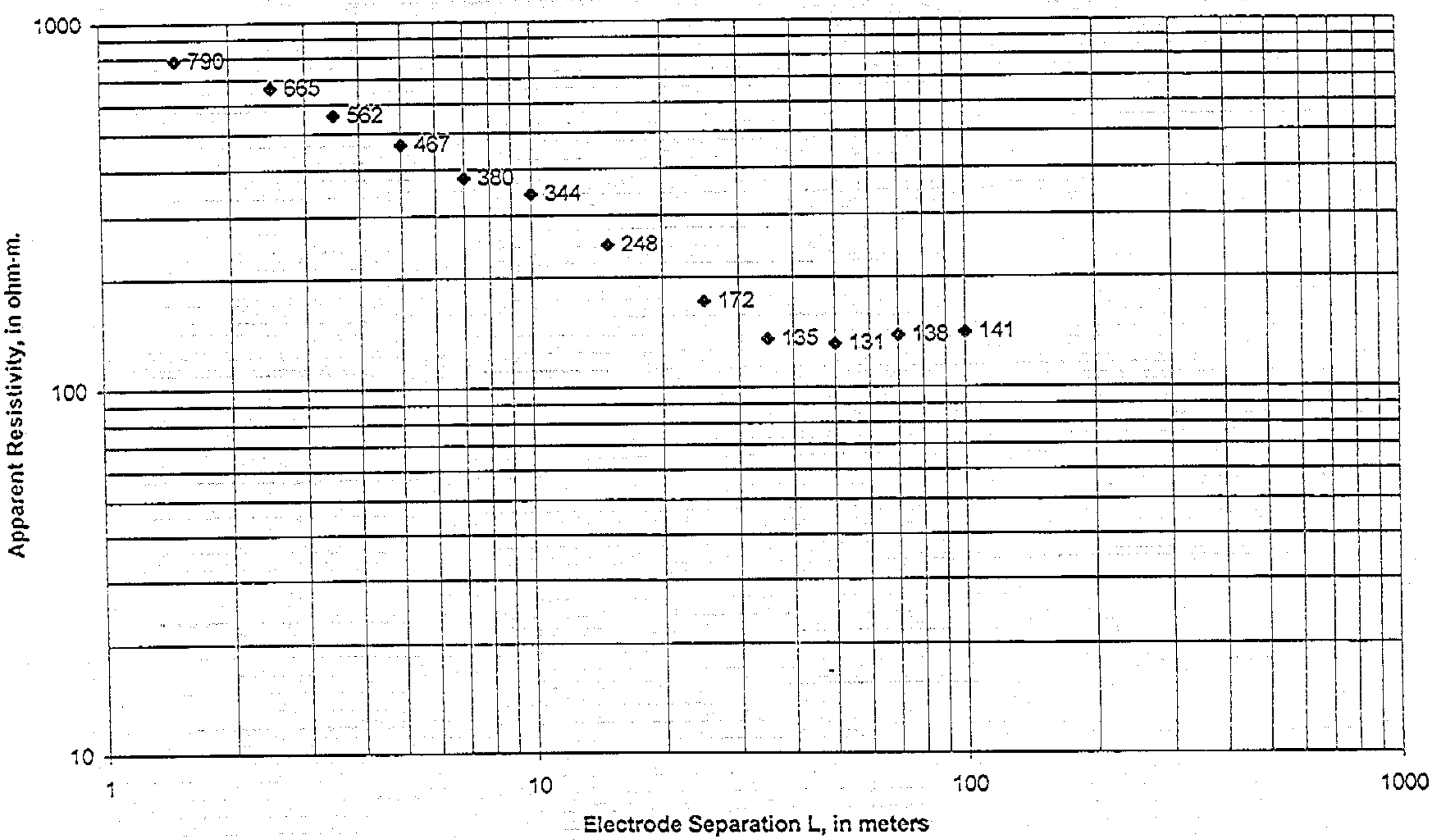
VES-9: CURA DAMSITE, STA. 0 + 420 M.



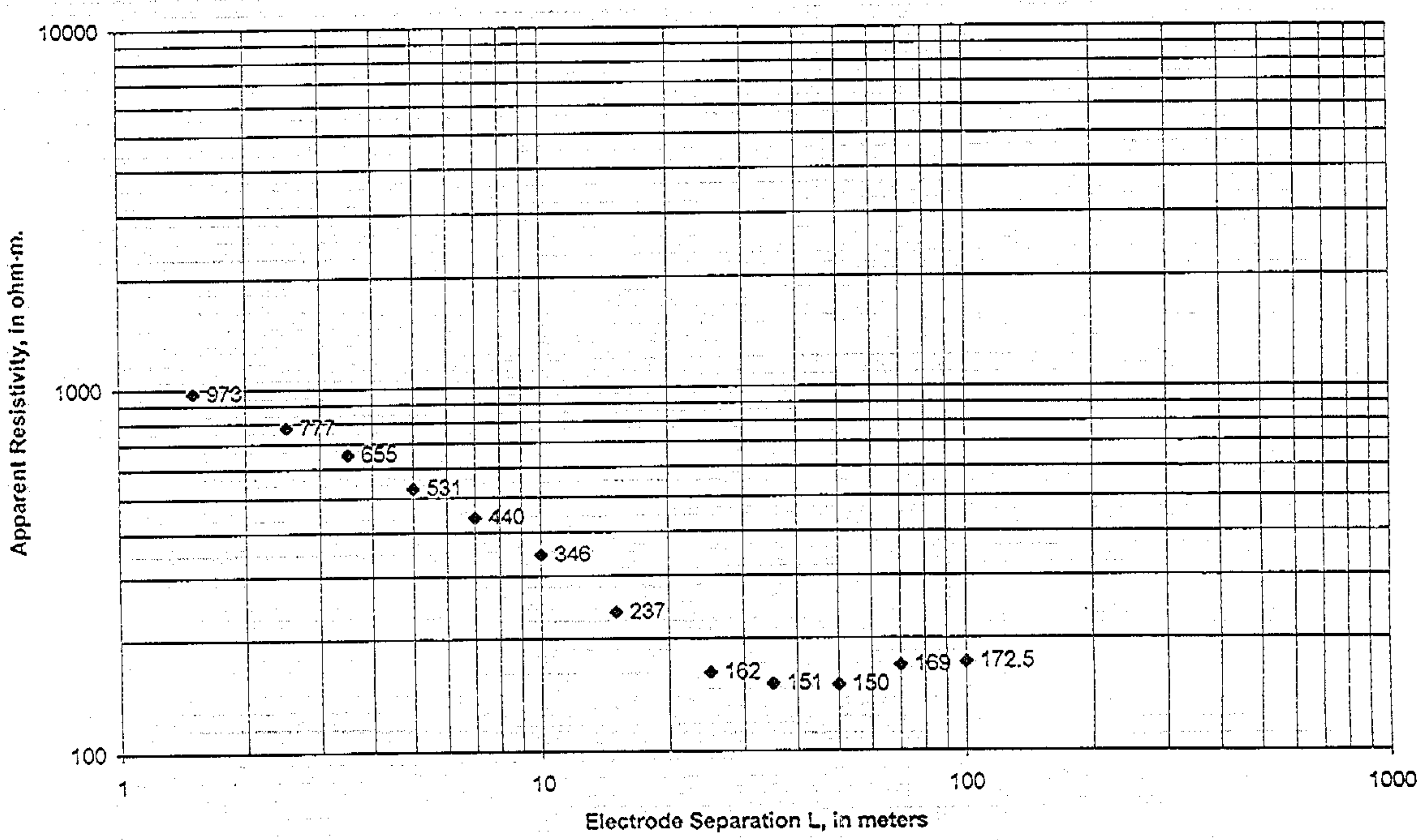
VES-1: CURA DAMSITE, NIS INTAKE



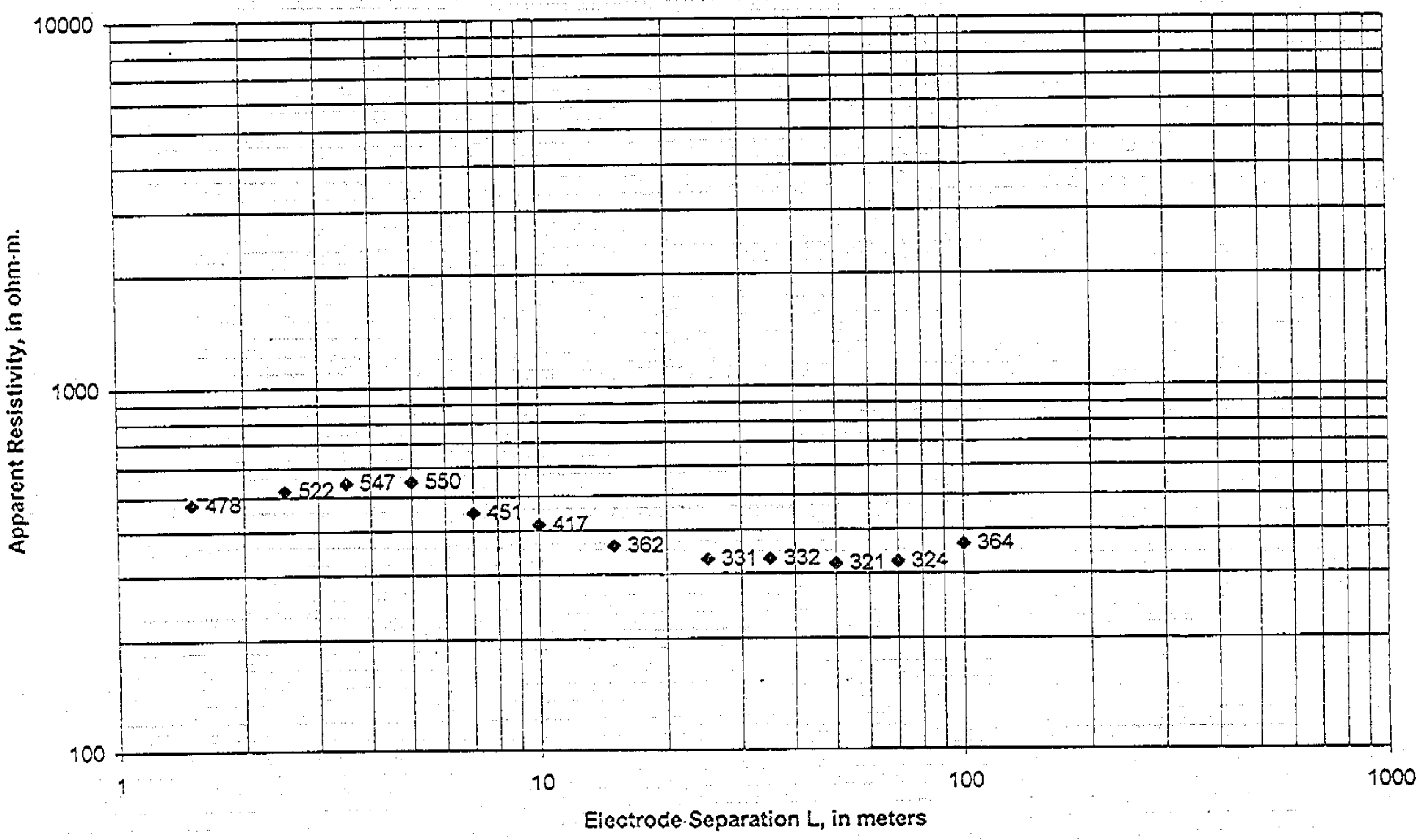
VES-2: CURA DAMSITE, NIS INTAKE



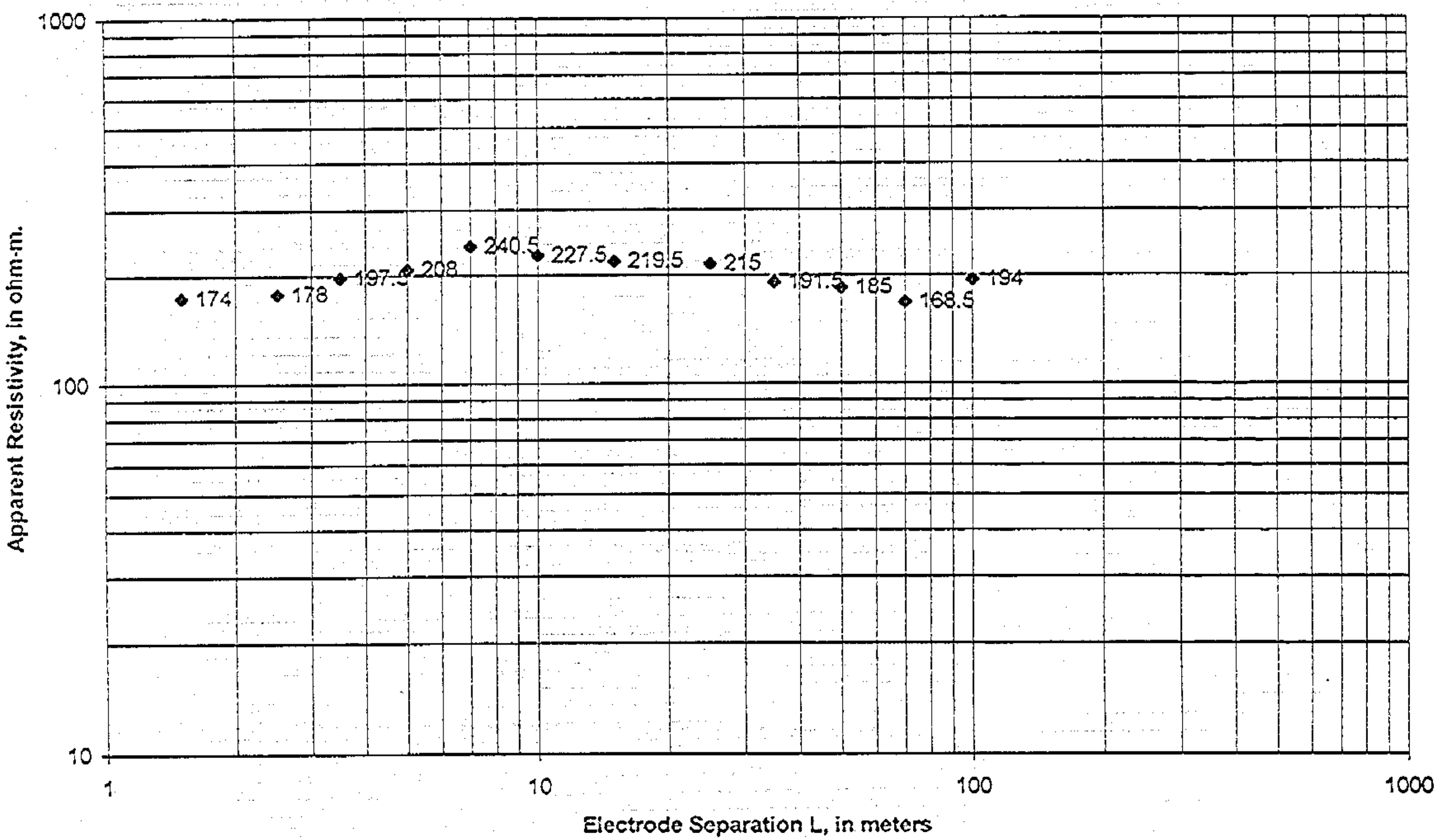
VES-3: CURA DAMSITE, NIS INTAKE



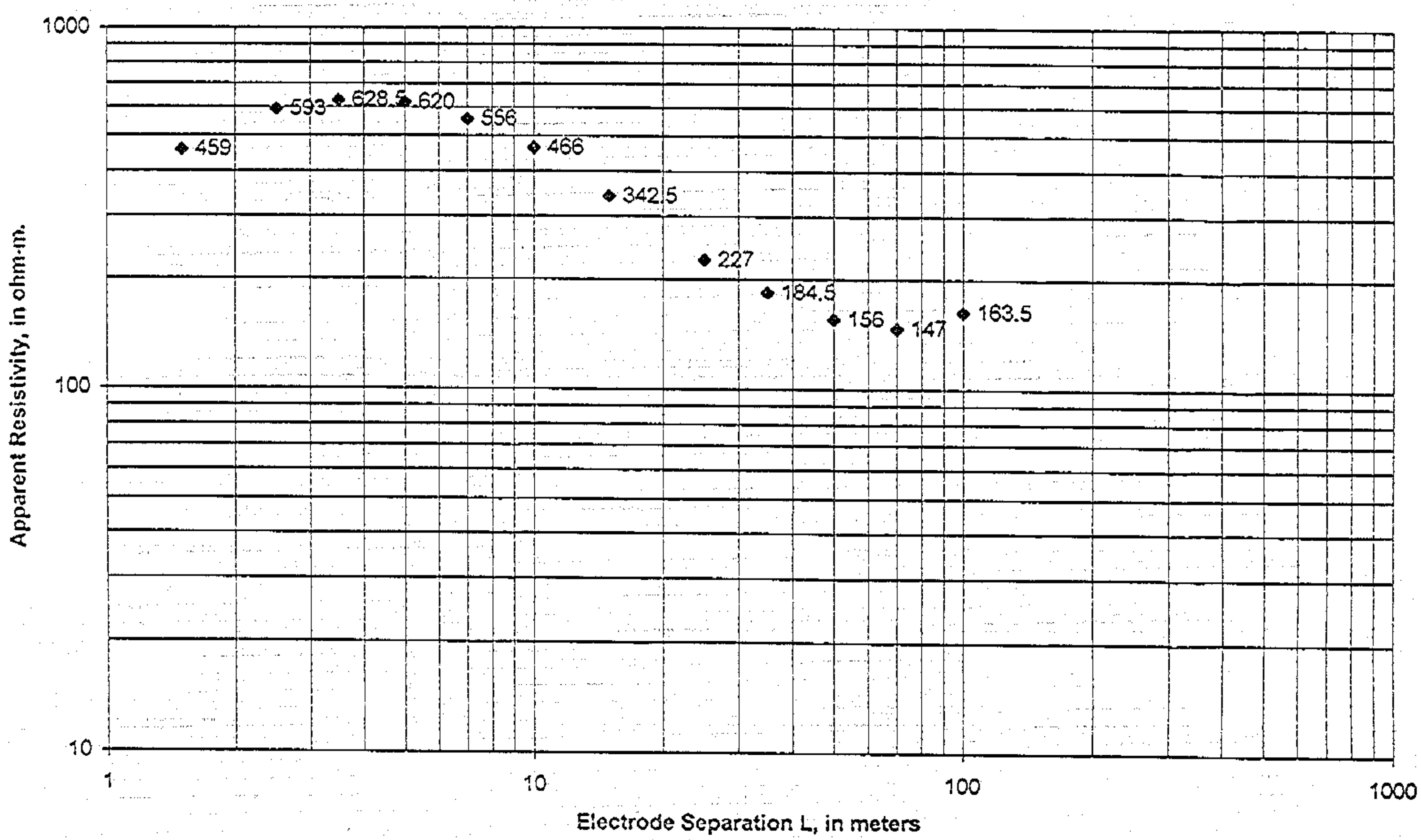
VES-4: CURA DAMSITE, NIS INTAKE



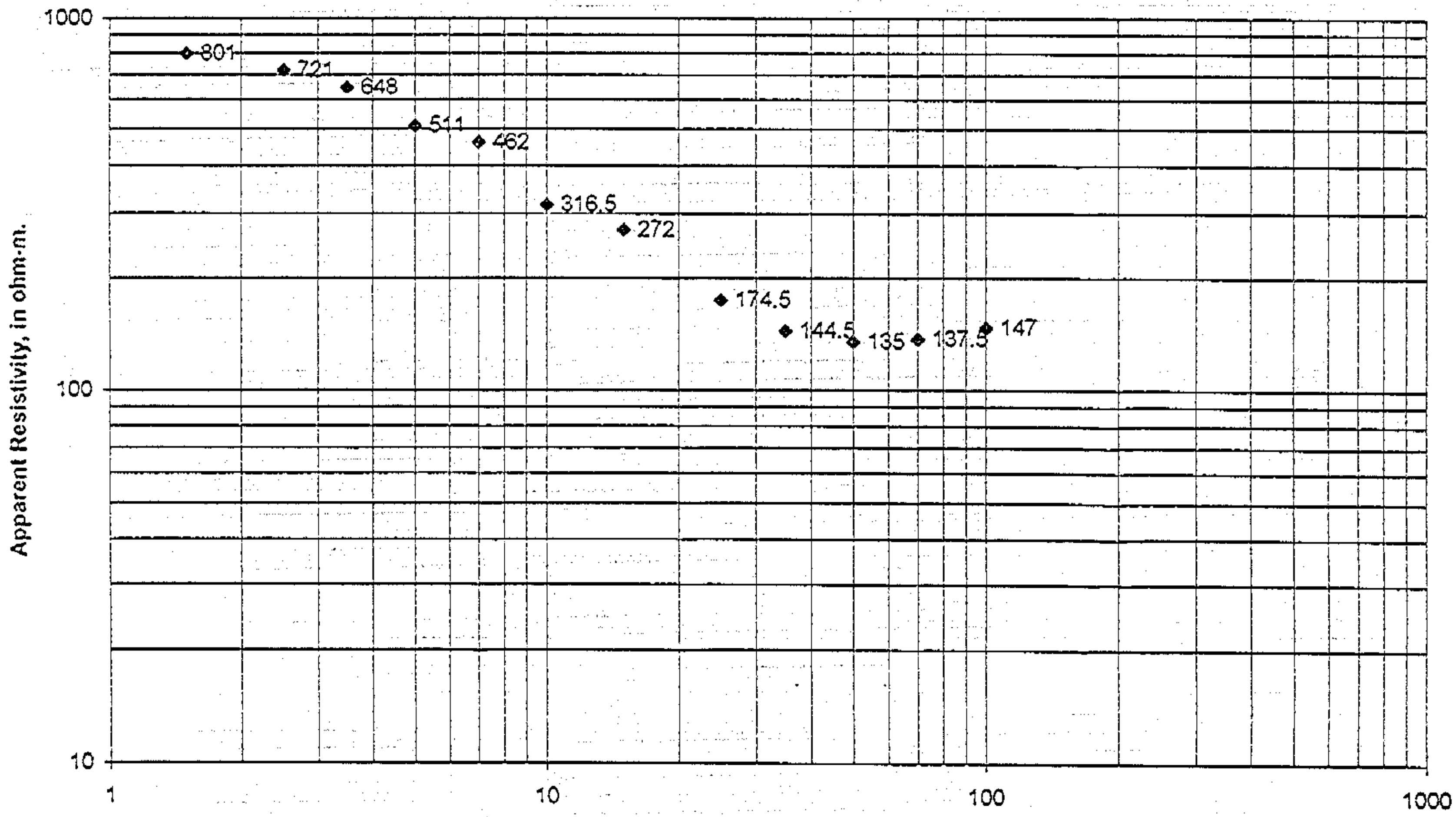
VES-5: CURA DAMSITE, NIS INTAKE



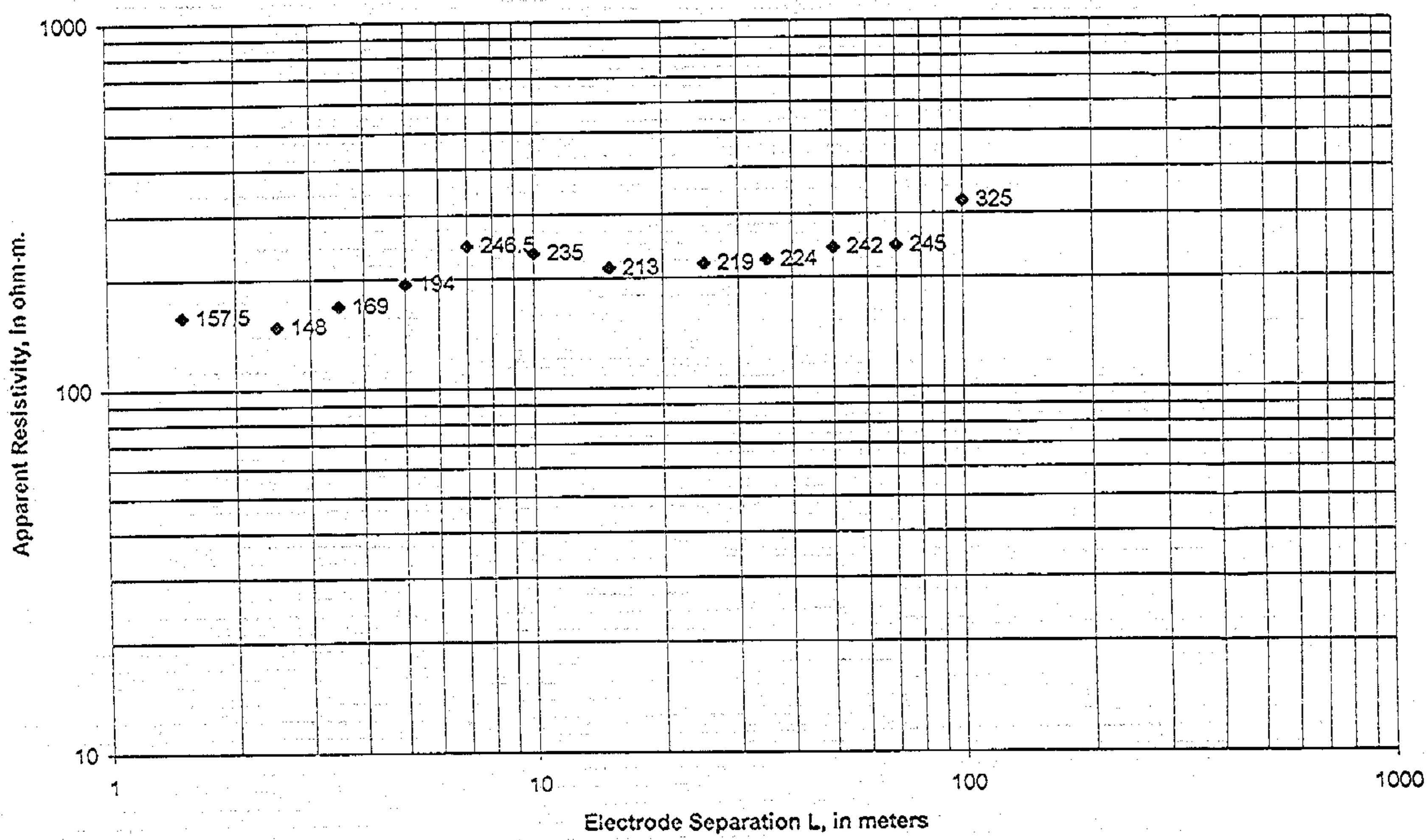
VES-6: CURA DAMSITE, NIS INTAKE



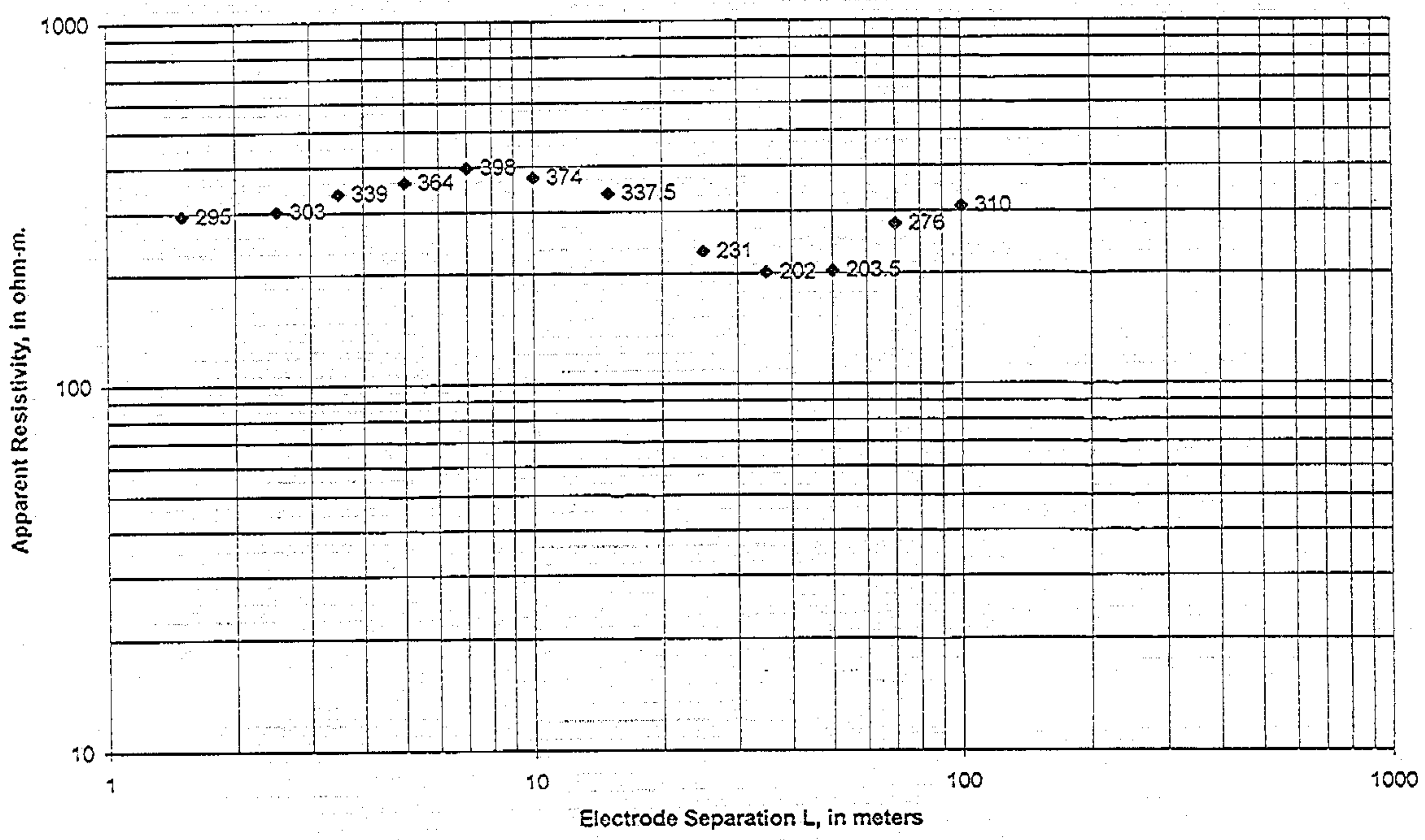
VES-7: NIS INTAKE



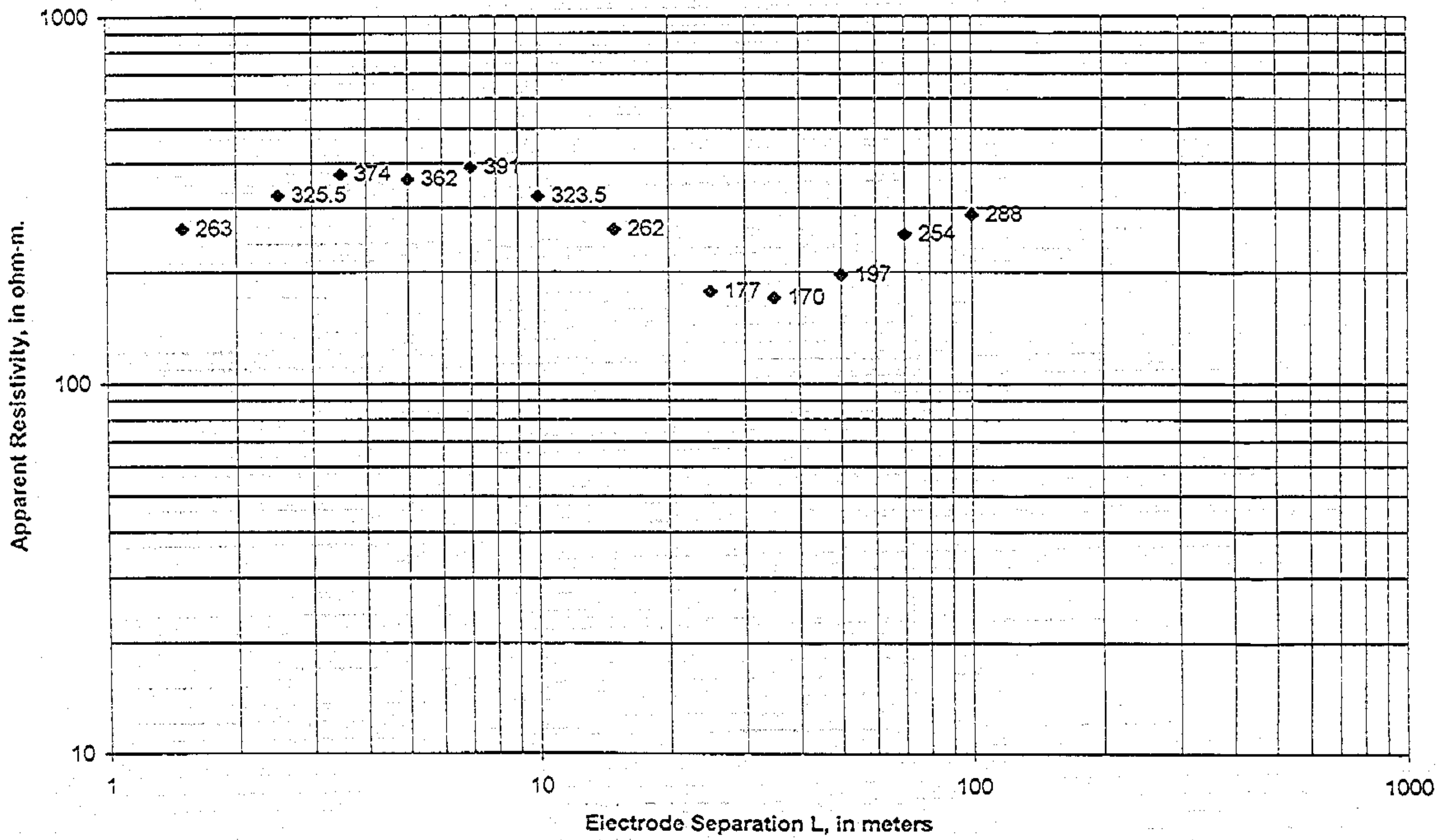
VES-1: IABUGAON DAMSITE, D-AXIS



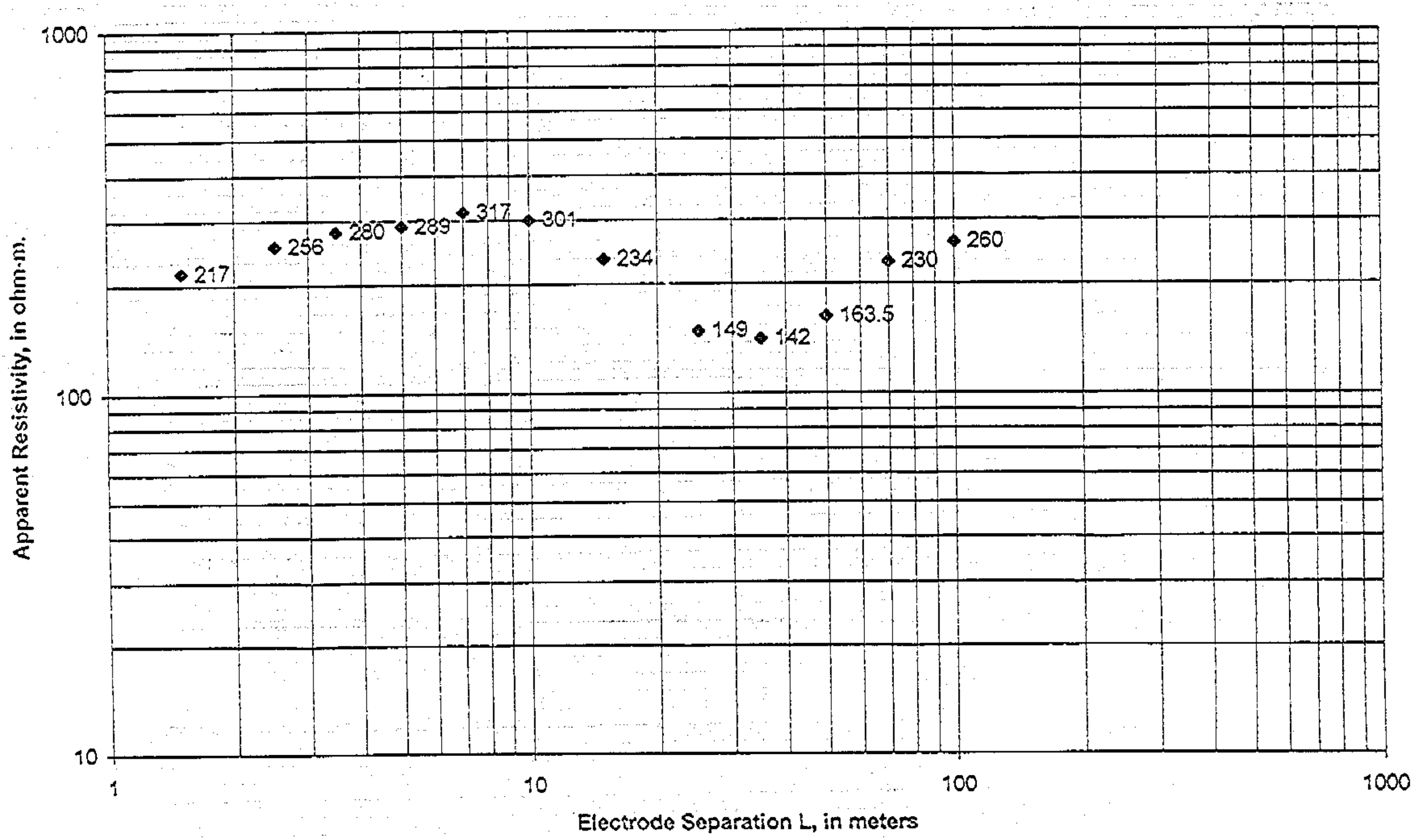
VES-2: LABUGAON DAMSITE, D-AXIS

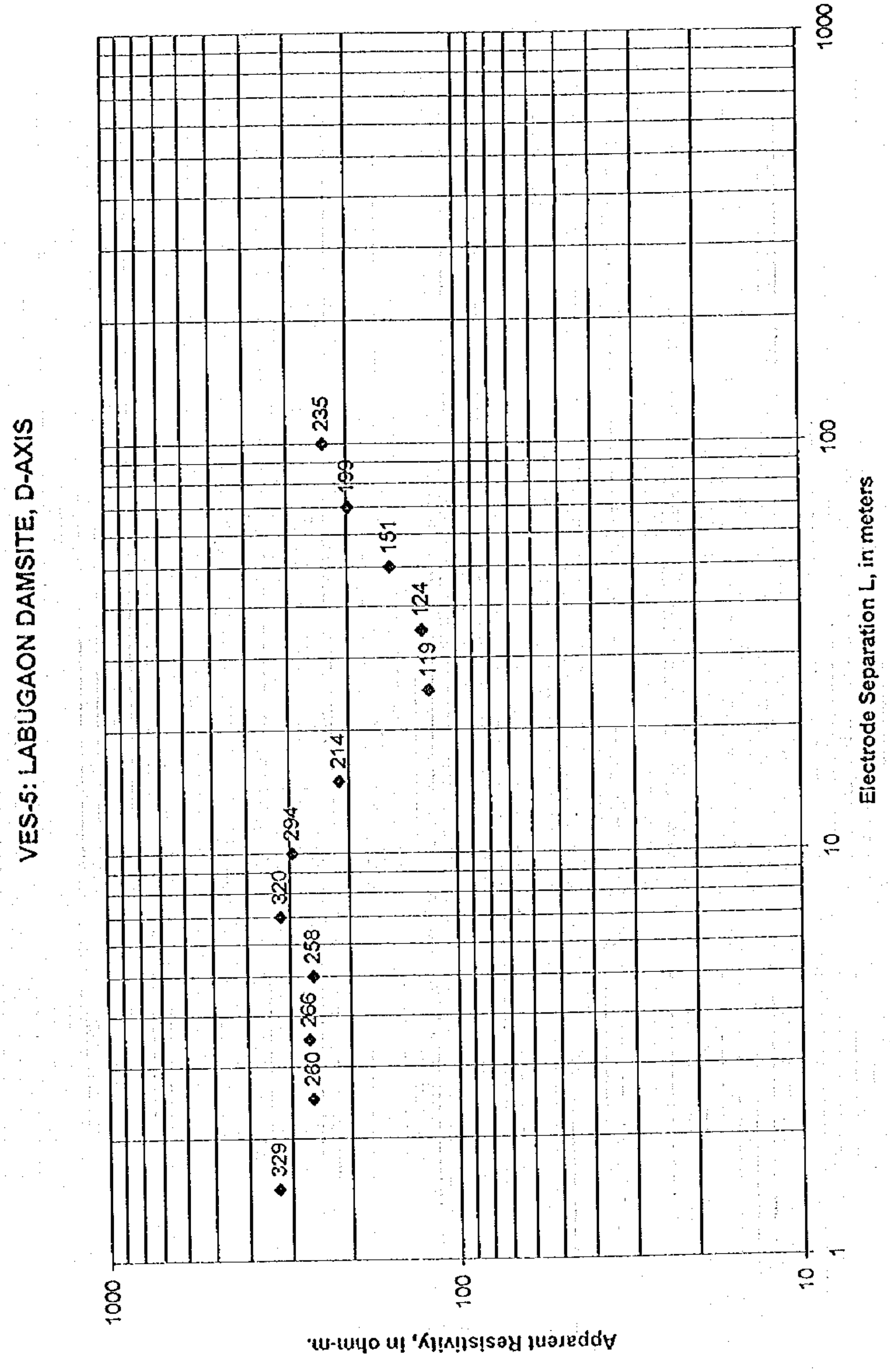


VES-3: LABUGAON DAMSITE, D-AXIS



VES-4: LABUGAON DAMSITE, D-AXIS




VES-5: LABUGAON DAMSITE, D-AXIS
Electrode Separation L, in meters
Apparent Resistivity, in ohm-m.
1
10
100
1000
10
100
1000
329
280
266
258
320
294
214
119
124
151
199
235

VES-6: LABUGAON DAMSITE, D-AXIS