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HYDROGEOLOGY OF TARAWA ATOLL, KIRIBATI

by

G. Jacobson & F.J. Taylor

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HYDROGEOLOGY OF TARAWA ATOLL, KIRIBATI

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G. Jacobson & F.J. Taylor

CONTENTS

ABSTRACT

Tarawa is a coral atoll in the Gilbert Islands; it consists of a number of low islands, several of which contain discrete freshwater lenses overlying salt water. Resistivity depth probes indicate that the largest untapped lens is on the northern island of Buariki, and that this lens is up to 29 m thick. The total safe yield of the Tarawa freshwater lenses is probably more than 12 l/s, and there is scope for the present groundwater development system of infiltration galleries to be extended.

INTRODUCTION

Tarawa is located at 1°30'N, 173°00'E (Fig. 1). It is one of the sixteen atolls which form the Gilbert Islands, and is the administrative centre of the Republic of Kiribati. It has a population of about 20 000.

In the urbanised southern half of Tarawa, a reticulated drinking water supply is derived from infiltration galleries which extract groundwater from freshwater lenses on the islands of Taeoraereke, Bonriki and Buota (Fig. 2). Non-potable groundwater is extracted at Betio, Bairiki and Bikenibeu. Some rainwater is also used for drinking and there are some private wells. Village water supplies in the northern part of the atoll are derived from shallow wells.

The Department of Housing & Construction requested BMR assistance with the investigation of the hydrogeology of Tarawa in 1980. The Department was briefed by the Australian Development Assistance Bureau to design an improved water supply system for the atoll.

Previous hydrogeological studies of Tarawa were done by the British government prior to Kiribati becoming independent in 1979. Mather (1973) identified several freshwater lenses in south Tarawa, and recommended development of the Bonriki and Buota lenses, which has since taken place. Richards and Dumbleton International (1978) carried out resistivity surveys of several freshwater lenses in south and north Tarawa, and modelled the predicted behaviour of the lenses in times of drought. They concluded that the lenses could not sustain a water supply in the second year of a 2% drought (Lloyd & others, 1980).

In the present investigation, additional resistivity surveys were carried out on several of the islands to define the configuration of the freshwater lenses. Concurrently a drilling program was carried out by the Central Investigation & Research Laboratory of the Department of Housing & Construction. Field work on Tarawa was done between September and December 1980, and BMR personnel involved were G. Jacobson (September-October) and A.W. Schuett (October-November). The interpretation of resistivity data was done by F.J. Taylor.

GEOLOGY

Tarawa is a coral atoll formed on top of a volcanic seamount which rises steeply from 4000 m of water. The atoll is roughly triangular in plan and comprises a chain of small islands on the south and northeast sides which partially enclose a central lagoon (Fig. 2). The islands are generally 2-3 m above present sea level.

The surface material of most of the islands is coral sand. In places, cemented coral hardpan forms a terrace 1.5-2 m above sea level. The first four bores drilled on Bonriki and Buariki intersected coral sand to depths of 7.5-11.5 m below the ground surface (Appendix 1). Beneath the sand, these bores intersected buried coral reef, 1.5-12.0 m thick. Beneath the buried coral reef, some of the bores encountered interbedded limestone and sand; others had a limestone sequence extending to 30 m below surface, the maximum depth of drilling.

The total thickness of the limestone sequence is unknown. The nearest atoll to Tarawa that has previously been drilled is Funafuti in the Ellice Islands (Fig. 1), where volcanic basement was not encountered even at 330 m. The nearest atoll where basement has been intersected is Enewetok in the Marshall Islands, where basalt was encountered beneath 1300 m of limestone.

GROUNDWATER

Freshwater lenses occur on many of the islands of Tarawa, in general where the width of island is more than 300 m. A summary of the known lenses is given in Table 1.

A freshwater lens on an oceanic island floats on saltwater. Theoretically, assuming static conditions, the approximate depth of the freshwater/saltwater interface is given by the Ghyben-Herzberg relation,

$$h_s = \frac{\rho_f}{\rho_s - \rho_f} h_f$$

where h_s is the depth of the interface below mean sea level, h_f is the height of the water table above sea level, ρ_s is the saltwater density

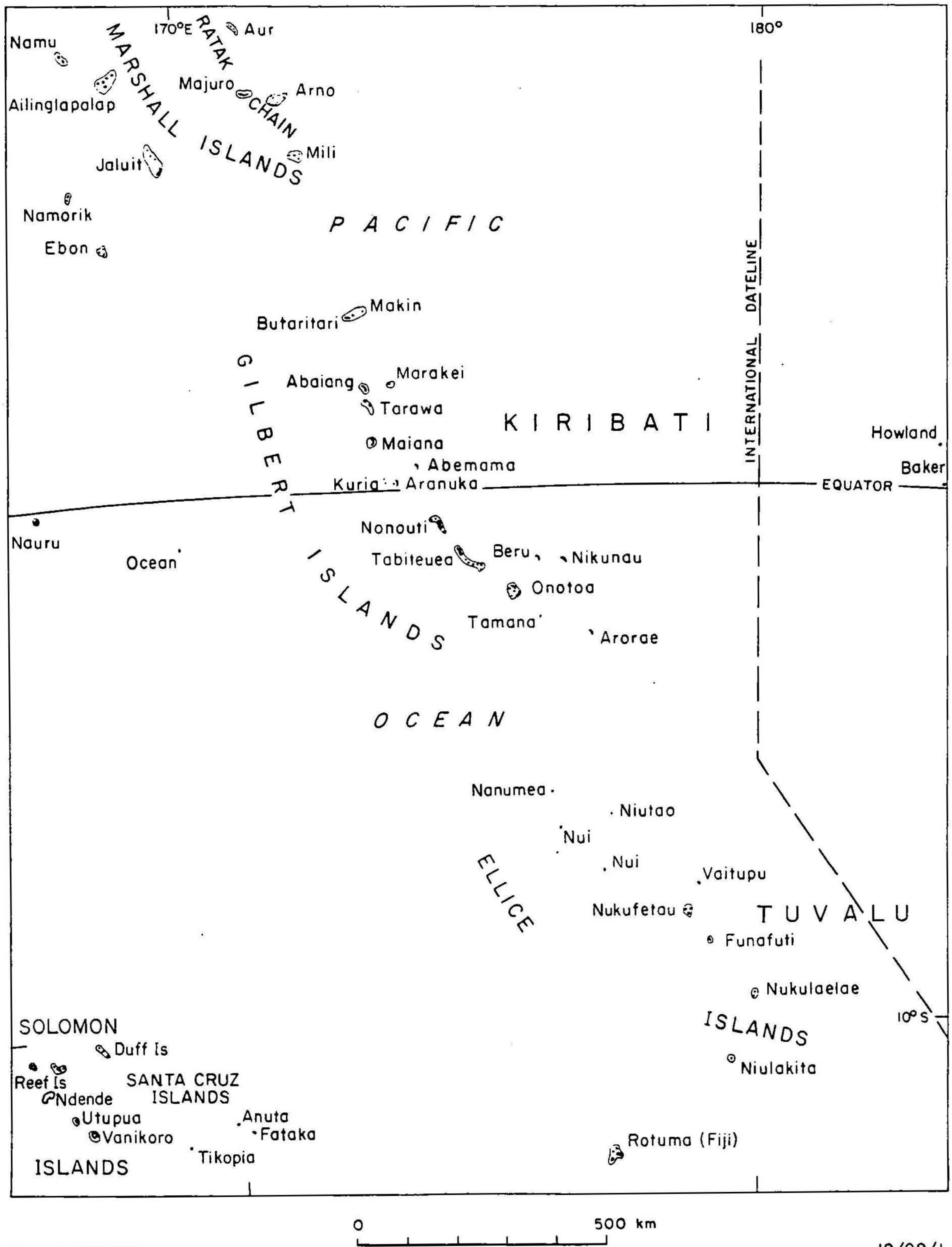

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Fig. 1 Location map

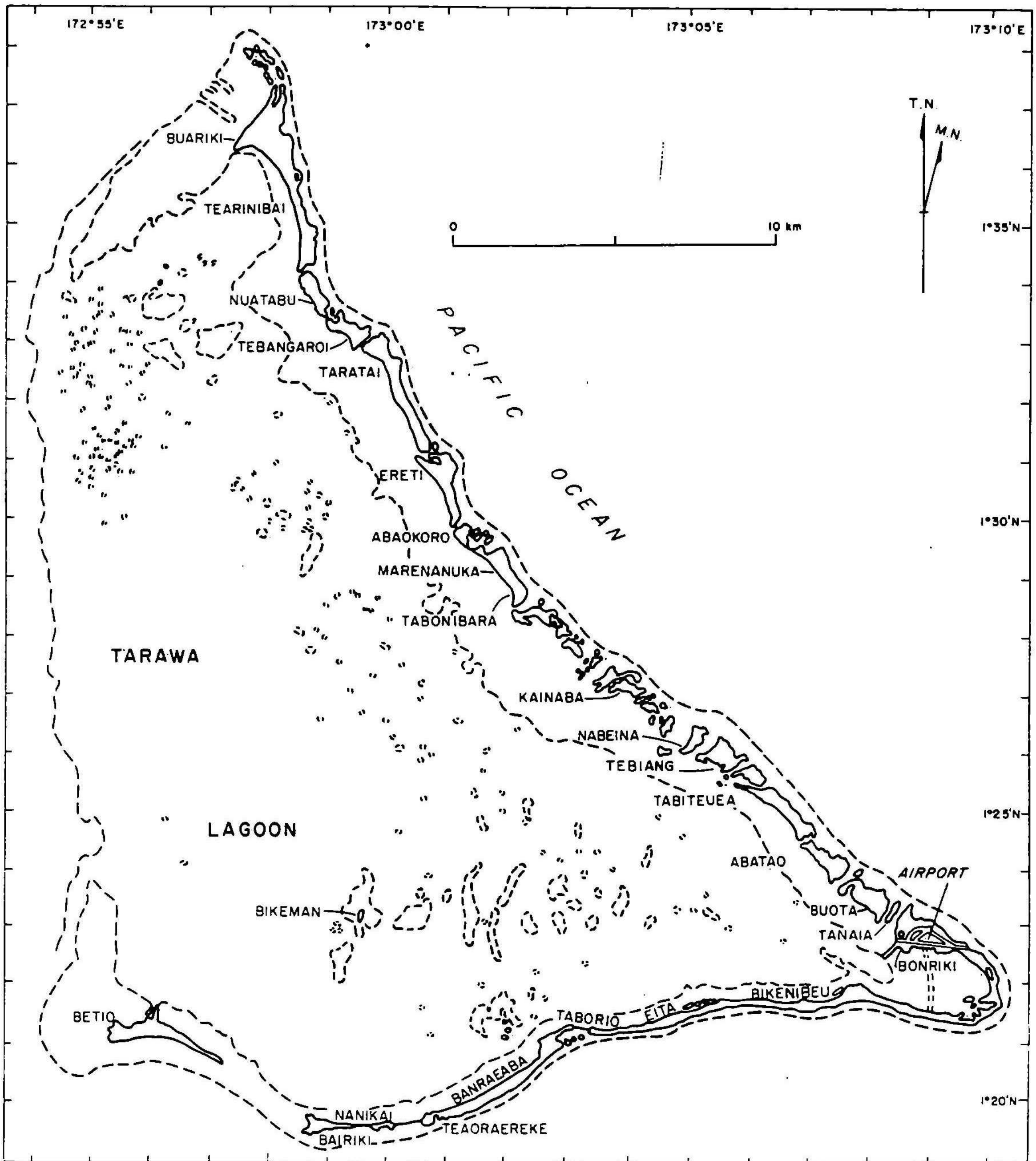

Fig: 2 Tarawa Atoll, Kiribati

and ρ_f is the freshwater density. Density measurements on Tarawa waters show that the saltwater is 1.0228 and the freshwater 0.9974. The Ghyben-Herzberg relation is thus

$$h_s = 39.27\ h_f$$

In nature, the freshwater lens is a dynamic system. Groundwater in the lens flows into the surrounding and underlying sea water and at the interface there is a transition zone of diffusion. The thickness of the transition zone is affected by the continuous reciprocative movement of the lens caused by ocean tides. The water table oscillates daily with the tides, and mean sea level itself changes over longer periods. Figure 3 shows variations in monthly mean sea level over several years at the Tarawa tide gauge; the monthly variation is up to 0.2 m.

Aquifer Transmissivity

During the present investigation, a pump test was carried out in bore 3 on the island of Buariki. The bore was pumped at a constant rate of 630 m^3/d and drawdown of the water table was observed in four observation bores, at distances ranging from 1 to 10 m from the pumped bore. Analysis of the results by a distance/drawdown plot (Fig. 4) indicates that the transmissivity of the aquifer was 5120 m^2/d. Over the 28 m aquifer section, the average hydraulic conductivity was 183 m/day. The section consists of about 8 m of sand, 8 m of buried coral reef, and 12 m of limestone. The results of in situ permeability tests in sections of several drillholes, indicate that the limestone is more permeable than the sand. The results of laboratory tests on core samples (Appendix 1) indicate that the limestone is intrinsically more permeable than the buried coral reef. The high average hydraulic conductivity of the aquifer section probably reflects the transmissive influence of major fractures in the limestone. The thickness of the freshwater lens tends to be greater where there is a thick, relatively impermeable, sand section.

RESISTIVITY SURVEY AND LENS CONFIGURATION

A variety of electrical resistivity methods can be applied to the search for groundwater. In the relatively simple layered situation of the freshwater lens on an oceanic island, resistivity depth probes are considered the most effective method. The technique has previously been used by BMR in surveys of freshwater lenses in New Ireland, Papua New Guinea (Dolan & others, 1975) and Niue Island (Jackson & Hill, 1980).

Resistivity depth probes were carried out on several of the Tarawa islands using the Wenner electrode configuration and an Atlas Copco SAS 300 Terrameter (Appendix 2). This modern instrument has stacking facilities as well as correlation between transmitted and received signals. It is light and portable which makes it particularly suitable for use on remote islands. Some qualifications on its use are given in Appendix 2.

The depth probes are numbered 2 to 47 (Appendix 3) with results of probes 3 and 27 not presented because of poor quality data. The results of probes 38, 41 and 43 do not model well but are included in the presentation. The interpretation of the depth probes was carried out using an inverse modelling program (Mooney, 1980; Davis, 1979; Merrick, 1977), and the field data, computed model and theoretical curve from this model were plotted on log-log scales. The program used to calculate the theoretical curve was based on papers by Ghosh (1971) and O'Neill (1975). This program does not handle high resistivity contrasts very well, and this is evident on some plots as oscillations in the theoretical curve for electrode spacings in the order of 100 m.

In all cases the models chosen were based on geological considerations, and the limits of the resistivity technique. The resistivity of the deepest layer was in most cases confined to 1 ohm-m to represent saline saturated sediments.

The general model which can be used for all the depth probes on these islands is 1-2 m of dry material overlying 5-20 m of sediments saturated with fresh water which in turn overlie sediments saturated with salt water. Areas close to the centre of the islands are expected to have the greatest thickness of fresh water saturated sediments. In general it is expected that a transition zone exists between the fresh-water and the salt water beneath it. This zone is not easily detected by the resistivity technique unless it is of comparable thickness to the overlying freshwater layer. In practice, the resistivity values

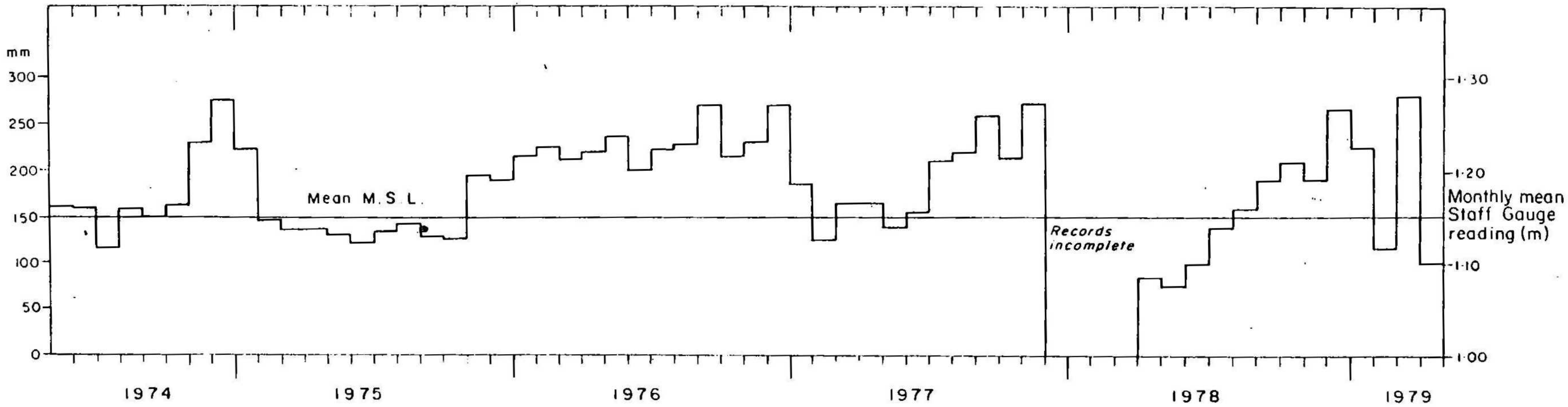

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Fig. 3 Tarawa - Variations in Monthly Mean Sea Level 1974 - 79, Betio Tide Gauge

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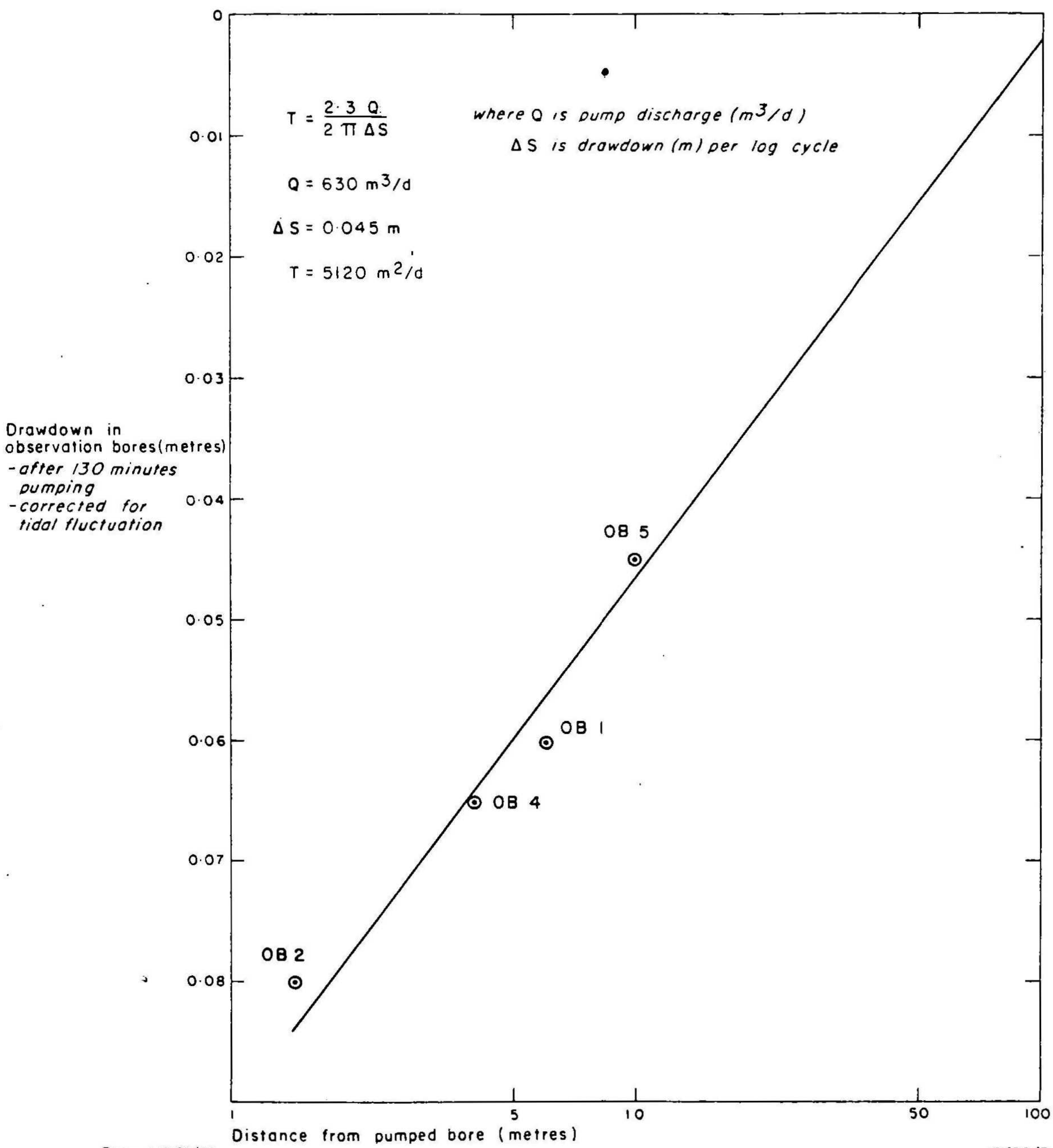

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Fig.4 Results of aquifer test, Buariki, bore 3
Drawdown in observation bores vs distance from pumped bore

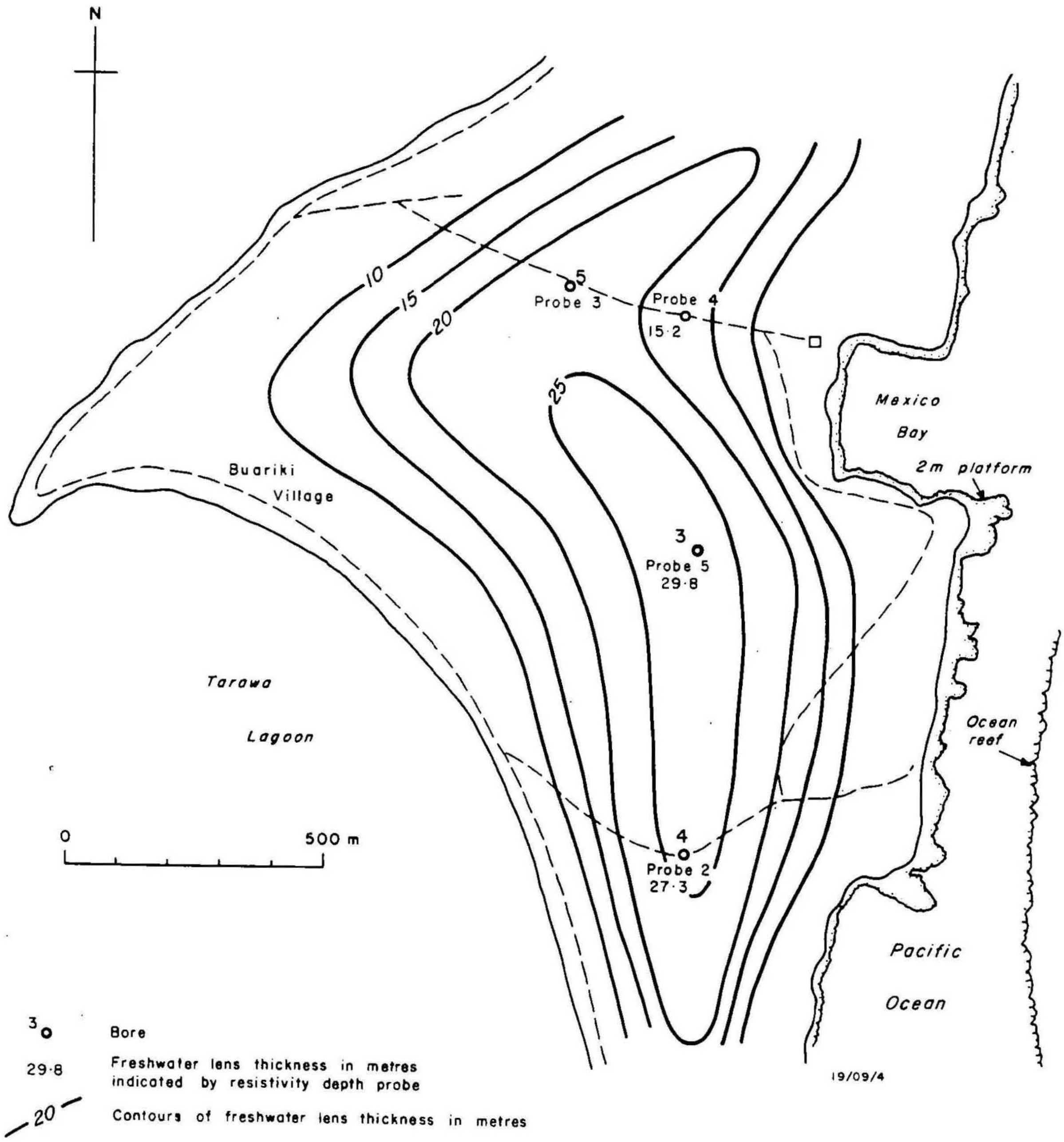

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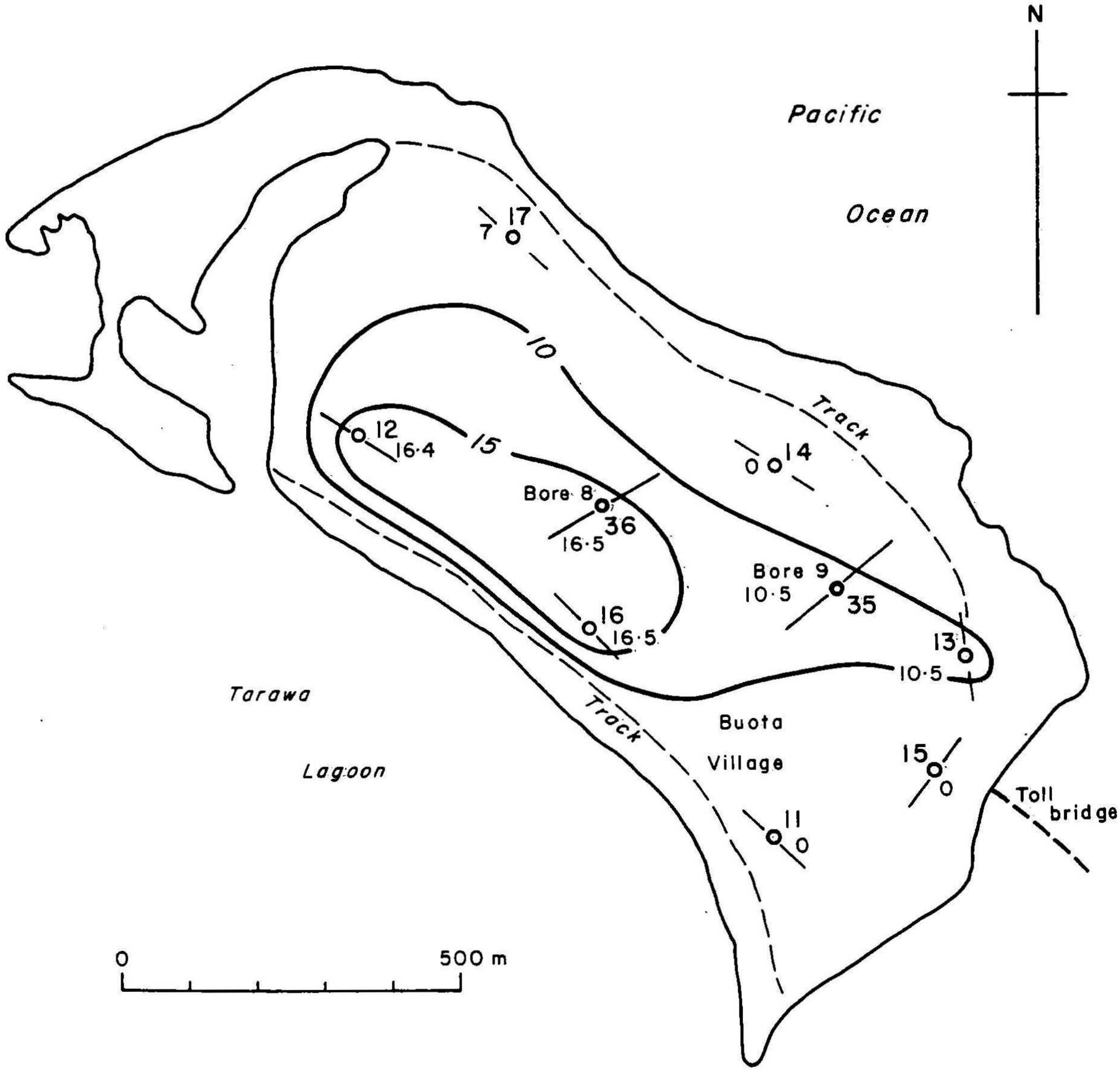
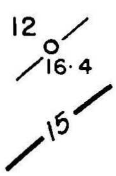
Fig. 5 Buariki freshwater lens





Resistivity depth probe with number and interpreted freshwater thickness in metres

Contours of freshwater lens thickness in metres

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Fig.6 Buota freshwater lens

interpreted for the freshwater layer represent the bulk resistivity of the freshwater and transition zones. When this value is comparatively high (40 ohm-m or greater), fresh water produces the dominant contribution. In cases where this value is comparatively low (20 ohm-m or less), saline or brackish water produces the dominant contribution.

Hence, it is expected that in areas where salt water is closer to the surface or where prolonged pumping has raised the salt water interface, the resistivity of the "freshwater" layer will be comparatively low.

Results obtained on four of the islands are summarised below.

<u>BUARIKI</u>

Results of three resistivity depth probes on Buariki indicate that the freshwater lens is up to 29 m thick. The resistivity of the freshwater saturated sediments ranges from 67 to 86 ohm-m. Inferred contours of freshwater lens thickness are shown in Figure 5. About 130 ha of Buariki is underlain by the freshwater lens with thickness probably greater than 9 m.

<u>BUOTA</u>

Results of 9 resistivity depth probes on Buota indicate that the freshwater lens is up to about 16 m thick. Five of the depth probes indicated freshwater saturated sediments with resistivity between 23 and 51 ohm-m. The thickest part of the lens is west of the centre of the island (Fig. 6) and about 35 ha is probably underlain by freshwater lens more than 9 m thick.

<u>BONRIKI</u>

Results of 21 resistivity depth probes on Bonriki indicate that the freshwater lens is up to 23 m thick. A total of 18 of the depth probes indicated freshwater saturated sediments with resistivity ranging from 64 to 216 ohm-m, and averaging 92 ohm-m. Inferred contours of the freshwater lens are shown in Figure 7. About 70 ha of Bonriki is underlain by freshwater lens more than 9 m thick.

BETIO

Results of 6 resistivity depth probes on Betio indicate that the freshwater lens is up to 16 m thick in the western part of the island. Resistivity of the freshwater saturated sediments ranges from 26 to 49 ohm-m. Brackish water with resistivity of 15-18 ohm-m is indicated in the centre of the island, where the lens has been disrupted by overpumping. Inferred contours of the freshwater lens are shown in Figure 8. A small area, up to 10 ha, may be underlain by a lens more than 9 m thick.

SAFE YIELD

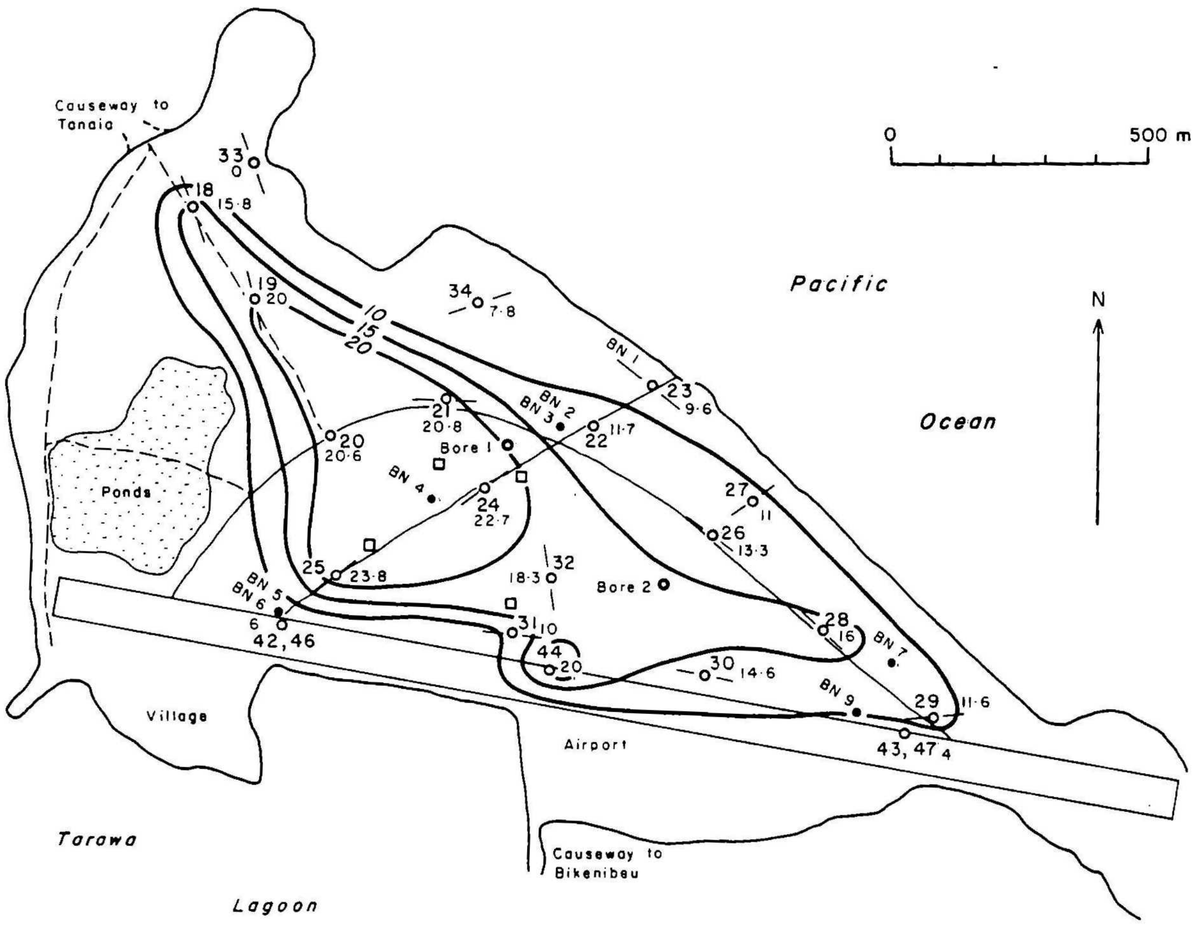
Runoff is negligible on Tarawa, and the water balance is: rainfall = evapotranspiration + recharge to groundwater aquifer.

Tarawa has a mean annual rainfall of 1948 mm, based on 1947-79 data. Considerable variations from the mean are evident (Fig. 9) and lengthy droughts occur.

There are various ways of estimating evapotranspiration and recharge, none of them satisfactory without detailed meteorological data. Some of the best documented hydrological studies of coral islands have estimated recharge as about 25% of rainfall, e.g. Bermuda (Vacher & Ayers, 1980) and Tongatapu (Hunt, 1979).

Mather (1973) assumed an average annual recharge of 254 mm for Tarawa, about 13% of the average rainfall, based on the estimated transpiration requirements of coconut trees. He allowed for the effects of the worst recorded drought, that of 1954-56, and recommended the following pumping rates for Tarawa freshwater lenses, allowing for the lenses to be drawn up to one-third of their original thickness.

Original depth to saltwater interface (m)	Recommended depth for lens development (m)	Recommended pumping rate (m^3/d/ha)
15	5	3.8
12	4	3.5
9	3	2.1



19 20·6 Resistivity depth probe with probe number and interpreted freshwater lens thickness in metres

15 Contours of freshwater lens thickness in metres

o 2 Bore

□ Infiltration gallery

Fig. 7 Bonriki freshwater lens

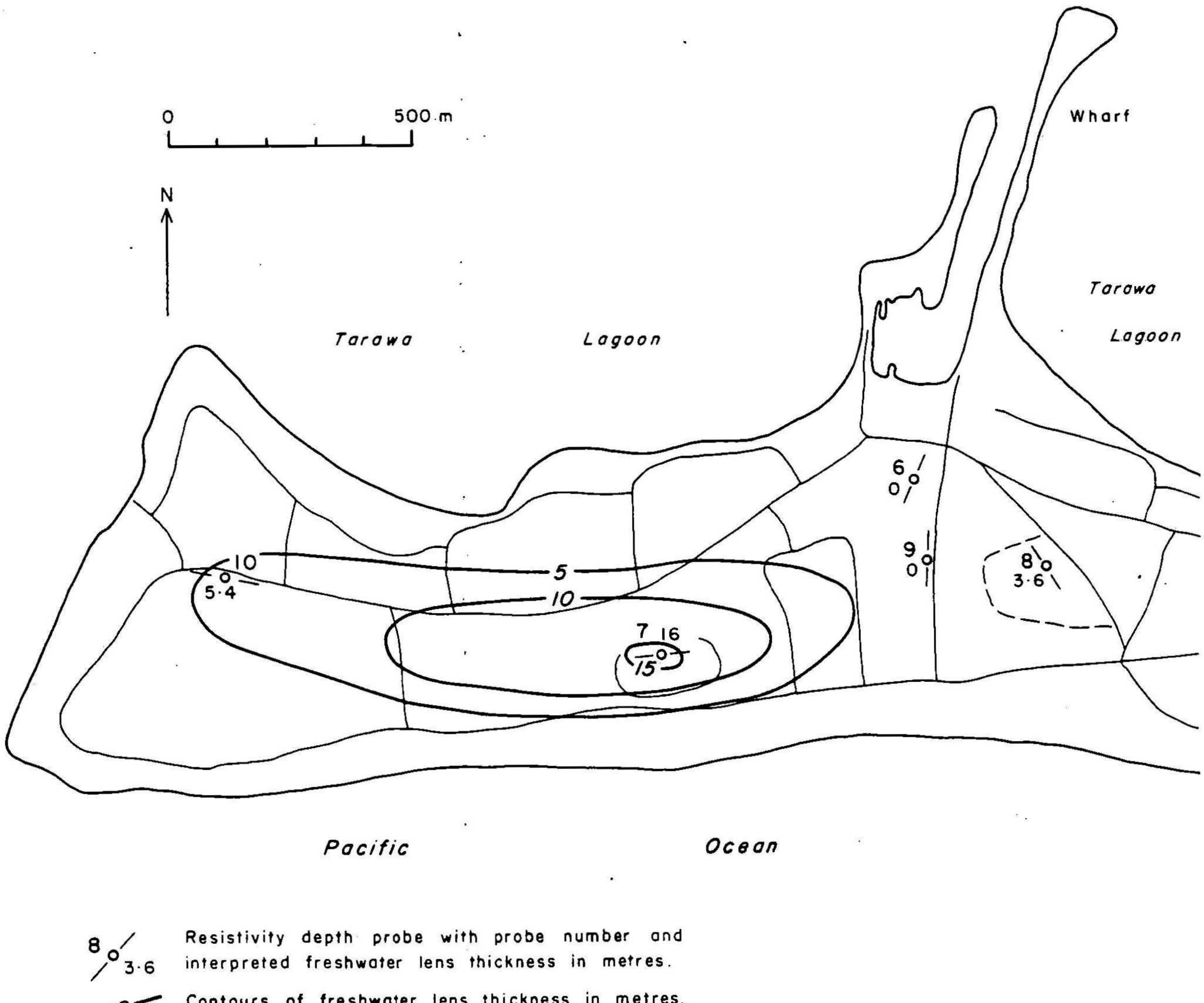


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Fig. 8 Betio freshwater lens

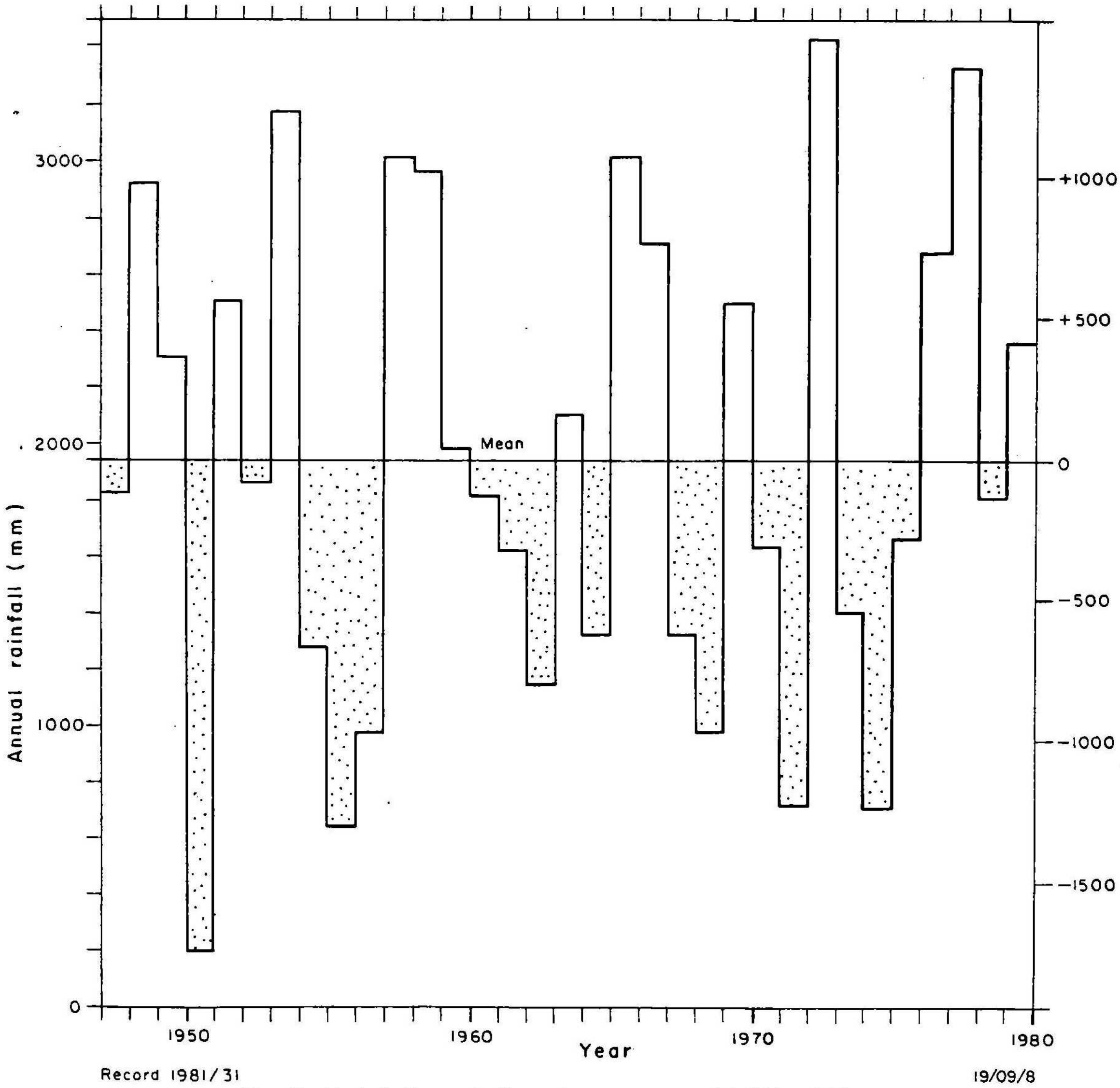

Fig. 9 Rainfall variation from mean, 1947 - 79

He recommended that the Tarawa lenses be developed by a network of infiltration galleries, each pumping at a rate of 27 m^3/d and each drawing from an area of 8 ha.

Subsequently the Bonriki, Buota, and Taeoraereke lenses were developed, and there are now 11 infiltration galleries on these three islands producing a total of about 168 m^3/d or 2 l/s. So far these galleries have produced freshwater within the World Health Organisation (1963) standards for drinking water. The highest electrical conductivities measured in the galleries were 2000 µS/cm on Taeoraereke in the dry months of August 1978 (Fig. 10) and October 1978, and 2300 µS/cm on Bonriki in June 1980. The galleries have so far operated in a period without a prolonged drought.

If the network of infiltration galleries were extended according to Mather's criteria to all the Tarawa freshwater lenses more than 9 m thick, then the potential yield would be:

Island	No. of galleries	Yield m^3/d
Buariki	16	432
Other North Tarawa islands	8	216
Bonriki	9	243
Buota	4	108
Taeoraereke	4	108
Total	41	1107

Thus, the total safe yield would be about 1100 m^3/d or 12.5 l/s. In practice, the Buariki and Bonriki lenses are more than 15 m thick and could be pumped at a greater rate than indicated above. Furthermore, Mather's estimate of groundwater recharge, about 13% of the average rainfall, may well be too low, and more detailed analysis could show that the potential yield of the Tarawa lenses is more than 12.5 l/s.

Judging by the available land area, there are substantial reserves of freshwater on at least two other atolls in the Gilbert Islands - Kuria and Nikunau. In the long term it may be necessary to consider shipping water in an emergency situation on Tarawa.

HYDROCHEMISTRY

Twelve chemical analyses of water samples are given in Table 2. One is of rainwater; six are of freshwater from operating galleries and wells; and five are of brackish water from bores drilled into the transition zone. For the freshwater samples, the relationship between total dissolved solids and electrical conductivity is shown in Figure 10. The maximum permissible total dissolved solids content is 1500 mg/l according to World Health Organisation (1963) standards. The equivalent electrical conductivity, which is the parameter commonly measured in the field, is about 2900 µS/cm.

The freshwater is a bicarbonate water with calcium the dominant cation. It is classified as very hard water, with more than 200 mg/l total hardness. The brackish water is a chloride water with solium the dominant cation.

The nitrate content of 12 mg/l in the Abatao well, though still at a safe level, probably indicates some contamination from farm animals.

CONCLUSIONS

1. Resistivity surveys indicate that the freshwater lens on Buariki is up to 29 m thick, and is the largest in the Tarawa atoll. The Bonriki lens is up to 23 m thick.

2. The total safe yield of the Tarawa freshwater lenses is probably more than 1100 m^3/d (12.5 l/s).

3. The present abstraction system - infiltration galleries - has so far proved a safe one, and there is scope for extending it.

4. The chemical quality of the freshwater is generally good, but the water is very hard.

5. There are believed to be substantial reserves of freshwater on the atolls of Kuria and Nikunau.

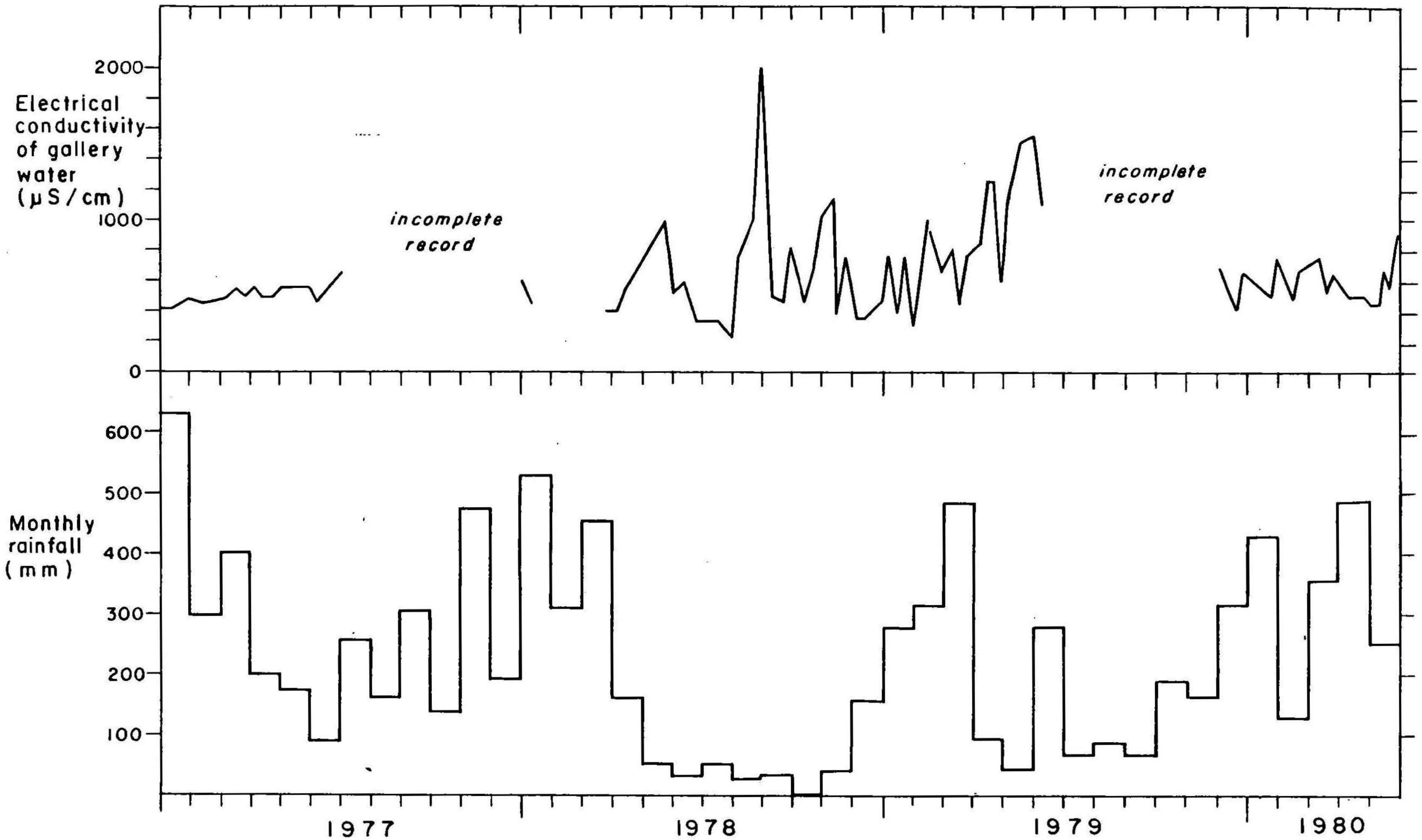

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Fig. 10 Salinity of groundwater, Teaoraereke Gallery 3, and monthly rainfall at Betio

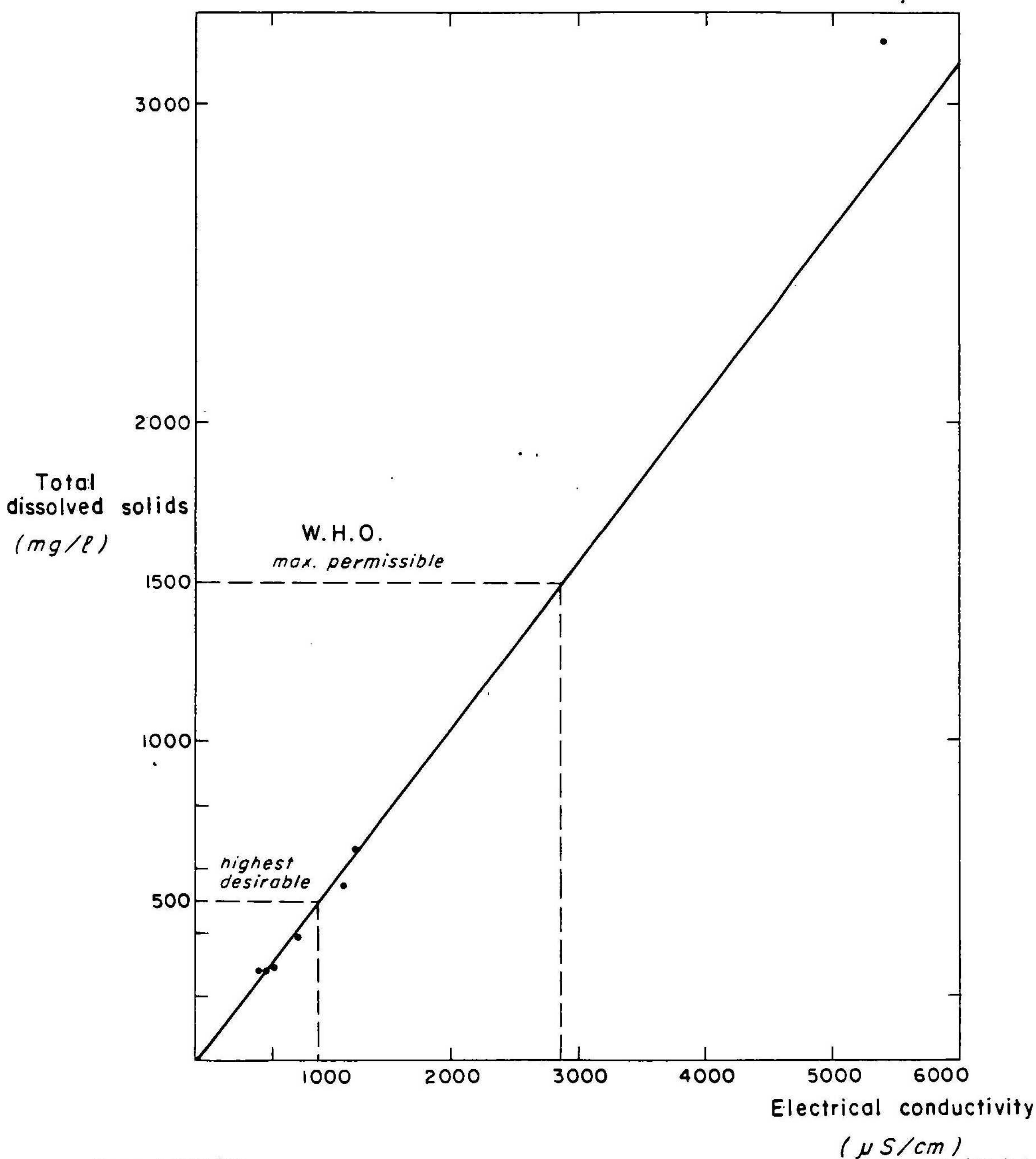

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Fig. 11 Relationship of total dissolved solids to electrical conductivity. Tarawa freshwater lenses

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TABLE 1 - FRESHWATER LENSES ON TARAWA

Freshwater lens	Present groundwater abstraction	Lens configuration	Scope for further development
Betio	Non-potable water abstracted	Thin lens, disrupted and not prospective for freshwater development	Nil - saltwater sewerage system introduced
Bairiki	Non-potable water abstracted	-	Nil - saltwater sewerage system
Teaoraereke	Abstraction from 4 infiltration galleries	Lens 9 m thick in centre	Lens has sustained 4 galleries for several years but probably this is its maximum capacity
Bikenibeu	Non-potable water abstracted	-	Nil - saltwater sewerage system
Bonriki	Abstraction from 4 infiltration galleries	Lens up to 23 m thick indicated by resistivity survey	Additional 5 galleries would bring total yield to 3 l/s. Possibly scope for heavier pumping.
Buota	Abstraction from 3 infiltration galleries	Lens up to 16 m thick indicated by resistivity survey	Possibly one additional gallery
Abatao	Local wells	RDI (1978) indicated lens 13 m thick	Possibly 1-2 galleries
Tabiteuea	Local wells	Lens up to 12 m thick according to BMR interpretation of RDI data	Possibly 1-2 galleries
Tebiang	Nil	Not investigated, but land area equivalent to Buota	Possibly 2 galleries
Marenanuka	Local wells	Lens probably 8-9 m thick according to BMR interpretation	Nil
Ereti	Local wells	Lens possibly 13 m thick	Possibly 1-2 galleries
Taratai	Local wells	Narrow lens up to 11 m thick	Possibly 1-2 galleries
Tearinibai	Local wells	Discrepancy between BMR and RDI interpretation; lens may only be 8 m thick	Nil
Buariki	Local wells	Lens up to 29 m thick indicated by resistivity survey	Largest fresh water lens in Tarawa. Possibly develop up to 16 galleries for yield of 5 l/s on existing criteria. Possibly scope for greater yield.

TABLE 2 – CHEMICAL ANALYSES OF WATER SAMPLES

	Tanaia Rainwater	Teaoraereke No. 3 Gallery	Bonriki No. 3 Gallery	Abatao Well with windmill	Buota No. 4 Gallery	Buariki Camp Well	Bikenibeu Gallery	Buariki Bore 3 during pump test	Buariki Bore 5	Abatao Bore 7	Buota Bore 8	Buota Bore 9
Calcium	1.3	69	78	75	76	105	69	96	130	185	230	275
Magnesium	0.4	18	13.5	17.5	42	34	42	135	165	270	430	600
Sodium	2.5	7.6	6.2	10.5	17.5	62	105	820	1200	2200	3550	5200
Potassium	0.8	0.6	0.5	1.8	0.6	1.7	5.8	31	45	84	135	185
Bicarbonate	5	291	293	297	441	427	371	395	409	373	390	404
Sulphate	1	9	7	10	10	22	41	95	285	520	800	1350
Chloride	6	14	13	16	29	104	166	1554	2210	3988	6577	9355
Nitrate	<1	3	2	12	<1	<1	6	<1	<1	<1	<1	<1
Electrical Conductivity	55	508	524	561	799	1145	1249	5397	7719	12569	19563	26108
Total Dissolved Solids	23	280	280	290	390	550	660	3200	4350	7500	12000	17000
Total Hardness	5	246	250	259	363	402	345	795	1004	1573	2344	3156
Carbonate Hardness	4	238	240	244	361	350	304	324	335	306	320	331
Non-Carbonate Hardness	1	8	10	15	1	52	41	471	669	1267	3024	2824
Total Alkalinity	4	238	240	244	361	350	304	324	335	306	320	331
pH	6.2	7.8	7.9	7.7	8.2	8.0	8.1	7.6	7.4	7.7	7.9	7.6

Chemical analyses in mg/l; electrical conductivity in S/cm

Samples collected October 1980 and analysed by AMDEL, Adelaide, December 1980

APPENDIX 1

LOGS OF BORES 1-4

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS **GEOLOGICAL LOG OF BORE HOLE**	LOCATION OF BORE Bonriki 1:100 000 SHEET Tarawa Atoll Kiribati SHEET NO. _____ GRID REFERENCE __________	R.N. Bore 1 I.N. __________ PROJECT __________
DOWNHOLE LOGGING	DRILLING METHOD Rotary	DATE HOLE COMMENCED 15/9/80 DATE HOLE COMPLETED 19/9/80	JOB NUMBER

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
					Grey sand	
			15/9/80 ▽		Coral hardpan	Rock roller 75 mm Water used in drilling - some water loss Conductivity of surface water 380 µS/cm
No Core 5 m					Medium-fine coral sand, off white-yellow, well sorted. Includes cobbles of cemented sand.	5·65 – 6·30 Piezometer test k = 36 m/d
10 %					Pieces of coral to 5 cm light green and white.	NmLc ↓
10 m 45 %					80 cm core recovered Coral reef (in situ material) Core losses due to large voids.	
		Water table aquifer				11·5 – 12·20 Piezometer test k = 131 m/d
15 %					Fragments of coral to 5 cm	More than half drilling water lost
100 % 15 m					Coral reef; off white to cream; highly porous material with cellular structure. To 14·9 m material fragmented; below 14·9 m one piece	
50 %					Coral reef material; mostly fragmented	
60 %					Coral limestone - soft rock, fragmented	
60 %					Coral limestone - off white to yellow. Friable soft rock - core mostly broken	
80 % 20 m					19·4 m — — — — Unconformity — — — — — — Limestone (lime mudstone) with shells etched out	

DRILLER P. Murphy, B. Turner, C.I.R.L.
DRILL TYPE Jacro
LOGGED BY G. Jacobson
Record 1981/31

PROJECT Tarawa Groundwater Invest.
BMR HOLE NUMBER __________
SHEET 1 OF 2
DRAWING NUMBER 16/09/37

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Bonriki

1:100000 SHEET Tarawa Atoll
Kiribati

SHEET NO. ____ GRID REFERENCE ________

R.N Bore 1

I.N. ________

PROJECT ________

DOWNHOLE LOGGING

DRILLING METHOD Rotary

DATE HOLE COMMENCED ________

DATE HOLE COMPLETED ________

JOB NUMBER

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
20 m						
50 %					Limestone - lime mudstone with shell and coral fragments etched out.	17·0 - 24·6 m drilled with hydropol
33 %					"	
60 %					"	

End of hole 24·6 m
Hole equipped with 63 mm I.D. slotted plastic casing
After drilling conductivity of water was
1400 µS/cm from 3 - 21 m

Conductivity of bore water 5/10/80
900 µS/cm at 3m
1150 " 12 m
1450 " 18 m

Ground level 12·383 m referred to Betio Base Datum (10 m)

Laboratory tests on core samples

Depth (m)	Effective porosity (%)	Permeability (md) V	Permeability (md) H
11·50	47	1550	2930
15·20	65	1	< 1
19·50	40	5460	9460
24·50	37	2800	2080

DRILLER ________

DRILL TYPE ________

LOGGED BY ________

PROJECT Tarawa Groundwater Invest.

BMR HOLE NUMBER ________

SHEET 2 OF 2

DRAWING NUMBER 16/09/37

Record 1981/31

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Bonriki

1:100000 SHEET Tarawa Attoll Kiribati

SHEET NO. _____ GRID REFERENCE __________

R N Bore 2

I. N __________

PROJECT __________

DOWNHOLE LOGGING

DRILLING METHOD Rotary

DATE HOLE COMMENCED 22/9/80

DATE HOLE COMPLETED 24/9/80

JOB NUMBER

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc*
				26/9/80 ▽	Off white - grey gravelly sand with coral fragments to boulder size	
100 %					Coral gravel; pebble to boulder size.	NmLc, hydropol
50 %					coarse sand to cobble gravel	"
5 m					No core -mainly sand	Rockroller
					Fine sand with coral fragments	Drive sample
0 % 10 m					No core -loose sand, white	NmLc using hydropol
100 %		Water table aquifer			coral reef; fragments to 15 cm pieces open, porous, off white - cream	hydropol, good circulation
20 %					fragments of coral, -harder, denser, greenish grey	
					unconformity	
40 %					coral limestone; off white, dense, some broken core	
15 m 0					No core; sand	
80 %					Loosely cemented limestone (calcarenite).	
60 %					soft white limestone (lime mudstone with shell and coral fragments) -friable rock.	

DRILLER P. Murphy, B Turner, C. I. R. L.

DRILL TYPE Jacro

LOGGED BY G. Jacobson

Record 1981/31

PROJECT Tarawa Groundwater Invest.

BMR HOLE NUMBER __________

SHEET 1 OF 2

DRAWING NUMBER 16/09/38

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Bonriki	R.N. Bore 2	
1:100000 SHEET Tarawa Atoll Kiribati	I.N.	
SHEET NO.	GRID REFERENCE	PROJECT
DOWNHOLE LOGGING	DRILLING METHOD Rotary	DATE HOLE COMMENCED 22/9/80
		DATE HOLE COMPLETED 24/9/80
JOB NUMBER		

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
20 m						
60 %					Limestone - soft, white, friable, limestone	NmLc, hydropol
45 %					Limestone - soft, white, friable, poorly cemented lime mudstone with shell and coral fragments. Broken core.	"
35 %					Limestone - soft, white, slightly better cemented. Broken core	"
15 %					Limestone - very soft lime mudstone - ground up fragments only recovered	"
25 m						

End of hole 25·25 m
Hole equipped with 63 mm I.D. slotted plastic casing.

Conductivity of bore water 5/10/80

1600 µS/cm	at	3 m
1700 "	"	12 m
2200 "	"	20 m

Ground level 12·643 m refered to Betio Base Datum (10 m)

DRILLER	PROJECT Tarawa Groundwater Invest.
DRILL TYPE	BMR HOLE NUMBER
LOGGED BY	SHEET 2 OF 2
Record 1981/31	DRAWING NUMBER 16/09/38

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Buariki		R.N. Bore 3
1:100000 SHEET Tarawa Atoll Kiribati		I.N.
SHEET NO.	GRID REFERENCE	PROJECT

DOWNHOLE LOGGING	DRILLING METHOD	DATE HOLE COMMENCED / COMPLETED	JOB NUMBER
	Rotary	DATE HOLE COMMENCED 28/9/80 DATE HOLE COMPLETED 2/10/80	

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS / YIELD / S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
15 %		2/10/80 ▽	coral conglomerate and sand	N m L c water used 0-6 m Elec. cond'y surface water 525 µS/cm
0 %		▽	No core - sand with coral boulders	Ran casing down without coring
5 m			No core - mainly sand	N m L c
			white sand with shells and coral pebbles	drive sample
20 %			Sand and coral fragments (coral fragments only recovered)	permeability test k = 77 m/d N m L c hydropol used below 6 m
10 m			coral fragments	
40 %		Water table aquifer	coral reef - open, porous, cream	
15 %			coral reef - fragments only recovered; med-fine sand beds, uncemented, not recovered	N m L c
15 m 20 %			coral reef - off white, denser, less porous.	
60 %			coral reef unconformity off white limestone - friable calcarenite with shell and coral fragments to 3cm.	
100 %			white limestone - friable calcarenite with coral fragments to 15 cm	

DRILLER P. Murphy, B. Turner
DRILL TYPE Jacro 500
LOGGED BY G. Jacobson

PROJECT Tarawa Groundwater Invest.
BMR HOLE NUMBER
SHEET 1 OF 2
DRAWING NUMBER 16/09/39

Record 1981/31

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Buariki

1:100 000 SHEET Tarawa Atoll Kiribati

SHEET NO. ____ GRID REFERENCE ____

R.N. Bore 3

I.N. ____

PROJECT ____

DOWNHOLE LOGGING

DRILLING METHOD

DATE HOLE COMMENCED ____

DATE HOLE COMPLETED ____

JOB NUMBER

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
20 m						
					white limestone; soft, friable calcarenite	NmLc, hydropol
75 %					" " includes coral fragments to 5 cm	
33 %					white limestone; soft friable calcarenite	
					white limestone; moderately hard calcarenite	
100 %					white limestone; soft friable to mod. hard calcarenite with shells and coral fragments	
90 % 25 m					white limestone; moderately hard but friable rock. More than 50 % shell and coral fragments up to several cm in sandy cemented matrix.	
35 %					white limestone; mod. hard calcarenite; broken core. Shells etched out by solution.	
20 %					white limestone; hard calcarenite fragments recovered. Softer material not cored.	
60 %					white limestone; hard calcarenite with coral fragments to several cm. Shells etched out by solution.	
30 m						

Hole cased with slotted P.V.C. pipe 63mm diam. and gravel packed. Hydropol dispersed with P.B.D.

Conductivity of bore water 3/10/80
1700 μS/cm at 5m
2100 28m

Pump test 9/10/80 using 4 observation piezometers up to 10m from pumped bore. Transmissivity T = 5120 m^2/d.

Top of casing R.L. 3·865 m referred to bench mark in Mexico Bay (Datum 3·000m). Ground level 3·405 m.

Laboratory tests on core samples

Depth (m)	Effective porosity (%)	Permeability (md) V	Permeability (md) H
10·50	62	385	< 1
19·70	47	6650	5360
24·00	45	9720	11180
24·40	49	8670	11640

DRILLER ____

DRILL TYPE ____

LOGGED BY ____

Record 1981/31

PROJECT Tarawa Groundwater Invest.

BMR HOLE NUMBER ____

SHEET 2 OF 2

DRAWING NUMBER 16/09/39

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF BORE HOLE

LOCATION OF BORE Buariki	R.N Bore 4	
1:100000 SHEET Tarawa Atoll Kiribati	I.N.	
SHEET NO. GRID REFERENCE	PROJECT	
DOWNHOLE LOGGING	DRILLING METHOD Rotary	DATE HOLE COMMENCED 8/10/80
		DATE HOLE COMPLETED
JOB NUMBER		

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
No core					Coral sand - medium grained, some gravel.	NmLc, hydropol
15 % 5 m					Coral sand, some gravel pieces of gravel recovered.	
No core					Coral sand, some gravel.	
30 % 10 m					Coral gravel, some sand, - bedded; pieces of gravel recovered.	
30 %					Coral gravel, some sand.	
80 %					Coral reef - cream, open, porous.	
25 %					Sand in section not recovered Limestone - white, moderately hard calcarenite with shells and coral fragments to several cm (conglomerate platform ?) Fossils include cowries and biscult urchin.	Lost mud circulation and hard to thicken mix.
15 m 12 %					Limestone - white, weakly cemented calcarenite. Fragments only recovered. - missing section probably sand.	
70 %					Limestone - soft to moderately hard but friable with shells and coral fragments. Some voids from solution of shells.	
					Limestone - hard and soft bands calcarenite with shelly fossils etched out.	

DRILLER P. Murphy, B. Turner, C.I.R.L.
DRILL TYPE Jacro 500
LOGGED BY G. Jacobson
Record 1981/31

PROJECT Tarawa Water Supply
BMR HOLE NUMBER
SHEET 1 OF 2
DRAWING NUMBER 16/09/40

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS **GEOLOGICAL LOG OF BORE HOLE**	LOCATION OF BORE Buariki 1:100000 SHEET Tarawa Atoll Kiribati SHEET NO. ____ GRID REFERENCE ____	R.N Bore 4 I.N. ____ PROJECT ____
DOWNHOLE LOGGING | DRILLING METHOD	DATE HOLE COMMENCED ____ DATE HOLE COMPLETED ____	JOB NUMBER

DEPTH (m) LIFT AND CORE RECOVERY	GRAPHIC LOG	AQUIFERS	YIELD	S.W.L.	SUBSTANCE DESCRIPTION *Type of material: grain characteristics, colour, structure, minor components*	ADDITIONAL INFORMATION *Drilling rate, water loss, mud circulation, drilling problems etc.*
20 m						
50 %					Limestone - cream, generally soft and friable. Half the rock consists of shells and coral fragments, in a sandy matrix. Shells etched out by solution.	N m L c, hydropol, tungsten bit.
100 %					Limestone - cream, soft friable rock consisting of 50% sand and silt. Some solution etching	
100 % 25 m					Limestone - cream, soft, friable rock consisting of 50% sand and silt.	
30 m						
31 m					Completed at 31m on 11/10/80 and equipped with slotted P.V.C. casing. Top of casing R.L. 3·370m referred to bench mark in Mexico Bay (datum 3·000 m) Ground level 3·370m.	

DRILLER ____
DRILL TYPE ____
LOGGED BY ____

PROJECT ____
BMR HOLE NUMBER ____
SHEET 2 OF 2
DRAWING NUMBER 16/09/40

APPENDIX 2

Technical note on the SAS 300 Terrameter system

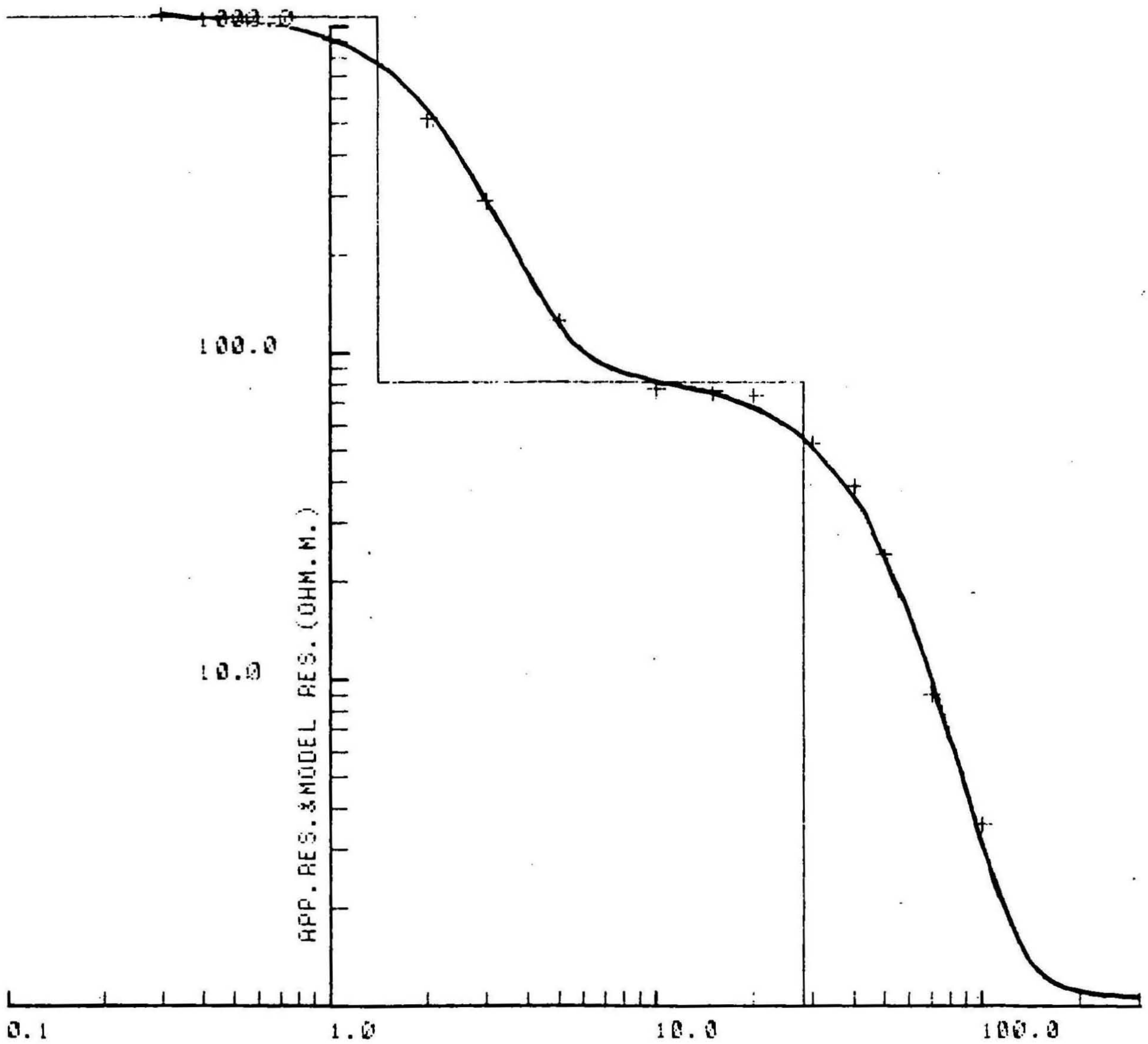
This instrument has a number of internal checks which assist in avoiding errors during field measurements. However, there is no check on whether the potential measuring circuit is correct and not open circuit or intermittent. Since the system is a stacking one in which successive measurements are averaged, any intermittent circuitry leading to false potential measurements will not be obvious to the operator. Hence it is important that the potential leads and electrodes be of high quality. It is suggested that brass electrodes (6 mm) be used and that the leads be bolted to the electrodes using brass bolts and washers. These leads and electrodes should be checked for continuity at least once per day.

APPENDIX 3

RESISTIVITY FIELD DATA AND INTERPRETED MODEL CURVES

Nos 2, 4-26, 28-47

TARAWA PROBE 2 , BUARIKI NO 4 BORE

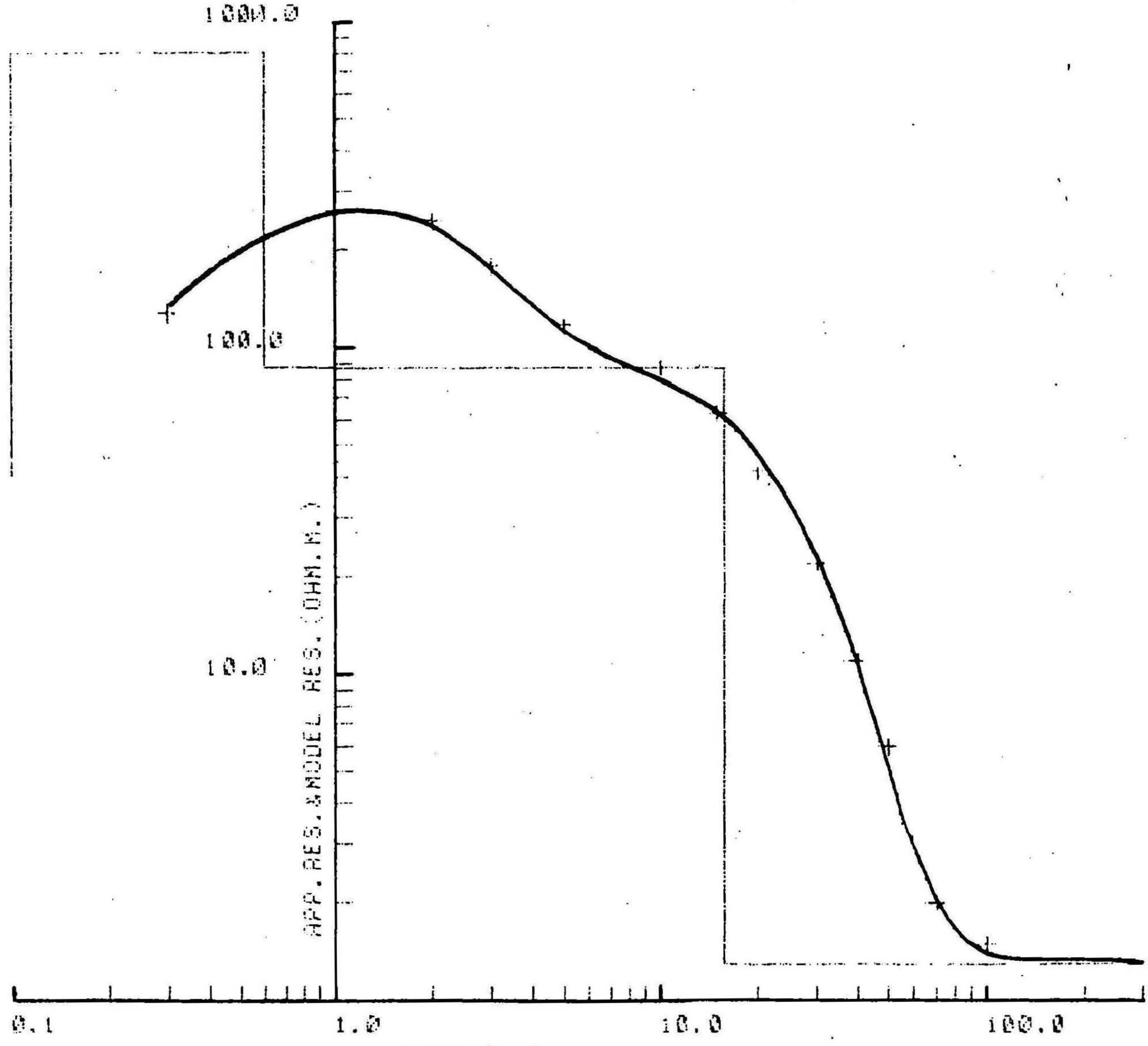


LAYER NO.	RESISTIVITY	THICKNESS
1	1070.0	1.4
2	81.0	27.0
3	1.0	

Record 1981/31

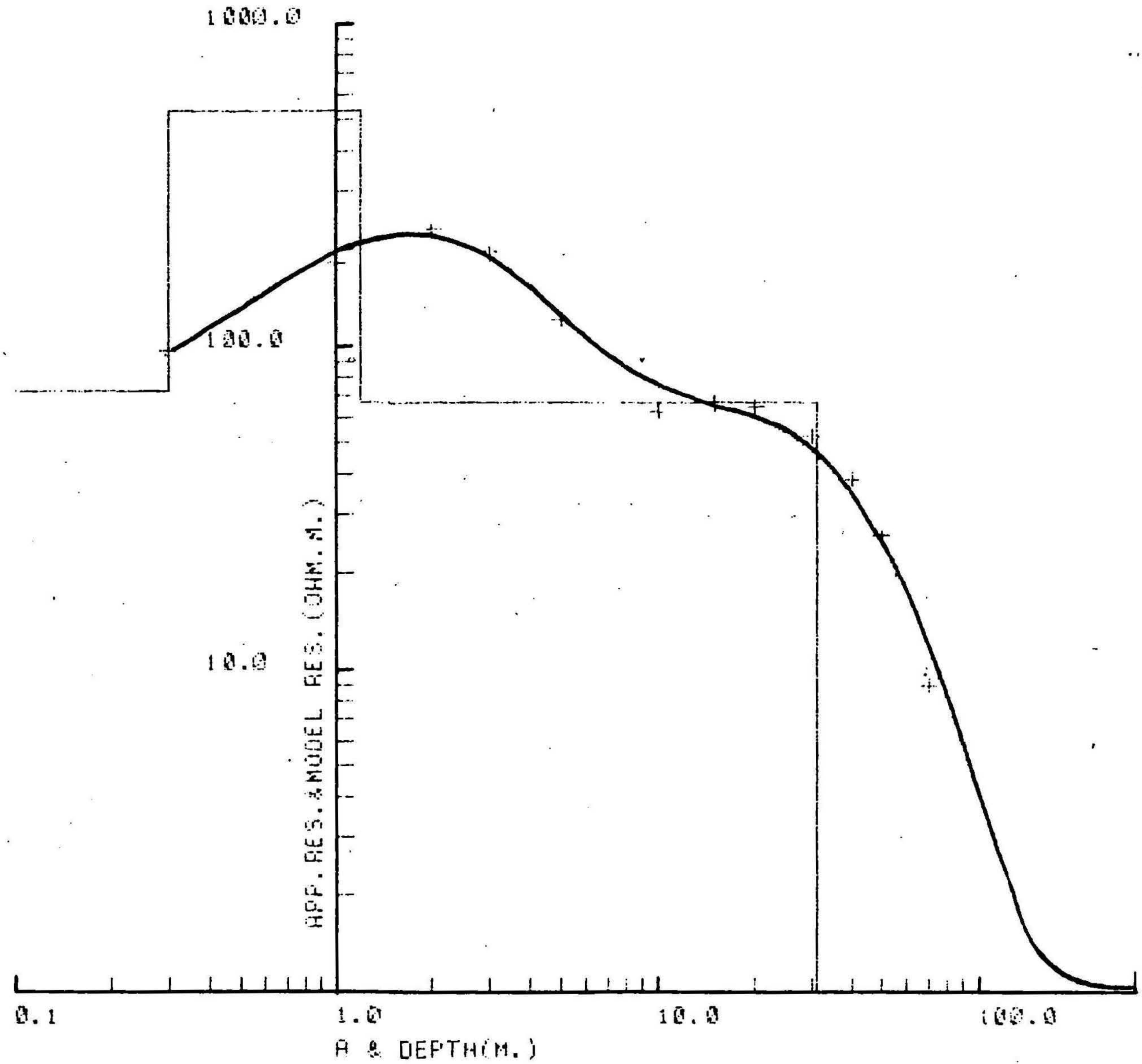
19/09/11

TARAWA PAORE + BUARIKI OFF NO 5



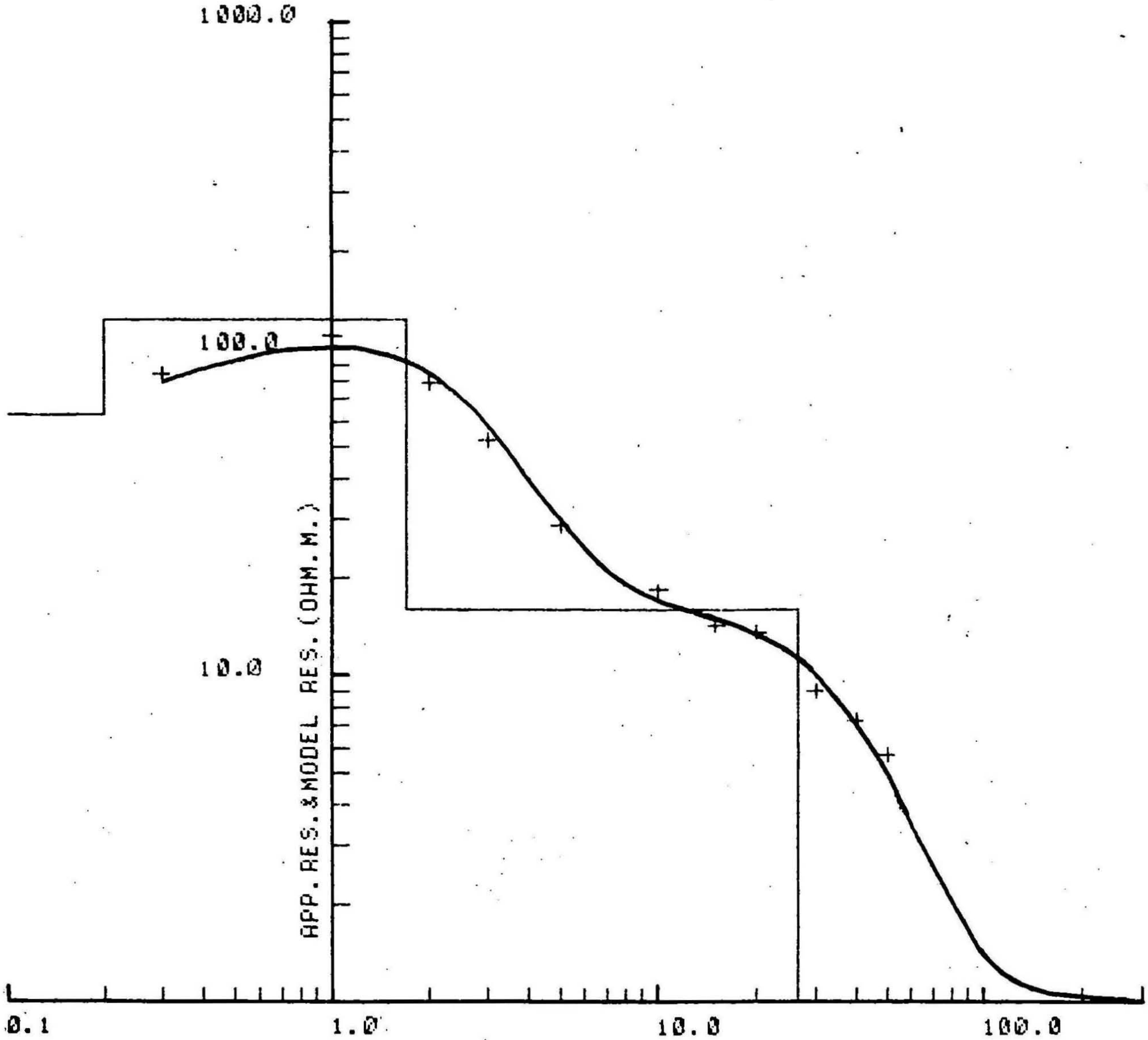
LAYER NO.	RESISTIVITY	THICKNESS
1	40.0	0.1
2	800.0	0.5
3	86.0	15.0
4	1.3	

TARAWA PROBE 5 NO 3 BOREHOLE BUARIKI



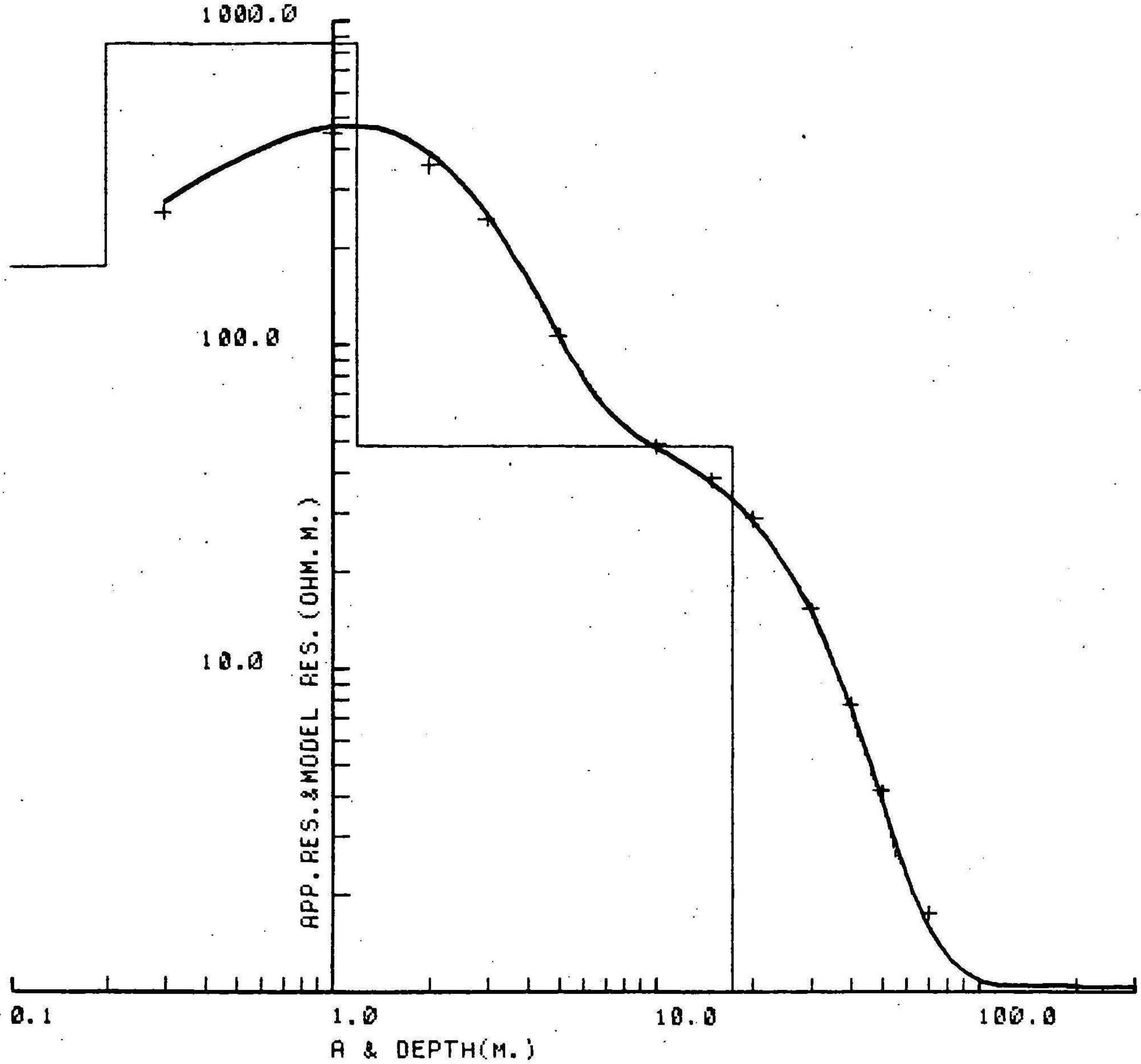
LAYER NO.	RESISTIVITY	THICKNESS
1	73.0	0.3
2	540.0	0.9
3	67.0	50.0
4	1.0	

TARAWA PROBES, BETIO BT 1



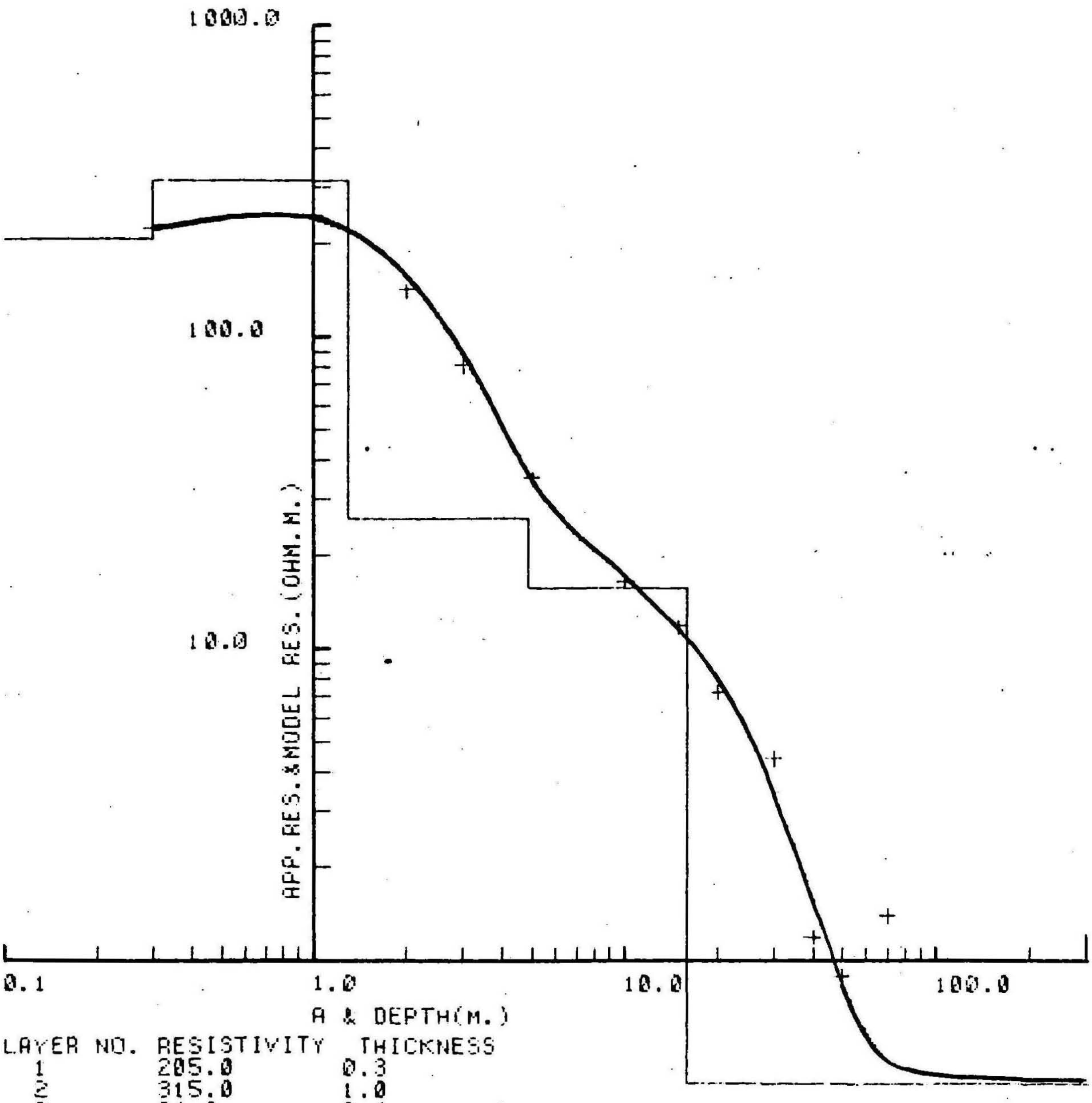
LAYER NO.	RESISTIVITY	THICKNESS
1	63.0	0.2
2	124.0	1.5
3	16.0	25.0
4	1.0	

TARAWA PROBE 7 BT 2 BETIO



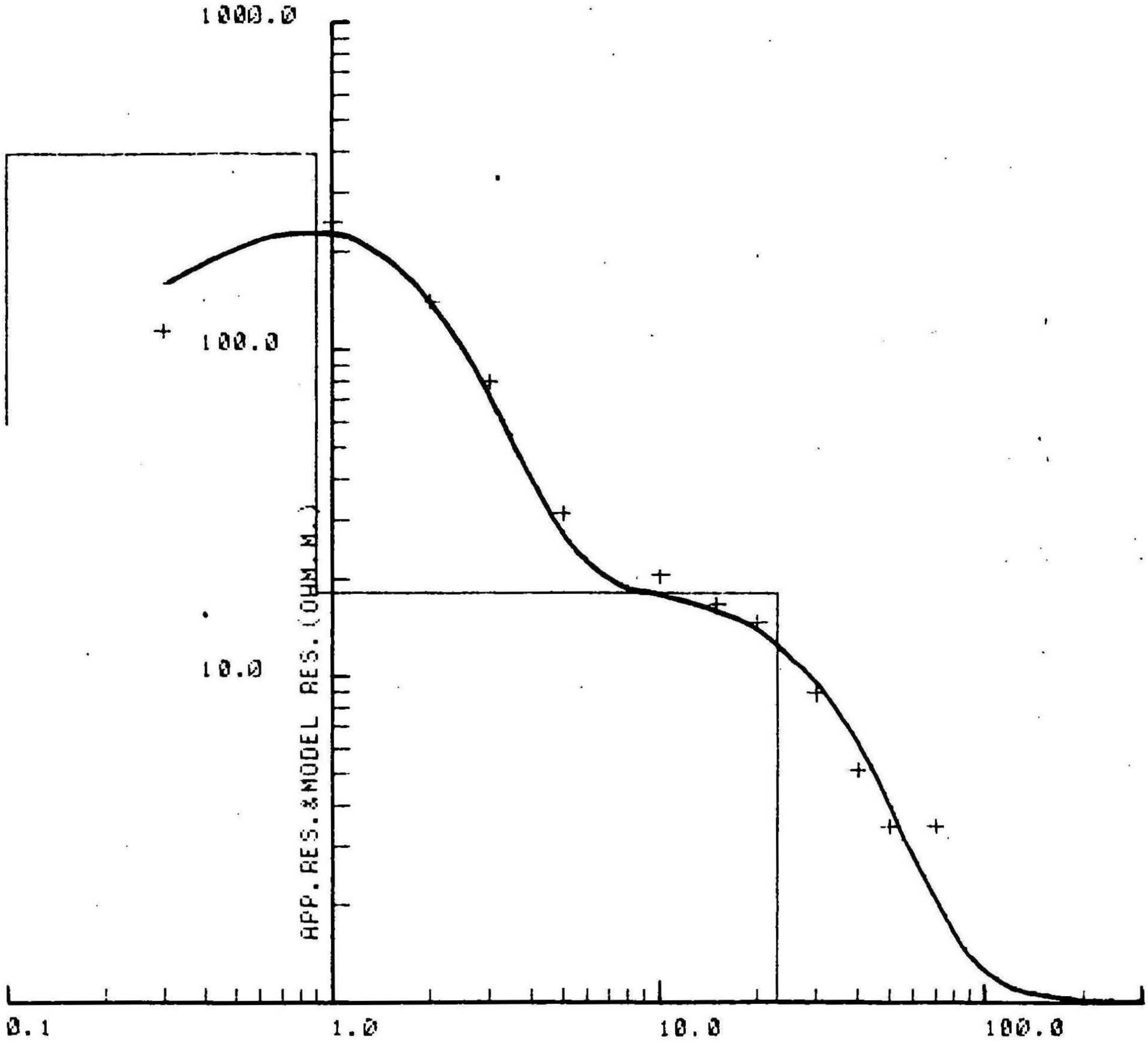
LAYER NO.	RESISTIVITY	THICKNESS
1	175.0	0.2
2	850.0	1.0
3	49.0	16.0
4	1.0	

TARAWA PROBE 8 BETIO



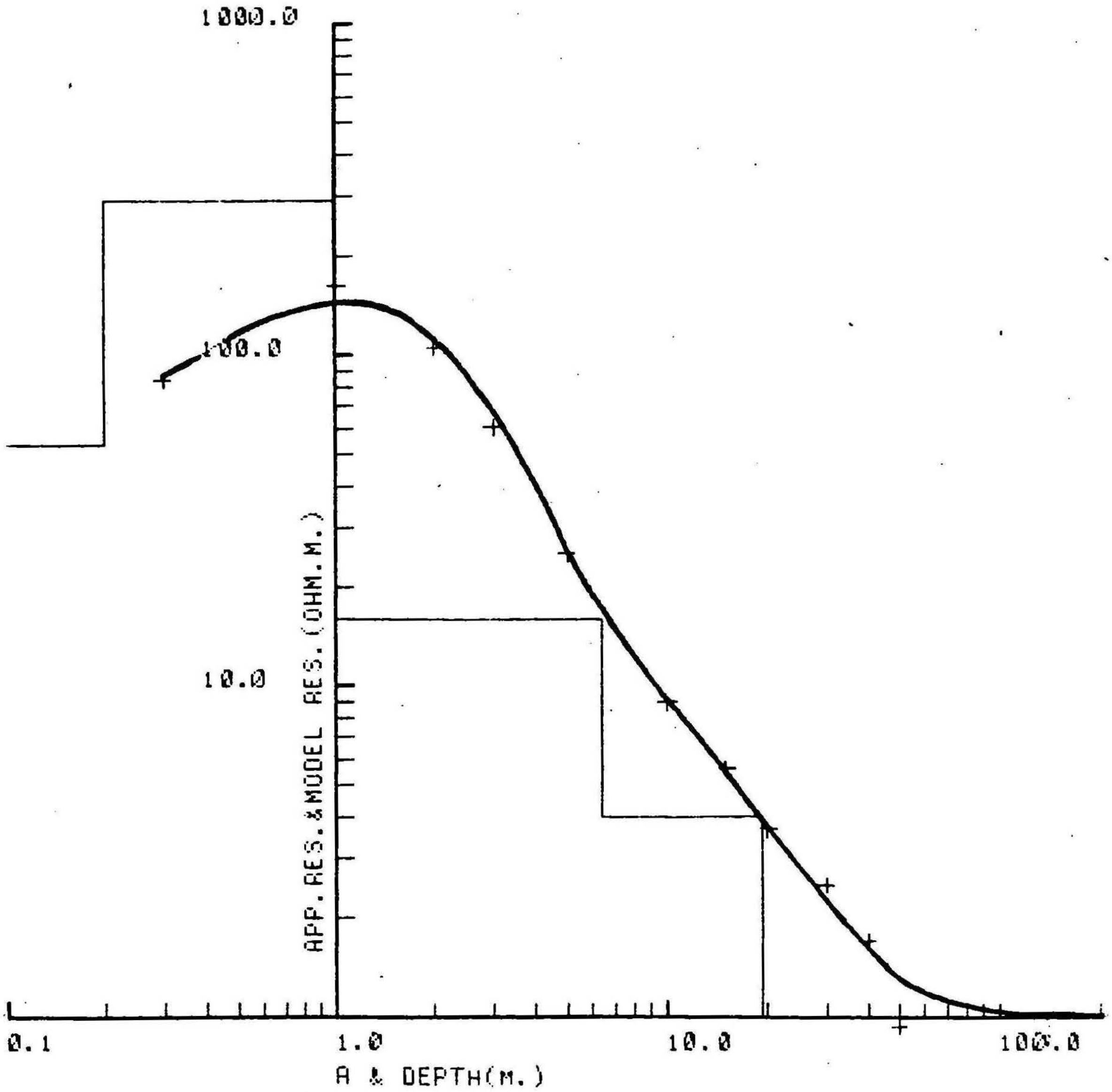
LAYER NO.	RESISTIVITY	THICKNESS
1	205.0	0.3
2	315.0	1.0
3	26.0	3.6
4	15.6	11.0
5	0.4	

TARAWA PROBE 9 BT 4 BETIO



LAYER NO.	RESISTIVITY	THICKNESS
1	59.0	0.1
2	396.0	0.8
3	18.0	22.0
4	1.0	

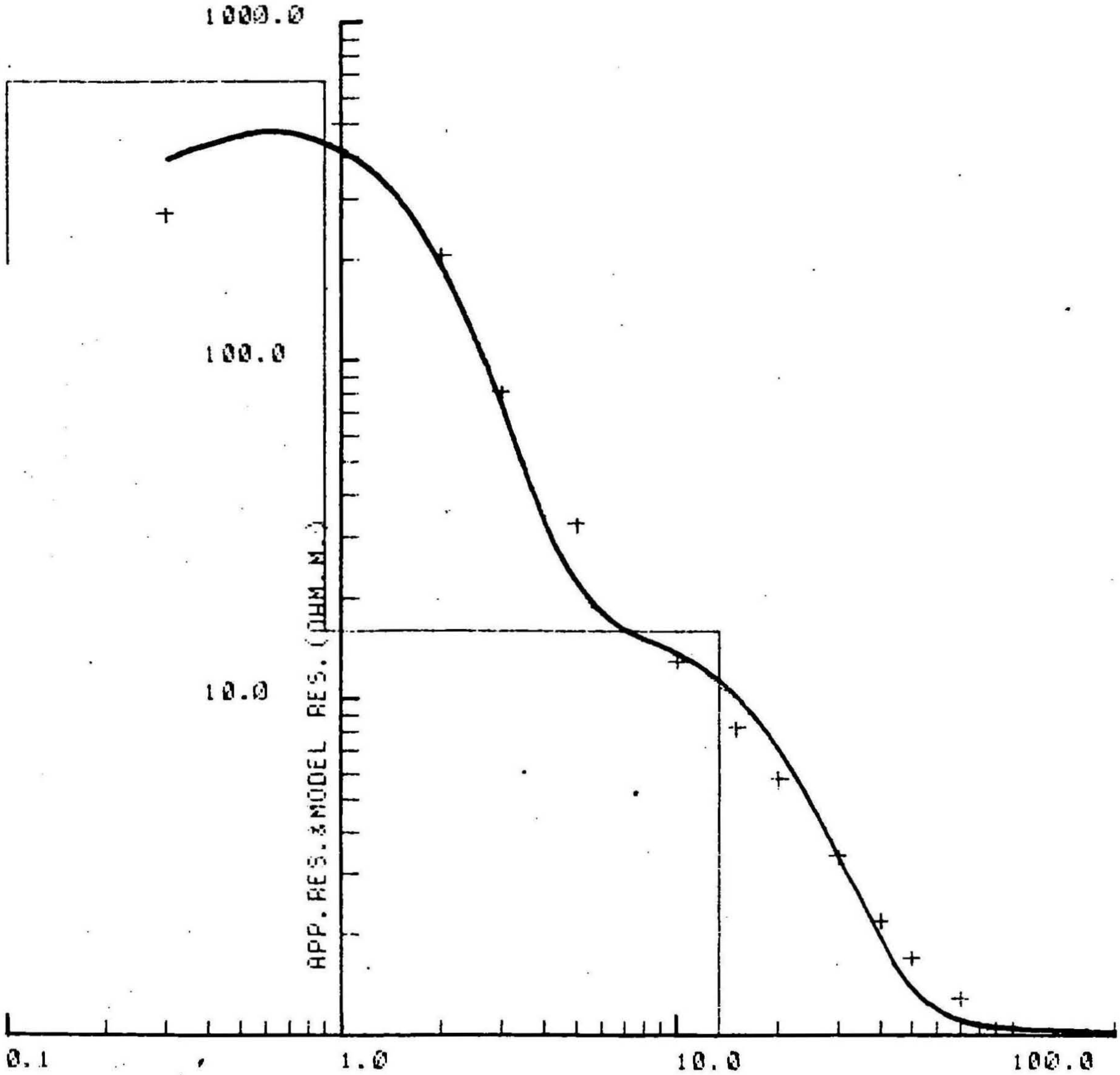
TARAWA PROBE 10 BT 5 BETIO



LAYER NO.	RESISTIVITY	THICKNESS
1	54.0	0.2
2	290.0	0.8
3	16.0	5.4
4	4.0	13.0
5	1.0	

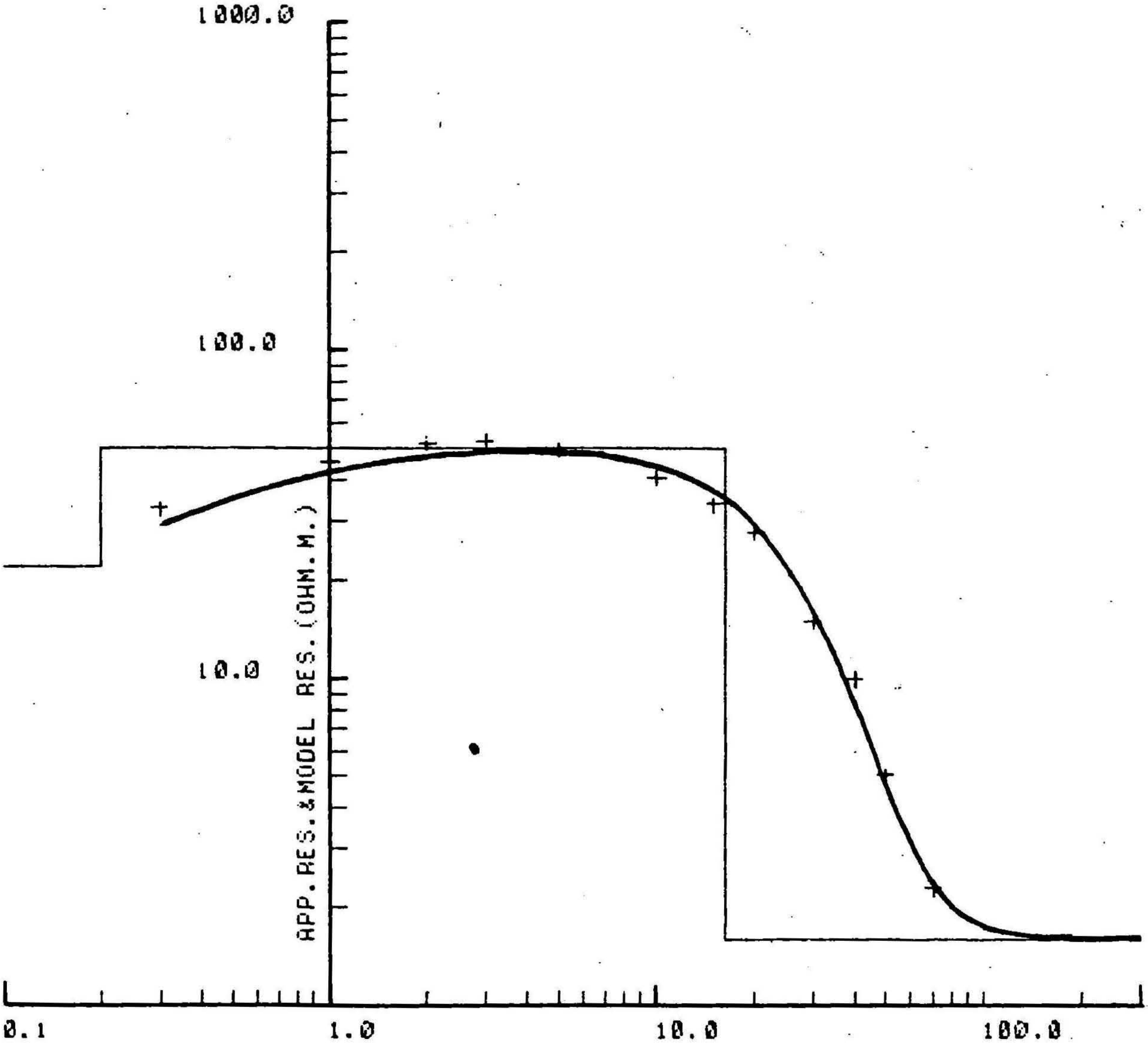
19/09/18

TARAWA PROBE 11 BU 1 BUOTA



LAYER NO.	RESISTIVITY	THICKNESS
1	193.0	0.1
2	670.0	0.8
3	16.0	12.5
4	1.0	

TARAWA PROBE 12 BU2 BUOTA

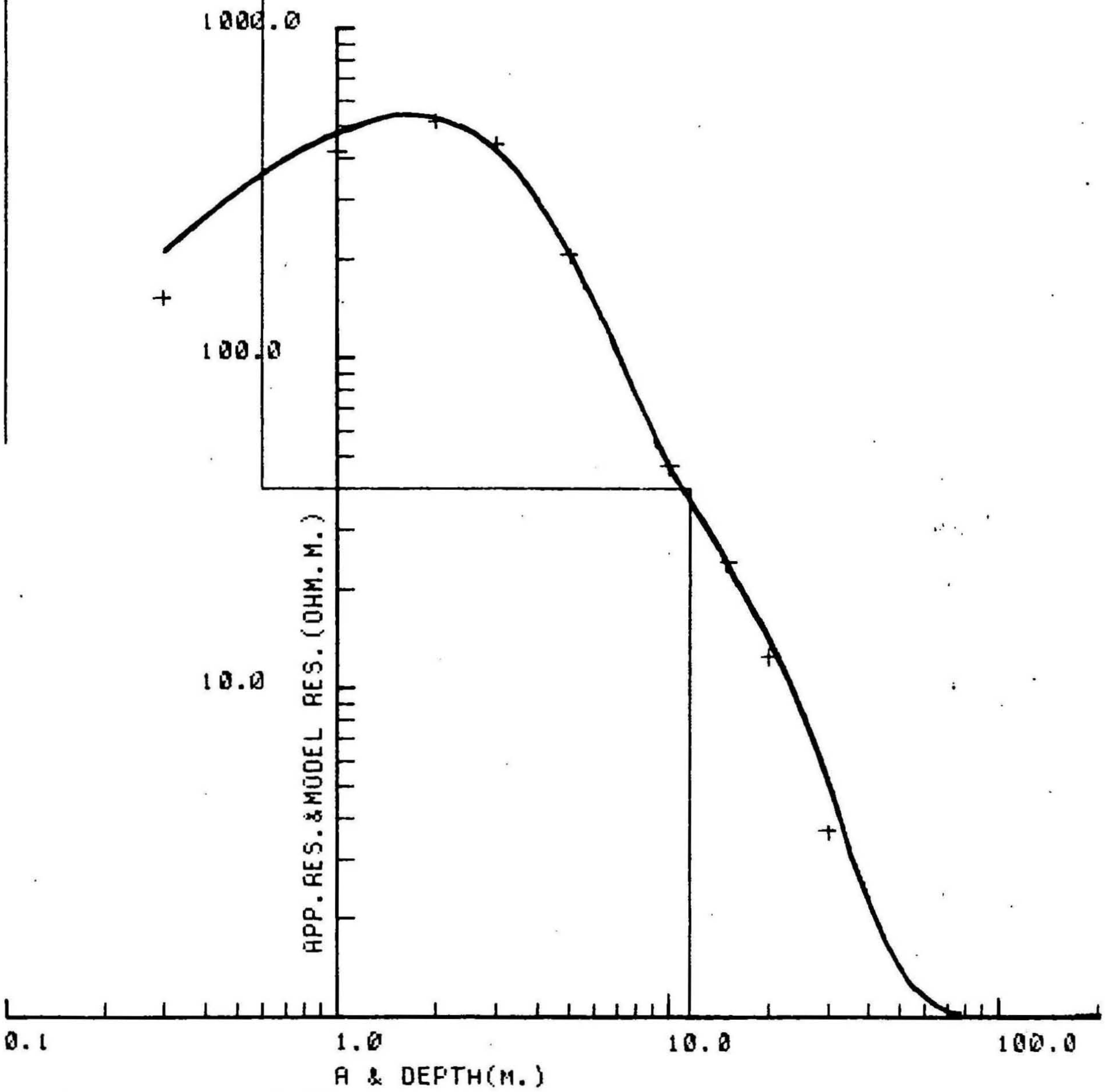


LAYER NO.	RESISTIVITY	THICKNESS
1	22.0	0.2
2	50.0	16.0
3	1.6	

Record 1981/31

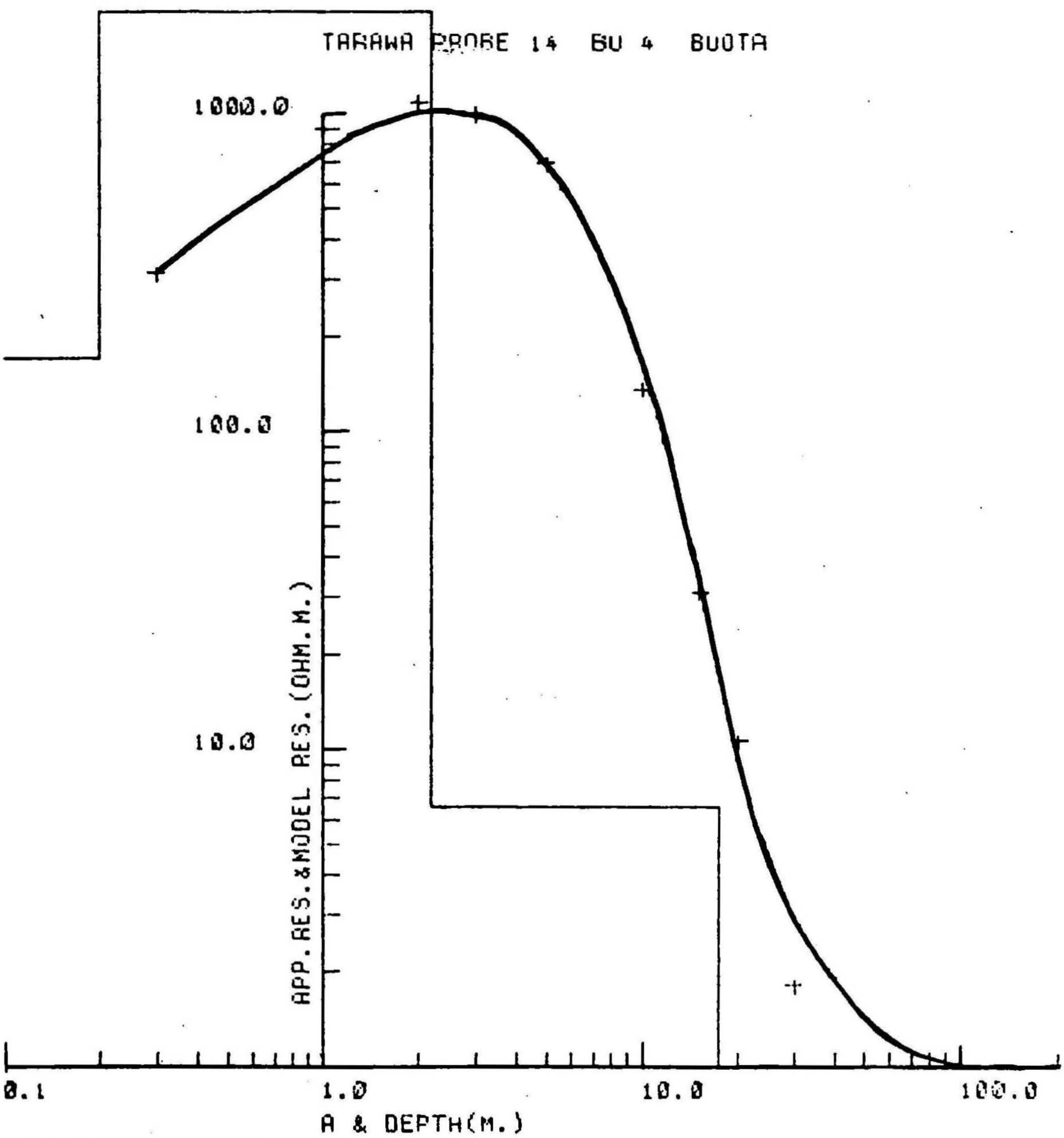
19/09/20

TARAWA PROBE 13 BU 3 BUOTA



LAYER NO.	RESISTIVITY	THICKNESS
1	55.0	0.1
2	2800.0	0.5
3	40.0	11.0
4	1.0	

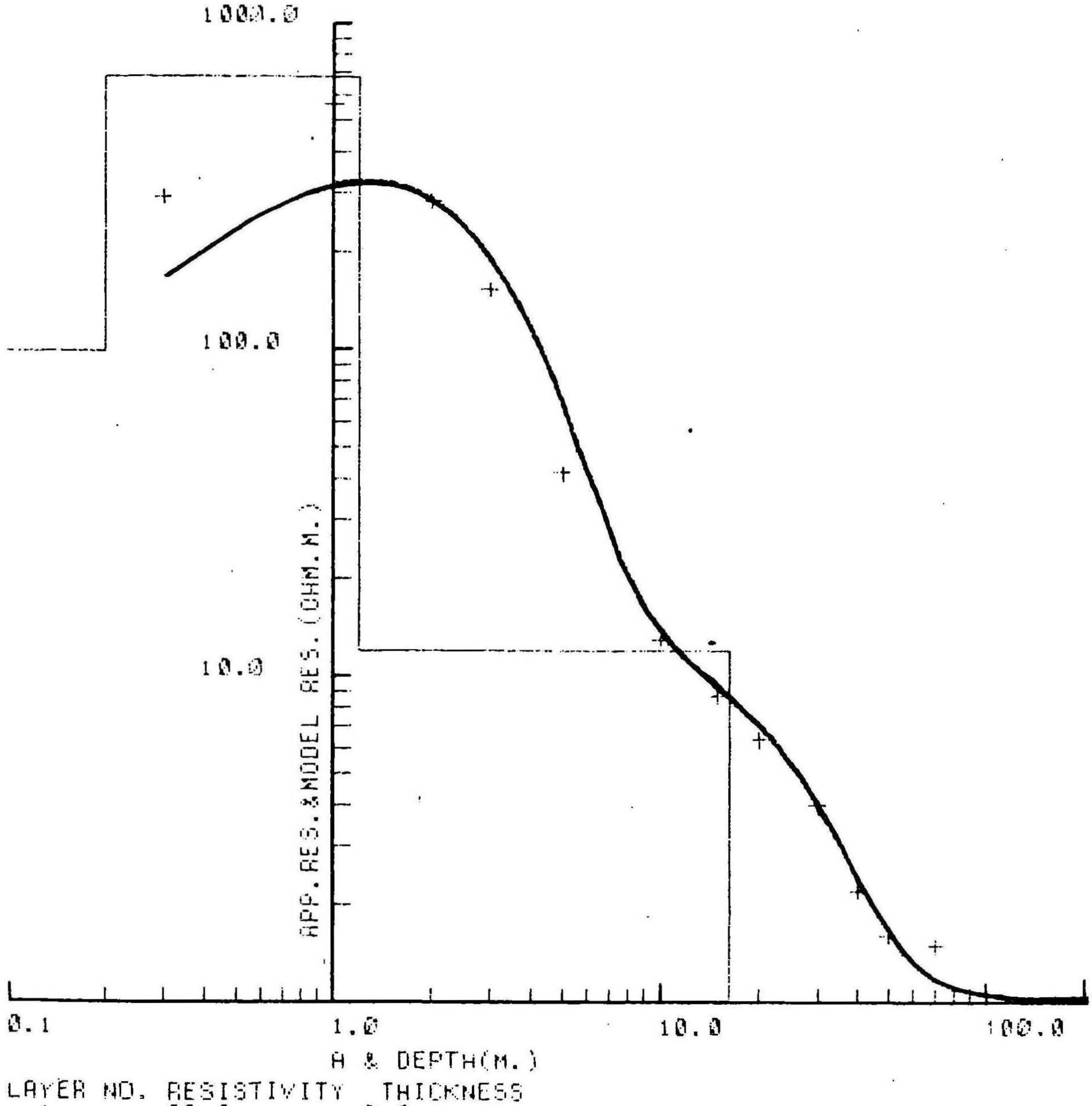
19/09/21



LAYER NO.	RESISTIVITY	THICKNESS
1	170.0	0.2
2	2100.0	2.0
3	6.6	15.0
4	1.0	

19/09/22

TARAWA PROBE 15 BO 5 BUOTA

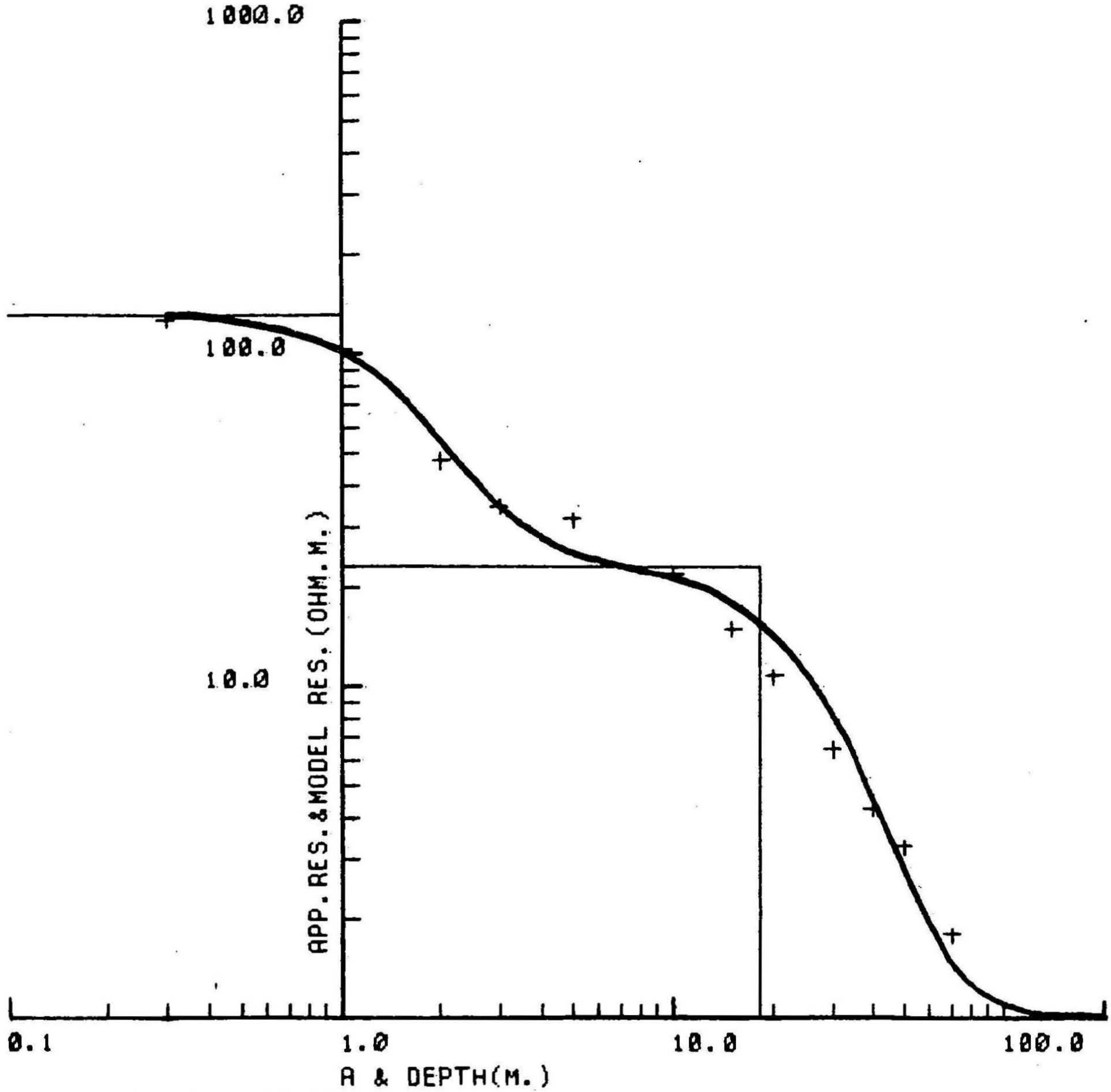


LAYER NO.	RESISTIVITY	THICKNESS
1	99.0	0.2
2	680.0	1.0
3	12.0	15.0
4	1.0	

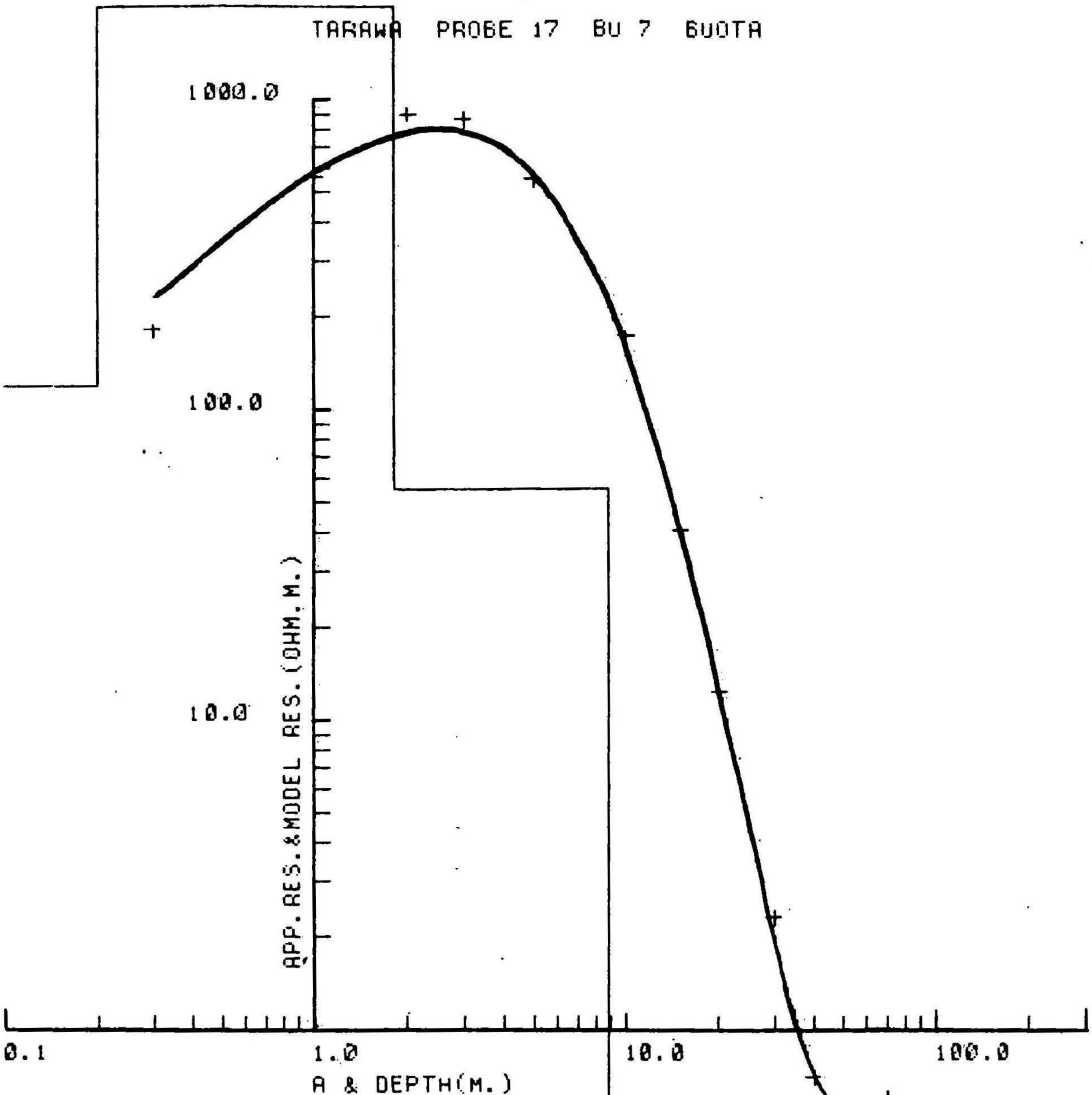
Record 1981/31

19/09/23

TARAWA PROBE 16 BU 6 BUOTA



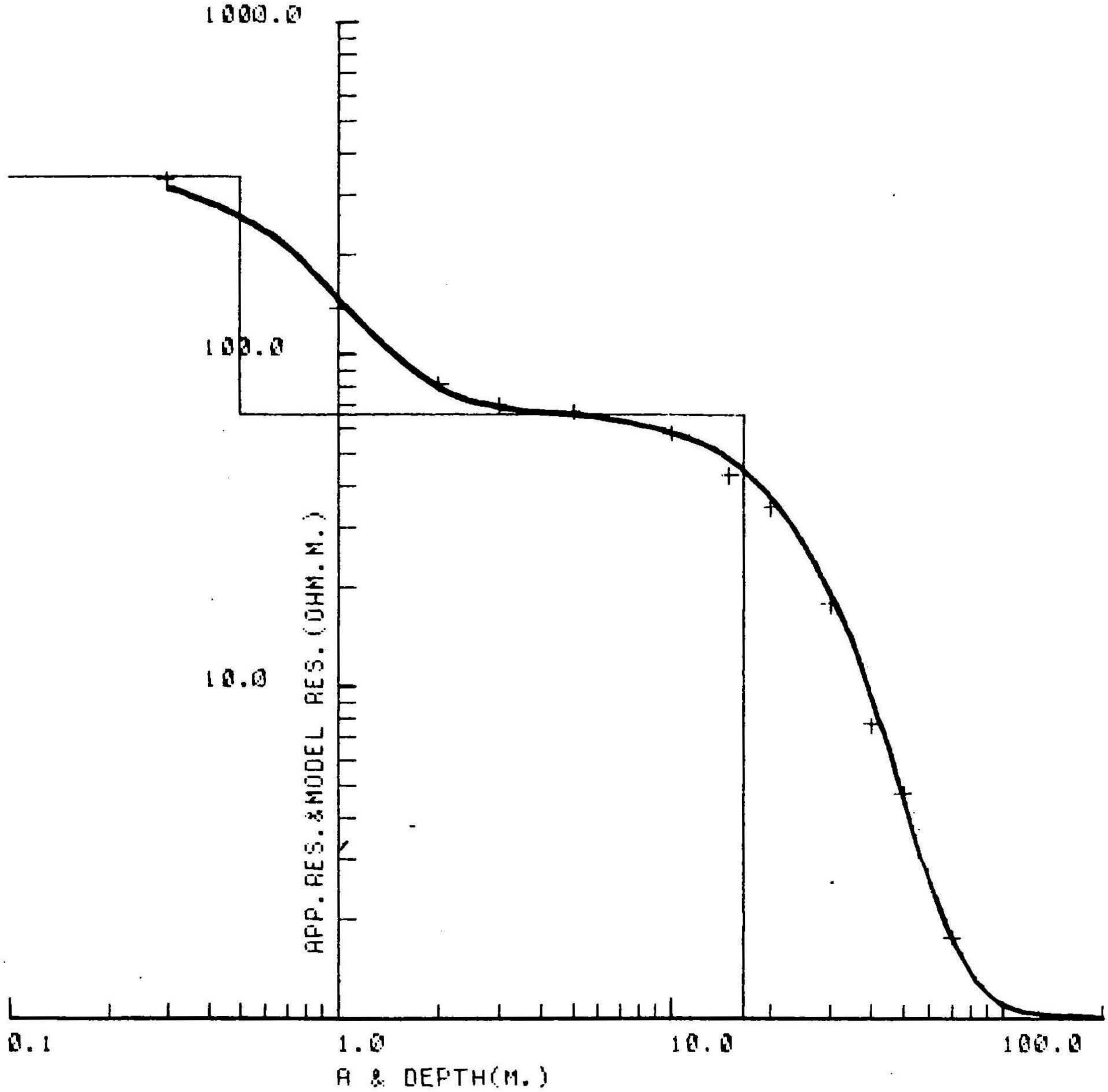
LAYER NO.	RESISTIVITY	THICKNESS
1	132.0	1.0
2	23.0	17.0
3	1.0	



LAYER NO.	RESISTIVITY	THICKNESS
1	120.0	0.2
2	2000.0	1.6
3	55.0	7.0
4	0.5	

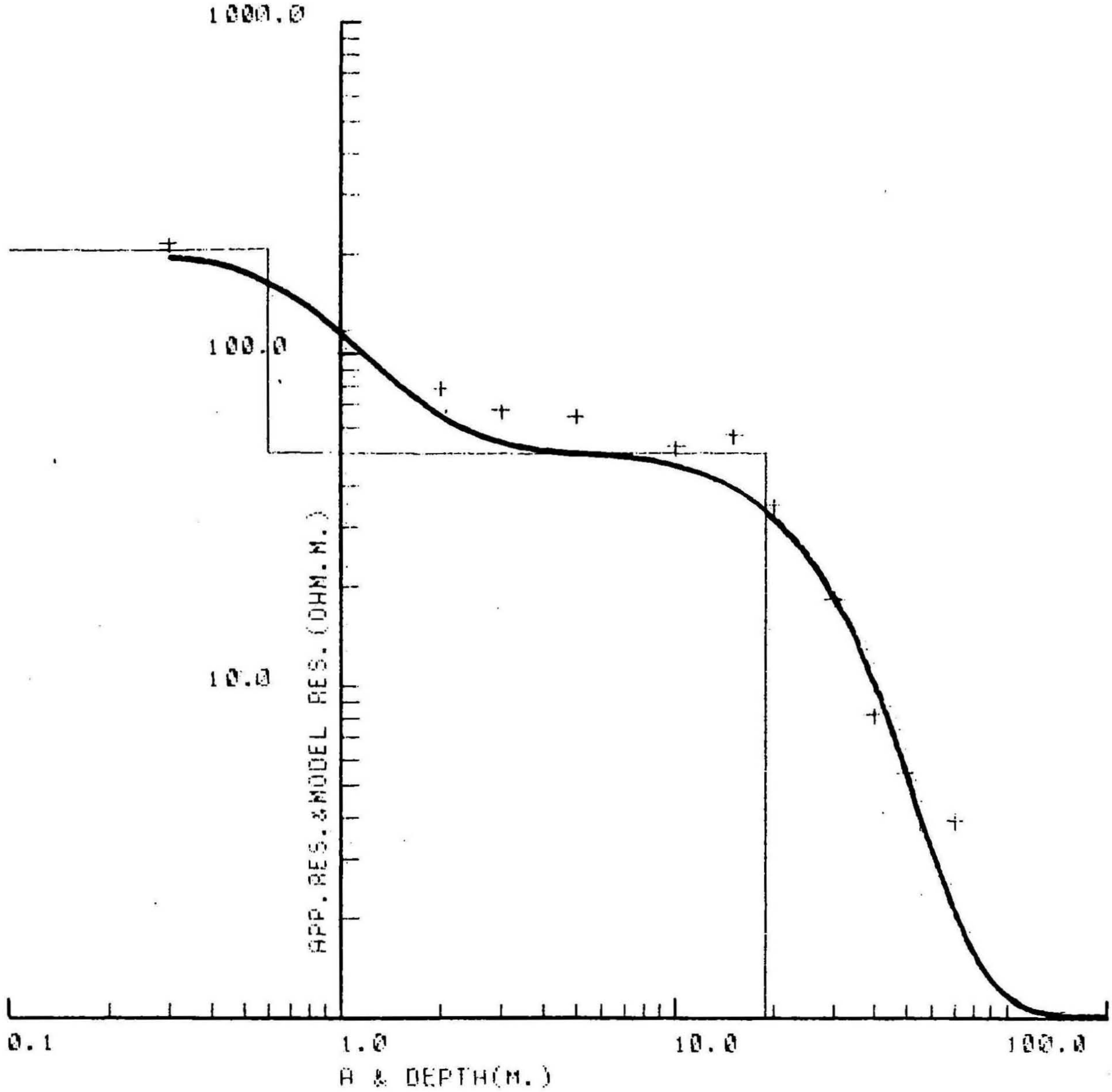
19/09/25

TARAWA PROBE 18 A 1 BONRIKI



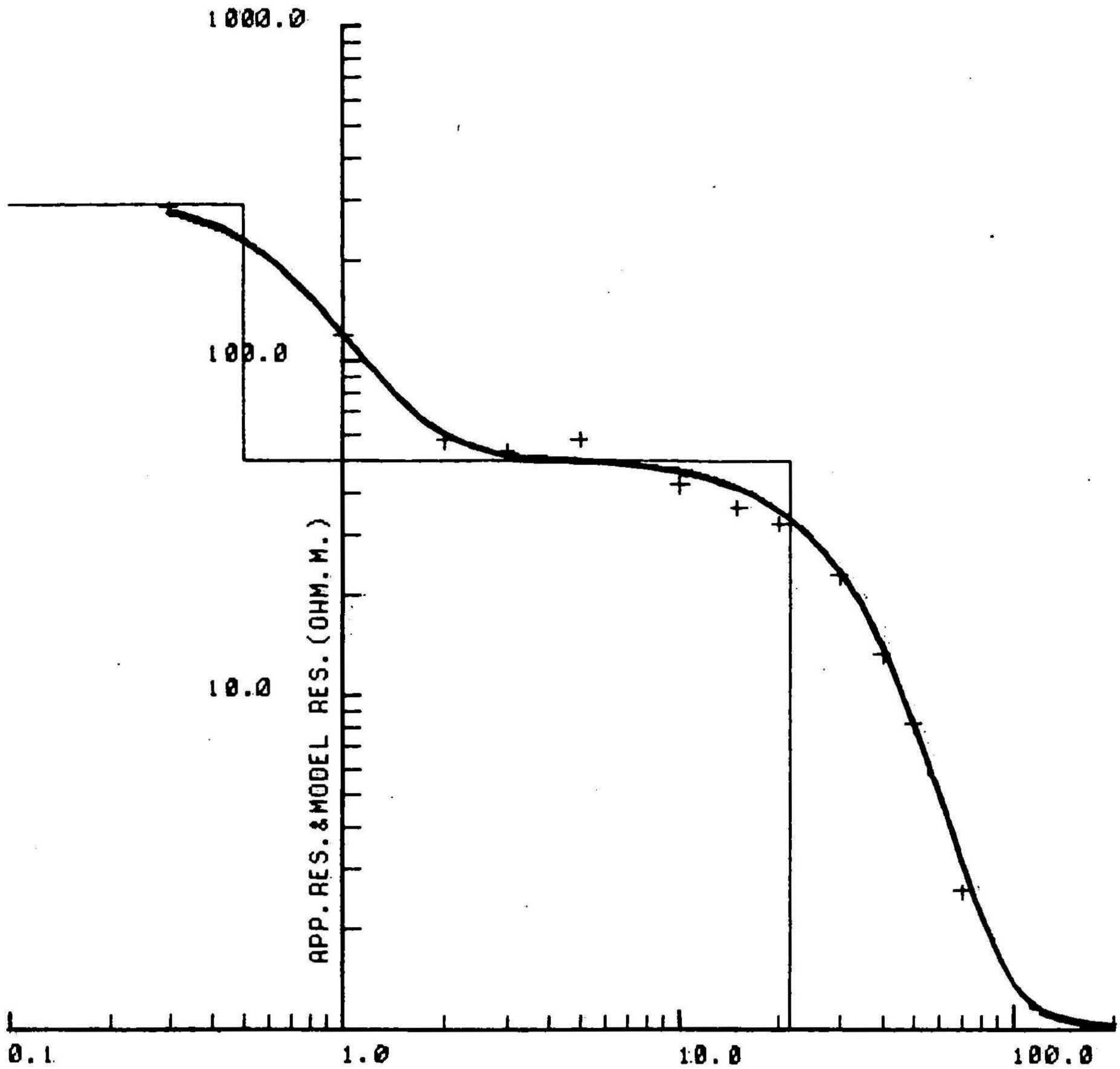
LAYER NO.	RESISTIVITY	THICKNESS
1	340.0	0.5
2	66.0	16.0
3	1.0	

TARAWA PROBE 19 R2 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	205.0	0.6
2	50.0	18.0
3	1.0	

TARAWA PROBE 20 R3 BONRIKI

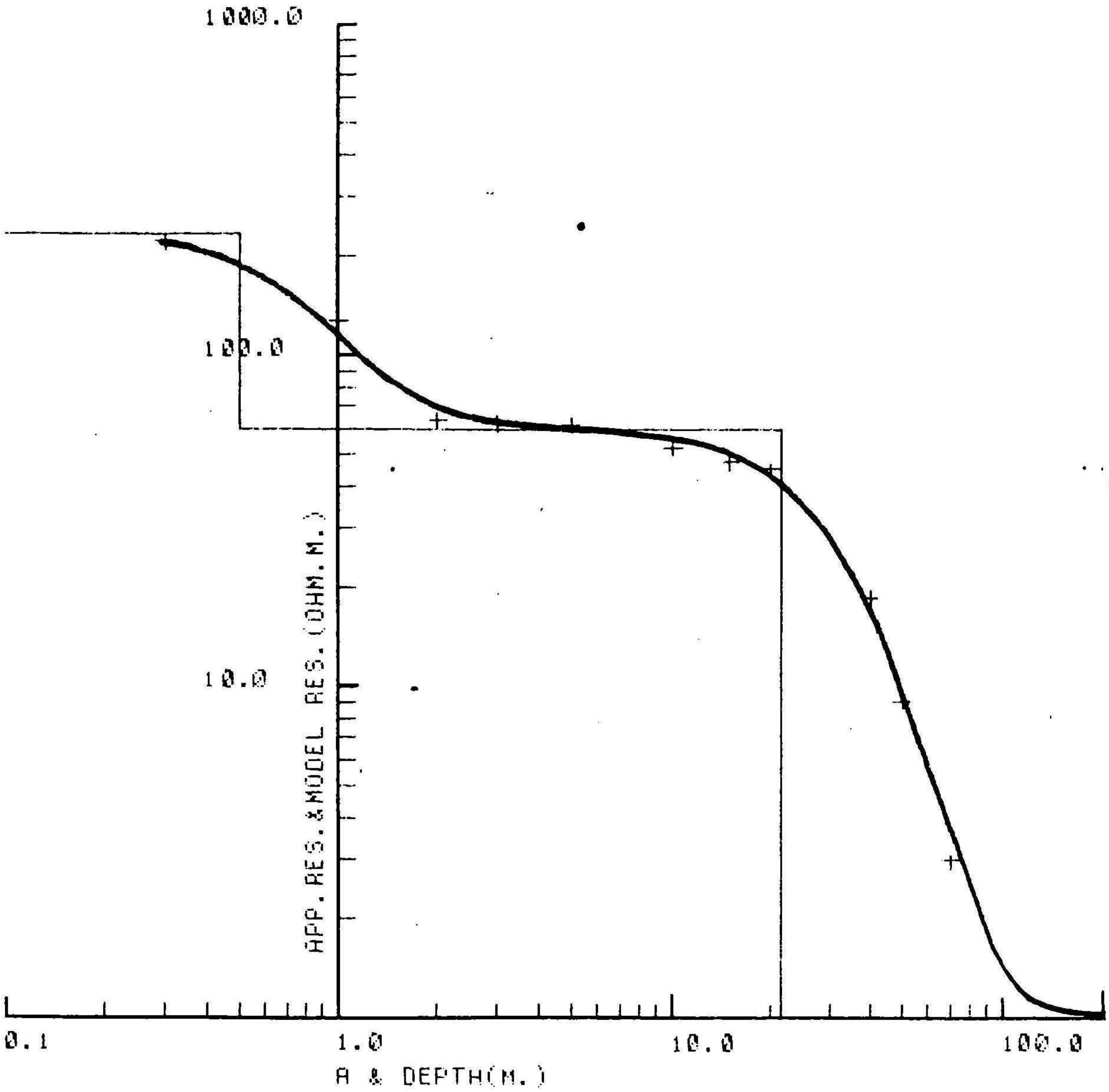


LAYER NO.	RESISTIVITY	THICKNESS
1	294.0	0.5
2	50.0	21.0
3	1.0	

Record 1981/31

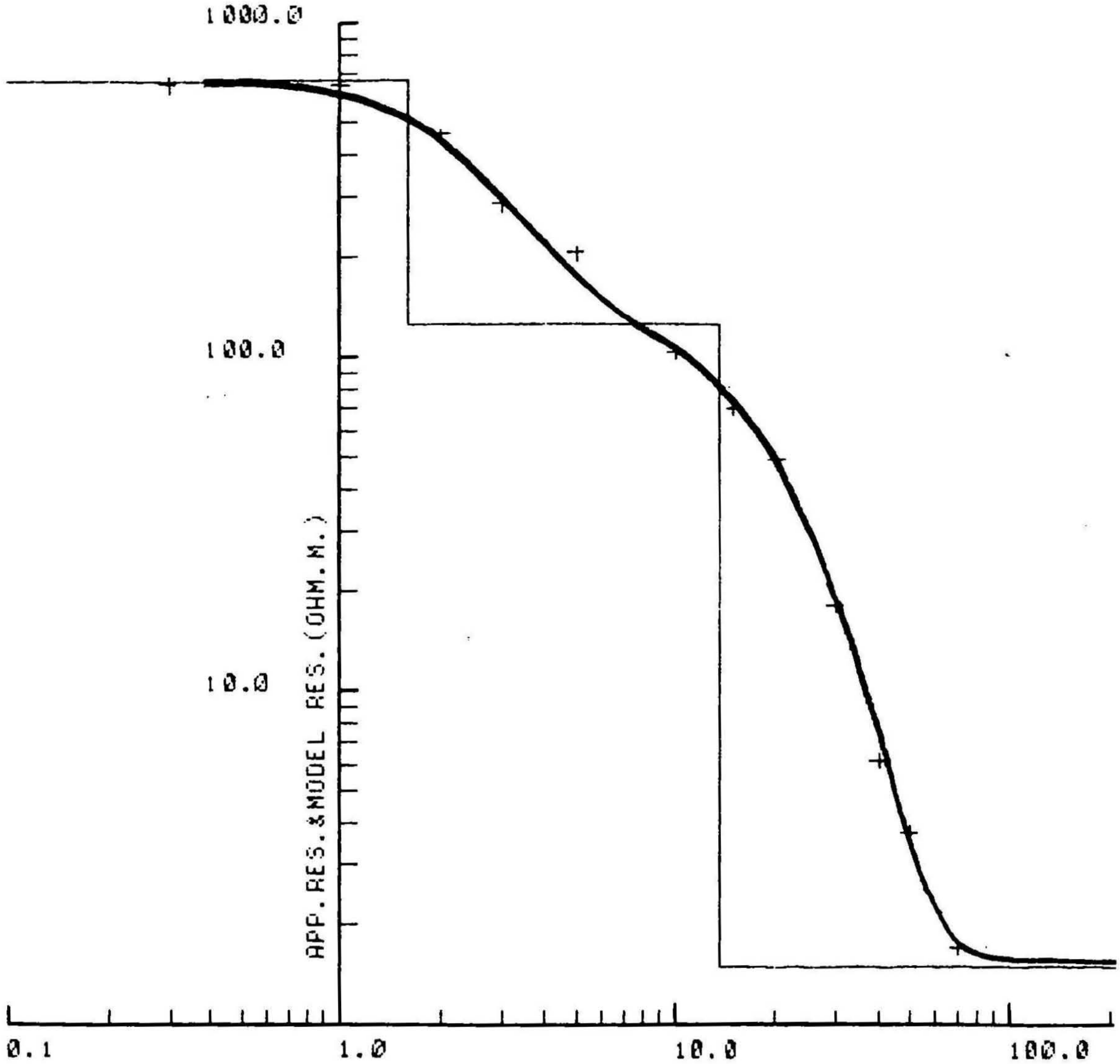
19/09/28

TARAWA PROBE 21 R 4 BONRIKI

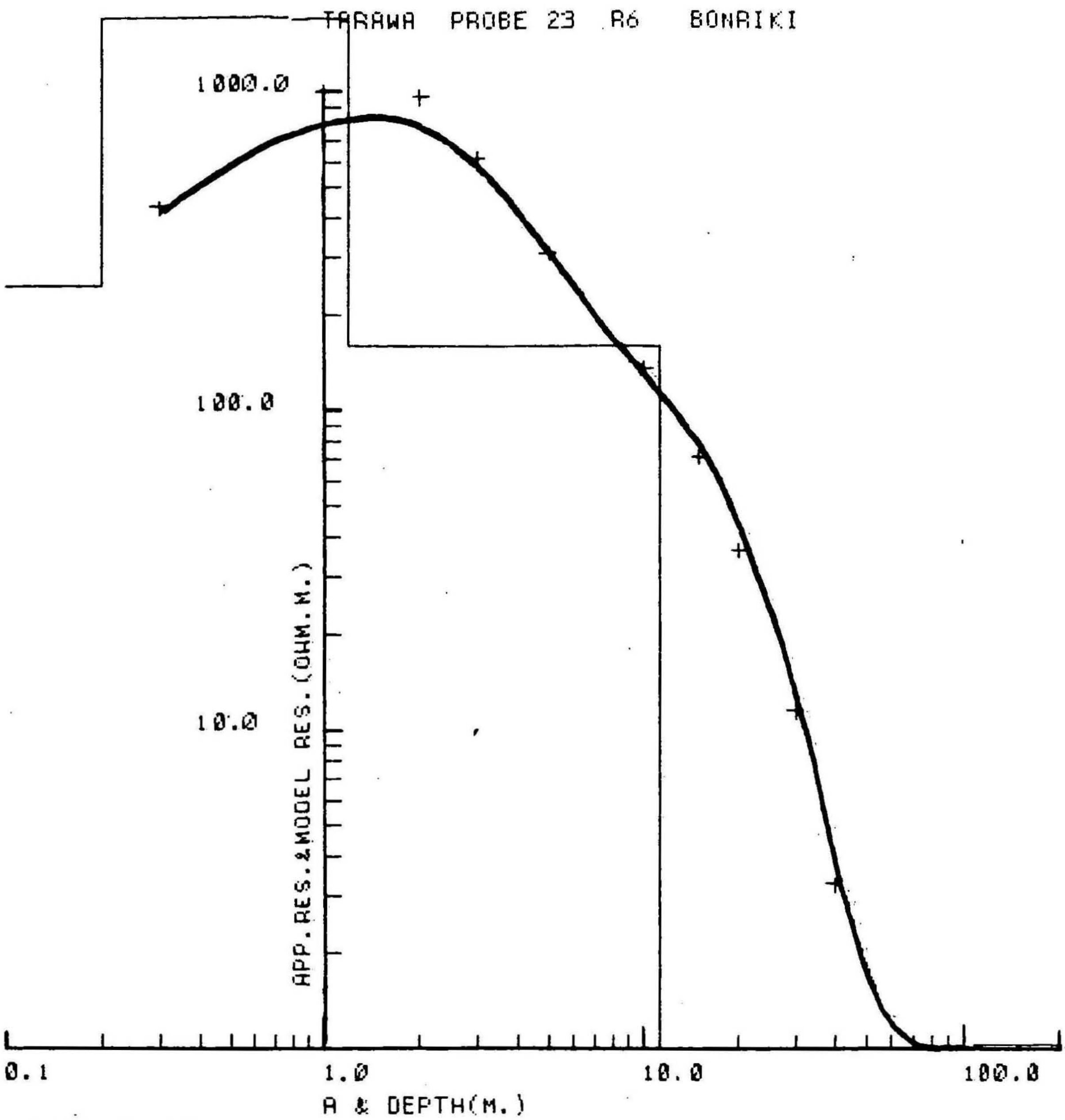


LAYER NO.	RESISTIVITY	THICKNESS
1	234.0	0.5
2	60.0	21.0
3	1.0	

TARAWA PROBE 22 R5 BONRIKI



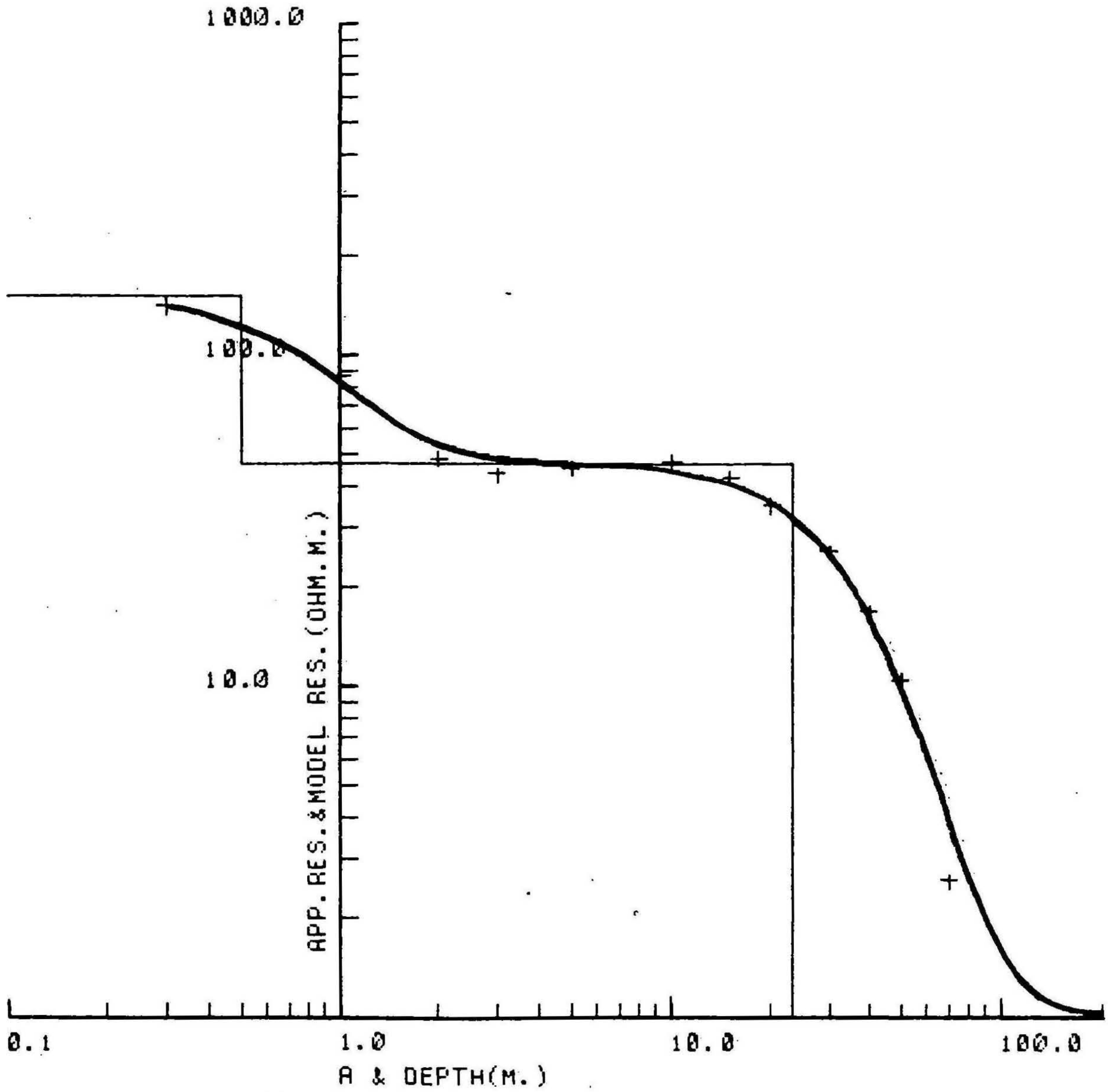
LAYER NO.	RESISTIVITY	THICKNESS
1	660.0	0.4
2	670.0	1.2
3	125.0	12.0
4	1.5	



LAYER NO.	RESISTIVITY	THICKNESS
1	245.0	0.2
2	1700.0	1.0
3	160.0	10.0
4	1.0	

19/09/31

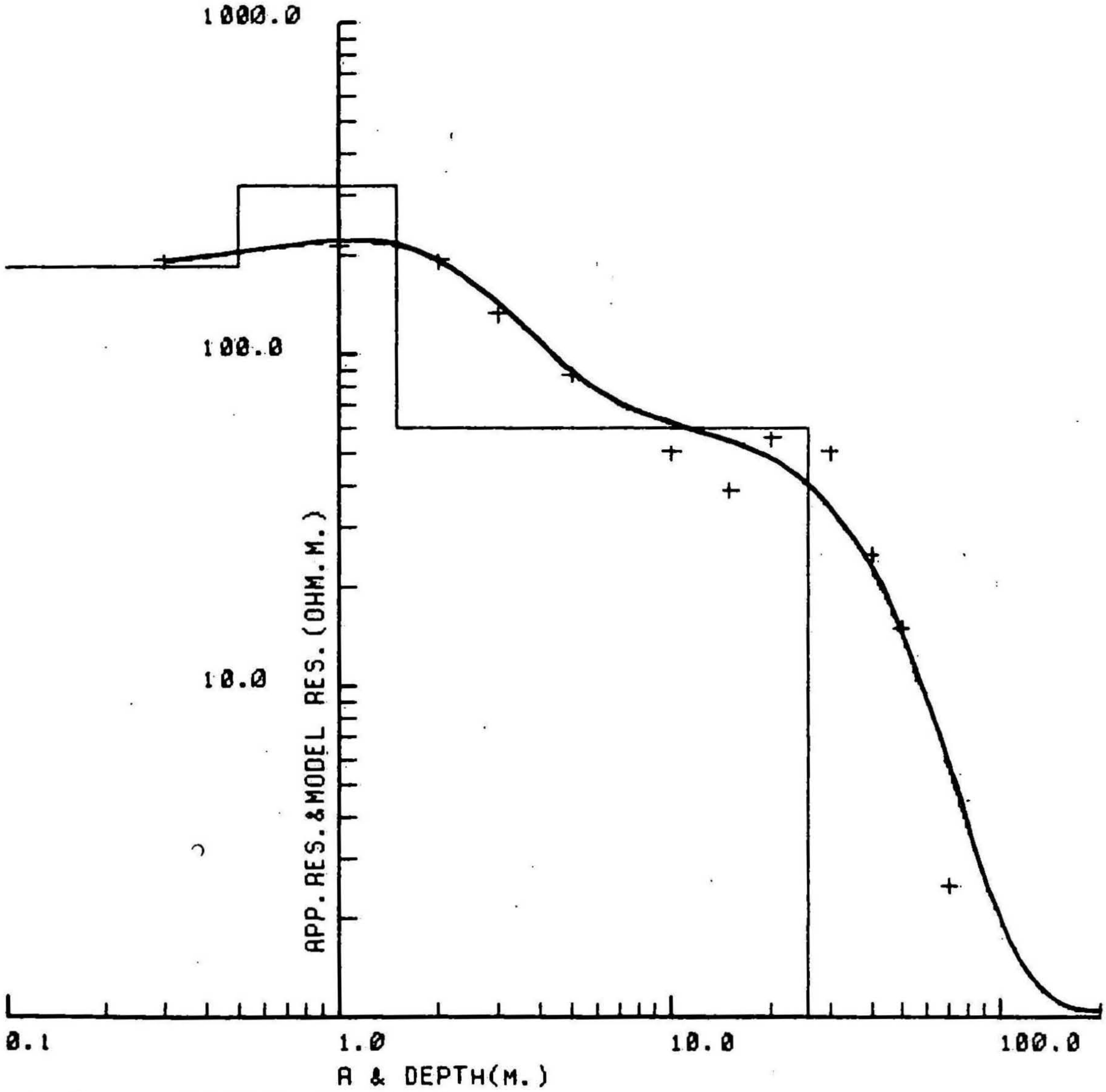
TARAWA PROBE 24 A7 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	151.0	0.5
2	47.0	23.0
3	1.0	

19/09/32

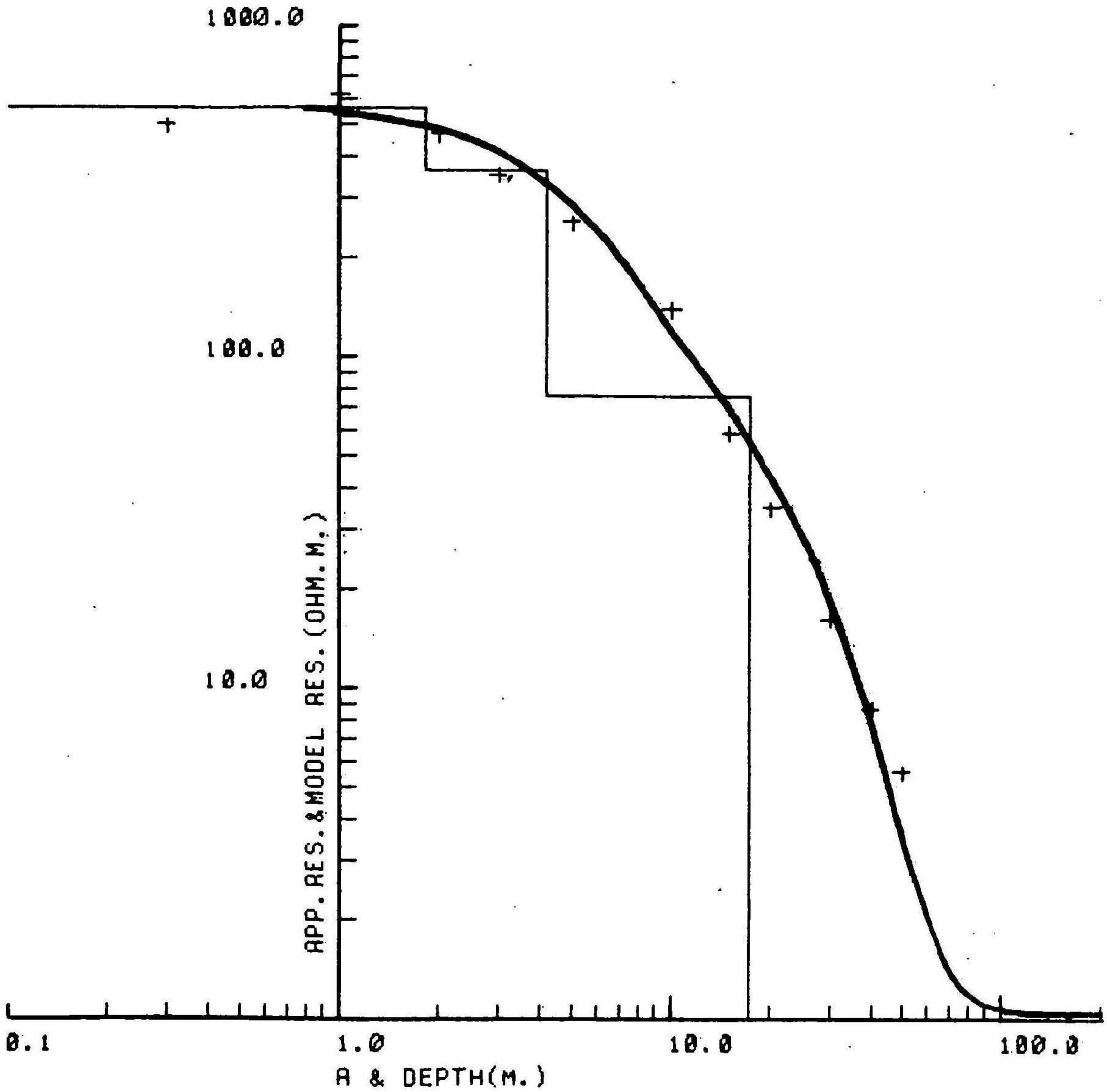
TARAWA PROBE 25 R8 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	185.0	0.5
2	320.0	1.0
3	60.0	24.0
4	1.0	

19/09/33

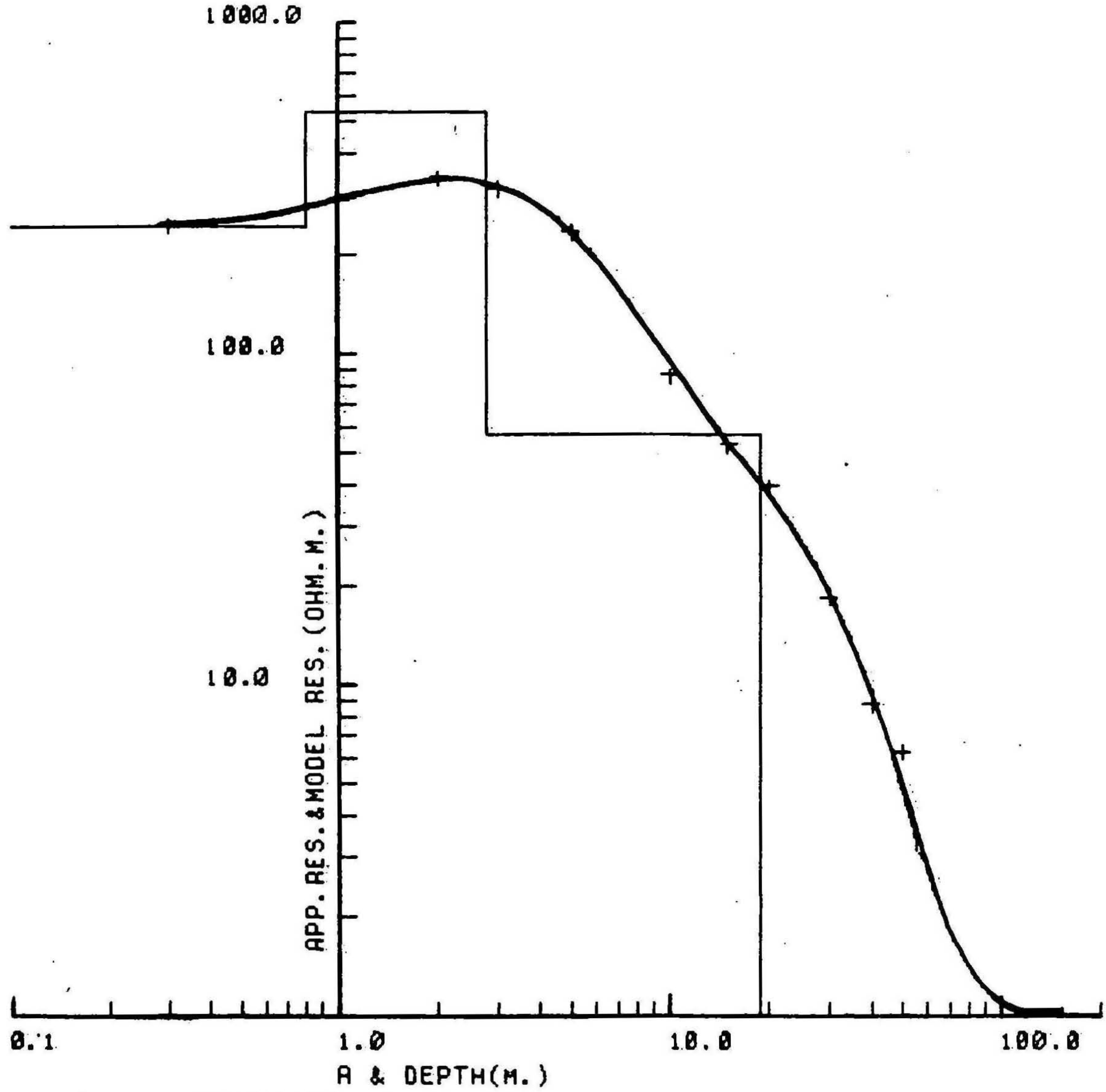
TARAWA PROBE 26 R 1.1 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	563.0	1.8
2	366.0	2.4
3	76.0	13.0
4	1.0	

19/09/34

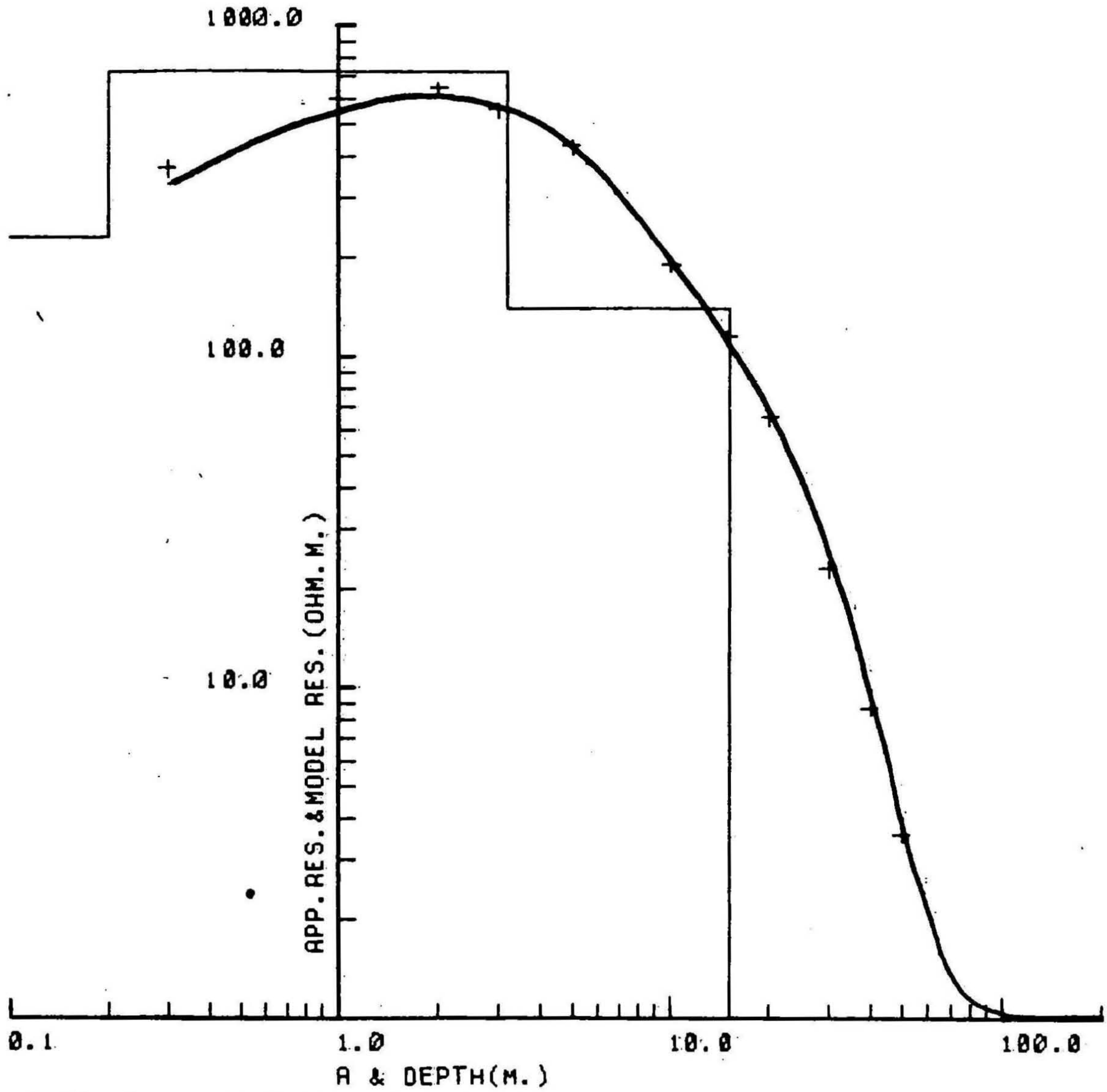
TARAWA PROBE 28 R 16 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	240.0	0.8
2	540.0	2.0
3	57.0	16.0
4	1.0	

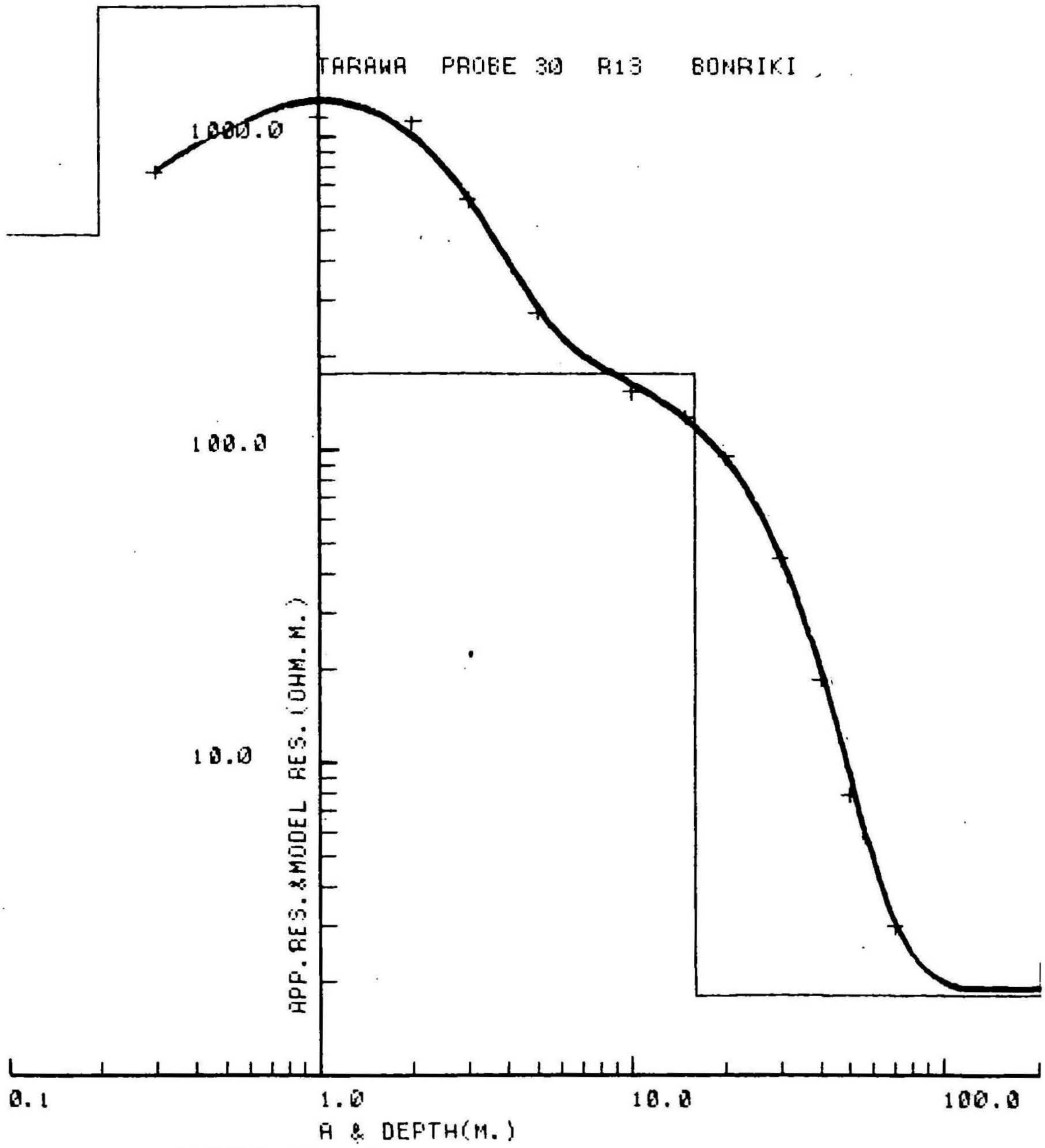
19/09/35

TARAWA PROBE 29 A 17 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	230.0	0.2
2	730.0	3.0
3	140.0	12.0
4	1.0	

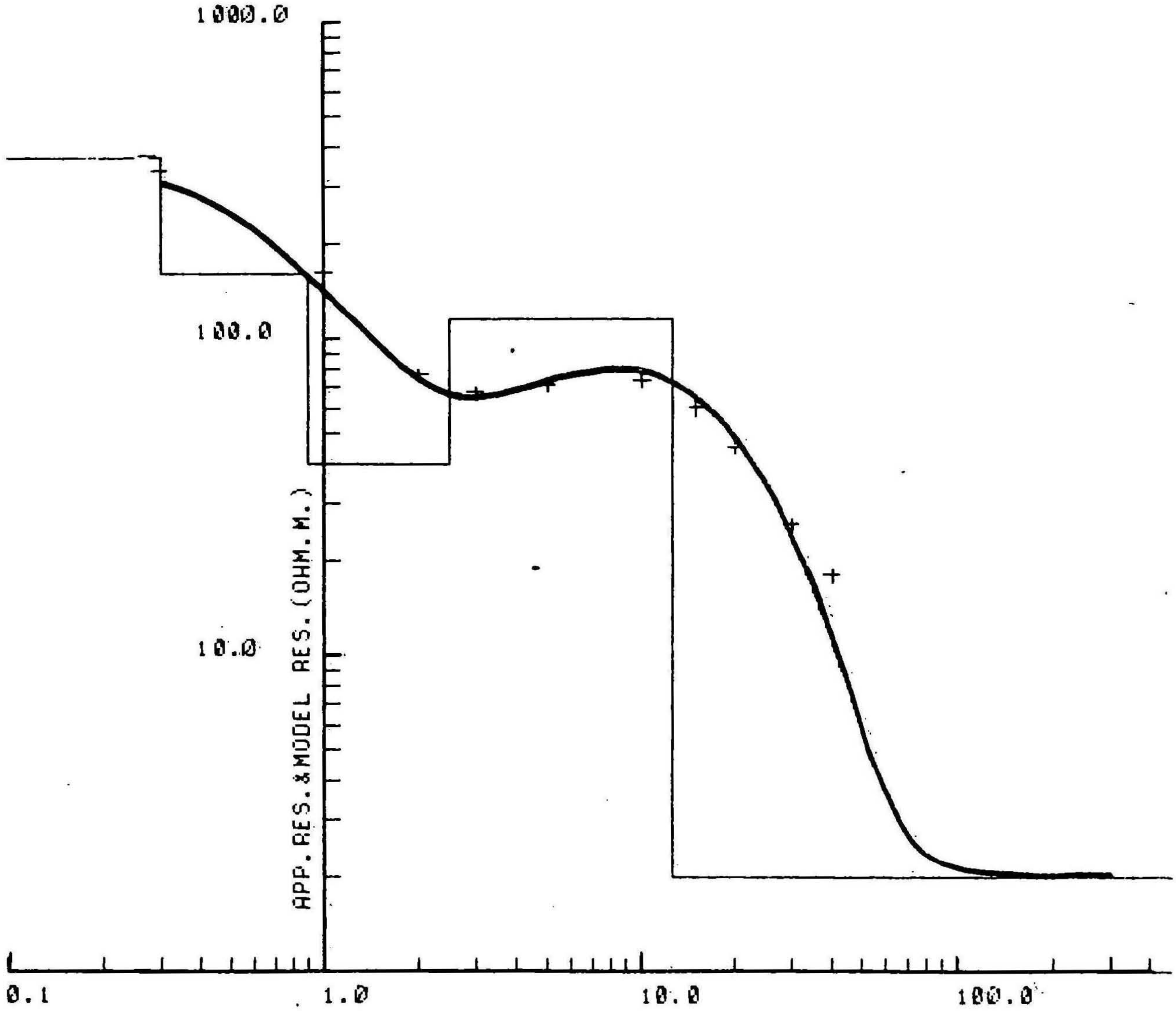
19/09/36



LAYER NO.	RESISTIVITY	THICKNESS
1	490.0	0.2
2	2600.0	0.8
3	175.0	15.0
4	1.6	

 19/09/37

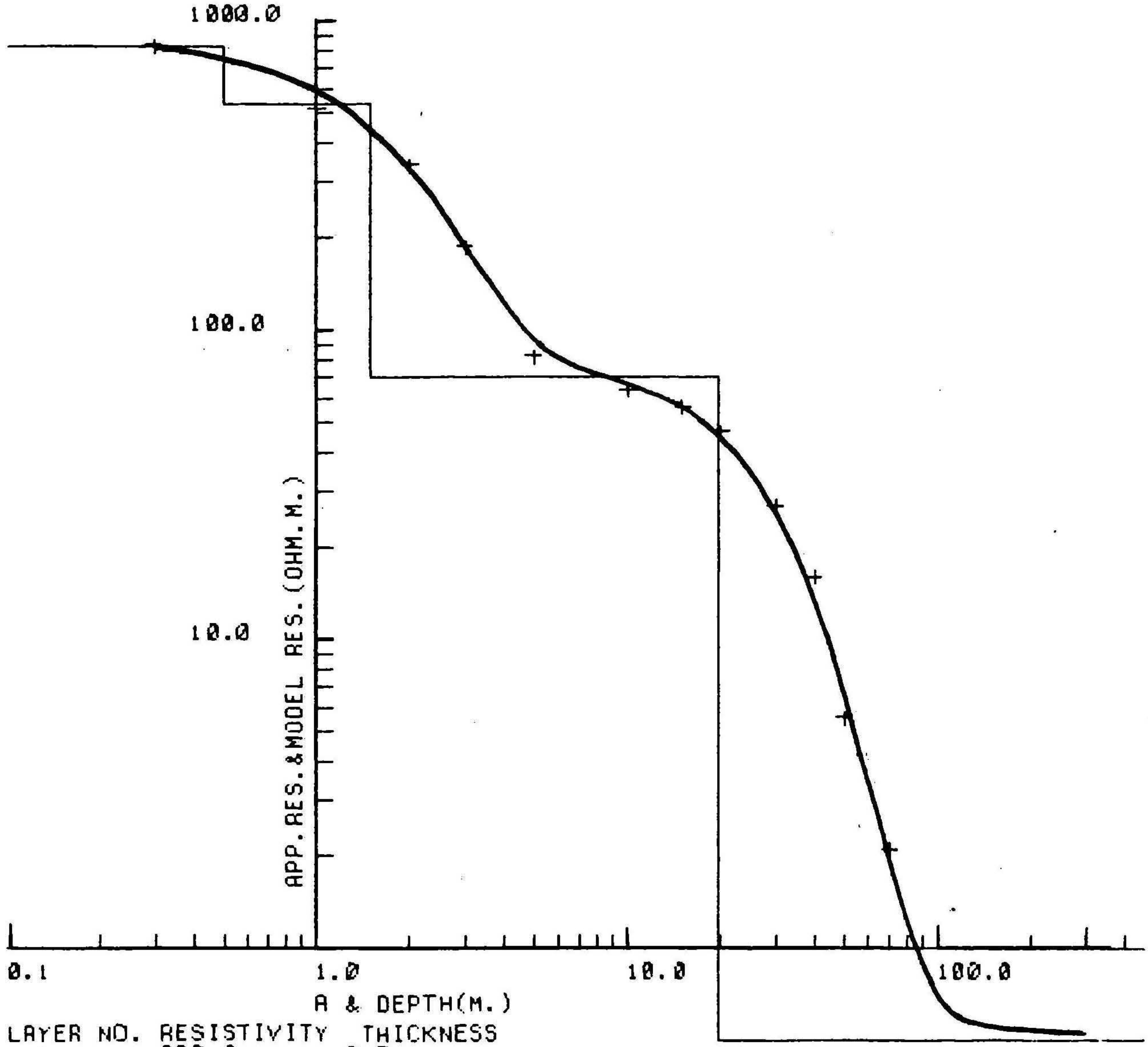
TARAWA PROBE 31 R14 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	370.0	0.3
2	160.0	0.6
3	40.0	1.6
4	115.0	10.0
5	2.0	

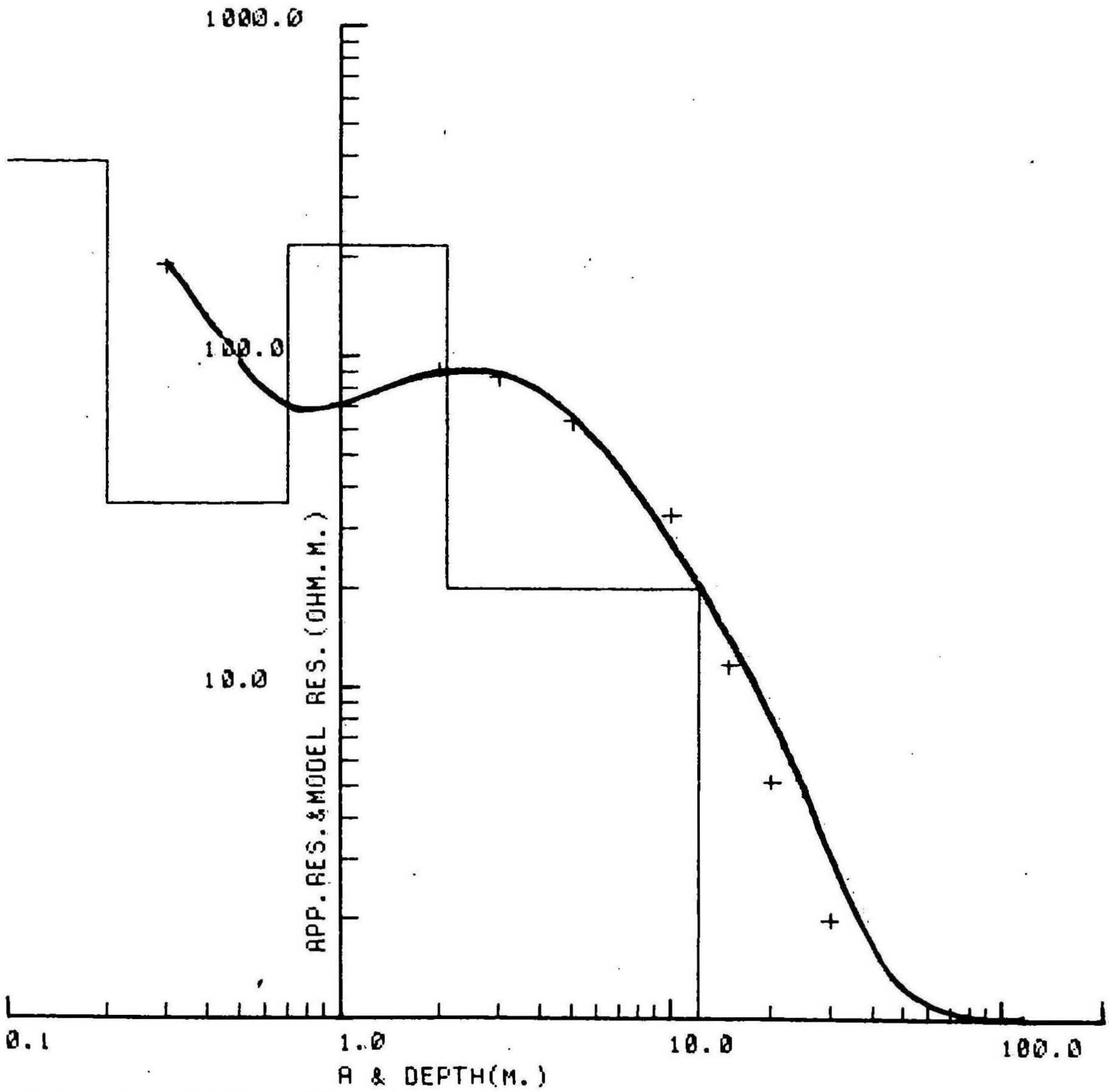
19/09/38

TARAWA PROBE 32 R 15 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	830.0	0.5
2	534.0	1.0
3	70.0	18.0
4	0.5	

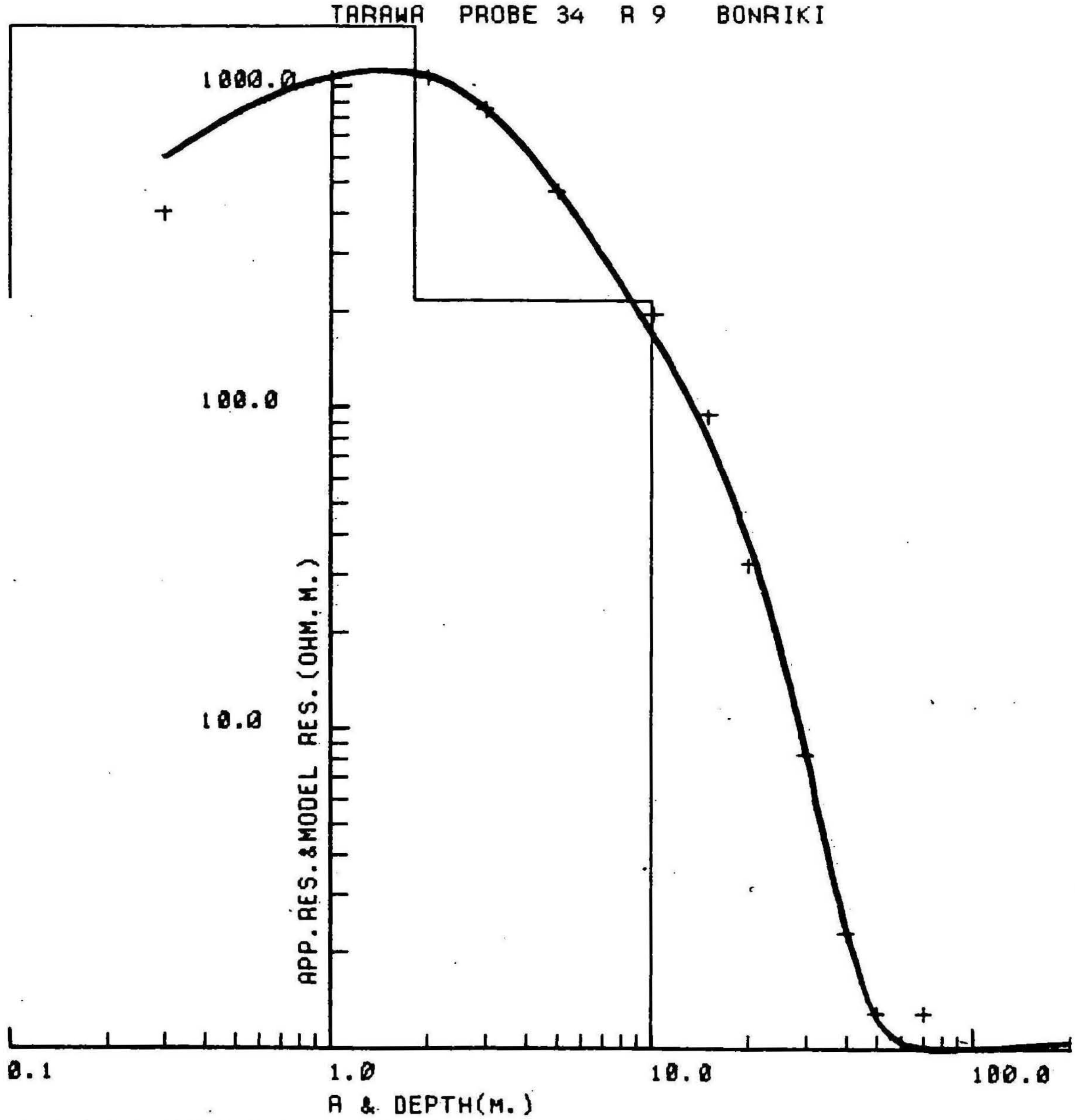
TARAWA PROBE 33 R10 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	390.0	0.2
2	36.0	0.5
3	216.0	1.4
4	20.0	10.0
5	1.0	

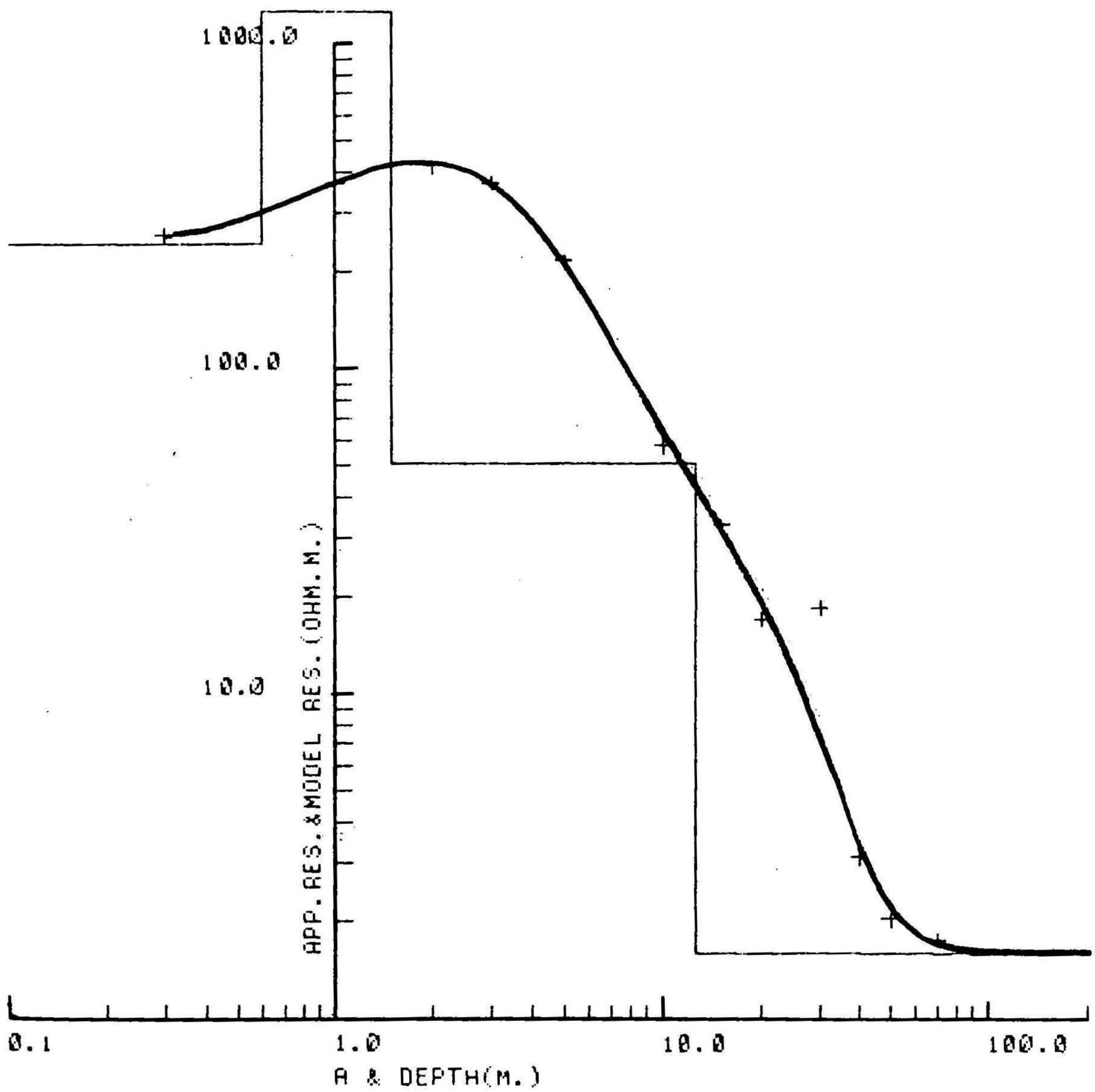
19/09/40

TARAWA PROBE 34 A 9 BONRIKI



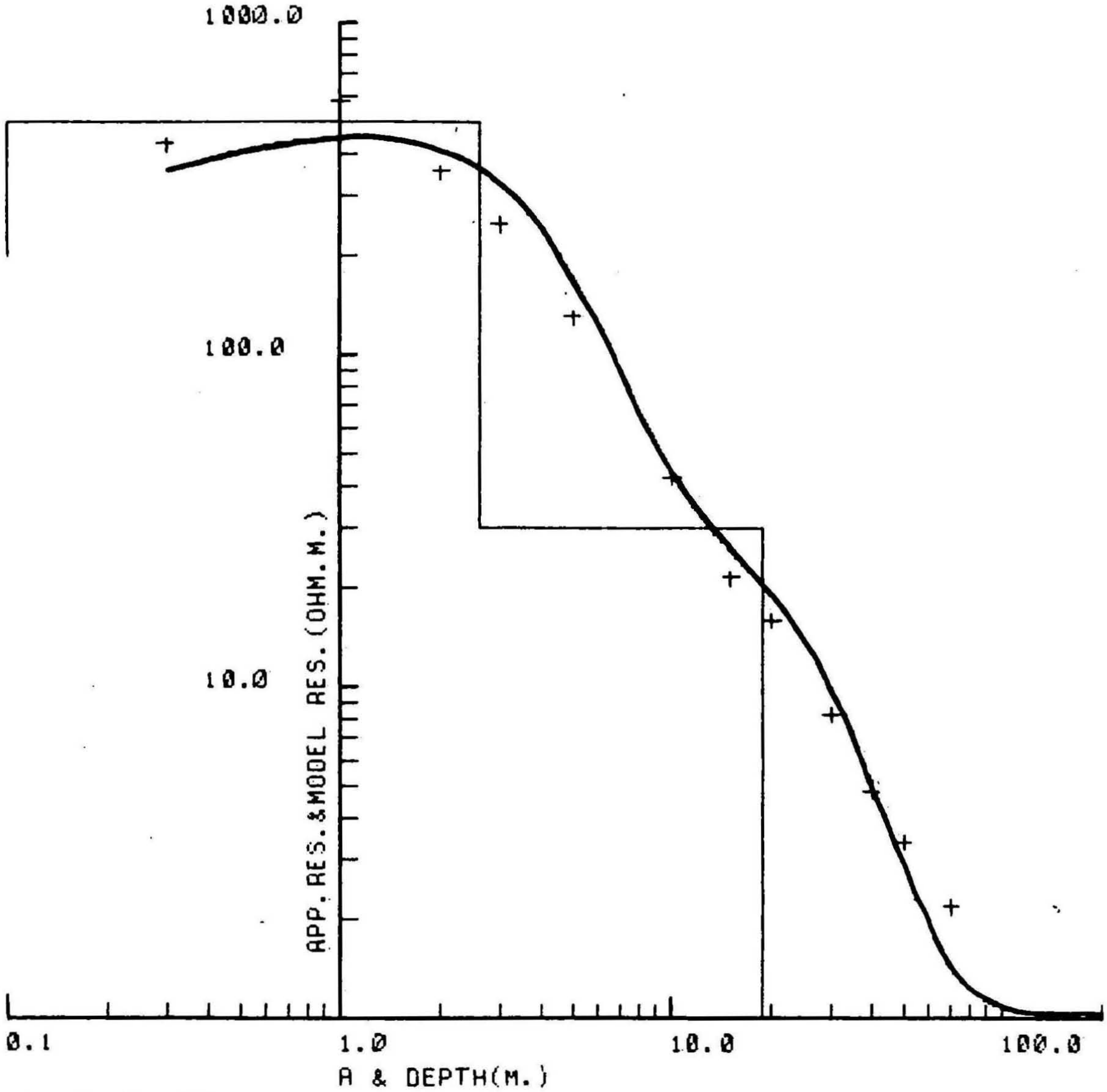
LAYER NO.	RESISTIVITY	THICKNESS
1	220.0	0.1
2	1550.0	1.7
3	216.0	8.0
4	1.0	

TARAWA PROBE 35 BORE 9 BUOTA



LAYER NO.	RESISTIVITY	THICKNESS
1	240.0	0.6
2	1250.0	0.9
3	51.0	11.0
4	1.6	

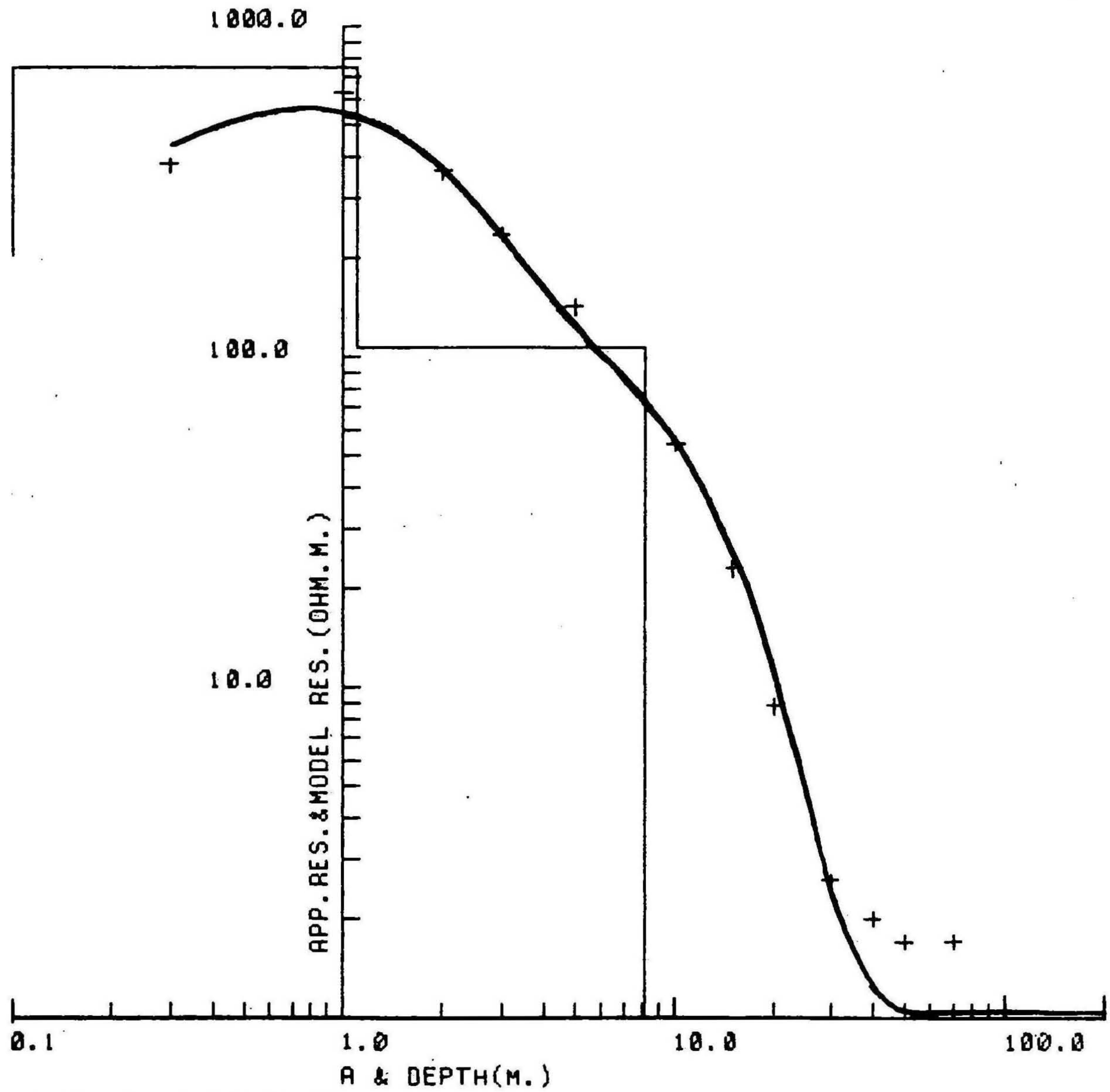
TARAWA PROBE 36 BORE 8 BUOTA



LAYER NO.	RESISTIVITY	THICKNESS
1	200.0	0.1
2	500.0	2.5
3	30.0	16.0
4	1.0	

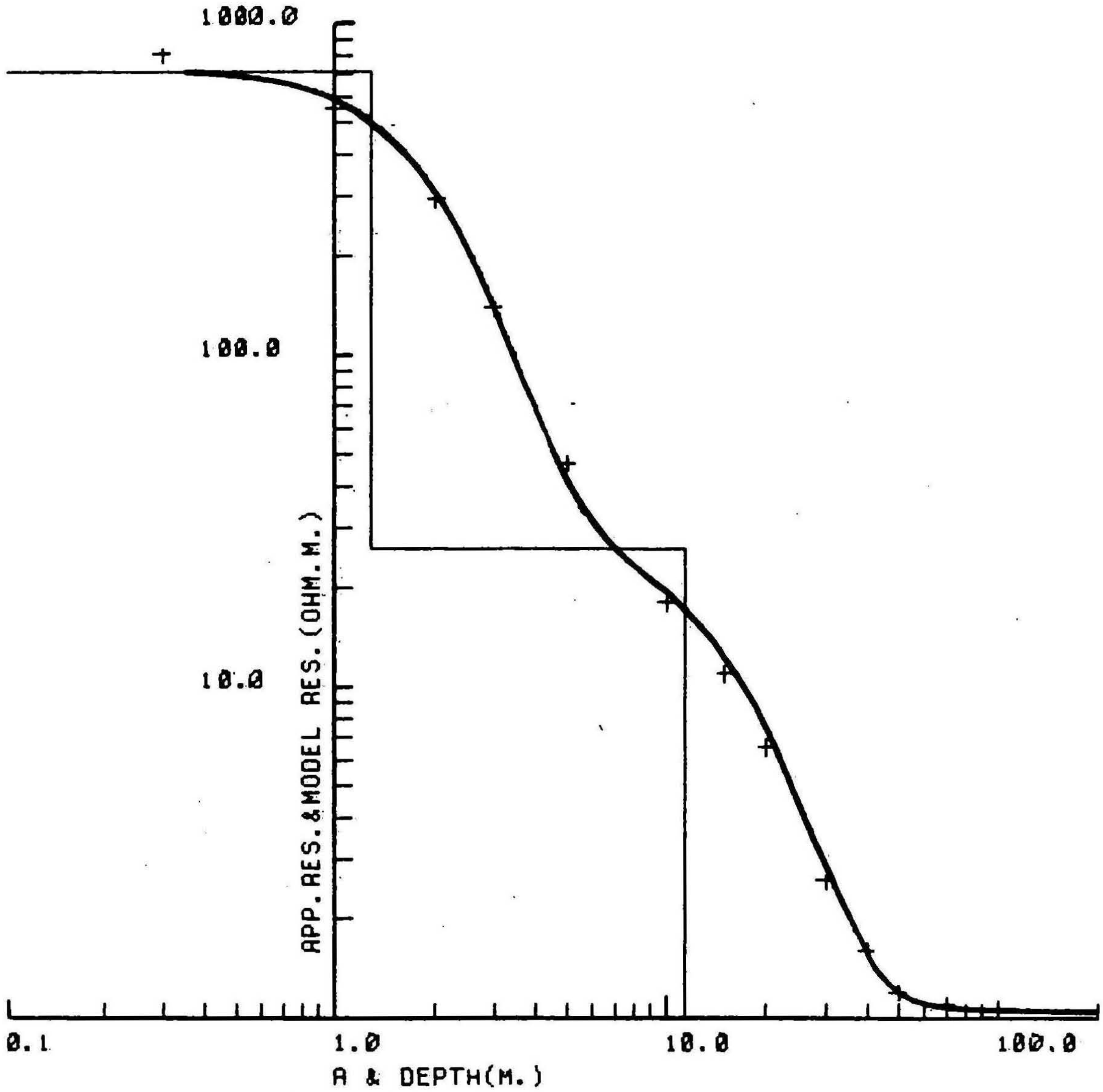
19/09/43

TARAWA PROBE 37 BORE 7 ABATAO



LAYER NO.	RESISTIVITY	THICKNESS
1	202.0	0.1
2	750.0	1.0
3	106.0	7.0
4	1.0	

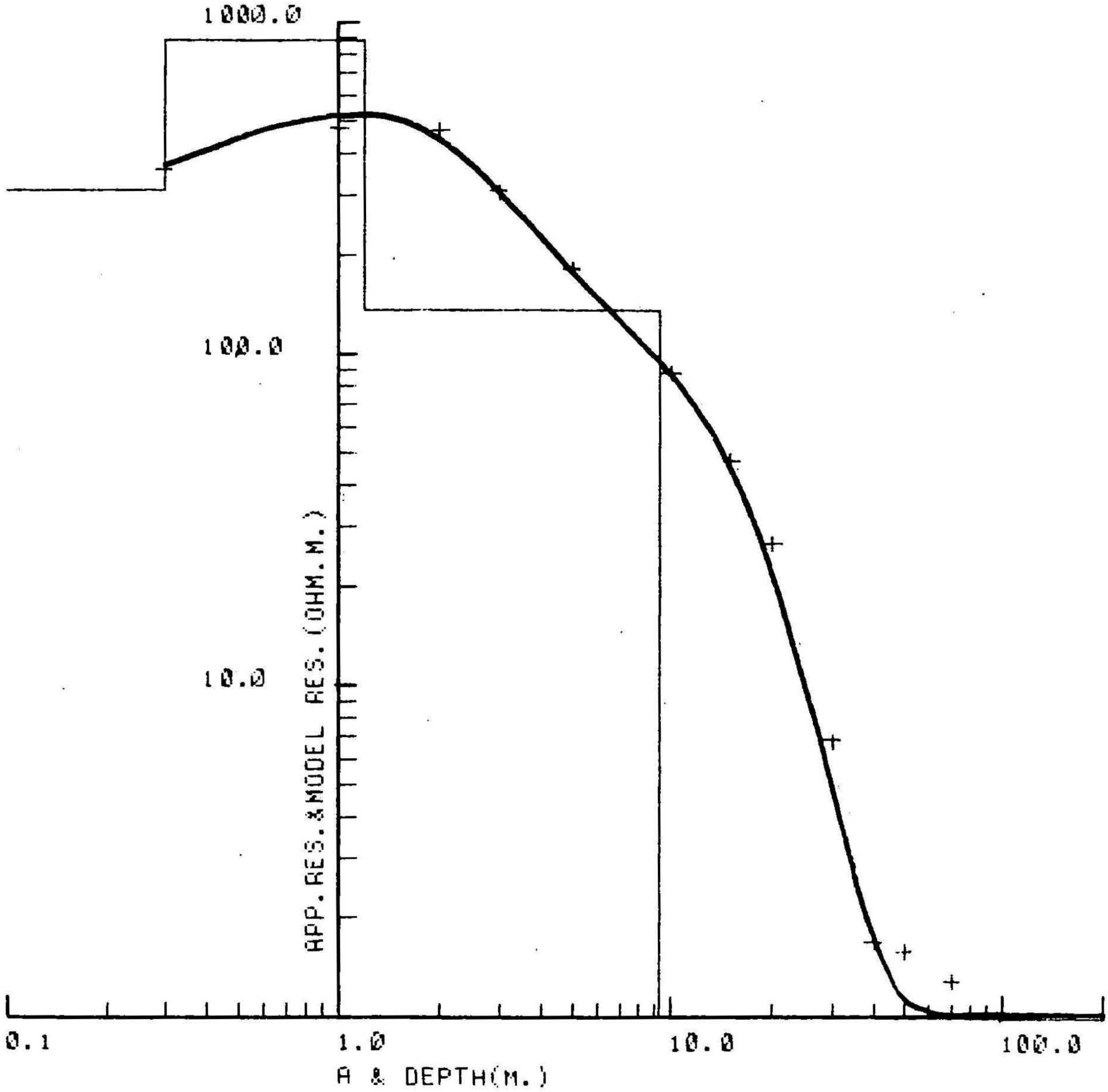
TARAWA PROBE 38 BORE 10 BIKENIBEU



LAYER NO.	RESISTIVITY	THICKNESS
1	720.0	1.3
2	26.0	10.0
3	1.0	

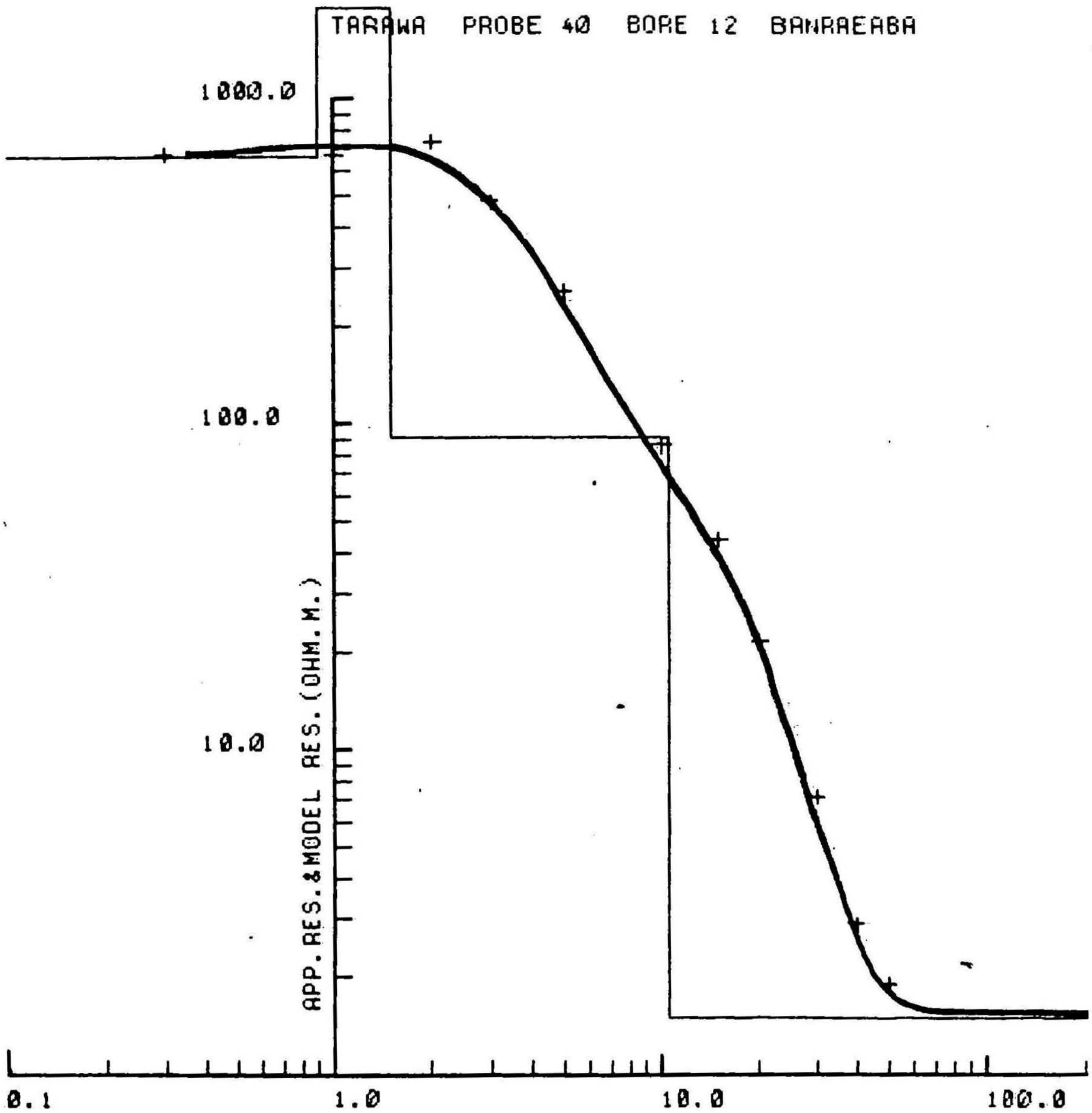
19/09/45

TARAWA PROBE 39 BORE 11 BANRAEABA



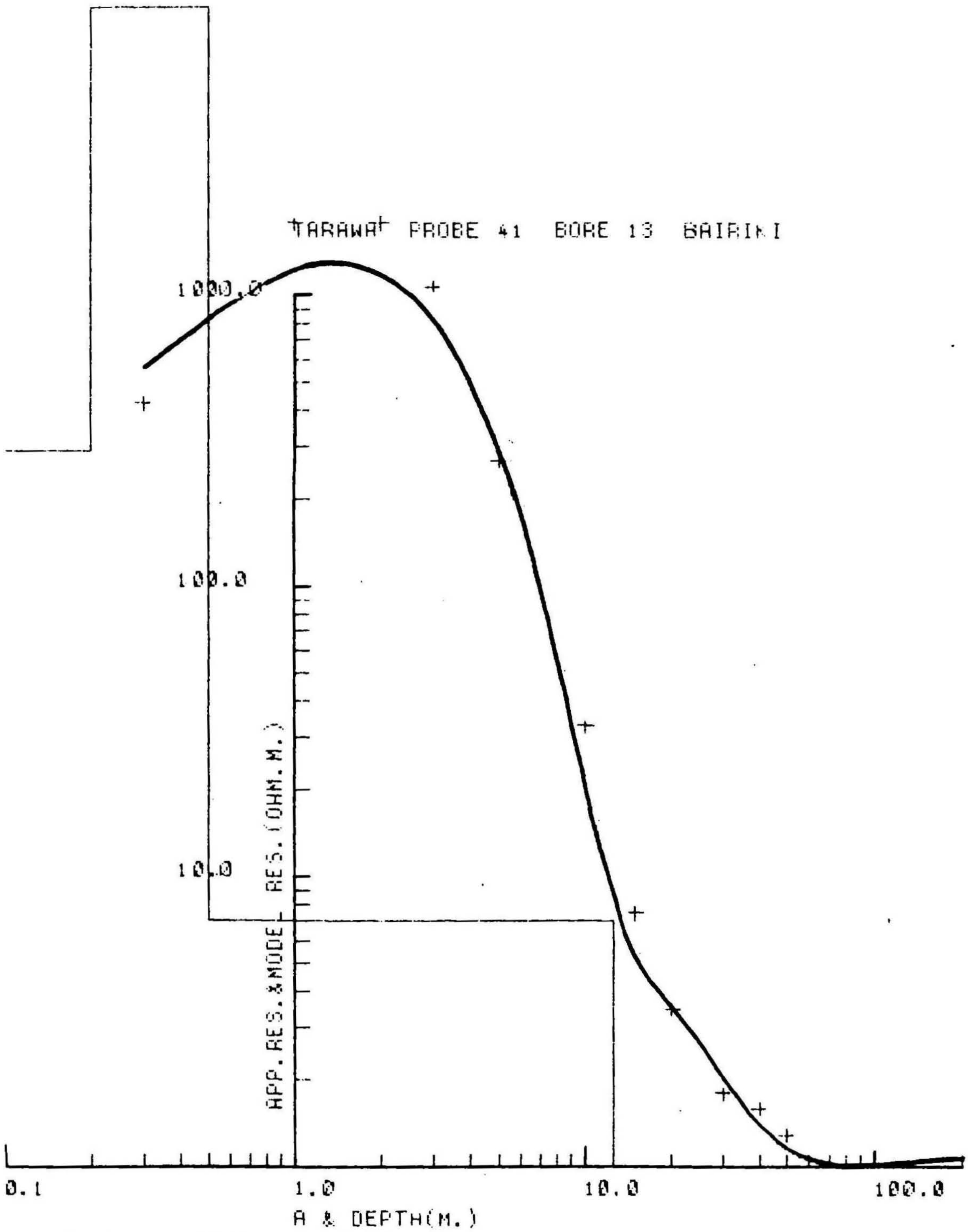
LAYER NO.	RESISTIVITY	THICKNESS
1	310.0	0.3
2	860.0	0.9
3	136.0	8.0
4	1.0	

19/09/46



LAYER NO.	RESISTIVITY	THICKNESS
1	660.0	0.9
2	1890.0	0.6
3	91.0	9.0
4	1.5	

19/09/47



LAYER NO.	RESISTIVITY	THICKNESS
1	290.0	0.2
2	9900.0	0.3
3	7.0	12.0
4	1.0	

Record 1981/31

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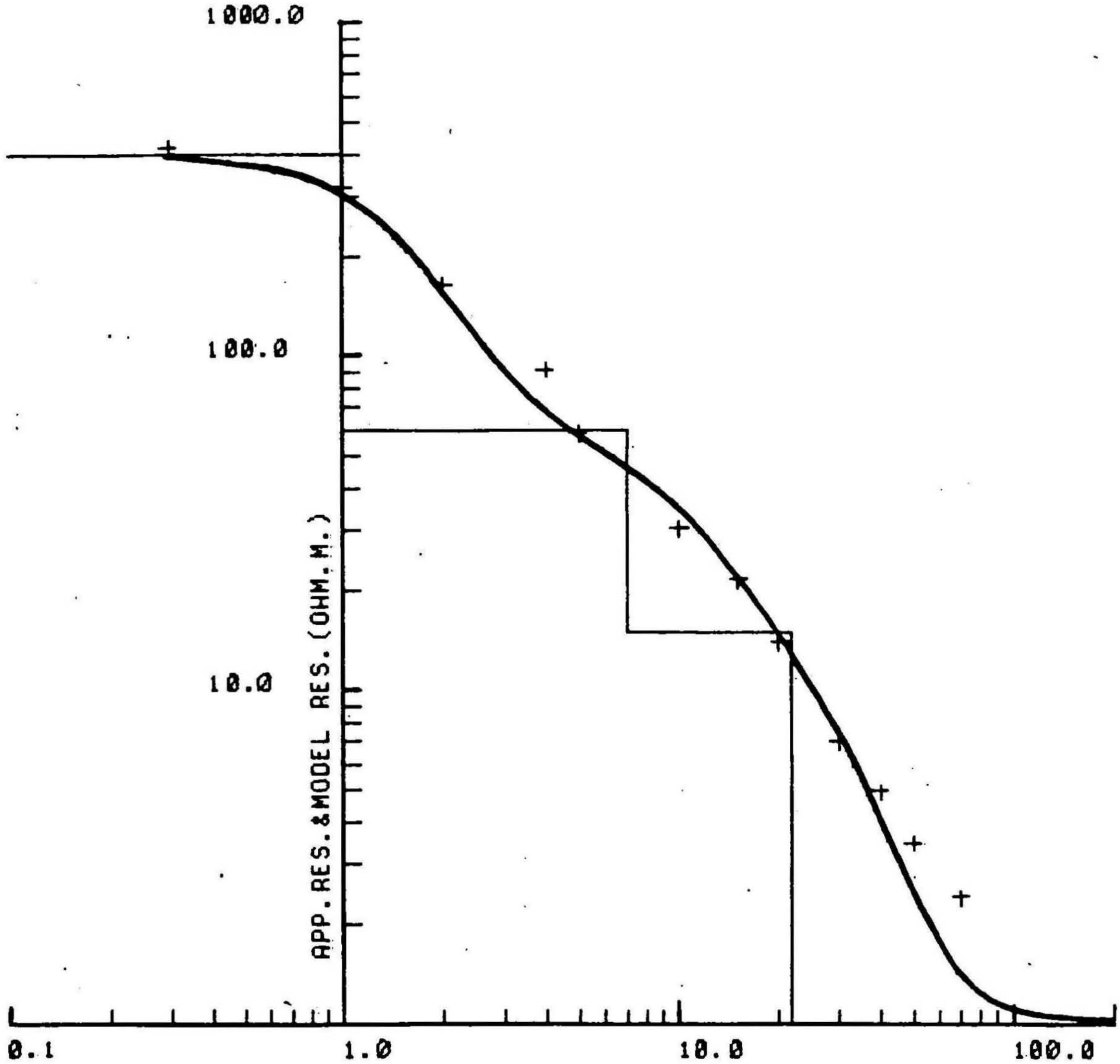
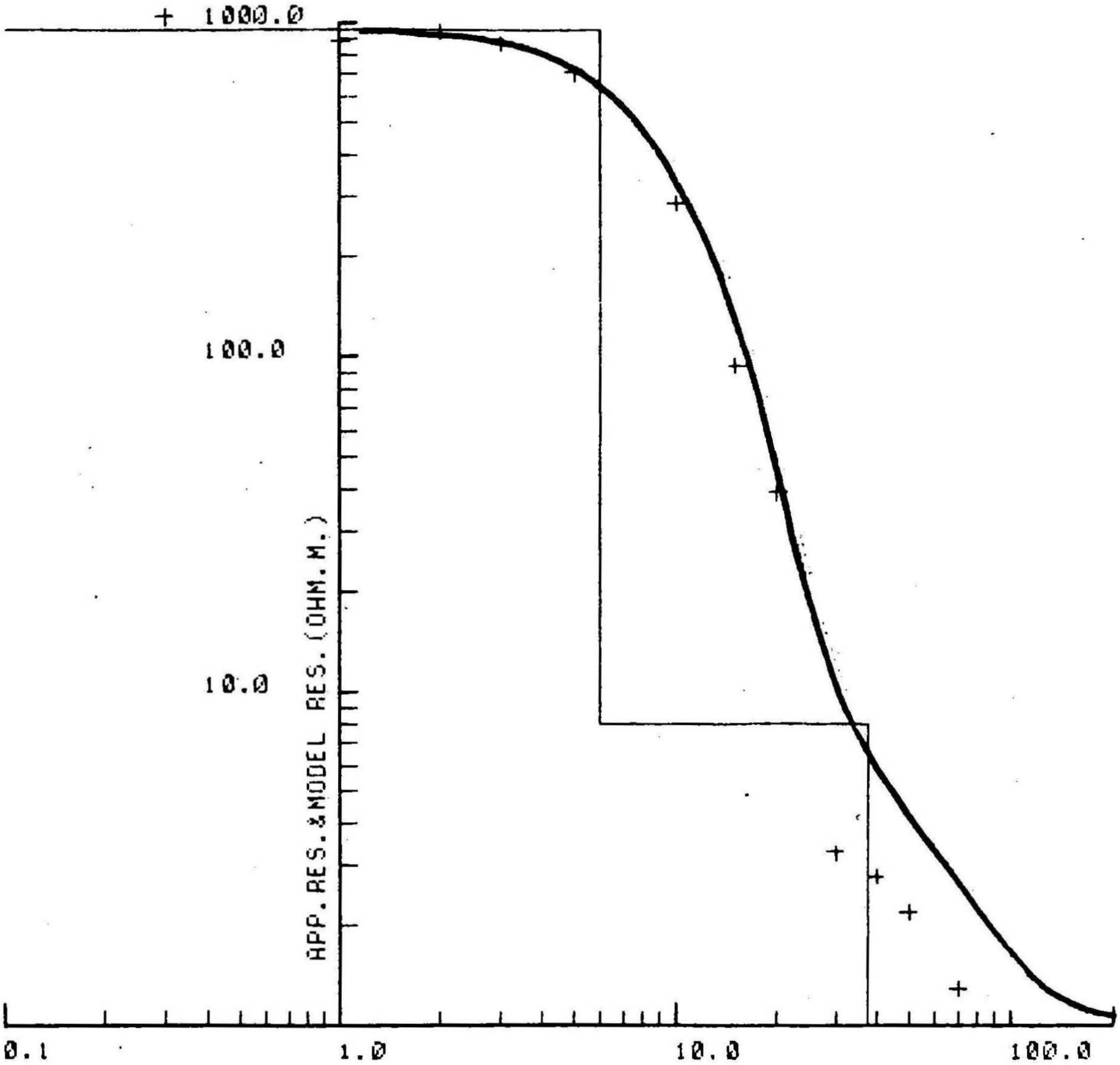
TARAWA PROBE 42 AIRP 1 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	400.0	1.0
2	60.0	6.0
3	15.0	15.0
4	1.0	

19/09/49

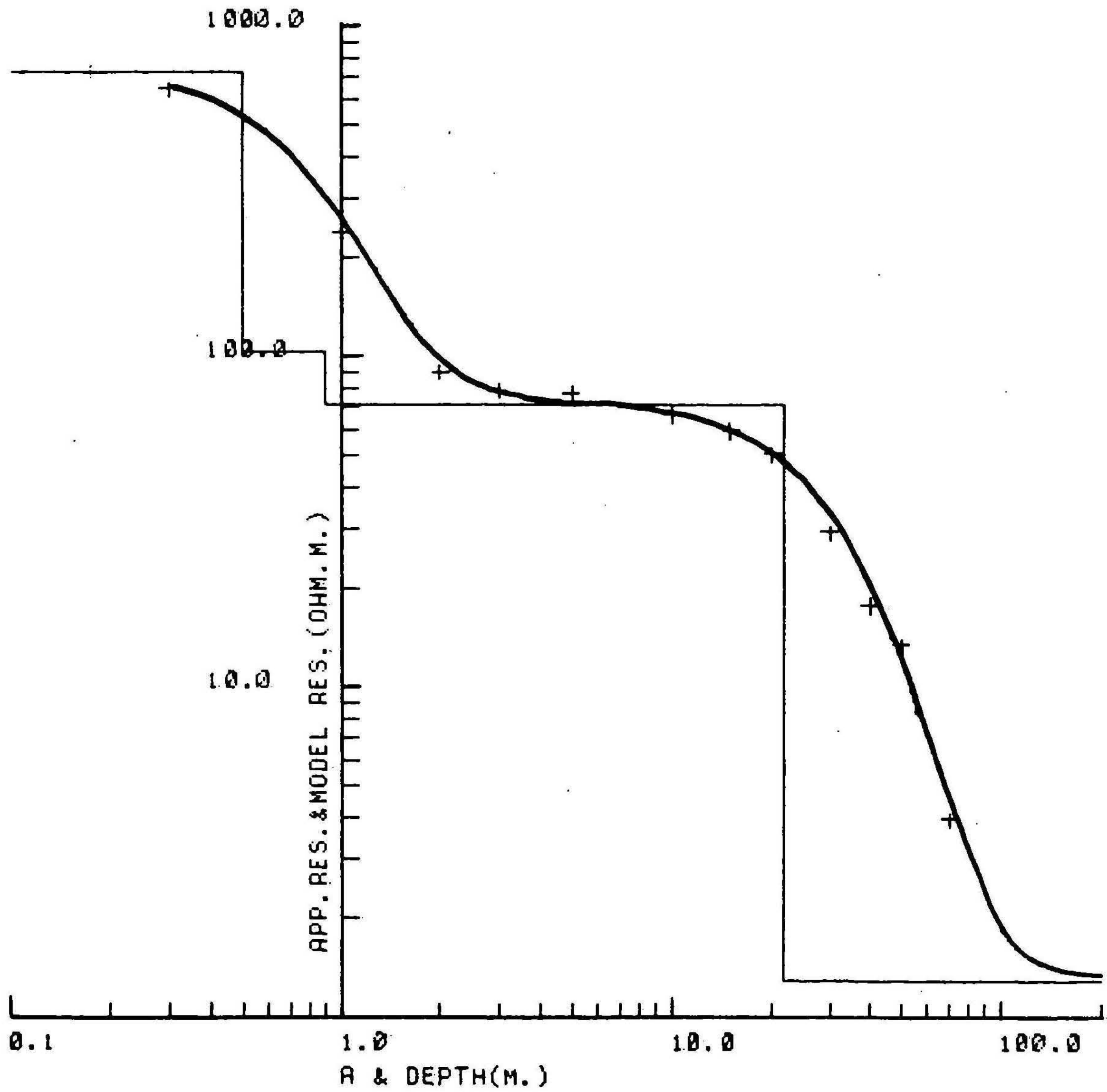
TARAWA PROBE 43 AIRP 2 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	950.0	6.0
2	8.0	32.0
3	1.0	

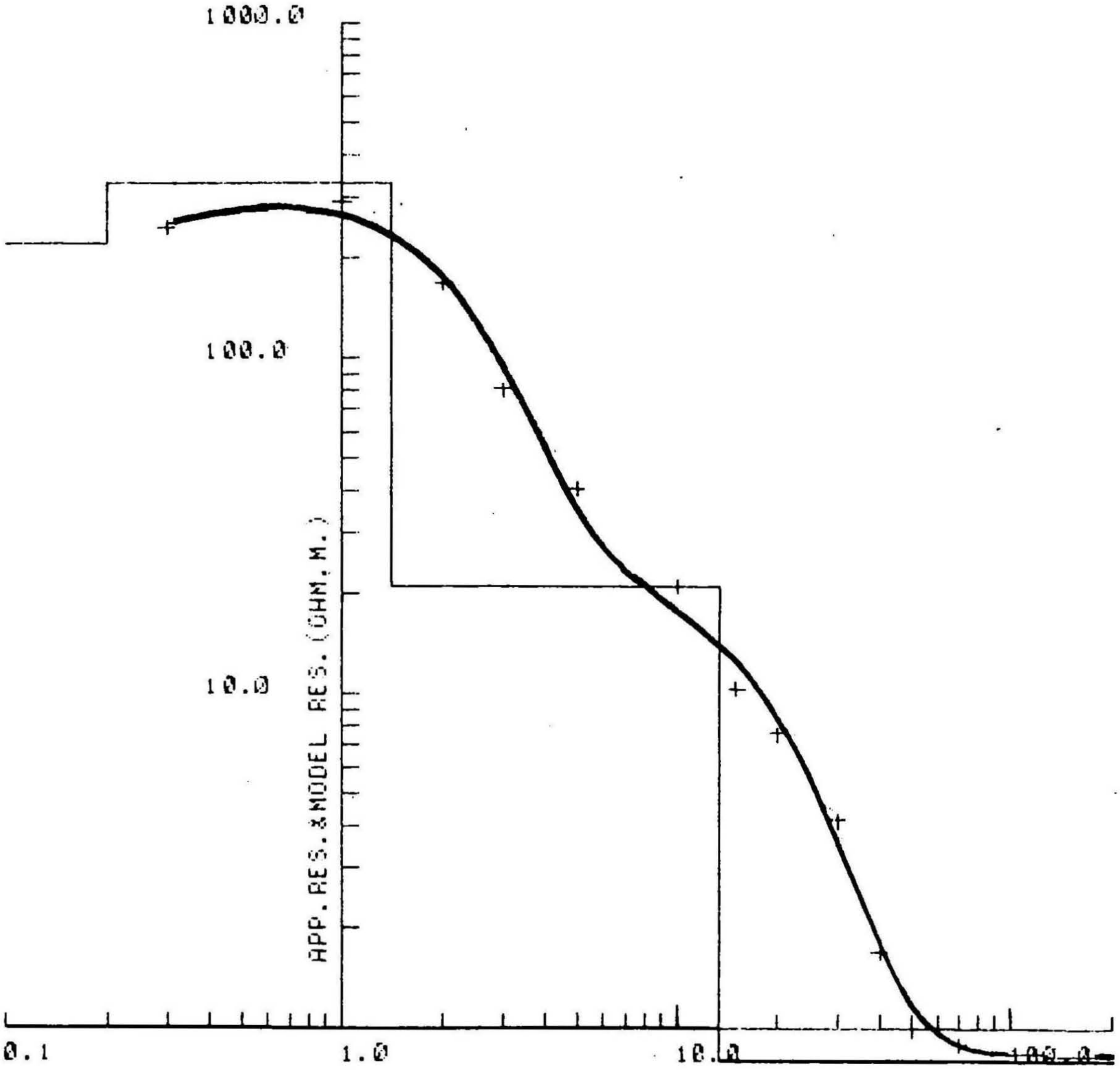
19/09/50

TARAWA PROBE44 AIRP 3 BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	725.0	0.5
2	103.0	0.4
3	71.0	21.0
4	1.3	

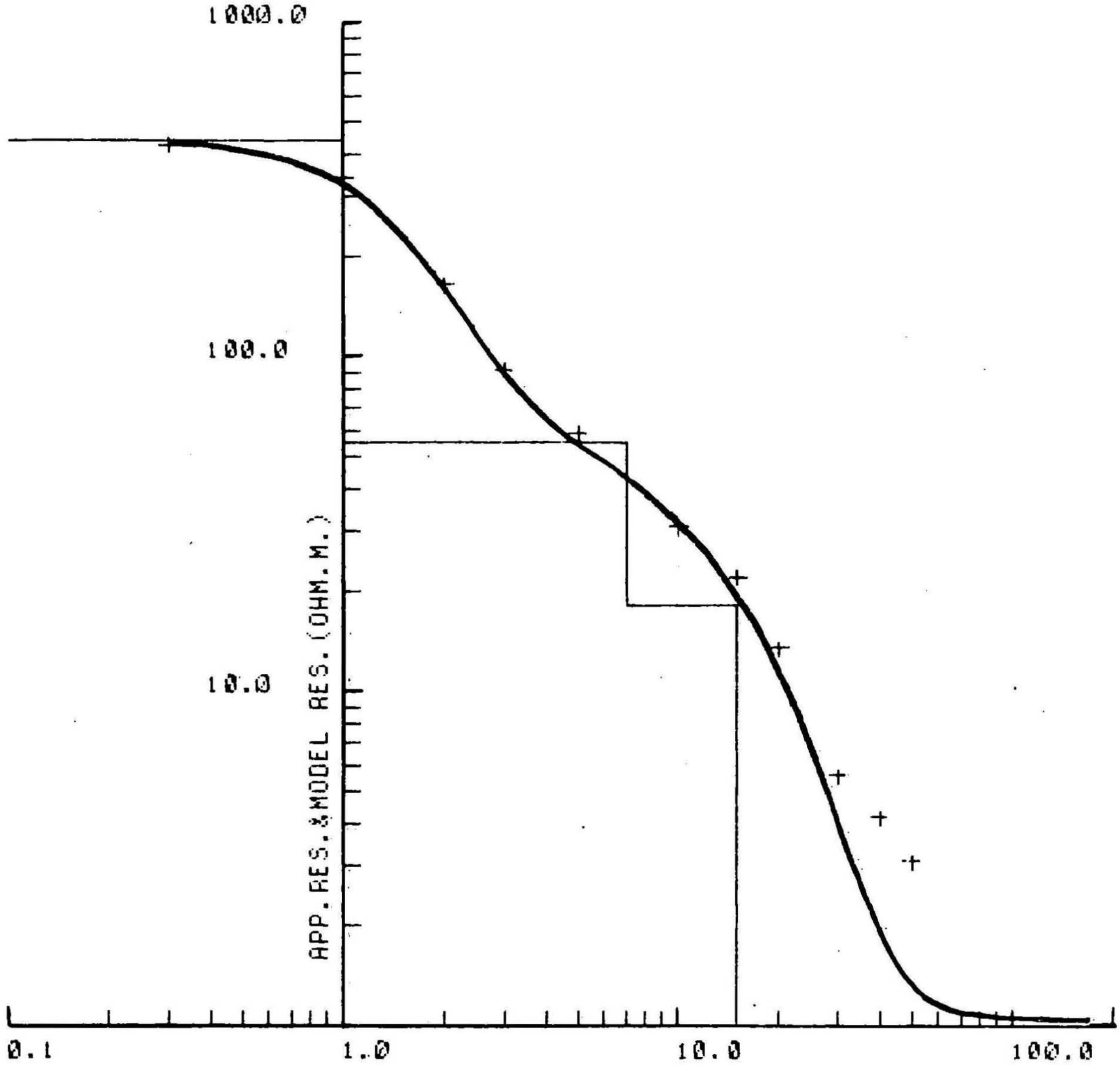
TARAWA PROBE 45 BORE 14 BETIO



LAYER NO.	RESISTIVITY	THICKNESS
1	220.0	0.2
2	330.0	1.2
3	21.0	12.0
4	0.8	

19/09/52

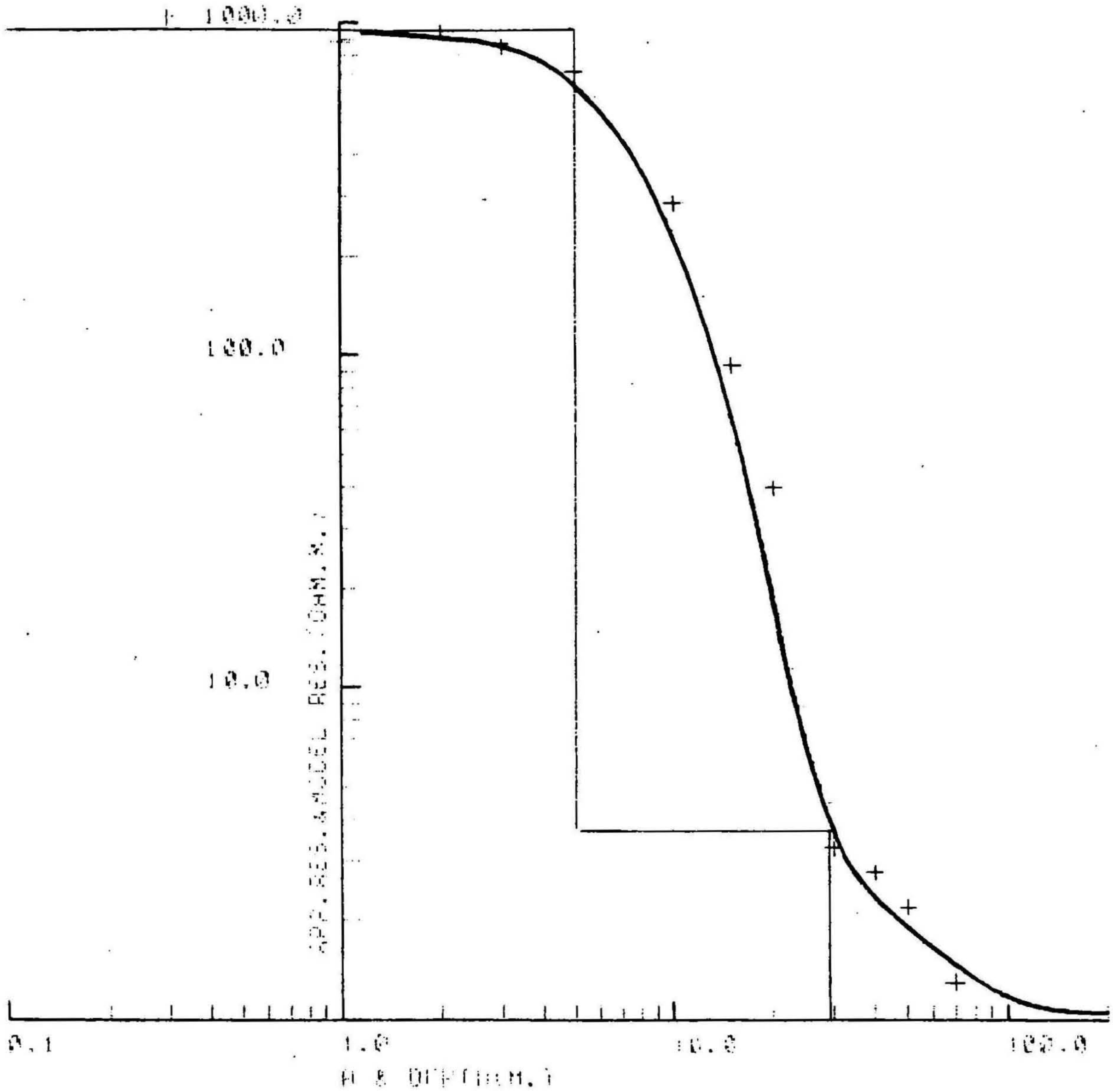
TARAWA PROBE 46 AIRP 1B BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	440.0	1.0
2	55.0	6.0
3	18.0	8.0
4	1.0	

19/09/53

TARAWA PROBE 47 AIRP 2B BONRIKI



LAYER NO.	RESISTIVITY	THICKNESS
1	950.0	5.0
2	3.7	24.0
3	1.0	