ADMINISTRAÇÃO - GERAL DO PORTO DE LISBOA

Hydro-morphological study Tagus Estuary

Part 1
Wave penetration model

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Text & figures

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PORT AND WATERWAY ENGINEERS

hydronamic bv

CONTENTS

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1. INTRODUCTION

The aim of the total study is to have an operational mathematical model with which it is possible to study the hydraulic and morphological consequences of various interventions in the present state. This first part of the study is dealing with the wave-penetration in the Bugio-region.
The results presented in this report can be used as a basis for further calculations later in this study, especially the morphological calculations. But they can also be used as boundary values for the design parameters for constructions planned in the Bugio-area.

Having an idea of the wave-climate in the outer estuary, the lay-out of harbour-basins, berths and jetties can be determined. Also the design of breakwaters depends on the waves to be expected in the area.

This report gives a short review of the approach to the problem, the used boundary values (deep water wave data, calibration data, geometry), a discussion of the results and a conclusion. A description of the mathematical background of the model is presented in Annex A. In Annex B the graphical output of the calculation is given.

2. SET-UP OF THE STUDY

The study is split-up into 3 different types of models:

- wave penetration models
- tidal current models
- sedimentological models

This report describes the results of the main wave penetration model, which gives a description of the way ocean waves penetrate into the estuary. The calculation has been carried out with the use of the computer programs available in our office. These programs are using linear wave theory and the Bouws/Battjes method to overcome the caustics problem. A detailed description of the mathematical background of these programs is given in annex A to this report.
The detailed wave model is not yet run, because it proved from the overall model, that running this model is only usefull, if the planned port-lay-out for the Bugio area is entered correctly in the model. For a description of the nowadays situation the overall method provides enough information. Therefore also wave-height charts and wave-direction charts were made of all the runs of the overall model; this in addition to the ray diagrams, as mentioned in the terms of reference. For the location of the overall model, see fig. 1.
It is suggested that the runs for the detailed model should be determined in discussion with the client.
In this report a description of the used input data for the wave penetration model is given and a discussion of the results.
Finally, some conclusions are drawn.

3. DETERMINATION OF INPUT DATA

Wave data

Basis for the calculation are the deep-water wave data as presented by the Instituto Hidrografico. These data consist of measurements near Costa Caparica and Largoa de l'Albufeira.
Because the data of Albufeira are measured on relativily deep water, they are used as input for the model, while the Caparica data are used for calibration. From Albufeira 702 observations are available, from August 27th, 1979 until April 30th, 1980. Although these data do not cover a full year, one may assume that these data are, as a first approximation representative for the wave climate in the area. When after some years more long term wave measurements are available it is possible to readjust the results of these calculations.
For such a readjustment it is not necessary to make all the computer-runs again. The results of the data presented in this report can be used, when some additional runs are made for special cases, following from the new measurements.
The required input-values for the model are wave-height, wave-period and wave-direction. For the wave-height the significant waveheight from the measurements is used. The zero-crossing period is used as input for the period.

In the table below the relation between H and T is given.
(table copied from data I.H.)

H \ T	3	4	5	6	7	8	9	10	11	12	13	14	15
0 m		0.42	2.42	1.99	2.85	2.27	1.57	1.28	0.43	0.43		0.14	
0.5 m	1.42	5.41	4.84	5.56	4.42	3.42	3.28	2.14	1.57	0.43	0.14		0.14
1.0 m	0.14	3.99	4.99	5.70	5.70	3.85	2.71	0.85	0.14	0.14			0.14
1.5 m		0.43	3.42	3.70	2.85	2.14	1.71	0.43	0.14				
2.0 m			1.28	1.85	1.57	1.57	0.57	0.43	0.14				
2.5 m				0.43	0.43	0.57	0.43	0.14					
3.0 m					0.43	0.14							
3.5 m					0.14								
4.0						0.14							

frequency of occurrance (%)

In this way the wave-climate is split up in 59 elements. Because this number of elements is too large, the elements are grouped.
For calculating the average value of each group for the wave-height the (weighed) root-mean-square value is used. For the periods the normal arithmetic (weighed) mean is used. This operation results in the following table:

H (m)	T (sec)	%
0.5	3.8	6.82
1.0	4.0	4.13
0.8	5.0	9.83
1.6	5.0	4.70
0.8	6.0	11.26
1.7	6.0	5.98
0.8	7.0	10.12
1.7	7.0	4.42

H (m)	T (sec)	%
0.8	8.0	7.27
1.6	8.0	3.73
0.8	9.0	5.99
1.6	9.0	2.27
2.8	7.7	2.28
0.6	10.5	5.27
3.5	10.2	1.28
0.7	14.3	0.43

The data of this table are also presented in an exceedance-diagram (see fig. 2)

With these 16 elements a large number of calculations has been made. During the calculations it proved however that splitting up the wave climate in 16 elements is not necessary. Therefore the last calculations have been made with only 8 elements, viz:

H (m)	T (sec)	%
0.72	3.8	10.96
0.79	3.5	21.09
1.71	5.6	10.68
1.15	7.8	33.79
2.80	7.7	2.18
0.60	10.5	5.27
3.50	10.2	1.28
0.70	14.3	0.43

According the information from the Instituto Hidrografico, the wave-directions are distributed as follows:

230°-260°	8.2 %
265°	13.9 %
270°	24.6 %
275°	19.0 %
280°	21.3 %
285°-320°	12.9 %

It can be seen that nearly 80% of the waves come from the directions 265°, 270°, 275°, 280°. Therefore, in first instance only these situations have been considered. Analysis of the relation between wave-period and wave-height indicated that there is a rather uniform distribution of periods and wave-heights over the direction.
So, in first intance 4 x 16= 64 wave-penetration runs were made. (runs TG01 until TG64).

The fact that all the waves come from western directions implies however that there are no waves from other directions. And because these data are supposed to be deep water wave data, it implies that on the western Atlantic Ocean there are no waves from other directions than west. Of course this cannot be true.

An explanation for this contradiction can be found in the fact that the observations of wave-height and wave-period are made with a wave-rider buoy, which as located at relatively deep water, while the wave directions were observed visually from the shore.
Thus: wave-heights and wave-periods are deep water data and wave directions are shallow water data.
To illustrate the effect of the depth on the wave direction six large scale wave-penetration calculations have been made (see fig. 20-25).
It can be seen that near the measuring station the wave is not very much refracted, but that near the coast all the waves come from western directions.

Because of this fact it is not possible to use the directional information from the I.H.-data. As a replacement the data from the "Ocean Wave Statistics" (Hogben & Lumb, HMSO London, 1967) have been used:

dir.	%		
180°	8%		
210°	10%	235°	3.2%
240°	18%	240°	5.6%
270°	24%	245°	4.3%
300°	20%	250°	4.9%
330°	20%		

Because detailed calculations for the directions 235° - 250° were available from initial runs the 18% from 240° has been split up in more detail.
Because waves from the south occur relatively seldom, no special calculations has been made for this direction. But in order to get the right results the occurrance of the 210° -waves has been increased with 8%. From fig. 24 and 27 follows clearly that waves from 300° and 330° do not reach the studied area, so they are omitted too. The total number of wave penetration calculations is therefore 80, not included the 6 calculations in the large scale model.

Calibration data

Because not very much wave-measurements were available from the area itself, it was difficult to find wave data for calibration of the model. The best data for this purpose were wave-measurements made by the Instituto Hidrografico just off Costa Caparica (426 observation from 10-07-1979 until 15-04-1980). The data provided were reprocessed and are presented in fig. 3. The direction of all the waves was 240°.

Geometry

The location of the modeled area is presented in figure 1. This area is devided into 40 x 66 = 2640 mesh points, each on a distance of 250 m. The depth information used is taken from the hydrographic charts, surveyed by the Instituto Hidrografico in 1965 (scale 1:5000). For the Bugio area a survey from 1974 has been used. The data were entered into the computer, with an accuracy of 0.1 m. A print-out of the entered data is added at the back of this report (table 1).

4. COMPUTATIONS

First a limited number of testruns were made in order to check if all programs did their job in the correct way. Then for all the 80 cases a wave-penetration calculation was carried out, resulting in wave-height data along the various wave-rays. For later reference these data were printed out and stored on computer disc. The data on disc were plotted, which resulted in the wave-ray diagrams as presented in Annex B. Because the rays do cross each other, frequently, the behaviour of the waves in such caustics cannot be derived from the ray-diagrams.
Therefore the stored data were processed again according the Bouws & Battjes method, which resulted into two matrices. The first matrix contains the average direction in each mesh-point, the second one the average wave-height in each mesh-point. These two matrices were also plotted. Plots are presented in Annex B.
The printed computer output (approx. 200 pages per run, thus in total approx. 14000 pages) are not added to the report, but are available upon request.

In ten seperate points (for their locations see fig. 4) the wave-climate is determined. The results were printed out (see table 2: "wave frequencies in selected points" at the end of this report) and plotted (fig. 5-14)

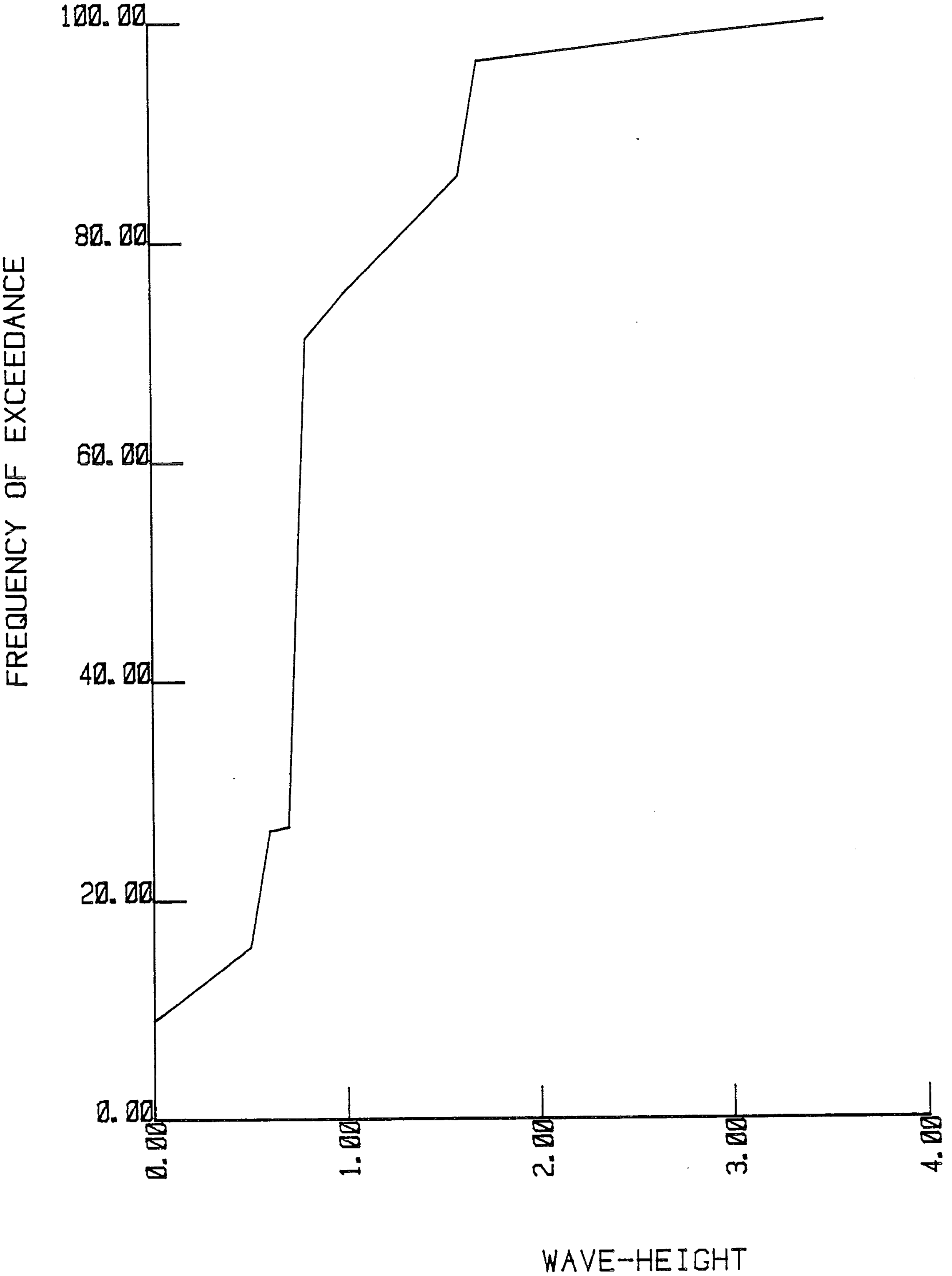
The results of point 10 should be more or less identical to the measured wave-climate from Costa Caparica. Both curves are plotted in figure 15.
From this figure one may conclude that the model describes the wave-penetration in the Bugio area rather well.

6. CONCLUSIONS

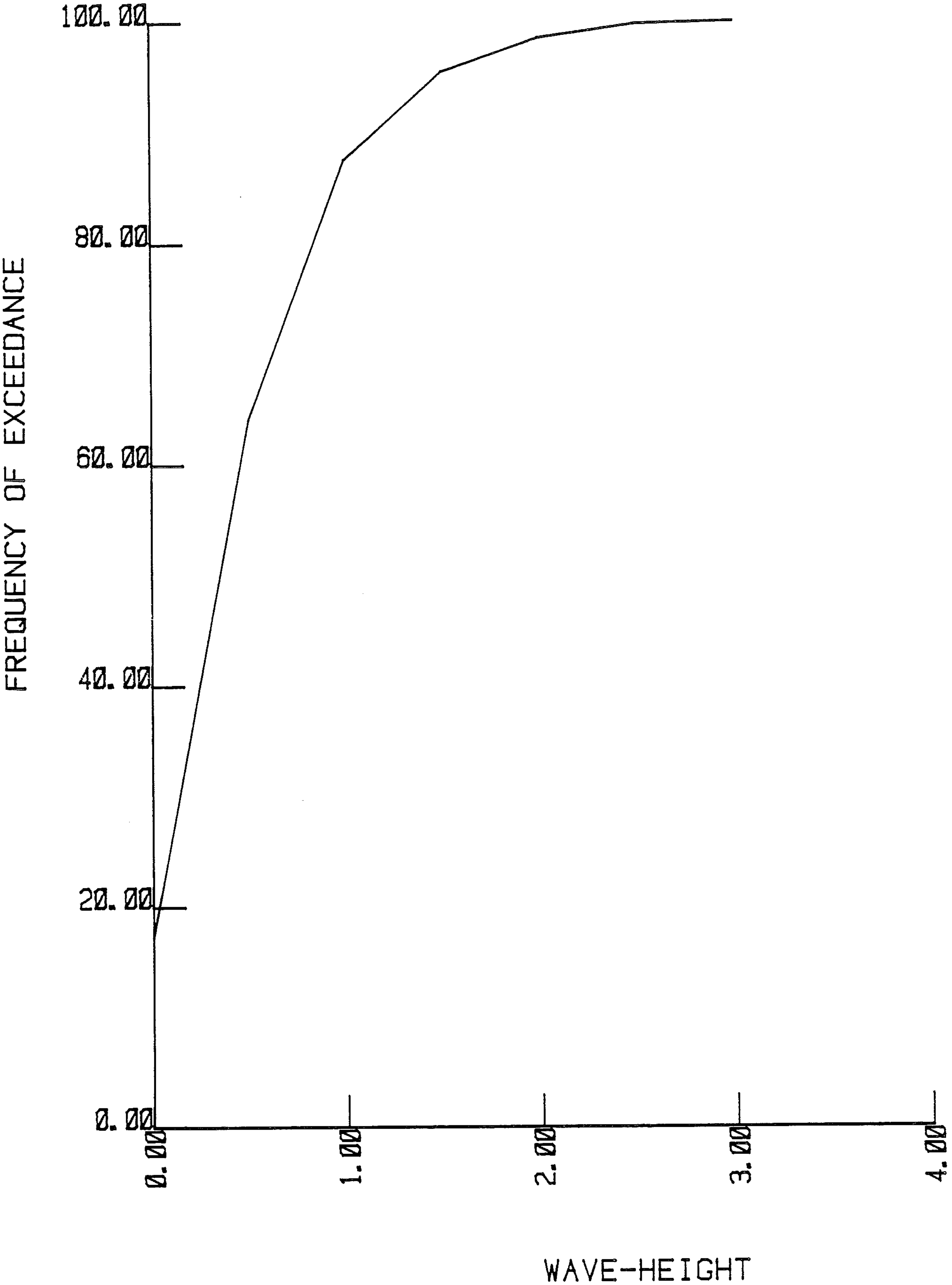
The wave climate in the Bugio-area is very irregular due to the irregular bottom-topography. Rough seas may be expected at any point south and southwest of Bugio.
The northern slope of the Bugio-bank is hardly exposed to wave-influence. Port facilities on this slope are not very much influenced by ocean waves.

In the Alpeidao region a very turbulent area is expected. Much sediment will be brought into suspension in this area. Wave heights on the Bugio-bank itself are very limited due to small waterdepths, although during high water the waveheight may rise to a considerable value.

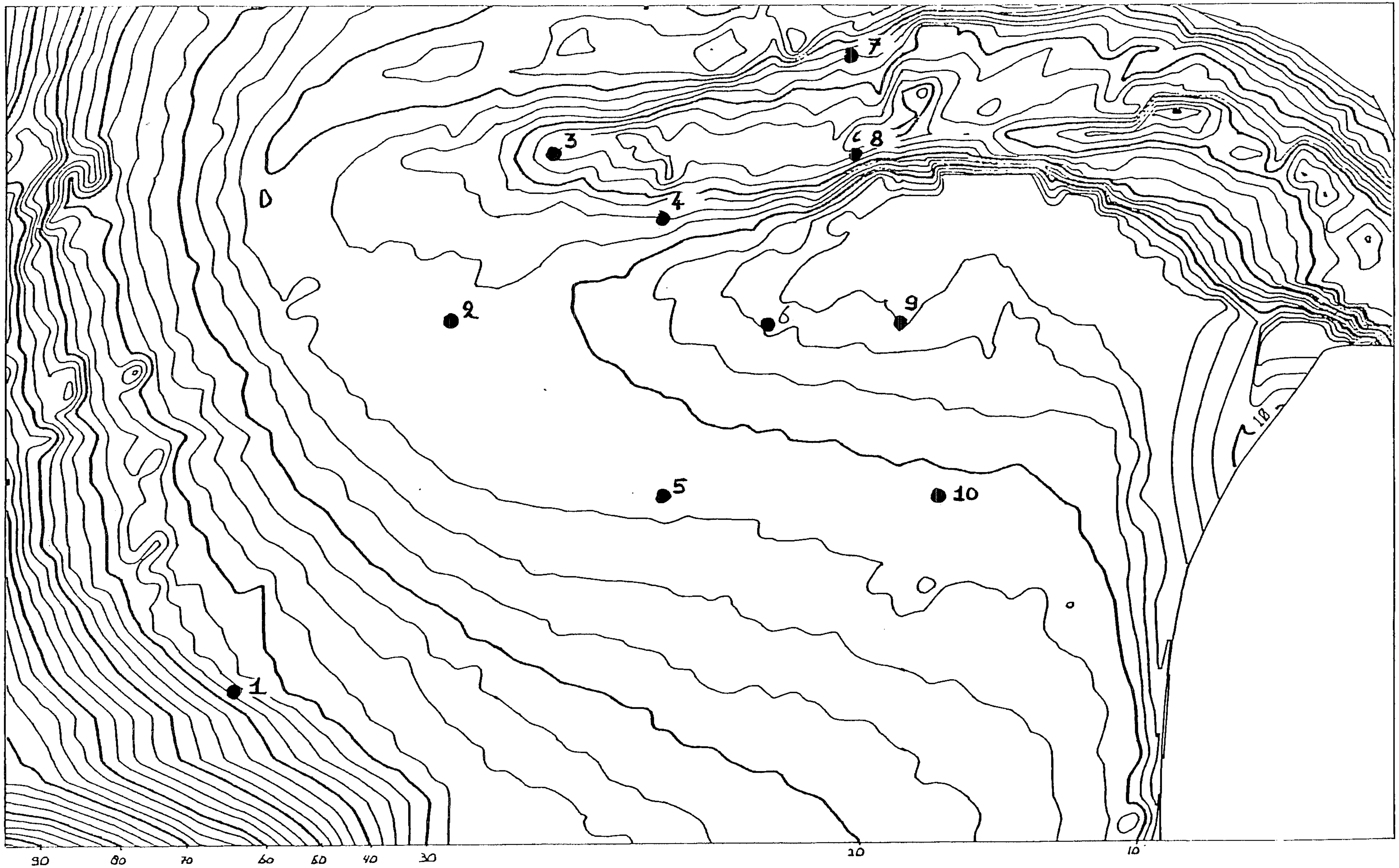
F I G U R E S



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS ALBUFEIRA
P473	FIG.: 2



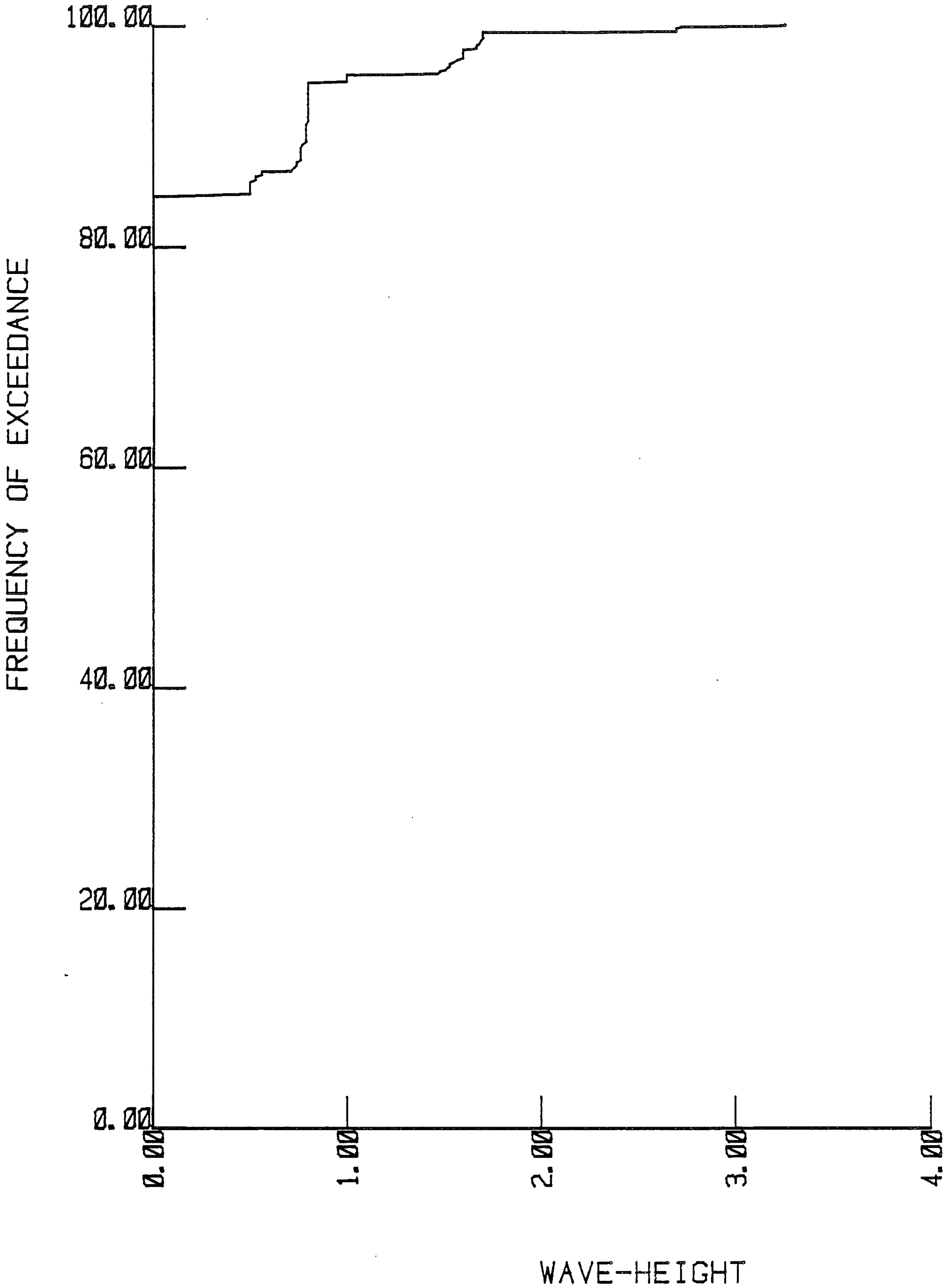
A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS COSTA CAPARICA
	P473	FIG.: 3



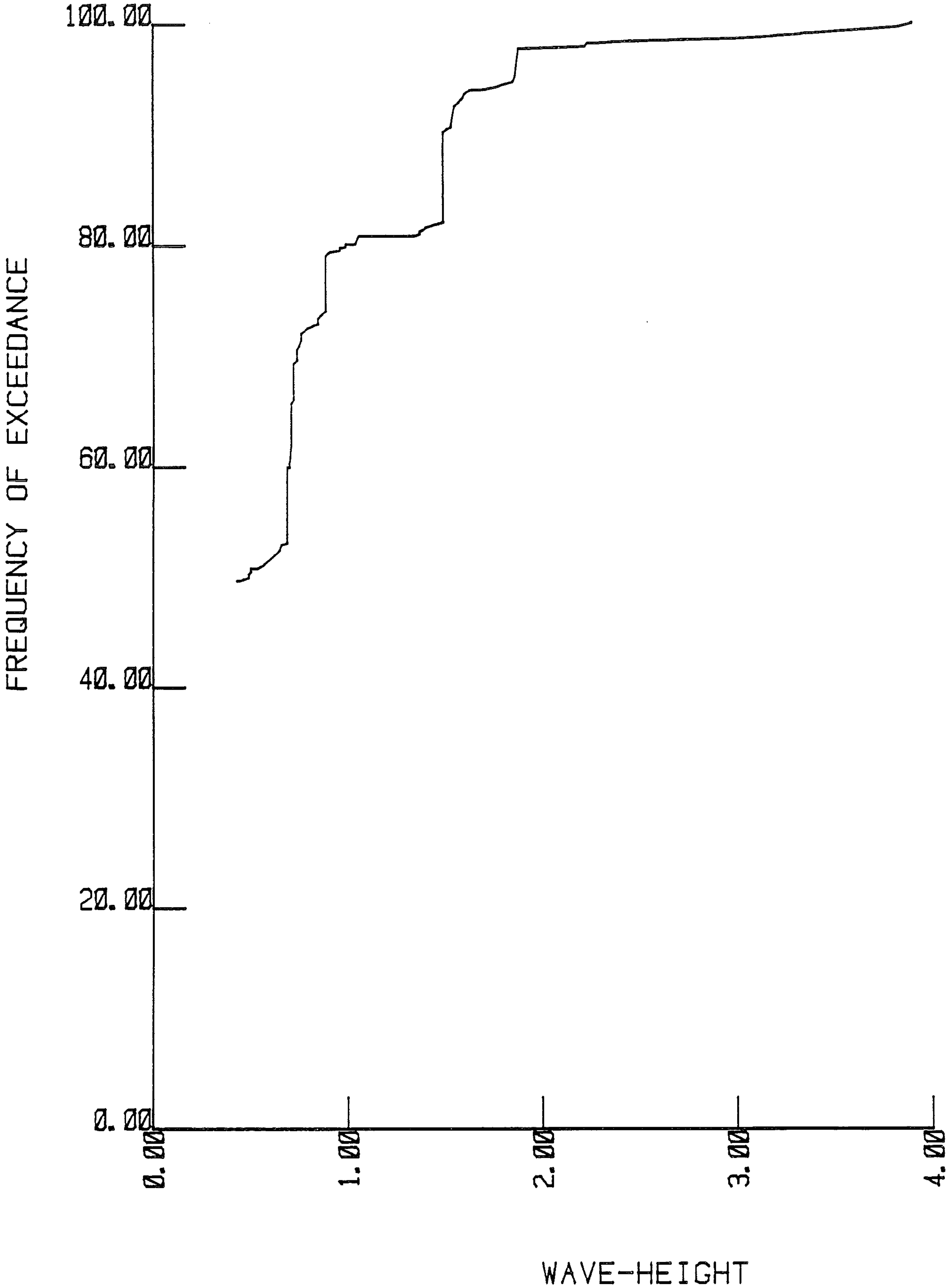
Locations of the calculated
wave climates.

hydronamic

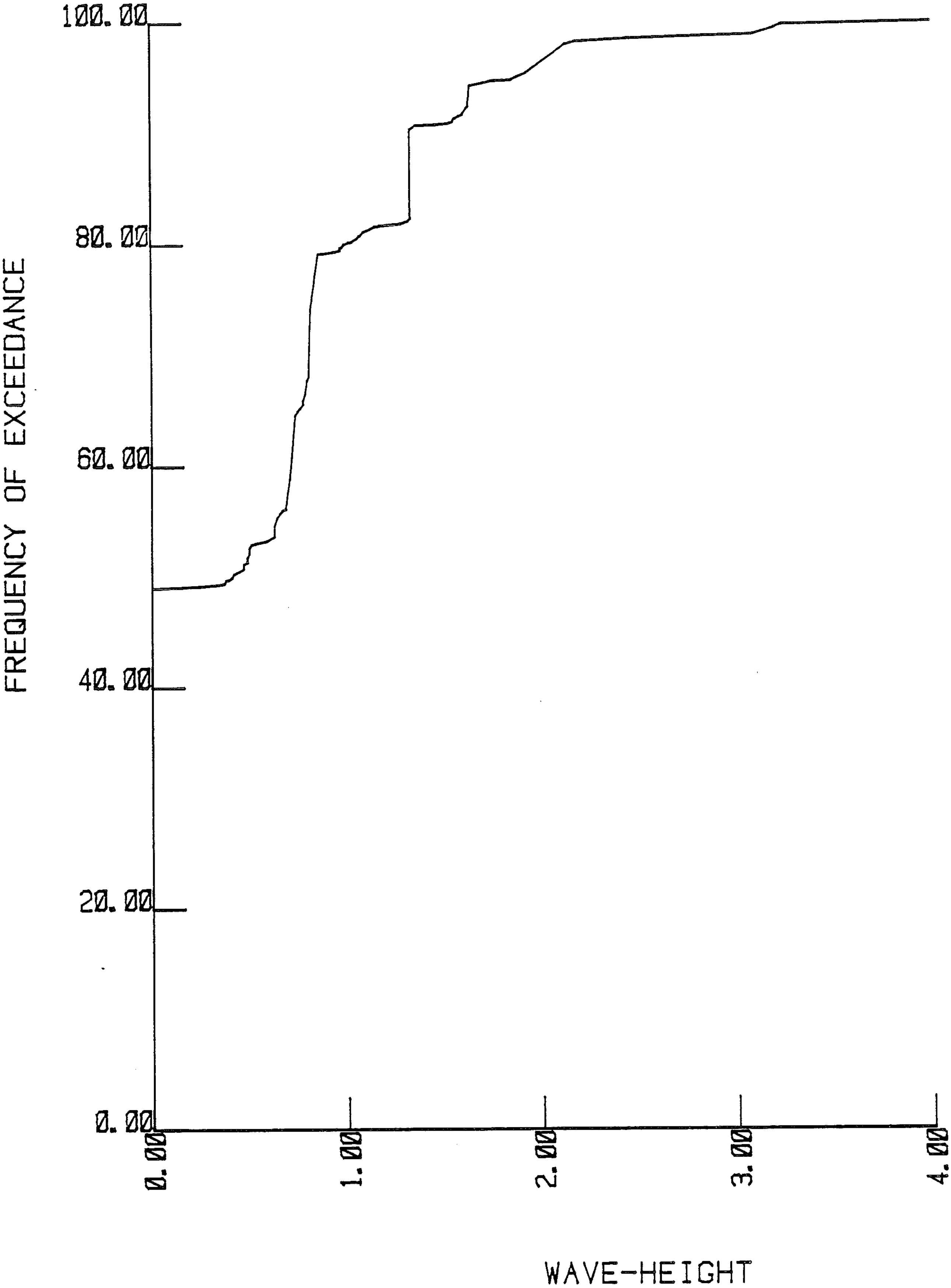
FIG.: 4



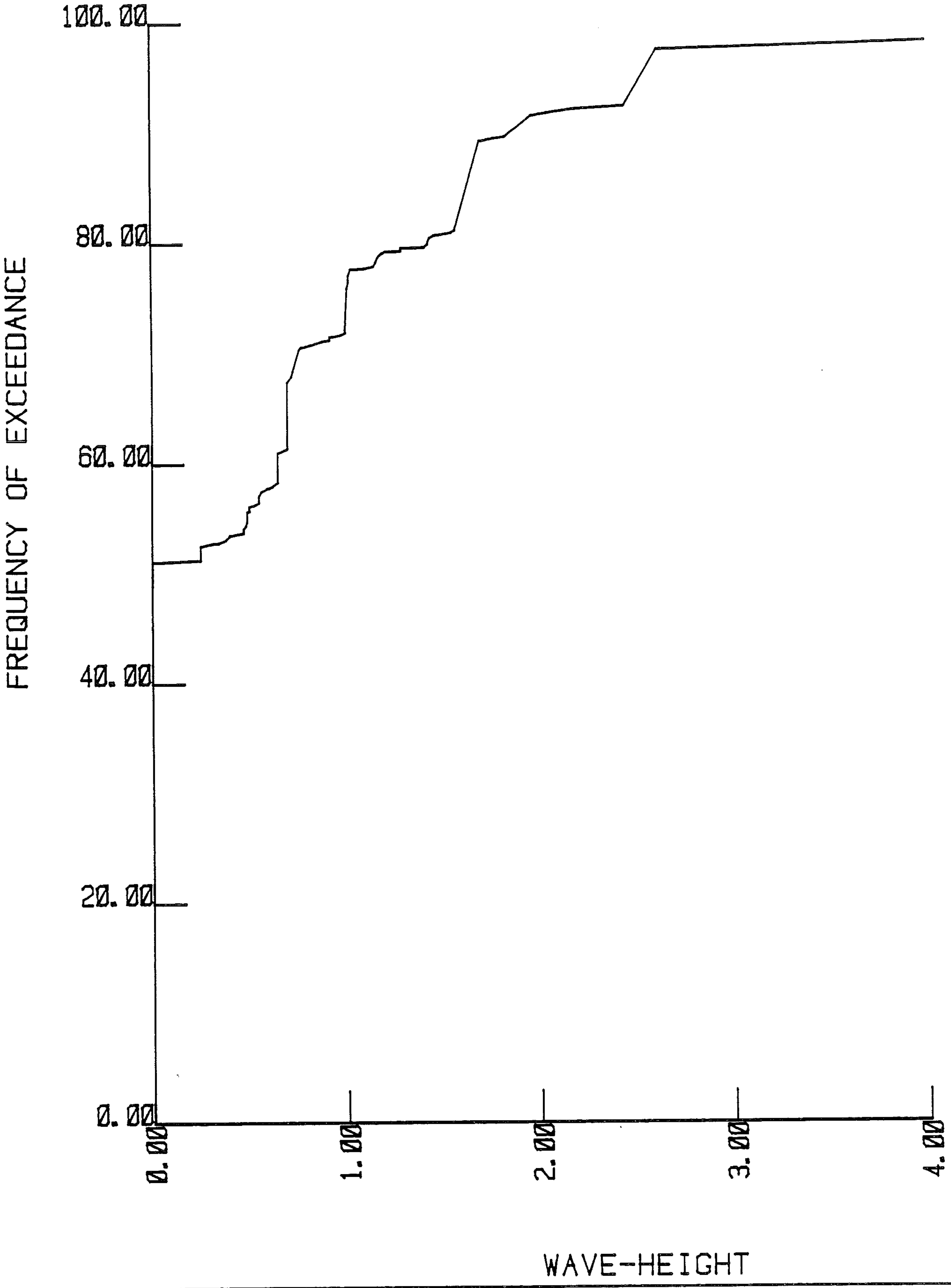
A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 1
P473	FIG.: 5



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 2
	P473		FIG.: 6

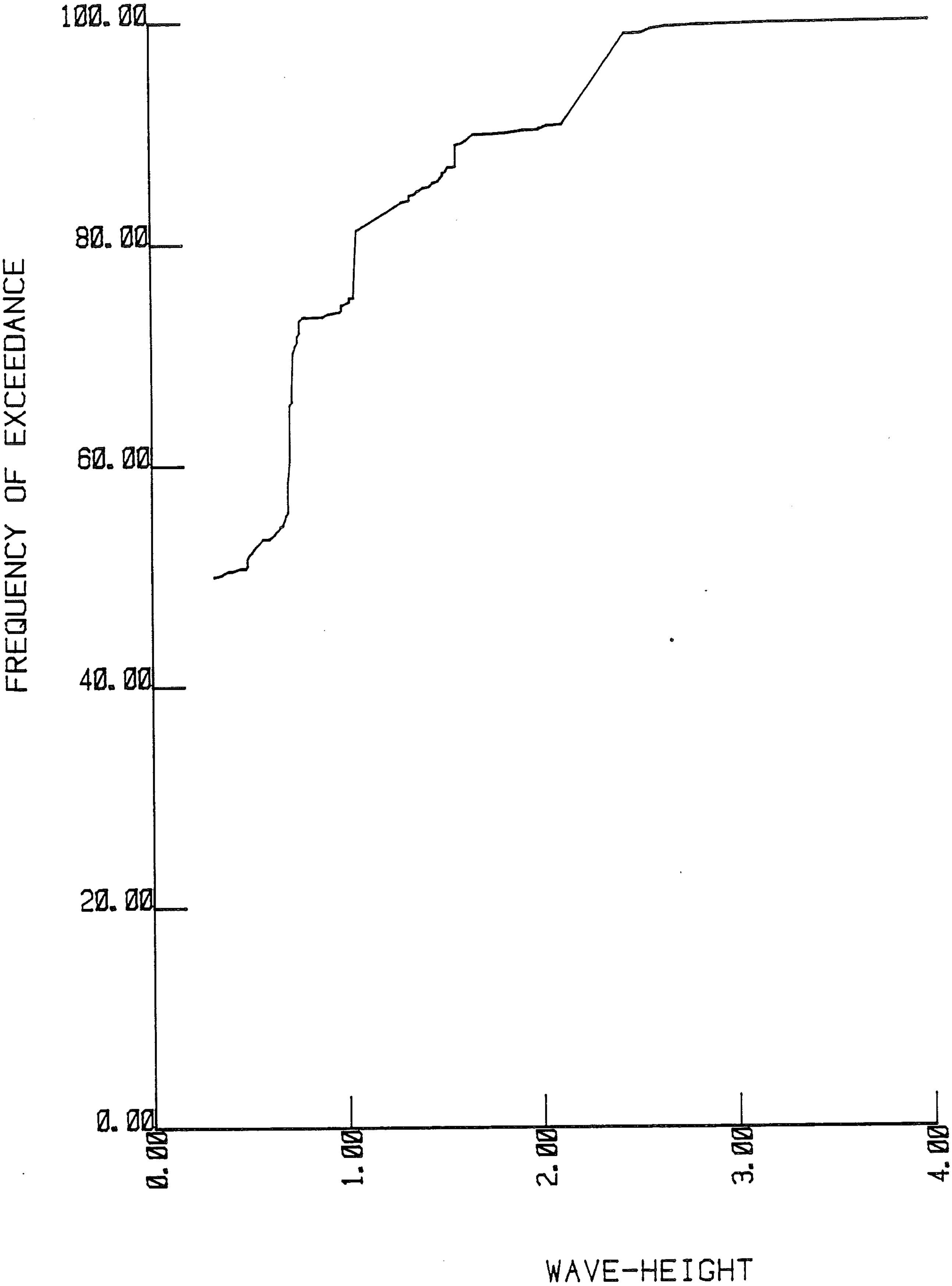


A.G.P.L.	MATHEMATICAL MODEL TAGUS ESTUARY		
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 3		
	P473		FIG.: 7

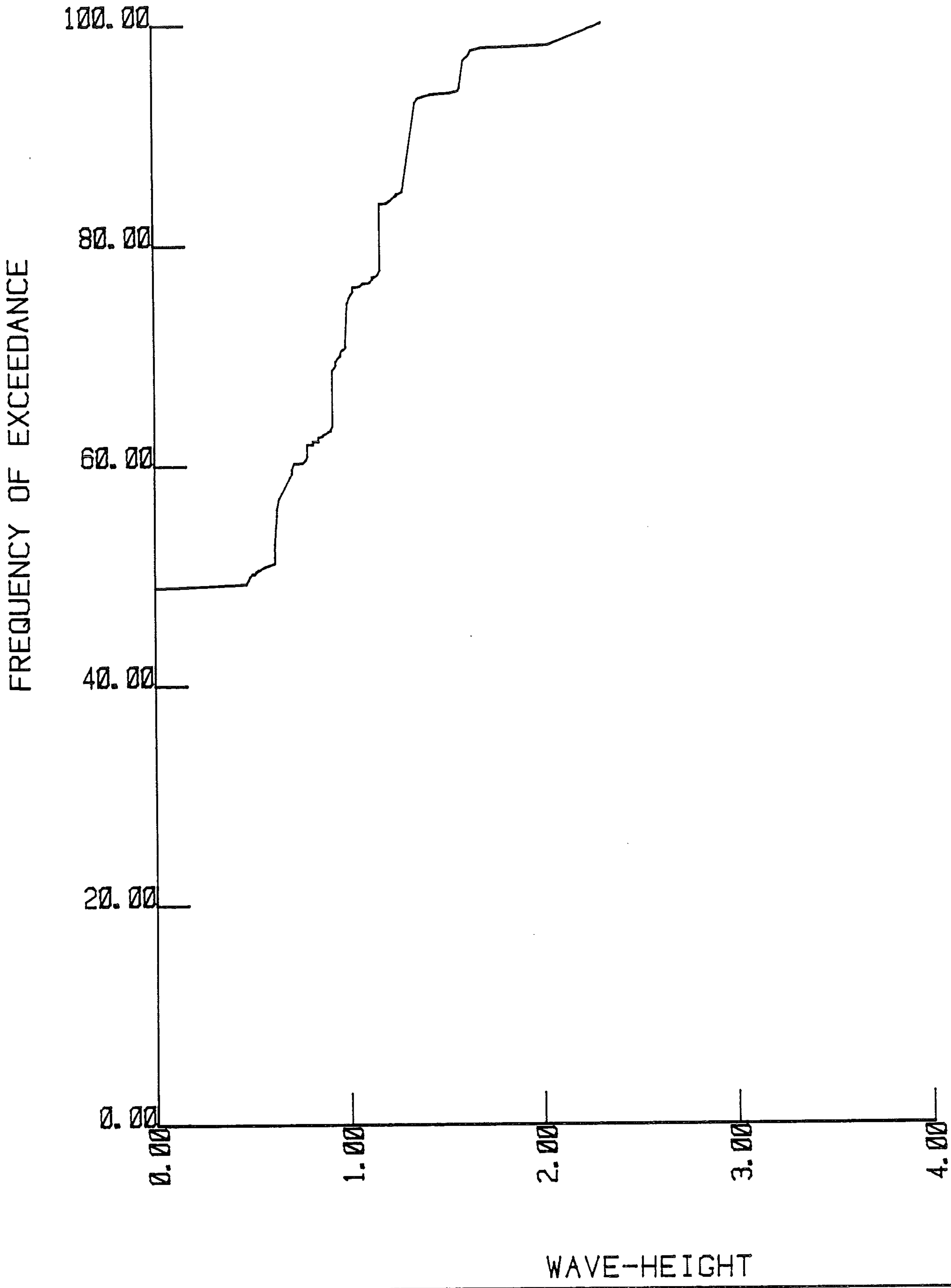


A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 4

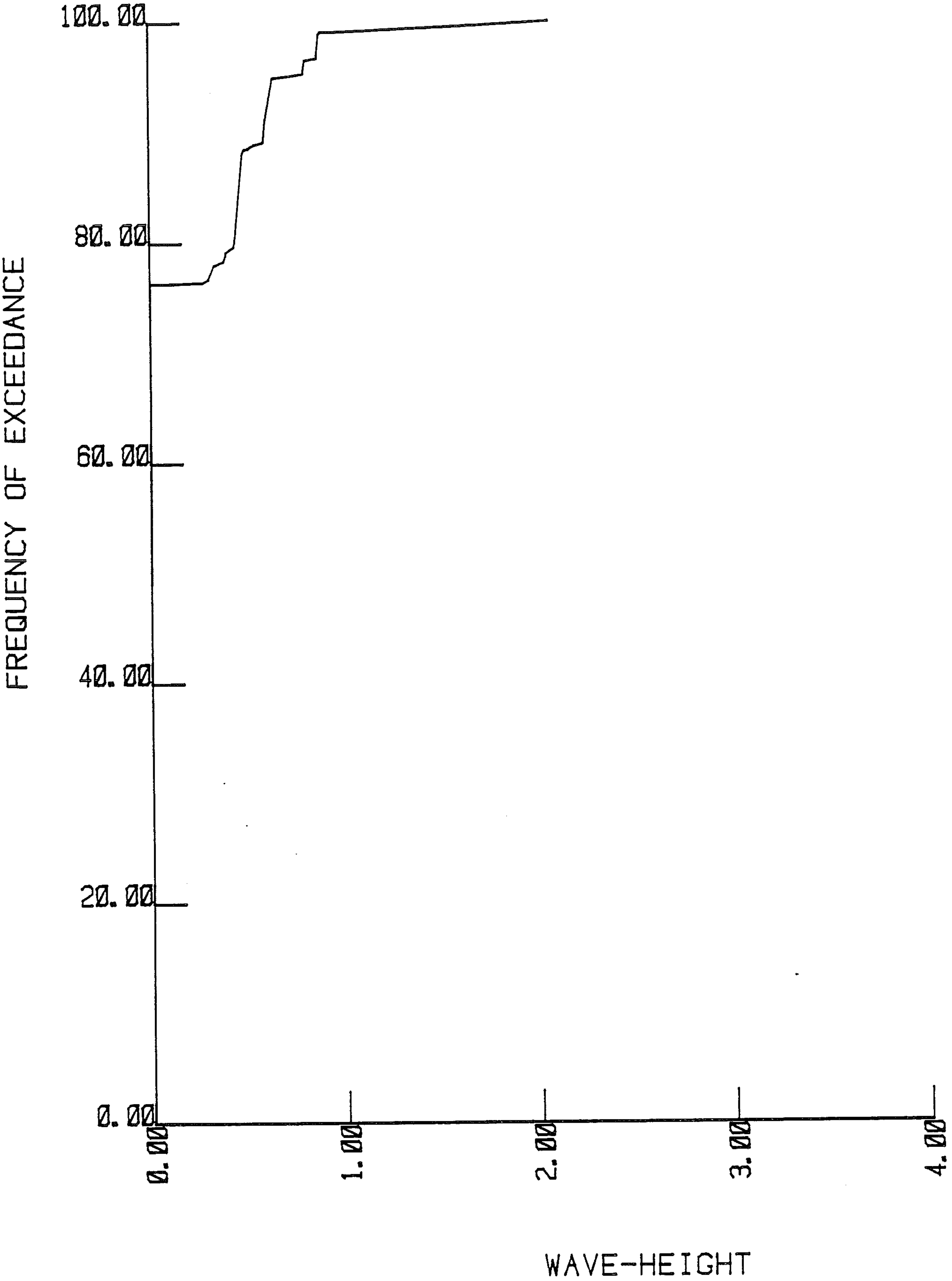
P473		FIG.: 8



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 5
	P473 | | FIG.: 9



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 6
	P473 | | FIG.: 10



A.G.P.L.

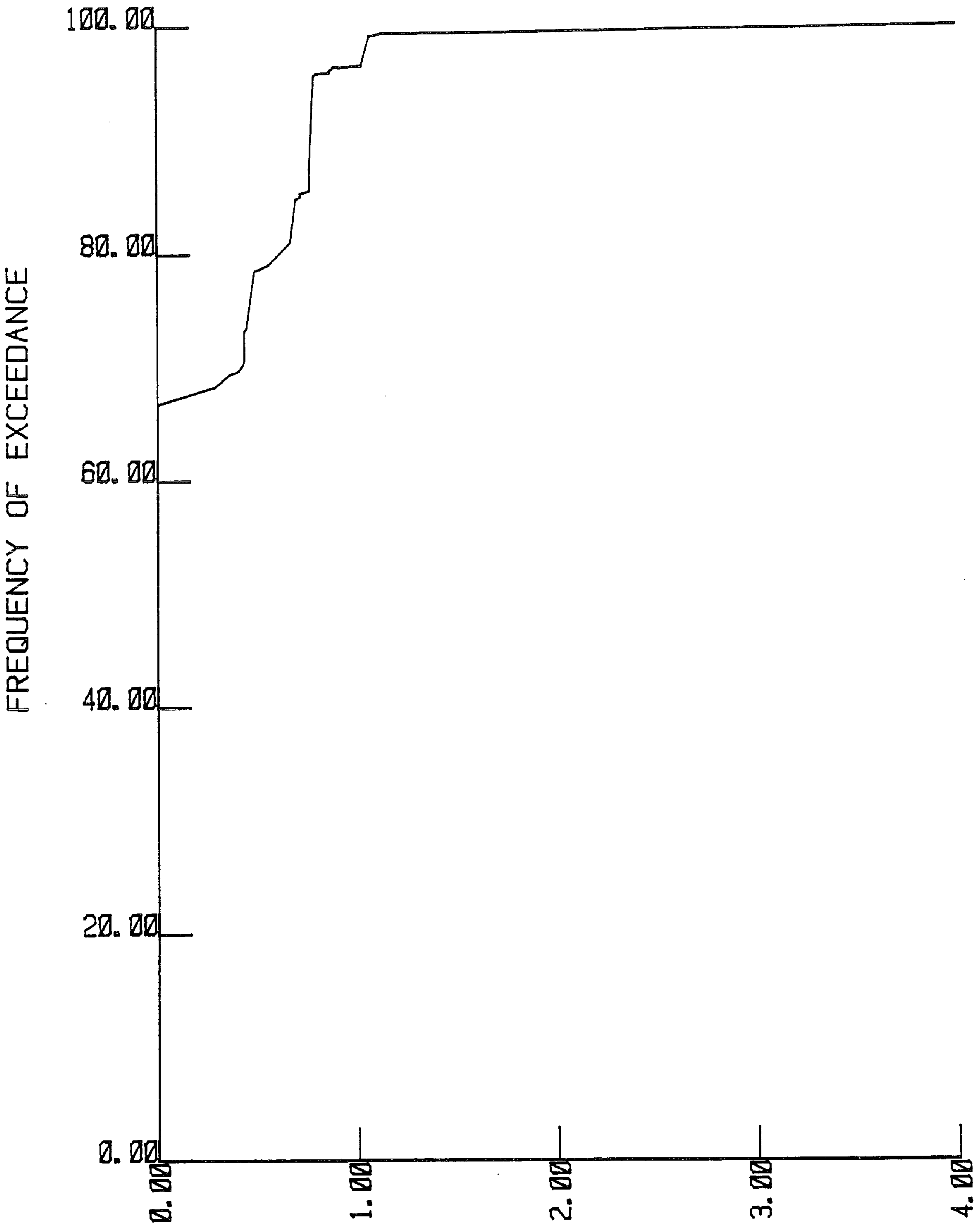
MATHEMATICAL MODEL TAGUS ESTUARY

hydronamic bv
sliedrecht holland

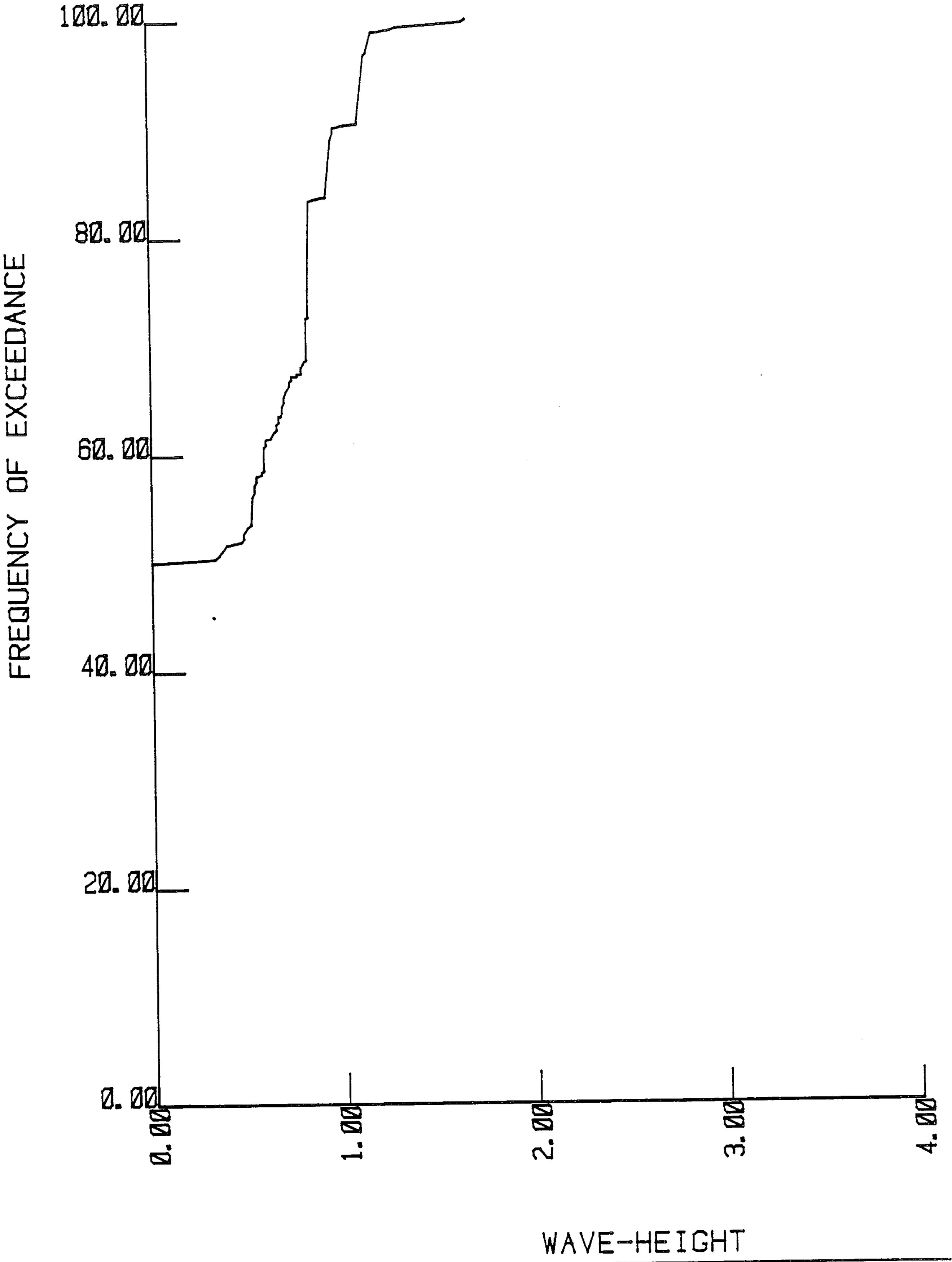
CALCULATED WAVE HEIGHTS
POINT 7

P473

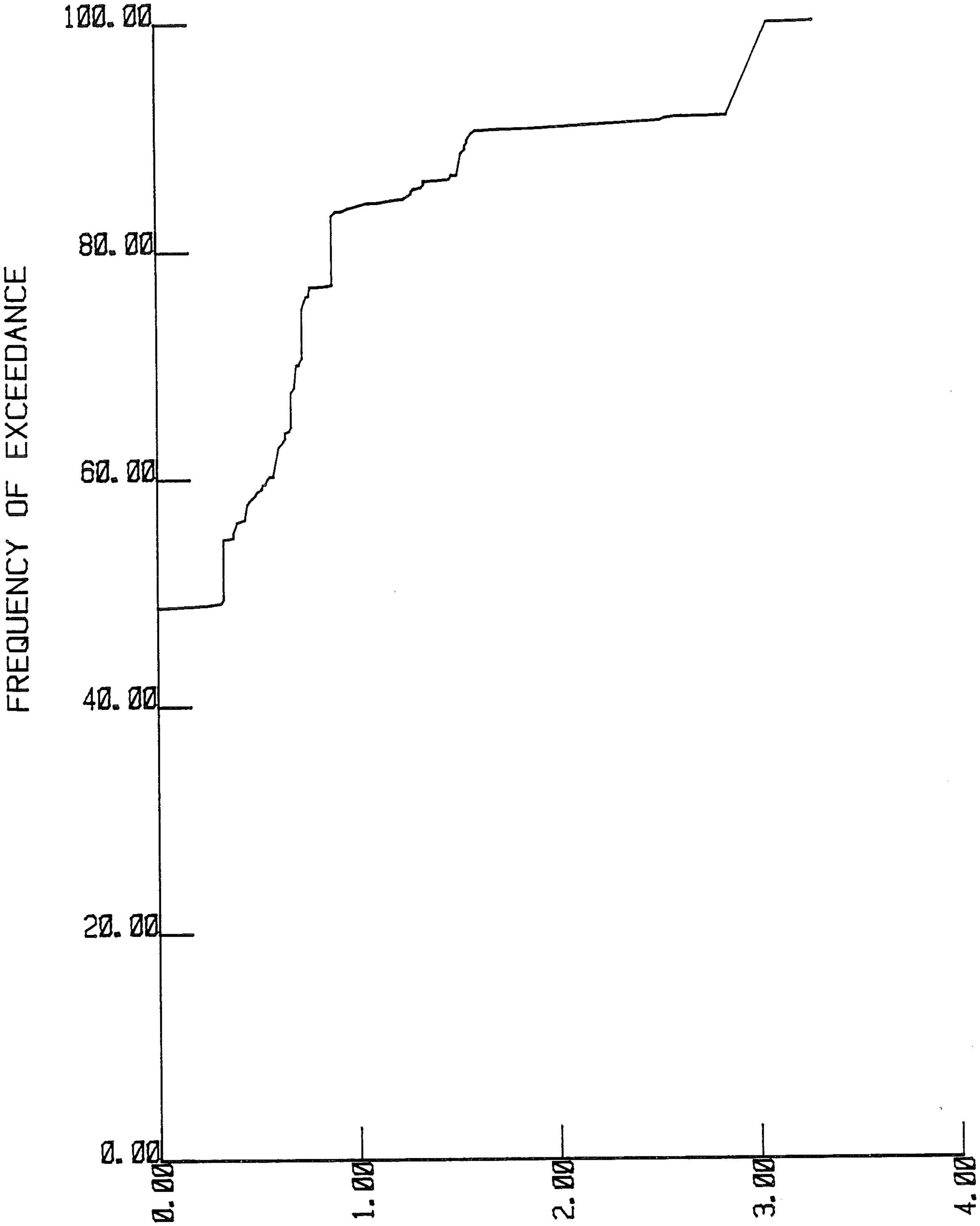
FIG.: 11



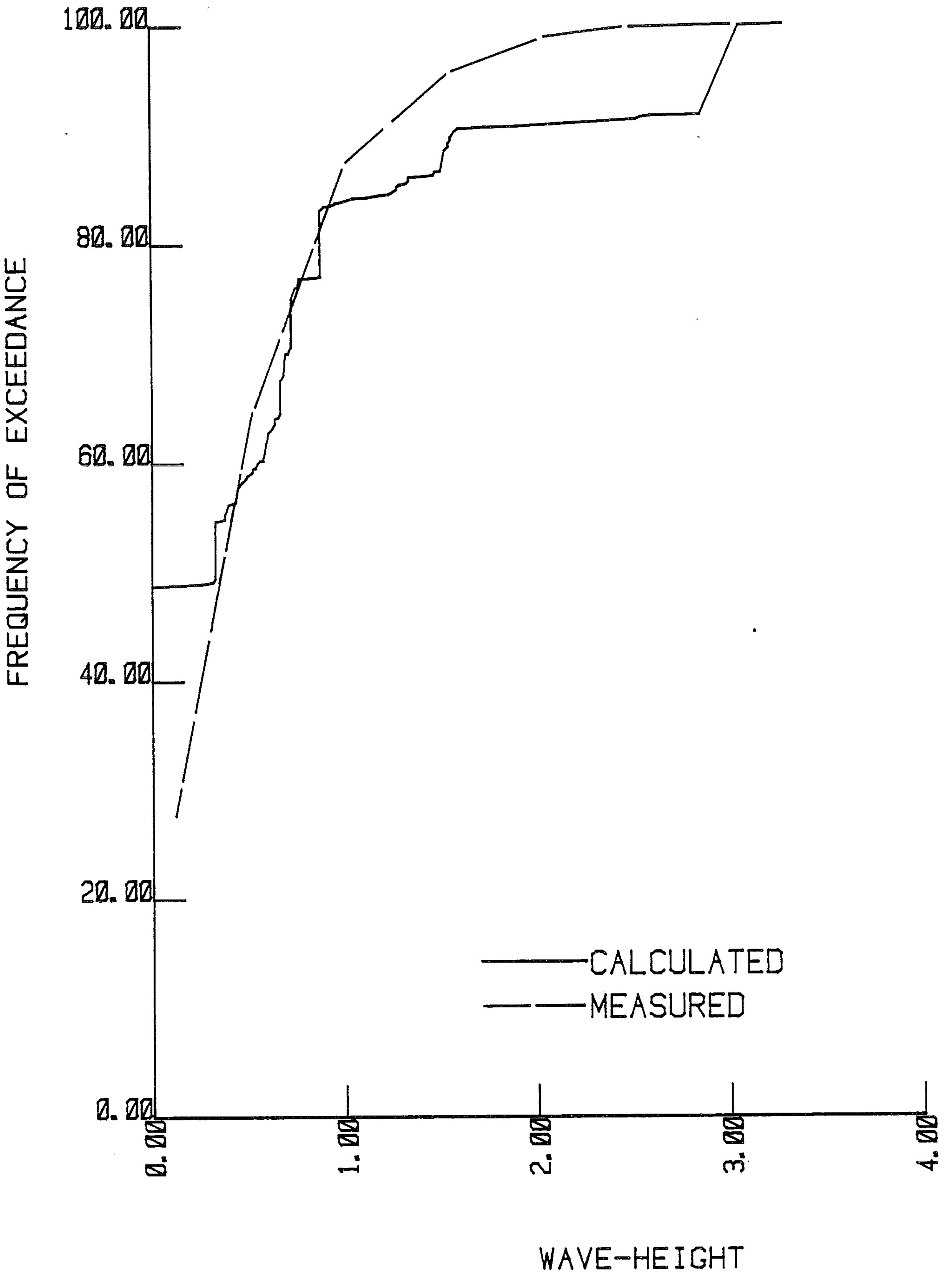
A.G.P.L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 8
	P473 FIG.: 12



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY		
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 9		
	P473		FIG.: 13



A.G.P.L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	CALCULATED WAVE HEIGHTS POINT 10
P473	FIG.: 14



A. G. P. L.	MATHEMATICAL MODEL TAGUS ESTUARY
hydronamic bv sliedrecht holland	MEASURED AND CALCULATED DATA COSTA CAPARICA

P 473		FIG.: 15

area's of extreme wave-height

FIG.: 16

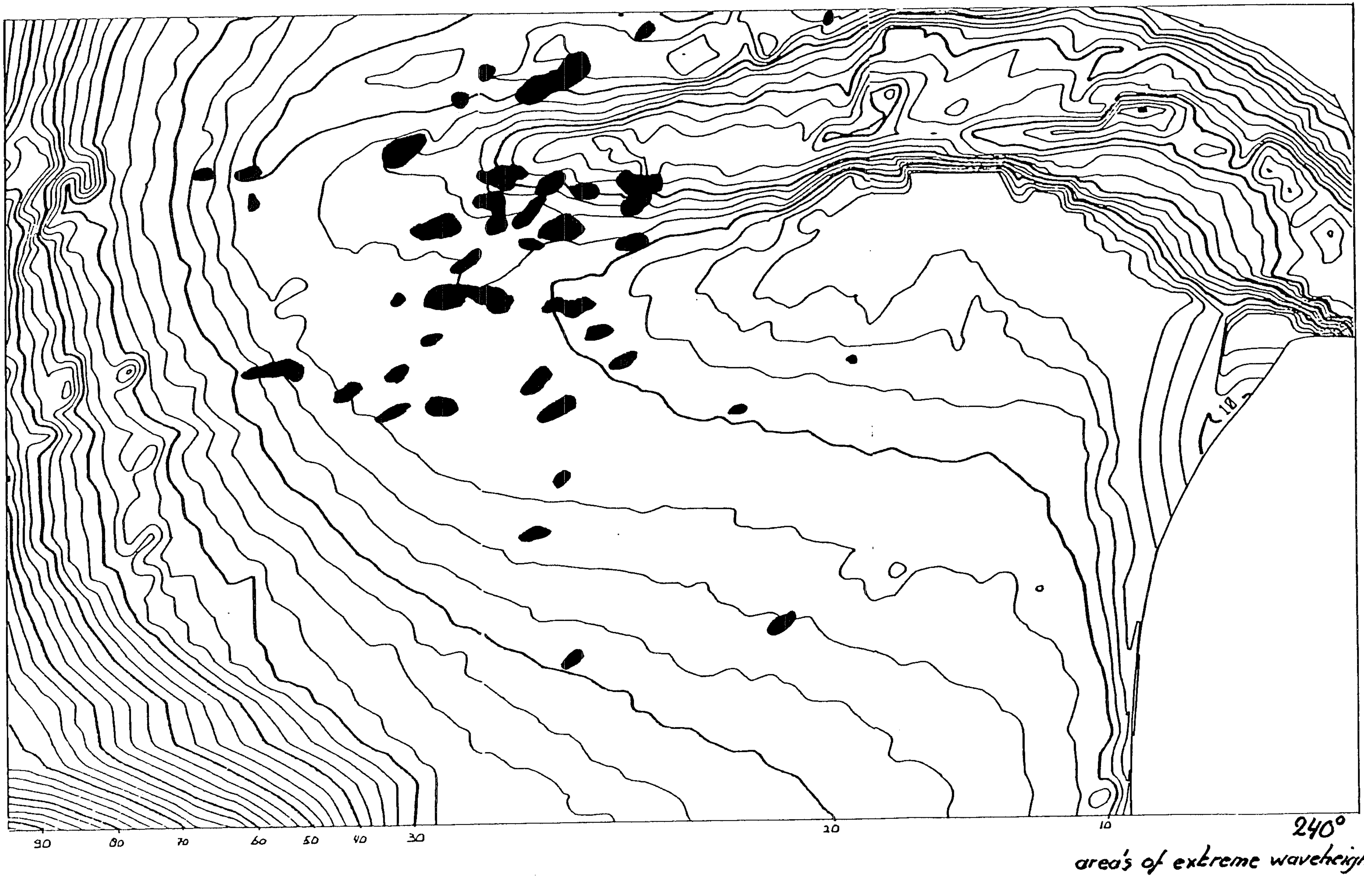


FIG.: 17

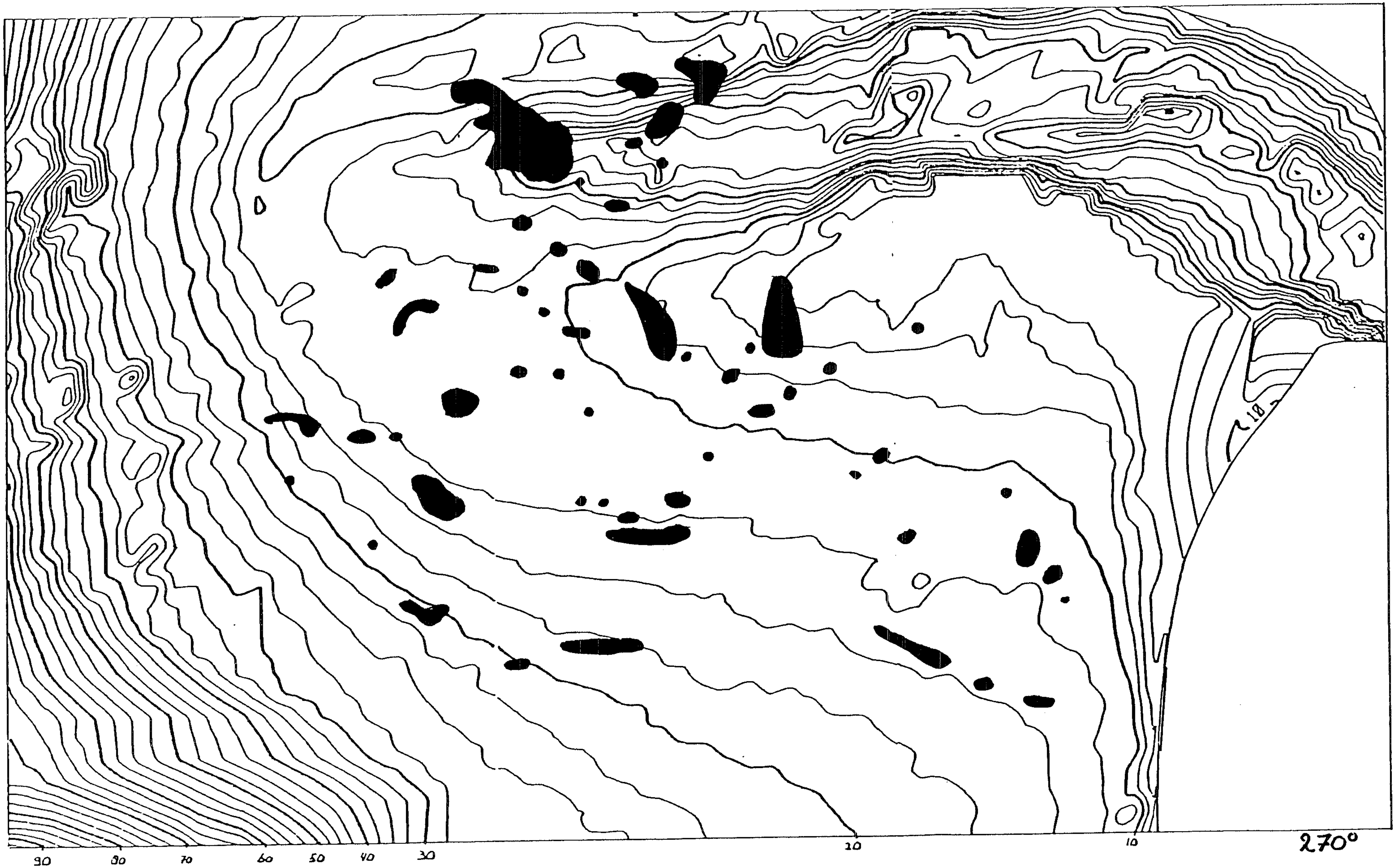


FIG.: 18

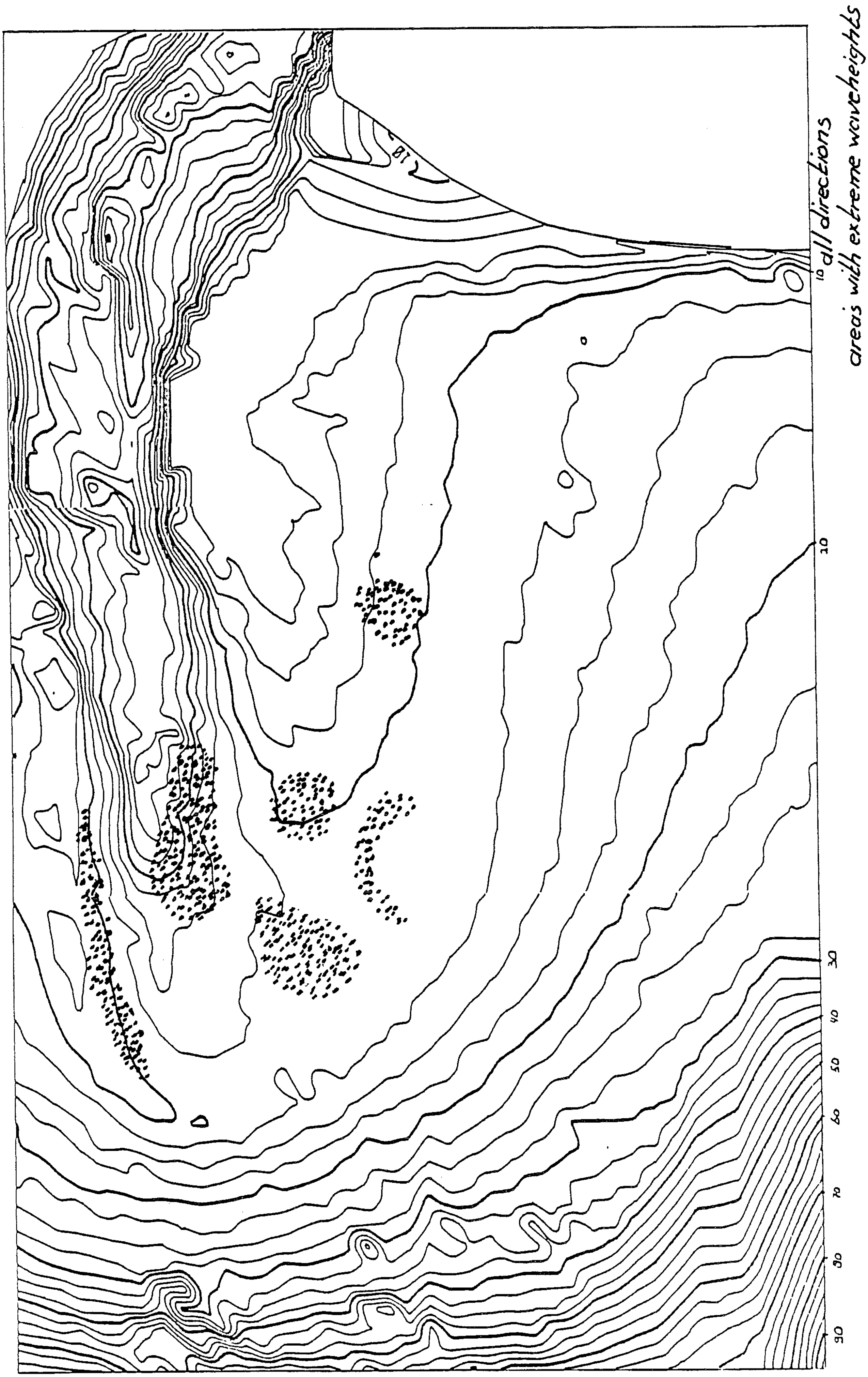
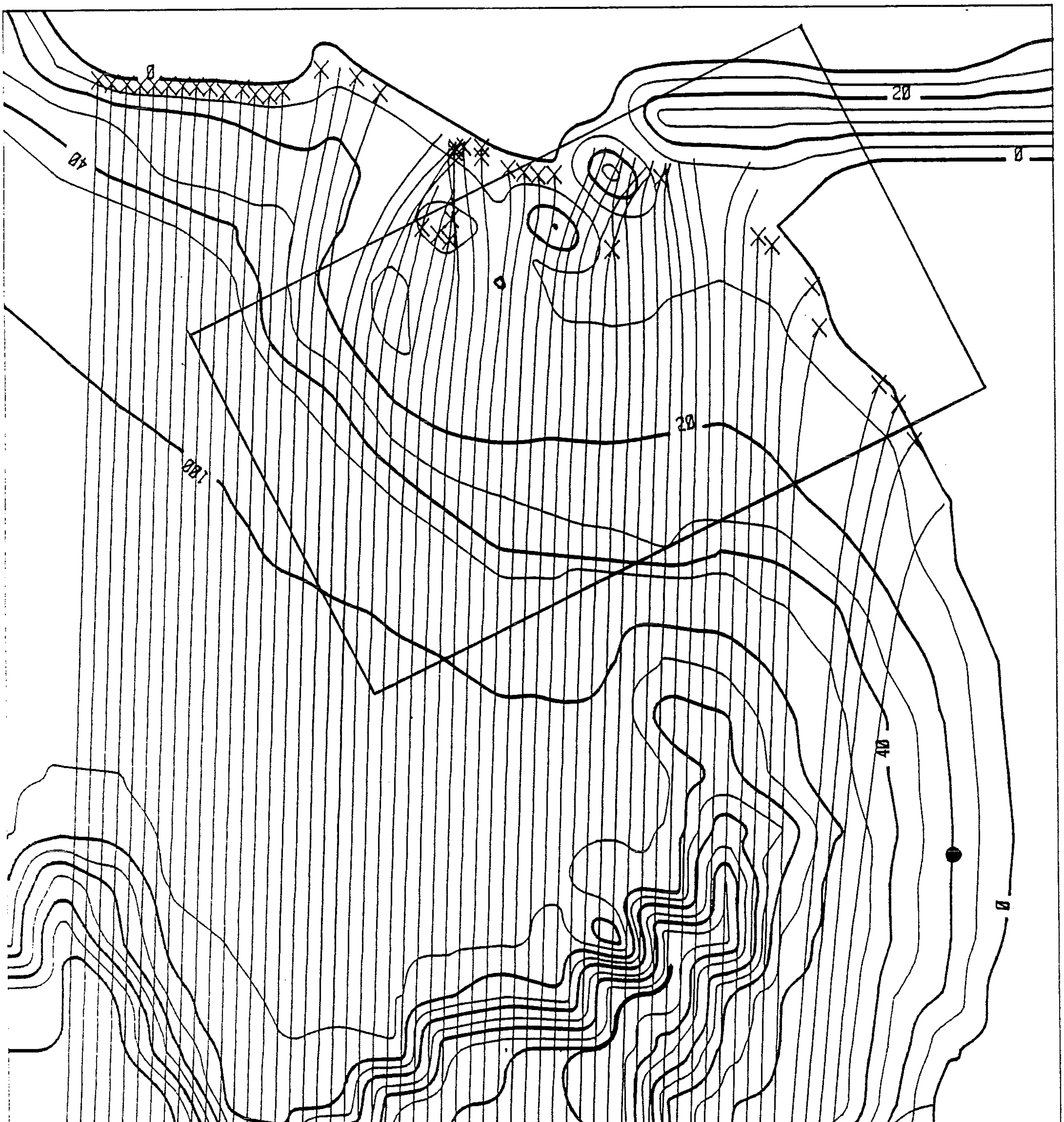


FIG.: 19



South
180
8°/s

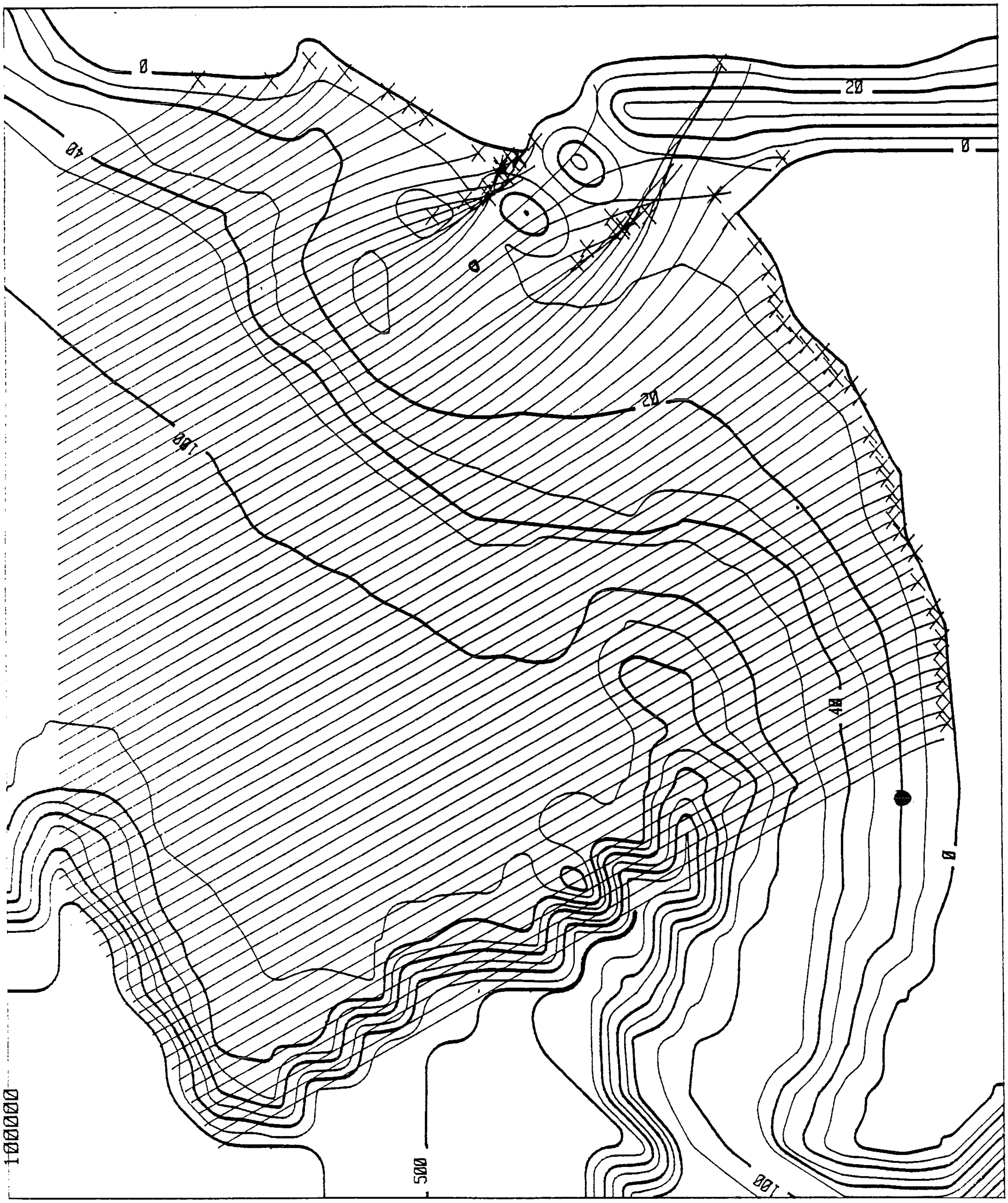
TAAG
SCALE 1:

FIG.: 20

TAAG

SCALE 1: 100000

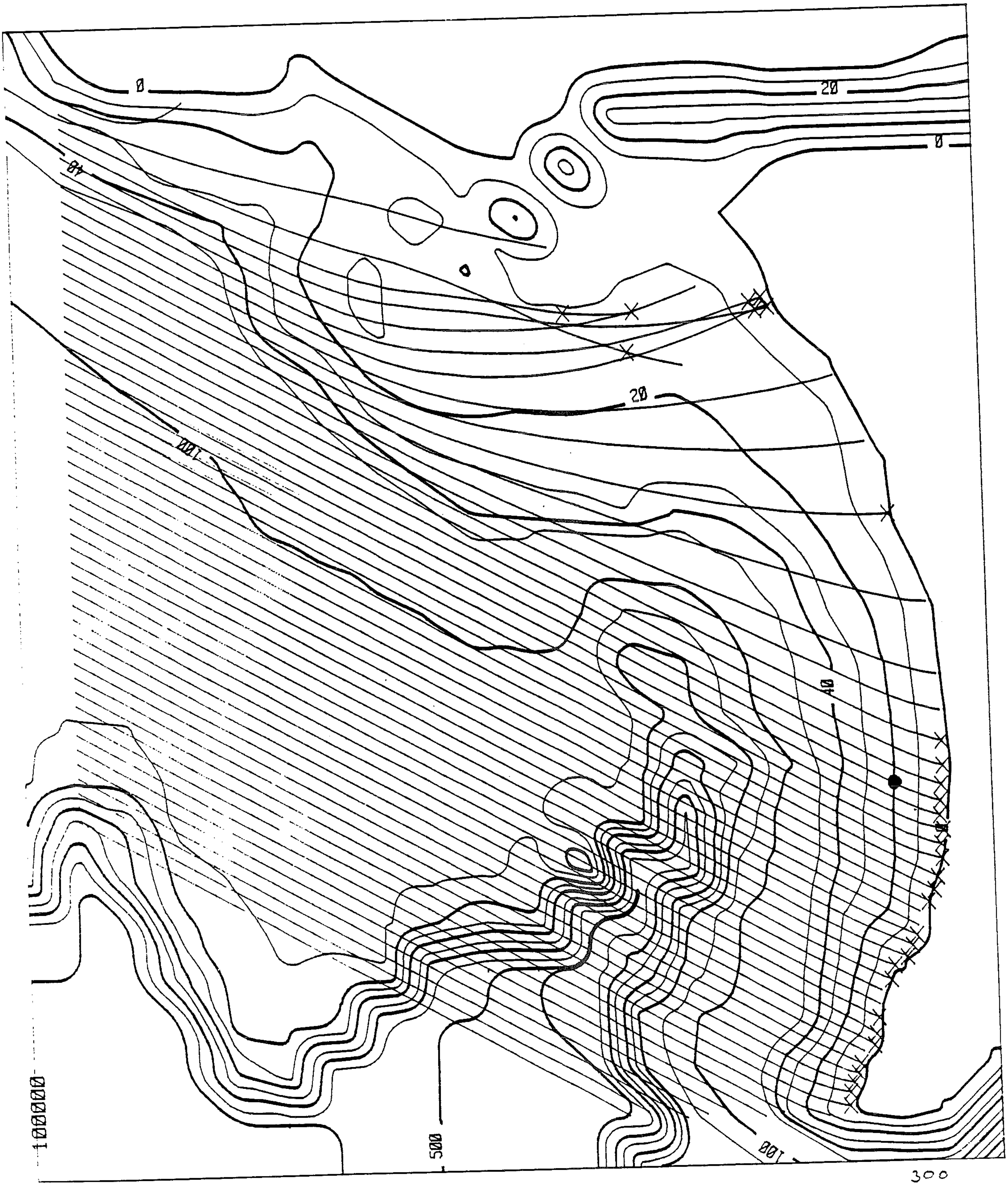
FIG.: 21



240
18%

TAAG
SCALE 1:

FIG.: 22



TAAG
SCALE 1: 100000

FIG.: 24

TABLES

WATER DEPTH DATA

Waterdepth data

Wave penetration model.

NUMBER OF HORIZON GRID LINES 66

NUMBER OF VERTICAL GRID LINES 40

GRID INTERVAL 250.0 M

56.0	52.8	46.6	43.1	37.4	33.2	30.1	27.0	25.0	22.4	22.0	20.1	[illegible]	19.1	[illegible]	[illegible]	[illegible]	12.5	[illegible]	11.7	11.7	[illegible]	[illegible]	[illegible]	[illegible]
56.4	51.4	45.8	41.2	36.0	31.1	28.4	25.6	24.0	23.0	21.5	19.1	18.0	15.5	14.7	13.5	12.2	11.2	10.7	10.4	10.1	9.8	9.1	8.5	7.9
55.8	50.9	44.3	39.0	35.2	30.0	27.2	24.5	23.0	21.0	19.4	18.7	17.3	14.9	13.5	12.2	11.3	10.0	9.6	9.1	7.3	7.0	6.7	9.5	9.6
55.0	49.1	45.1	37.0	33.2	29.1	27.0	24.1	23.4	19.9	18.5	17.3	15.4	13.6	11.9	11.1	8.6	7.8	7.2	6.9	6.2	7.2	7.7	7.6	7.3
55.0	47.4	41.5	36.6	32.7	28.0	26.3	23.0	21.0	19.5	17.7	14.5	14.1	12.5	9.7	9.1	7.9	8.1	8.5	8.7	8.9	8.4	9.3	10.6	9.2
50.8	46.2	41.7	35.9	31.5	28.0	25.6	23.4	21.9	19.1	17.1	14.6	12.5	11.1	8.5	8.7	9.5	9.9	10.3	10.8	10.8	11.5	12.4	13.6	14.0
47.0	46.7	46.3	35.4	31.0	26.0	25.0	23.0	20.8	18.0	18.0	13.5	10.9	9.0	9.5	10.6	10.9	11.2	12.5	12.6	13.9	12.2	14.0	17.0	19.0
44.0	49.3	48.4	38.9	38.4	27.2	25.3	23.2	21.0	18.1	15.6	12.5	10.2	9.4	11.0	11.7	12.2	13.0	14.6	15.6	16.0	16.5	16.9	17.3	20.5
48.8	49.6	39.3	28.8	39.4	26.9	23.0	22.4	20.7	17.5	15.8	12.2	10.1	10.7	11.9	12.2	12.9	11.5	14.4	14.5	14.4	14.4	15.7	16.2	18.8
54.8	43.4	39.5	28.4	28.3	28.0	24.0	21.4	26.1	17.2	14.5	12.9	9.8	10.3	12.2	12.2	13.4	13.7	13.6	14.0	14.4	14.4	14.7	16.6	15.9
53.2	49.8	32.0	34.3	30.5	29.8	25.1	21.4	20.6	17.8	15.5	13.2	10.1	11.3	12.1	12.2	12.9	13.6	13.1	14.6	14.5	12.6	14.0	14.6	14.5
53.3	46.4	40.2	32.0	31.5	28.3	25.1	23.0	21.1	18.6	16.5	12.7	11.2	11.1	12.6	11.9	12.5	12.6	12.1	12.4	14.1	12.8	13.7	13.6	13.2
53.9	42.5	40.5	35.5	31.5	28.9	25.5	23.8	21.3	20.1	16.2	11.5	12.5	11.6	11.5	11.4	12.2	12.4	12.3	12.2	12.0	12.0	12.2	13.3	13.2
54.8	46.2	41.5	37.0	33.2	30.8	26.1	24.0	21.7	19.4	17.7	15.1	12.9	11.9	13.3	12.3	12.2	12.1	11.7	11.4	11.4	11.6	12.5	12.6	12.3
54.3	46.0	42.2	37.8	34.8	30.2	27.1	25.0	22.6	20.1	18.0	16.6	14.5	12.5	11.5	11.1	11.3	11.5	10.6	11.6	11.7	11.5	11.7	12.0	12.1
53.5	48.0	45.2	38.5	34.0	31.0	28.0	25.7	22.2	20.9	19.1	17.3	14.7	13.0	14.5	11.2	11.2	11.5	11.5	11.4	11.2	11.1	11.1	11.5	11.7
51.8	48.9	43.3	36.9	35.4	31.6	29.2	26.7	24.6	21.8	20.7	18.6	15.6	14.5	12.5	12.0	11.3	11.3	11.6	11.3	11.1	10.8	10.5	11.6	11.6
56.3	48.6	41.8	47.4	35.5	33.3	38.3	27.5	23.9	22.4	21.6	20.7	16.6	15.6	13.9	12.7	12.1	11.6	11.5	11.3	10.9	10.6	10.4	10.5	10.5
53.1	48.7	45.6	49.0	36.8	32.7	30.4	27.9	26.0	25.9	20.8	20.0	18.7	16.9	15.2	13.7	12.5	12.1	10.8	11.4	11.1	10.6	10.9	10.3	10.9
55.8	51.3	45.2	40.6	37.5	34.5	31.9	28.9	26.7	25.0	22.5	20.5	18.7	17.6	15.5	14.7	13.8	12.3	12.2	11.6	11.4	11.6	10.6	10.4	10.4
56.0	53.0	53.4	49.5	41.0	36.4	35.3	32.7	31.0	28.7	25.3	23.4	21.2	18.7	17.0	15.4	14.5	14.5	13.0	12.2	11.9	11.4	11.2	10.7	10.2
57.5	51.8	47.6	42.7	39.5	36.4	33.3	37.3	29.0	26.2	24.5	22.4	21.0	19.6	17.6	16.3	15.5	14.3	13.5	12.7	12.4	11.9	11.7	11.4	11.3
60.2	52.5	47.5	43.6	39.5	37.0	35.0	33.2	29.3	27.0	26.0	23.8	21.9	20.8	19.3	16.7	17.1	15.7	14.7	13.5	12.9	12.4	12.1	12.1	11.8
51.9	52.7	47.5	44.0	41.5	36.2	36.0	34.0	31.0	29.0	26.5	25.0	23.0	21.4	20.3	19.5	17.6	16.9	15.7	14.8	14.1	13.4	13.0	12.5	12.4
61.0	53.3	48.5	44.2	41.3	38.7	34.0	33.5	31.2	29.2	27.7	26.5	24.0	22.8	21.6	20.8	19.6	16.3	16.7	15.5	15.0	14.3	14.5	13.7	13.3
61.5	52.7	47.7	44.6	42.2	38.8	33.7	38.5	32.6	31.2	28.2	27.5	25.5	24.7	21.6	21.6	20.1	19.1	16.6	16.8	16.3	15.6	15.1	14.6	14.1
62.0	55.0	51.9	44.7	42.3	38.7	37.5	33.5	31.0	31.4	29.7	28.3	27.1	26.0	25.6	22.8	21.5	20.2	19.3	18.3	17.0	16.7	16.6	15.4	15.2
63.0	57.1	52.6	47.5	42.5	41.1	38.1	38.5	32.6	32.7	30.8	29.5	30.0	26.1	25.1	24.3	23.3	21.9	20.5	19.7	18.5	18.3	17.3	16.6	16.2
64.0	59.0	55.6	51.4	47.2	43.0	38.8	36.7	35.3	33.1	31.2	30.9	30.0	27.3	26.6	25.3	24.1	23.4	22.4	21.2	20.4	19.5	18.1	17.6	17.4
65.0	66.9	56.9	52.9	43.9	41.9	40.9	36.9	35.5	31.3	32.7	30.9	30.0	28.6	27.7	26.6	25.4	24.3	23.6	23.6	21.6	20.8	19.2	19.1	18.7
66.1	62.3	58.9	55.3	51.3	48.3	44.8	41.3	37.6	34.3	33.4	31.9	30.0	29.3	27.9	26.9	26.0	25.2	24.2	21.5	22.0	21.7	21.0	20.2	19.4
67.0	63.3	60.0	56.9	53.8	50.7	47.6	44.5	41.4	36.3	35.2	32.1	31.0	29.4	28.5	27.7	27.0	26.3	26.7	25.0	23.7	22.7	23.2	21.2	20.5
68.0	66.0	63.2	60.2	57.2	54.2	51.2	48.2	45.2	42.2	39.2	36.2	33.2	30.7	29.2	28.5	27.5	27.1	27.2	25.6	24.5	23.3	22.8	22.3	21.5
69.0	67.5	66.0	63.2	60.1	57.6	54.6	52.0	49.2	46.4	43.6	40.8	38.0	35.2	32.4	29.6	28.3	27.4	27.0	26.3	25.5	24.4	23.5	23.5	22.6
70.0	68.5	67.1	63.0	61.0	57.9	54.1	52.6	[illegible]	47.2	44.5	42.1	45.0	37.0	35.2	32.8	30.1	28.0	27.7	26.5	26.0	25.0	24.6	24.2	23.4
71.0	69.3	66.0	65.0	61.5	58.2	54.8	52.4	50.2	47.8	45.0	43.4	41.2	39.0	36.8	34.0	32.4	30.2	28.0	27.5	26.7	26.5	25.7	24.0	24.1
72.0	71.0	69.3	67.0	61.6	62.2	59.9	57.5	55.2	52.8	50.5	48.1	45.8	43.4	41.1	38.6	36.5	34.0	31.8	29.4	27.4	26.8	26.3	25.6	25.0
75.0	76.8	75.5	72.9	70.4	67.6	65.4	62.7	60.2	57.6	55.1	52.5	50.0	47.1	44.6	42.3	39.8	37.2	34.7	32.1	29.6	27.0	26.7	26.2	25.4
84.0	83.2	82.1	79.8	77.2	74.7	71.7	68.9	66.1	62.6	60.6	58.8	55.5	52.2	48.9	45.7	42.0	38.5	35.5	32.1	29.3	27.0	26.9	26.9	26.3
94.0	91.5	89.0	86.5	84.0	81.5	78.6	75.0	72.6	68.0	66.5	65.0	61.0	57.0	53.0	49.0	44.6	40.6	38.6	32.6	29.0	27.0	26.8	26.9	26.7

TABLE : 1

9.3	9.0	9.1	9.3	9.3	10.0	9.4	10.0	10.9	10.5	9.2	3.4	-1.0	-1.4	-1.0	-1.0
7.3	10.2	12.3	8.6	7.8	6.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
8.1	6.4	4.8	5.8	5.6	7.0	8.5	6.5	8.5	5.0	6.7	7.3	-1.0	3.0	7.4	4.0
17.3	18.5	16.7	15.0	14.0	13.0	6.2	5.6	2.3	1.2	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
9.2	4.3	4.7	5.1	5.4	5.3	5.7	5.2	2.1	4.5	5.6	8.5	1.2	9.9	12.4	14.3
22.0	20.2	16.6	20.4	20.2	17.3	15.6	16.0	12.7	8.5	4.5	2.2	-.5	-1.0	-1.0	-1.0
7.1	6.9	6.9	7.5	7.0	7.3	7.2	6.9	4.9	5.4	11.2	15.6	15.0	15.6	17.8	16.7
22.5	22.5	22.6	18.5	18.5	21.6	21.0	21.6	18.2	15.0	12.0	6.7	4.1	-.5	-2.1	-1.0
10.8	11.6	11.2	19.0	11.1	12.6	13.2	14.9	18.6	18.0	18.6	16.9	21.0	20.0	20.5	22.0
25.2	26.1	26.3	27.0	27.1	25.5	23.7	24.5	19.8	18.6	17.5	14.2	9.5	4.2	.6	-5.0
16.7	17.0	17.1	15.9	16.0	18.7	22.5	24.0	22.8	21.5	23.0	24.0	24.0	22.2	24.5	24.0
26.0	25.0	24.0	21.0	38.2	10.5	38.0	33.4	27.3	23.6	19.5	17.6	13.9	12.3	6.5	-1.2
22.5	24.5	25.0	26.3	28.7	27.7	24.0	27.0	25.1	25.0	26.7	25.8	26.5	27.0	24.5	31.5
34.0	36.0	35.3	35.0	32.0	33.5	35.3	32.0	29.8	28.0	21.0	24.0	20.0	12.8	11.0	9.2
23.5	25.6	25.0	24.3	27.0	29.0	27.5	25.0	26.0	26.2	26.4	27.3	25.7	26.3	27.1	24.3
29.0	27.6	26.5	25.2	25.5	26.0	28.0	31.4	34.2	32.9	25.9	34.8	29.8	20.0	12.9	10.0
20.8	21.6	19.6	23.4	22.5	22.5	28.2	23.5	22.3	22.6	25.0	23.8	23.9	22.6	18.7	11.2
20.0	24.0	24.7	23.0	22.8	23.3	24.2	25.8	29.0	30.0	31.0	37.9	30.4	30.0	21.7	13.5
16.0	15.1	16.0	17.5	18.7	18.8	17.2	19.5	17.1	18.1	18.0	15.3	13.7	15.7	8.8	3.4
.0	1.3	15.9	20.0	20.0	21.4	22.0	23.3	24.6	25.3	28.2	30.5	37.9	34.1	30.0	22.5
14.2	13.4	14.2	13.7	14.0	14.3	15.0	12.7	12.2	12.0	11.0	8.2	7.6	4.4	1.3	2.4
-1.0	1.1	1.3	7.0	11.3	15.5	16.8	20.8	23.5	25.0	26.6	30.0	32.7	31.0	34.3	30.0
13.1	12.7	12.3	12.6	12.4	12.0	11.0	9.4	9.1	8.4	9.1	5.6	6.8	3.4	2.8	1.6
.8	1.2	1.2	2.3	6.3	9.1	11.0	16.9	20.2	24.4	26.5	28.1	32.6	35.0	38.0	33.5
12.5	10.8	11.8	11.8	10.6	9.3	7.8	7.2	6.7	5.8	3.6	3.8	3.0	1.6	.9	1.3
.9	1.0	.9	2.3	1.3	4.1	11.0	16.2	19.6	23.9	25.6	28.3	31.0	33.0	36.0	34.2
11.8	10.5	9.6	9.5	9.8	8.3	6.4	6.4	5.7	4.7	3.9	3.3	1.9	1.3	2.2	2.3
1.0	1.3	1.5	1.6	1.9	3.0	6.2	12.0	17.1	20.0	24.0	29.6	33.0	33.9	34.0	34.7
11.2	10.8	9.3	8.8	8.5	7.9	8.2	5.5	5.2	5.3	4.4	2.5	2.7	2.0	2.7	3.7
1.7	.6	1.3	1.4	.1	.1	.5	1.0	9.2	12.6	11.1	14.0	23.0	34.0	33.7	34.4
11.7	11.3	10.0	9.0	8.7	8.1	7.6	5.6	5.6	5.8	5.5	4.5	5.2	3.6	3.6	4.1
2.5	2.5	2.1	1.0	1.5	.2	-2.8	-3.7	-4.0	8.0	1.4	.9	2.5	13.0	29.2	31.6
11.5	11.1	10.4	9.5	9.2	8.6	6.2	8.1	7.9	6.5	5.7	5.8	5.2	5.2	5.0	5.3
3.2	2.3	2.2	1.2	.1	-1.2	-1.0	-1.0	-.6	.0	-.7	.7	.5	.6	1.1	20.0
11.5	11.6	11.2	10.6	10.0	9.2	8.9	9.0	8.7	7.4	7.3	7.3	6.7	6.5	6.9	6.6
5.0	4.0	3.0	1.3	.2	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
10.4	10.4	10.5	10.9	10.5	10.3	9.9	9.8	9.2	8.9	8.5	8.9	8.0	7.9	8.3	7.6
6.2	6.5	5.5	3.0	-3.5	-4.4	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
10.2	10.1	10.4	10.5	10.5	10.5	10.5	10.1	9.7	9.4	9.6	9.5	9.6	9.2	8.9	8.7
7.4	7.2	6.6	3.6	-1.6	-5.2	-1.0	-1.0	-1.0	-1.0	11.6	-1.0	-1.0	-1.0	-1.0	-1.0
10.3	10.4	10.4	10.3	10.3	10.2	10.7	10.5	10.4	10.3	10.1	10.2	9.9	9.6	9.9	9.5
8.4	8.1	7.8	4.2	-1.0	-5.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
11.6	10.9	11.0	10.7	10.6	10.7	10.8	10.6	10.6	10.4	10.4	10.4	10.5	10.5	10.4	10.1
8.8	8.5	7.6	6.3	1.3	-4.7	-1.0	-1.0	11.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
11.7	11.6	11.9	11.1	11.1	11.1	11.2	11.3	11.0	11.1	11.1	11.0	11.6	10.9	10.9	10.7
9.1	9.2	8.1	1.3	1.6	-4.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
12.2	12.2	12.9	12.1	12.1	12.0	12.0	12.0	11.5	11.6	11.4	11.5	11.5	11.4	11.5	11.3
9.8	4.4	8.2	2.8	1.4	-1.9	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
13.1	12.9	13.6	12.7	12.6	12.6	12.4	12.7	12.6	12.6	12.6	12.3	12.0	12.1	12.0	11.0
10.3	9.4	8.3	4.2	2.6	-3.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
13.9	13.4	13.5	13.5	13.4	13.4	13.5	13.3	13.4	13.1	12.5	12.5	12.5	12.6	12.3	12.2
10.3	9.8	1.9	6.3	2.9	-2.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
14.6	14.4	13.5	13.6	14.2	14.1	11.3	13.9	13.4	13.4	12.8	12.9	12.9	12.8	12.7	12.7
10.8	10.1	9.2	8.8	3.1	1.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
15.9	15.4	15.3	15.2	15.2	15.0	11.9	11.1	14.0	14.9	13.0	13.0	13.4	13.3	13.1	12.6
12.6	10.9	9.5	6.2	3.1	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
16.9	16.9	16.3	16.0	15.8	15.8	15.6	15.5	15.1	15.1	13.6	13.3	13.9	13.9	13.4	13.2
12.5	11.5	10.0	6.7	2.1	-1.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
18.0	17.0	17.2	17.2	17.1	16.2	16.6	15.9	15.6	15.4	15.3	14.8	15.0	14.7	11.9	[illegible]
12.2	12.1	10.1	7.2	2.4	-.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0

1.4	3.7	7.0	6.0	5.8	6.3	3.3	4.4	5.0
7.6	13.0	21.0	20.5	19.8	19.4	15.8	15.0	16.0
14.5	14.1	20.5	20.2	22.9	13.6	[illegible]	[illegible]	22.5
18.1	25.2	24.3	25.0	24.1	21.7	[illegible]	[illegible]	[illegible]
19.6	30.0	33.8	26.7	23.0	23.5	22.8	23.2	24.0
24.3	29.1	30.0	24.2	23.2	21.5	23.8	25.5	25.7
30.3	30.5	28.0	26.9	27.6	27.0	30.6	31.5	32.5
20.2	21.2	19.5	19.0	19.4	24.3	27.0	28.5	27.5
4.3	8.8	-1.0	.2	.8	1.4	.9	1.0	12.0
3.2	1.2	-1.0	1.7	1.3	-1.0	.3	-1.0	-1.0
1.6	-1.0	-1.0	1.6	1.6	1.5	1.4	-1.0	.9
.6	.3	.6	1.0	2.2	2.1	2.2	.7	.9
1.3	1.7	1.7	2.3	2.5	2.7	2.3	.7	.3
1.2	2.4	2.1	2.4	3.0	3.1	3.3	1.4	1.1
2.6	1.8	2.5	2.7	3.7	3.7	5.3	2.8	1.8
4.2	2.2	3.7	3.6	4.3	4.4	5.8	6.4	3.3
4.6	4.7	4.8	5.1	5.7	4.8	5.3	5.3	5.0
6.6	6.5	6.3	6.5	5.7	5.1	5.3	5.6	5.4
7.4	7.3	6.9	6.8	6.7	6.8	6.0	6.0	6.5
8.7	8.2	8.8	7.6	7.7	7.3	7.3	7.2	7.6
9.2	8.8	9.2	8.6	8.6	8.3	8.3	8.3	8.4
10.0	9.7	9.9	9.6	9.6	9.3	9.3	9.5	9.9
10.7	10.4	10.1	10.2	10.1	10.0	[illegible]	10.0	9.8
11.2	10.9	10.7	10.7	10.7	10.4	10.1	10.3	10.1
11.5	11.4	11.2	11.3	11.6	10.8	10.5	10.6	10.4
12.6	11.9	11.7	11.6	11.3	11.2	10.8	11.0	10.8
12.5	12.3	12.1	12.0	11.5	11.6	11.1	11.3	11.3
12.0	12.0	12.7	12.6	12.6	12.4	12.3	12.4	12.3
13.1	12.6	12.1	13.3	12.9	12.9	12.5	13.6	12.4
14.1	13.8	13.0	13.5	13.3	13.6	12.9	12.8	12.3

TABLE : 1 (cont.)

19.0	18.5	18.5	18.0	17.8	17.5	17.3	16.5	16.5	16.5	16.2	16.2	15.7	15.5	15.4	14.7	14.4	14.5	14.1	14.0	13.7	13.5	13.3	13.0	12.6
12.3	12.2	10.7	8.2	2.5	-.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
20.2	19.5	19.4	19.1	18.5	18.4	17.7	17.6	17.1	17.0	16.6	16.7	16.4	16.5	16.1	15.8	15.2	15.0	14.6	14.6	14.0	13.8	13.7	13.4	13.2
12.8	12.4	11.0	8.9	2.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
21.3	20.4	20.2	20.0	19.5	19.2	18.7	17.9	17.6	17.4	17.9	17.3	17.5	17.3	16.9	16.3	16.6	16.3	15.4	16.1	15.0	14.4	14.2	14.2	13.9
13.4	12.5	11.7	9.7	2.8	-.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
21.9	21.4	21.6	20.8	20.3	20.3	19.3	18.9	19.0	18.5	18.8	18.0	17.8	17.4	17.3	17.2	17.1	16.6	16.7	15.8	15.6	15.3	15.1	14.6	14.2
13.7	13.4	12.2	10.0	4.5	-1.3	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
23.1	22.4	21.6	21.7	21.6	20.3	20.2	19.5	19.5	19.2	18.8	18.6	18.5	18.3	18.1	18.3	17.6	17.2	16.9	16.3	15.9	16.0	15.5	15.0	14.9
11.1	13.0	12.9	10.0	1.7	-2.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
23.0	23.0	22.8	22.2	21.8	21.2	20.8	20.4	20.4	19.8	19.5	19.4	19.1	18.3	18.7	18.1	18.0	17.7	17.4	17.2	16.7	16.4	15.6	15.3	15.0
13.9	12.6	12.1	11.6	5.7	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
24.7	24.5	24.1	22.7	22.0	21.8	21.1	20.6	21.2	20.6	20.2	20.3	19.7	19.4	19.0	18.3	18.5	17.9	17.2	17.3	17.0	17.0	16.1	15.5	15.0
14.0	13.0	12.0	9.0	3.6	-.7	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
25.6	25.2	24.8	24.6	23.7	22.5	22.4	22.0	21.5	21.3	21.4	20.6	20.3	20.1	19.8	19.3	18.9	19.0	18.1	18.6	17.5	16.8	16.5	16.1	15.1
14.3	13.3	11.9	8.7	3.9	-.8	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
25.8	25.6	25.1	24.0	24.1	23.6	23.1	22.9	22.3	22.0	21.7	21.4	20.5	20.3	20.0	19.8	19.2	18.8	18.6	18.3	18.4	17.1	16.6	15.8	15.5
14.5	13.3	12.3	14.0	5.8	-4.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									
26.5	26.0	25.7	25.5	25.7	24.2	23.6	23.3	22.5	22.3	21.7	21.4	21.1	20.4	20.2	20.0	19.3	19.0	18.8	18.3	17.7	17.2	16.5	16.0	15.2
14.4	13.0	12.1	10.3	3.2	-.3	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0									

TABLE: 1 (cont.)

		1	2	3	4	5	6	7	8	9	10
TGA01	.22%	.50	.50	.49	.47	.49	.52	.87	.42	.48	.47
TGA02	.13%	1.00	.99	.97	.92	.98	1.12	.51	.87	.90	.94
TGA03	.31%	.80	.74	.81	.59	.72	.71	.41	.43	.55	.67
TGA04	.15%	1.60	1.49	1.63	1.19	1.44	1.59	.80	.87	1.10	1.34
TGA05	.36%	.80	.72	.63	.56	.70	.62	.00	.00	.47	.55
TGA06	.19%	1.70	1.53	1.33	1.18	1.48	.94	.00	.00	1.10	1.18
TGA07	.32%	.79	.75	.75	.47	.76	.79	.00	.00	.69	1.55
TGA08	.14%	1.68	1.59	1.60	1.00	1.62	1.08	.00	.00	.74	3.29
TGA09	.23%	.76	.69	.36	.31	.91	.62	.00	.00	.66	.44
TGA10	.12%	1.53	1.38	.53	.62	1.82	1.22	.00	.00	.82	.88
TGA11	.19%	.74	.85	.24	.25	.51	.62	.00	.00	.63	.38
TGA12	.07%	1.48	1.70	.39	.50	1.02	.57	.00	.00	.77	.76
TGA13	.07%	2.70	2.58	1.20	1.29	3.57	.77	.00	.00	.77	1.72
TGA14	.17%	.56	.90	.41	.00	1.36	.87	.00	.00	.58	.32
TGA15	.04%	3.24	3.36	.98	1.23	2.00	1.14	.00	.00	.79	2.86
TGA16	.01%	.71	1.34	.00	.34	.48	.85	.00	.00	.88	.00
TGA17	.38%	.50	.49	.50	.49	.50	.47	.38	.41	.70	.53
TGA18	.23%	1.00	.96	.99	1.00	.98	.93	.43	.77	1.02	1.01
TGA19	.55%	.80	.76	.79	.88	.74	.97	.39	.56	.50	.77
TGA20	.26%	1.60	1.51	1.58	1.77	1.49	1.29	.76	1.13	.81	1.56
TGA21	.63%	.80	.74	.64	1.03	.66	.79	.00	.00	.97	.73
TGA22	.33%	1.69	1.57	1.36	2.18	1.40	.92	.00	.00	.80	1.55
TGA23	.57%	.79	.72	1.62	1.02	.76	.72	.00	.00	.71	.74
TGA24	.25%	1.57	1.44	3.23	2.05	1.52	1.03	.30	.29	.55	1.48
TGA25	.41%	.76	.89	1.09	.00	.69	.71	.00	.00	.54	.67
TGA26	.21%	1.52	1.77	2.18	.00	1.37	1.02	.00	.00	.58	1.34
TGA27	.33%	.73	.74	.42	.00	.78	.95	.00	.00	.52	.33
TGA28	.13%	1.47	1.47	.69	.00	1.57	1.07	.00	.00	.54	.66
TGA29	.13%	2.70	3.02	3.09	.00	2.12	1.38	.00	.00	.59	2.60
TGA30	.30%	.53	.57	.38	.40	.39	1.44	.00	.00	.54	.26
TGA31	.07%	3.11	3.21	1.03	.00	.88	1.21	.00	.00	.82	1.48
TGA32	.02%	.66	.70	.37	.00	.41	.82	.00	.00	.68	.44
TGA33	.29%	.50	.49	.51	.48	.49	.49	.00	.45	.79	.50
TGA34	.18%	1.00	.96	1.07	1.02	.97	.99	.00	1.03	1.15	1.05
TGA35	.42%	.80	.69	.78	.65	.75	1.17	.44	.00	1.65	1.28
TGA36	.20%	1.60	1.37	1.56	1.29	1.50	1.99	.87	.00	1.67	2.55
TGA37	.48%	.80	.66	1.15	.73	.68	1.64	.00	.00	.48	.73
TGA38	.26%	1.70	1.40	2.45	1.55	1.45	1.13	.00	.00	.55	1.56
TGA39	.44%	.79	.85	1.75	.55	.63	1.25	.00	.00	.97	.69
TGA40	.19%	1.67	1.80	2.83	1.15	1.33	1.13	.00	.00	.67	1.47
TGA41	.31%	.76	.69	.78	.38	1.02	.90	.00	.00	.74	.64
TGA42	.16%	1.53	1.37	1.55	.77	2.04	.78	.00	.00	.59	1.29
TGA43	.26%	.74	.82	.76	.00	1.01	.82	.00	.00	.70	.56
TGA44	.10%	1.48	1.63	1.28	.00	2.02	.91	.00	.00	.65	1.12
TGA45	.10%	2.70	2.72	3.24	.00	2.81	.98	.00	.00	.87	1.87
TGA46	.23%	.53	1.06	.67	.00	.45	.50	.00	.00	.54	.33
TGA47	.05%	3.11	3.34	1.85	1.10	2.53	2.05	.00	.00	.93	.71
TGA48	.02%	.61	1.04	.49	.00	.60	.87	.00	.00	.00	.00
TGA49	.33%	.50	.50	.49	.50	.49	.48	.54	.44	.33	.49
TGA50	.20%	1.00	.99	.97	.98	.98	.96	.39	.80	.60	.96
TGA51	.48%	.80	.79	.66	.72	.75	.79	1.48	.36	.66	.64
TGA52	.23%	1.60	1.58	1.32	1.43	1.50	1.58	.59	.72	1.31	1.28
TGA53	.55%	.80	.76	.50	.55	.72	1.01	.00	.33	.73	.75

TABLE: 2

TGA54	.29%	1.70	1.62	1.06	1.16	1.53	.94	.00	.72	1.28	1.60
TGA55	.50%	.79	1.05	.47	1.17	.76	1.03	2.06	.00	.60	.63
TGA56	.22%	1.67	2.23	1.01	1.57	1.61	1.16	.80	.00	.79	1.33
TGA57	.36%	.77	1.60	.47	.70	1.33	.85	.00	.00	.73	.38
TGA58	.18%	1.54	3.19	.94	1.21	2.65	.99	.89	.00	.70	.77
TGA59	.29%	.76	1.85	.59	.92	.52	.56	.00	.00	.67	.46
TGA60	.11%	1.51	2.36	1.17	1.83	1.04	.53	.00	.00	.86	1.24
TGA61	.11%	2.72	3.33	1.46	1.41	4.24	1.54	.27	.00	.77	1.34
TGA62	.26%	.56	.86	.00	1.46	.36	.00	.00	.00	.67	.52
TGA63	.06%	3.26	2.43	.00	2.78	2.00	1.26	.00	.00	.83	1.51
TGA64	.02%	.68	.76	.00	1.71	.67	.51	.00	.00	.00	.58
TGA65	1.97%	.00	.71	.72	.76	.71	.70	.60	.67	.59	.70
TGA66	3.80%	.00	.71	.74	1.01	.73	1.00	.64	.70	.82	.73
TGA67	1.92%	.00	1.55	1.64	1.97	1.57	2.32	.88	.77	1.18	1.53
TGA68	6.08%	.00	.69	.82	.70	1.06	1.17	.00	.00	1.14	.88
TGA69	.41%	.00	1.86	1.93	1.02	2.58	1.65	.00	.00	.64	2.53
TGA70	.95%	.00	.43	.63	.49	.57	.64	.81	.00	.39	.40
TGA71	.23%	.00	2.22	1.88	2.45	3.19	1.70	.00	.00	.93	2.13
TGA72	.08%	.00	.54	.67	.60	.74	.91	.00	.00	.00	.54
TGA73	2.63%	.00	.72	.71	.65	.70	.63	.00	1.07	.83	.67
TGA74	5.06%	.00	.89	.86	2.62	.71	.92	.00	.49	.96	.33
TGA75	2.56%	.00	1.88	2.13	8.22	1.29	1.61	.00	.44	.53	.61
TGA76	8.11%	.00	1.49	1.33	1.70	2.44	1.36	.48	.79	.84	3.06
TGA77	.55%	.00	3.83	3.20	1.44	1.66	.63	.00	4.00	.69	1.58
TGA78	1.27%	.00	.65	.80	.25	.32	.62	.33	.24	.00	.45
TGA79	.31%	.00	3.90	4.63	.00	1.91	1.37	.49	.89	.35	.90
TGA80	.10%	.00	.91	1.53	.40	.66	1.26	.00	.00	.00	.86

WAVE FREQUENCIES IN SELECTED PIONTS

TABLE: 2 (cont.)