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Sites for Wind-Power Installations: PHYSICAL MODELING OF THE WIND FIELD OVER KAHUKU POINT, OAHU, HAWAII

FINAL REPORT

by

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October 1979

Prepared for the United States
Department of Energy
Division of Distributed Solar Technology
Federal Wind Energy Program

DOE Contract No. DE-AS06-77ET20292, A004

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CER79-80HCC-RNM-VAS25

NOTICE

EXECUTIVE SUMMARY

Oahua Island, Hawaii, is known to possess a rich windpower resource due to the prevailing trade wind boundary layer. Several Wind Energy Conversion System (WECS) installations have been proposed for the Kahuku Point region. Although limited field measurements have now been performed at certain proposed sites, other wind power sites or regions may exist which might have greater local potential. The present study of wind tunnel tests over a Kahuku Point model is to extend the value of field results and to provide detailed information for WECS installations in this region. Field measurements were used to validate the wind-tunnel results at several selected sites.

A contoured model of the Kahuku Point area was prepared to an undistorted scale of 1:3840. Local terrain roughness due to topography features was simulated. The approach flow over the model was adjusted to match a typical marine trade wind boundary layer.

For three different wind directions, which encompass the predominate directions from which the Pacific trade wind blows over the Kahuku Point region, measurements of wind speed and turbulence at proposed WECS sites and 40 additional grid locations were performed. These measurements were used to produce horizontal contour plots of relative wind power.

After careful examination of field measurement and wind tunnel test conditions, nineteen comparable data pairs were identified. The linear correlation between field and laboratory measurements of these data pairs was found to be 0.71. A correlation by rank of relative wind speed for these data pairs revealed a simulation at a level of 0.84.

To evaluate several currently proposed methods for speed-up prediction of flow over hills, one semi-empirical and one analytical technique were applied to several selected WECS sites. Comparison with the laboratory results indicates that both methods predict values which braket typical topography amplification. Improvement in prediction of the approach flow appears to be the first step in reducing the uncertainty of the speed-up prediction.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Dr. William Pennell of Battelle, Pacific Northwest Laboratories, for their technical review and advice, to Dr. P. Anders Daniels, University of Hawaii at Manoa, for his cooperative showing of the results from his field program, and to Drs. George Tennyson and Louis Divóne of the Department of Energy, Wind Systems Branch, for their support and advice.

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LIST OF SYMBOLS

Symbol	Definition	Dimensions
$A\ (z)$	Amplification factor at height z, i.e., $\bar{U}_i(z)/\bar{U}_o(z)$	
b	Half width for an ellipsoidal hill	L
c	Constant $c = z_{REF}/H$	
C_f	Skin friction coefficient	
$C_{f_{10}}$	Skin friction coefficient at 10 m height	
D_i	Rank difference for Site i, Eq. (4.7)	L
H	Height of hill	
k	von Karman constant	
L_d	Downwind characteristic hill length	L
L_u	Upwind characteristic hill length	L
L_{u_x}	Longitudinal integral scale	L
L_+	Upstream distance where a hill contour changes sign of slope	L
L_-	Downstream distance where a hill contour changes sign of slope	L
L_1	Hill half length: distance from crest to half height	L
L_o	Length for an ellipsoidal hill	
r	Sample correlation coefficient, Eq. (4.6)	
ΔS	Fractional speed-up ratio	
T_E	Integral time scale, Eq. (3.2)	T
U_{Fs}	Free stream velocity	LT^{-1}
$\bar{U}\ (z)$	Mean longitudinal velocity at height z for Site i	LT^{-1}
U_*	Shear velocity	LT^{-1}
u'	Local fluctuating component of longitudinal velocity	LT^{-1}

Symbol	Definition	Dimensions
z	Height above ground level	L
z_o	Equivalent roughness height	L
α	Exponent for power law velocity profile	
δ	Boundary layer thickness	L
Λ_x	Integral length scale	L

Subscripts

θ^i	Test wind direction: $\theta^1 = 45°$, $\theta^2 = 66.7°$ and $\theta^3 = 90°$.	
θ_i	Wind direction at Site i	
θ_{REF}	Wind direction at fixed reference site	
F	Field measurement	
M	Model test result	
o	Upstream reference velocity profile	
REF	Fixed reference site	
i	Site i	

1.0 INTRODUCTION

This report presents the results of a wind-tunnel model evaluation of the wind patterns and velocity magnitudes which occur over the Kahuku Point region, Oahu, during trade wind seasonal conditions. These measurements of wind speed, turbulence and flow direction may be used to evaluate the wind power resource of the Kahuku Peninsula. The wind-tunnel results have been compared with a set of field measurements provided by the Department of Meteorology of the University of Hawaii at Manoa. Measurements taken with mobile meteorological stations have been used to verify the wind-tunnel results and also to indicate the limitation of wind prospecting by modeling. Topographical amplification of the wind provided by the model Kahuku terrain was combined with semi-empirical and analytical prediction formulae provided by Bouwmeester et al. (1978) and Hunt (1978) respectively to suggest a range of confidence for site evaluation techniques.

The project is part of an extensive examination of the influence of complex terrain on the atmospheric surface layer as it relates to Wind Energy Conversion System (WECS) operation. Past research by Bouwmeester et al. (1978) and Meroney et al. (1978) has demonstrated that physical modeling can provide credible information about WECS wind characteristics over complex terrain. The present examination of the flow over Kahuku Point provides a first opportunity to utilize this methodology in a region where WECS energy form construction may be feasible and a moderate size (200 kw) WECS is scheduled in the near future.

1.1 WIND POWER RESOURCE OF KAHUKU POINT, OAHU

The State of Hawaii with total area of 16.700 km^2 was recently estimated by Elliot (1978) to possess an average mean annual wind power of more than 300 w/m^2, which is the result of a mean wind speed of 7 m/sec at 10 m Above Ground Level (AGL). Among the islands of this state, the highest average annual wind speed of 10 m/sec at 10 m AGL was obtained over Oahu island due to trade winds which prevail 80-95 percent of the time during the period May through September and 50-80 percent of the time during the period October through April.

A wind power survey conducted by the University of Hawaii reveals that the Kahuku Point region provides a most promising location for wind energy generation. Thus, several WECS installations have been proposed for this region as reported by Lindley et al. (1977) and Ramage et al. (1977). Although limited field measurements have now been performed at certain proposed sites, other wind power sites or regions may exist which have not been explored. Extended field measurement programs are expensive and time consuming. Hence, the wind-tunnel tests over Kahuku Point can extend the value of field results. Moreover, the field measurements can be used to validate the wind-tunnel results at selected sites.

1.2 PRESENT STUDY OBJECTIVES

Earlier studies in the wind tunnel provided fundamental understandings of flow characteristics over generic hills and ridges. The Rakaia Gorge study by Meroney et al. (1978) establishes the range of reliability to be expected between wind-tunnel and field data. For actual WECS installation the results need to be applied to real topography where windmill sites are proposed. Hence, a model study of Kahuku Point, an area proposed for WECS development, was undertaken. The data of these tests were compared with limited field measurements to verify the wind-tunnel physical modeling technique. Additional wind power rich zones were identified from a thorough wind characteristic survey mode over the extended Kahuku model. Predictions, semi-empirical and analytical, by Bouwmeester et al. (1978) and Hunt (1978) respectively, for predicting wind amplification or speedup over ridges or obstacles were applied to the WECS sites. Calculated values were compared to the wind-tunnel test data to support the degree of reliability of those formulas in practical cases.

To be more specific, the present study objectives were:

1. To provide information for WECS installations at Kahuku Point, Oahu.
2. To confirm, validate and extend the wind-tunnel and field information.
3. To validate and reinforce the semi-empirical and analytical speedup prediction formulas.

1.3 PRIOR PHYSICAL MODELING EXPERIENCE

A project to examine the influence of complex terrain on the atmospheric surface layer and its effects on WECS operation has been carried on at

Colorado State University since 1975. Achievement of earlier stages of this effort has been reported by Meroney et al. (1978) for the wind-tunnel simulation of the influence of two-dimensional ridges, and by Bouwmeester et al. (1978) on the general wind characteristics over ridges.

Earlier efforts of laboratory simulation of flows over complex terrains were discussed and summarized in the report by Meroney et al. (1976). The report of the Rakaia Gorge effort by Meroney et al. (1978) provided a detailed comparison between field and laboratory measurements of flow over complex terrain. The validity of physical modeling of flow over complex terrain for WECS application was initially confirmed. Subsequently, Holmes et al. (1979) reported the comparison of field and laboratory measurements of maximum gust velocities over Castle Hill of 286 m height near Townsville, Australia. Linear correlation coefficients ranging from 0.68 to 0.78 were obtained in both experiments.

Other related efforts were also reported by Wilson (1977), Hunt et al. (1978) and Britter et al. (1979). Among them, the latest was found to be directly related to the WECS study. Through carefully design experiments by changing roughness condition, they proved that linear superposition of roughness and elevation effects predicts their joint effects on velocity amplification over hills as initially suggested by Jensen and Peterson (1978).

1.4 PREVIOUS ACHIEVEMENTS OF CSU GENERIC HILL STUDIES

The initial stages of the Wind Power Siting project examined the various aspects of wind flow over two-dimensional ridges and three-dimensional hills. These investigations led to a detailed understanding of the flow characteristics over hills and ridges. Details of the CSU generic hills study were reported by Rider and Sandborn (1977b) and Meroney et al. (1978b).

Bouwmeester et al. (1978) reported detailed surveys of neutral flow over triangular-shaped and sinusoidal-shaped model ridges with varying upstream and downstream slopes. The upwind boundary condition was also changed to determine the upwind turbulence effect on flow characteristics over two-dimensional ridges. The results of Bouwmeester's experiments are also summarized in Meroney et al. (1978). Bouwmeester et al. (1978) conclusions which are relevant and important to the present study are recapitulated as follows:

1. Largest speedup occurs over symmetrically-shaped ridges which just avoid downwind separation.
2. Downwind separation of a ridge depends on both upwind and downwind slopes of the ridge.
3. The ratio of ridge height to boundary layer thickness does not affect the downwind separation of a ridge.
4. For a ridge of $H/L_u > 1/2$, upwind separation occurs.
5. Speedup over round-crested and sharp-crested ridges are essentially equal for ridges with the same parameter values of H/L_u and H/L_d.
6. Upwind surface roughness and turbulence level of the approach wind increase the possibility of downwind separation. If either upwind surface roughness is large or turbulence level of the approach wind is high due to upwind topography, downwind separation could happen for a fairly gentle sloped hill.

Bouwmeester proposed a semi-experimental method of predicting the speedup over ridges. This method will be discussed in Chapter 5.

In a separate but related project Meroney et al. (1978a) performed a validation study of wind characteristics over a complex terrain at Rakaia Gorge, New Zealand. Typical field data were compared to the wind-tunnel test data over both contoured and terraced models of the Rakaia River Gorge region using an undistorted geometric scale of 1:5000. Their study affirmed the validity of physical modeling to simulate the atmospheric shear layer flowing over complex terrain. The conclusions of the Rakaia Gorge study important to the present program are:

1. Physical modeling reproduced the relative wind speeds found over complex terrain to sample and rank correlation coefficients equal to 0.78 to 0.95 respectively.
2. Adequate physical modeling of adiabatic shear flow over complex terrain requires attention to surface roughness and terrain shape as well as upstream velocity profiles, turbulence intensity, and turbulence eddy structures.
3. Terraced models are not as effective as contoured models which include surface texture when modeling flows over complex terrains.

1.5 FIELD PROGRAM OF UNIVERSITY OF HAWAII

In 1974, researchers at the University of Hawaii, Manoa, started to examine wind energy potential for Oahu. By January, 1977, they were able to identify and characterize the strong wind areas on Oahu. The strong wind areas are shown in Figure 1.1 with measured annual mean wind velocity noted for each area. Among those strong wind areas, Kahuku Point is considered to provide the most promising site for wind energy generation.

To pinpoint the strong wind sites over Kahuku Point, two methods of data sampling were used. For a site in a rugged and heavily populated topography, a fixed station sampling method was used to collect the long-term characteristics of local wind, such as wind direction, wind speed, turbulence intensity, etc. Four fixed stations over Kahuku Point were operated. In all these stations the instruments were placed at 10 m AGL on masts to be clear of surrounding terrain and vegetation.

A mobile station sampling method was also used to provide more extended wind power surveys over accessible terrain. Three vans equipped with 30 ft telescoping masts, which could be set up in 30 minutes, were used. At each site statistical properties of local wind were measured continuously during a time period of at least 24 hours.

Six-minute and hourly average values were obtained for every station and are available on magnetic tape or as numerical printouts; these values were used to evaluate the statistical properties of the wind at each location. Properties evaluated were: mean wind direction, mean wind speed, standard deviation of wind direction, standard deviation of wind speed, etc.

A specific site Kahuku Upper Point was selected as a reference site. Mean values of data measured during a specific period of time at this reference site are used to normalize the data measured during the same period of time at other sites.

1.6 ORGANIZATION OF REPORT

The experimental setup for the wind-tunnel test is discussed in Chapter 2 which includes discussions of the wind-tunnel facility, the Kahuku Point model and measurement techniques. The preliminary test, which examined flow pattern over a complete but smaller scale model of Kahuku, is also discussed in this chapter.

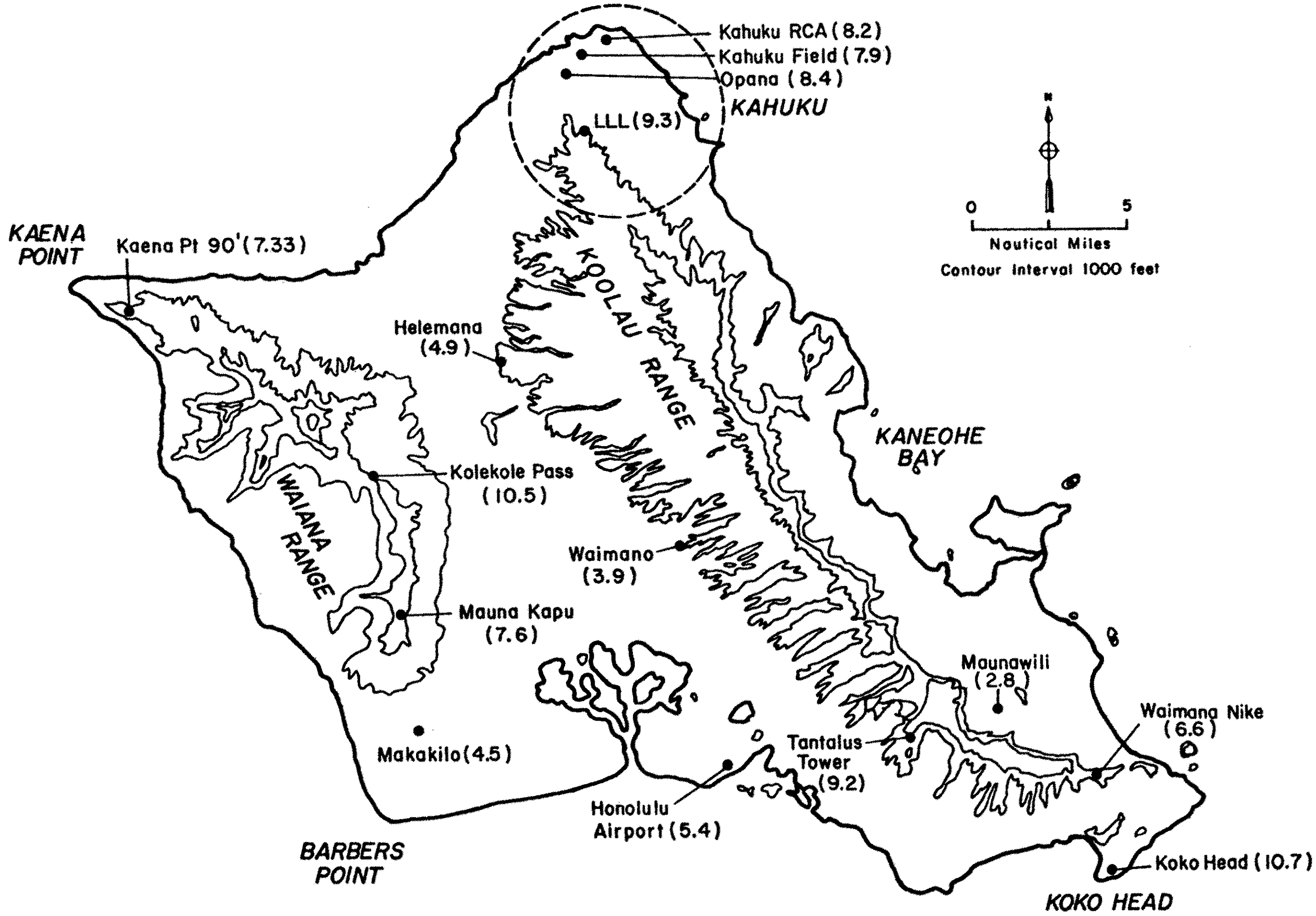

FIGURE 1.1. Annual Mean Wind Velocity (m/sec) at Sites Over Oahu Island and the Area Covered in the Model Test.

A discussion of laboratory results is presented in Chapter 3. The results include mean wind profiles and longitudinal turbulence profiles at each WECS site proposed, and the spectra and wind characteristics of the approach flow field. These results and more detailed surveys were used to generate contoured maps of wind amplification over the Kahuku region at 10 m and 50 m AGL for three possible wind directions which bracket the predominate wind directions of the trade wind.

Laboratory data is compared with limited field data in Chapter 4. Due to the possible uncertainty between laboratory and field test conditions, various criteria for data selection are discussed. Based on these criteria, specific comparisons between the wind-tunnel and field measurements were made.

Chapter 5 includes comparisons of the speedup ratio measured in the laboratory to values predicted by a semi-empirical and an analytical formula respectively. An approximation scheme and limitation for both formulas are discussed briefly.

Conclusions and recommendations concerning the program objectives are summarized in Chapter 6.

2.0 EXPERIMENTAL FACILITIES AND DATA ACQUISITION

The methods used to make laboratory measurements and the techniques used to convert these measured quantities to meaningful field equivalent quantities are discussed in this chapter. Attention has been drawn to the limitations in the techniques in an attempt to prevent misinterpretation or misunderstanding of the results presented in the subsequent chapters. Some of the methods used are conventional and need little elaboration.

2.1 WIND-TUNNEL FACILITIES

The simulation of the atmospheric boundary layer flow over Kahuku Point, Oahu, was performed in the Environmental Wind Tunnel (EWT) at CSU, shown in Figure 2.1. This wind tunnel is specially designed to study atmospheric boundary layers. It incorporates features such as adjustable ceiling, rotating turntables, transparent boundary walls, and a long test section to permit development of adequate boundary layer thickness. Mean wind speeds of 0.2 to 50 ft/sec can be obtained in the EWT. The flexible test section roof is adjustable in height to permit the longitudinal pressure gradient to be set to zero or specific values. For the WECS study over Kahuku Point, the approach surface configuration arranged in this wind tunnel has a wind speed maximum level equivalent to 600 m height, which is similar to that for the prevailing trade wind boundary layer over Oahu Island.

The Transpiration Wind Tunnel, shown in Figure 2.2, was used for preliminary examination of the flow pattern over the entire Oahu Island. This preliminary study was carried out to insure that no unsimulated distortion of flow occurred over the full versus the partial model of Kahuku Point. The Transpiration Wind Tunnel also has a flexible ceiling, which could be adjusted to a zero pressure gradient condition.

2.2 DESCRIPTION OF KAHUKU POINT MODEL

An undistorted contoured model of Kahuku Point area designed to a scale of 1:3840 was constructed from layered polyurethane foam and sanded to terrain levels. This model has a diameter of 3.66 m. The dotted circle shown on Figure 1.1 indicates the area covered in the model. Figure 2.3 shows a detail of this region and the location of each proposed measurement site.

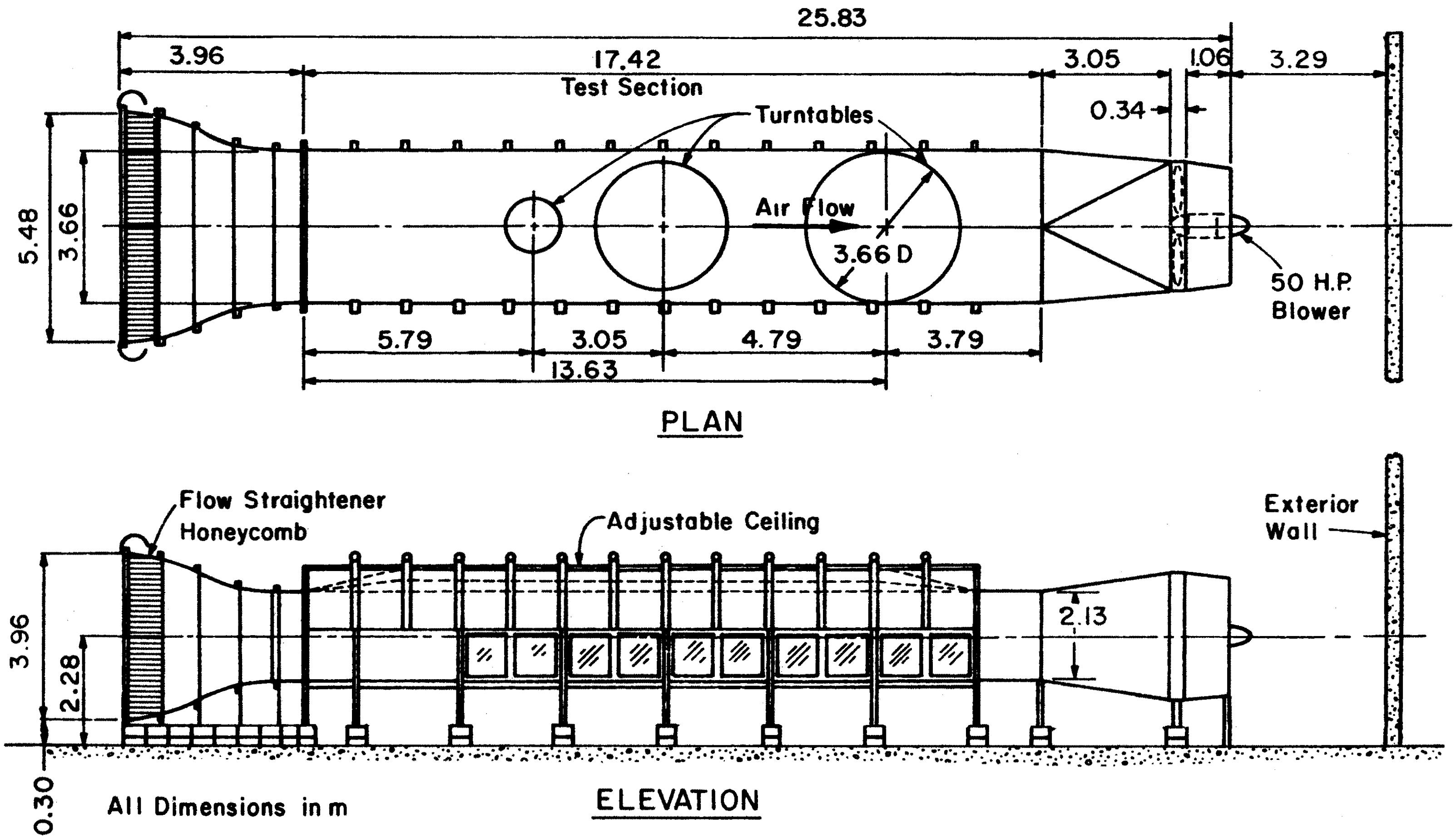

FIGURE 2.1. Environmental Wind Tunnel (EWT) Facility at Colorado State University.

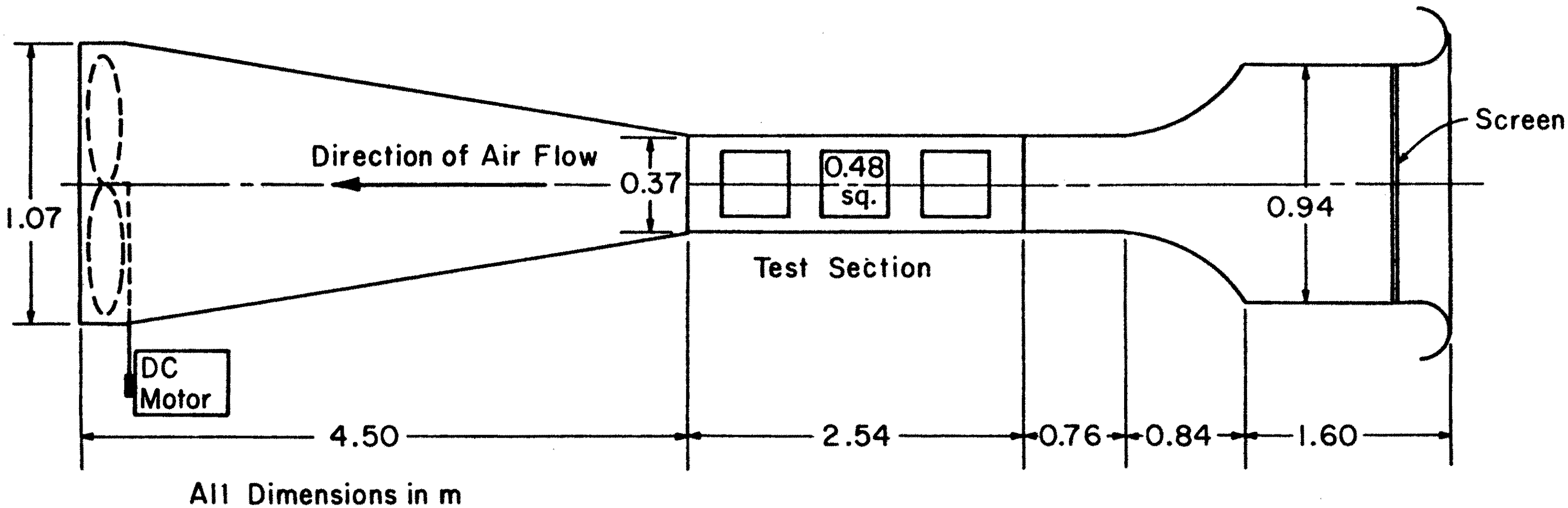

FIGURE 2.2. Transpiration Wind Tunnel Facility at Colorado State University.

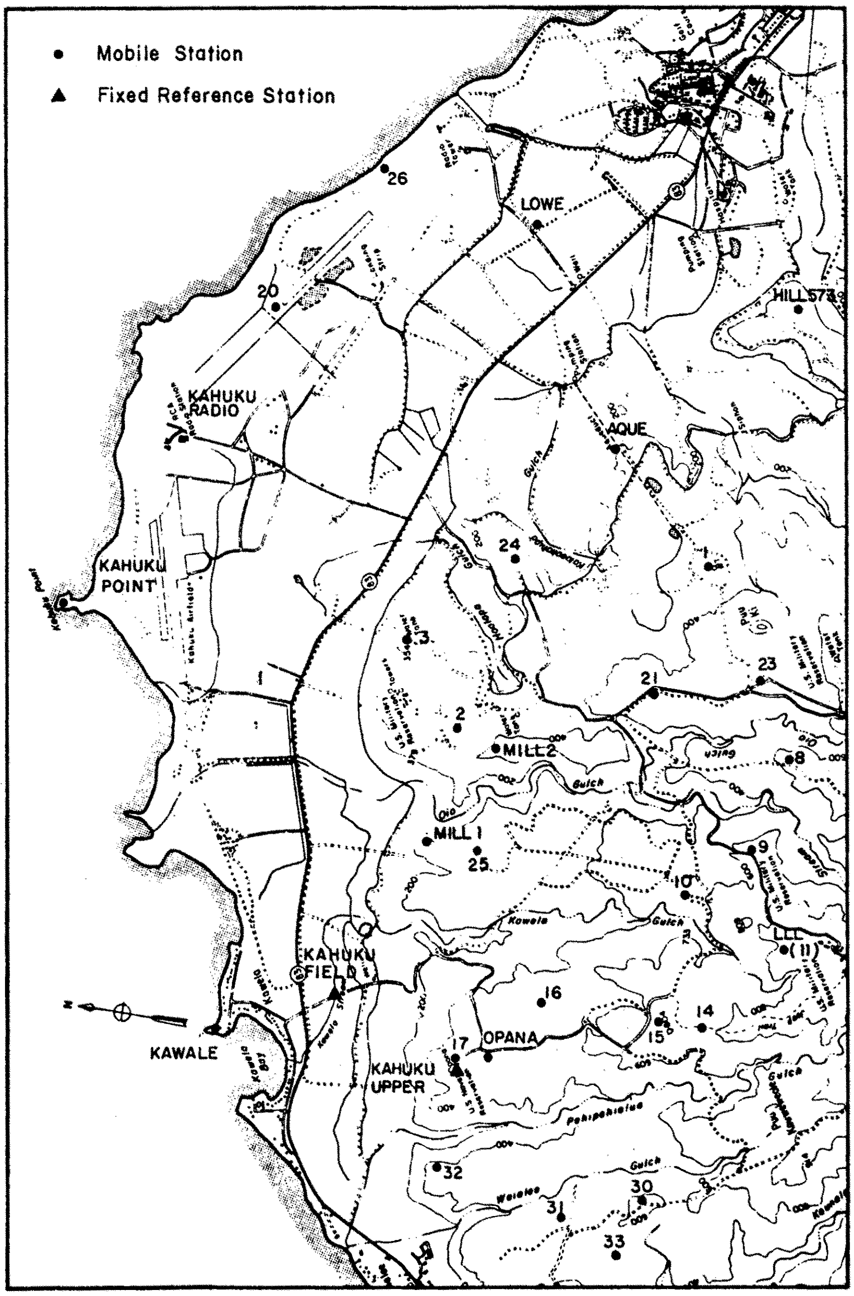

FIGURE 2.3. Contoured Map for Kahuku Point Area and Locations of WECS Site in this Area.

Measurements made over the Rakaia Gorge, New Zealand, simulation reported by Meroney et al. (1978a) demonstrated that local surface roughness must be estimated to assure adequate physical modeling. To do so, the report, "Detailed Land Classification--Island of Oahu," published by Land Study Bureau of University of Hawaii in 1972 was used to prepare the model surface texture. Based on the aerial photos, zones of different surface features such as grazing, sugarcane field, forest, etc. can be identified over the area covered by the Kahuku Point model. Epoxy crated "aqua-pebbles" of mean radius ranging from 2.0 mm to 6.0 mm were selected as media to simulate local surface roughness. By gluing such pebbles with variable densities in zones where different features were observed, it was possible to simulate the local terrain roughness over the Kahuku Point model.

2.3 FLOW VISUALIZATION: PRELIMINARY TEST AND FINAL MODEL

To insure that the flow field was properly modeled when the Kahuku Point model was placed in the EWT, a preliminary test was made in the Transpiration Wind Tunnel. A contoured model of scale 1:250,000 for the island of Oahu was used in this test. The scaled trade wind boundary layer was simulated by means of barriers and graveled upstream surface roughness. Then, flexible string tufts were glued evenly over this small model as indicators of local wind directions.

At a wind speed of 10 m/sec, the flow pattern over the Kahuku Point area was determined from the alignment of the tuft directions. A vertical barrier was then mounted parallel to the free stream direction between the model to the wind-tunnel ceiling to simulate the line which matches the EWT boundary with the Kahuku Point model. The tuft directions over the Kahuku Point area were observed at the same wind speed of 10 m/sec. Comparison of flow patterns obtained for the two conditions was an indication of the effect of the wind-tunnel side wall boundary on the flow field over the Kahuku Point model.

For the measurements over the 1:3840 model which will be discussed in the following section, the hot-wire probe was set perpendicular to the free stream direction by assuming that the local wind direction is not affected by local topography. This assumption was justified by employing local direction indicators. Small flags of 1.0 cm height were used to indicate the local wind directions. The flags were also used to identify the local flow separation zones over the topography.

2.4 MEASUREMENTS

Vertical, mean velocity and longitudinal turbulence intensity profiles at each WECS site, shown in Figure 2.3, were measured using a constant temperature hot-wire anemometer. These measurements were reported for three different wind directions (they are designated as 45°, 66.7° and 90° from true north) which encompass the predominate directions from which the pacific trade wind blows over the Kahuku Point region. These wind directions were obtained by simply rotating the Kahuku model. For each wind direction, 40 additional locations over the model were selected for mean velocity and turbulent intensity measurements to supplement the field designated locations. Measurements at the prespecified field sites together with the additional locations provided data for a detailed wind power contour map.

During the measurements the EWT movable carriage was positioned manually at any desired site above the model. A control unit outside the tunnel monitors the vertical movement of the probes from heights of 0.3 cm to 50 cm above the model. This actuator system provides a constant voltage change for a particular change in height. The probe support was attached to the carriage by a 0.5 m extension frame. At this length, flow distortion at a measuring location caused by the actuator system is negligible.

Measurements of power spectra at several heights were obtained at three locations for a wind direction of 45°. The locations were: Site Mill 1, Site LLL, and a location which is 8 m from the inlet of the EWT along the centerline. A System 5500 Thermal Systems, Inc. constant temperature hot-wire anemometer was used for all velocity measurements. A Hewlett Packard System 1000 digital data acquisition system was used to manage data.

3.0 RESULTS OF MEASUREMENTS

The results of the laboratory measurements are discussed and interpreted in this chapter. Justification of the approach flow field which assures the correct simulation of the trade wind boundary layer over the Kahuku Point region is addressed. Contour plots which indicate the wind power resource distribution over this region are also presented.

3.1 APPROACH FLOW FIELD

The uniformity of the approach flow, boundary layer thickness and turbulent structure in the EWT were determined without the Kahuku Point model in place in order to properly locate the model and to define the local wind characteristics in the EWT. At a free stream velocity of about 10 m/sec, measurements were made over a rectangular grid overlapping the model location. After the air passes the honeycombs at the wind-tunnel inlet, the boundary layer grows gradually over the smooth wind-tunnel floor in a regular two-dimensional manner.

At each location evaluated, the velocity measured at a height of 15 cm (600 m equivalent above ground) was found to be a maximum. Thus, the velocity at this height was used to normalize the vertical velocity profile for each specific location. Figure 3.1 shows the normalized velocity and turbulence intensity profiles along the wind-tunnel centerline at locations of 8, 10, 12, and 14 meters from the wind-tunnel inlet. It was found that the boundary layer in the EWT reaches an equilibrium condition with a boundary layer thickness $\delta \sim 15$ cm at 8 meters from the entrance nozzle.

At the 8 cm location measurements were made spanwise at every 0.5 meters from the wind-tunnel center toward both tunnel walls. These measurements, shown in Figures 3.2 and 3.3, demonstrate that the approach flow at $U_{FS} \cong$ 10 m/sec was uniform. As a result of this survey, the Kahuku Point model was installed directly downstream of the 8 m line.

The approach velocity profiles have a power-law exponent of 0.13 ~ 0.15, which fit the data from an equivalent height of about 200 meters. The semi-logarithmical profile $\bar{U}(z)/U_* = \frac{1}{k} \ln \frac{z}{z_o}$ fits the profiles from an equivalent height of 10 m to 150 m when the equivalent parameters are $z_o = 11$ cm, $U_*/\bar{U}_\delta = 0.047$ and $k = 0.40$. Resultant skin friction coefficients were

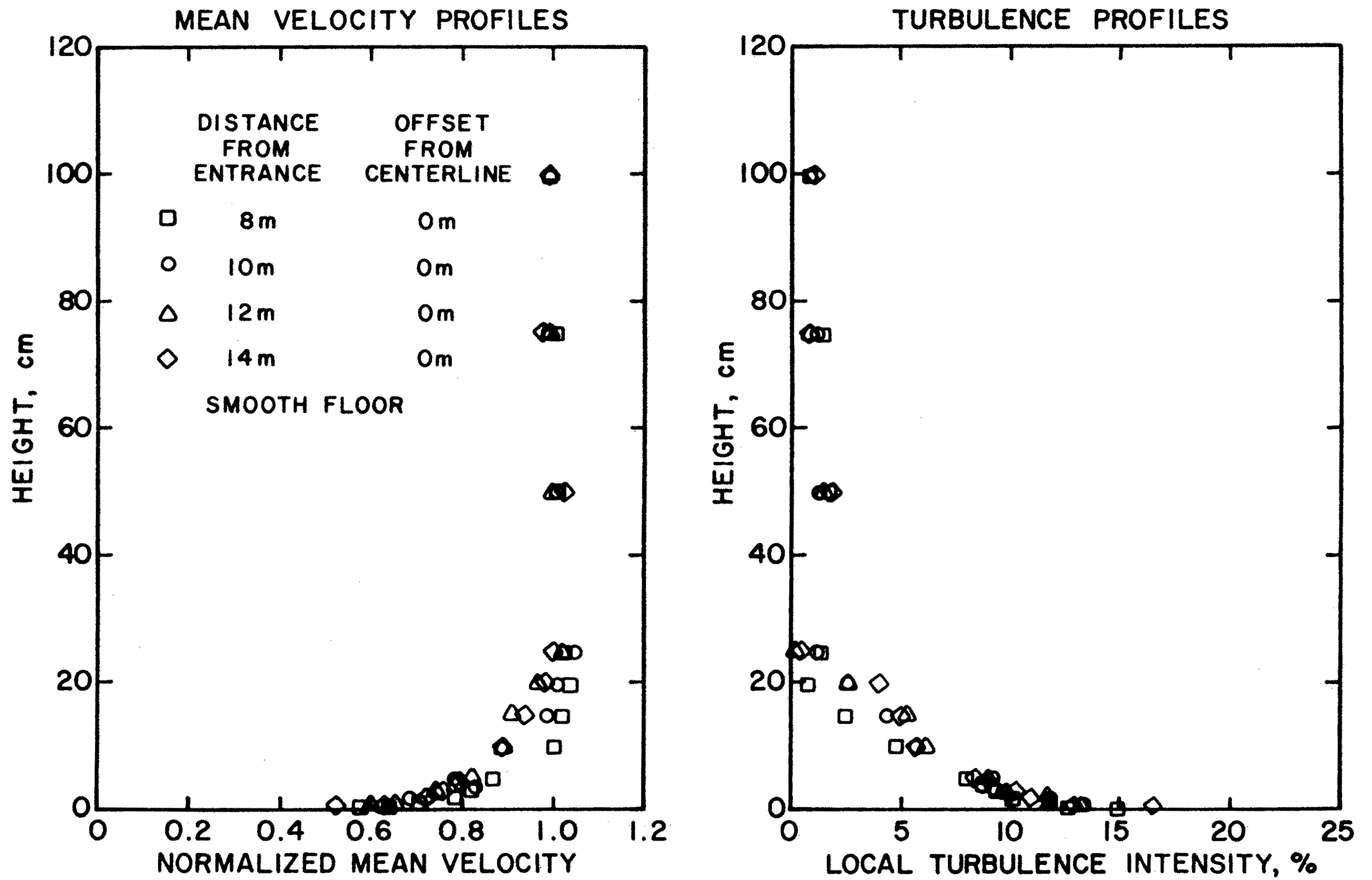

FIGURE 3.1. Velocity and Turbulence Intensity Profiles Measured Along the Centerline at 8, 10, 12 and 14 m from the Wind Tunnel Entrance over the Smooth Floor of EWT. Velocity Profiles were Normalized with Velocity Measured at 50 cm Height.

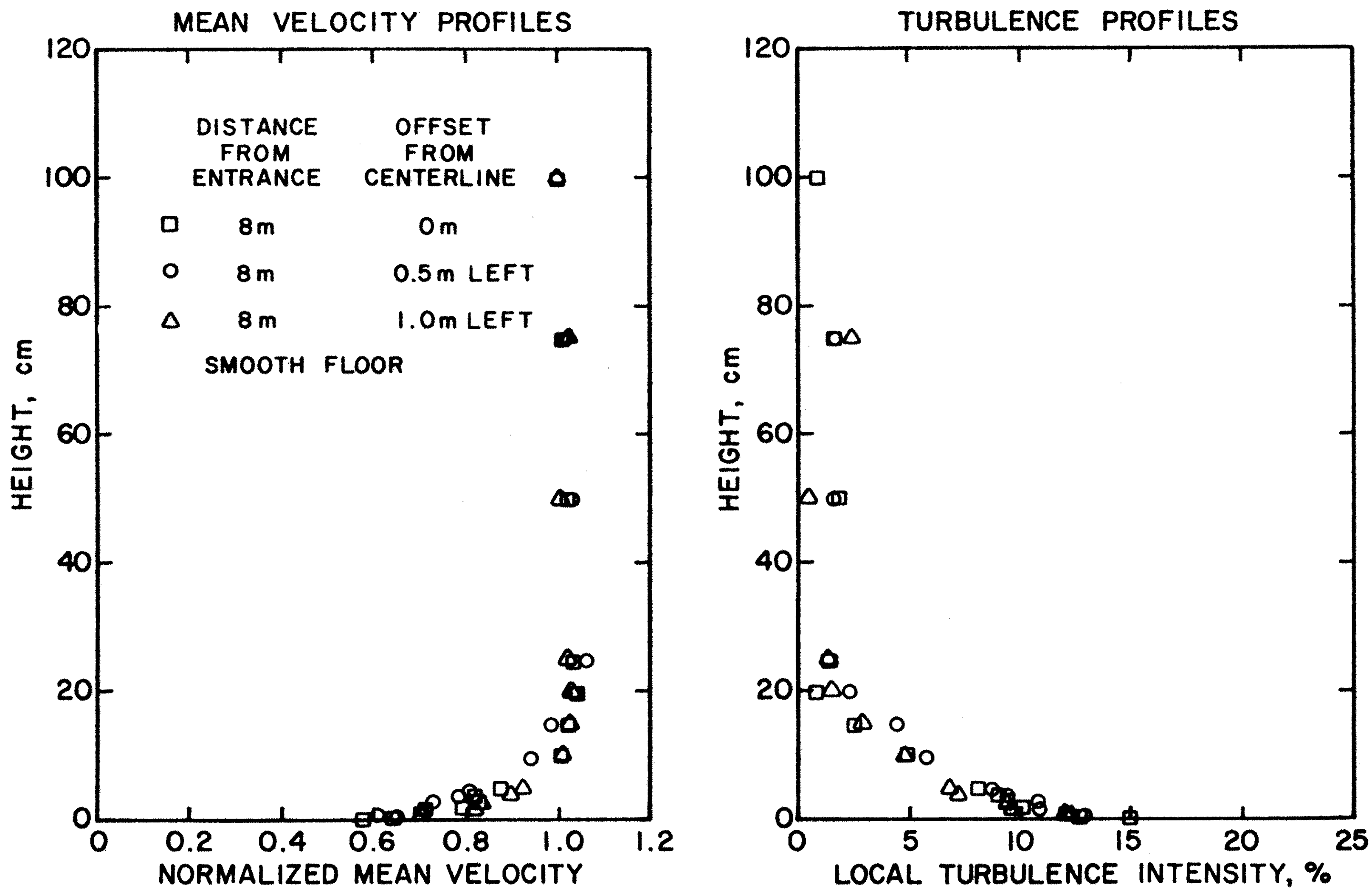

FIGURE 3.2. Velocity and Turbulence Intensity Profiles Measured at Spanwise Locations at 8 m Location over the Smooth Floow of EWT. Velocity Profiles were Normalized with Velocity Measured at 50 cm Height.

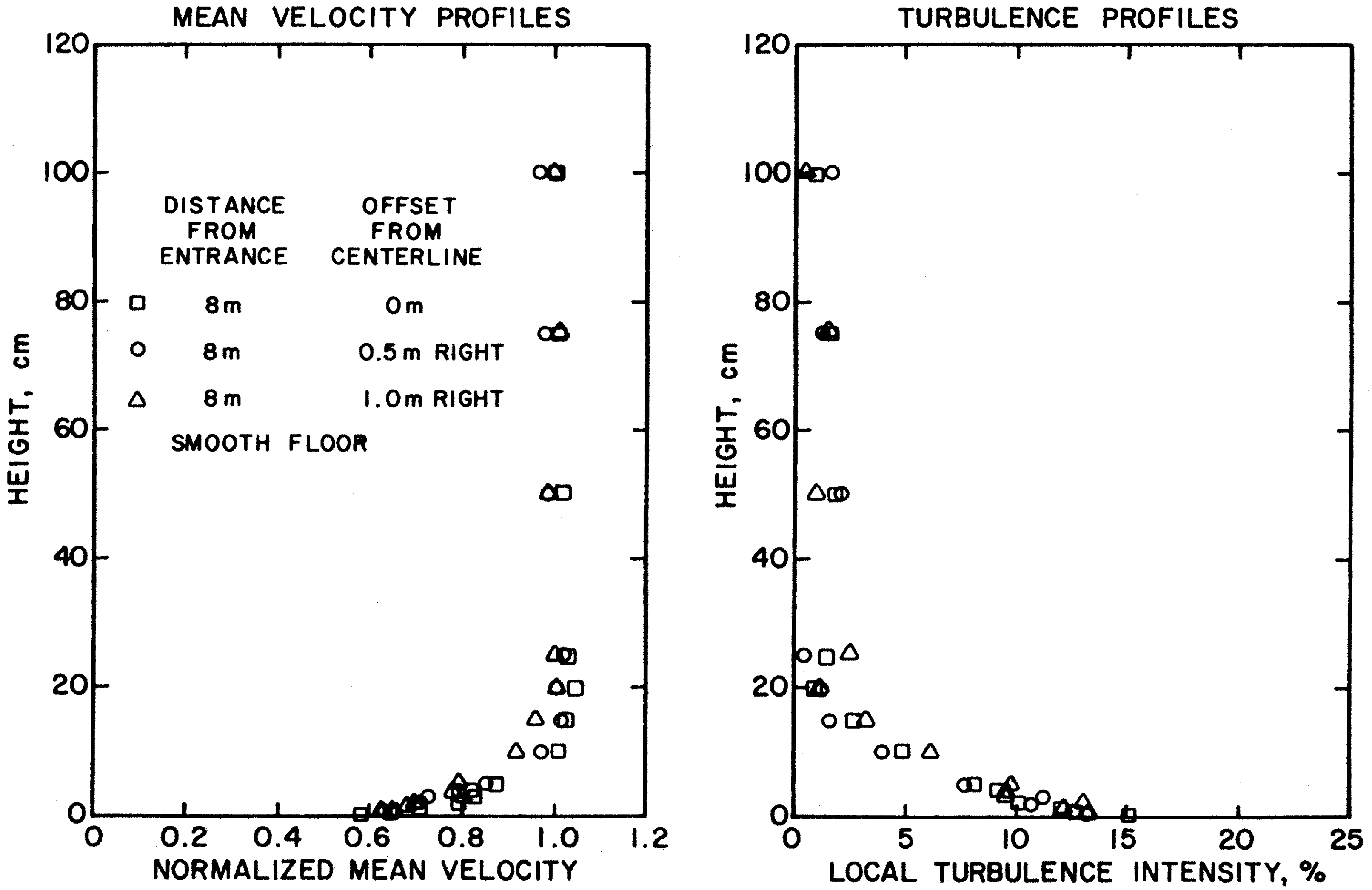

FIGURE 3.3. Velocity and Turbulence Intensity Profiles Measured at Spanwise Locations at 8 m Location over the Smooth Floor of EWT. Velocity Profiles were Normalized with Velocity Measured at 50 cm Height.

$C_f/2 = (U_*/\bar{U}_\delta)^2 = 0.0022$ or $C_{f_{10}} = 2\ (U_*/\bar{U}(10))^2 = 0.0149$. The local longitudinal turbulence intensity at the surface was 17 ~ 18 percent at z = 10 m.

With the model in the EWT, spanwise measurements at the 8 m line were made. Figures 3.4 and 3.5 show the results, which again demonstrate the uniformity of the approach flow with the Kahuku Point model in place. Moreover, comparison of these profiles to those shown in Figures 3.2 and 3.3 indicates that the model does not appear to affect the approach flow structure.

A few velocity profiles for the marine trade wind boundary layers have been reported by Augstein (1979). Two typical profiles designated as BOMEX and pacific trade wind boundary layers were used to compare with the boundary layer simulated over the Kahuku Point model. The comparison is shown on Figure 3.6 wherein each profile has been normalized by the velocity maximum measured at the 600 m height. The typical trade wind boundary layer characteristics have been simulated approximately to a 1000 m equivalent height. Typical sea roughness length may vary from 10^{-7} cm to 1 cm depending upon the state of the sea surface and the average surface shear stress (Roll, 1965). The modeled sea surface roughness appears to be about 10 cm. Since this represents a smooth wind-tunnel floor condition, it is the minimum roughness attainable at a scale of 1:3840.

3.2 POWER SPECTRA

Three locations were selected for longitudinal power spectra measurements. They were: Site Mill 1, Site 2 and the intersection of the 8 m line and centerline which was designated as Site Ocean as shown in Figure 2.4. The summary of the results are tabulated in Table 3.1. Figure 3.7 shows the comparison of power spectra at the equivalent 10 m height for three locations mentioned above with the semi-universal spectrum proposed by Harris. These spectra indicate that there is no distinct single length scale over the Kahuku Point model under test.

Integral scales were estimated from the spectra peak:

$$L_{u_{x_{spec}}} = \frac{0.146}{k_p} = 0.146\ \frac{\bar{U}}{n} \qquad (3.1)$$

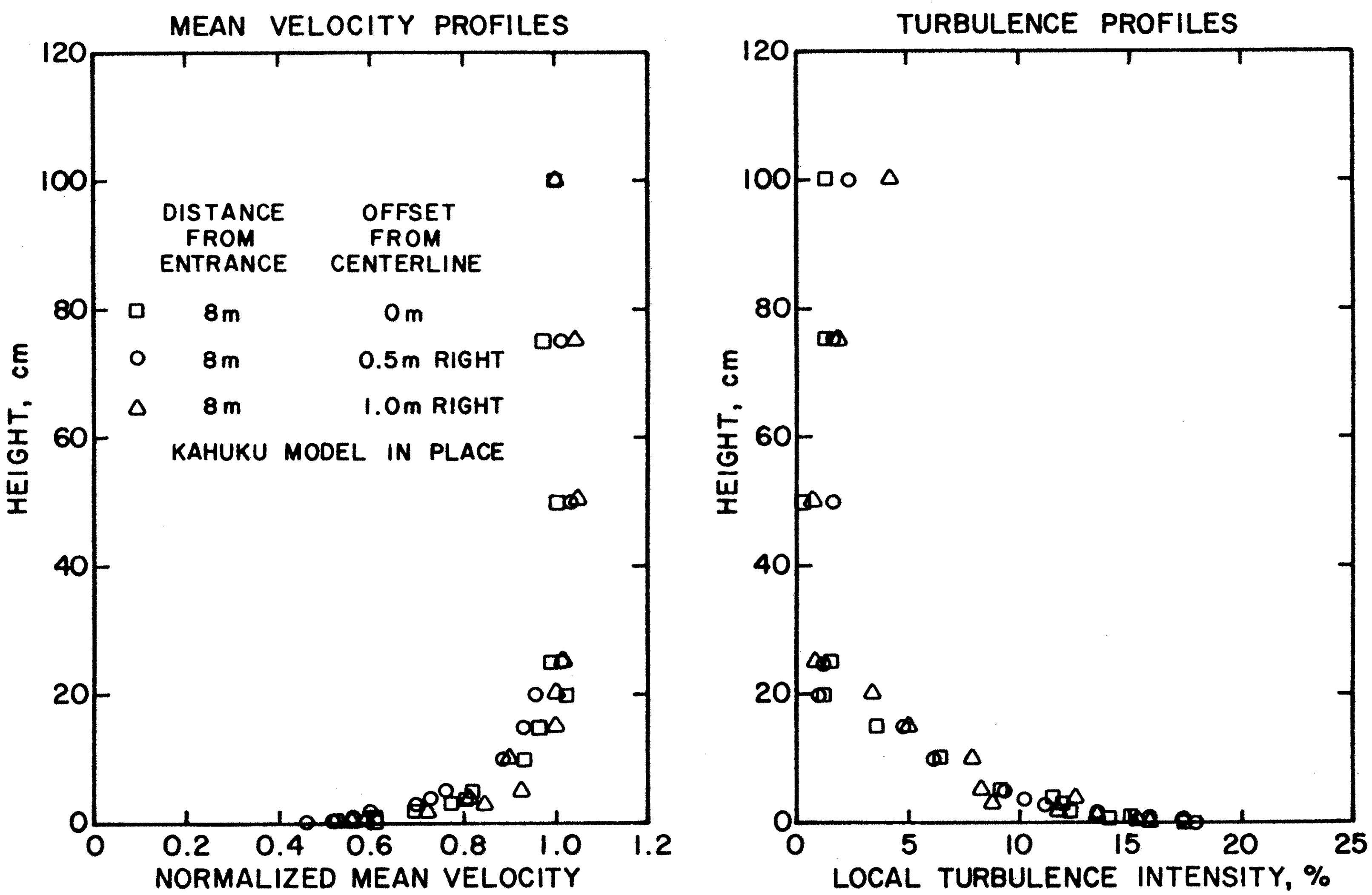

FIGURE 3.4. Velocity and Turbulence Intensity Profiles Measured Upstream of the Kahuku Model at 8 m Location. Velocity Profiles were Normalized with Velocity Measured at 50 cm Height.

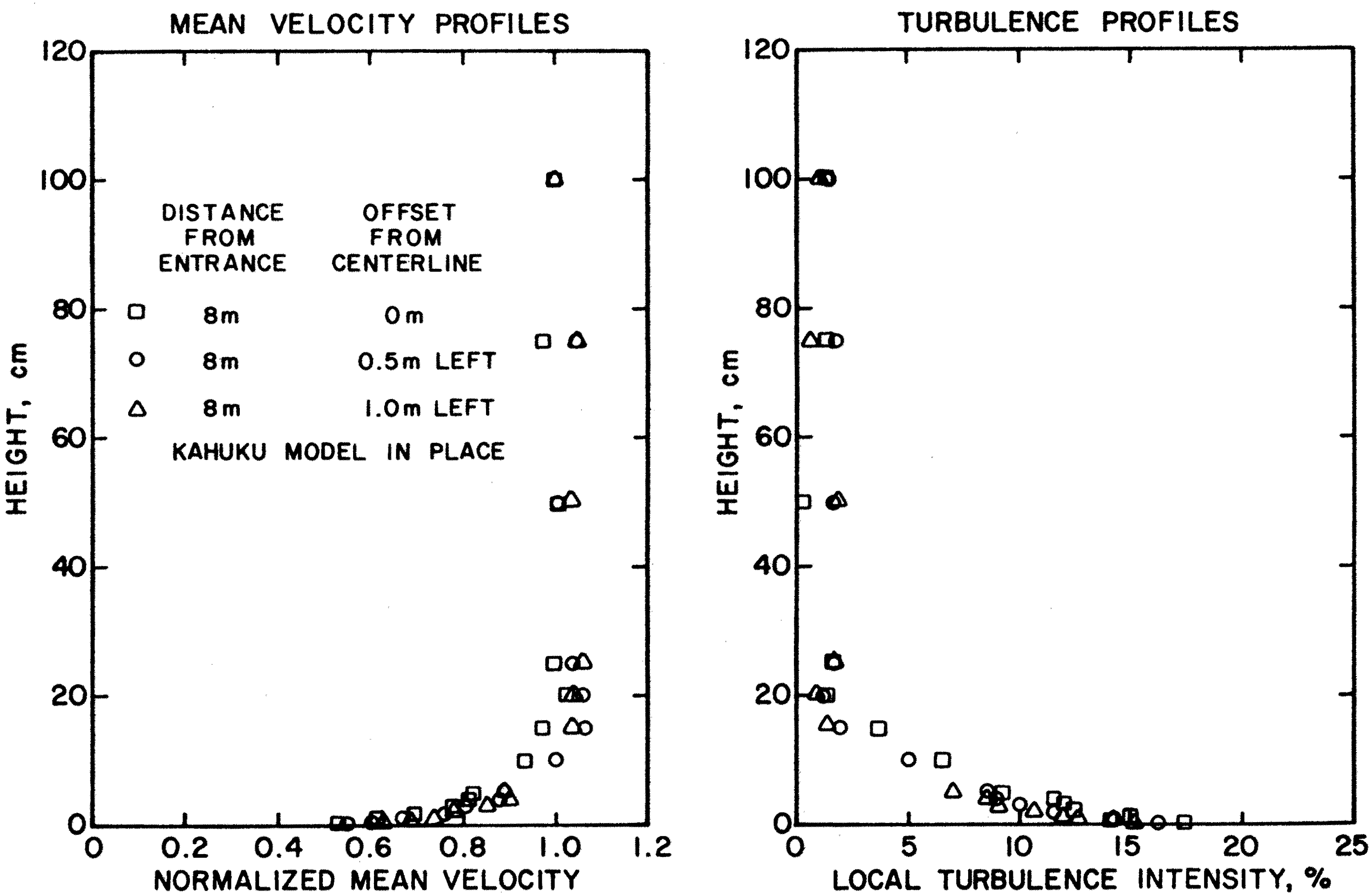

FIGURE 3.5. Velocity and Turbulence Intensity Profiles Measured Upstream of the Kahuku Model at 8 m Location. Velocity Profiles were Normalized with Velocity Measured at 50 cm Height.

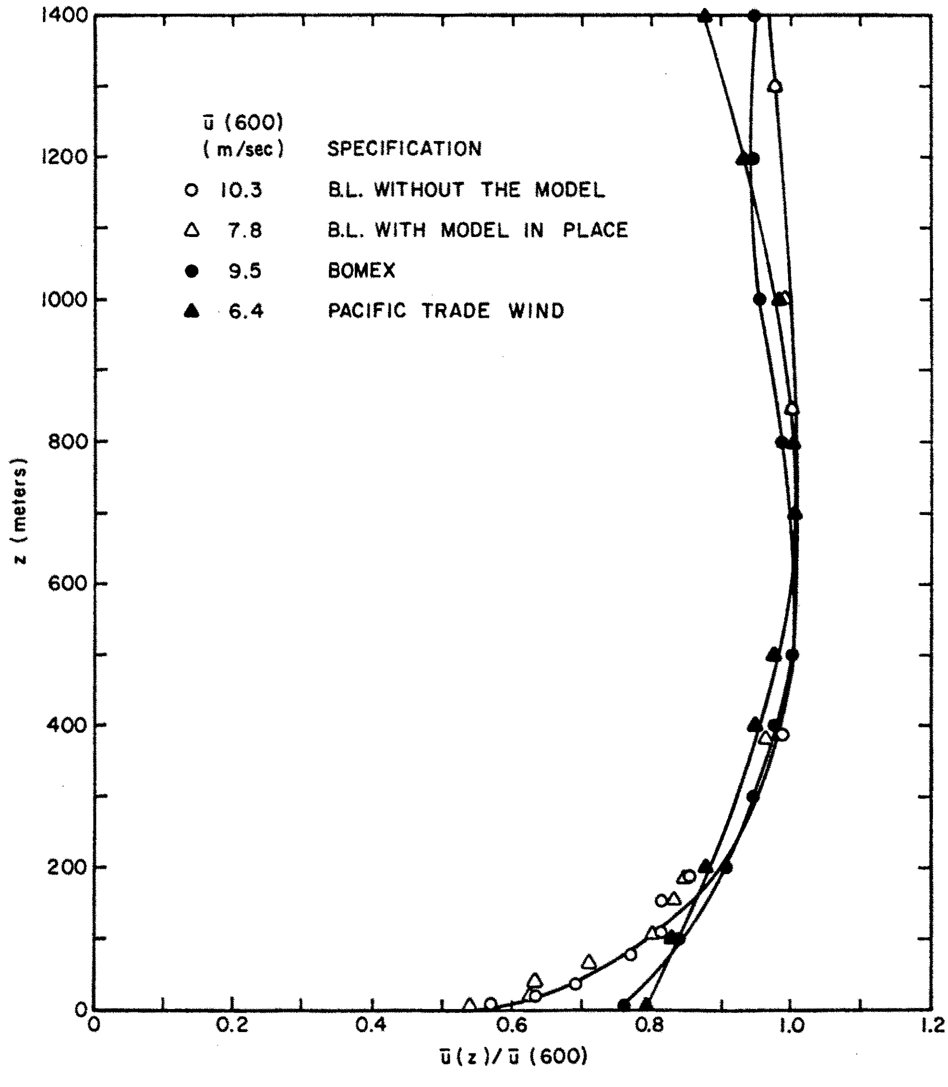

FIGURE 3.6. Comparison of Simulated Trade Wind Boundary Layer in EWT with Marine Trade Wind Boundary Layer Reported by Augstein (1979).

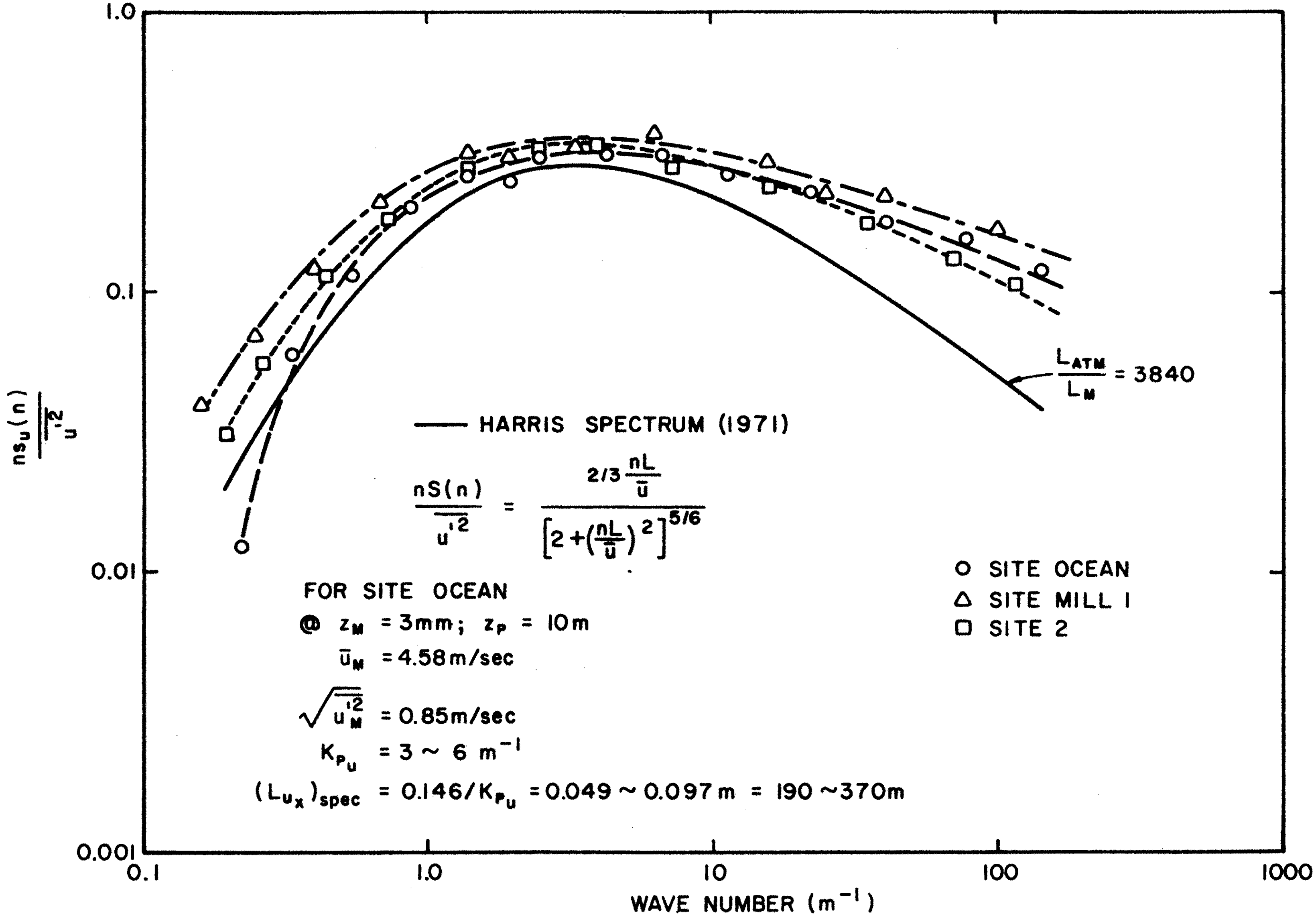

FIGURE 3.7. Comparison of Longitudinal Power Spectra Measured at Three Sites Over the Kahuku Model with Harris Spectrum at 10 m Height.

TABLE 3.1. Summary of Spectra Measurements over the Kahuku Point Model

Equivalent Height (m)	$\bar{U}$ (m/s)	$\sqrt{\overline{u'^2}}/\bar{U}$ (%)	T_E (sec)	$L_{u_{x_{TE}}}$ (m)
Site Ocean				
10	4.58	18.5	.009	167
33	6.07	14.5	.021	450
67	6.86	11.6	.022	518
165	7.72	8.73	.027	725
Site Mill 1				
10	6.32	13.4	.013	315
20	6.27	13.7	.020	481
33	6.39	14.8	--	--
67	6.85	12.6	.028	736
165	7.62	9.0	--	--
Site 2				
10	5.21	15.3	.013	260
20	5.92	13.9	.016	363
33	6.53	14.4	.026	651
67	6.94	11.2	.024	639
165	7.77	8.27	.025	745

or from the integral time scale:

$$L_{u_{x_{TE}}} = T_E \bar{U} \tag{3.2}$$

The values at the equivalent 10 m height range from 150 m to 350 m depending upon the method used and also the peak value selected.

Based on the discussions of Sections 3.1 and 3.2, overall characteristics of flow over the Kahuku Point model are tabulated in Table 3.2 together with compatible full-scale atmospheric boundary layer characteristics compiled by Counihan (1975).

3.3 FLOW VISUALIZATION

Mean wind direction pattern and obvious separation zones over Kahuku Point for each wind direction are sketched as shown on Figures 3.8, 3.9 and 3.10 respectively. These figures indicate that the flow pattern over the model slightly altered with apparoach wind direction especially behind gulches. However, over regions which cover all the proposed WECS sites the wind direction remains essentially the same as that of the approach flow direction.

3.4 VELOCITY AND TURBULENT INTENSITY MEASUREMENTS

Measurements at 29 proposed WECS sites were made at 45°, 66.7° and 90° wind directions from true north respectively. A free stream velocity of approximately 10 m/sec was used for each profile. Slight variations in the approach velocity were encountered during the course of the study. The measured results were presented in the appendix. Listings of the results for the measurements over the additional 120 locatins are not presented in this report; they were used along with data taken at above WECS sites to prepare the detailed wind power mapping over the Kahuku Point area.

Detailed contour plots of the velocities at the equivalent 10 m and 50 m heights referenced to the velocity at equivalent 600 m height are shown on Figures 3.11 through 3.16. These contour plots were constructed from the velocity measurements, the flow visualization results, and author's judgement concerning the extent of the local topographic influences. Data smoothing techniques were also employed to obtain the contours.

TABLE 3.2. Comparison of Approach Boundary Layer in the EWT with Atmospheric Boundary Layer Compiled by Counihan (1975)

Parameters	Length Scale 3840:1 — Boundary Layer in the EWT	Length Scale 3840:1 — Neutral Stability Atmospheric B.L.
Roughness Height (z_o)	0.11 m	0.11 m
Power Law Coefficient α_o	0.13 - 0.15	0.14 ± 0.02
Boundary Layer Thickness δ	600 m	600 m ± ?
Turbulence Intensity at 10 m $\sqrt{\overline{u'^2}}/\bar{U}$	17 ~ 18%	15 ± 5%
C_f at 10 m	0.0149	0.0128
$\sqrt{\overline{u'^2}}/U_*$ at 10 m	2.78	2.5 ± 5
Λ_x at 10 m	167 m	100 - 170 m

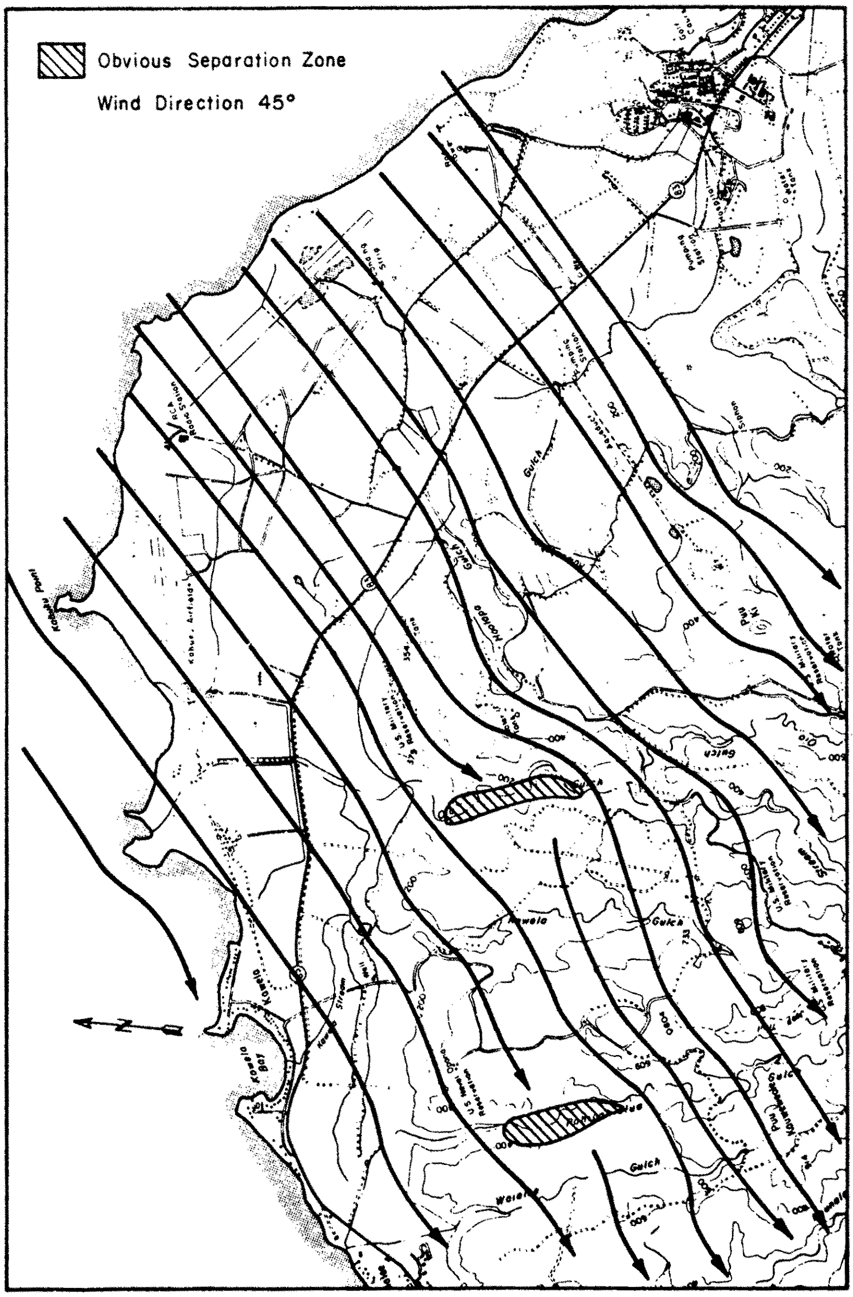

FIGURE 3.8. Flow Pattern Over the Kahuku Point Model for Approaching Wind Direction of 45° from North.

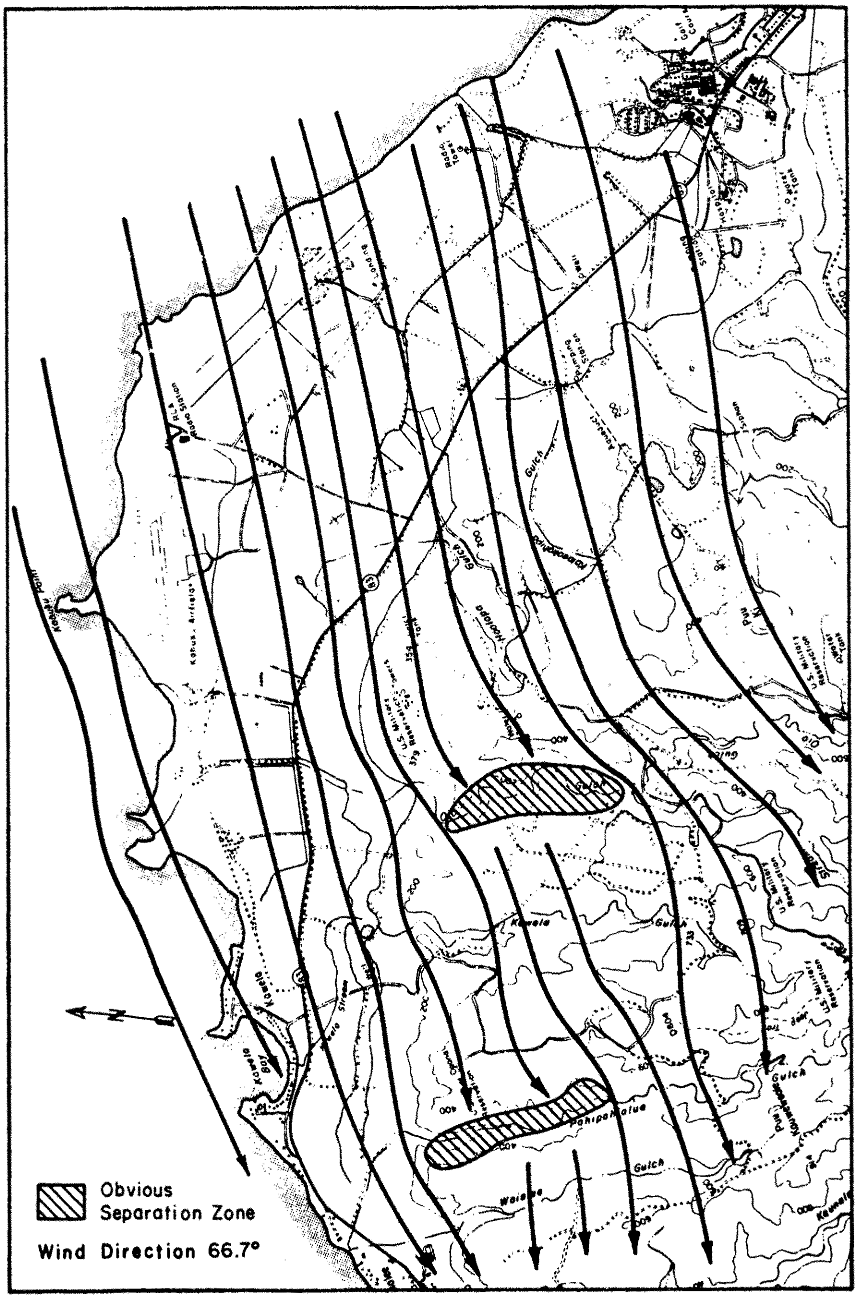

FIGURE 3.9. Flow Pattern over the Kahuku Point Model for Approaching Wind Direction of 66.7° from North.

FIGURE 3.10. Flow Pattern over the Kahuku Point Model for Approaching Wind Direction of 90° from North.

FIGURE 3.11. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 10 m Height for Wind Direction of 45° from North.

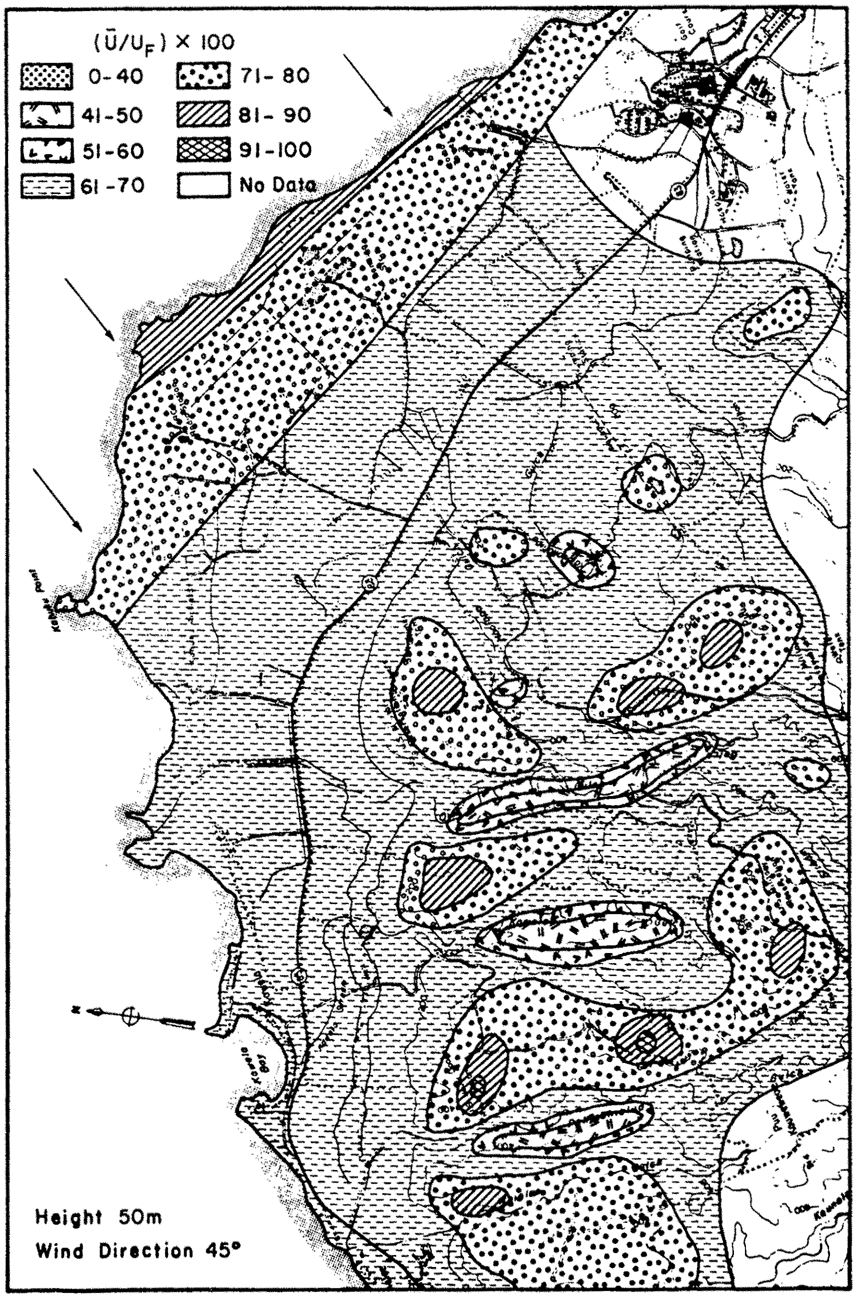

FIGURE 3.12. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 50 m Height for Wind Direction of 45° from North.

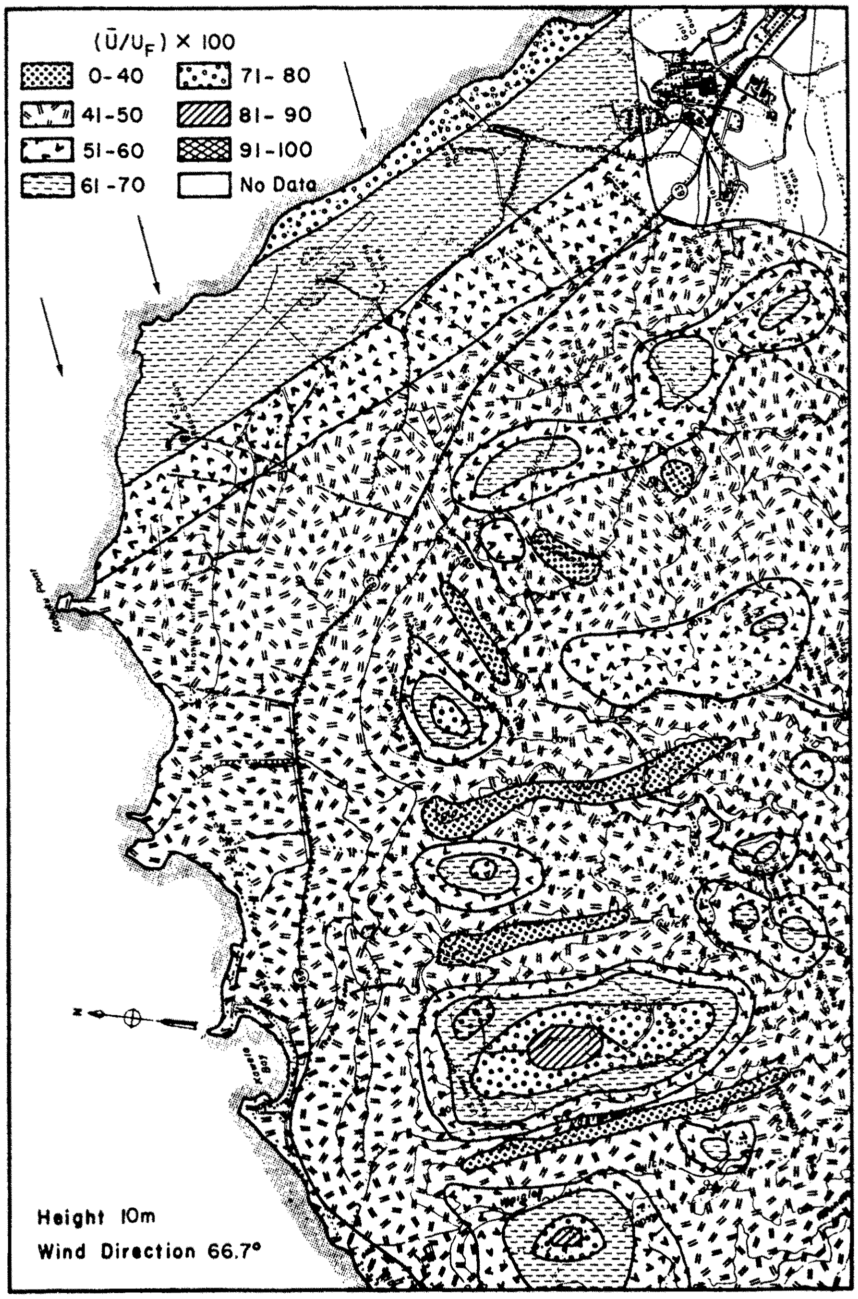

FIGURE 3.13. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 10 m Height for Wind Direction of 66.7° from North.

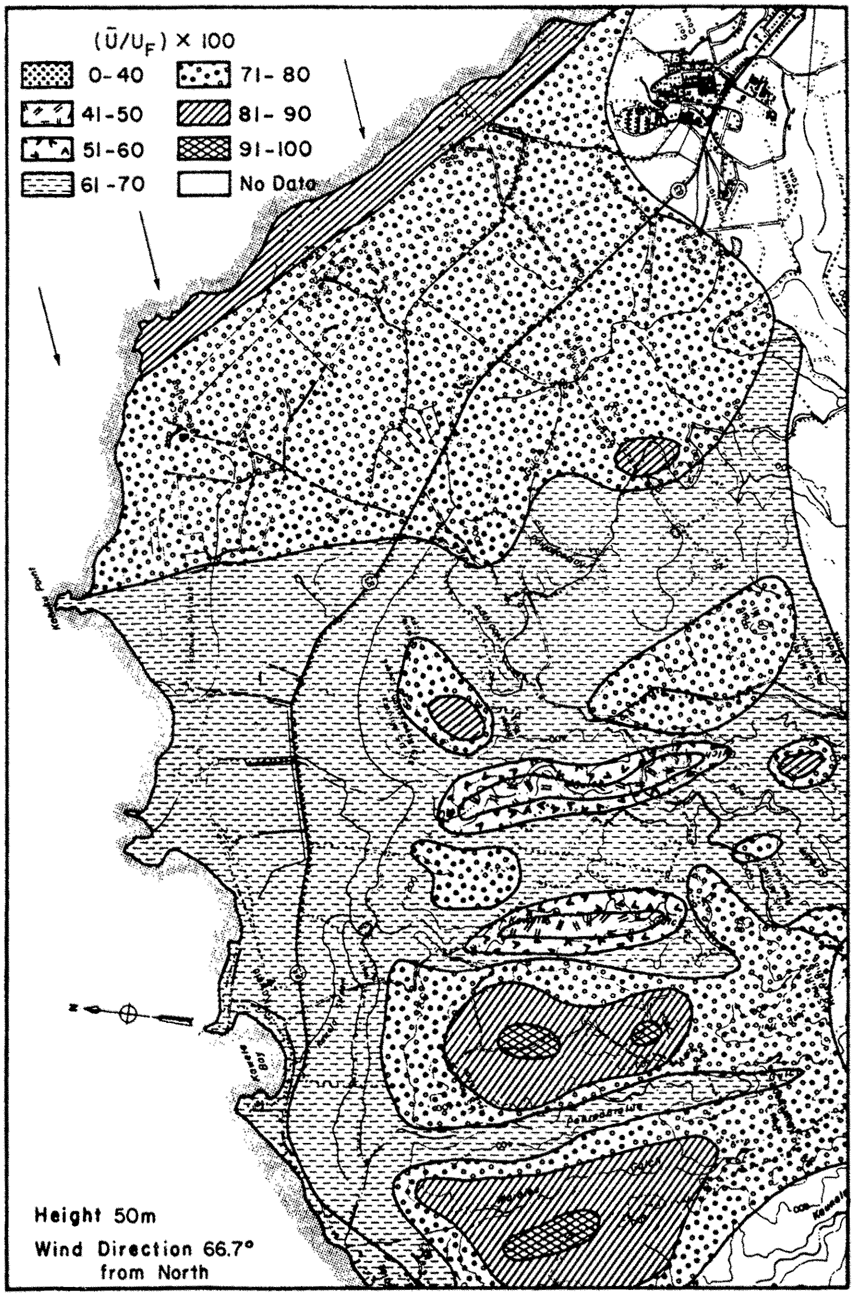

FIGURE 3.14. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 50 m Height for Wind Direction of 66.7° from North.

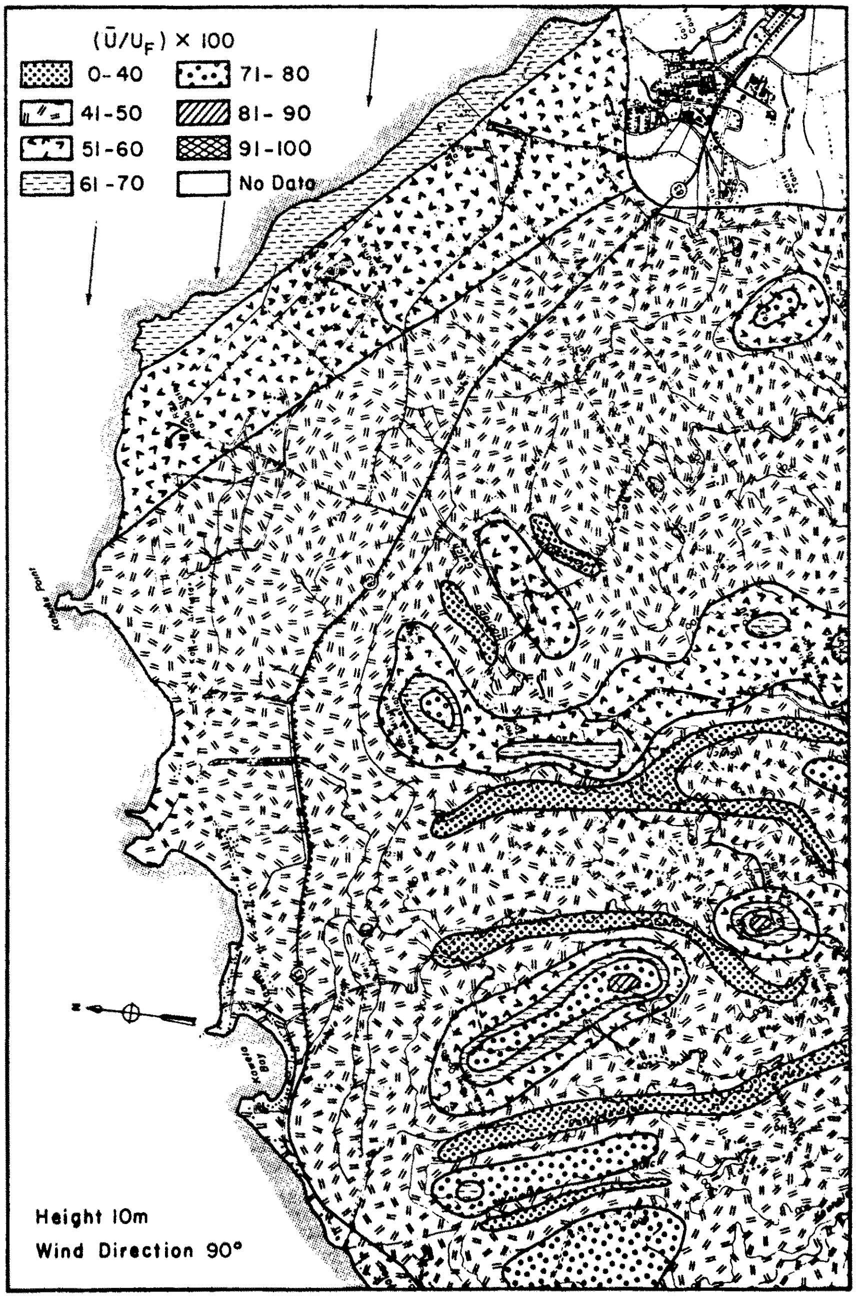

FIGURE 3.15. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 10 m Height for Wind Direction of 90° from North.

FIGURE 3.16. Contour Plot of Relative Velocities over the Kahuku Point Model at Equivalent 50 m Height for Wind Direction of 90° from North.

These contour plots confirm the following conclusions made by Ramage (1979) regarding the field measurements of wind power in the Hawaiian Islands:

> First, near the beach a sharp acceleration between sea and land is associated with confluence and acceleration. Second, over the flat land immediately inland, the winds are frictionally slowed. Third, over gently sloping hills still further inland, distance from the corner and the sea-land discontinuity and frictional slowing are overcome by acceleration as the flow is constricted between terrain and the overlying inversion; still farther inland up the ridge distance from the corner and frictional slowing combine to overcome the hill effect resulting in less speed with land elevation.

Moreover, those maps provide a clear picture of the more promising areas over Kahuku Point area and also areas where WECS sites should be avoided.

4.0 COMPARISON WITH FIELD MEASUREMENT DATA

Field and laboratory measurements taken at corresponding locations are compared with each other in this chapter. Field measurement configurations which were not simulated in this study were identified and field data measured under such conditions were eliminated. Linear correlation and correlation by rank were performed for the remaining data.

4.1 IDENTIFICATION OF COMPARABLE DATA SETS

The field program, as mentioned in Section 1.5, was performed by researchers at the University of Hawaii. Summary measurements at the proposed WECS sites over Kahuku Point area from 8 August to 10 October of 1978 were provided to the authors by Dr. Anders Daniels, Department of Meterology, University of Hawaii. The sets of data for each mobile measurement station during the test time period include: mean wind speed, standard deviation of wind speed, mean wind direction, and wind speed ratio with respect to the mean speed at a fixed reference site. The fixed reference site selected by University of Hawaii staff was Site Kahuku Upper.

Continuous hourly averaged data at each mobile station and four fixed sites (Kahuku Upper, Kahuku Road, Kahuku Oyster 90 and Kahuku Oyster 30) were also examined. An examination of the field data suggested that not all measurements were taken under circumstances comparable with the conditions chosen for physical simulation in the wind tunnel. Hence data sets were eliminated from the field data provided before a direct model to field comparison was attempted. Three reassuring data trends were identified for which criteria could be assigned to isolate inappropriate measurement pairs; i.e.

Category I: Field data obtained for wind directions which were beyond the wind direction range covered in the wind tunnel test.

Category II: Field data taken during a period of time when flow directions recorded at two or more reference locations were frequently inconsistent with the trend visualized over the model.

Category III: Field data presented turbulent intensity far in excess of values obtained in the wind tunnel study or expected for well exposed anemometer sites.

Field data of Category I indicates approach wind speed atmospheric conditions different from that which were simulated in the laboratory. Since the atmospheric flow expected to be dominately a trade wind from the northeast to east, the data of Category I were not analyzed further. Category II implies a test period exists during which the local mountain-valley winds dominate over the trade wind. This situation was not simulated in the wind tunnel study. Data of Category III may be caused by vegetation sheltered wind locations for the field or model measurements. The possibility also exists that improper simulation of vegetation over model was at fault.

One can determine if data at a specific site falls into Category I or III simply by examining the mean and orientation at a fixed site or the turbulent intensity at the mobile site. However, to identify the data of Category II, one must examine the complete hourly data records.

It was noticed that whenever wind direction taken at fixed station Kahuku Road veered to the north from wind direction measured at fixed station Kahuku Upper, the other mobile site displayed erratic wind approach orientations not associated with neutral stratification. The orientations were unreasonable in the sense that they represented wind directions normal to or opposed to the approach wind direction upstream. It is suspected that these periods of strong direction variation are associated with strong upslope or sea breeze phenomena. Although such characteristics may be modeled in boundary-layer wind tunnels (Meroney et al., 1975 and Petersen et al., 1978), they were not simulated during this research. If such situations are frequent they must be simulated to produce representative results when predicting local wind energy availability. Since the intention herein was to only simulate the Kahuku area during the strong tradewind condition it is considered appropriate to eliminate such cases from the validation exercise. It was concluded a screening criterion could be constructed from this northerly veering behavior at Kahuku Road. The number of hours for which wind veering occurred during each measurement period was evaluated. The ratio of this number to the total number of hours during a specific measurement period provided a criteria for the frequency of occurrence of wind veering over the entire Kahuku region.

Table 4.1 records the measurement period for each WECS site. Also presented in this table are the hours of wind veering, total hours, and wind veering frequency during each measurement period. High wind veering frequency values in excess of 35% were noted for the following dates:

Period	Wind Veering Frequency
4 September - 9 September	~ 70%
15 September - 19 September	~ 50%
30 September - 10 October	~ 35%

TABLE 4.1. Measurement Period, Wind Veering Hours, Total Hours and Wind Veering Frequency for Each WECS Site.

August 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 September 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

LEGEND:

|← Test Period →|

(Hous of Wind Veering) / (Total Hours of Measurement) (Wind Veering Frequency)

Site	(Hours of Wind Veering) / (Total Hours of Measurement)	Wind Veering Frequency
1	30/119	.25
2		
3		
6	80/114	.70
8	93/158	.58
9	11/86	.13
10	12/118	.10
LLL (11)	11/86	.13
14	12/114	.10
15	32/160	.20
16	56/285	.20
17	56/280	.20
20	51/144	.36
23	30/106	.28
24	30/119	.25
25		
26	0/190	0.0
30		
31		
32		
33		
34		
35	80/114	.70
Hill 200		
Aque		
Kahuku Radio	0/117	0.0
Lowe		
Mill 1		
Mill 2		
Opana Ambulance	11/86	0.13
Makahoa Point		

TABLE 4.1. Continued.

Site	Test Period (September 14 – October 15)	(Hous of Wind Veering) / (Total Hours of Measurement)	(Wind Veering Frequency)
1			
2	Sep 24 – Oct 9	112 / 1915	.06
3	Sep 23 – Sep 29	30 / 121	0.24
6			
8			
9			
10			
LLL(11)			
14			
15			
16			
17			
20			
23			
24			
25	Sep 24 – Sep 29	30 / 121	0.24
26			
30	Sep 14 – Sep 19	61 / 120	.52
31	Sep 14 – Sep 17	28 / 61	.47
32	Sep 14 – Sep 19	59 / 120	.50
33	Sep 14 – Sep 18	49 / 99	.50
34			
35			
Hill 200	Oct 10 – Oct 15	86 / 114	.75
Aque	Oct 10 – Oct 15	90 / 116	.77
Kahuku Radio			
Lowe	Oct 8 – Oct 14	85 / 140	.61
Mill 1	Sep 30 – Oct 9	81 / 236	.35
Mill 2	Sep 30 – Oct 8	72 / 189	.38
Opana Ambulance			
Makahoa Point	Sep 19 – Sep 23	35 / 102	.35

LEGEND:

|← Test Period →|

(Hous of Wind Veering) / (Total Hours of Measurement) (Wind Veering Frequency)

Moreover, judging from photos taken during a site visit, we concluded vegetative interaction was probable at several locations. Table 4.2 tabulates the sites removed from correlation and the justification.

Table 4.2. WECS Sites for Which Comparison Between Field and Laboratory Measurements are Questionable.

Site	Comment
34, 2, Hill 220, AQUE, LOWE	Category I
6, 20, 30, 35	Category II
10	Category III
17	Site visit suggested that the station is placed too close to trees upstream
23	Site is within the wake of Hill Puu Ki (data is variable)

4.2 COMPARISON OF RESULTS

The relevant data and results which can serve as a direct comparison between field and laboratory measurements are tabulated in Table 4.3. Columns 2 and 3 list mean wind directions recorded at the reference site, Kahuku Upper and a WECS station, respectively for the same measuring period. Column 4 includes the laboratory evaluated relative wind speed at each site for three wind directions. These were calculated in the following manner: (assuming the same wind direction at both mobile and reference station)

$$\left[\frac{\overline{U}_i(10)}{\overline{U}_{REF}(10)}\right]_{\theta^i,M} \cong \frac{\left[\frac{\overline{U}_i(10)}{\overline{U}_i(600)}\right]_{\theta^i,\,M}}{\left[\frac{\overline{U}_{REF}(10)}{\overline{U}_{REF}(600)}\right]_{\theta^i,\,M}} \quad ,\ i=1,2,3 \qquad (4.1)$$

with $\theta^1 = 45°$, $\theta^2 = 66.7°$ and $\theta^3 = 90°$ respectively. In the above calculation, $\overline{U}_i(600)$ was assumed to be equivalent to $\overline{U}_{REF}(600)$. $[\overline{U}_i(10)/\overline{U}_i(600)]_{\theta^i,M}$ and $[\overline{U}_{REF}(10)/\overline{U}_{REF}(600)]_{\theta^i,M}$ were obtained directly from listed data or normalized velocity profiles contained in the Appendix.

Column 5 contains turbulence intensities obtained in field and laboratory measurements at each site. Column 6 tabulates relative wind speed recorded at each site during the same period of time for the wind directions noted in Columns 2 and 3. The corresponding laboratory evaluated relative speed of each site was obtained using the following weighted average approach.

Let $\theta^1 = 45°$, $\theta^2 = 66.7°$ and $\theta^3 = 90°$ respectively. The local relative wind speeds at a mobile station i or the reference site at reference wind direction $(\overline{\theta}_{ref})_F$ were calculated as follows:

For $\theta^3 \leq (\overline{\theta}_{ref})_F \leq \theta^3 + 10°$,

$$\left[\frac{\overline{U}_i(10)}{\overline{U}_i(600)}\right]_M \cong \left[\frac{\overline{U}_i(10)}{\overline{U}_i(600)}\right]_{\theta^3,M} \qquad (4.2)$$

For $\theta^1 \geq (\bar{\theta}_{ref})_F \geq \theta^1 - 10°$

$$\left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_M \cong \left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_{\theta^1,M} \qquad (4.3)$$

For $\theta^1 \leq \theta^i < (\bar{\theta}_{ref})_F < \theta^j \leq \theta^3$.

$$\left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_M \cong \left[1.0 - \frac{\theta^j - (\bar{\theta}_{ref})_F}{\theta^j - \theta^i}\right] \cdot \left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_{\theta^j,M}$$

$$+ \left[1.0 - \frac{(\bar{\theta}_{ref})_F - \theta^i}{\theta^j - \theta^i}\right] \cdot \left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_{\theta^i,M} \qquad (4.4)$$

Finally, $\left[\frac{\bar{U}_i(10)}{\bar{U}_{REF}(10)}\right]_M$ is the relative wind speed with respect to a fixed station. These values were calculated by using

$[\ \bar{U}_i(10)/\bar{U}_i(600)\ ]_M$ and $[\ \bar{U}_{REF}(10)/\bar{U}_{REF}(600)\ ]_M$

obtained from equation (4.2) or (4.3) or (4.4), i.e.

$$\left[\frac{\bar{U}_i(10)}{\bar{U}_{REF}(10)}\right]_M \cong \frac{\left[\frac{\bar{U}_i(10)}{\bar{U}_i(600)}\right]_M}{\left[\frac{\bar{U}_{REF}(10)}{\bar{U}_{REF}(600)}\right]_M} \qquad (4.5)$$

where $\bar{U}_i(600) \cong \bar{U}_{REF}(600)$ was again assumed.

The $[\ \bar{U}_i(10)/\bar{U}_{REF}(10)\ ]_M$ values are tabulated in Column 7, except for Site 34, Site 2, Site Hill 220, Site AQUE and Site LOWE. These sites were

TABLE 4.3. Comparison of Filed and Laboratory Measurements of Relative Wind Speed Referenced to Wind Speed at Kahuku Upper

Column 1	Column 2	Column 3	Column 4			Column 5				Column 6	Column 7
Site	$(\bar{\theta}_{ref})_F$ (Degree)	$(\bar{\theta}_i)_F$ (Degree)	$\bar{U}_i(10)/\bar{U}_{ref}(10)$ θ^i,M			Field	Turbulence Intensity (%) Model			$\frac{\bar{U}_i(10)}{\bar{U}_{ref}(10)}_F$	$\frac{\bar{U}_i(10)}{\bar{U}_{ref}(10)}_M$
			$\theta^1 = 45°$	$\theta^2 = 66.7°$	$\theta^3 = 90°$		45°	66.7°	90°		
1	77.4	89.1	.90	.67	.70	18	18	-	22	.68	.69
2	79.6	107.4	.90	1.15	1.15	22	16	13	13	.65	-
3	81.0	80.0	.95	.77	.80	18	15	18	16	.86	.79
6	71.2	88.4	.82	1.20	1.01	19	21	32	16	.75	1.16
8	81.6	69.7	.95	.83	.89	13	15	15	18	.61	.86
9	66.6	85.6	.84	.90	.74	24	18	15	24	.76	.90
10	74.9	94.7	.66	.76	.81	32	24	18	16	.69	.77
LLL(11)	68.0	77.1	1.11	.92	1.03	20	17	20	15	1.07	.93
14	71.6	74.5	.89	1.01	1.10	26	17	16	25	1.01	1.03
15	80.0	65.3	1.15	1.11	1.10	20	14	11	15	1.05	1.10
16	78.0	78.0	.88	.81	.89	22	15	18	17	.90	.85
17	79.0	83.3	.78	1.07	.85	21	15	13	19	.61	.95
20	80.1	79.2	.56	1.00	.93	14	15	13	15	.73	.96
23	76.5	93.4	.75	.78	.88	16	25	19	19	.69	.82
24	78.1	84.2	.90	.74	.80	18	14	16	15	.72	.77
25	78.2	89.4	1.20	1.10	1.05	16	13	10	10	.86	1.07
26	77.2	100.3	.81	.92	.96	15	18	13	13	.95	.94
30	79.0	88.0	.89	1.01	.92	24	17	23	19	.70	.96
31	81.0	84.1	.97	1.00	.92	20	15	12	20	.82	.95
32	81.2	83.2	.89	.90	1.04	14	20	20	15	.92	.98
33	80.6	76.8	.90	.88	.80	23	16	15	23	.78	.83
34	75.9	105.8	.83	.96	1.00	14	18	14	18	.62	-
35	74.9	90.5	.58	.93	.98	22	25	13	13	.68	.94
HILL 200	29.8	155.6	1.04	1.01	.94	42	15	13	15	.51	-
AQUE	30.5	167.5	.70	.90	.69	38	20	18	20	.48	-
KAHUKU RADIO	71.5	87.7	.86	1.17	.79	19	16	12	18	.83	1.09
LOWE	51.0	54.0	.76	.91	.72	32	18	13	19	.62	-
MILL 1	79.2	87.2	1.24	.91	.91	19	11	11	28	.76	.90
MILL 2	79.9	88.2	.83	.66	.87	18	16	23	16	.62	.77
OPANA AMBULANCE	67.2	77.9	1.00	.90	.93	18	16	13	17	.80	.90
MAKAHOA POINT	87.1	76.8	.83	.85	.92	12	18	15	13	.90	.91
KAHUKU UPPER	-	-	-	-	-	16~25	21	12	17	1.00	1.00

not calculated because their test conditions fall into elimination Category I discussed in the previous section.

4.3 CORRELATION OF RELATIVE WIND POWER DATA

For the data tabulated in Table 4.3 the relative wind speed ratio, shown in Column 6 and Column 7, were appropriated for a quantitative comparison between laboratory and field measurements. By assuming the laboratory test data as an "independent" variable x and the field data a "dependent" variable y, the sample correlation coefficient r between a set (x, y) was calculated as

$$r = \frac{n \Sigma x y - \Sigma x \Sigma y}{\left\{ [n \Sigma x^2 - (\Sigma x)^2] [n \Sigma y^2 - (\Sigma y)^2] \right\}^{\frac{1}{2}}} \tag{4.6}$$

where n is the total number of (x, y) pairs used. Scatter diagram and the sample regression line for the 26 data pairs used for above calculation, excluding data belonging to eliminating Category I, are plotted on Figure 4.1. The sample correlation coefficient r calculated for these data was 0.45. This value of correlation is lower than would be desired.

If all the questionable sites tabulated in Table 4.2, and site Kahuku Radio where the measurement was biased due to the nearby model conjunction at 66.7° were excluded, the sample correlation coefficient obtained for the remaining 19 data pairs is 0.71. Figure 4.2 shows the scatter diagram and the sample regression line for these data pairs.

4.4 RANKING WECS SITES BY WIND SPEED

An alternative way to compare field data and laboratory data is the correlation of the site rank, when both sets of data are ordered according to the relative wind speed magnitude. The correlation by rank was calculated by

$$r = 1.0 - \frac{6 \sum_{i=1}^{n} D_i^2}{n(n^2-1)} \tag{4.7}$$

where $D_i = \text{Rank}_{\text{FIELD STATION}} - \text{Rank}_{\text{MODEL STATION}}$

n = total number of data pairs used.

Table 4.4 provide a relative wind speed rank test for 18 Kahuku point data. The calculated rank correlation for these sites is r = 0.84.

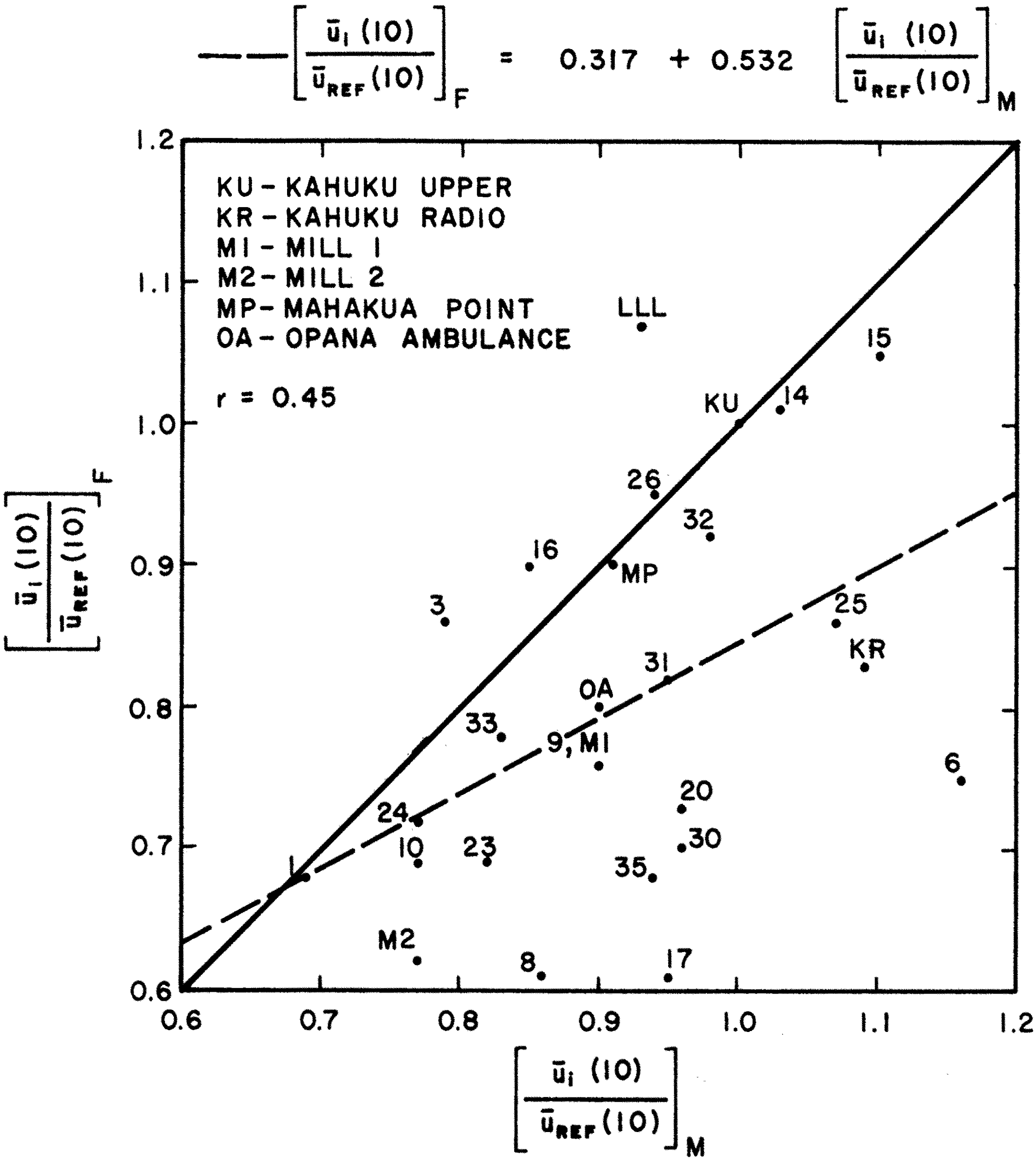

FIGURE 4.1. Scatter diagram and sample regression line for 27 data pairs.

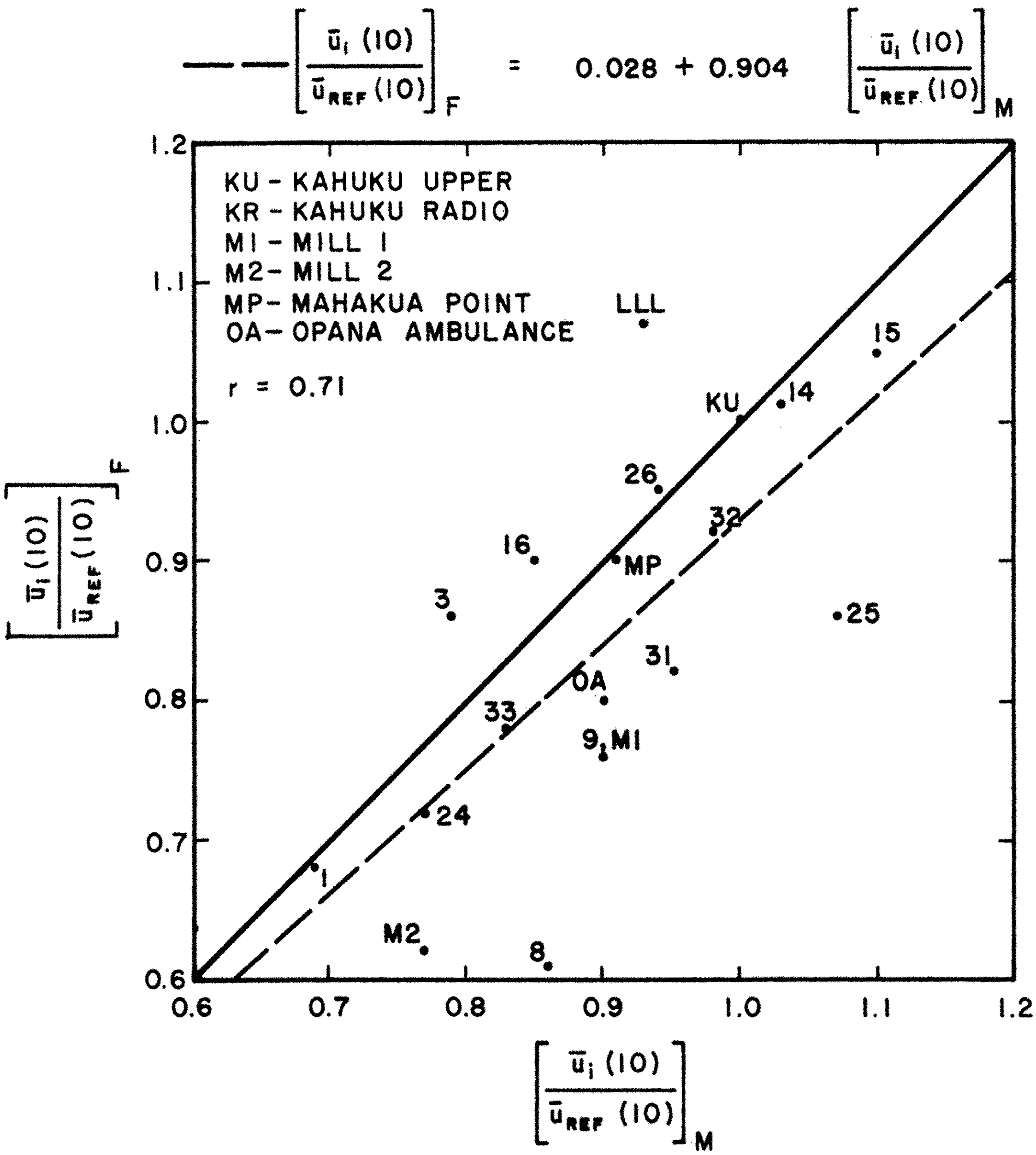

FIGURE 4.2. Scatter diagram and sample regression line for 19 data pairs.

TABLE 4.4. Rank Test for 18 WECS Sites in Kahuku Point Area.

Rank	Field Measurement	Laboratory Measurement
1	11(LLL)	15
2	15	25
3	14	14
4	Kahuku Upper	Kahuku Upper
5	26	32
6	32	31
7	16, Makahoa Point	26
8	25, 3	11(LLL)
9	31	Makahoa Point
10	Opana Ambulance	9, Opana Ambulance, Mill 1
11	33	16
12	9, Mill 1	33
13	24	3
14	1	Mill 2, 24
15	Mill 2	1

5.0 COMPARISON WITH SEMI-EMPIRICAL AND ANALYTICAL TECHNIQUES FOR TOPOGRAPHY AMPLIFICATION PREDICTIONS

One of the final goals of this study was to evaluate some of the techniques which have been proposed to make a quantitative prediction of the effects of topography upon the wind flow. Various techniques which include numerical, semi-empirical and analytical methodologies have been proposed by many researchers such as Jackson and Hunt (1975), Hunt (1975), Hunt (1978), Britter et al. (1979), Bouwmeester (1979), Derickson and Meroney (1975) and Lavoie (1974). As might be expected, different assumptions were used, which lead to various degree of accuracy and computational complication. Existing techniques, which were known to the present authors, are compared one with another, as shown in Table 5.1. Based on the initial survey, there is no specific technique which seems to be better than the others.

This study provides an opportunity to evaluate some of these techniques as they may be applied to actual hill modified flow fields. Comparison of the laboratory data to values obtained by various techniques could justify their assumptions and, hopefully, provide further information which may be used for improvement. In this study, the semi-empirical and the analytical techniques proposed by Bouwmeester (1979) and Hunt (1978), respectively, were chosen to compare with our laboratory results.

5.1 AMPLIFICATION FACTORS OVER SELECTED MEASUREMENT SITES FROM THE WIND TUNNEL TEST

One way of identifying the wind power potential of a specific site is to evaluate the amplification factor of the hill over which the site is to be built. The amplification factor at a location, $A_i(z)$, is defined as

$$A_i(z) = \overline{U}_i(z)/\overline{U}_o(z) \tag{5.1}$$

In the above equation, $\overline{U}_o(z)$ is the mean velocity at height z of a reference velocity profile and $U_i(z)$ is the mean velocity at the same height z at a specific site.

$A_i(z)$ values were obtained by the following approximation:

$$A_i(z) \cong \frac{\left[\overline{U}_i(z)/\overline{U}_i(2000)\right]_M}{\left[\overline{U}_o(z)/\overline{U}_o(2000)\right]_M} \tag{5.2}$$

TABLE 5.1. Techniques for Predicting Topography Amplification

Classification	Proposed by	Approach	Limitation or Disadvantage
Analytical	Lamb (1924)	Potential flow solution with approach shear flow which must be a sinusoidal function to linearize the Poisson Equation.	Only good for gently sloped hills; for steep hills, assumption of constant vorticity along a streamline is inappropriate.
	Jackson and Hunt (1975)	Perturbation method which divides the boundary layers into inner and outer regions. Non-linear form for the approach velocity was used.	Complicated, computations require matching velocity between inner and outer regions.
	Hunt (1975)	Same as above. Consider flow over an escarpment.	As above
	Hunt (1978)	Inviscid shear flow over a nearly two-dimensional object.	Good for gently sloped hills.
Semi-empirical	Britter, Hunt & Richards (1979)	Perturbations caused by change in elevation associated with change in roughness were considered.	Complicated in computation.
	Bouwmeester (1979)	Effects of upwind and downwind slopes upon flow speed-up over two-dimensional ridges were considered. Graphical results were presented.	Roughness change effect upon speed-up was not embodied in the prediction.
Numerical	Derickson and Meroney (1975)	Prescribed approach-shear flow over gently hills. Inviscid flow approach. Finite difference method.	Resolution becomes difficult near the hill surface
	Lavoie (1974)	Simulation of air flow over a complex terrain based on a few known data.	Quantitatively fail to provide informations at specific site.

In the above approximation, $\bar{U}_i(2000) = \bar{U}_o(2000)$ was assumed if they were measured for the same approach wind angle. This assumption seems reasonable since the perturbation of a hill is only expected to a height equivalent to the characteristic length L for the hill. L has a maximum value of 600 meters in this study. The approach velocity profiles shown in Figures 3.4 and 3.5 were used as the reference velocity profiles. These profiles all have $[\bar{U}_o(100)/\bar{U}(2000)]_M = 0.53$.

From the velocity profile data listed in the Appendix, the $[\bar{U}_i(10)/\bar{U}_i(2000)]_M$ value for a specific wind direction θ_i was obtained by utilizing the approximation scheme described by equations (4.2), (4.3) and (4.5), where $[\bar{U}_i(10)/\bar{U}_i(600)]_M$ is replaced by $[\bar{U}_i(10)/\bar{U}_i(2000)]_M$. Then $A_i(10)$ for a wind direction θ_i was obtained from equation (5.2) at $z = 10$ meter. Table 5.2 tabulates the calculated results for several selected sites.

5.2 BOUWMEESTER'S SEMI-EMPIRICAL TECHNIQUE FOR PREDICTING SPEED-UP OVER RIDGES

From studies of the flow over two-dimensional ridges, Bouwmeester (1979) proposed a semi-empirical speed-up prediction technique. Detailed explanation of this technique is given in Bouwmeester's doctoral thesis (1978) and a report by Meroney et al. (1978).

The predictions were derived for isolated and smooth two-dimensional ridges merged in an atmosphere boundary layer which has a constant velocity profile exponent. The Bouwmeester algorithm is outlined briefly in the following paragraphs.

Let α_o and α_c be the power law exponents for the referenced upstream station and at the crest of the ridge respectively, and let H be the height of the ridge crest. The amplification factor at a height z above the crest, $A_i(z)$, may be expressed in terms of known velocities at some reference height z_{REF} such that

$$A_i(z) = \frac{\bar{U}_i(z)}{\bar{U}_o(z)} = \frac{\bar{U}_i(z_{REF})}{\bar{U}_o(z_{REF})} \cdot \frac{\bar{U}_i(z)}{\bar{U}_i(z_{REF})} \cdot \frac{\bar{U}_o(z_{REF})}{\bar{U}_o(z)}$$

$$= A_i(z_{ref}) \left(\frac{z}{z_{REF}}\right)^{\alpha_c} \cdot \left(\frac{z}{z_{REF}}\right)^{\alpha_o}$$

$$= A_i(z_{REF}) \left(\frac{z}{z_{REF}}\right)^{\alpha_c - \alpha_o} \qquad (5.8)$$

TABLE 5.2. Topography Amplification Factor Obtained in Laboratory for Several Selected WECS Sites

Site	$\frac{[\bar{U}_i(10)/\bar{U}_i(2000)]_M}{[\bar{U}_o(10)/\bar{U}_o(2000)]_M}$		Wind Direction	Amplification Factor
	66.7°	90°	θ_i (°)	$A_i(10)$
3	1.00	1.26	80.1	1.15
6	1.66	1.40	88.4	1.43
10	1.06	1.41	94.7	1.41
LLL(11)	1.25	1.49	77.1	1.35
14	1.42	1.37	74.5	1.40
15	1.58	1.5	65.3	1.52
16	1.69	1.67	78.0	1.68
17	1.38	1.09	83.0	1.18
23	1.10	1.20	93.4	1.20
24	1.05	1.24	84.2	1.19
30	1.39	1.29	88.0	1.29
32	1.30	1.41	83.2	1.38
33	1.16	1.13	76.8	1.15
35	--	1.35	90.5	1.35
Mill 2	--	1.41	88.2	1.40
Opana Ambulance	1.52	1.20	77.9	1.36

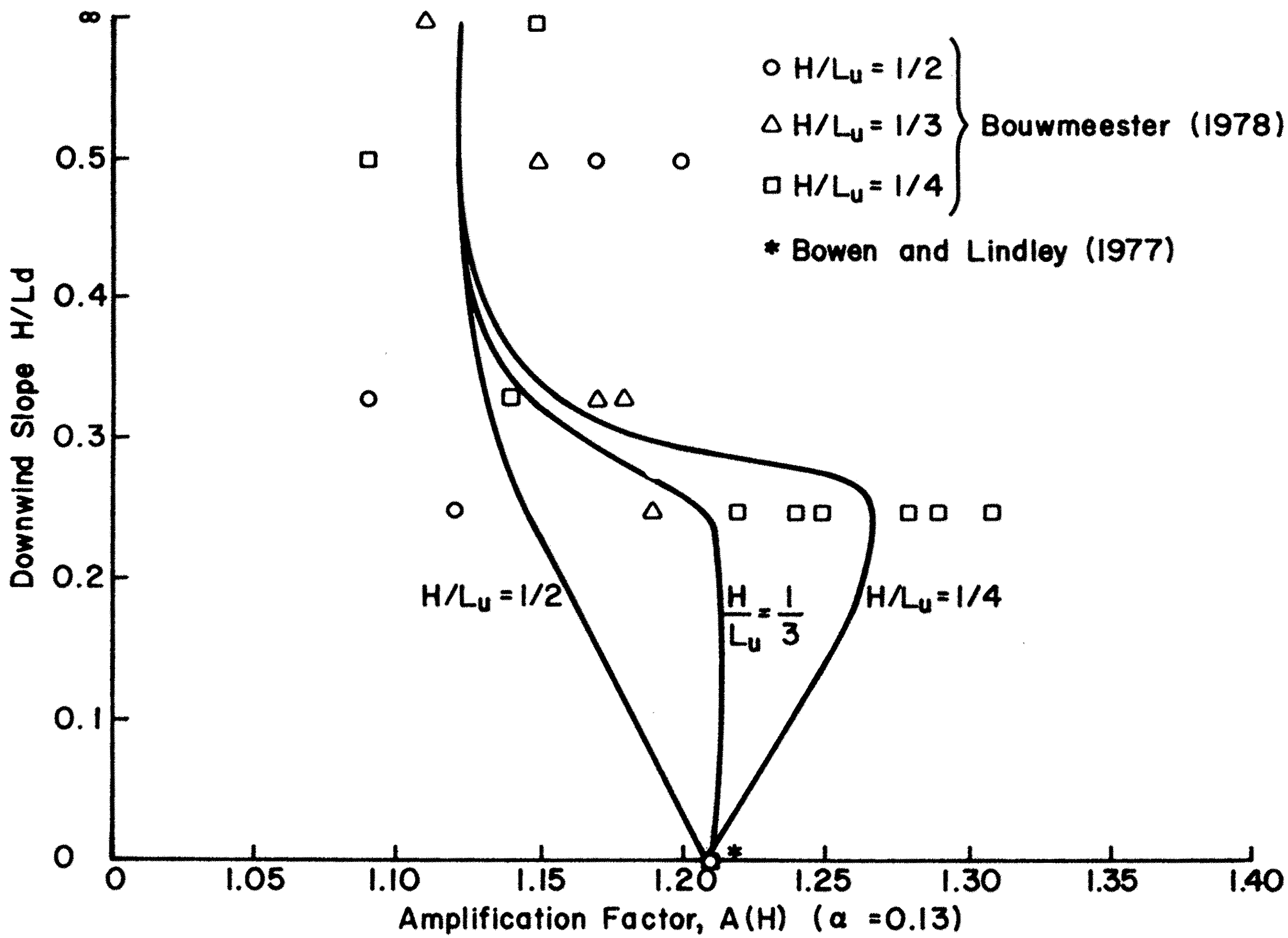

FIGURE 5.1. Dependency of Crest-amplification Factor on Downwind Slope for $\alpha_o = 0.13$.

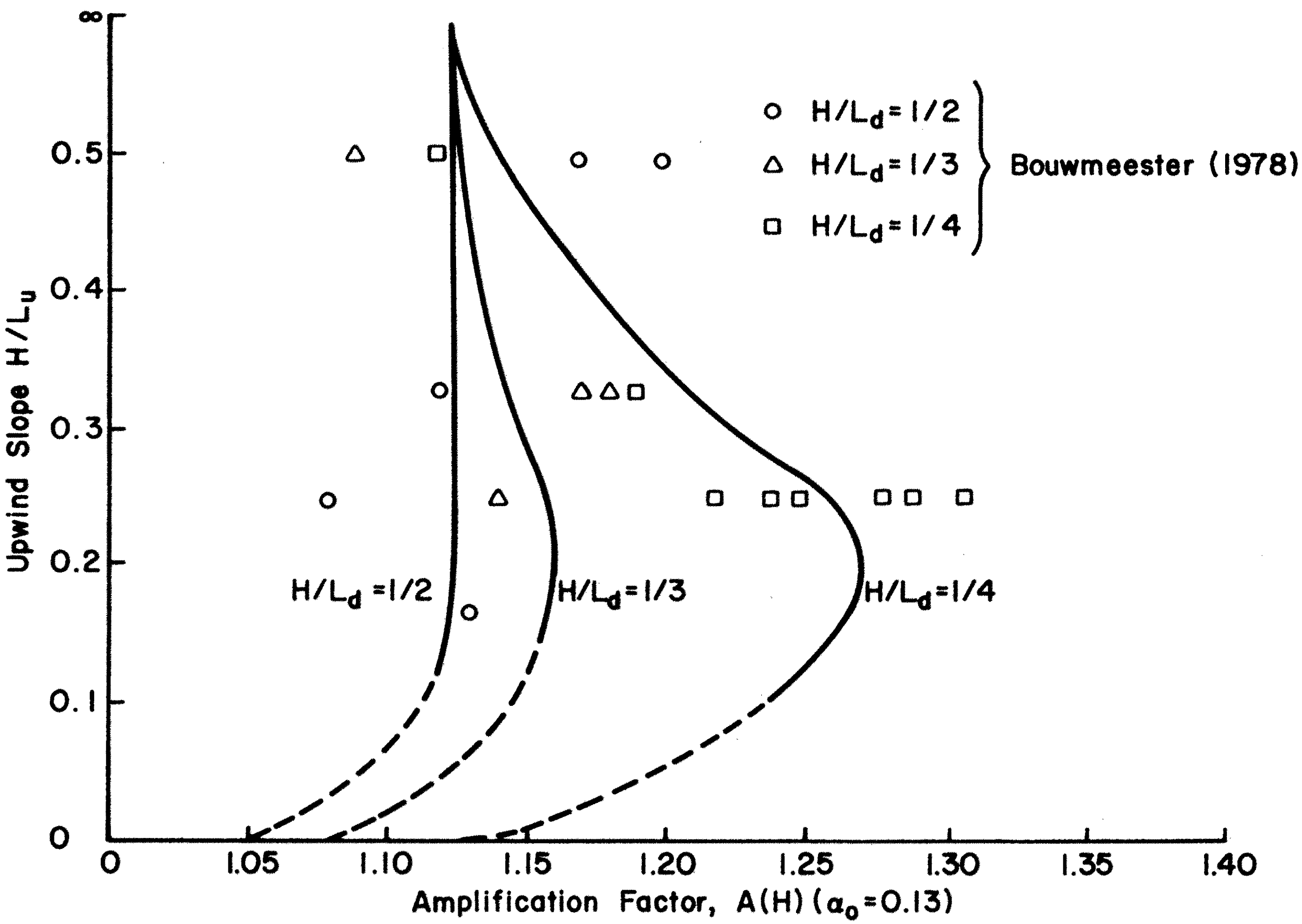

FIGURE 5.2. Dependecy of Crest-amplification Factor on Upwind Slope for $\alpha_o = 0.13$.

Selecting a parameter s so that $A(z) = 1.0$ when $s = z/H$ and a parameter b so that $c = z_{REF}/H$, then

$$A_i(z{=}sH) = A_i(cH)\ (\frac{sH}{cH})^{\alpha_c-\alpha_o} = 1.0 \qquad A_i(cH) = (\frac{s}{c})^{\alpha_o-\alpha_c} \tag{5.9}$$

It was shown using the model test results that $(\alpha_o-\alpha_c)$ and $A(H)$ were highly correlated when $c = 1$ and $s \simeq 8.5$. Equation (5.9) then becomes

$$A_i(H) = (8.6)^{\alpha_o-\alpha_c} \tag{5.10}$$

By letting $z_{REF} = H$ and substituting equation (5.10) into (5.8), we have

$$A_i(z) = (\frac{z}{8.5H})^{\alpha_c-\alpha_o} \tag{5.11}$$

Further examination of the experimental results indicated that, α_o and α_c were related to each other by

$$\alpha_c = \alpha_o - \frac{A_i(H) - 1}{2.3}$$

which was used to simplify equation (5.11)

$$A_i(z) = A_i(H)\ (\frac{z}{H})^{\frac{1 - A_i(H)}{2.3}} \tag{5.12}$$

$A_i(H)$ is a function of both the upstream slope (L_u/H) and the downstream slope (L_d/H) of a hill. Its dependency on L_u/H and L_d/H is shown in Figures 5.1 and 5.2 for $\alpha_o = 0.13$. If $\alpha_o = 0.13$ was assumed $A_i(H)$ for a ridge of known L_u/H and L_d/H could be obtained from either one of these figures. And $A_i(z)$ could be calculated by utilizing the equation (5.12).

To apply this technique to a prospective site, the vertical topography contour of the site and its surrouding area for a specific direction was sketched. Figures 5.3 and 5.4 show typical contours for Site 6 and Site LLL and their surroudings respectively. Based on the contour configurations, characteristic values of L_u/H and L_d/H for the hill or ridge where a site is located were obtained by drawing the characteristic upwind and downwind tangents to the hill contour about its top. Obviously, this procedure is very subjective as can be seen from Figure 5.3 and 5.4.

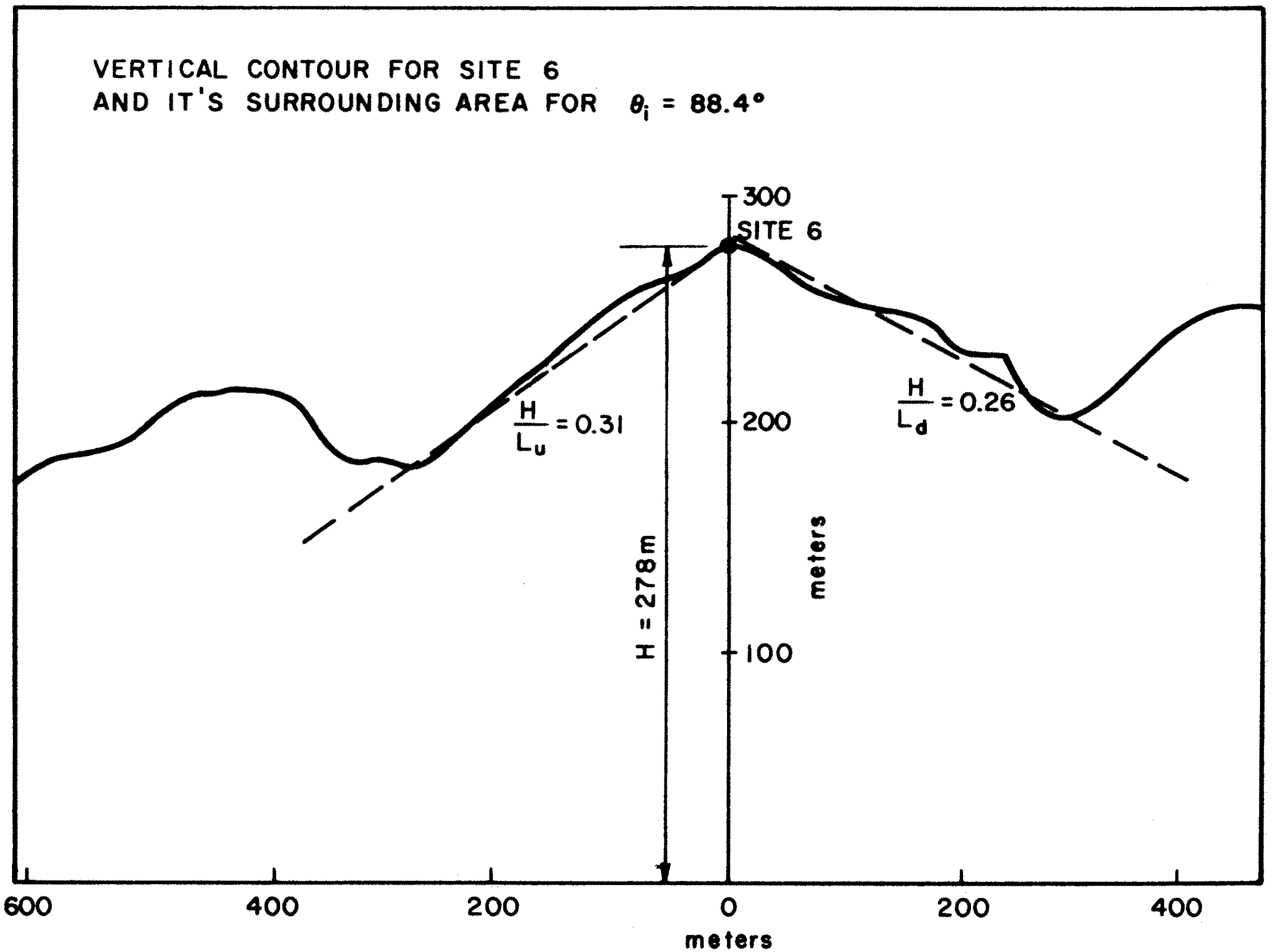

FIGURE 5.3. Vertical contour for Site 6 and Its Surrounding Area and Characteristic Parameters Used in Bouwmeester's Speed-up Prediction Techique.

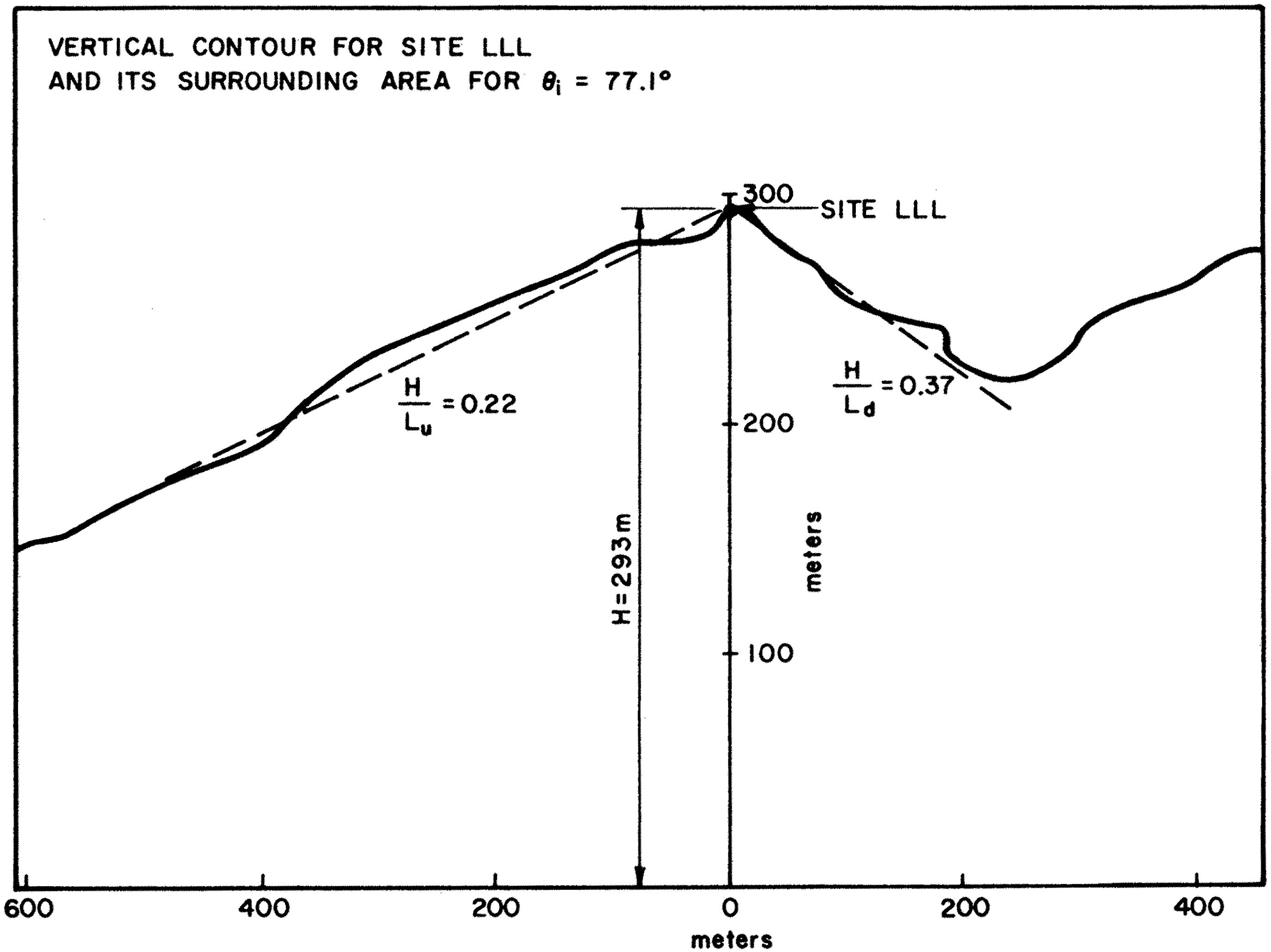

FIGURE 5.4. Vertical Contour for Site LLL and Its Surroudning Area and Characteristic Parameters Used in Bouwmeester's Speed-up Prediction Technique.

As discussed in Section 3.1, the approach velocity profiles of the wind tunnel test have power law coefficients of $\alpha_o = 0.13 \sim 0.15$. Thus, Figures 5.1 and 5.2 were used directly to determine $A_i(H)$. Equation (5.12) was then used to calculate $A_i(10)$ for each site. Table 5.3 summarizes the relevant values used in the calculations and the results. The values listed in Column 7 of this table were obtained by dividing $A_i(10)$ at each site by $A(10)$ at Site Kahuku Upper. These values may be viewed as equivalent to

$$\left[\frac{\overline{U}_i(10)}{\overline{U}_{REF}(10)}\right]_{\theta_i,\theta_F,M}$$

discussed in Chapter 4.0.

5.3 ANALYTICAL APPROXIMATION PROPOSED BY HUNT

In a recent review paper about the wind over hills, Hunt (1978) proposed an analytical approximation relation for the wind speed-up prediction. The relation is simply a modification of the inviscid potential flow theory for a uniform airstream over an obstacle with dimensions shown in Figure 5.5. If $H/L_o \ll 1.0$ and $H/b \ll 1$, the increase in velocity over the obstacle, $\Delta U/U_o$, will be

$$\frac{\Delta U}{U_o} \cong \frac{H}{L_o} \sigma\ (x,z) \tag{5.13}$$

where U_o is the uniform freestream velocity, and $\sigma\ (x,y) \sim O(1)$ depends on the shape of the hill. If the hill is further assumed to be effectively two-dimensional $(L_o \geq 2b)$ with the slope of $H/L_1\ df(\xi)/d\xi$ at $\xi = x/L$, then

$$\sigma(x,\ z \sim \ell) \cong \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{df(\xi)/d\xi}{\xi - x/L_1}\, d\xi \tag{5.14}$$

In the above relation ℓ is the depth of the inner layer defined by

$$\ell = \frac{z_o}{8} \left(\frac{L}{z_o}\right)^{0.9} \tag{5.15}$$

where z_o is the equivalent local roughness height.

TABLE 5.3. Amplification Factors Calculated for Several Selected WECS Sites by Using Bouwmeester's Prediction Technique Including Parameters Used.

Column 1 Site	2 H/L_u	3 H/L_d	4 A(H)	5 H(m) from Sea Level	6 $A_i(10)$	7 $\frac{A(10)}{A(10)_{REF}}$
3	.56	.83	1.12	108	1.268	.96
6	.31	.26	1.22	278	1.677	1.27
10	.19	.21	1.30	177	1.892	1.43
LLL	.22	.37	1.15	293	1.43	1.08
14	.18	.33	1.16	234	1.445	1.09
15	.21	.21	1.27	216	1.822	1.37
16	.16	.072	1.23	164	1.627	1.23
17	.13	.083	1.25	137	1.66	1.25
23	.19	$\approx$ 0	1.21	169	1.567	1.18
24	.21	$\approx$ 0	1.21	70	1.445	1.09
30	.265	.156	1.25	192	1.724	1.30
32	.625	$\approx$ 0	1.21	140	1.54	1.16
33	.083	.19	1.25	157	1.687	1.26
35	.21	$\approx$ 0	1.21	148	1.548	1.17
M2	.16	.47	1.125	121.9	1.29	.97
Opana Amb.	.058	.16	1.2	157	1.52	1.148

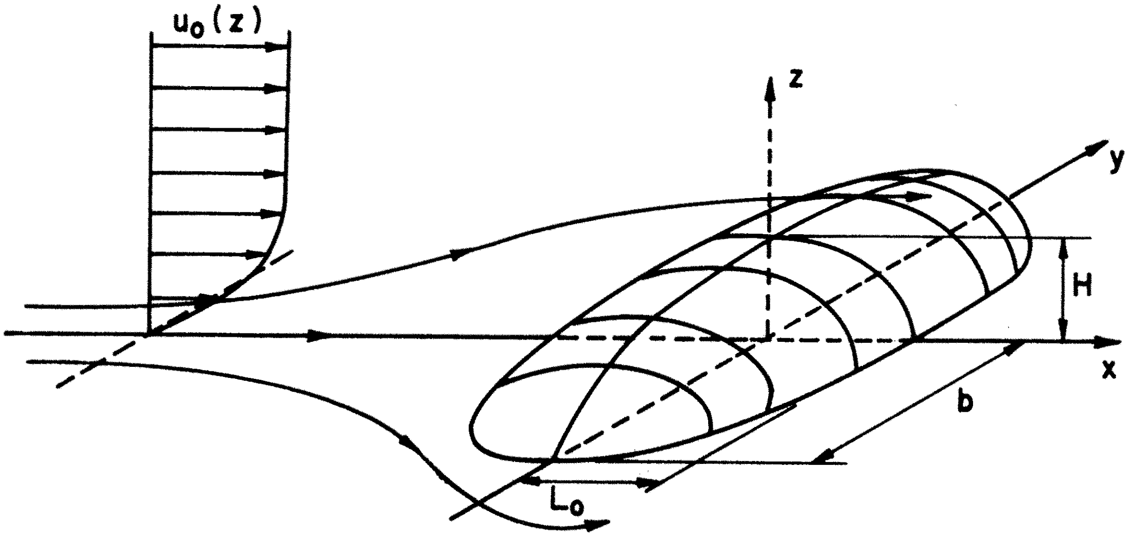

FIGURE 5.5. Coordinates and Notations for Potential Flow Over an Ellipsoidal Hill

For a typical boundary layer shear profile, equation (5.13) needs to be modified as

$$\frac{\Delta U}{U(L)} \cong \frac{H}{L_o} \sigma(x,z) \tag{5.16}$$

The amplification factor $A_i(x,z)$ can then be evaluated as

$$A_i(x,z) \cong 1 + \frac{\Delta U}{U(L)} \cong 1 + \frac{H}{L_o} \sigma_i(x,z) \tag{5.17}$$

To evaluate the integral of equation (5.14), the vertical topography contour for each WECS site was used. By selecting the location of each WECS site as the origin of the x-coordinate, equation (5.14) maybe simplified to

$$\sigma(x = 0,\ z \sim \ell) \cong \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{df(\xi)/d\xi}{\xi} d\xi \tag{5.19}$$

As a first approximation, the above integral was approximated by

$$\sigma(x = 0,\ z \sim \ell) \cong \int_{L_-/L_d}^{L_+/L_u} \frac{df(\xi)/d\xi}{\xi} d\xi \tag{5.19}$$

In this integral, L_+ and L_- were selected as distances upstream and downstream of the hill, where the slope of the hill changes sign distinctly as illustrated in Figure 5.6 for the contours of Site 6.

The integral in equation (5.19) was then evaluated by applying the simple graphical integration technique using the Trapezoidal Rule, as demonstrated in Figure 5.6 for Site 6. Table 5.4 lists the result obtained together with values of the inner layer depth ℓ for several WECS sites. The amplification factor increases when measured toward the crest of the hill; hence, $A_i(10)$ should be slightly higher than $A_i(\ell)$ for each WECS site if $\ell > 10$ meters.

5.4 AMPLIFICATION FACTOR COMPARISONS

Amplification factors presented on the previous tables in this chapter are summarized in Table 5.5 for the convenience of direct comparison. Individual deviation from the laboratory results for both techniques are also presented. It is obvious that Bouwmeester's technique tends to overpredict, while Hunt's analytical formula tends to underestimate the amplification factors. Overall average deviations from our laboratory results are + 16% and - 18% respectively.

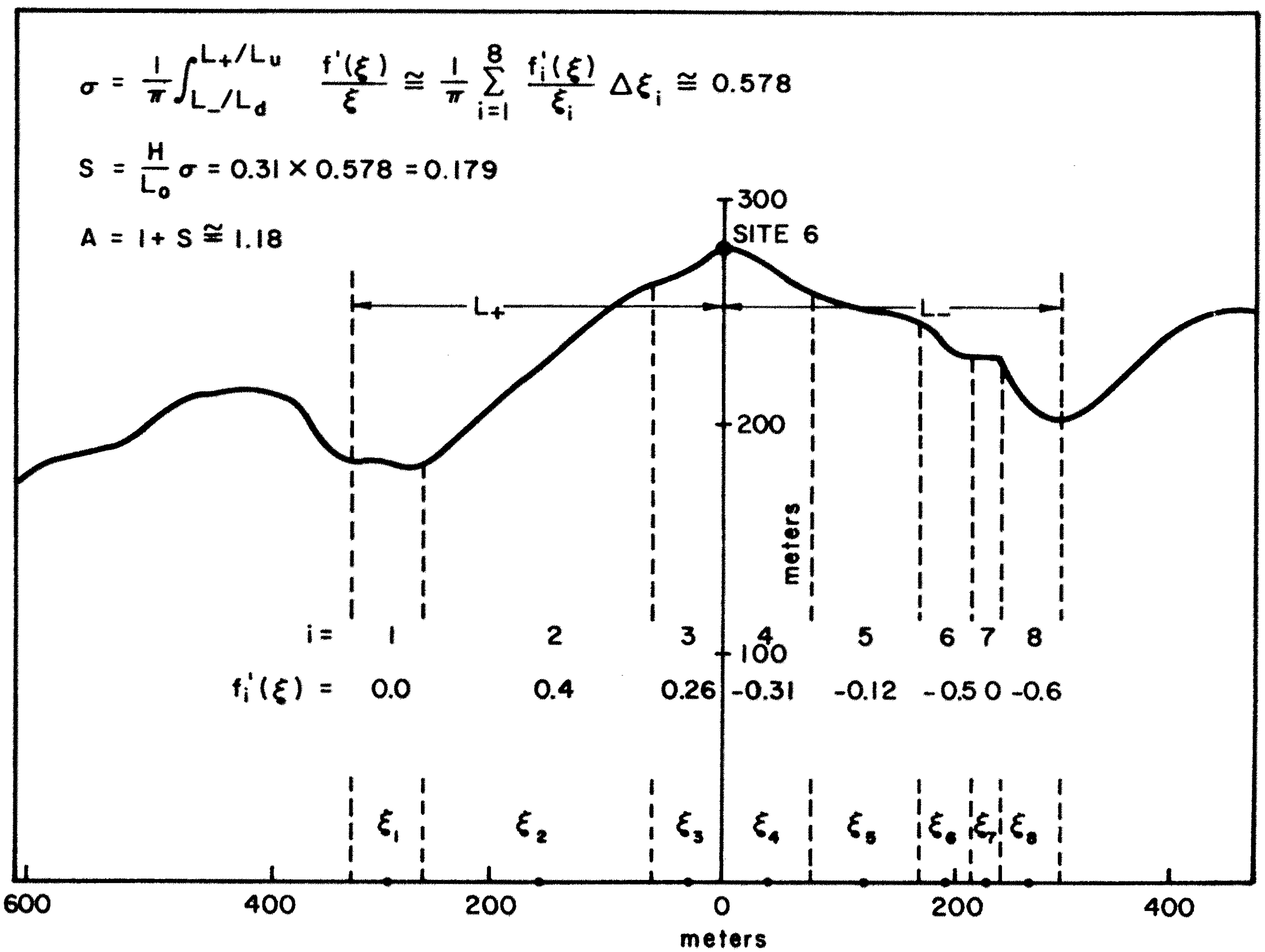

FIGURE 5.6. Demonstration for Definition of L_+ and L_- , and Approximation Scheme for Evaluating Equation (5.19) in Hunt's Analytical Technique.

TABLE 5.4. Amplification Factors Calculated by Using Hunt's Prediction Techniques for Several Selected WECS Sites.

Site	$\sigma(x,z\sim\ell)$	$A_i(\ell)$
1	.232	1.03
6	.578	1.18
9	.477	1.13
10	.343	1.065
LLL	1.022	1.225
14	.479	1.08
15	.396	1.08
16	.152	1.02
17	.241	1.03
23	.163	1.03
24	.144	1.03
25	.282	1.04
30	.35	1.09
31	.33	1.08
32	.69	1.43
33	.216	1.02
35	.194	1.05
M1	.3010	1.08
M2	.679	1.11
Opana Amb.	.200	1.01
Kahuku Upper	.682	1.17

TABLE 5.5. Comparison of Measured Amplification Factors with Values Predicted by Applying Bouwmeester's and Hunt's Techniques for Several Selected WECS Sites.

Site	$A_i(10)$ Laboratory	$A_i(10)$ Bouwmeester	$\frac{A_{i_B} - A_L}{A_{i_L}}$ (%)	$A_i(10)$ Hunt	$\frac{A_{i_H} - A_{i_L}}{A_{i_L}}$
3	1.15	1.268	+10	--	--
6	1.43	1.677	+17	1.18	-17
10	1.41	1.892	+34	1.065	-24
LLL(11)	1.35	1.43	+ 6	1.225	- 9
14	1.40	1.445	+ 3	1.08	-24
15	1.52	1.822	+19	1.08	-29
16	1.68	1.627	- 3.5	1.02	-39
17	1.18	1.66	+40	1.03	-13
23	1.20	1.567	+30	1.03	-14
24	1.19	1.445	+21	1.03	-13
30	1.29	1.724	+33	1.09	-15
32	1.38	1.54	+11	1.43	+ 3.6
33	1.15	1.687	+25	1.02	-11
35	1.35	1.548	+10	1.05	-22
Mill 2	1.40	1.29	- 8	1.11	-21
Opana Amb.	1.36	1.52	+11	1.01	-26
		Overall Average	+16%	Overall Average	-18%

The above comparison not only indicates the trends of both techniques, but also reveals the importance of upstream effects on the predictions of speed-up over a complex terrain. In addition to the lack of isolation, smoothness and two-dimensionality of hills, the assumption of a constant approach flow velocity provile was distorted by the topography features upstream and the associated turbulence structure. If further experimental work could provide some information about the above effects on speed-up, this technique may be modified to provide a more satisfactory prediction method.

The absence of consideration of the upstream topography affects in Hunt's analytical approach is likely to be the main cause of its under-estimation. In this technique, upstream turbulent momentum transfer near the topography surfaces was neglected. Also, the equal weighting of the upstream and the downstream slopes on local speed-up is suspect when separation is possible.

6.0 CONCLUSIONS AND RECOMMENDATION

The results discussed in the previous chapters enable us to draw conclusion concerning WECS installations on Kahuku Point, Oahu, and to make recommendation concerning future WECS siting procedures.

6.1 INFORMATION FOR THE WECS INSTALLATIONS AT KAHUKU POINT

A 1:3840 model of Kahuku Point was tested in the Colorado State University, Environmental Wind Tunnel. The model was placed at a location 8 meters from the wind tunnel inlet, where an equilibrium boundary layer was established. Boundary layer thickness, and turbulent structure were similar to the observed trade wind boundary layer. A small scale wind tunnel study was performed to insure the tunnel walls did not adversely distort the flow over the model. Local modeling of the roughness features of the topography were also included in the study.

Wind speed, turbulence, and spectral scales were measured and found compatible with an average adiabatic wind profile condition as modified by trade and characteristics.

6.2 CORRELATION OF LABORATORY AND FIELD MEASUREMENTS

Thirty-two field test site measurements were made available by the University of Hawaii. Of these field measurements, sixteen were found to correspond to the conditions modeled in the wind tunnel. Direct correlation of the laboratory and field measurements for the 19 sites produced a linear correlation coefficient of $r = 0.71$. The value of the correlation by rank for the 19 sites was 0.84. The remaining 8 sites did not correspond to the test conditions in the wind tunnel.

6.3 WIND-POWER RICH REGIONS AT KAHUKU POINT

Additional measurements at locations evenly selected over the Kahuku Point model together with flow visualization studies provide information that may be used to identify likely WECS site locations. Contoured maps were prepared which indicate the wind-power resource distributions over Kahuku Point.

Experimentally it appears that Site 16 may have the maximum high wind power potential. This site was not considered during the field measurements.

6.4 FEASIBLE TOPOGRAPHY AMPLIFICATION PREDICTION FORMULA

The need to develop relations which can be used to estimate the velocity amplification over a complex topography is obvious.

By applying the semi-empirical and the analytical relations, which were proposed by Bouwmeester and Hunt respectively, to several WECS sites, the two methods were found to bracket typical topography amplification. Bouwmeester's analysis tends to over predict the wind amplification, whereas Hunt's method predicted too small an amplification. Evidently, the methods suffer from the lack of internal specification of the turbulent structure due to the upstream topography features. Improvement in prediction of the approach flow would appear to be a first step in reducing the uncertainty of the predictions.

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APPENDIX A

Wind tunnel measurements of longitudinal velocity and turbulence intensity at 30 WECS sites and several other sites for three wind directions are listed in this section. In the listing of each profile, the power law exponent, α_o , and reference velocity, U(HMAX) , are also noted. Table A tabulates the profiles presented.

TABLE A. List of Profiles Presented

Site	Approach Wind Direction (degree from true north)		
	45°	66.7°	90°
1	*	NA	*
2	*	*	*
3	*	*	*
4	*	*	*
5	*	*	*
6	*	*	*
7	*	*	*
8	*	*	*
9	*	*	*
10	*	*	*
LLL	*	*	*
14	*	*	*
15	*	*	*
16	*	*	*
17	*	*	*
20	*	*	*
23	*	*	*
24	*	*	*
25	*	*	*
26	*	*	*
30	*	*	*
31	*	*	*
32	*	*	*
33	*	*	*
34	*	*	*
35	*	*	*
Hill 200	*	NA	*
Aque	*	*	*
Kakuku Radio	*	*	*
Lowe	*	*	*
Mill 1	*	*	*
Mill 2	*	*	*
Opana Ambulance	*	*	*
Kahuku Upper	*	*	*
Laie	*	*	*
Hill 365	*	*	*
Hill 183	*	*	*
puu Ki	*	*	*
Kahuku Point	*	*	NA
Makahoa Point	*	*	*

SITE: 1 WIND DIRECTION: 45°

EXPONENT = .1113 U(HMAX) = 31.06
RMS ERROR = 3.1%UMAX MAX ERROR = 5.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.52	3.252	17.56
2	.56	18.24	3.004	16.47
3	.75	17.63	2.866	16.25
4	.96	20.72	2.805	13.54
5	1.39	20.67	2.662	12.88
6	1.95	21.11	2.813	13.32
7	2.85	22.81	2.529	11.09
8	3.96	23.14	2.299	9.93
9	4.89	25.24	2.201	8.72
10	9.85	26.96	1.507	5.59
11	14.97	28.68	1.065	3.71
12	19.98	28.04	.449	1.60
13	25.07	29.60	.281	.95
14	30.08	28.82	.386	1.34
15	40.09	29.42	.149	.51
16	50.14	29.50	.236	.80

SITE: 2 WIND DIRECTION: 45°

EXPONENT = .0933 U(HMAX) = 33.8
RMS ERROR = 2.7%UMAX MAX ERROR = 5.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.62	3.151	15.28
2	.54	22.74	3.251	14.29
3	.76	22.97	3.071	13.37
4	.94	23.39	2.956	12.64
5	1.45	23.35	2.784	11.92
6	1.87	24.52	2.830	11.54
7	2.94	26.17	2.494	9.53
8	3.94	27.03	2.431	8.99
9	4.94	26.15	2.686	10.27
10	9.94	30.33	1.798	5.93
11	14.93	31.49	1.696	5.39
12	19.92	32.94	.476	1.44
13	25.01	31.29	.302	.96
14	29.94	32.24	.167	.52
15	39.90	32.05	.388	1.21
16	49.95	32.35	.271	.84

SITE: 3 WIND DIRECTION: 45°

EXPONENT = .0971 U(HMAX) = 31.49
RMS ERROR = 5.7%UMAX MAX ERROR =12.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	18.40	2.720	14.79
2	.57	20.47	2.337	11.41
3	.98	20.52	2.540	12.38
4	1.24	21.10	2.260	10.71
5	1.51	22.40	2.458	10.98
6	2.21	23.79	2.103	8.84
7	3.21	23.60	2.553	10.82
8	4.33	26.72	1.749	6.54
9	10.26	30.85	1.434	4.65
10	15.07	30.22	.668	2.21
11	20.24	31.18	1.367	4.39
12	25.36	28.64	.524	1.83
13	30.20	29.13	.697	2.39
14	39.98	28.79	.445	1.54
15	50.19	28.10	.417	1.48

SITE: 6 WIND DIRECTION: 45°

EXPONENT = .1396 U(HMAX) = 32.01
RMS ERROR = 3.2%UMAX MAX ERROR = 6.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.04	3.356	20.93
2	.56	16.75	3.298	19.69
3	.73	17.38	3.483	20.04
4	.94	17.40	3.483	20.01
5	1.37	19.03	3.900	20.49
6	1.95	20.33	3.725	18.32
7	2.86	21.63	3.187	14.74
8	3.96	23.29	2.566	11.02
9	4.95	23.86	2.470	10.35
10	9.90	26.66	1.904	7.14
11	14.86	28.48	1.239	4.35
12	19.96	29.53	.673	2.28
13	24.92	29.62	.416	1.41
14	29.95	29.47	.392	1.33
15	39.93	28.97	.418	1.44
16	49.95	30.05	.385	1.28

SITE: 8 WIND DIRECTION: 45°

EXPONENT = .1119 U(HMAX) = 31.66
RMS ERROR = 2.8%UMAX MAX ERROR = 6.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.51	19.22	3.029	15.76
2	.93	19.61	2.785	14.20
3	1.09	19.82	3.236	16.33
4	1.63	22.64	3.307	14.61
5	2.11	22.38	2.817	12.59
6	3.03	23.00	2.119	9.21
7	4.28	23.25	1.714	7.37
8	10.13	26.74	1.291	4.83
9	15.16	29.43	.821	2.79
10	20.19	29.37	1.201	4.09
11	25.14	30.13	1.188	3.94
12	30.02	29.65	1.289	4.35
13	40.25	30.49	1.262	4.14
14	50.13	29.74	1.280	4.30

SITE: 9 WIND DIRECTION: 45°

EXPONENT = 1195 U(HMAX) = 32.67
RMS ERROR = 2.8%UMAX MAX ERROR = 5.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.99	3.064	18.03
2	.54	19.42	3.032	15.61
3	.75	19.99	3.002	15.02
4	.95	19.80	3.178	16.05
5	1.39	21.66	3.037	14.02
6	1.94	21.25	2.717	12.79
7	2.86	23.90	2.596	10.86
8	3.94	24.33	2.437	10.02
9	4.95	24.88	2.300	9.24
10	9.87	28.04	1.535	5.48
11	14.96	29.16	.914	3.14
12	20.09	30.70	.271	.88
13	25.05	30.77	.677	2.20
14	30.05	30.63	.491	1.60
15	40.01	29.98	.364	1.21
16	50.02	30.88	.494	1.60

SITE: 10 WIND DIRECTION: 45°

EXPONENT = .1460 U(HMAX) = 35.20
RMS ERROR = 4.3%UMAX MAX ERROR =10.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.28	13.90	3.363	24.20
2	.76	19.43	3.503	18.03
3	.76	19.32	3.330	17.24
4	1.19	21.38	3.320	15.52
5	1.75	22.80	3.557	15.60
6	2.07	22.92	3.632	15.84
7	3.03	24.13	3.359	13.92
8	4.09	25.82	3.161	12.24
9	10.08	28.01	1.502	5.36
10	15.18	30.59	.895	2.92
11	20.10	32.42	1.198	3.69
12	25.05	30.95	1.186	3.83
13	30.00	33.40	1.294	3.88
14	40.01	32.30	1.366	4.23
15	50.02	31.51	1.311	4.16

SITE: LLL WIND DIRECTION: 45°

EXPONENT = .0704 U(HMAX) = 31.45
RMS ERROR = 2.8%UMAX MAX ERROR = 5.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	22.62	3.792	16.76
2	.73	23.01	2.572	11.18
3	.97	23.45	2.814	12.00
4	1.18	23.24	2.620	11.27
5	1.48	24.73	2.822	11.41
6	2.42	23.71	2.741	11.56
7	3.33	26.95	2.529	9.39
8	3.93	27.00	2.594	9.61
9	10.24	29.40	.888	3.02
10	15.32	29.49	.787	2.67
11	20.22	30.36	1.254	4.13
12	25.38	30.64	1.285	4.19
13	30.23	30.06	1.202	4.00
14	40.51	30.12	1.293	4.29
15	50.18	30.17	1.242	4.12

SITE: 15 WIND DIRECTION: 45°

EXPONENT = .0465 U(HMAX) = 30.16
RMS ERROR = 2.7%UMAX MAX ERROR = 5.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	23.46	3.177	13.54
2	.59	25.76	2.719	10.56
3	.96	24.51	3.252	13.27
4	.97	24.10	2.997	12.44
5	1.52	25.67	3.015	11.75
6	2.35	26.18	2.446	9.34
7	2.97	26.94	2.351	8.73
8	4.04	26.52	2.113	7.97
9	10.07	27.92	1.364	4.89
10	15.27	29.59	.564	1.91
11	20.18	30.52	1.221	4.00
12	25.06	29.80	1.256	4.21
13	30.17	29.08	1.257	4.32
14	40.31	28.74	1.093	3.81
15	50.02	29.18	.769	2.64

SITE: 14 WIND DIRECTION: 45°

EXPONENT = .0747 U(HMAX) = 31.21
RMS ERROR = 4.9%UMAX MAX ERROR = 8.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.73	3.090	16.50
2	.46	20.71	3.052	14.74
3	.90	23.29	2.813	12.08
4	1.20	25.00	2.628	10.51
5	1.56	24.96	2.133	8.55
6	2.11	25.38	1.961	7.73
7	2.98	26.88	1.859	6.91
8	4.01	27.83	2.037	7.32
9	10.05	28.76	.912	3.17
10	15.23	30.07	1.202	4.00
11	20.20	29.39	1.061	3.61
12	25.04	30.62	1.290	4.21
13	30.15	28.13	1.264	4.49
14	40.07	28.87	1.248	4.32
15	50.20	28.70	1.238	4.31

SITE: 16 WIND DIRECTION: 45°

EXPONENT = .1294 U(HMAX) = 34.74
RMS ERROR = 7.3%UMAX MAX ERROR =17.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	11.74	3.886	33.10
2	.52	21.23	3.124	14.71
3	.74	20.86	3.022	14.49
4	.96	22.82	3.119	13.67
5	1.38	23.15	3.165	13.67
6	1.93	24.12	3.464	14.36
7	2.95	27.01	2.936	10.87
8	3.93	27.22	2.336	8.59
9	4.93	28.00	2.361	8.43
10	9.91	29.54	1.693	5.73
11	14.91	31.18	1.017	3.26
12	19.92	30.86	.284	.92
13	24.92	30.55	.391	1.28
14	29.95	31.23	.441	1.41
15	39.93	30.90	.524	1.69
16	50.03	30.41	.482	1.59

SITE: 17 WIND DIRECTION: 45°

EXPONENT = .1806 U(HMAX) = 35.13
RMS ERROR = 8.3%UMAX MAX ERROR =16.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	8.47	2.676	31.59
2	.56	14.38	3.387	23.55
3	.72	18.17	2.751	15.14
4	.93	19.55	2.643	13.52
5	1.37	21.22	2.457	11.58
6	1.95	22.74	2.635	11.59
7	2.94	24.28	2.328	9.59
8	3.95	24.90	2.319	9.31
9	4.95	26.07	1.974	7.57
10	9.95	25.83	1.538	5.95
11	14.94	29.87	.102	.34
12	19.85	29.06	.873	3.00
13	24.95	30.22	.608	2.01
14	29.95	30.59	.351	1.15
15	39.94	30.78	.537	1.74
16	49.87	29.28	.309	1.06

SITE: 20 WIND DIRECTION: 45°

EXPONENT = .0987 U(HMAX) = 32.53
RMS ERROR = 4.6%UMAX MAX ERROR =10.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.56	2.568	14.62
2	.93	21.06	2.761	13.11
3	1.48	23.26	2.589	11.13
4	1.48	23.16	2.610	11.27
5	2.02	24.73	2.559	10.35
6	2.49	25.52	2.393	9.37
7	3.51	25.70	2.577	10.03
8	4.55	26.77	2.280	8.52
9	10.27	29.42	1.369	4.65
10	15.75	31.25	.526	1.68
11	20.52	30.51	.438	1.44
12	25.99	30.79	.660	2.14
13	30.71	30.02	.278	.93
14	40.67	29.89	.473	1.58
15	50.44	29.19	.324	1.11

SITE: 23 WIND DIRECTION: 45°

EXPONENT = .1301 U(HMAX) = 34.84
RMS ERROR = 4.0%UMAX MAX ERROR = 7.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.27	4.032	24.78
2	.56	19.79	3.375	17.06
3	.73	18.92	3.312	17.51
4	.96	20.45	3.304	16.16
5	1.37	22.60	3.242	14.35
6	1.95	23.63	3.422	14.48
7	2.96	25.09	2.775	11.06
8	3.85	26.45	2.742	10.37
9	4.95	26.44	2.600	9.83
10	9.98	30.53	1.498	4.91
11	14.91	31.37	1.438	4.58
12	19.97	31.78	.429	1.35
13	24.98	31.47	.434	1.38
14	29.92	31.41	.381	1.21
15	39.98	31.11	.460	1.48
16	50.03	32.68	.622	1.90

SITE: 24 WIND DIRECTION: 45°

EXPONENT = .0925 U(HMAX) = 29.95
RMS ERROR = 3.5%UMAX MAX ERROR = 8.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.71	2.832	15.13
2	.67	20.08	2.638	13.14
3	.91	20.97	2.755	13.14
4	1.26	21.01	2.685	12.78
5	1.70	21.09	2.698	12.80
6	2.07	22.14	2.368	10.70
7	3.09	22.95	2.044	8.91
8	4.27	23.48	2.271	9.67
9	9.83	27.64	1.766	6.39
10	15.36	27.38	.737	2.69
11	20.17	29.36	.816	2.78
12	25.44	28.82	.518	1.80
13	30.02	29.21	.823	2.82
14	40.02	28.25	.805	2.85
15	49.74	27.39	.799	2.92

SITE: 25 WIND DIRECTION: 45°

EXPONENT = .0761 U(HMAX) = 28.96
RMS ERROR = 3.3%UMAX MAX ERROR = 6.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.58	2.666	12.96
2	.59	19.78	2.179	11.02
3	.82	19.75	2.332	11.81
4	1.00	21.23	2.766	13.03
5	1.74	21.75	2.908	13.37
6	2.22	23.30	3.048	13.08
7	3.14	23.94	2.592	10.83
8	4.03	25.20	2.115	8.39
9	10.43	27.65	.945	3.42
10	15.19	26.83	.496	1.85
11	20.21	26.91	.942	3.50
12	25.51	27.33	1.146	4.19
13	30.42	28.46	1.207	4.24
14	39.75	27.65	.986	3.57
15	50.31	27.37	1.059	3.87

SITE: 26 WIND DIRECTION: 45°

EXPONENT = .1264 U(HMAX) = 33.66
RMS ERROR = 3.7%UMAX MAX ERROR = 7.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.27	2.958	17.13
2	.57	19.19	2.621	13.66
3	.73	20.51	2.606	12.70
4	.97	19.95	2.763	13.84
5	1.39	20.09	2.605	12.97
6	1.95	22.95	2.798	12.19
7	2.87	23.16	2.673	11.54
8	3.96	24.61	2.292	9.31
9	4.96	24.35	2.358	9.68
10	9.98	30.05	1.350	4.49
11	14.95	30.87	.900	2.92
12	19.92	30.55	.380	1.24
13	24.96	32.04	.468	1.46
14	29.94	30.50	.379	1.24
15	39.95	31.90	.433	1.36
16	49.96	31.05	.077	.25

SITE: 30 WIND DIRECTION: 45°

EXPONENT = .0952 U(HMAX) = 33.39
RMS ERROR = 4.3%UMAX MAX ERROR =10.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.58	3.313	16.92
2	.55	21.44	3.493	16.29
3	.71	22.32	3.422	15.33
4	.94	22.34	3.668	16.42
5	1.45	22.34	3.249	14.54
6	1.87	25.02	2.968	11.86
7	2.95	26.52	2.808	10.59
8	3.95	26.81	2.769	10.33
9	4.95	28.70	2.366	8.25
10	9.95	30.61	1.571	5.13
11	14.91	31.95	1.144	3.58
12	19.87	31.45	.691	2.20
13	24.96	30.64	.040	.13
14	29.99	31.86	.377	1.18
15	40.08	30.97	.438	1.41
16	50.02	30.02	.481	1.60

SITE: 31 WIND DIRECTION: 45°

EXPONENT = .0981 U(HMAX) = 33.23
RMS ERROR = 4.2%UMAX MAX ERROR = 7.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.87	3.119	14.95
2	.53	20.30	3.077	15.16
3	.70	21.57	3.385	15.69
4	.94	20.84	3.700	17.76
5	1.44	22.63	3.898	17.22
6	1.94	23.37	3.773	16.14
7	2.94	26.84	3.025	11.27
8	3.95	27.57	2.580	9.36
9	4.94	27.90	2.309	8.27
10	9.94	29.80	1.966	6.60
11	14.94	31.19	1.423	4.56
12	19.91	31.24	.212	.68
13	25.04	31.88	.331	1.04
14	30.02	30.81	.560	1.82
15	40.07	30.06	.273	.91
16	50.06	31.13	.406	1.30

SITE: 32 WIND DIRECTION: 45°

EXPONENT = .0680 U(HMAX) = 31.64
RMS ERROR = 5.4%UMAX MAX ERROR =14.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.67	3.508	19.85
2	.56	25.32	2.544	10.05
3	.72	26.03	2.455	9.43
4	.95	26.37	2.487	9.43
5	1.35	24.69	2.532	10.26
6	1.94	26.05	2.627	10.08
7	2.95	26.82	2.419	9.02
8	3.94	25.39	2.264	8.91
9	4.94	27.17	2.427	8.93
10	9.96	28.91	1.939	6.71
11	14.98	28.69	1.513	5.27
12	19.94	29.51	.853	2.89
13	25.00	31.65	.514	1.63
14	29.98	30.52	.333	1.09
15	40.06	31.06	.381	1.23
16	50.04	29.25	.073	.25

SITE: 33 WIND DIRECTION: 45°

EXPONENT = .1008 U(HMAX) = 33.15
RMS ERROR = 4.1%UMAX MAX ERROR = 9.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.40	3.241	15.88
2	.56	19.41	3.142	16.19
3	.73	22.02	3.185	14.46
4	.93	21.79	3.362	15.43
5	1.45	23.16	3.432	14.82
6	1.86	22.86	3.335	14.59
7	2.95	25.25	3.127	12.38
8	3.95	26.52	3.406	12.84
9	4.94	26.50	2.373	8.96
10	9.94	29.26	1.793	6.13
11	14.96	31.30	.985	3.15
12	19.91	32.24	.050	.16
13	24.94	31.72	.461	1.45
14	29.95	31.79	.177	.56
15	40.15	30.27	.116	.38
16	49.97	30.11	.183	.61

SITE: 34 WIND DIRECTION: 45°

EXPONENT = .1162 U(HMAX) = 31.17
RMS ERROR = 3.4%UMAX MAX ERROR = 7.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.82	2.956	18.69
2	.54	18.13	3.262	17.99
3	.74	19.35	3.274	16.92
4	.94	19.16	3.071	16.03
5	1.45	20.68	2.929	14.16
6	1.87	22.71	2.597	11.43
7	2.96	22.70	2.572	11.33
8	3.96	23.88	2.526	10.57
9	4.94	24.72	2.122	8.59
10	9.93	27.11	1.465	5.40
11	14.94	27.71	.829	2.99
12	19.89	29.39	.219	.74
13	24.99	28.15	.335	1.19
14	29.97	29.06	.368	1.27
15	39.96	28.90	.121	.42
16	50.08	28.89	.390	1.35

SITE: 35 WIND DIRECTION: 45°

EXPONENT = .1699 U(HMAX) = 32.08
RMS ERROR = 4.5%UMAX MAX ERROR =11.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	11.84	2.865	24.20
2	.55	14.92	2.955	19.80
3	.73	14.72	2.751	18.69
4	.96	17.00	2.993	17.60
5	1.39	18.09	3.029	16.74
6	1.93	18.87	2.756	14.60
7	2.86	20.61	2.532	12.29
8	3.95	21.88	2.250	10.28
9	4.85	22.77	2.282	10.02
10	9.86	25.69	1.590	6.19
11	14.96	27.72	1.091	3.94
12	20.00	28.79	.728	2.53
13	25.08	28.79	.034	.12
14	30.14	28.53	.600	2.10
15	39.91	28.78	.451	1.57
16	50.15	28.30	.258	.91

SITE: HILL 220 WIND DIRECTION: 45°

EXPONENT = .0802 U(HMAX) = 28.36
RMS ERROR = 3.8%UMAX MAX ERROR = 7.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.59	2.816	14.38
2	.54	21.45	2.844	13.26
3	.73	19.78	2.519	12.74
4	.93	18.94	2.724	14.38
5	1.43	21.88	2.470	11.29
6	1.85	22.30	2.772	12.43
7	2.94	22.20	2.279	10.27
8	3.94	21.16	2.525	11.93
9	4.94	21.90	2.329	10.64
10	9.86	25.02	1.518	6.07
11	14.92	27.40	.925	3.38
12	19.94	27.70	.518	1.87
13	24.90	26.64	.319	1.20
14	29.97	26.99	.642	2.38
15	39.89	27.79	.320	1.15
16	49.95	28.72	.549	1.91

SITE: KAHUKU UPPER WIND DIRECTION: 45°

EXPONENT = .1040 U(HMAX) = 33.68
RMS ERROR = 8.0%UMAX MAX ERROR =20.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	12.82	2.743	21.40
2	.58	22.94	2.272	9.91
3	.96	25.38	2.344	9.24
4	.98	25.23	2.395	9.49
5	1.49	24.09	2.146	8.91
6	1.98	25.92	2.174	8.39
7	3.04	27.36	2.135	7.80
8	3.97	28.79	1.769	6.14
9	10.12	28.43	.939	3.30
10	15.10	30.76	.904	2.94
11	20.13	30.91	1.307	4.23
12	25.28	31.29	1.208	3.86
13	30.07	30.80	1.316	4.27
14	40.47	30.01	1.266	4.22
15	50.28	30.22	1.296	4.29

SITE: LAIE WIND DIRECTION: 45°

EXPONENT = .1180 U(HMAX) = 31.74
RMS ERROR = 3.3%UMAX MAX ERROR = 6.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.82	2.561	15.22
2	.56	17.38	2.562	14.74
3	.73	19.05	2.475	12.99
4	.95	19.75	2.523	12.78
5	1.37	20.55	2.857	13.90
6	1.96	22.51	2.427	10.78
7	2.87	24.02	2.085	8.68
8	3.95	25.68	2.257	8.79
9	4.95	24.39	2.322	9.52
10	9.90	26.80	1.263	4.71
11	14.86	28.30	1.142	4.04
12	19.94	28.55	.837	2.93
13	24.93	29.32	.417	1.42
14	29.90	30.30	.571	1.88
15	39.85	29.09	.365	1.26
16	49.87	29.66	.227	.76

SITE: LOWE   WIND DIRECTION: 45°

EXPONENT = .1753   U(HMAX) = 33.13
RMS ERROR = 5.4%UMAX   MAX ERROR =11.2%UMAX

DATA POINT	HEIGHT CM	UMEAN CM/S	U-RMS CM/S	TURB INT PERCENT
1	.30	9.75	2.590	26.57
2	.52	15.08	2.498	16.57
3	.84	18.14	2.539	14.00
4	1.06	17.64	2.261	12.82
5	1.51	19.97	2.382	11.93
6	2.12	20.74	2.457	11.84
7	3.11	21.81	2.297	10.54
8	4.05	21.23	2.030	9.56
9	10.18	26.11	1.547	5.92
10	15.15	27.85	1.019	3.66
11	20.22	29.04	.262	.90
12	25.16	28.77	.795	2.76
13	30.07	29.50	.847	2.87
14	39.84	29.81	.792	2.66
15	50.41	29.52	.737	2.50

SITE: MILL 1   WIND DIRECTION: 45°

EXPONENT = .0662   U(HMAX) = 30.81
RMS ERROR = 3.2%UMAX   MAX ERROR = 7.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	22.76	2.572	11.30
2	.29	22.09	2.949	13.35
3	.67	22.89	2.458	10.74
4	1.13	24.15	2.432	10.07
5	1.91	24.60	2.273	9.24
6	2.23	22.68	2.061	9.09
7	3.26	24.92	1.747	7.01
8	4.22	26.50	1.984	7.49
9	10.18	28.98	.346	1.19
10	15.18	29.59	.404	1.37
11	20.54	30.09	1.203	4.00
12	25.41	30.48	1.274	4.18
13	30.54	29.70	1.263	4.25
14	40.64	29.14	1.274	4.37
15	50.28	29.97	1.190	3.97

SITE: AQUE WIND DIRECTION: 45°

EXPONENT = .1419 U(HMAX) = 33.87
RMS ERROR = 4.3%UMAX MAX ERROR =10.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	14.57	2.954	20.28
2	.55	16.88	3.063	18.15
3	.73	18.26	3.047	16.69
4	.94	20.25	2.815	13.91
5	1.45	20.46	2.787	13.62
6	1.85	22.45	2.618	11.66
7	2.93	24.11	2.611	10.83
8	3.93	24.89	2.207	8.87
9	4.90	25.63	2.005	7.82
10	9.93	28.17	1.435	5.09
11	14.96	30.24	.773	2.56
12	19.92	30.61	.478	1.56
13	24.86	30.18	.314	1.04
14	29.94	30.48	.472	1.55
15	39.97	31.03	.486	1.57
16	49.93	30.49	.546	1.79

SITE: KAHUKU RADIO WIND DIRECTION: 45°

EXPONENT = .1183 U(HMAX) = 34.68
RMS ERROR = 3.7%UMAX MAX ERROR = 7.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.86	3.016	15.99
2	.58	19.31	2.765	14.32
3	.77	20.46	2.756	13.47
4	.96	21.13	2.736	12.95
5	1.43	23.14	2.789	12.05
6	1.90	23.56	2.721	11.55
7	2.97	26.33	2.788	10.59
8	3.92	26.67	2.382	8.93
9	4.93	26.60	2.531	9.52
10	9.99	30.92	1.756	5.68
11	14.89	31.58	.678	2.15
12	19.93	30.76	.136	.44
13	25.01	33.10	.502	1.52
14	29.98	32.57	.675	2.07
15	40.08	31.40	.434	1.38
16	50.01	32.15	.642	2.00

SITE: PUU KI WIND DIRECTION: 45°

EXPONENT = .1030 U(HMAX) = 32.17
RMS ERROR = 4.8%UMAX MAX ERROR =11.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.49	4.435	28.63
2	.52	20.57	3.548	17.25
3	.75	21.13	3.081	14.58
4	.93	22.91	2.976	12.99
5	1.35	22.79	2.882	12.64
6	1.94	23.38	2.744	11.74
7	2.95	24.50	2.218	9.05
8	3.95	26.63	2.081	7.82
9	4.94	26.58	2.127	8.00
10	9.94	28.72	1.471	5.12
11	14.94	28.63	1.129	3.94
12	19.97	29.88	.223	.75
13	24.98	30.29	.514	1.70
14	29.98	30.32	.555	1.83
15	40.14	29.88	.349	1.17
16	49.98	28.57	.240	.84

SITE: KAHUKU POINT WIND DIRECTION; 45°

EXPONENT = .1417 U(HMAX) = 35.60
RMS ERROR = 4.6%UMAX MAX ERROR =10.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	14.92	2.783	18.65
2	.71	20.29	2.622	12.92
3	.85	20.75	2.655	12.80
4	1.15	20.41	2.586	12.67
5	1.54	22.62	2.783	12.30
6	2.09	23.62	2.154	9.12
7	3.19	24.00	2.334	9.72
8	4.07	25.73	2.238	8.70
9	10.30	30.38	1.596	5.25
10	15.11	31.18	.229	.73
11	20.35	33.62	.782	2.32
12	25.05	32.40	.860	2.66
13	29.96	33.16	.628	1.89
14	40.15	30.97	.921	2.97
15	49.96	32.87	.310	.94

SITE: HILL 365 WIND DIRECTION: 45°

EXPONENT = .0900 U(HMAX) = 29.00
RMS ERROR = 2.5%UMAX MAX ERROR = 5.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.91	2.908	17.19
2	.56	19.83	2.687	13.55
3	.74	20.69	2.733	13.21
4	.92	20.34	2.583	12.70
5	1.44	21.30	2.487	11.68
6	1.94	21.79	2.470	11.34
7	2.94	22.36	1.996	8.93
8	3.93	22.87	2.005	8.77
9	4.93	23.24	2.000	8.61
10	10.09	25.60	1.514	5.91
11	15.00	26.96	.547	2.03
12	19.93	27.57	.634	2.30
13	24.99	27.08	.297	1.10
14	29.89	28.10	.431	1.53
15	40.05	27.80	.365	1.31
16	50.08	27.37	.283	1.03

SITE: HILL 183 WIND DIRECTION: 45°

EXPONENT = .1416 U(HMAX) = 32.14
RMS ERROR = 3.1%UMAX MAX ERROR = 6.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.29	2.787	17.11
2	.54	16.59	2.629	15.85
3	.72	17.38	2.595	14.93
4	.92	18.69	2.793	14.95
5	1.44	19.13	2.728	14.26
6	1.94	19.58	2.664	13.61
7	2.94	20.49	2.541	12.40
8	4.08	22.51	2.194	9.75
9	4.91	22.68	2.365	10.43
10	9.92	25.70	1.913	7.45
11	14.94	29.21	1.105	3.78
12	19.95	29.91	.421	1.41
13	24.88	29.86	.417	1.40
14	29.95	30.30	.479	1.58
15	39.98	30.29	.286	.94
16	50.14	29.97	.278	.93

SITE: MILL 2 WIND DIRECTION: 45°

EXPONENT = .1072 U(HMAX) = 35.37
RMS ERROR = 3.7%UMAX MAX ERROR = 6.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.82	3.044	16.17
2	.69	23.02	2.907	12.63
3	.89	22.11	2.762	12.49
4	1.06	22.97	2.692	11.72
5	1.51	25.51	2.696	10.57
6	2.09	25.61	2.713	10.59
7	3.13	28.42	2.137	7.52
8	4.11	26.37	2.263	8.58
9	9.90	30.32	.793	2.62
10	15.12	32.84	1.296	3.95
11	20.10	33.59	1.437	4.28
12	24.95	32.48	1.421	4.38
13	29.97	33.43	1.357	4.06
14	40.17	32.46	1.383	4.26
15	50.33	33.18	1.242	3.74

SITE: OPANA AMBULANCE WIND DIRECTION: 45°

EXPONENT = .0711 U(HMAX) = 33.24
RMS ERROR = 3.7%UMAX MAX ERROR = 7.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.78	3.334	16.05
2	.55	22.98	2.998	13.04
3	.73	25.45	3.170	12.46
4	.92	25.37	2.973	11.72
5	1.44	28.02	2.656	9.48
6	1.95	27.80	2.482	8.93
7	2.95	27.04	2.395	8.86
8	3.93	27.51	2.417	8.78
9	4.94	29.76	2.351	7.90
10	9.95	29.89	1.704	5.70
11	14.95	30.19	1.435	4.75
12	19.95	31.51	.220	.70
13	24.86	32.46	.287	.88
14	29.96	32.09	.301	.94
15	39.96	30.55	.594	1.94
16	49.97	32.05	.425	1.33

SITE: MAKAHOA POINT WIND DIRECTION: 45°

EXPONENT = .1308 U(HMAX) = 31.36
RMS ERROR = 2.8%UMAX MAX ERROR = 7.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.87	2.836	17.87
2	.54	16.93	2.452	14.48
3	.74	18.24	2.855	15.65
4	.94	18.95	2.775	14.64
5	1.39	20.00	2.612	13.06
6	1.96	19.34	2.370	12.25
7	2.89	21.35	2.272	10.64
8	3.95	24.04	2.015	8.38
9	4.85	22.92	2.183	9.52
10	9.92	24.94	1.979	7.94
11	14.85	27.65	1.278	4.62
12	19.88	29.15	.996	3.42
13	24.98	28.84	.241	.84
14	29.98	29.68	.431	1.45
15	40.08	30.25	.224	.74
16	50.06	29.10	.412	1.42

SITE: 2 WIND DIRECTION: 66.7°

EXPONENT = .0588 U(HMAX) = 34.30
RMS ERROR = 2.8%UMAX MAX ERROR = 6.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	25.93	3.244	12.51
2	.54	26.54	3.062	11.54
3	.79	25.03	2.700	10.79
4	.92	27.57	2.741	9.94
5	1.50	28.19	2.611	9.26
6	2.06	28.35	2.455	8.66
7	2.97	28.27	2.390	8.46
8	4.03	30.14	2.152	7.14
9	10.06	31.21	1.455	4.66
10	15.11	32.84	.493	1.50
11	20.01	34.72	.777	2.24
12	25.20	33.32	.861	2.58
13	30.13	32.22	.578	1.80
14	40.04	33.41	.763	2.28
15	50.10	33.18	.642	1.94

SITE: 3 WIND DIRECTION: 66.7°

EXPONENT = .1241 U(HMAX) = 31.20
RMS ERROR = 3.4%UMAX MAX ERROR = 7.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	14.74	2.618	17.76
2	.48	17.52	2.257	12.88
3	.75	19.12	2.659	13.91
4	1.12	19.04	2.379	12.50
5	1.58	21.02	2.385	11.35
6	1.99	21.40	2.365	11.05
7	3.08	22.44	2.475	11.03
8	4.22	25.41	2.191	8.62
9	10.07	26.50	1.353	5.11
10	15.09	27.93	.250	.90
11	20.29	27.33	.217	.79
12	25.38	28.46	.535	1.88
13	30.11	28.74	.613	2.13
14	40.20	29.25	.319	1.09
15	49.99	29.50	.640	2.17

SITE: 6 WIND DIRECTION: 66.7°

EXPONENT = .0640 U(HMAX) = 30.86
RMS ERROR = 3.9%UMAX MAX ERROR = 7.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	24.34	7.889	32.41
2	.63	22.40	2.414	10.78
3	.77	22.82	2.067	9.06
4	1.09	23.09	2.241	9.71
5	1.55	23.43	1.816	7.75
6	1.94	24.29	2.000	8.23
7	3.07	26.48	1.425	5.38
8	4.05	27.13	1.666	6.14
9	10.17	30.04	.217	.72
10	15.01	29.48	.371	1.26
11	20.05	30.51	.587	1.93
12	24.99	29.42	.530	1.80
13	29.97	29.93	.638	2.13
14	40.00	29.31	.402	1.37
15	50.00	29.28	.744	2.54

SITE: 7 WIND DIRECTION: 66.7°

EXPONENT = .1031 U(HMAX) = 31.60
RMS ERROR = 5.1%UMAX MAX ERROR = 9.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.59	2.532	15.26
2	.64	19.12	2.818	14.74
3	.87	19.84	2.873	14.48
4	1.08	21.50	2.831	13.17
5	1.46	23.30	2.266	9.72
6	2.14	24.78	2.248	9.07
7	2.99	25.65	2.017	7.86
8	4.04	25.70	1.856	7.22
9	9.99	29.64	.648	2.19
10	14.97	29.09	.575	1.98
11	20.00	28.28	.528	1.87
12	25.01	29.39	.675	2.30
13	30.00	28.41	.536	1.89
14	39.96	29.12	.702	2.41
15	50.02	29.17	.645	2.21

SITE: 9 WIND DIRECTION: 66.7°

EXPONENT = .0982 U(HMAX) = 31.28
RMS ERROR = 2.9%UMAX MAX ERROR = 6.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	17.50	2.681	15.32
2	.70	20.79	2.593	12.47
3	.88	21.68	2.701	12.46
4	1.06	22.41	2.362	10.54
5	1.54	22.13	2.466	11.14
6	2.08	22.61	2.413	10.67
7	2.96	24.05	2.180	9.06
8	4.05	24.01	1.974	8.22
9	9.97	27.48	1.484	5.40
10	14.98	28.07	.834	2.97
11	19.97	30.46	.505	1.66
12	25.02	29.25	.617	2.11
13	29.96	29.36	.708	2.41
14	40.00	30.13	.621	2.06
15	49.98	29.31	.215	.73

SITE: 10 WIND DIRECTION: 66.7°

EXPONENT = .1243 U(HMAX) = 33.14
RMS ERROR = 4.1%UMAX MAX ERROR = 9.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.80	2.799	17.71
2	.53	18.36	3.011	16.40
3	.88	20.34	3.078	15.13
4	.99	20.59	3.086	14.99
5	1.58	21.73	2.924	13.46
6	2.05	23.98	2.668	11.13
7	3.08	23.80	2.350	9.88
8	3.99	24.90	2.200	8.84
9	10.10	28.25	1.083	3.83
10	15.03	30.51	.274	.90
11	20.06	30.73	.618	2.01
12	25.07	30.40	.513	1.69
13	30.04	30.96	.704	2.27
14	40.04	30.29	.632	2.09
15	50.08	29.95	.672	2.24

SITE: LLL WIND DIRECTION: 66.7°

EXPONENT = .1045 U(HMAX) = 34.00
RMS ERROR = 2.9%UMAX MAX ERROR = 6.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.87	2.850	14.34
2	.60	21.32	2.576	12.08
3	.87	22.08	2.648	11.99
4	1.01	23.17	2.844	12.28
5	1.43	22.99	2.931	12.75
6	2.04	23.77	3.026	12.73
7	3.08	24.65	3.378	13.70
8	4.14	26.17	3.884	14.84
9	10.10	30.11	1.556	5.17
10	15.01	31.44	.507	1.61
11	19.96	32.33	.526	1.63
12	24.97	32.48	.663	2.04
13	29.98	32.05	.676	2.11
14	39.97	32.00	.737	2.30
15	50.27	31.80	.663	2.09

SITE: 14 WIND DIRECTION: 66.7°

EXPONENT = .0591 U(HMAX) = 29.23
RMS ERROR = 3.2%UMAX MAX ERROR = 5.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.99	3.099	15.50
2	.45	22.87	2.843	12.43
3	.77	24.12	2.385	9.89
4	1.09	23.78	2.637	11.09
5	1.51	23.66	2.535	10.72
6	2.01	23.64	2.647	11.20
7	3.07	24.44	2.718	11.12
8	3.95	24.52	2.468	10.06
9	10.03	27.39	1.330	4.86
10	15.03	28.64	.515	1.80
11	20.06	28.27	.458	1.62
12	25.04	28.89	.619	2.14
13	30.03	28.30	.651	2.30
14	39.98	27.51	.552	2.01
15	49.98	28.04	.473	1.69

SITE: 15 WIND DIRECTION: 66.7°

EXPONENT = .0427 U(HMAX) = 33.18
RMS ERROR = 3.0%UMAX MAX ERROR = 5.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	24.79	2.793	11.27
2	.44	27.45	2.851	10.39
3	.76	26.64	2.793	10.48
4	1.04	28.82	2.593	9.00
5	1.50	29.22	2.942	10.07
6	1.96	30.00	2.374	7.91
7	3.11	29.75	1.857	6.24
8	4.12	31.29	1.702	5.44
9	9.96	30.80	1.528	4.96
10	15.00	32.64	.425	1.30
11	19.97	32.14	.785	2.44
12	25.02	32.22	.745	2.31
13	29.98	32.67	.763	2.34
14	39.96	32.02	.425	1.33
15	50.02	31.26	.738	2.36

SITE: 16 WIND DIRECTION: 66.7°

EXPONENT = .0330 U(HMAX) = 31.56
RMS ERROR = 3.0%UMAX MAX ERROR = 6.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	25.49	2.951	11.58
2	.59	27.52	2.864	10.41
3	.75	27.14	2.787	10.27
4	.93	27.55	2.515	9.13
5	1.53	28.91	2.556	8.84
6	2.03	27.98	2.184	7.80
7	3.04	28.69	1.823	6.35
8	3.98	30.33	1.708	5.63
9	10.03	30.99	.513	1.65
10	15.08	31.48	.401	1.28
11	20.11	31.27	.656	2.10
12	25.01	31.10	.650	2.09
13	30.03	29.69	.529	1.78
14	40.04	31.59	.628	1.99
15	50.03	29.52	.677	2.29

SITE: 17 WIND DIRECTION: 66.7°

EXPONENT = .0776 U(HMAX) = 33.49
RMS ERROR = 2.5%UMAX MAX ERROR = 5.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	22.56	3.020	13.38
2	.76	24.14	3.090	12.80
3	.88	23.86	3.302	13.84
4	1.01	24.41	3.092	12.67
5	1.51	25.97	2.526	9.73
6	2.07	25.09	2.509	10.00
7	2.97	27.34	2.205	8.06
8	4.06	28.36	2.266	7.99
9	9.96	31.43	1.363	4.34
10	14.98	30.73	1.153	3.75
11	19.96	32.33	.588	1.82
12	25.02	31.88	.597	1.87
13	29.97	30.83	.667	2.16
14	40.01	32.23	.648	2.01
15	49.97	32.67	.360	1.10

SITE: 20 WIND DIRECTION: 66.7°

EXPONENT = .0867 U(HMAX) = 31.00
RMS ERROR = 2.6%UMAX MAX ERROR = 4.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.04	2.690	13.42
2	.47	20.62	2.313	11.22
3	.85	20.77	2.416	11.63
4	1.03	21.16	2.229	10.54
5	1.57	23.42	2.164	9.24
6	2.14	23.50	2.413	10.27
7	3.10	24.91	1.952	7.83
8	3.99	25.98	1.527	5.88
9	9.94	28.12	.812	2.89
10	15.01	28.88	.778	2.69
11	19.94	28.76	.802	2.79
12	24.90	29.28	.813	2.78
13	30.02	29.78	.797	2.68
14	40.18	28.87	.783	2.71
15	50.11	29.98	.838	2.79

SITE: 23 WIND DIRECTION: 66.7°

EXPONENT = .1016 U(HMAX) = 32.28
RMS ERROR = 4.0%UMAX MAX ERROR = 8.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.28	16.44	3.033	18.46
2	.51	20.29	2.915	14.37
3	.79	21.98	2.464	11.21
4	1.03	22.67	2.471	10.90
5	1.39	22.91	2.286	9.98
6	2.16	23.76	2.105	8.86
7	2.96	25.15	2.252	8.95
8	4.03	25.99	1.849	7.11
9	10.15	29.21	1.108	3.79
10	15.21	30.28	.281	.93
11	20.11	29.30	.646	2.21
12	25.20	29.92	.567	1.90
13	30.13	30.11	.651	2.16
14	40.11	30.14	.676	2.24
15	50.01	29.72	.524	1.76

SITE: 24 WIND DIRECTION: 66.7°

EXPONENT = .1352 U(HMAX) = 30.75
RMS ERROR = 5.2%UMAX MAX ERROR =13.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	13.98	2.216	15.85
2	.50	15.57	2.134	13.71
3	.73	17.25	2.384	13.81
4	1.14	18.73	2.433	12.99
5	1.50	20.00	2.237	11.18
6	1.98	20.34	2.234	10.99
7	3.01	21.37	2.005	9.38
8	4.09	24.03	1.607	6.69
9	10.05	27.21	.584	2.15
10	15.08	27.51	.461	1.67
11	20.12	28.38	.621	2.19
12	24.97	27.67	.527	1.91
13	30.03	28.71	.624	2.17
14	40.04	27.98	.237	.85
15	50.03	26.71	.372	1.39

SITE: 25 WIND DIRECTION: 66.7°

EXPONENT = .0649 U(HMAX) = 33.35
RMS ERROR = 3.5%UMAX MAX ERROR = 9.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	24.20	2.471	10.21
2	.48	24.76	2.549	10.29
3	.75	25.51	2.666	10.45
4	1.16	25.76	2.686	10.43
5	1.54	25.06	2.439	9.73
6	1.94	25.96	2.466	9.50
7	3.01	28.34	2.235	7.88
8	3.94	29.82	1.840	6.17
9	10.02	29.78	1.788	6.00
10	15.02	32.21	1.676	5.20
11	20.01	32.25	.539	1.67
12	25.02	33.30	.794	2.38
13	29.98	33.12	.761	2.30
14	40.10	32.41	.711	2.19
15	50.04	30.34	.746	2.46

SITE: 26 WIND DIRECTION: 66.7°

EXPONENT = .0897 U(HMAX) = 28.82
RMS ERROR = 4.5%UMAX MAX ERROR = 9.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.09	2.267	13.26
2	.52	19.29	2.080	10.78
3	.82	19.06	2.134	11.19
4	1.08	20.22	2.214	10.95
5	1.62	21.63	1.925	8.90
6	2.05	21.42	2.265	10.57
7	3.07	23.77	1.862	7.83
8	3.92	23.63	2.104	8.90
9	9.99	27.69	.814	2.94
10	15.15	27.15	.493	1.82
11	20.23	28.02	.744	2.65
12	24.98	26.53	.720	2.71
13	30.06	26.98	.791	2.93
14	40.12	26.61	.814	3.06
15	50.02	26.28	.750	2.86

SITE: 30 WIND DIRECTION: 66.7°

EXPONENT = .1311 U(HMAX) = 38.67
RMS ERROR =11.4%UMAX MAX ERROR =28.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	8.99	4.656	51.79
2	.48	25.79	3.752	14.55
3	.79	27.88	3.369	12.08
4	1.12	28.93	3.291	11.38
5	1.54	28.38	3.112	10.96
6	2.03	29.57	3.305	11.18
7	3.07	31.05	2.213	7.12
8	3.94	28.16	1.979	7.03
9	10.04	31.60	1.869	5.91
10	14.97	34.23	.751	2.19
11	20.10	33.18	.301	.91
12	24.97	35.00	.974	2.78
13	30.05	33.65	.646	1.92
14	40.00	33.64	.633	1.88
15	49.95	34.54	.270	.78

SITE: 31 WIND DIRECTION: 66.7°

EXPONENT = .0104 U(HMAX) = 29.30
RMS ERROR = 5.4%UMAX MAX ERROR =10.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.32	25.71	3.113	12.11
2	.57	26.07	3.319	12.73
3	.98	29.16	2.938	10.08
4	1.10	27.94	3.158	11.30
5	1.53	28.74	2.964	10.31
6	2.04	28.58	2.818	9.86
7	3.08	30.25	2.317	7.66
8	4.10	31.43	1.673	5.32
9	10.13	31.90	.885	2.78
10	15.07	29.66	.657	2.22
11	20.01	27.71	.643	2.32
12	25.04	28.05	.333	1.19
13	30.09	28.52	.561	1.97
14	40.12	28.05	.596	2.12
15	50.02	28.10	.661	2.35

SITE: 32 WIND DIRECTION: 66.7°

EXPONENT = .1180 U(HMAX) = 35.33
RMS ERROR = 9.8%UMAX MAX ERROR =24.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	10.54	2.174	20.63
2	.49	24.08	2.709	11.25
3	.82	26.67	2.244	8.41
4	1.14	26.05	2.407	9.24
5	1.61	25.73	2.310	8.98
6	2.04	26.05	2.570	9.86
7	3.08	27.29	2.415	8.85
8	4.01	27.67	2.731	9.87
9	10.04	31.88	.581	1.82
10	15.03	30.44	.596	1.96
11	20.05	32.80	.709	2.16
12	25.05	31.85	.697	2.19
13	30.11	31.73	.711	2.24
14	40.03	31.35	.778	2.48
15	50.04	30.73	.183	.59

SITE: 33 WIND DIRECTION: 66.7°

EXPONENT = .1170 U(HMAX) = 36.74
RMS ERROR = 4.0%UMAX MAX ERROR = 8.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.32	19.39	2.977	15.36
2	.46	21.52	3.274	15.22
3	.79	21.40	3.482	16.27
4	.95	22.30	3.682	16.51
5	1.57	24.45	3.805	15.56
6	2.00	25.01	3.497	13.98
7	3.08	29.06	2.901	9.98
8	3.95	30.00	2.468	8.23
9	10.06	31.33	1.712	5.46
10	15.03	32.16	1.311	4.08
11	20.04	34.30	.410	1.20
12	25.02	33.93	.582	1.72
13	30.06	35.09	.695	1.98
14	40.02	34.23	.787	2.30
15	49.97	33.46	.744	2.22

SITE: 34 WIND DIRECTION: 66.7°

EXPONENT = .0960 U(HMAX) = 30.62
RMS ERROR = 3.4%UMAX MAX ERROR = 6.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.55	2.547	13.73
2	.54	19.92	2.389	11.99
3	.73	20.89	2.268	10.86
4	1.08	20.43	2.371	11.61
5	1.57	22.46	2.443	10.88
6	1.96	21.07	2.275	10.80
7	3.05	22.45	2.388	10.64
8	4.12	25.52	1.521	5.96
9	10.00	28.15	.531	1.89
10	15.07	28.01	.723	2.58
11	20.18	29.42	.610	2.07
12	25.17	28.14	.369	1.31
13	30.21	29.50	.708	2.40
14	40.25	28.67	.539	1.88
15	50.10	29.17	.632	2.17

SITE: 35 WIND DIRECTION: 66.7°

EXPONENT = .1033 U(HMAX) = 29.74
RMS ERROR = 3.0%UMAX MAX ERROR = 5.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.32	17.72	2.319	13.09
2	.64	18.30	2.464	13.47
3	.94	19.81	2.227	11.25
4	1.09	20.86	2.214	10.61
5	1.51	19.65	2.382	12.12
6	2.16	21.32	2.524	11.84
7	2.99	22.70	2.349	10.35
8	4.09	22.90	2.029	8.86
9	10.06	25.33	1.487	5.87
10	15.11	27.66	1.178	4.26
11	20.00	28.24	.407	1.44
12	25.12	28.98	.206	.71
13	29.93	27.94	.540	1.93
14	39.99	27.50	.491	1.79
15	50.01	28.31	.602	2.13

SITE: AQUE WIND DIRECTION: 66.7°

EXPONENT = .1124 U(HMAX) = 28.04
RMS ERROR = 3.4%UMAX MAX ERROR = 8.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.37	2.775	18.05
2	.47	16.71	2.266	13.56
3	.92	17.04	2.244	13.17
4	1.05	18.90	2.178	11.53
5	1.56	20.76	2.371	11.42
6	2.10	22.63	2.155	9.52
7	3.07	21.57	2.378	11.03
8	3.94	21.53	2.219	10.31
9	10.09	23.46	2.134	9.10
10	15.23	24.86	1.587	6.38
11	20.01	25.42	1.115	4.39
12	24.98	26.18	.763	2.91
13	30.13	28.25	.337	1.19
14	40.07	27.59	.608	2.20
15	40.07	27.28	.573	2.10

SITE: KAHUKU RADIO WIND DIRECTION: 66.7°

EXPONENT = .0663 U(HMAX) = 29.01
RMS ERROR = 3.0%UMAX MAX ERROR = 5.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	21.50	2.530	11.77
2	.53	20.80	2.320	11.16
3	.78	23.58	2.297	9.74
4	.92	20.94	2.303	11.00
5	1.54	23.17	2.124	9.17
6	2.11	22.93	2.146	9.36
7	3.17	24.61	1.906	7.74
8	4.16	23.21	2.089	9.00
9	10.11	25.98	1.470	5.66
10	15.16	26.52	.235	.88
11	20.09	28.54	.609	2.13
12	25.29	28.25	.785	2.78
13	29.95	28.66	.614	2.14
14	40.18	27.67	.820	2.96
15	50.08	29.11	.822	2.82

SITE: LOWE WIND DIRECTION: 66.7°

EXPONENT = .0917 U(HMAX) = 28.77
RMS ERROR = 4.8%UMAX MAX ERROR =10.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	18.01	2.277	12.65
2	.56	18.73	2.127	11.36
3	.77	19.12	2.075	10.85
4	1.12	19.74	2.098	10.63
5	1.57	20.45	2.124	10.38
6	2.00	22.38	2.154	9.62
7	3.15	21.08	1.909	9.06
8	3.96	23.83	1.919	8.05
9	10.15	26.58	1.123	4.23
10	15.15	28.76	.700	2.43
11	20.21	28.06	.731	2.61
12	24.94	26.93	.804	2.98
13	30.18	26.30	.829	3.15
14	40.17	27.30	.792	2.90
15	50.02	26.10	.788	3.02

SITE: MILL 1 WIND DIRECTION: 66.7°

EXPONENT = .0970 U(HMAX) = 34.50
RMS ERROR = 3.2%UMAX MAX ERROR = 6.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.29	20.12	2.289	11.38
2	.45	21.37	2.080	9.73
3	.80	22.98	2.701	11.75
4	1.12	23.74	3.099	13.06
5	1.54	24.35	3.430	14.09
6	2.00	24.92	3.261	13.09
7	3.07	28.42	2.457	8.65
8	3.92	28.06	2.607	9.29
9	10.03	30.44	1.800	5.91
10	15.04	32.08	.814	2.54
11	20.04	32.58	.658	2.02
12	25.00	32.45	.555	1.71
13	29.96	32.39	.679	2.10
14	40.05	31.57	.557	1.76
15	49.99	32.72	.431	1.32

SITE: MILL 2 WIND DIRECTION: 66.7°

EXPONENT = .1439 U(HMAX) = 33.72
RMS ERROR = 5.5%UMAX MAX ERROR = 9.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	14.09	3.285	23.31
2	.53	17.88	3.413	19.09
3	.85	19.09	3.085	16.16
4	1.04	19.19	3.026	15.77
5	1.61	19.59	3.270	16.69
6	2.01	21.62	3.316	15.34
7	3.13	25.00	3.021	12.09
8	3.98	25.12	2.011	8.01
9	10.05	29.12	1.480	5.08
10	15.06	31.33	.634	2.02
11	20.02	30.79	.609	1.98
12	25.02	30.24	.641	2.12
13	30.04	29.37	.367	1.25
14	40.03	30.27	.507	1.67
15	50.02	30.39	.617	2.03

SITE: OPANA AMBULANCE WIND DIRECTION: 66.7°

EXPONENT = .0560 U(HMAX) = 29.10
RMS ERROR = 2.2%UMAX MAX ERROR = 6.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	22.19	2.975	13.41
2	.53	22.97	2.813	12.25
3	.72	22.84	2.623	11.49
4	1.16	22.93	2.429	10.59
5	1.52	23.43	2.389	10.20
6	2.02	24.08	2.182	9.06
7	3.10	24.46	1.853	7.57
8	3.94	25.35	2.101	8.29
9	10.02	28.48	.363	1.27
10	15.02	27.38	.977	3.57
11	20.02	27.93	.372	1.33
12	25.02	28.30	.416	1.47
13	30.12	27.60	.481	1.74
14	40.06	27.95	.596	2.13
15	49.98	29.17	.674	2.31

SITE: KAKUKU UPPER WIND DIRECTION: 66.7°

EXPONENT = .0793 U(HMAX) = 32.22
RMS ERROR = 3.1%UMAX MAX ERROR = 7.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	21.37	2.571	12.03
2	.47	21.73	2.498	11.50
3	.75	23.43	2.654	11.33
4	1.10	23.65	2.599	10.99
5	1.52	23.83	2.503	10.50
6	1.96	24.70	2.466	9.99
7	3.03	25.30	1.887	7.46
8	3.92	27.38	1.902	6.94
9	10.00	29.22	.942	3.23
10	15.06	31.17	.694	2.23
11	20.00	30.94	.529	1.71
12	24.98	30.80	.727	2.36
13	30.00	31.22	.481	1.54
14	39.96	30.58	.678	2.22
15	50.12	29.77	.613	2.06

SITE: LAIE WIND DIRECTION: 66.7°

EXPONENT = .0259 U(HMAX) = 30.36
RMS ERROR = 2.6%UMAX MAX ERROR = 5.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	26.13	2.785	10.66
2	.50	26.75	2.357	8.81
3	.80	26.71	2.224	8.32
4	1.04	28.01	2.288	8.17
5	1.43	27.54	2.024	7.35
6	2.13	28.41	2.030	7.15
7	2.89	28.10	1.885	6.71
8	4.53	29.83	1.390	4.66
9	9.96	28.36	1.562	5.51
10	15.26	29.43	1.083	3.68
11	20.00	31.32	1.234	3.94
12	25.26	30.25	1.129	3.73
13	29.86	29.47	1.278	4.34
14	40.18	30.41	1.180	3.88
15	50.18	28.67	1.292	4.51

SITE: HILL 365 WIND DIRECTION: 66.7°

EXPONENT = .0810 U(HMAX) = 30.03
RMS ERROR = 4.7%UMAX MAX ERROR = 9.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	20.52	2.417	11.78
2	.47	19.79	2.305	11.65
3	.83	22.14	2.207	9.97
4	1.02	20.27	2.743	13.53
5	1.72	23.59	1.847	7.83
6	2.05	23.42	1.924	8.22
7	3.03	21.96	1.654	7.53
8	4.07	27.35	1.293	4.73
9	10.15	24.87	1.707	6.86
10	15.10	29.50	.624	2.12
11	20.07	27.36	.778	2.84
12	25.20	29.73	.298	1.00
13	30.03	29.53	.360	1.22
14	40.01	28.33	.235	.83
15	50.29	28.68	.482	1.68

SITE: PUU KI WIND DIRECTION: 66.7°

EXPONENT = .1153 U(HMAX) = 30.01
RMS ERROR = 4.2%UMAX MAX ERROR = 7.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.12	2.676	16.60
2	.63	17.31	2.668	15.41
3	.87	17.30	2.627	15.18
4	1.00	19.16	2.825	14.74
5	1.51	20.62	2.595	12.58
6	2.00	20.92	2.261	10.81
7	2.95	23.09	1.969	8.53
8	4.15	24.82	1.571	6.33
9	10.07	27.32	.256	.94
10	15.14	26.70	.551	2.07
11	19.96	26.84	.265	.99
12	25.03	27.25	.510	1.87
13	29.96	27.98	.600	2.14
14	40.21	27.91	.229	.82
15	50.10	27.93	.609	2.18

SITE: HILL 183 WIND DIRECTION: 66.7°

EXPONENT = .1069 U(HMAX) = 30.74
RMS ERROR = 4.6%UMAX MAX ERROR =10.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.55	2.377	14.37
2	.61	18.83	2.216	11.76
3	.81	18.99	2.303	12.13
4	1.04	20.66	2.206	10.68
5	1.62	21.04	1.964	9.33
6	2.07	22.13	2.064	9.33
7	3.17	24.44	1.873	7.66
8	3.95	24.99	1.783	7.13
9	10.16	28.47	.728	2.56
10	15.11	27.84	.256	.92
11	20.25	28.73	.591	2.06
12	25.07	29.19	.536	1.84
13	30.22	28.53	.672	2.36
14	40.11	28.08	.564	2.01
15	50.30	27.64	.619	2.24

SITE: KAHUKU POINT WIND DIRECTION: 66.7°

EXPONENT = .1175 U(HMAX) = 29.57
RMS ERROR = 5.2%UMAX MAX ERROR = 9.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	14.15	2.330	16.46
2	.48	16.56	2.317	13.99
3	.83	18.19	2.213	12.17
4	1.17	19.25	2.051	10.66
5	1.46	20.30	2.060	10.15
6	2.13	20.96	1.868	8.91
7	3.16	23.70	1.540	6.50
8	4.20	23.46	1.578	6.73
9	10.09	26.40	.436	1.65
10	15.07	27.98	.733	2.62
11	20.03	26.46	.513	1.94
12	25.04	27.09	.752	2.78
13	30.19	26.67	.784	2.94
14	40.00	26.90	.810	3.01
15	50.15	26.64	.751	2.82

SITE: MAKAHOA POINT WIND DIRECTION: 66.7°

EXPONENT = .0928 U(HMAX) = 29.53
RMS ERROR = 6.4%UMAX MAX ERROR =12.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.31	16.46	2.434	14.79
2	.62	17.97	1.958	10.90
3	.84	19.74	1.911	9.68
4	1.10	21.53	2.112	9.81
5	1.44	21.38	1.948	9.11
6	2.00	22.55	1.752	7.77
7	3.07	25.03	1.479	5.91
8	4.16	27.01	1.237	4.58
9	10.09	27.84	.653	2.35
10	14.96	28.39	.763	2.69
11	19.98	27.59	.676	2.45
12	24.92	27.27	.311	1.14
13	30.00	26.67	.349	1.31
14	39.93	27.24	.399	1.46
15	50.03	25.93	.650	2.51

SITE: 1 WIND DIRECTION: 90°

EXPONENT = .1265 U(HMAX) = 33.60
RMS ERROR = 6.1%UMAX MAX ERROR =12.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	14.59	3.169	21.72
2	.42	17.10	3.047	17.81
3	.69	19.13	3.401	17.78
4	.91	21.32	3.329	15.62
5	1.39	23.35	2.968	12.71
6	1.88	23.52	2.707	11.51
7	2.97	26.21	2.258	8.61
8	3.89	26.35	2.169	8.23
9	9.94	29.67	.867	2.92
10	14.96	31.11	.548	1.76
11	19.96	29.56	.845	2.86
12	24.93	30.73	.217	.71
13	29.93	30.11	.600	1.99
14	39.88	30.41	.441	1.45
15	49.90	29.49	.467	1.58

SITE: 2 WIND DIRECTION: 90°

EXPONENT = .0752 U(HMAX) = 30.86
RMS ERROR = 2.1%UMAX MAX ERROR = 4.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	21.65	2.701	12.48
2	.61	21.71	2.587	11.92
3	.79	22.59	2.659	11.77
4	.98	22.98	2.894	12.59
5	1.44	23.41	2.824	12.07
6	1.88	23.47	2.660	11.33
7	3.03	25.80	2.847	11.04
8	3.96	24.65	2.206	8.95
9	9.90	27.48	2.011	7.32
10	14.93	28.22	1.297	4.60
11	20.04	29.37	.986	3.36
12	24.92	30.65	.589	1.92
13	29.95	29.98	.701	2.34
14	39.97	30.04	.572	1.91
15	49.86	29.66	.538	1,82

SITE: 3 WIND DIRECTION: 90°

EXPONENT = .0819 U(HMAX) = 32.11
RMS ERROR = 4.3%UMAX MAX ERROR = 7.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.72	2.939	15.70
2	.44	22.10	2.836	12.84
3	.69	22.75	2.696	11.85
4	.91	24.25	2.591	10.68
5	1.38	25.77	2.506	9.73
6	1.94	24.50	2.713	11.07
7	2.85	25.15	2.410	9.58
8	3.86	25.96	2.129	8.20
9	9.93	28.22	1.632	5.78
10	14.97	31.63	.819	2.59
11	19.91	30.41	.760	2.50
12	24.95	30.72	.691	2.25
13	29.92	31.56	.275	.87
14	39.94	29.58	.585	1.98
15	49.88	29.62	.671	2.26

SITE: 6 WIND DIRECTION: 90°

EXPONENT = .0734 U(HMAX) = 37.34
RMS ERROR = 3.1%UMAX MAX ERROR = 7.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	24.96	4.107	16.45
2	.41	25.44	3.990	15.69
3	.75	26.87	3.614	13.45
4	.91	29.14	3.251	11.16
5	1.41	28.30	3.233	11.43
6	1.90	30.72	3.052	9.94
7	2.95	29.88	3.243	10.86
8	3.96	31.17	2.967	9.52
9	9.87	33.65	2.239	6.65
10	14.87	37.04	1.082	2.92
11	19.90	35.53	.536	1.51
12	24.93	35.59	.837	2.35
13	29.97	35.71	.194	.54
14	39.97	34.98	.825	2.36
15	49.98	35.57	.516	1.45

SITE: 7 WIND DIRECTION: 90°

EXPONENT = .1100 U(HMAX) = 36.80
RMS ERROR = 5.5%UMAX MAX ERROR =10.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	21.44	3.764	17.56
2	.45	21.96	3.943	17.96
3	.73	22.42	4.032	17.99
4	.91	21.63	3.909	18.07
5	1.40	24.69	3.956	16.02
6	1.90	25.66	3.897	15.19
7	2.94	26.68	3.560	13.34
8	3.85	28.71	3.323	11.58
9	9.88	34.32	1.791	5.22
10	14.87	35.90	1.105	3.08
11	19.93	35.85	.790	2.20
12	24.93	34.29	.944	2.75
13	29.93	33.85	.523	1.55
14	39.86	33.47	.475	1.42
15	49.86	32.79	.807	2.46

SITE: 9 WIND DIRECTION: 90°

EXPONENT = .1654 U(HMAX) = 38.63
RMS ERROR = 6.1%UMAX MAX ERROR =10.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.46	4.188	23.99
2	.43	18.47	4.184	22.65
3	.74	19.35	4.169	21.54
4	.93	16.67	4.060	24.36
5	1.40	19.91	4.748	23.85
6	1.93	21.59	4.750	21.99
7	2.97	25.72	4.162	16.18
8	3.94	25.81	3.490	13.52
9	9.89	33.47	1.863	5.57
10	14.88	35.20	.936	2.66
11	19.89	35.55	.560	1.58
12	24.93	35.33	.347	.98
13	29.94	35.59	.596	1.68
14	39.98	33.59	.692	2.06
15	49.88	34.58	.357	1.03

SITE: 10 WIND DIRECTION: 90°

EXPONENT = .0849 U(HMAX) = 37.81
RMS ERROR = 3.3%UMAX MAX ERROR = 6.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	25.16	4.039	16.05
2	.43	24.86	4.211	16.94
3	.71	24.86	3.902	15.70
4	.94	26.70	4.159	15.58
5	1.40	27.76	4.173	15.03
6	1.89	28.91	3.568	12.34
7	2.85	29.93	3.511	11.73
8	3.95	30.45	3.144	10.33
9	9.88	35.28	1.028	2.91
10	14.91	36.20	.411	1.14
11	19.94	36.11	.642	1.78
12	24.93	36.13	1.005	2.78
13	29.89	35.83	.559	1.56
14	39.85	35.09	.517	1.47
15	49.85	35.68	.638	1.79

SITE: LLL WIND DIRECTION: 90°

EXPONENT = .1000 U(HMAX) = 38.97
RMS ERROR =13.2%UMAX MAX ERROR =33.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	10.35	4.619	44.64
2	.44	27.86	4.208	15.10
3	.73	32.49	3.286	10.11
4	.97	33.49	3.165	9.45
5	1.40	33.02	2.946	8.92
6	1.90	31.76	3.205	10.09
7	2.96	31.85	3.108	9.76
8	3.97	32.87	2.488	7.57
9	9.86	35.43	1.281	3.61
10	14.90	34.64	1.310	3.78
11	19.90	35.57	.753	2.12
12	24.90	35.33	.362	1.03
13	29.88	33.50	.869	2.59
14	39.87	33.99	.756	2.22
15	49.98	34.82	.429	1.23

SITE: 14 WIND DIRECTION: 90°

EXPONENT = .1198 U(HMAX) = 34.47
RMS ERROR = 9.6%UMAX MAX ERROR =22.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	10.91	2.689	24.65
2	.53	22.26	3.220	14.47
3	.77	23.16	3.164	13.66
4	1.02	24.95	3.222	12.92
5	1.50	24.96	3.240	12.98
6	1.98	25.07	3.170	12.64
7	3.10	26.51	3.323	12.54
8	3.94	29.18	2.872	9.84
9	9.91	32.10	1.015	3.16
10	14.90	31.06	.656	2.11
11	20.11	31.10	.496	1.59
12	24.86	31.04	.717	2.31
13	29.86	29.80	.609	2.04
14	39.97	29.32	.290	.99
15	49.97	30.58	.301	.99

SITE: 15 WIND DIRECTION: 90°

EXPONENT = .0515 U(HMAX) = 34.75
RMS ERROR = 4.1%UMAX MAX ERROR = 6.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	25.13	3.811	15.17
2	.55	27.03	3.846	14.23
3	.79	26.25	4.335	16.52
4	.98	28.90	3.795	13.13
5	1.45	28.84	3.381	11.73
6	1.94	31.39	2.898	9.23
7	2.94	32.18	2.630	8.17
8	3.87	31.76	2.120	6.68
9	9.88	33.36	.932	2.79
10	14.86	34.33	.471	1.37
11	19.88	33.99	.306	.90
12	24.89	32.29	.787	2.44
13	29.90	32.60	.608	1.86
14	39.86	32.56	.680	2.09
15	49.99	33.55	.420	1.25

SITE: 16 WIND DIRECTION: 90°

EXPONENT = .0483 U(HMAX) = 33.51
RMS ERROR = 3.2%UMAX MAX ERROR = 5.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	26.67	3.024	11.34
2	.43	28.58	2.905	10.16
3	.72	26.31	3.016	11.46
4	.95	26.33	3.315	12.59
5	1.41	27.15	3.072	11.31
6	1.89	27.98	3.155	11.27
7	2.94	28.23	2.815	9.97
8	3.98	30.79	2.496	8.11
9	9.92	31.99	.807	2.52
10	14.92	32.55	1.031	3.17
11	19.93	33.06	.554	1.68
12	24.94	33.24	.583	1.75
13	29.93	32.55	.477	1.47
14	39.99	32.96	.495	1.50
15	50.11	31.73	.602	1.90

SITE: 17 WIND DIRECTION: 90°

EXPONENT = .1334 U(HMAX) = 34.01
RMS ERROR = 3.1%UMAX MAX ERROR = 6.3%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.43	3.247	18.63
2	.48	18.48	3.010	16.28
3	.76	19.68	3.096	15.73
4	.93	19.21	3.066	15.97
5	1.41	20.84	3.435	16.48
6	1.92	20.83	3.433	16.48
7	2.86	22.67	3.530	15.57
8	3.89	25.24	3.073	12.17
9	9.91	28.86	1.807	6.26
10	14.90	30.46	1.471	4.83
11	19.90	31.51	.790	2.51
12	24.89	31.52	.670	2.13
13	29.91	31.55	.443	1.41
14	39.88	31.81	.674	2.12
15	49.89	31.86	.550	1.73

SITE: 20 WIND DIRECTION: 90°

EXPONENT = .1019 U(HMAX) = 31.17
RMS ERROR = 3.3%UMAX MAX ERROR = 6.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.50	2.569	14.67
2	.38	18.22	2.714	14.90
3	.67	19.97	2.844	14.24
4	.88	21.57	2.523	11.70
5	1.37	22.20	2.722	12.26
6	1.94	23.49	2.576	10.97
7	2.92	22.02	2.400	10.90
8	3.94	25.68	2.269	8.84
9	9.86	27.80	1.502	5.40
10	14.85	28.00	1.694	6.05
11	19.85	27.53	1.778	6.46
12	24.87	29.29	.922	3.15
13	29.91	29.24	1.284	4.39
14	39.95	30.86	.490	1.59
15	49.86	29.06	.556	1.91

SITE: 23 WIND DIRECTION: 90°

EXPONENT = .0945 U(HMAX) = 31.72
RMS ERROR = 4.0%UMAX MAX ERROR = 7.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.95	3.416	19.03
2	.42	18.86	3.580	18.98
3	.74	21.85	3.460	15.84
4	.97	22.81	3.155	13.83
5	1.41	23.99	2.821	11.76
6	1.89	24.18	2.747	11.36
7	2.85	24.34	2.605	10.70
8	3.86	24.70	2.472	10.01
9	9.89	29.17	1.333	4.57
10	14.93	30.51	.554	1.82
11	19.91	28.91	.953	3.30
12	24.93	29.74	.665	2.24
13	29.93	29.08	.828	2.85
14	39.85	29.66	.751	2.53
15	50.02	29.81	.803	2.69

SITE: 24 WIND DIRECTION: 90°

EXPONENT = .1154 U(HMAX) = 31.05
RMS ERROR = 3.0%UMAX MAX ERROR = 5.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.18	2.442	13.44
2	.42	16.80	2.254	13.42
3	.68	18.66	2.486	13.32
4	.90	20.01	2.428	12.13
5	1.39	20.21	2.354	11.65
6	1.87	20.69	2.330	11.26
7	2.94	22.83	2.271	9.95
8	3.88	23.26	2.037	8.76
9	9.93	24.91	1.489	5.98
10	14.95	27.63	1.211	4.38
11	19.94	29.43	.765	2.60
12	24.94	30.08	.453	1.51
13	29.94	29.86	.508	1.70
14	39.96	29.22	.427	1.46
15	49.90	29.24	.539	1.84

SITE: 25 WIND DIRECTION: 90°

EXPONENT = .1871 U(HMAX) = 33.03
RMS ERROR = 5.4%UMAX MAX ERROR =13.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	12.86	3.905	30.37
2	.42	12.31	3.850	31.28
3	.72	14.24	4.122	28.94
4	.94	14.65	4.221	28.81
5	1.38	17.09	4.233	24.77
6	1.91	18.35	3.766	20.53
7	2.85	21.07	2.926	13.89
8	3.98	22.43	2.754	12.28
9	9.95	26.48	1.821	6.88
10	14.92	28.67	1.104	3.85
11	19.89	29.48	.644	2.18
12	24.93	29.31	.612	2.09
13	29.91	28.82	.330	1.15
14	39.88	29.69	.566	1.91
15	50.02	28.56	.672	2.35

SITE: PUU KI WIND DIRECTION: 90°

EXPONENT = .0651 U(HMAX) = 29.10
RMS ERROR = 2.9%UMAX MAX ERROR = 7.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	21.22	2.924	13.78
2	.45	21.60	2.940	13.61
3	.71	22.18	2.694	12.15
4	.94	22.83	2.651	11.61
5	1.43	22.17	2.645	11.93
6	1.87	22.63	2.566	11.34
7	2.86	23.55	2.762	11.73
8	3.86	24.16	2.084	8.63
9	9.93	28.23	1.009	3.57
10	14.93	27.58	.373	1.35
11	19.93	28.15	.601	2.14
12	24.89	28.38	.640	2.26
13	29.92	28.55	.301	1.05
14	39.88	27.31	.359	1.32
15	49.88	28.18	.600	2.13

SITE: MAKAHOA POINT WIND DIRECTION: 90°

EXPONENT = .1078 U(HMAX) = 29.90
RMS ERROR = 3.9%UMAX MAX ERROR = 8.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.25	2.202	12.76
2	.41	17.25	2.390	13.86
3	.71	18.36	2.247	12.24
4	.93	18.96	2.324	12.25
5	1.38	20.41	2.138	10.48
6	1.91	20.88	2.164	10.36
7	2.85	23.03	2.119	9.20
8	3.85	22.73	1.963	8.64
9	9.91	27.43	1.185	4.32
10	14.93	27.93	.687	2.46
11	19.95	28.06	.468	1.67
12	24.93	27.93	.731	2.62
13	29.93	27.72	.585	2.11
14	39.89	28.01	.621	2.22
15	49.91	27.26	.732	2.69

SITE: HILL 365 WIND DIRECTION: 90°

EXPONENT = .0546 U(HMAX) = 30.06
RMS ERROR = 3.4%UMAX MAX ERROR = 7.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.56	2.762	13.43
2	.41	23.90	2.602	10.88
3	.71	24.99	2.451	9.81
4	.95	23.79	2.409	10.13
5	1.39	24.65	2.335	9.47
6	1.88	25.41	2.271	8.94
7	2.88	25.79	2.056	7.97
8	3.86	26.88	1.857	6.91
9	9.90	29.04	1.034	3.56
10	14.95	28.81	.264	.92
11	19.91	29.77	.389	1.31
12	24.93	28.38	.274	.97
13	29.93	28.73	.660	2.30
14	39.94	28.16	.564	2.00
15	49.95	29.20	.536	1.84

SITE: HILL 183 WIND DIRECTION: 90°

EXPONENT = .1312 U(HMAX) = 33.21
RMS ERROR = 3.9%UMAX MAX ERROR = 8.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	15.81	2.622	16.59
2	.40	16.97	2.520	14.85
3	.71	18.11	2.625	14.49
4	.90	20.14	2.752	13.66
5	1.37	21.58	2.512	11.64
6	1.88	22.71	2.400	10.57
7	2.94	23.55	2.223	9.44
8	3.86	24.47	2.050	8.38
9	9.89	28.35	1.319	4.65
10	14.94	29.92	.764	2.55
11	19.94	30.79	.518	1.68
12	24.93	30.01	.534	1.78
13	29.92	30.84	.320	1.04
14	39.88	30.22	.257	.85
15	49.87	30.31	.390	1.29

SITE: KAHUKU UPPER WIND DIRECTION: 90°

EXPONENT = .0887 U(HMAX) = 33.00
RMS ERROR = 2.5%UMAX MAX ERROR = 4.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.47	3.435	16.78
2	.42	22.05	3.327	15.08
3	.73	24.05	3.462	14.40
4	.95	22.95	3.158	13.76
5	1.43	24.47	3.426	14.00
6	1.90	23.84	3.279	13.75
7	2.91	24.64	3.514	14.26
8	3.87	25.06	3.070	12.25
9	9.93	29.48	1.509	5.12
10	14.94	30.64	1.247	4.07
11	19.96	31.81	1.035	3.25
12	24.90	31.32	1.199	3.83
13	29.93	30.85	.525	1.70
14	39.89	31.95	.839	2.63
15	49.94	32.41	.563	1.74

SITE: LAIE WIND DIRECTION: 90°

EXPONENT = .1115 U(HMAX) = 33.27
RMS ERROR = 3.4%UMAX MAX ERROR = 6.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.05	2.433	12.77
2	.30	18.13	2.372	13.08
3	.71	20.61	2.496	12.11
4	.94	20.56	2.350	11.43
5	1.42	21.63	2.526	11.68
6	1.91	22.94	2.427	10.58
7	2.93	25.26	2.389	9.46
8	3.92	26.67	2.157	8.09
9	9.97	30.07	1.653	5.50
10	14.94	30.16	.949	3.14
11	19.98	31.23	.682	2.18
12	24.91	30.14	.812	2.69
13	29.96	30.52	1.153	3.78
14	39.95	30.82	.830	2.69
15	49.90	31.75	.717	2.26

SITE: LOWE WIND DIRECTION: 90°

EXPONENT = .1510 U(HMAX) = 33.05
RMS ERROR = 3.7%UMAX MAX ERROR = 8.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	14.00	2.641	18.86
2	.37	14.77	2.560	17.33
3	.73	17.62	2.750	15.60
4	.90	18.52	2.633	14.22
5	1.42	19.97	2.765	13.85
6	1.90	21.04	2.623	12.47
7	2.94	23.08	2.349	10.18
8	3.92	23.06	2.171	9.42
9	9.94	25.87	1.671	6.46
10	14.93	29.04	1.159	3.99
11	19.91	30.30	.763	2.52
12	24.93	30.01	.545	1.82
13	29.89	29.85	.760	2.55
14	39.86	30.25	.517	1.71
15	49.92	30.20	.571	1.89

SITE: MILL 1 WIND DIRECTION: 90°

EXPONENT = .1874 U(HMAX) = 34.29
RMS ERROR = 5.9%UMAX MAX ERROR =12.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	13.46	3.710	27.56
2	.41	13.57	3.707	27.32
3	.71	14.66	4.198	28.64
4	.94	15.60	4.387	28.13
5	1.35	16.06	4.481	27.89
6	1.89	17.61	4.470	25.38
7	2.95	22.24	3.122	14.04
8	3.93	23.82	2.459	10.32
9	9.91	28.21	1.683	5.96
10	14.91	31.59	.709	2.24
11	19.91	28.91	.616	2.13
12	24.91	29.30	.438	1.49
13	29.92	30.38	.527	1.74
14	39.89	31.21	.789	2.53
15	49.96	30.17	.474	1.57

SITE: MILL 2 WIND DIRECTION: 90°

EXPONENT = .0852 U(HMAX) = 30.49
RMS ERROR = 2.4%UMAX MAX ERROR = 5.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.38	2.650	13.01
2	.42	19.65	2.425	12.34
3	.72	21.22	2.845	13.41
4	.92	21.02	2.654	12.63
5	1.40	22.91	2.808	12.26
6	1.90	22.65	2.671	11.79
7	2.86	23.97	2.430	10.14
8	3.94	24.73	2.252	9.11
9	9.90	26.40	1.675	6.34
10	14.91	29.06	1.056	3.63
11	19.91	29.31	.625	2.13
12	24.92	28.82	.499	1.73
13	29.89	29.29	.380	1.30
14	39.88	29.43	.577	1.96
15	49.88	28.93	.501	1.73

SITE: OPANA AMBULANCE WIND DIRECTION: 90°

EXPONENT = .1202 U(HMAX) = 34.41
RMS ERROR = 4.3%UMAX MAX ERROR = 7.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.76	3.364	17.03
2	.46	20.31	2.965	14.60
3	.74	21.56	3.145	14.59
4	.97	21.47	2.947	13.73
5	1.38	21.42	3.095	14.45
6	1.95	21.69	3.134	14.45
7	2.88	22.24	3.182	14.31
8	3.88	22.84	3.412	14.94
9	9.93	30.73	1.651	5.37
10	14.93	31.69	1.342	4.24
11	19.95	32.39	.631	1.95
12	24.94	32.87	.561	1.71
13	29.94	32.92	.663	2.01
14	39.85	32.50	.377	1.16
15	49.86	33.04	.586	1.77

SITE: AQUE WIND DIRECTION: 90°

EXPONENT = .1472 U(HMAX) = 33.87
RMS ERROR = 5.5%UMAX MAX ERROR =11.1%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	13.93	2.829	20.31
2	.38	14.74	2.703	18.34
3	.68	19.09	2.669	13.98
4	.89	19.45	2.770	14.24
5	1.43	19.91	2.596	13.04
6	1.85	23.21	2.478	10.67
7	2.93	23.38	2.755	11.79
8	3.93	25.17	1.968	7.82
9	9.89	29.59	.859	2.90
10	14.92	29.98	.707	2.36
11	19.91	29.48	.481	1.63
12	24.89	30.82	.681	2.21
13	29.87	29.77	.398	1.34
14	39.94	30.79	.638	2.07
15	49.96	30.10	.607	2.02

SITE: KAKUKU RADIO WIND DIRECTION: 90°

EXPONENT = .0935 U(HMAX) = 30.81
RMS ERROR = 3.6%UMAX MAX ERROR = 6.6%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.41	2.306	12.52
2	.42	19.96	2.344	11.74
3	.70	20.31	2.264	11.15
4	.93	20.74	2.259	10.89
5	1.40	22.59	2.318	10.26
6	1.87	22.67	2.176	9.60
7	2.87	25.48	2.201	8.64
8	3.88	22.68	2.060	9.08
9	9.92	27.46	1.695	6.17
10	14.93	29.56	.699	2.36
11	19.93	29.68	.586	1.97
12	24.97	28.51	.378	1.33
13	29.93	28.71	.398	1.38
14	39.90	29.17	.643	2.20
15	49.95	29.11	.437	1.50

SITE: 30 WIND DIRECTION: 90°

EXPONENT = .1010 U(HMAX) = 33.30
RMS ERROR = 5.0%UMAX MAX ERROR = 9.2%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.46	3.690	18.96
2	.45	20.46	3.602	17.60
3	.74	20.95	3.798	18.12
4	.99	22.17	3.995	18.02
5	1.47	22.83	3.993	17.49
6	1.96	22.88	3.754	16.40
7	2.89	25.62	3.645	14.23
8	3.91	28.43	2.672	9.40
9	9.97	31.30	.890	2.84
10	14.96	31.76	.756	2.38
11	20.01	31.93	.423	1.32
12	24.94	30.88	.821	2.66
13	29.86	30.64	.568	1.85
14	39.95	30.47	.670	2.20
15	49.95	30.23	.618	2.04

SITE: 26 WIND DIRECTION: 90°

EXPONENT = .0973 U(HMAX) = 33.47
RMS ERROR = 3.5%UMAX MAX ERROR = 8.0%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	19.25	2.557	13.29
2	.40	20.56	2.380	11.58
3	.73	22.14	2.367	10.69
4	.92	22.17	2.285	10.31
5	1.38	23.36	2.331	9.98
6	1.88	25.24	2.180	8.64
7	2.86	26.63	2.100	7.88
8	3.86	27.12	2.082	7.68
9	9.93	31.27	.934	2.99
10	14.92	30.14	1.146	3.80
11	19.92	31.86	.755	2.37
12	24.91	30.56	1.000	3.27
13	29.92	30.65	.832	2.72
14	39.90	31.50	.852	2.70
15	49.85	31.62	.649	2.05

SITE: 31 WIND DIRECTION: 90°

EXPONENT = .1001 U(HMAX) = 30.64
RMS ERROR = 4.5%UMAX MAX ERROR = 8.4%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	17.77	3.516	19.78
2	.43	18.29	3.467	18.96
3	.77	19.24	3.374	17.53
4	.99	20.49	3.542	17.29
5	1.46	20.96	3.337	15.92
6	1.98	22.94	3.283	14.32
7	2.94	25.26	2.828	11.19
8	3.92	24.91	2.595	10.42
9	9.96	28.62	.927	3.24
10	14.95	29.06	.621	2.14
11	19.96	27.56	.298	1.08
12	24.94	28.44	.554	1.95
13	29.98	28.53	.349	1.22
14	39.99	28.46	.567	1.99
15	49.96	28.05	.451	1.61

SITE: 32 WIND DIRECTION: 90°

EXPONENT = .0997 U(HMAX) = 33.12
RMS ERROR = 3.8%UMAX MAX ERROR = 6.5%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	22.03	3.350	15.20
2	.46	20.78	3.231	15.55
3	.74	21.02	3.386	16.11
4	.97	21.89	3.466	15.84
5	1.43	22.58	3.421	15.15
6	2.04	23.33	3.060	13.12
7	2.92	23.59	3.001	12.72
8	3.89	24.42	2.832	11.60
9	9.93	28.96	1.830	6.32
10	14.97	30.58	1.367	4.47
11	19.97	32.11	.646	2.01
12	24.95	32.69	.647	1.98
13	29.97	32.19	.639	1.98
14	39.94	31.55	.666	2.11
15	49.97	31.14	.679	2.18

SITE: 33 WIND DIRECTION: 90°

EXPONENT = .1209 U(HMAX) = 32.74
RMS ERROR = 4.7%UMAX MAX ERROR = 9.7%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	16.68	3.753	22.49
2	.40	17.75	3.527	19.87
3	.78	19.29	3.886	20.14
4	.94	19.89	3.909	19.66
5	1.43	20.50	3.574	17.43
6	1.95	23.60	3.441	14.58
7	2.90	23.84	2.917	12.23
8	3.93	26.64	2.757	10.35
9	9.94	29.47	1.127	3.82
10	14.92	30.02	.366	1.22
11	19.92	29.75	.474	1.59
12	24.94	30.03	.559	1.86
13	29.91	30.17	.241	.80
14	39.90	29.90	.358	1.20
15	49.86	29.56	.868	2.94

SITE: 34 WIND DIRECTION: 90°

EXPONENT = .0722 U(HMAX) = 31.30
RMS ERROR = 2.8%UMAX MAX ERROR = 4.8%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	20.19	3.679	18.22
2	.42	21.90	3.809	17.39
3	.73	23.70	2.784	11.75
4	.95	23.72	2.616	11.03
5	1.42	24.78	2.520	10.17
6	1.91	25.38	2.598	10.23
7	2.85	25.93	2.292	8.84
8	3.93	25.47	2.078	8.16
9	9.91	28.53	1.433	5.02
10	14.88	30.19	.647	2.14
11	19.89	29.61	.637	2.15
12	24.90	30.54	.317	1.04
13	29.89	28.67	.948	3.31
14	40.00	29.69	.691	2.33
15	49.87	30.51	.553	1.81

SITE: 35 WIND DIRECTION: 90°

EXPONENT = .0945 U(HMAX) = 29.61
RMS ERROR = 2.5%UMAX MAX ERROR = 6.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.82	2.512	13.34
2	.48	18.55	2.451	13.21
3	.73	20.05	2.564	12.79
4	.96	20.26	2.432	12.00
5	1.39	20.46	2.352	11.50
6	1.89	21.89	2.014	9.20
7	2.94	22.41	2.095	9.35
8	3.88	22.83	2.059	9.02
9	9.89	25.66	1.799	7.01
10	14.96	28.47	.814	2.86
11	19.91	28.12	.641	2.28
12	24.91	27.92	.774	2.77
13	29.94	27.22	.406	1.49
14	39.86	28.35	.526	1.86
15	50.01	28.93	.180	.62

SITE: HILL 220 WIND DIRECTION: 90°

EXPONENT = .0941 U(HMAX) = 28.27
RMS ERROR = 4.2%UMAX MAX ERROR = 7.9%UMAX

DATA POINT	HEIGHT CM	UMEAN FT/S	U-RMS FT/S	TURB INT PERCENT
1	.30	18.74	2.445	13.05
2	.30	19.33	2.259	11.69
3	.73	16.78	1.936	11.53
4	.95	19.71	2.137	10.84
5	1.44	18.76	2.271	12.11
6	1.95	20.57	2.239	10.89
7	2.91	21.50	2.234	10.39
8	3.92	20.46	2.184	10.68
9	9.97	24.49	2.761	11.27
10	14.97	26.09	1.397	5.35
11	19.98	27.43	1.819	6.63
12	24.97	27.99	.950	3.39
13	29.94	27.02	1.078	3.99
14	39.97	27.34	.604	2.21
15	49.91	27.61	.804	2.91

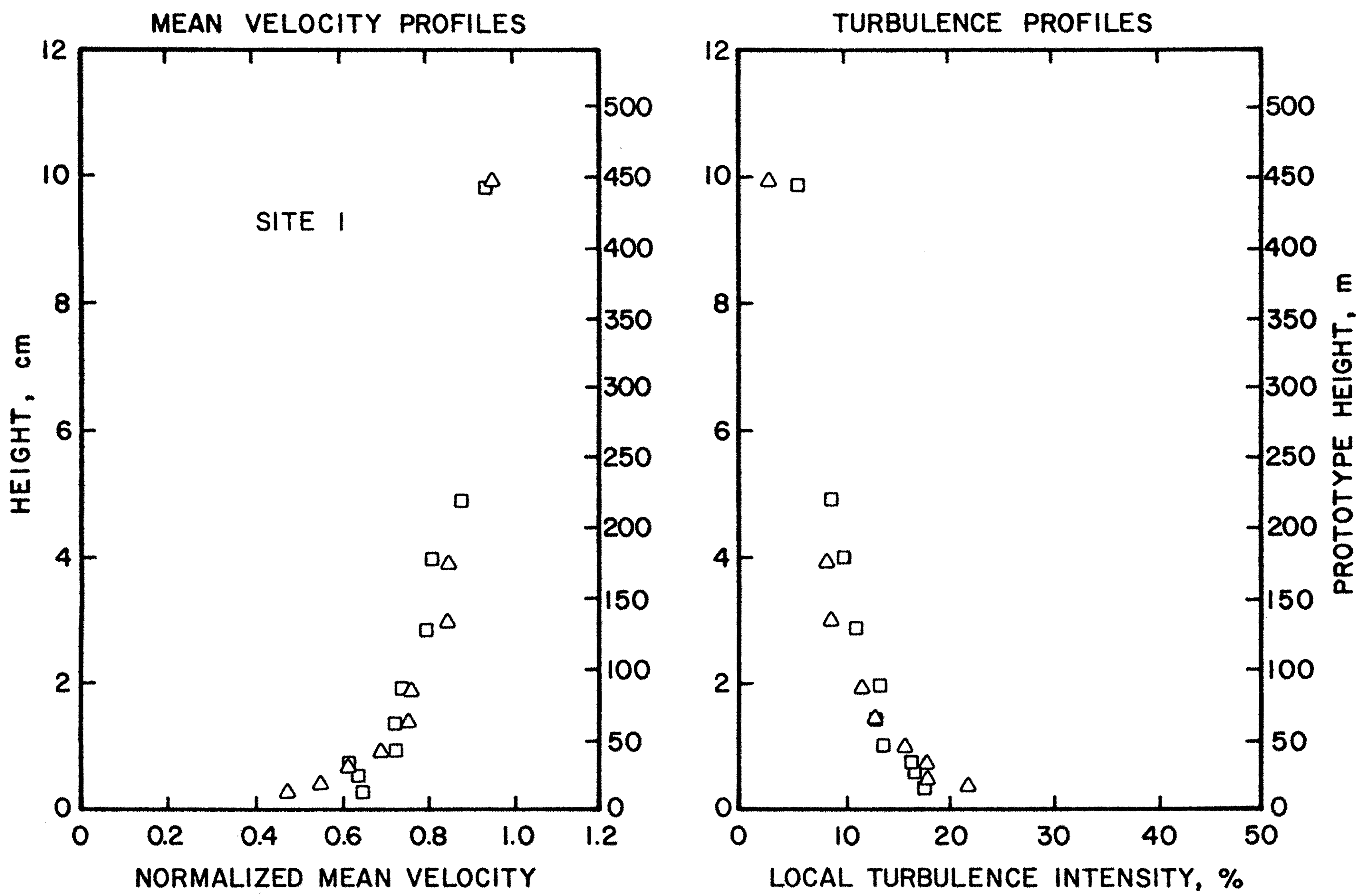
APPENDIX B

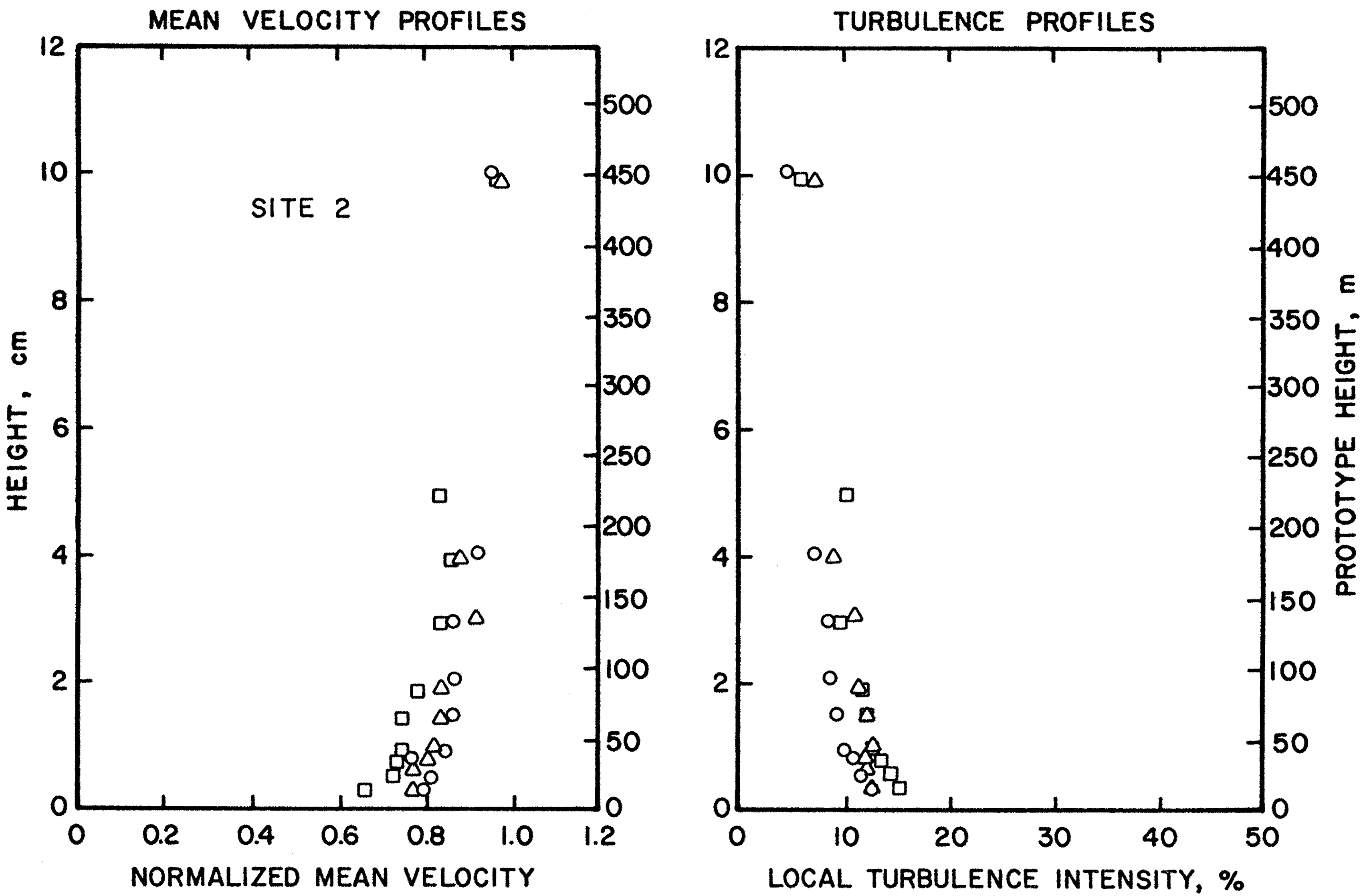
Longitudinal velocity and turbulence intensity profiles listed in Appendix A have been plotted and are presented in this section. The velocity measured at 15 cm height for each velocity profile was used to normalize the velocity profile. In each figure, profiles for three wind directions were plotted together. Following symbols were used for data measured at different wind orientation:

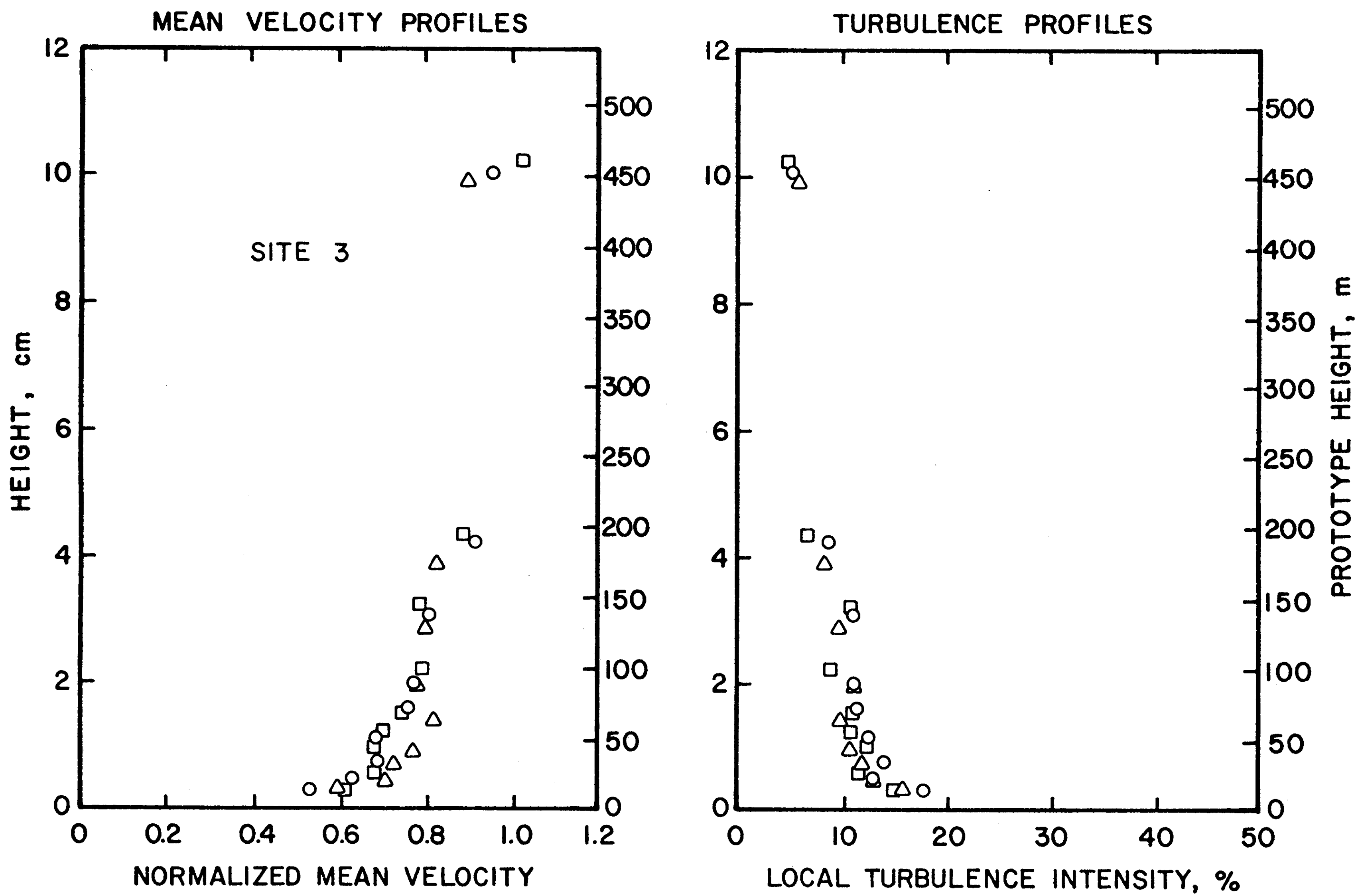
□ 45° from N

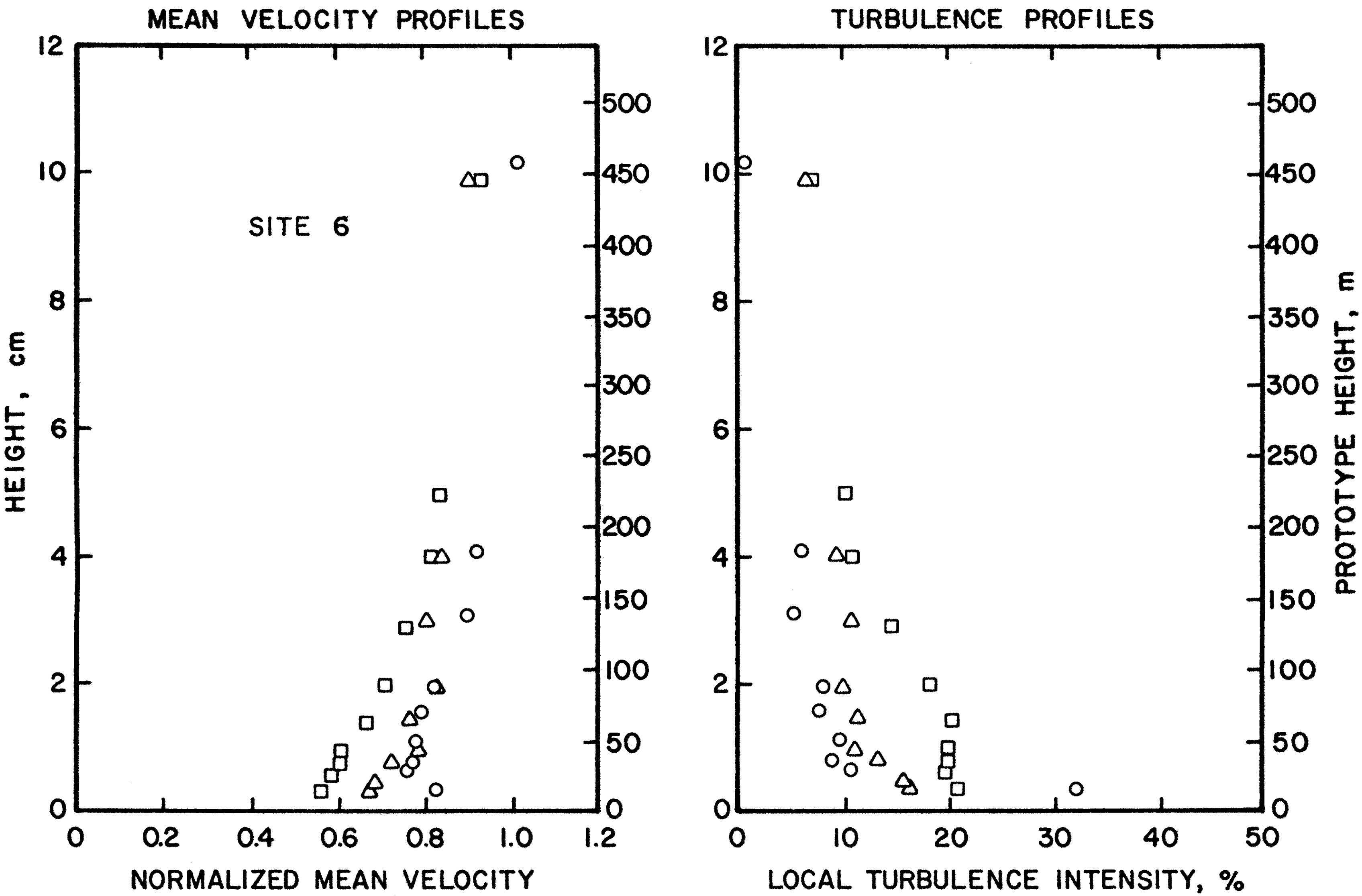
o 66.7° from N

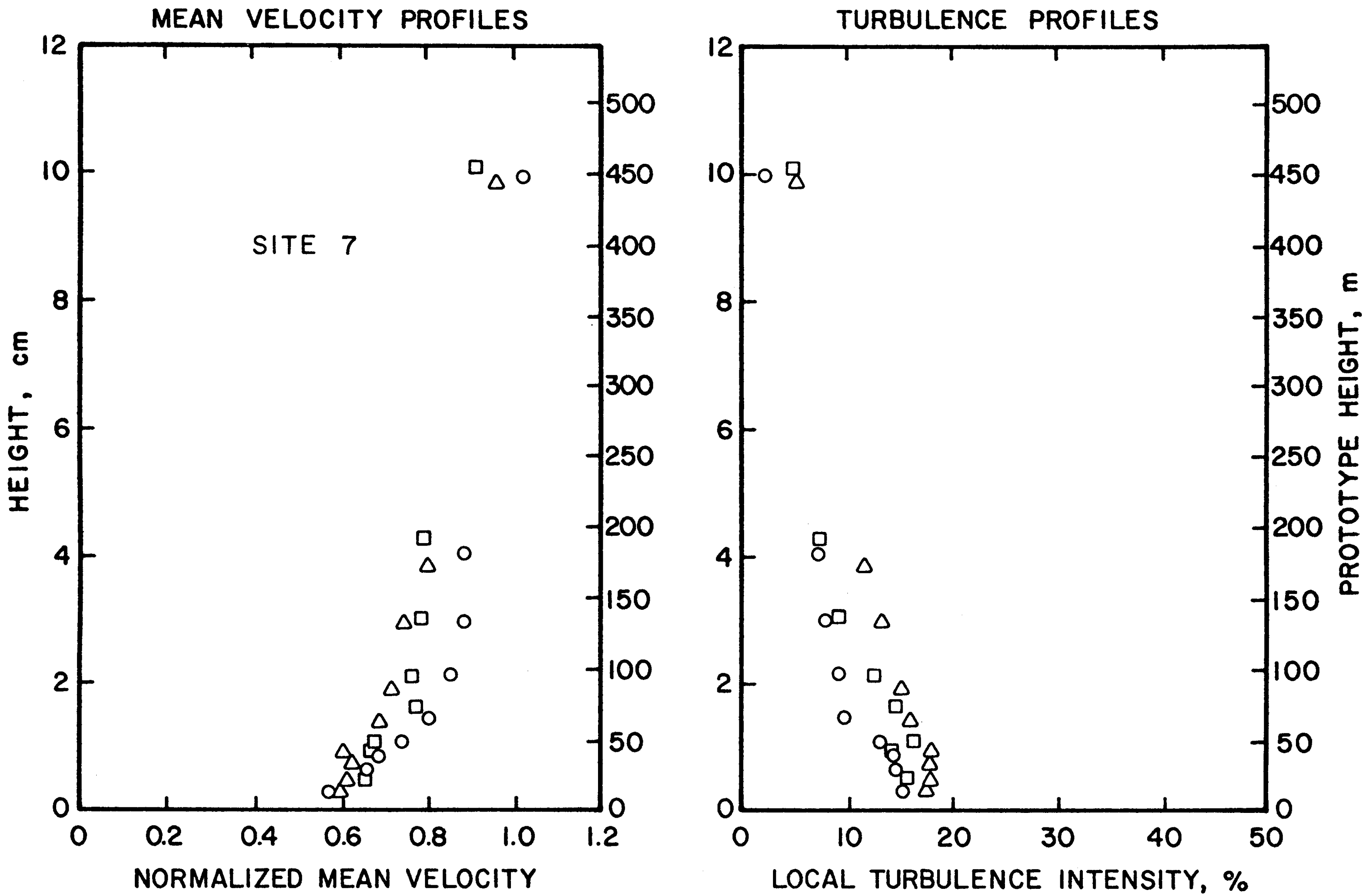
Δ 90° from N.

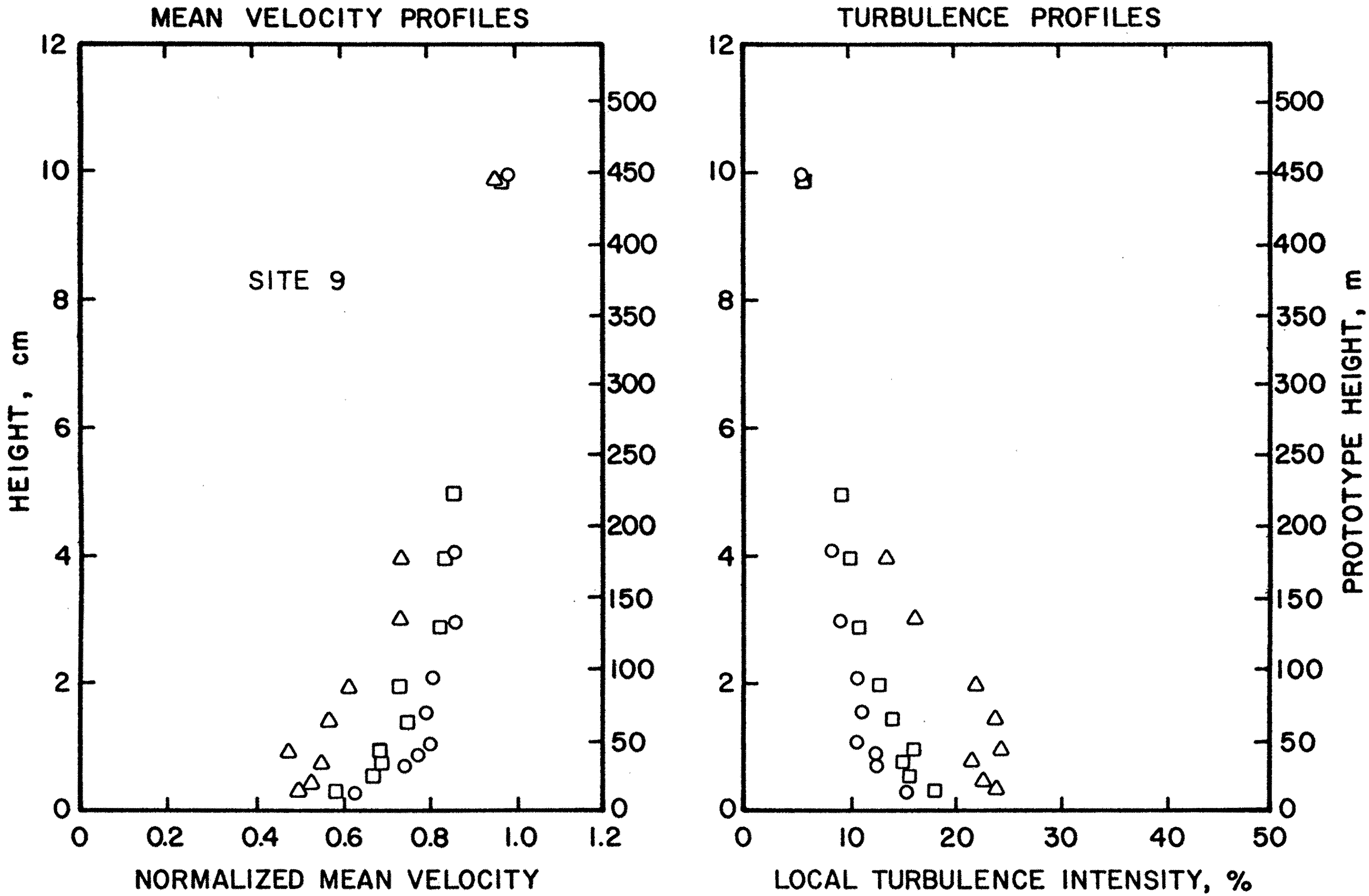

MEAN VELOCITY PROFILES
SITE 1
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
0
10
20
30
40
50

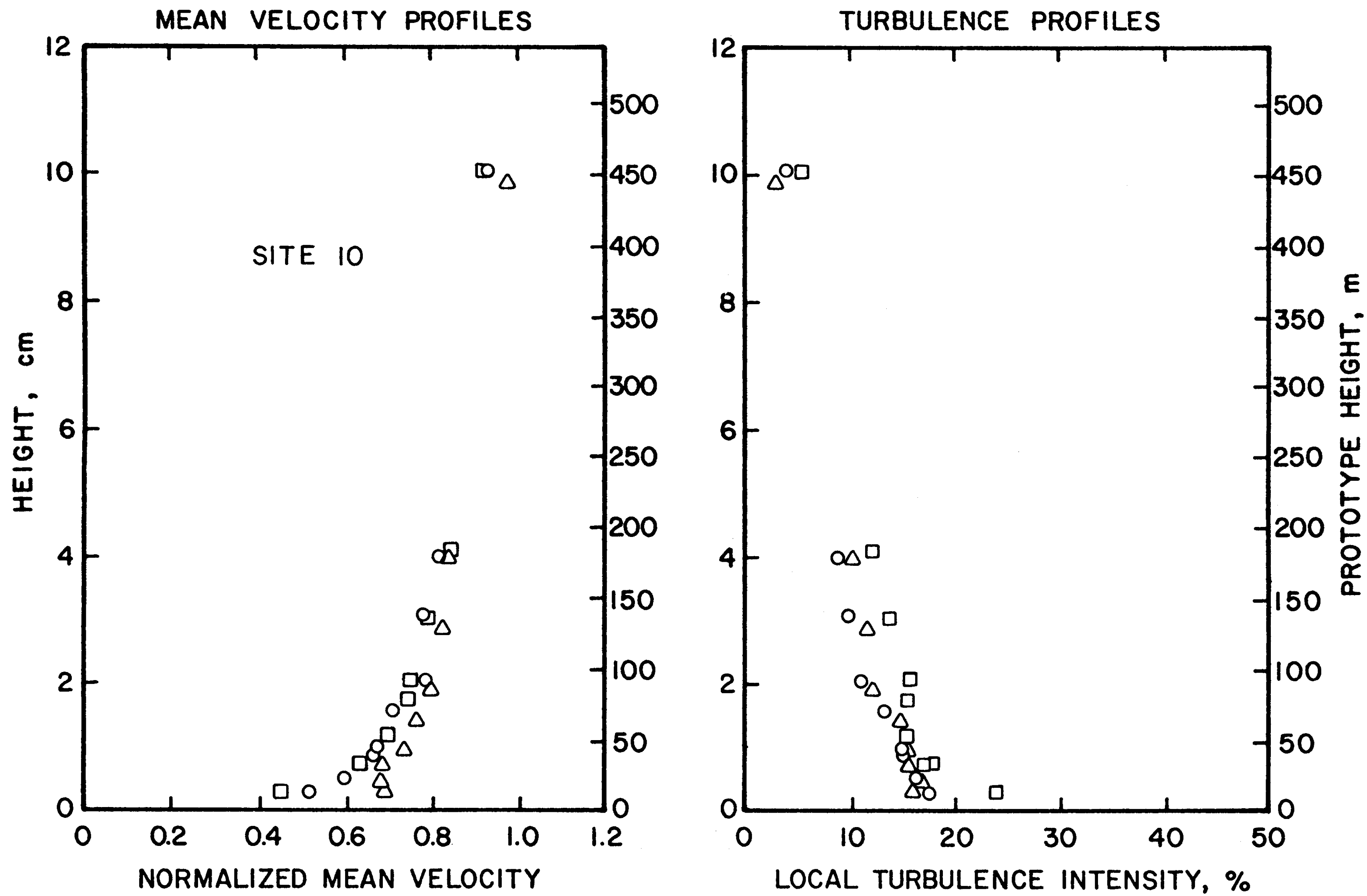

MEAN VELOCITY PROFILES
SITE 2
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
0
10
20
30
40
50

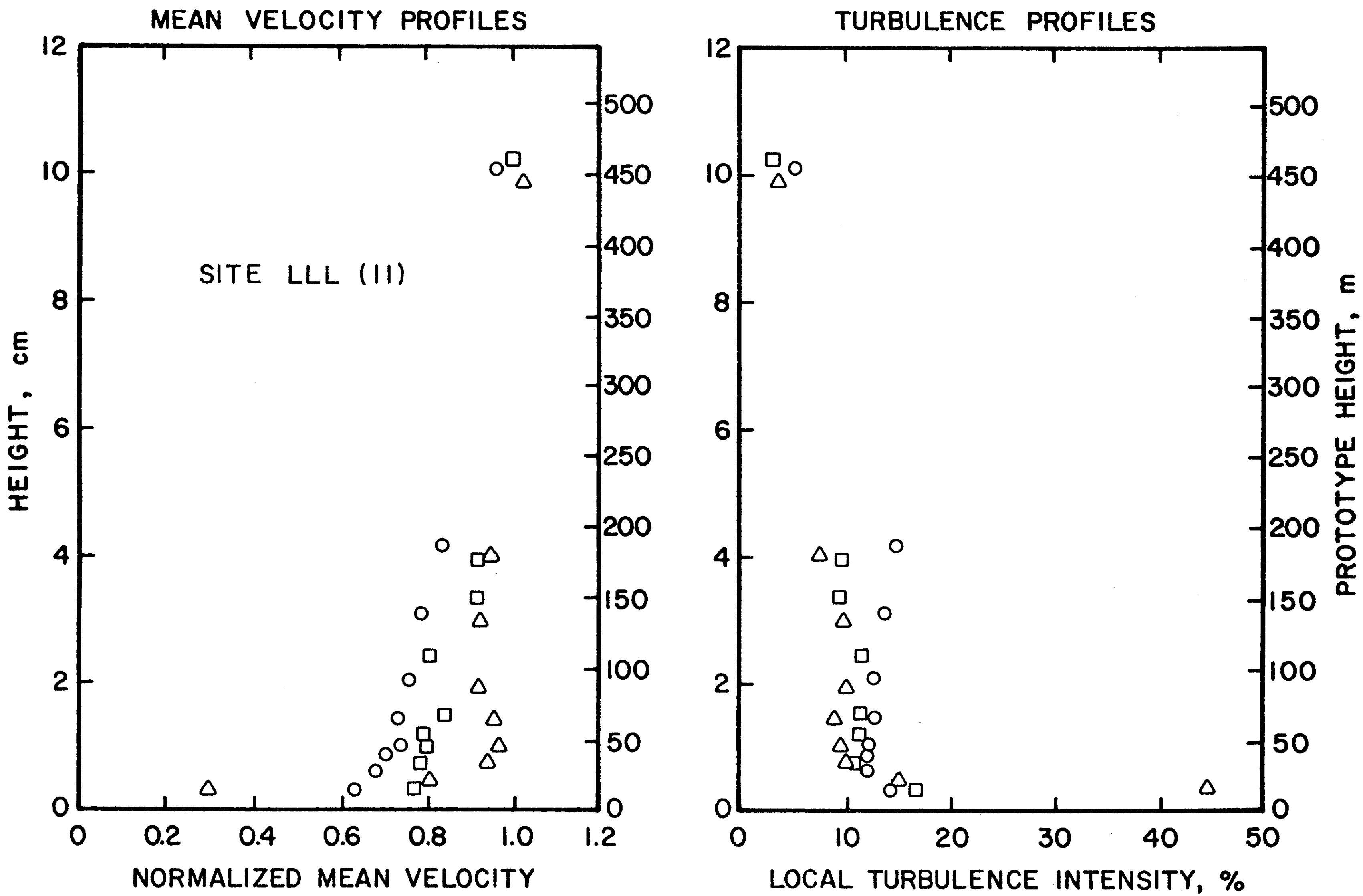

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 3
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500

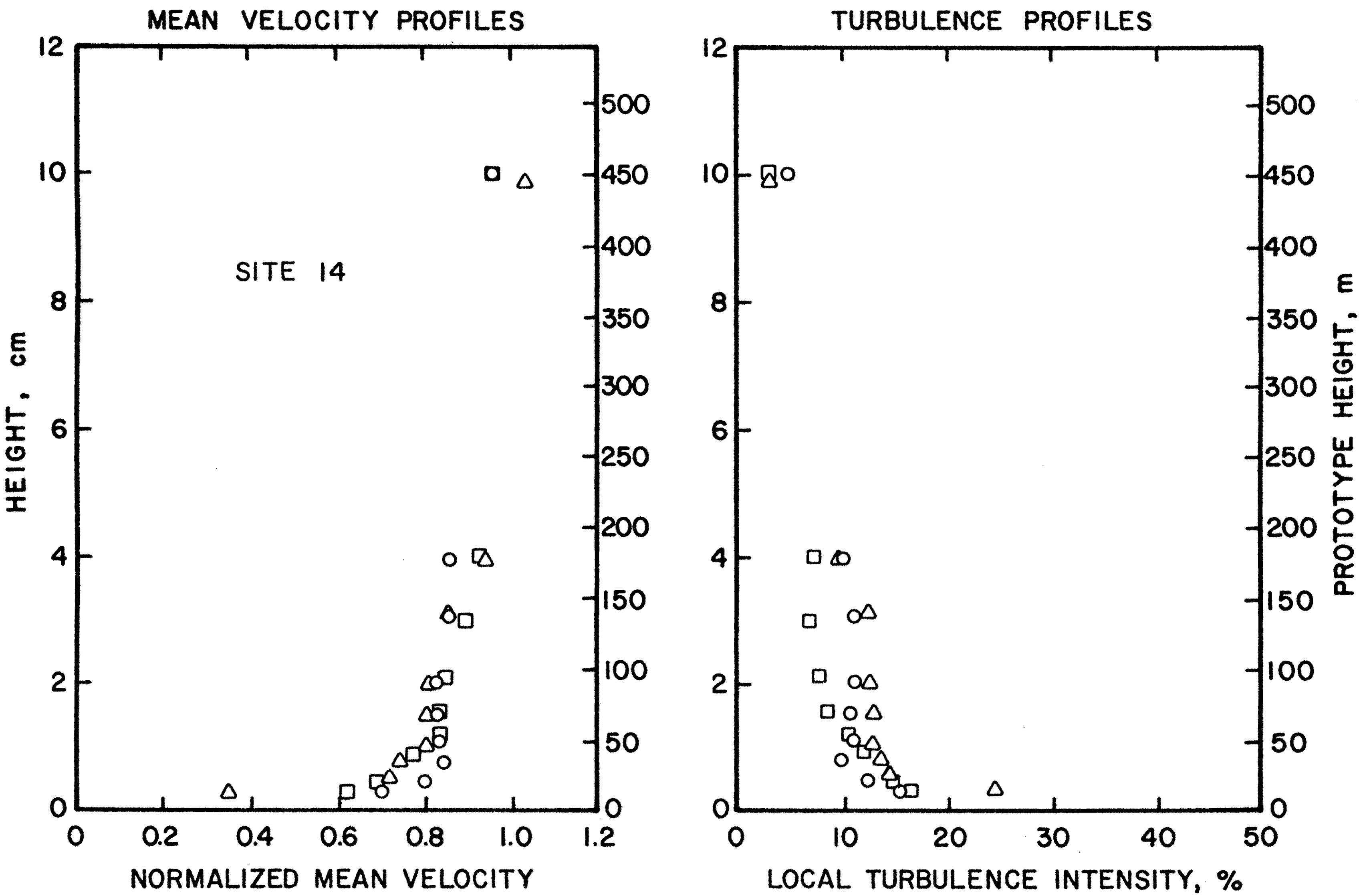

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 6
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500

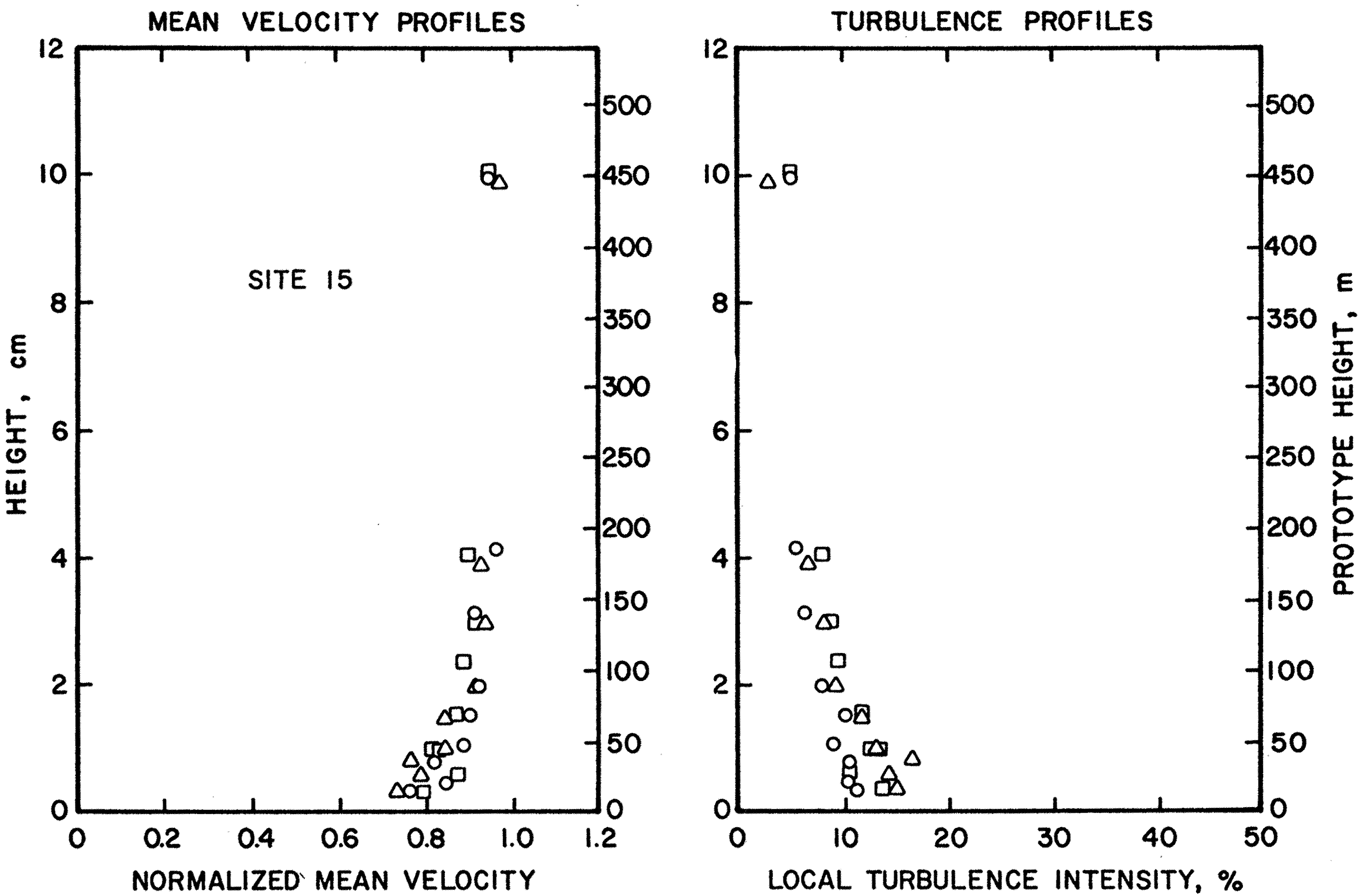

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 7
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500

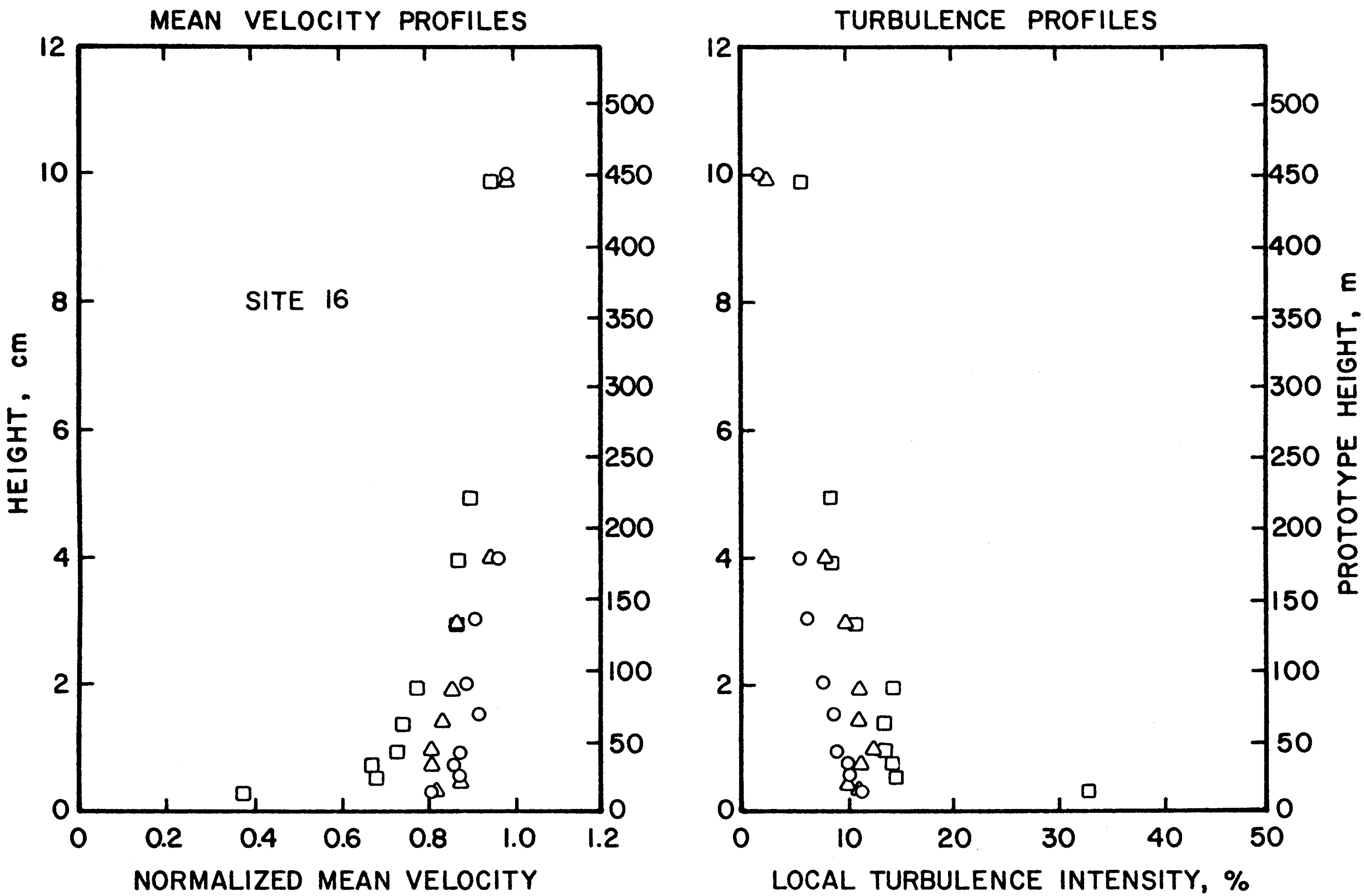

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 9
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

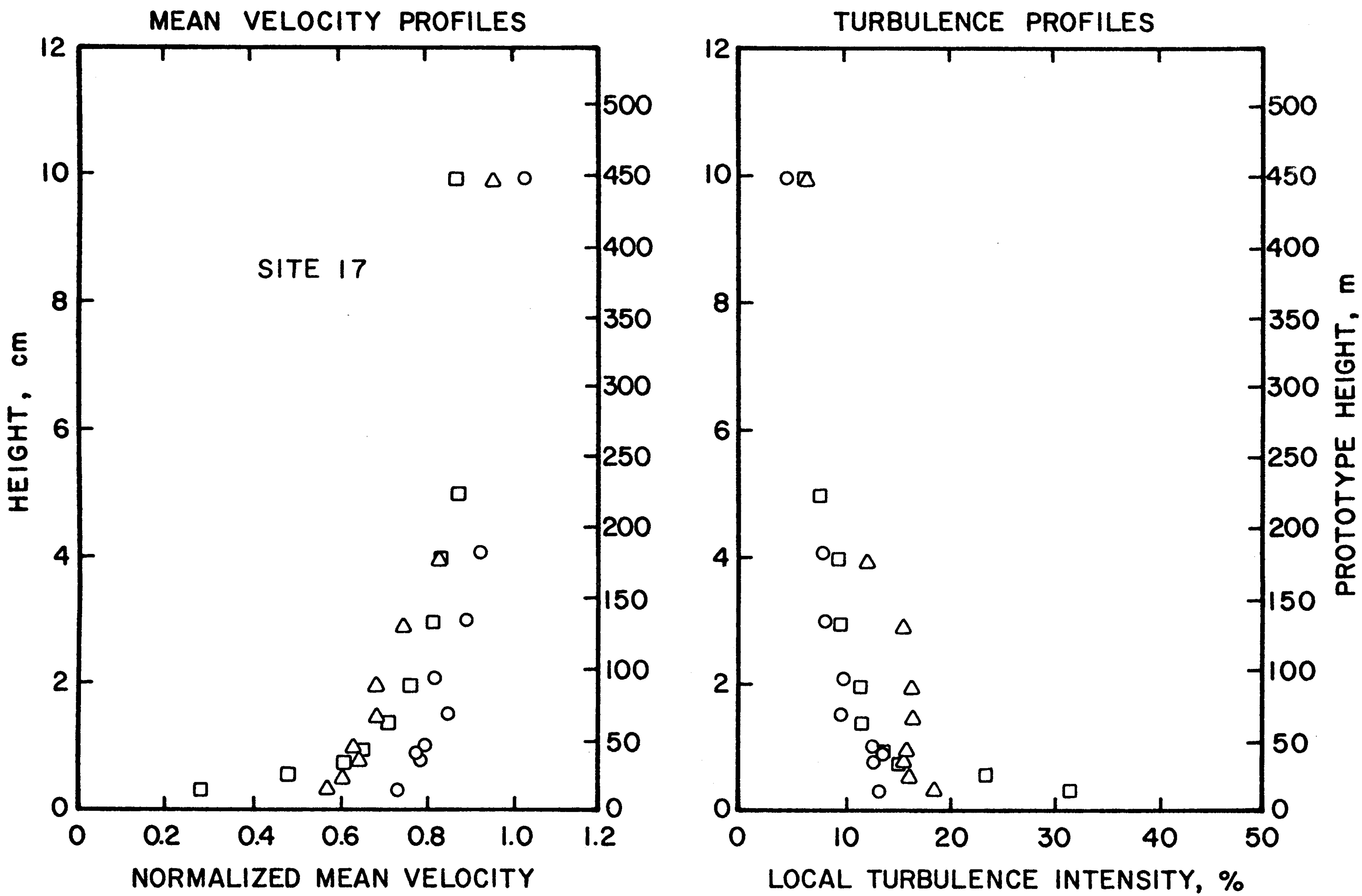

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 10
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

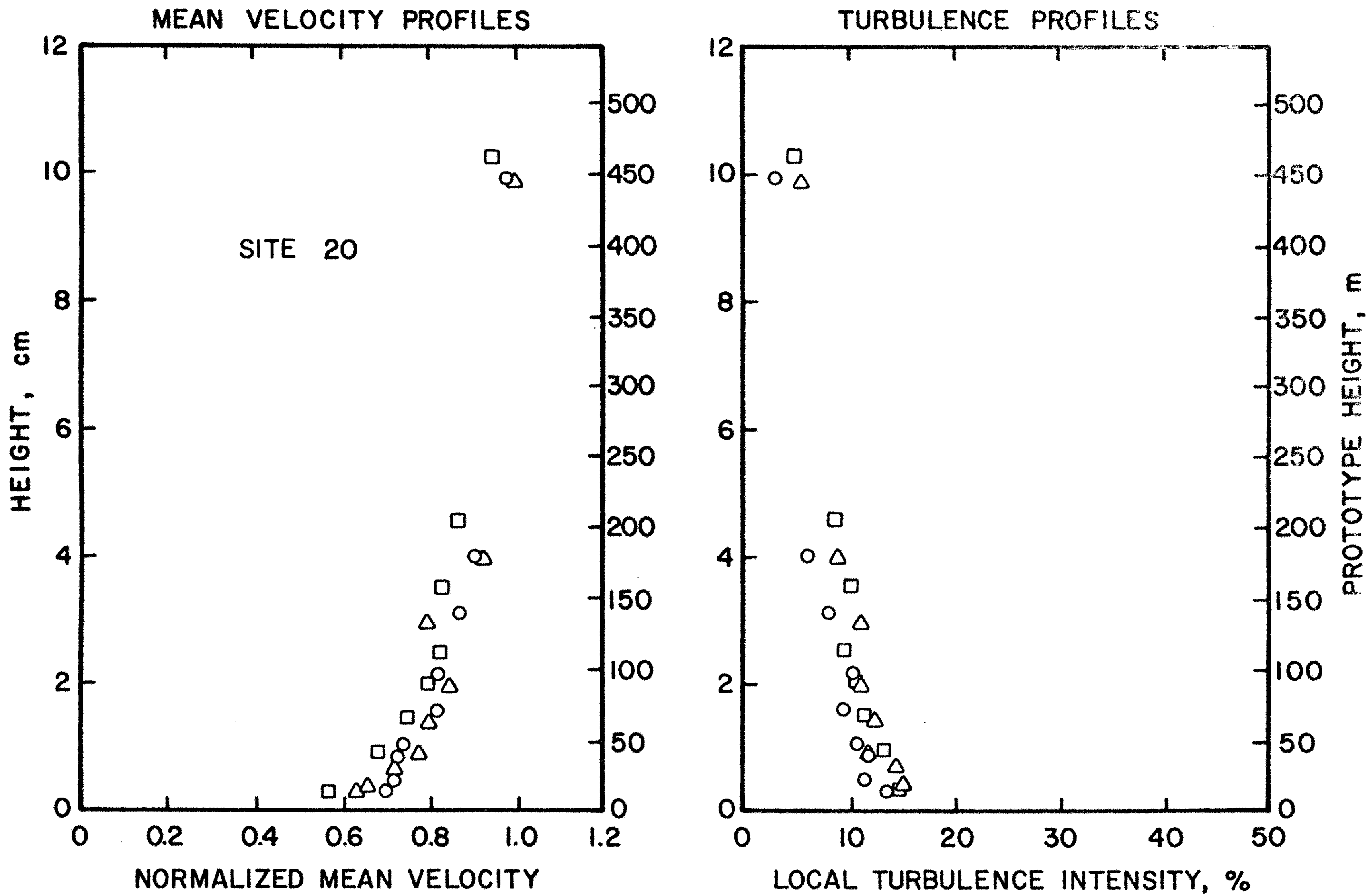

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE LLL (II)
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40

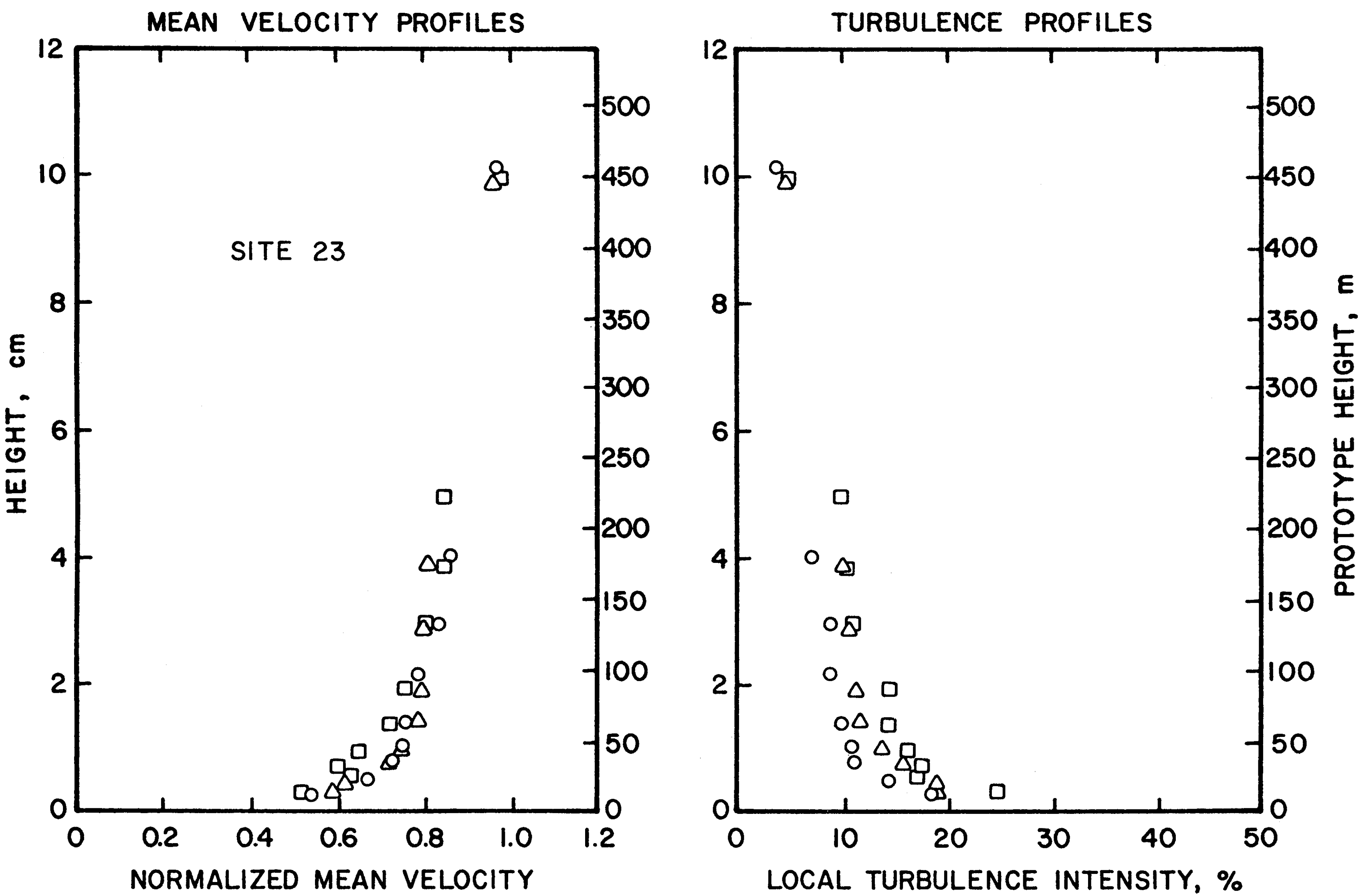

MEAN VELOCITY PROFILES
SITE 14
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
0
10
20
30
40
50
PROTOTYPE HEIGHT, m


MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 15
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %

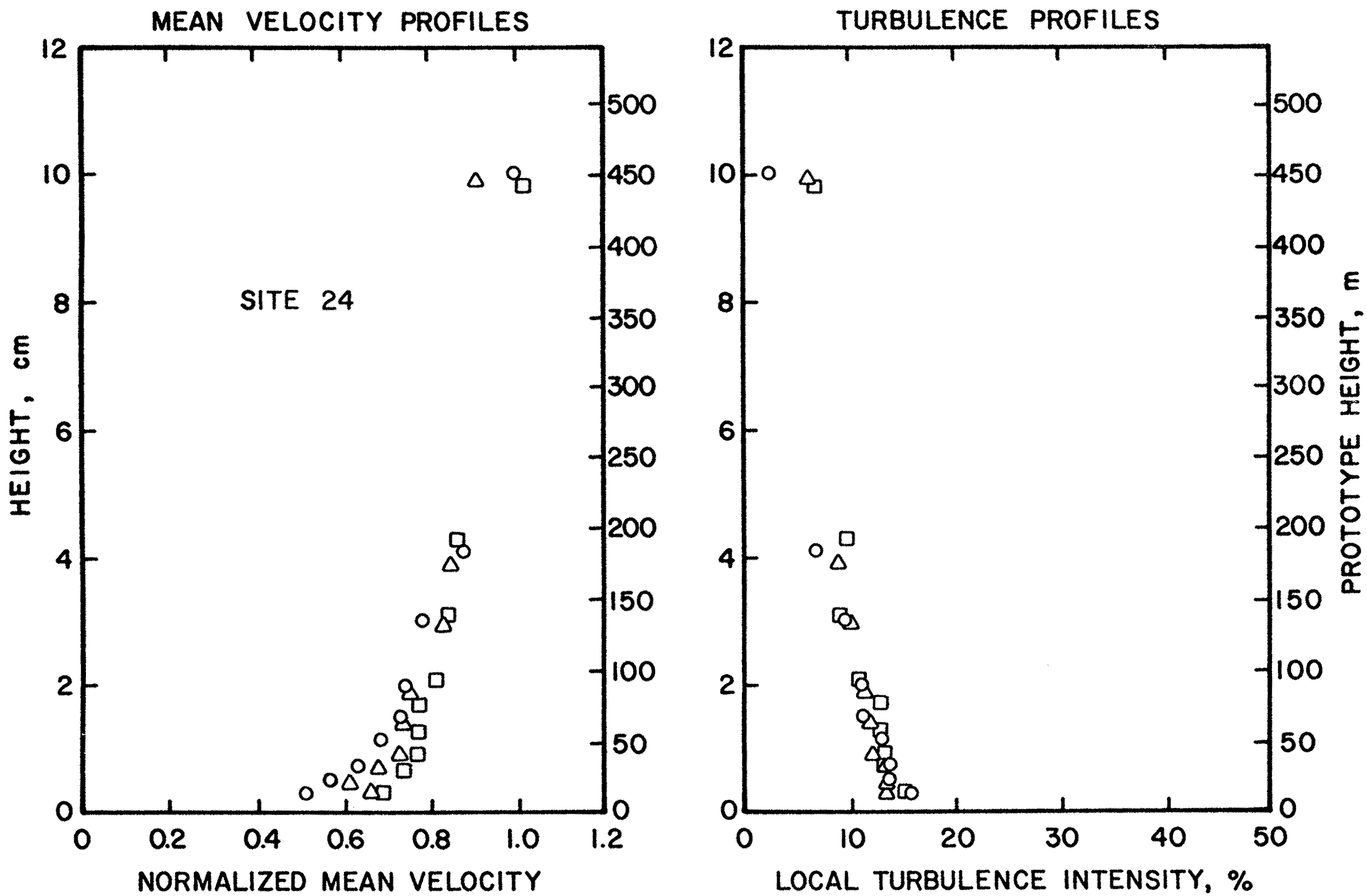

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 16
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500


MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 17
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500

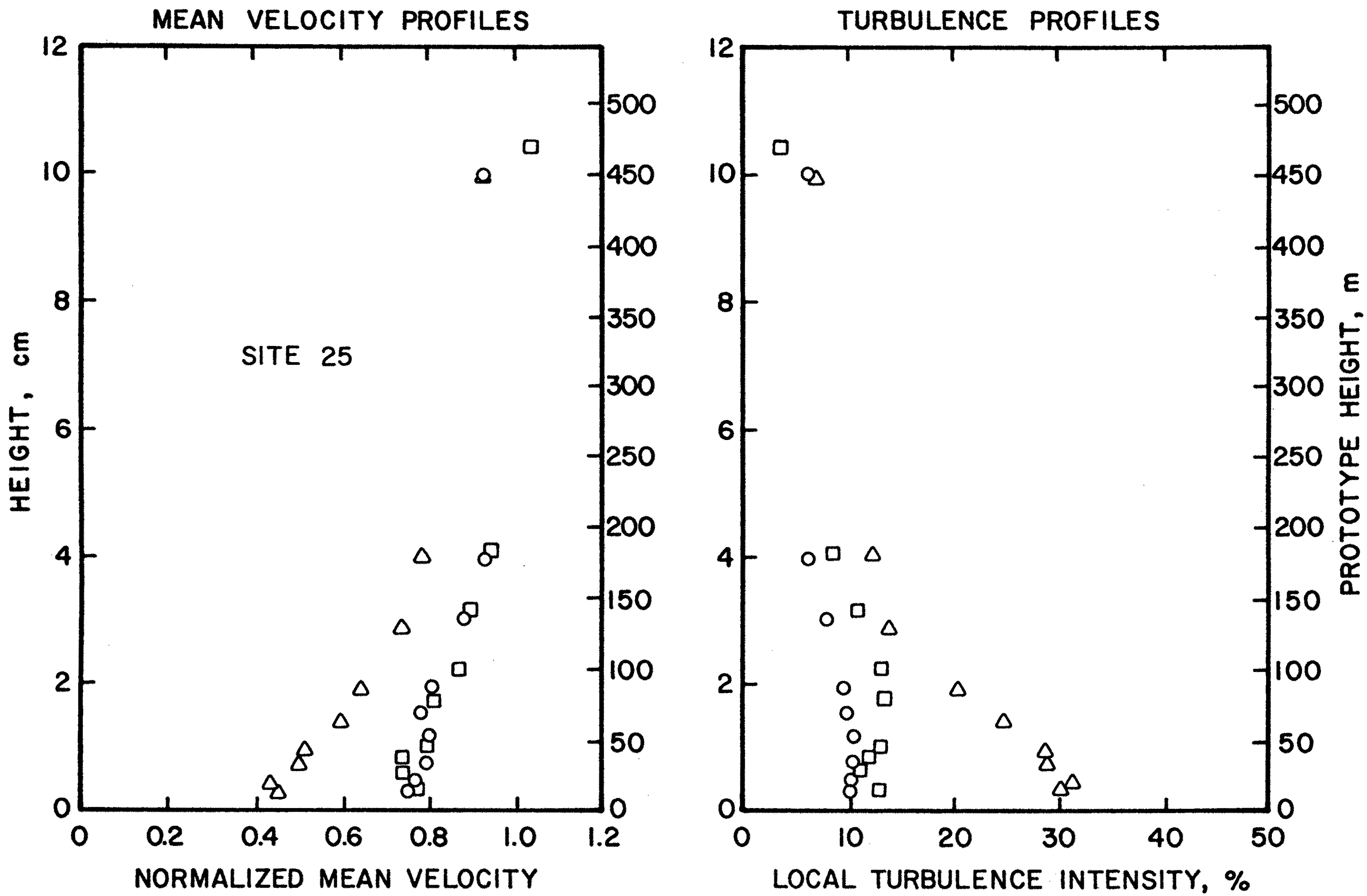

MEAN VELOCITY PROFILES
SITE 20
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
0
10
20
30
40
50
PROTOTYPE HEIGHT, m

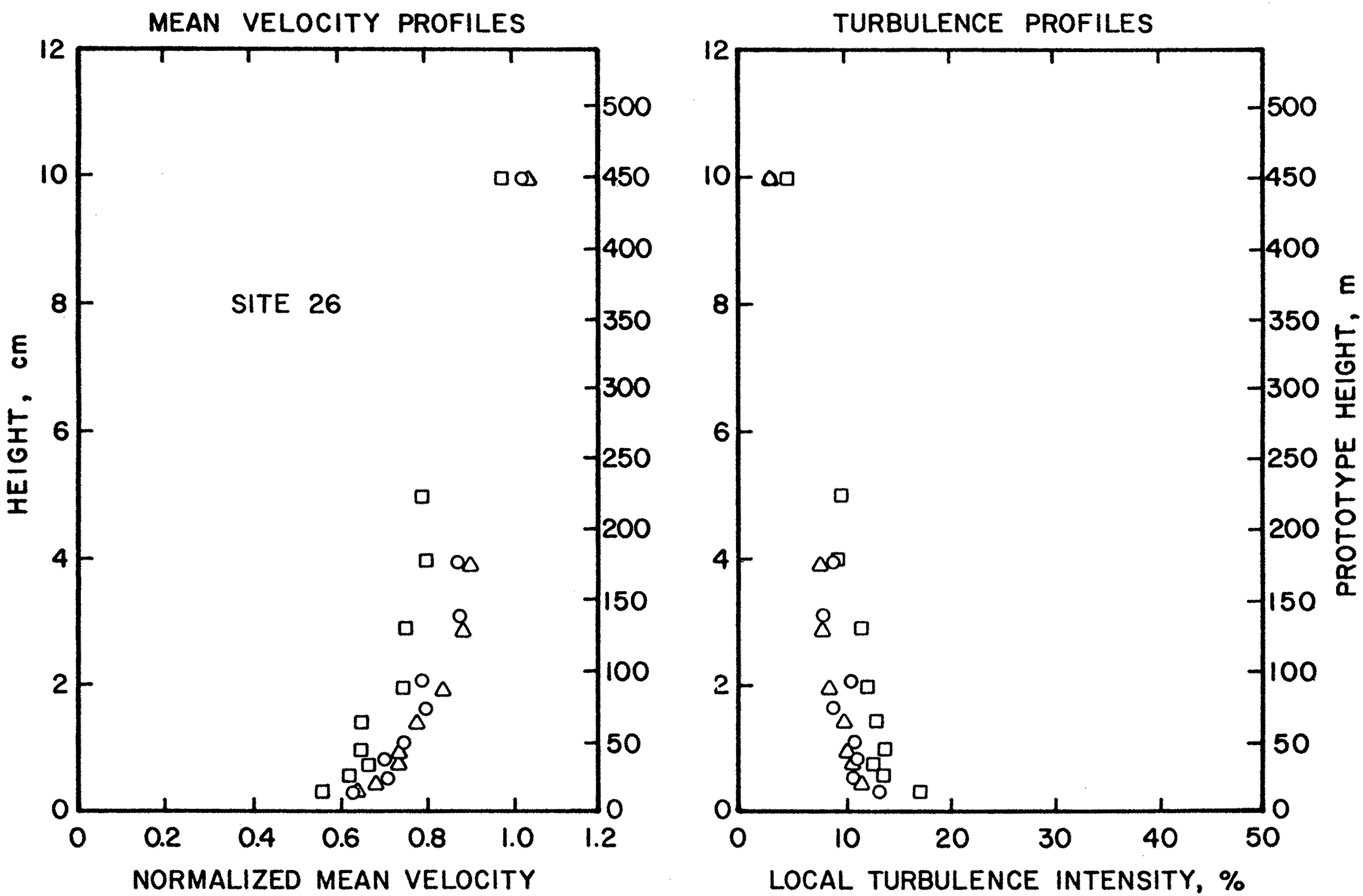


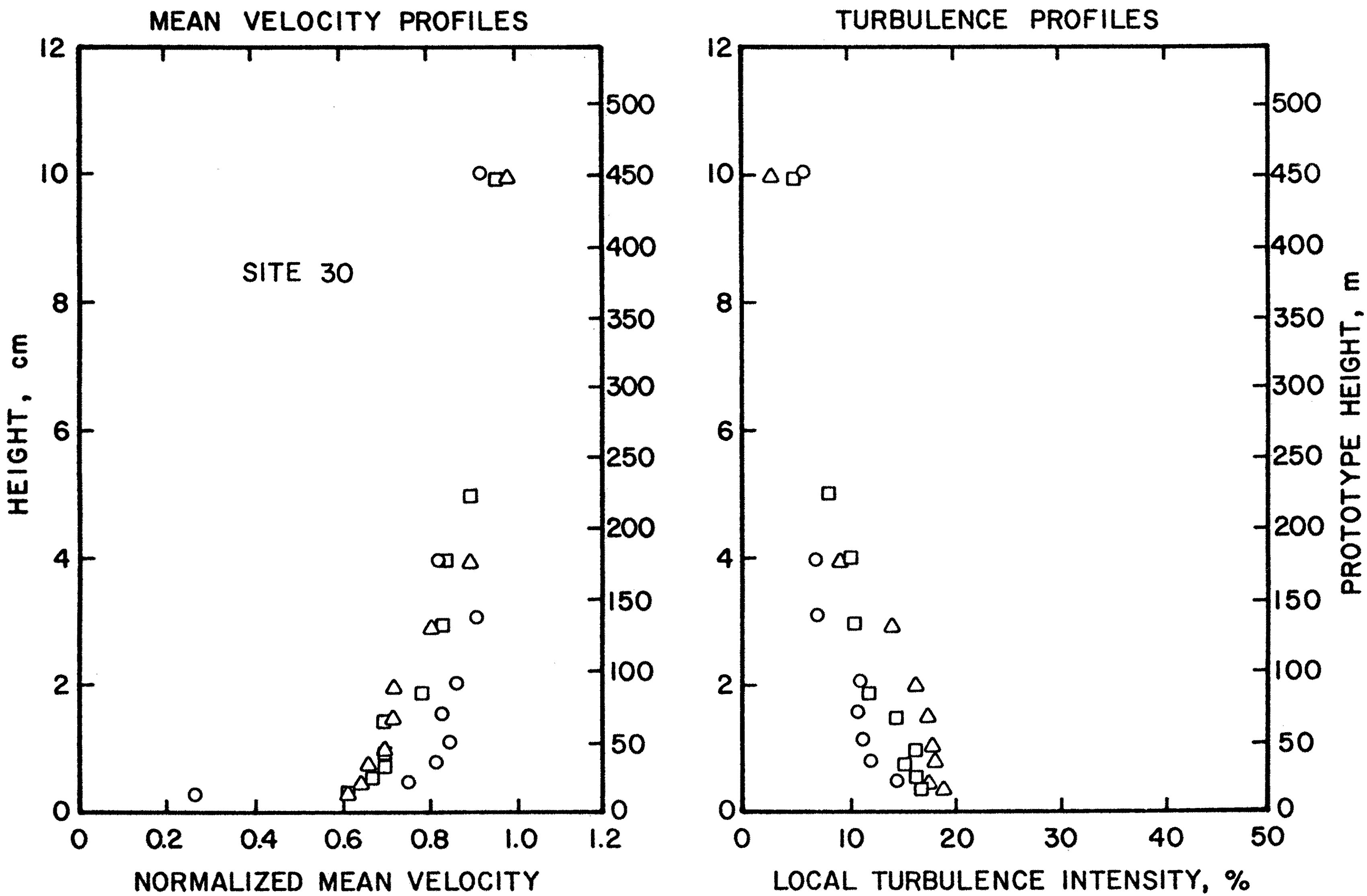
MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 23
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

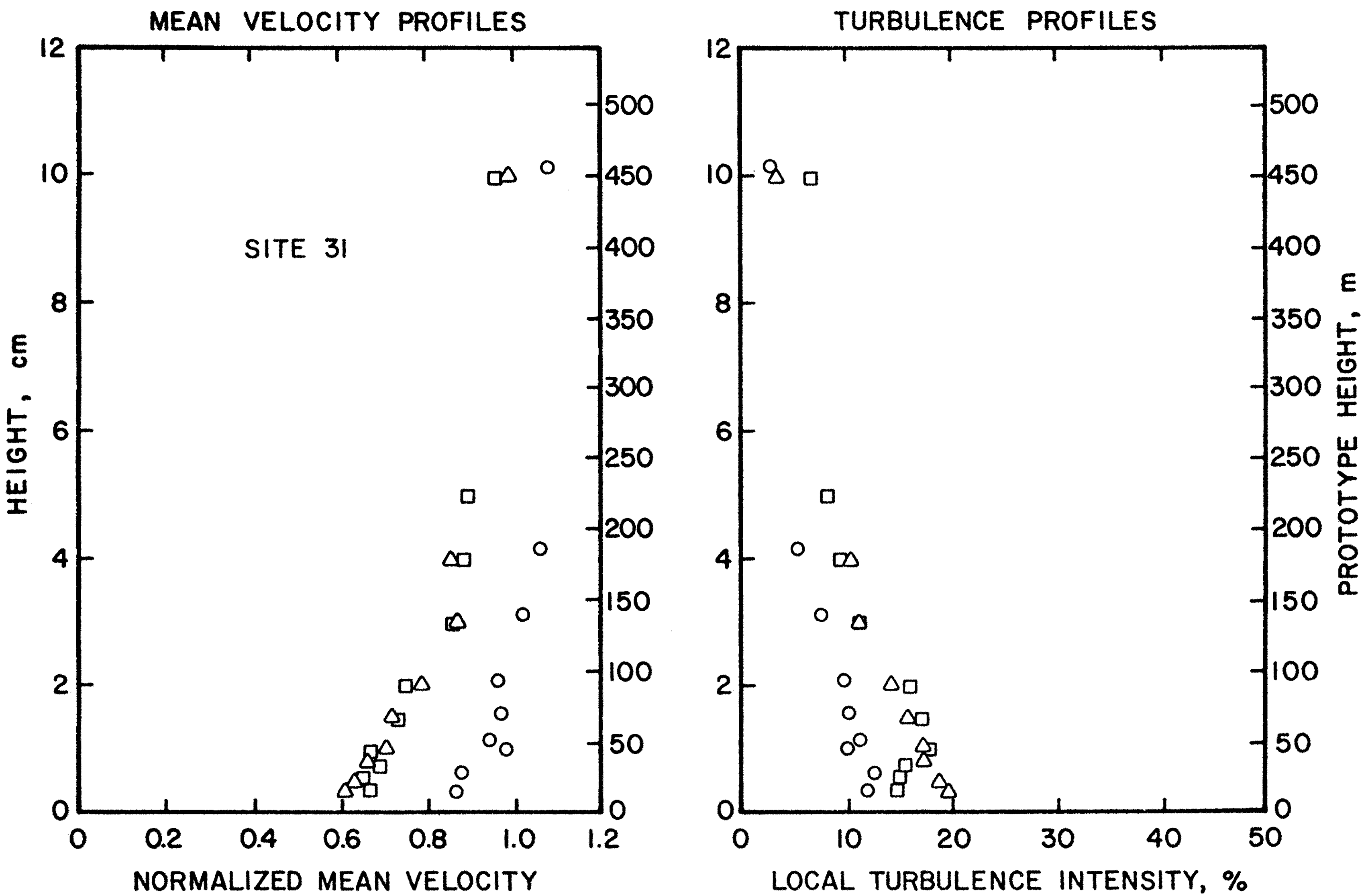


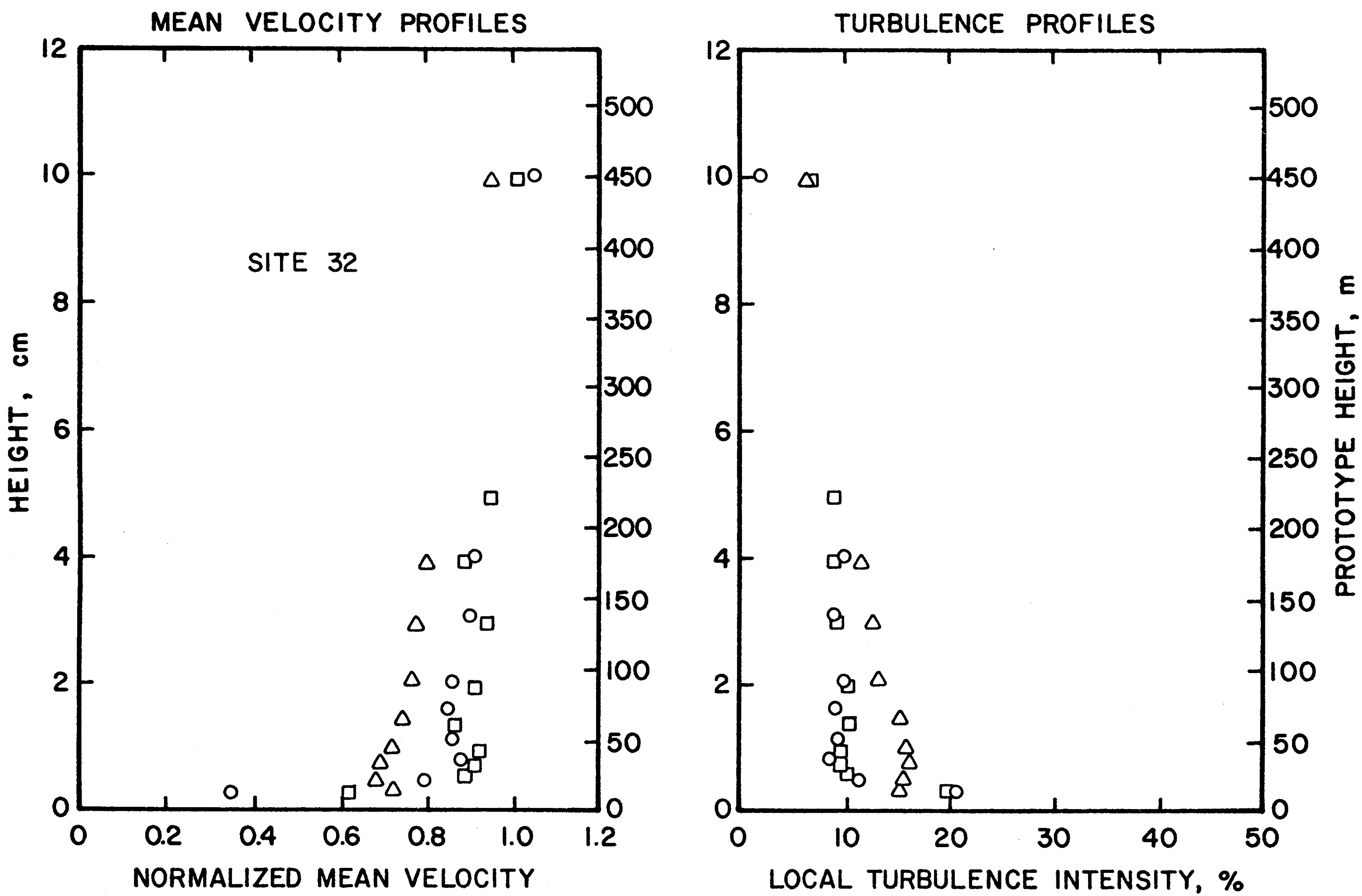
MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 24
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500

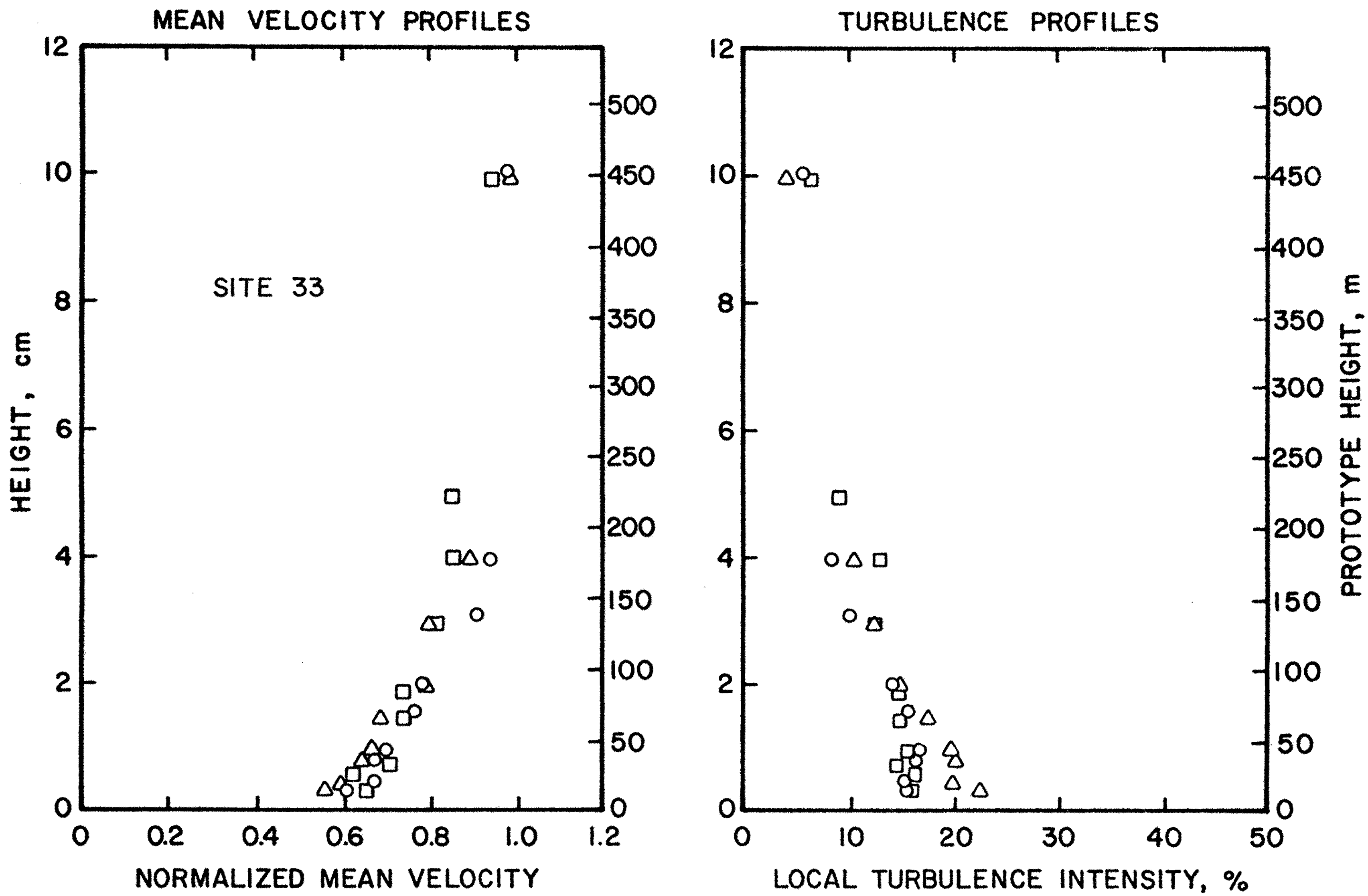

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 25
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
0
0.2
0.4
0.6
0.8
1.0
1.2
0
10
20
30
40
50

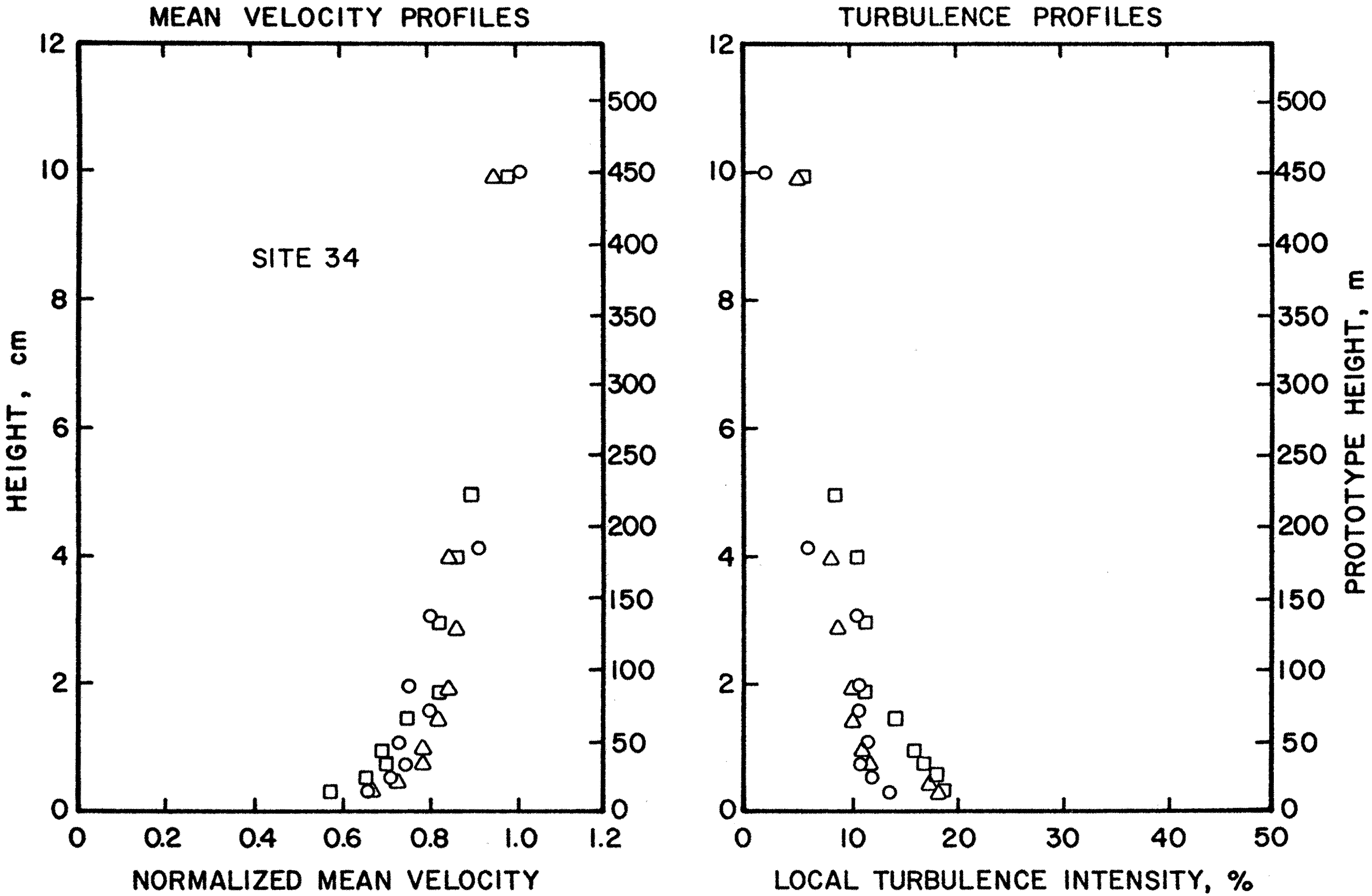

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 26
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500

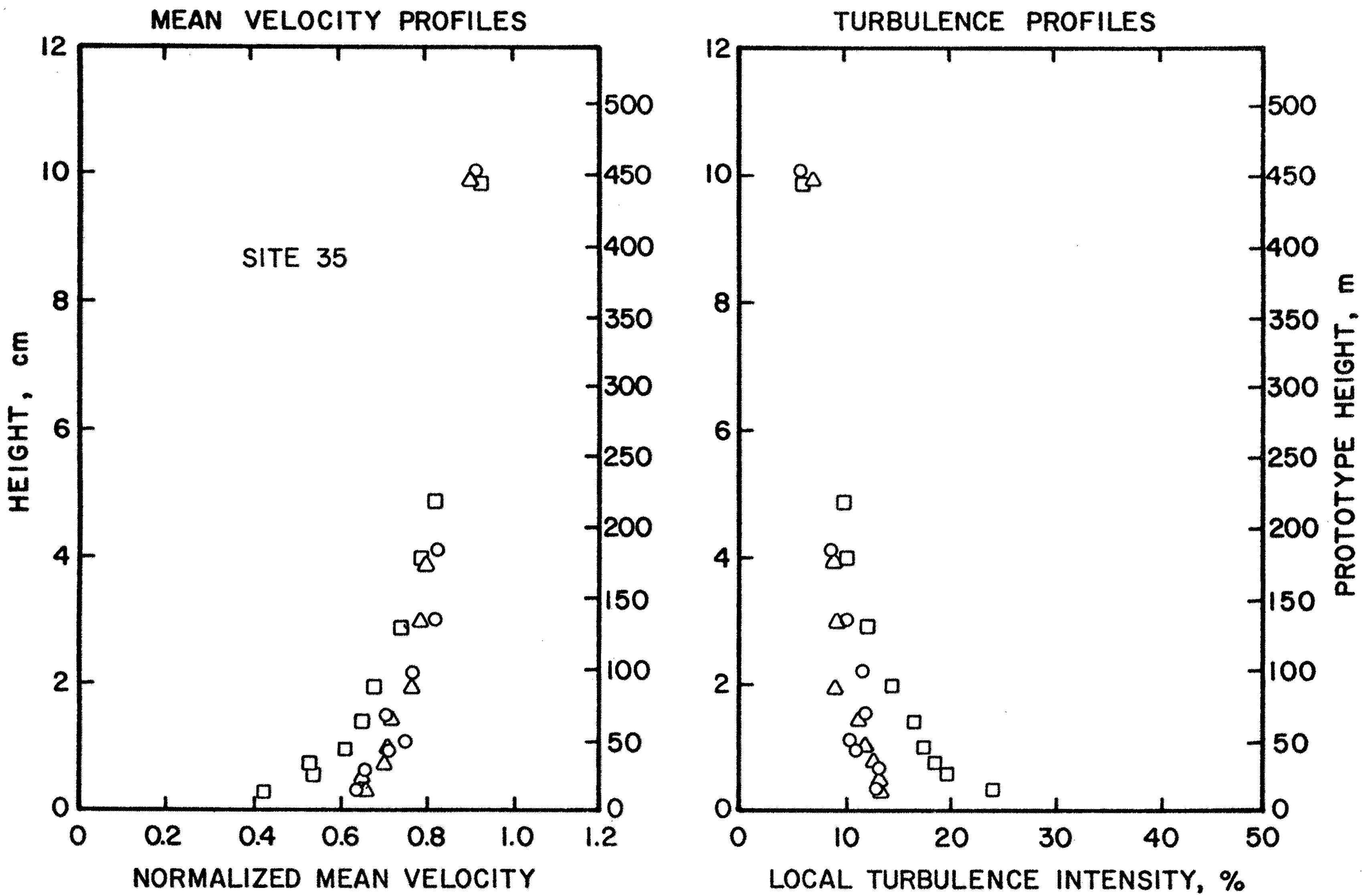

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 30
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

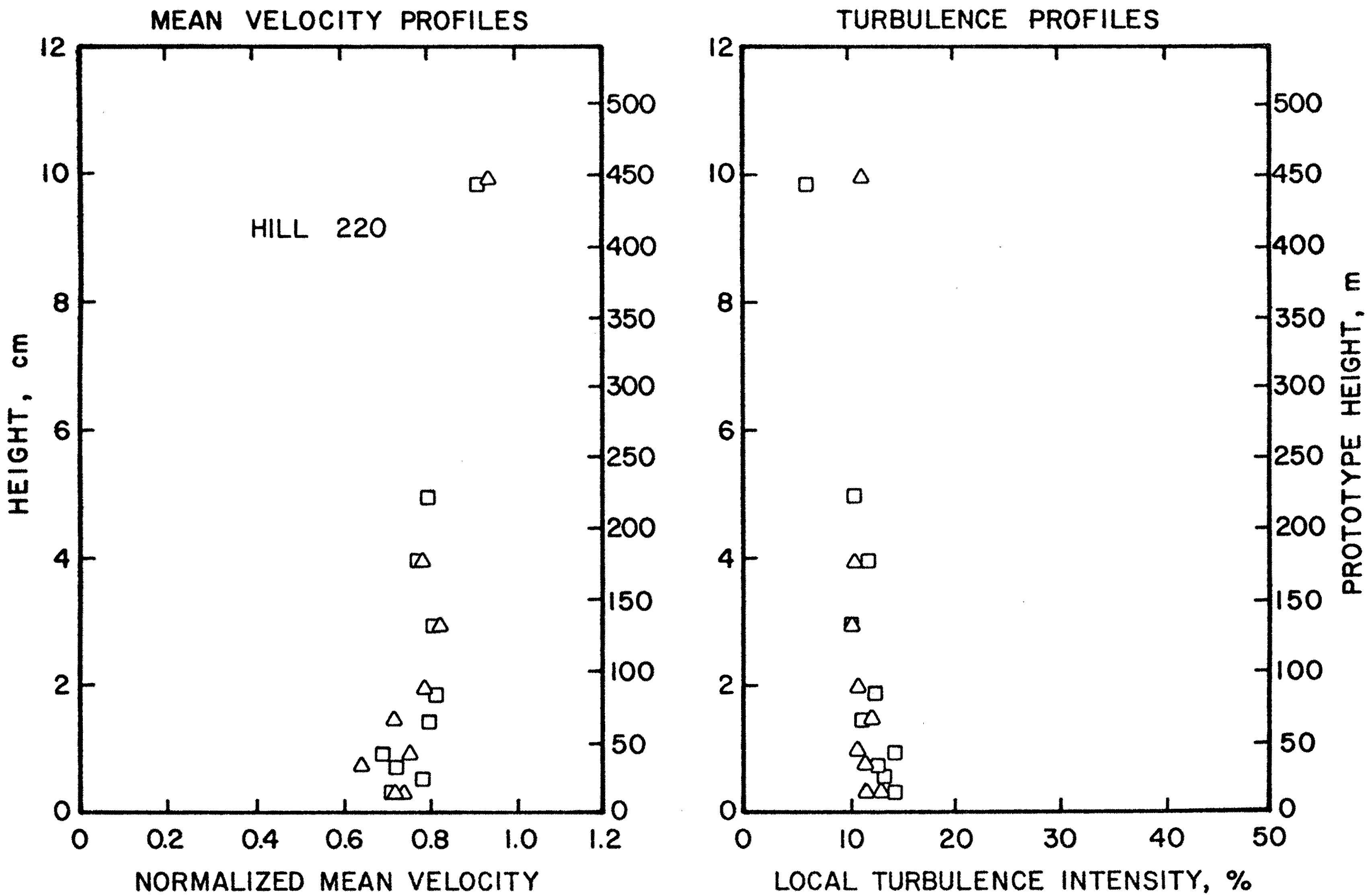

MEAN VELOCITY PROFILES
SITE 31
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
0
10
20
30
40
50
PROTOTYPE HEIGHT, m

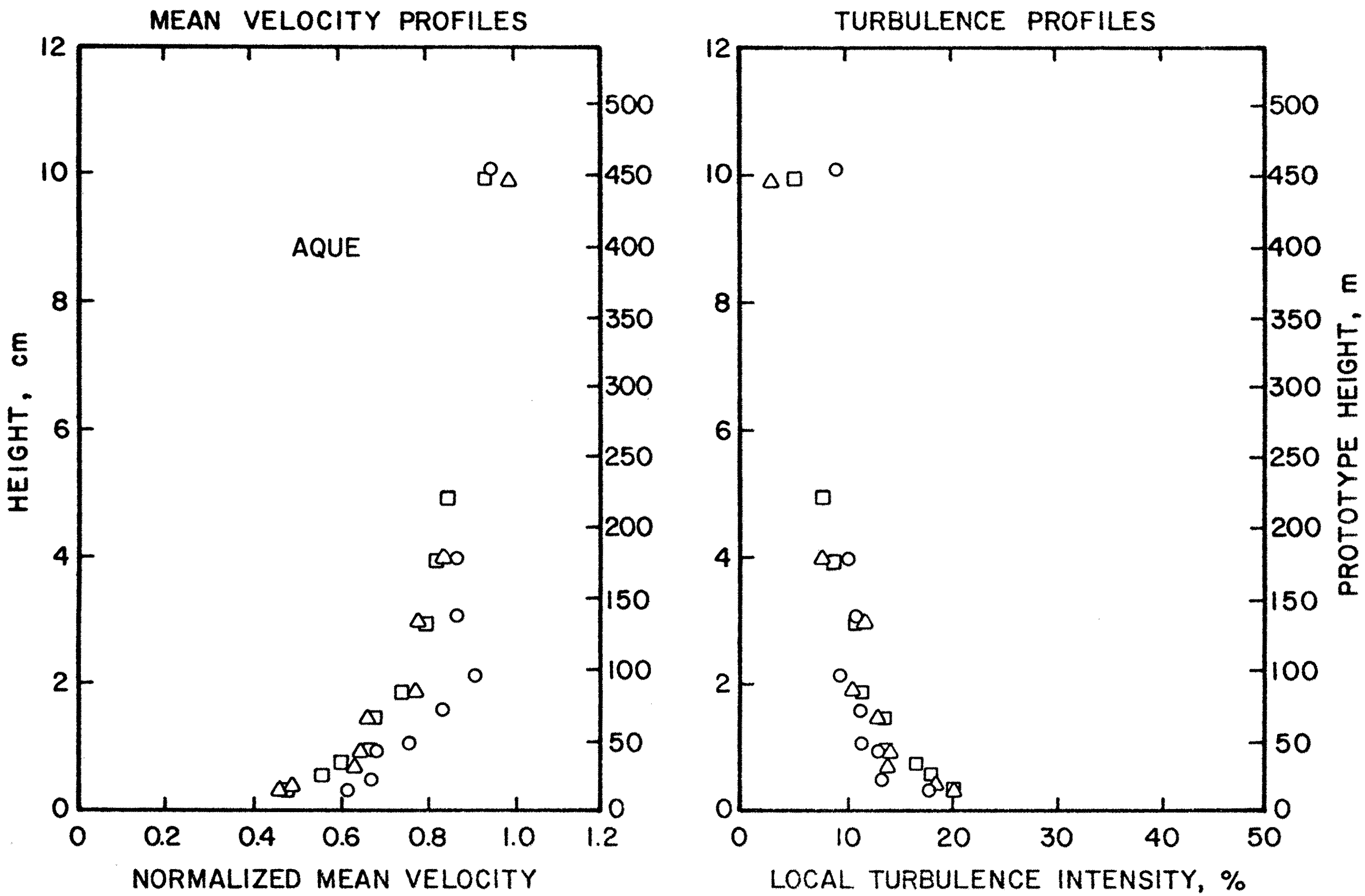

MEAN VELOCITY PROFILES
SITE 32
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
10
20
30
40
50

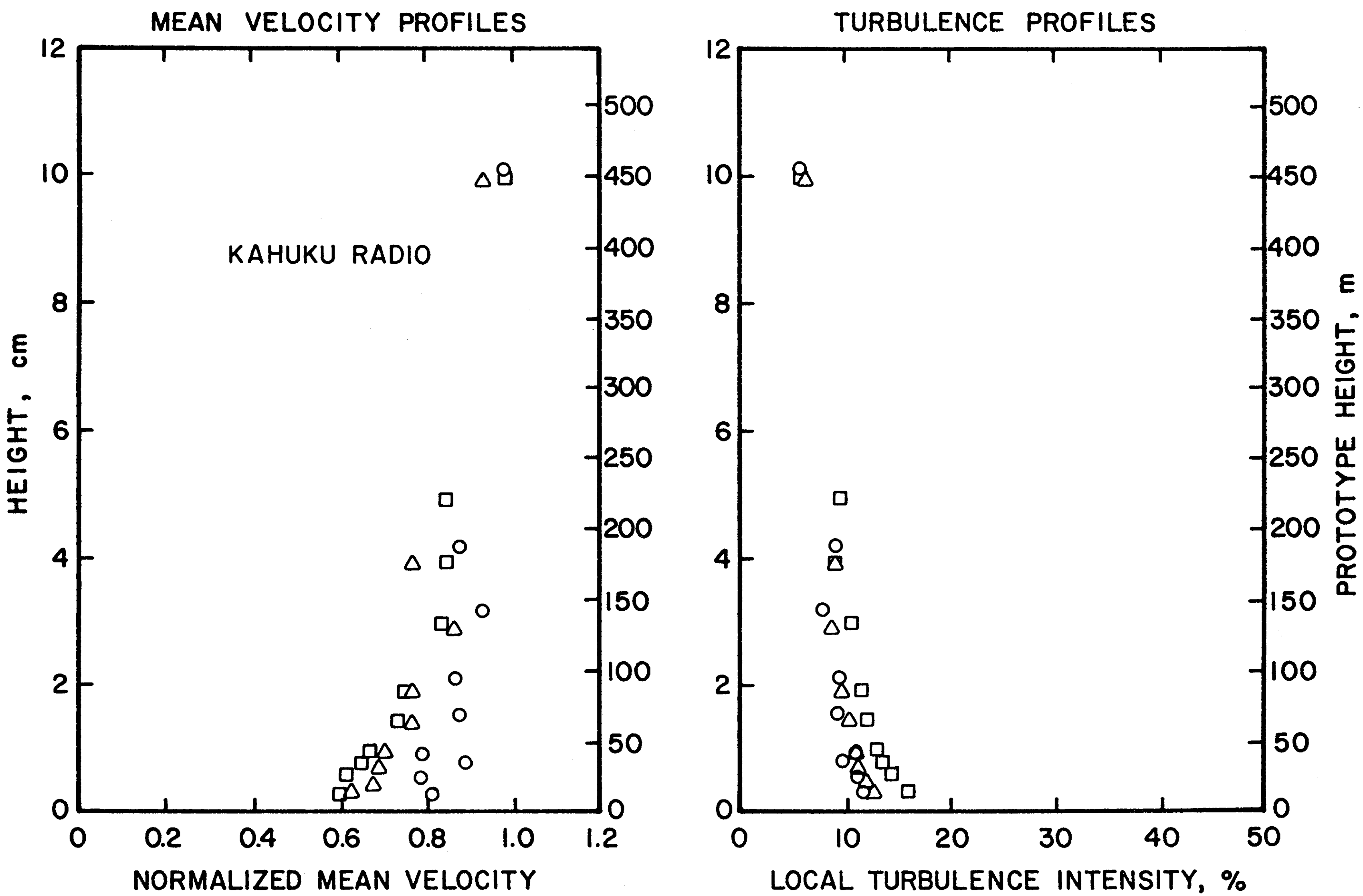

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 33
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

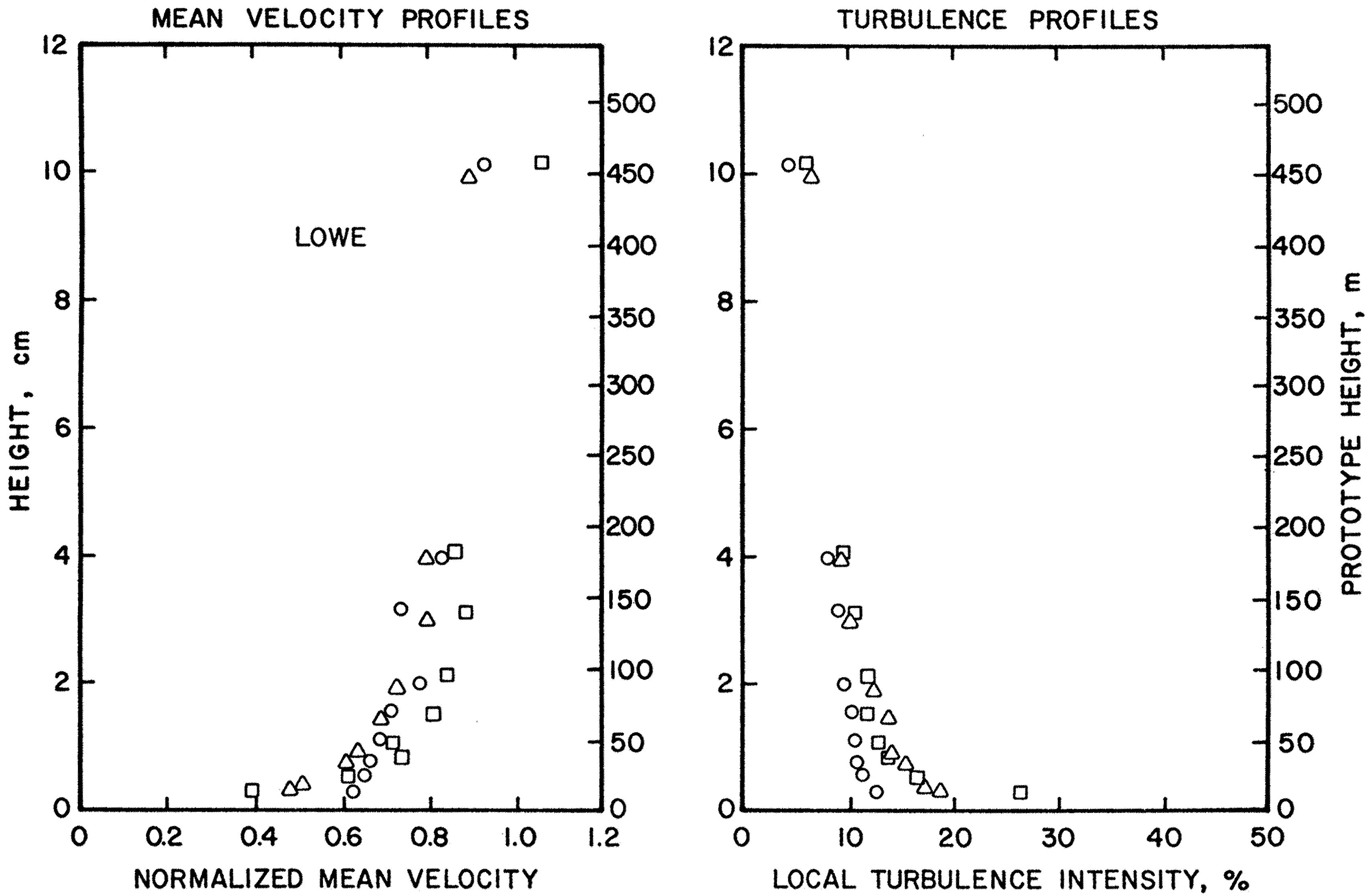

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
SITE 34
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

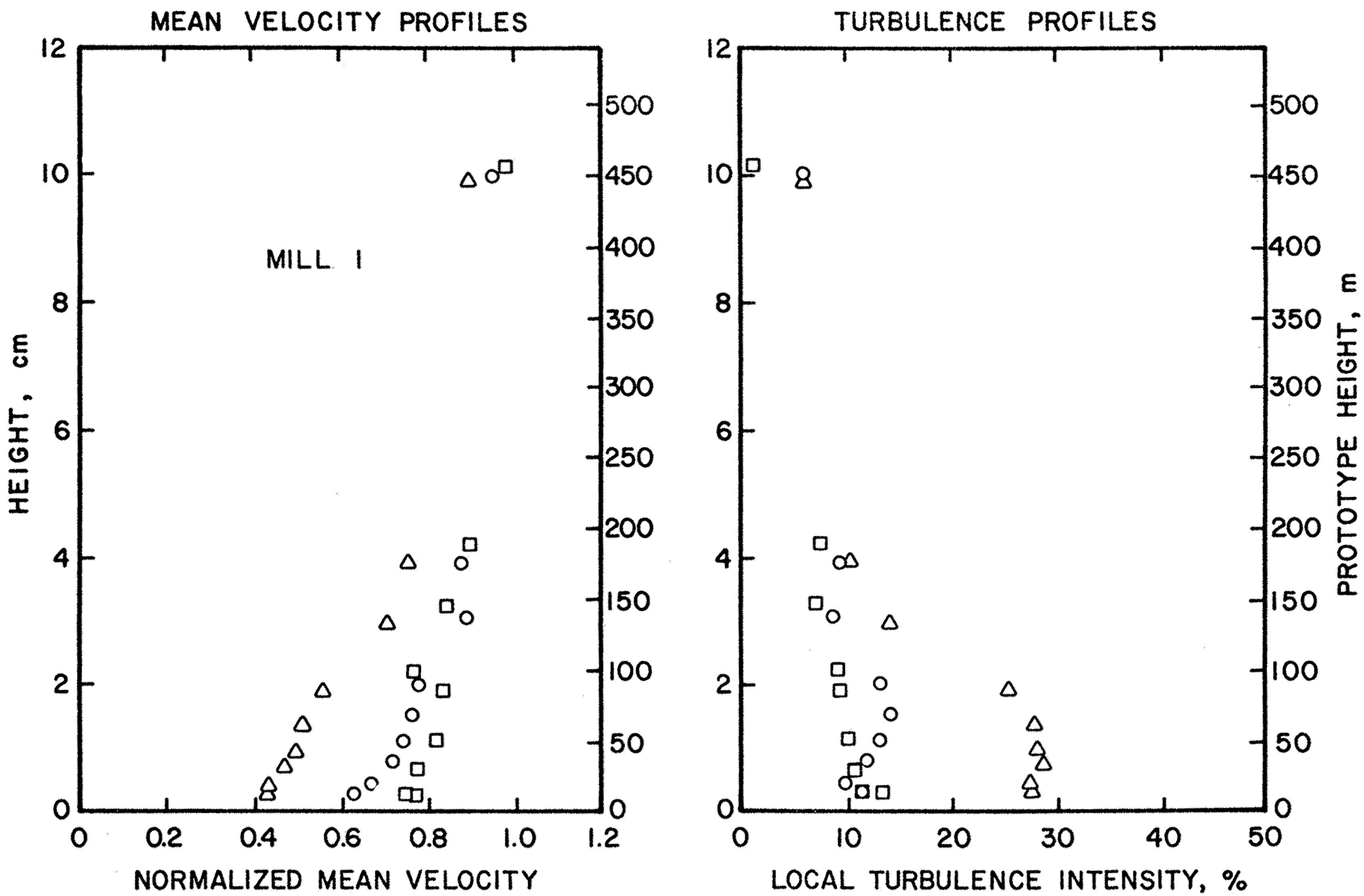

MEAN VELOCITY PROFILES
SITE 35
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
0
10
20
30
40
50

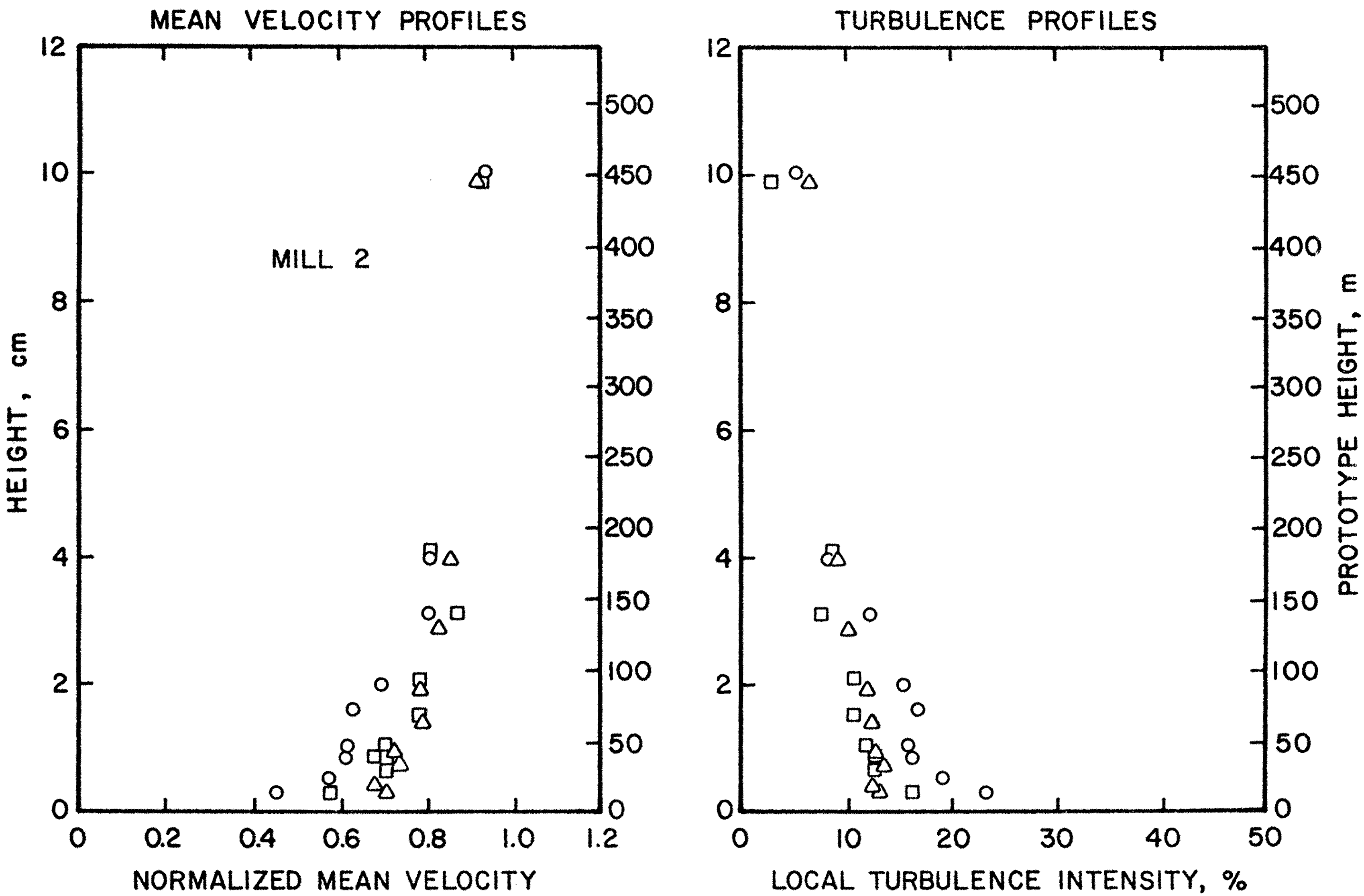

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
HILL 220
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500

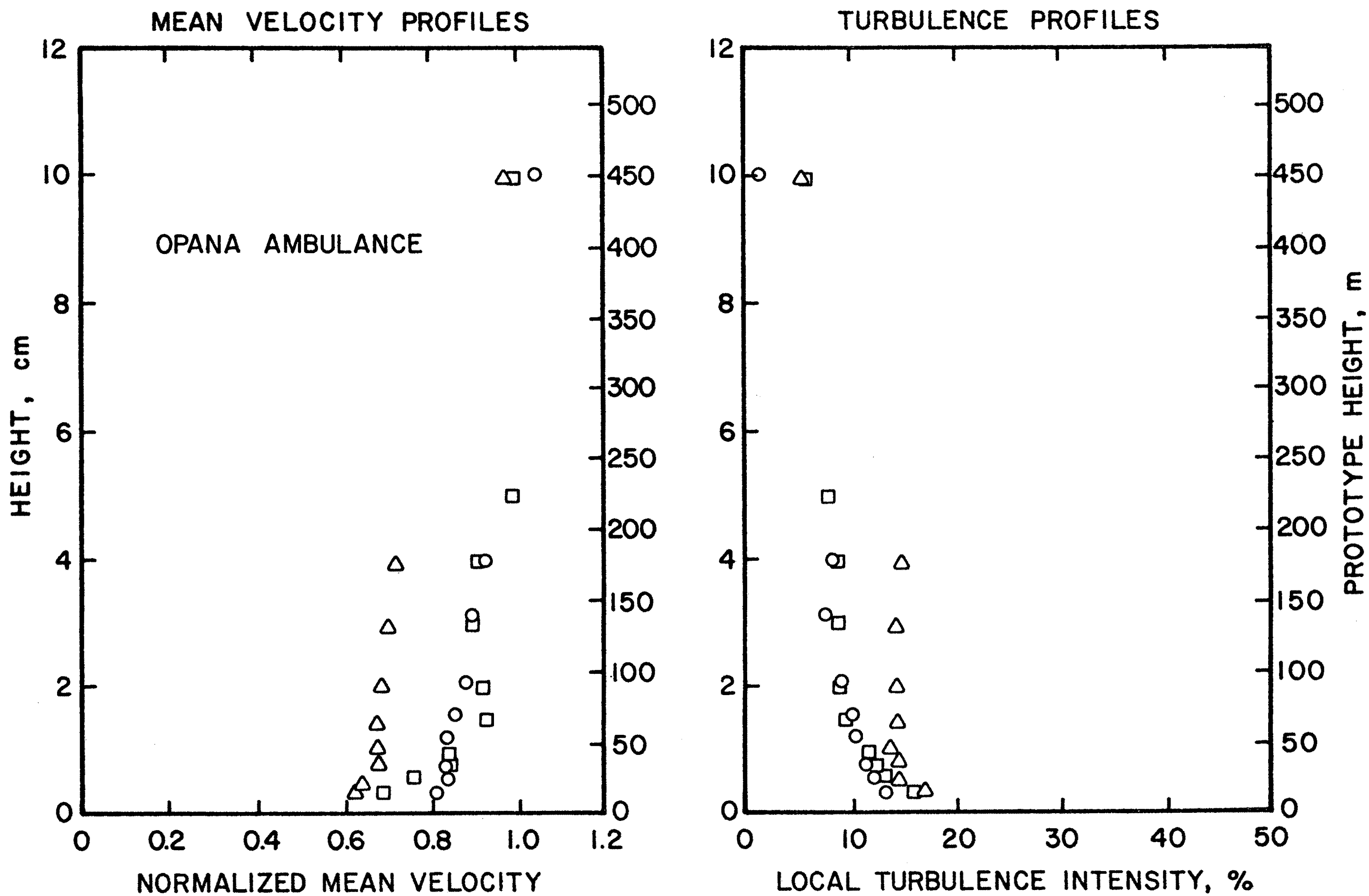

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
AQUE
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500


MEAN VELOCITY PROFILES
TURBULENCE PROFILES
KAHUKU RADIO
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
0
0.2
0.4
0.6
0.8
1.0
1.2
0
10
20
30
40
50

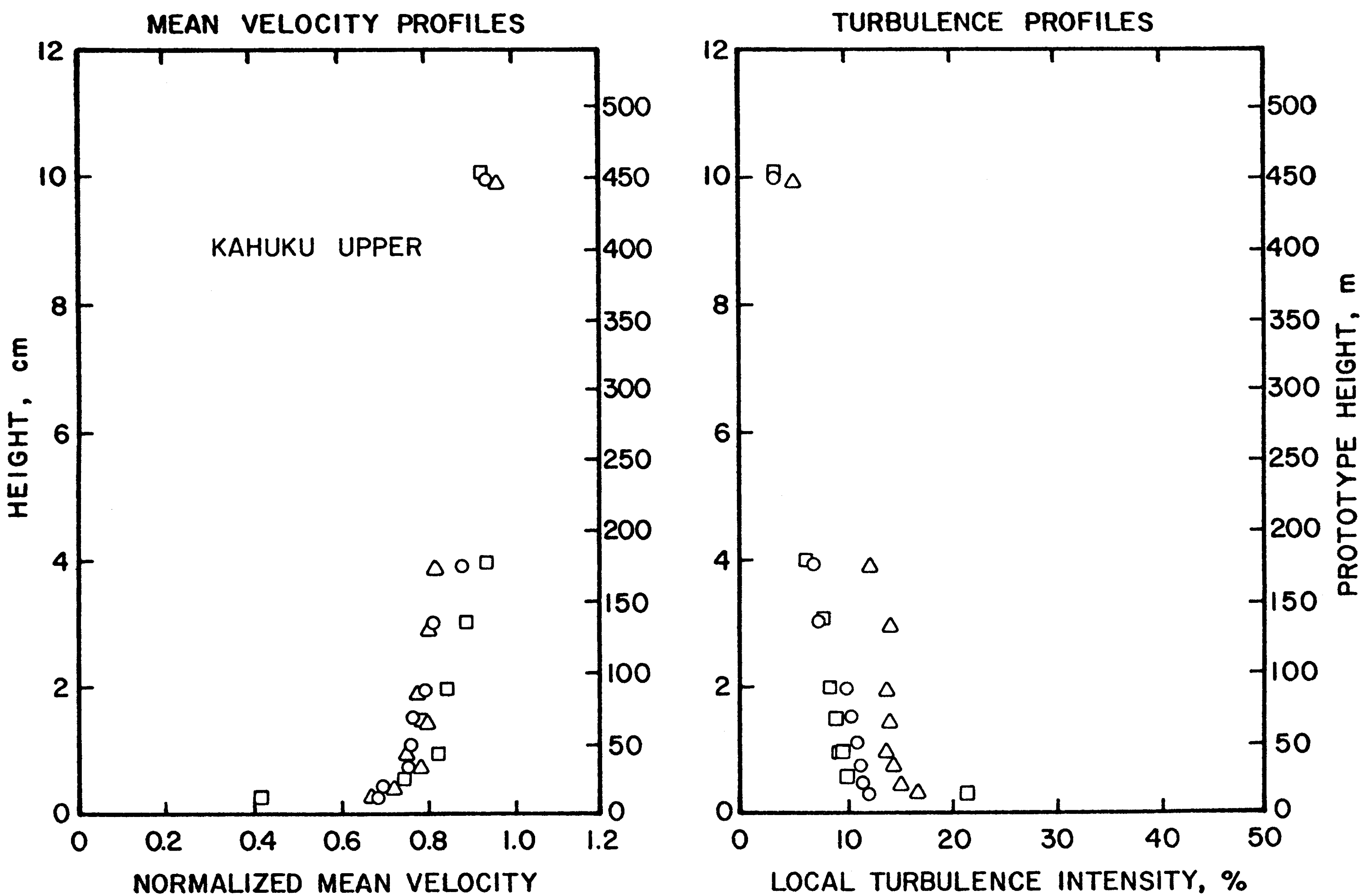

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
LOWE
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

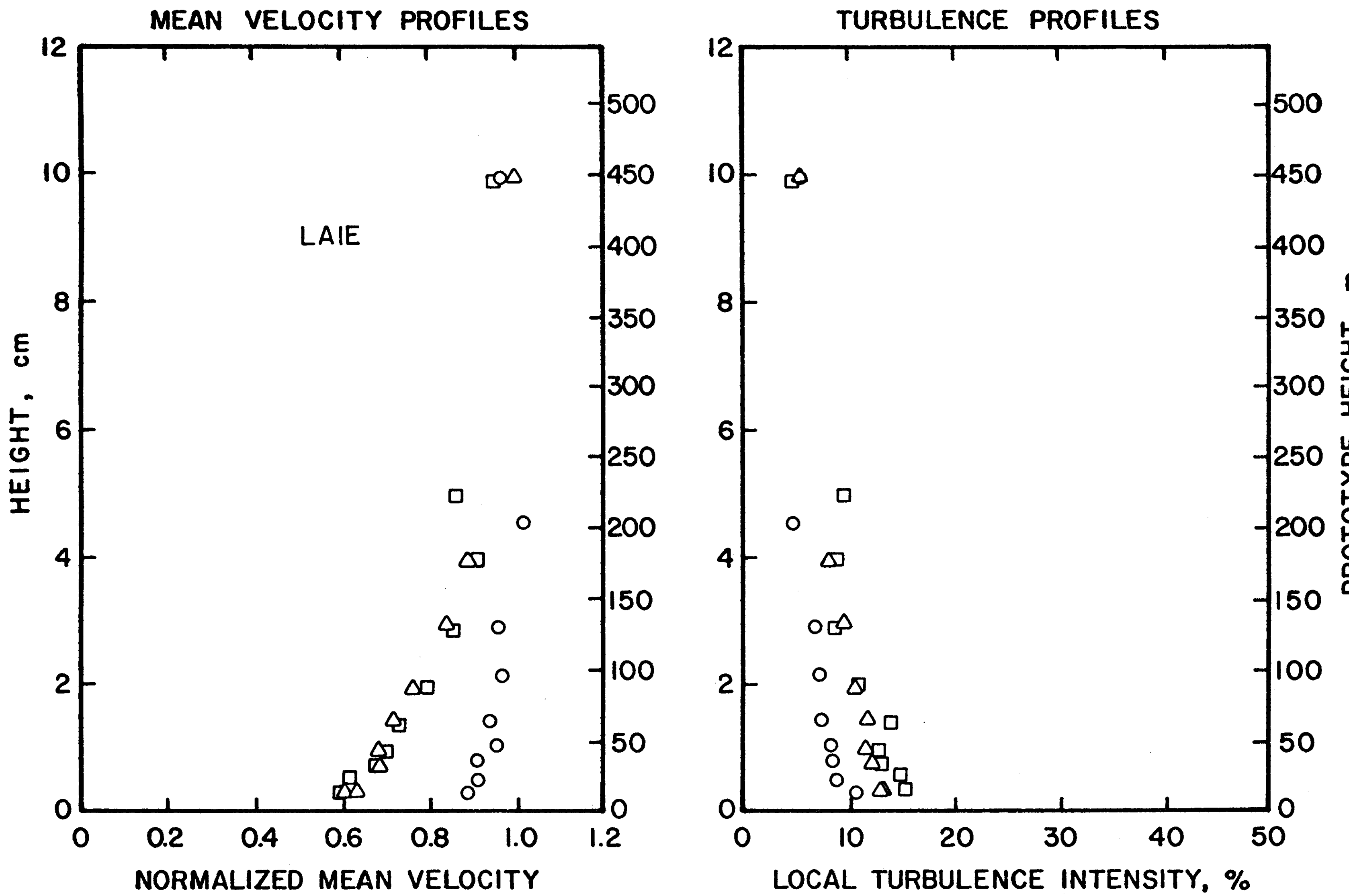

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
MILL I
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
50
100
150
200
250
300
350
400
450
500
20
30
40

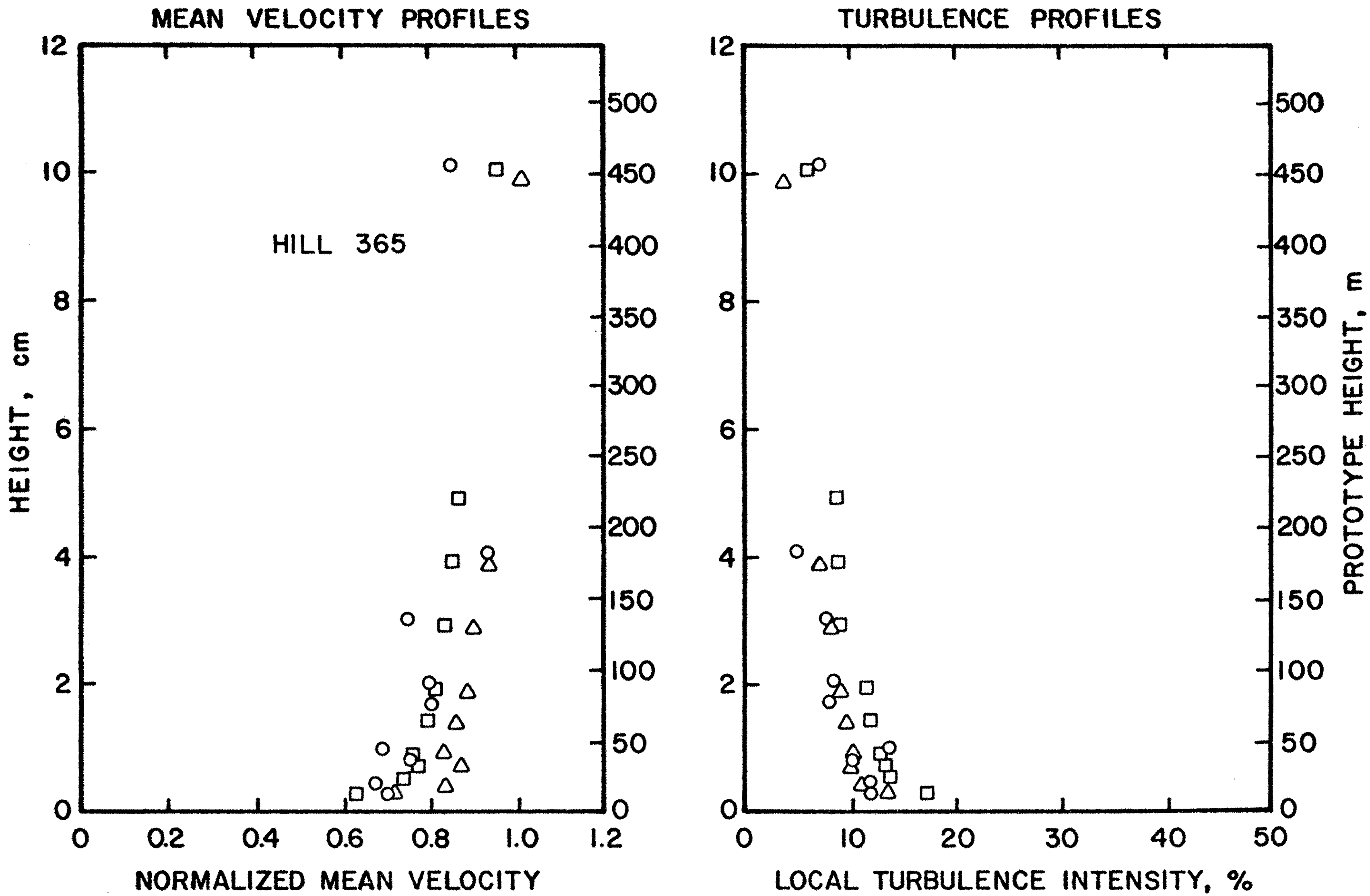

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
MILL 2
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
2
4
6
8
12
100
150
200
250
300
350
400
450
500



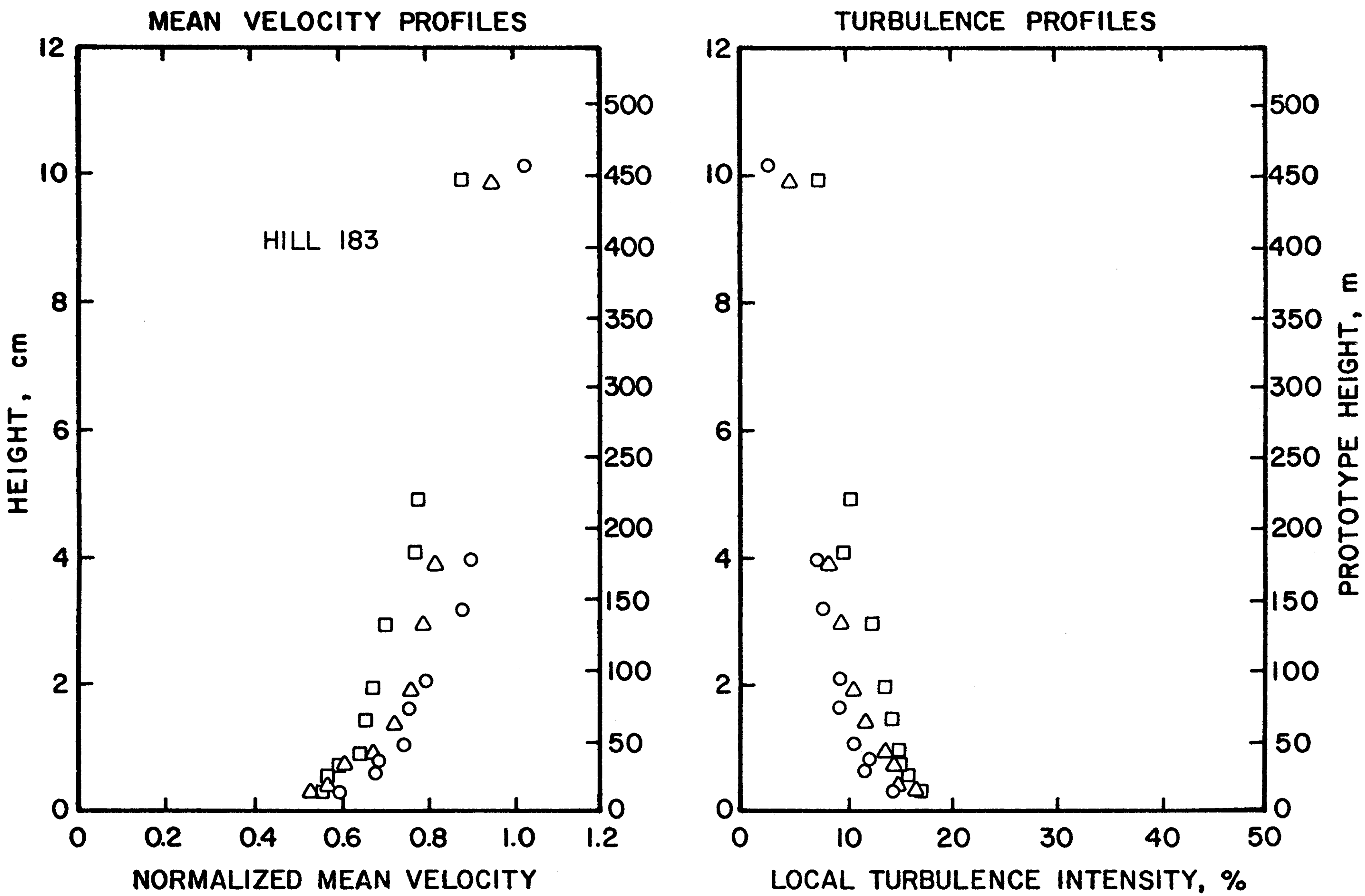
MEAN VELOCITY PROFILES
OPANA AMBULANCE
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
10
20
30
40
50

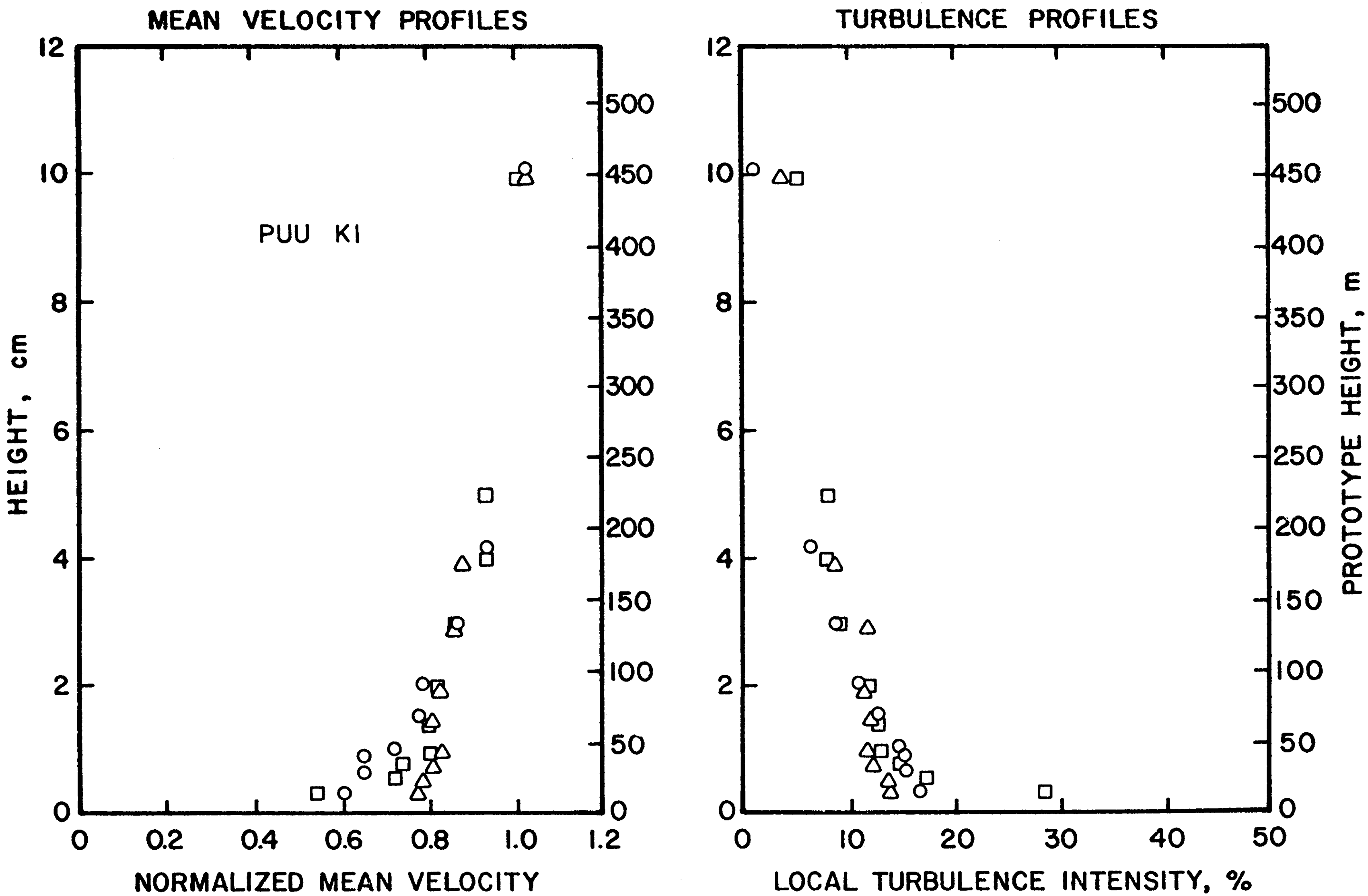

MEAN VELOCITY PROFILES
KAHUKU UPPER
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0
0.2
0.4
0.6
0.8
1.0
1.2
0
2
4
6
8
10
12
50
100
150
200
250
300
350
400
450
500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m
0
10
20
30
40
50

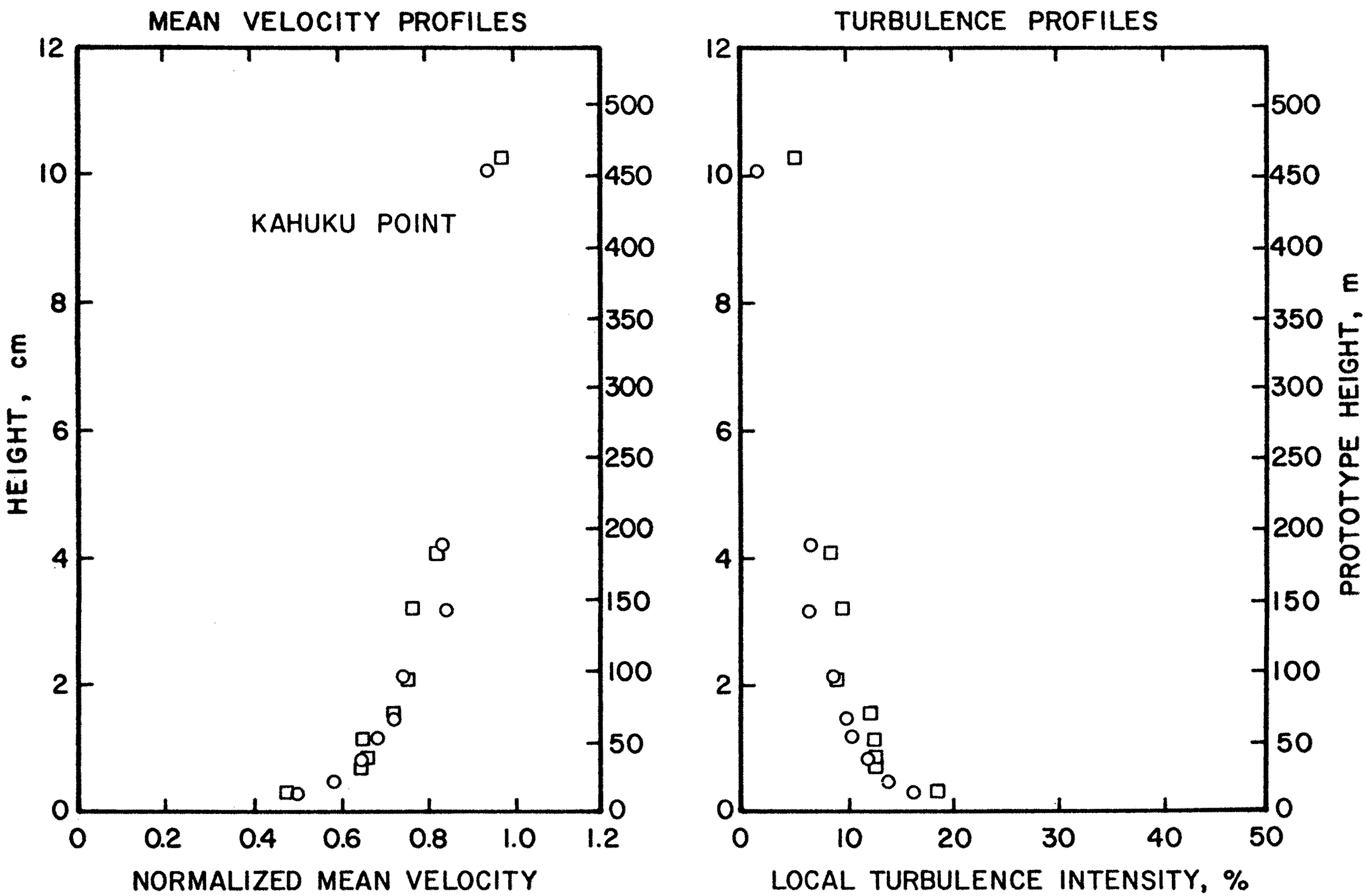

MEAN VELOCITY PROFILES
TURBULENCE PROFILES
LAIE
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500

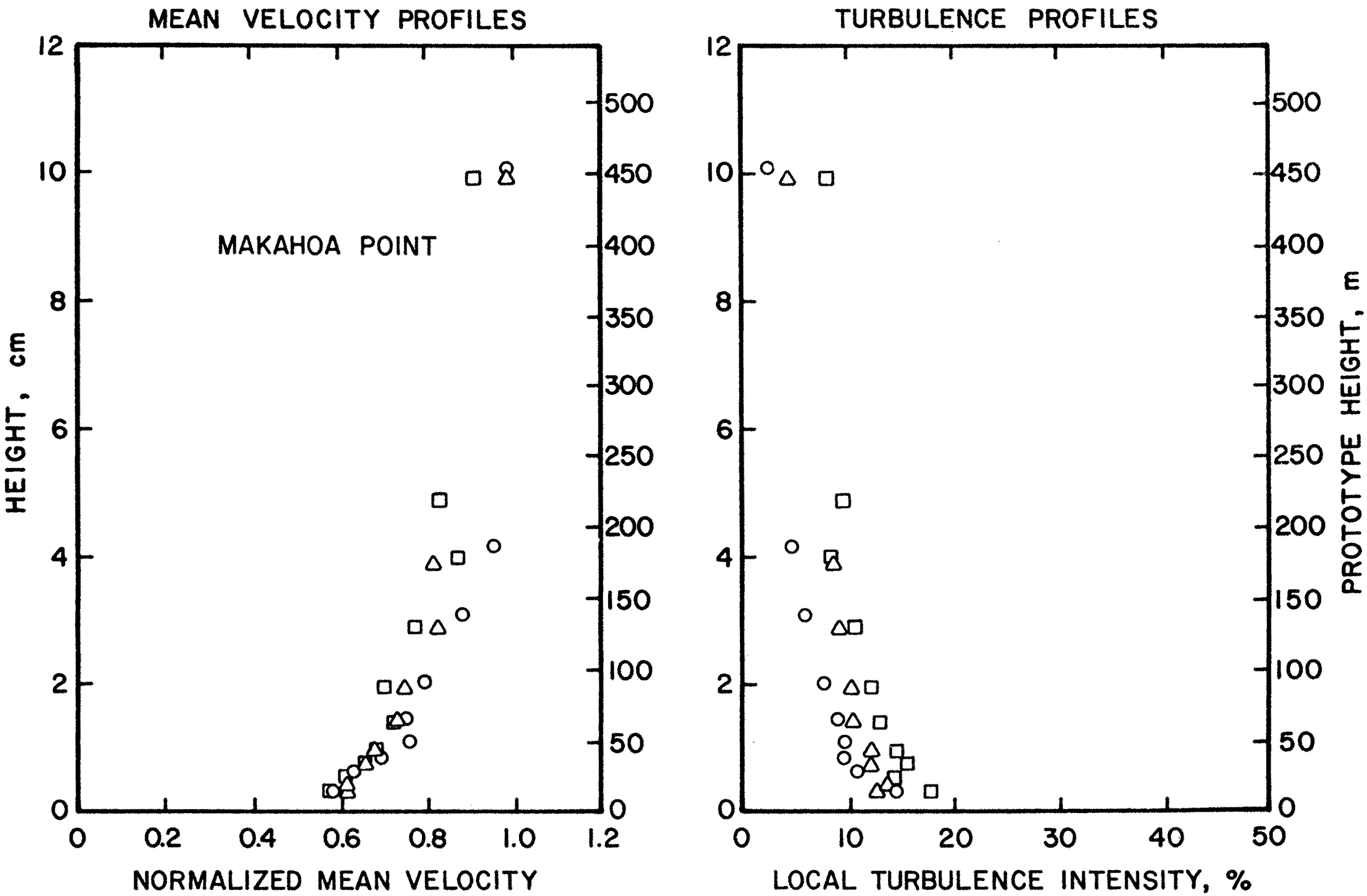


MEAN VELOCITY PROFILES
TURBULENCE PROFILES
HILL 365
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
0
0.2
0.4
0.6
0.8
1.0
1.2
0
10
20
30
40
50


MEAN VELOCITY PROFILES
HILL 183
HEIGHT, cm
NORMALIZED MEAN VELOCITY
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m


MEAN VELOCITY PROFILES
PUU KI
HEIGHT, cm
NORMALIZED MEAN VELOCITY
0 0.2 0.4 0.6 0.8 1.0 1.2
0 2 4 6 8 10 12
0 50 100 150 200 250 300 350 400 450 500
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
0 10 20 30 40 50
PROTOTYPE HEIGHT, m


MEAN VELOCITY PROFILES
KAHUKU POINT
HEIGHT, cm
NORMALIZED MEAN VELOCITY
TURBULENCE PROFILES
LOCAL TURBULENCE INTENSITY, %
PROTOTYPE HEIGHT, m


MEAN VELOCITY PROFILES
TURBULENCE PROFILES
MAKAHOA POINT
HEIGHT, cm
PROTOTYPE HEIGHT, m
NORMALIZED MEAN VELOCITY
LOCAL TURBULENCE INTENSITY, %
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
20
30
40
50
100
150
200
250
300
350
400
450
500