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THE PREDICTION AND EVALUATION OF THE GROUND LEVEL WIND ENVIRONMENT

by

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SUMMARY

Acceptance criteria for ground level wind speeds are presented together with a description of an experimental approach to the prediction of the ground level wind environment. The method of prediction relies on the use of models to determine the ratios of the ground level mean and gust speeds to a reference speed at a height well clear of the influence of terrain roughness. The measured wind speed ratios are then used in conjunction with the known statistics of the reference speed to predict the ground level climate. In the Sydney area the statistics of the reference speed were derived from balloon data.

The approach to the prediction of ground level winds was applied to obtain an estimate of the wind climate at the site of an existing ground level (20m) meteorological station. Agreement between the predicted wind climate and the actually observed over a period of five years was found to be satisfactory.

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INTRODUCTION

The problem of excessive ground level winds in the vicinity of tall structures is one in which there are deficiencies in the basic knowledge and techniques required to produce satisfactory solutions. The present paper outlines acceptance criteria and describes an approach to the prediction of ground level wind speeds. The method is illustrated with particular reference to the Sydney area. The results are applied to the prediction of the wind climate at Observatory Hill, Sydney, a location at which an anemometer has been sited for over seventy years and for which the wind climate is well established. While the comparison of the observed and predicted wind climate indicates deficiencies, the general agreement is encouraging and, in view of the difficulties of defining acceptance criteria, is generally satisfactory.

ACCEPTANCE CRITERIA

Vickery and Apperley (1) discuss the significant wind speeds in relation to the usage of various areas. Based on observations by Melbourne and Joubert (2) and Penwarden (3) the limiting wind speeds listed below are suggested.

Table 1 - Acceptance Cirteria for Ground Level Wind Speeds

Area Description	Limiting Wind Speed	Frequency of Occurrence
Plazas & Parks	Occasional gusts to about 6 m/s	10% of the time or about 1000 hours/year
Walkways & other areas subject to Pedestrian access	Occasional gusts to about 12 m/s	1 or 2 times per month or about 50 hours/year
All of above	Occasional gusts to about 20 m/s	About 5 hours/year
All of above	Occasional gusts to about 25 m/s	Less than 1 hour/year

The criteria proposed above are subjective and have been arrived at in the absence of reliable data with the exception of data defining the wind speed necessary to cause unbalance and possibly knock a frail person to the ground (2).

DEFINITION OF BASIC WIND CLIMATE

The basic wind climate is defined as that which is independent of the local topography. In Sydney the ground level anemometer stations are so located that there are difficulties in estimating the variation of mean speed with height. There is, however a considerable amount of data for upper level winds, obtained from balloons released over the past twenty years.

The nature of these data and the methods by which it can be used to provide a measure of the upper level wind climate is described elsewhere (4).

The directional distribution of wind speeds at a height of about 200m is shown in Fig.1 for wind speeds in excess of 18 m/s. It will be noted that the wind speed distribution tends to be organized into three main groups which will be referred to as the West, South and North-East groups.

The probability distribution of the mean speed at about 200m is given in Fig.3 for each of the three directional groups and for the three groups combined.

A major difficulty in environmental investigations of this type is the excessive number of observations necessary to define the wind climate throughout a major development area. A large development may require observations at perhaps one hundred points and, unless simplifications are accepted, twenty or more wind directions.

The time and hence the cost of such a study is likely to be prohibitive and it becomes necessary to adopt an approach which will reduce the number of observations to an economically feasible level. For studies in the Sydney area the authors have chosen to limit initial studies to the three major wind directions defined in Fig.1 and to extend the study to other wind directions only at points which appear critical.

A COMPARISON OF OBSERVED AND PREDICTED WIND SPEEDS AT OBSERVATORY HILL, SYDNEY

The experimental approach described above was employed in the prediction of the wind climate at the anemometer site on Observatory Hill, Sydney. The model employed in the study was constructed at a scale of 1:500. A hot-wire was mounted vertically at the site of the anemometer and the signal filtered using a low pass filter adjusted to yield a scaled frequency response similar to that of the anemometer on site. Measurements were made of the ratio of the mean speed at the anemometer site to the mean speed at about 200m. The measured wind speed ratios are shown in Fig.4. Upstream from the detailed model the roughness and the floor elevation was chosen to approximate the approach to the site. The upstream arrangement of ground roughness is indicated in Fig.4.

Also shown in Fig.4 is the wind speed ratio deduced from a comparison of the directional probability distribution measured at 200m and at the anemometer. In general the measured wind speed ratios are in fair agreement with those deduced from actual field measurements. The measured values for winds approaching the anemometer from the city are consistently low (an average value of about 0.45 as compared with the deduced ratio of about 0.55). The discrepancy may well be due to the fact that the model employed was constructed to represent the city as at the end of 1973 whereas the probability distribution at the anemometer was based on data collected during the years 1965 to 1969 inclusive. A model constructed to represent the city during 1965-69 would of course offer reduced shielding and hence higher values of the wind speed ratio. The influence of new buildings on the wind speeds recorded at the anemometer is demonstrated by the two curves shown for the south-west segment. The marked difference between the two curves is due to the construction of a single building located at a distance of about 300m to 400m from the anemometer. The measured wind speed ratios for the three dominant directions to West, 10° East of South and 30° East of North are 0.75, 0.47 and 0.55 respectively. These values may be used to derive the wind climate at the anemometer. The calculations necessary to determine the number of hours per year for which the mean speed exceeds 10 m/s are set out below.

i) West Group:

$$\frac{\bar{V}_{BUREAU}}{\bar{V}_{200}} = 0.75$$

$$\bar{V}_{200} = \frac{10}{0.75} = 13.3 \text{ m/s}$$

from Fig.3; $\bar{V}_{200}$ exceeds 13.3 m/s for 270 hrs/yr.

ii) South Group:

$$\bar{V}_{200} = \frac{10}{0.47} = 21.3 \text{ m/s}$$

which is exceeded for 10 hrs/yr.

iii) North-East Group:

$$\bar{V}_{200} = \frac{10}{0.55} = 18.2 \text{ m/s}$$

which is exceeded for 15 hrs/yr.

Summing over the three major wind groups we have that the wind speed at the anemometer will exceed 10 m/s for 295 hrs/yr. The observed value determined directly from five years of continuous records at the Bureau is 210 hrs/yr. While the discrepancy may appear large it is not so when viewed in terms of wind speed; the deduced wind speed for 210 hrs/yr being 11 m/s rather than 10 m/s. This discrepancy of 10% in wind speed is barely significant compared to the doubt surrounding the suggested acceptance criteria. The wind climate as predicted from model tests and that determined from the five years of analysed data is shown in Fig.5. The average discrepancy between the two curves is approximately 10% when expressed in terms of wind speed.

While the agreement between the predicted and observed wind climate is generally satisfactory there are some discrepancies in the directional distribution which deserve comment. The directional distribution for wind speeds in excess of 10 m/s is good agreement with the predicted dominance of the west wind but at the lower speed of 5 m/s the distribution shows a marked contribution from the North-east, a contribution which is underestimated by the model studies. The reason for this discrepancy is difficult to define but could well be associated with faults in the assumption of a neutral atmosphere, an assumption which is forced by the difficulty of adequately modelling thermal effects in a boundary layer tunnel. The low speed 'north-easter' is commonly a sea breeze associated with thermal effects which cannot be modelled in conventional boundary layer tunnels. A second feature of the atmospheric boundary layer which cannot be modelled is the directional change with height, this effect has been ignored in the comparison of upper level and ground level data and it may well contribute to the observed discrepancies between the observed ground level wind climate and that predicted from upper level data.

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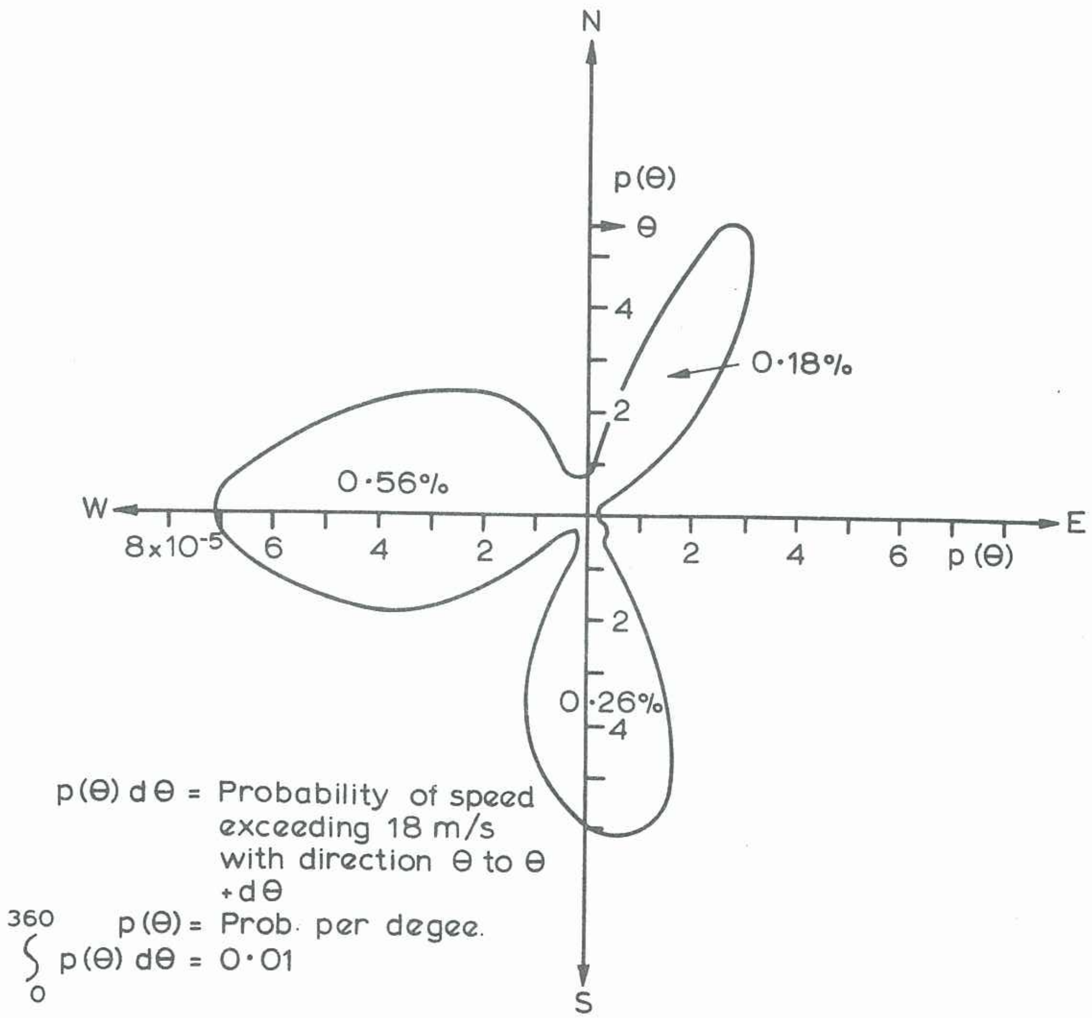

FIG. 1 DIRECTIONAL DISTRIBUTION OF WIND SPEEDS IN EXCESS OF 18 m/s AT 200 m

S.D.	S.N.	W.D.	W.N.	Total	
5·71	1·42	1·32	0·54	9·0	NE
3·82	2·06	2·34	1·03	9·3	S
1·53	1·04	4·72	3·60	10·9	W
11·06	4·52	8·38	5·17	29·2%	Total

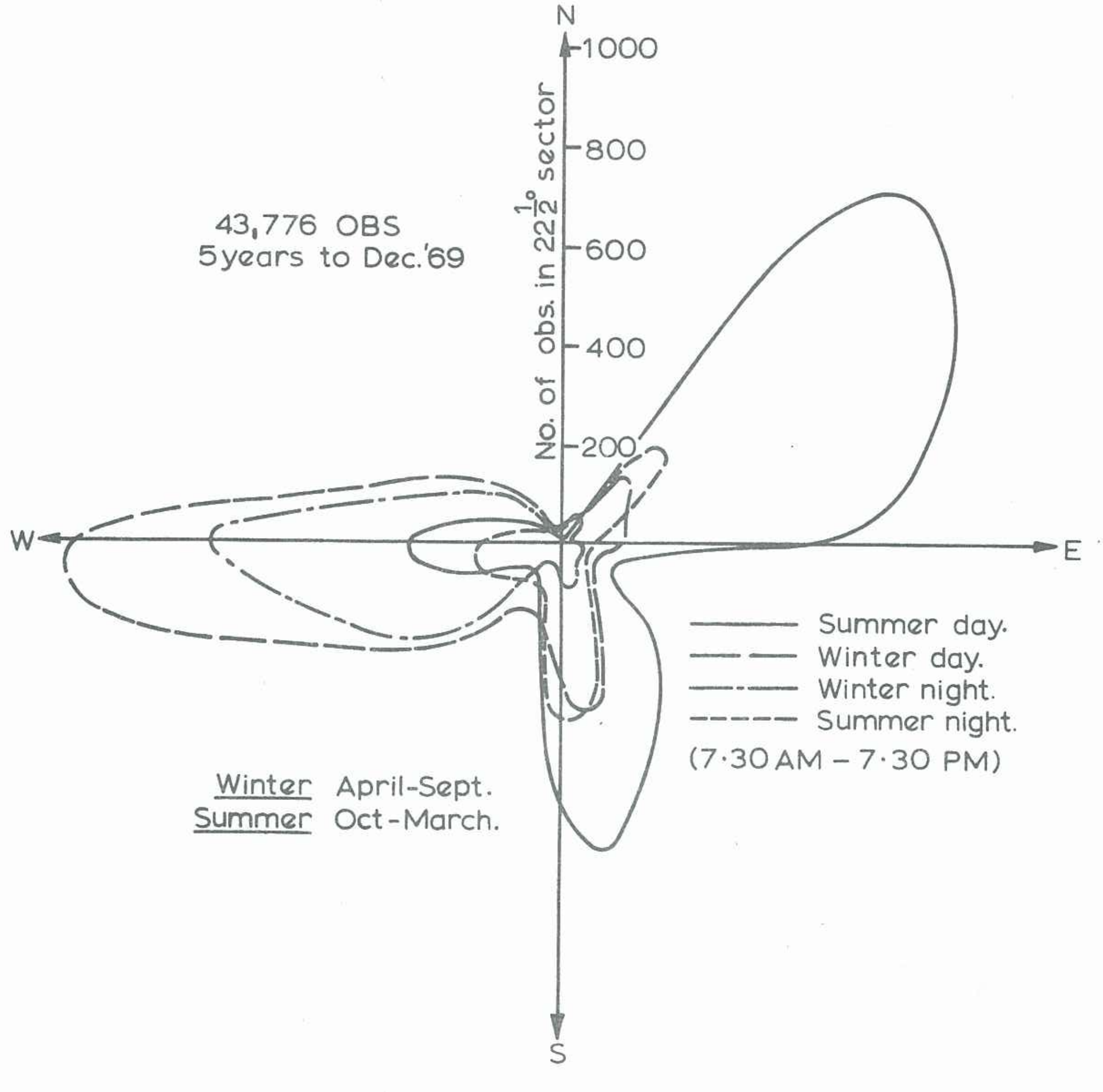

FIG. 2 DIRECTIONAL DISTRIBUTION OF MEAN SPEEDS IN EXCESS OF 5m/s AT OBSERVATORY HILL, SYDNEY.

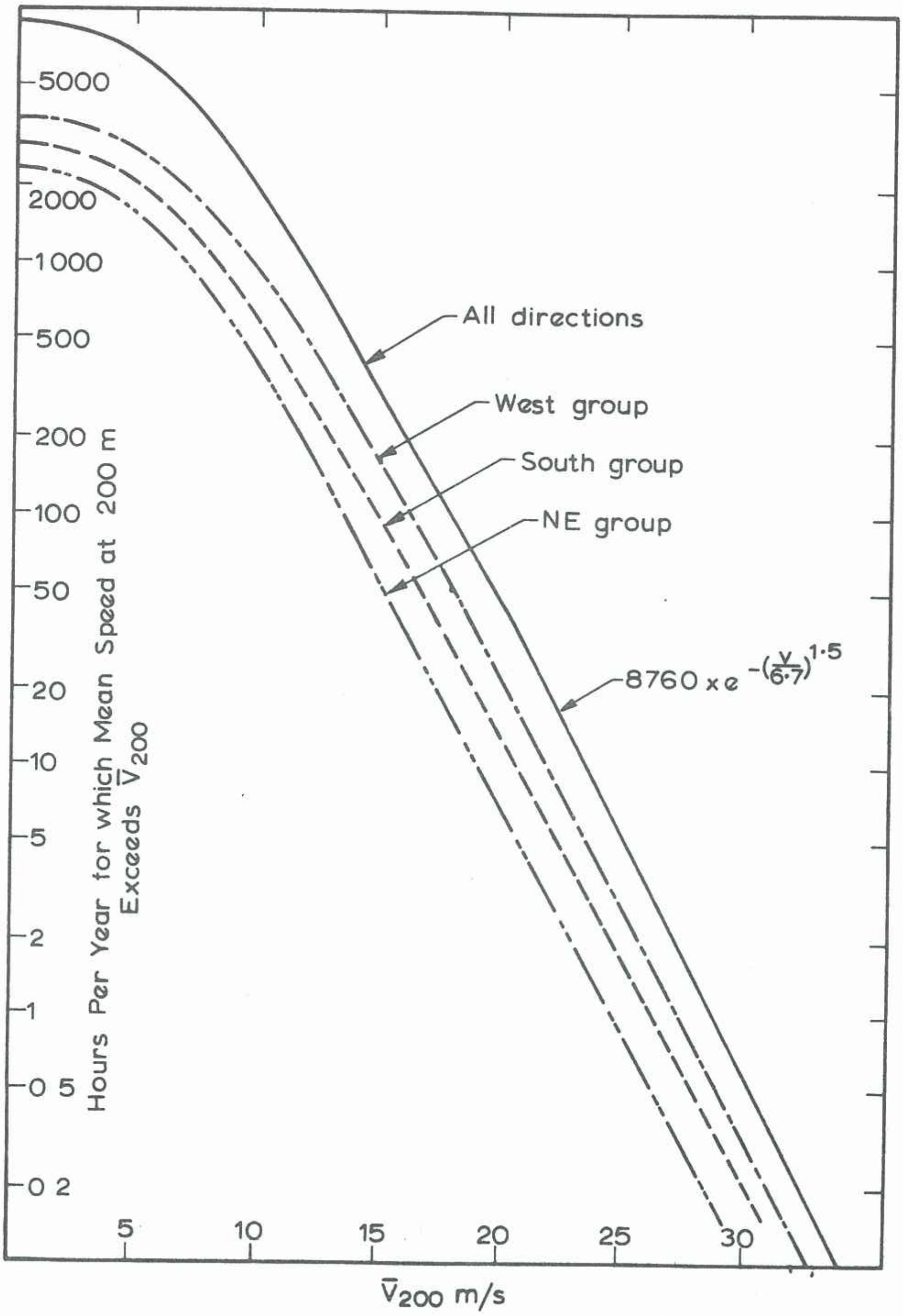

FIG. 3 PROBABILITY DISTRIBUTION OF THE MEAN HOURLY WIND SPEED AT 200 m

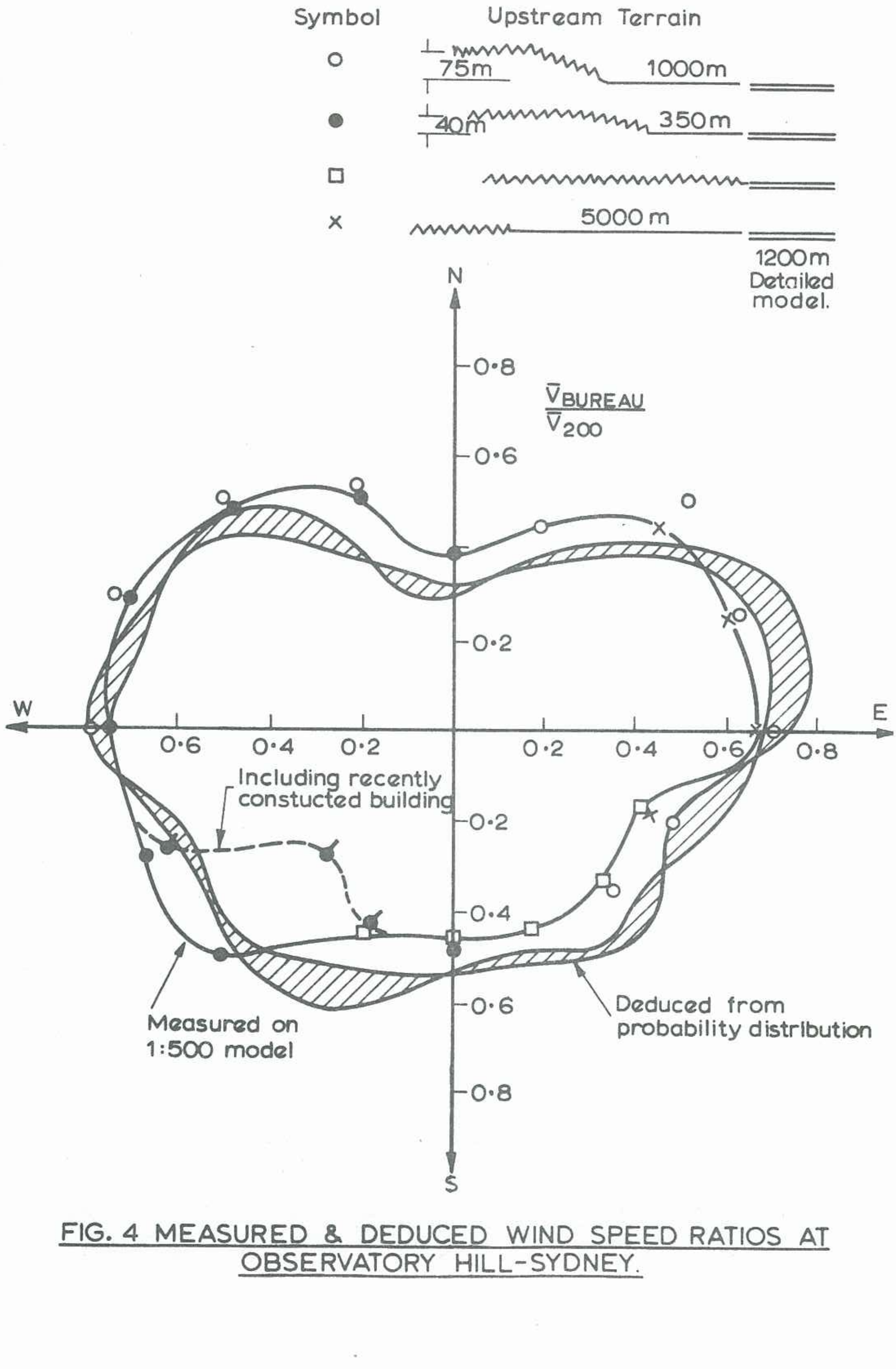

FIG. 4 MEASURED & DEDUCED WIND SPEED RATIOS AT OBSERVATORY HILL-SYDNEY.

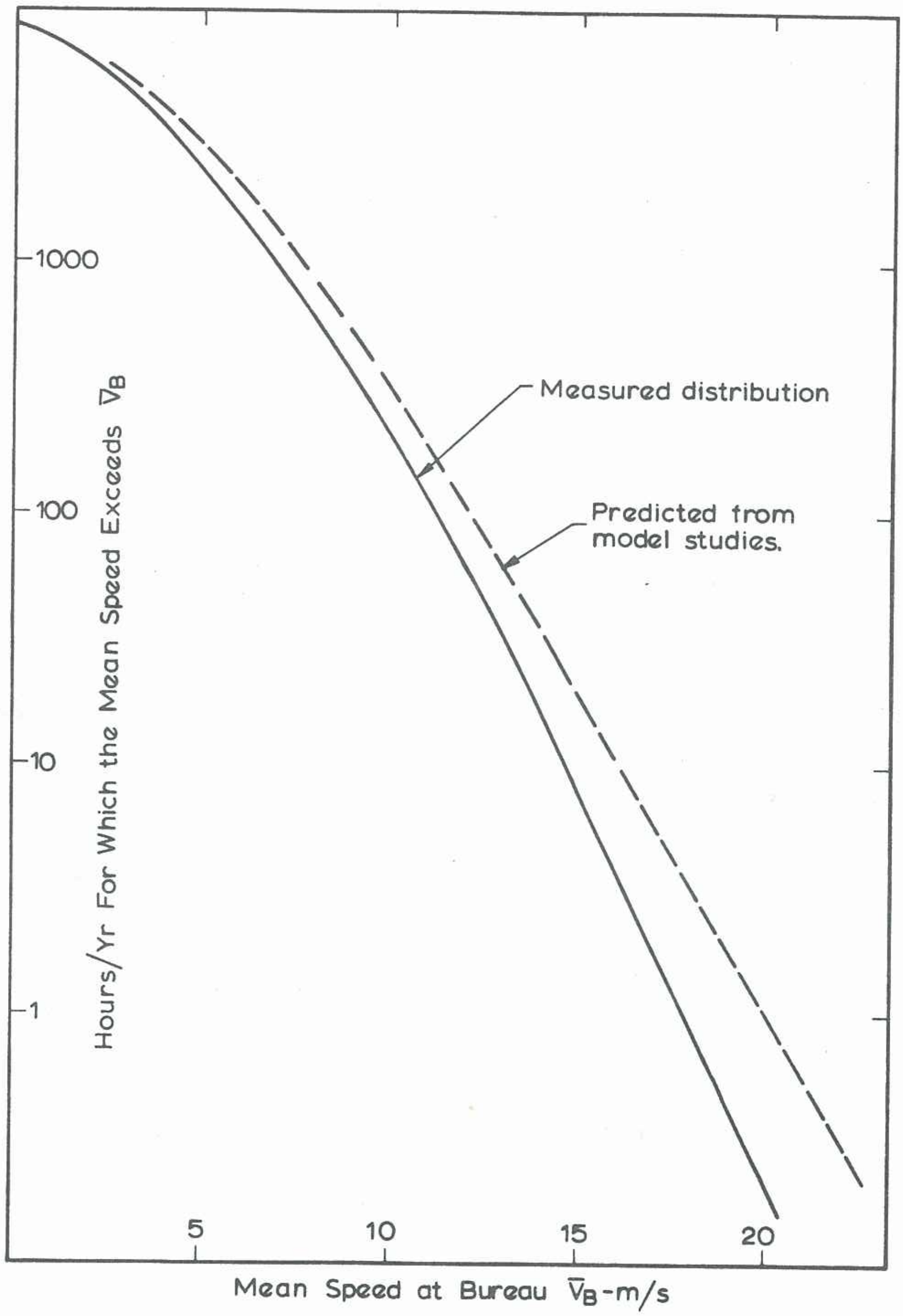

FIG. 5 MEASURED & PREDICTED WIND SPEED DISTRIBUTIONS AT SYDNEY WEATHER BUREAU. (OBSERVATORY HILL)