01120339

APPENDIX H

ANNUAL REPORT

THE METEOROLOGICAL PROGRAM AT THE PRAIRIE ISLAND NUCLEAR POWER STATION SITE

June 1, 1971 - May 31, 1972

Prepared For

NORTHERN STATES POWER COMPANY

By

T. C. Koss

July 1972

Environmental Safeguards Division

NUS Corporation
4 Research Place
Rockville, Maryland 20850

Incorporated into Updated Safety Analysis Report

Revision 4 12/85

THIS PAGE IS LEFT INTENTIONALLY BLANK

APPENDIX H

TABLE OF CONTENTS

Page

I. SUMMARY H.I-1
II. SITE METEOROLOGICAL PROGRAM H.II-1
III. METEOROLOGICAL DATA REDUCTION H.III-1
IV. METEOROLOGICAL DATA RECOVERY H.IV-1
V. METEOROLOGICAL DATA ANALYSIS H.V-1
  A. Wind Direction and Speed H.V-1
  B. Wind Direction Persistence H.V-3
  C. Atmospheric Stability H.V-3
VI. AVERAGE ATMOSPHERIC DILUTION H.VI-1
VII. HYPOTHETICAL ACCIDENT METEOROLOGY H.VII-1
VIII. REFERENCES H.VIII-1

01120339

TABLE OF CONTENTS [Continued]

LIST OF TABLES

TABLE I	HORIZONTAL σΘ STABILITY CATEGORIES
TABLE II	VERTICAL STABILITY ΔT CLASSIFICATIONS
TABLE III	METEOROLOGICAL DATA RECOVERY RATE PRAIRIE ISLAND (6/1/71 - 5/31/72)
TABLE IV	PRAIRIE ISLAND 40-FOOT WIND SPEED DATA
TABLE V	PRAIRIE ISLAND 40-FOOT σΘ DATA (6/1/71 - 5/31/72) ANNUAL HORIZONTAL STABILITY AND WIND SPEED DISTRIBUTIONS
TABLE VI	PRAIRIE ISLAND ΔT 140′-40′ DATA (6/1/71 - 5/31/72) ANNUAL VERTICAL STABILITY AND WIND SPEED DISTRIBUTION
TABLE VII	PRAIRIE ISLAND 40-FOOT σΘ DATA (6/1/71 - 5/31/72) ATMOSPHERIC HORIZONTAL STABILITY (%)
TABLE VIII	PRAIRIE ISLAND ΔT 140′-40′ DATA (6/1/71 - 5/31/72) ATMOSPHERIC VERTICAL STABILITY (%)
TABLE IX	JOINT FREQUENCY OF σΘ (40′) AND ΔT 140′-40′ DATA (%) PRAIRIE ISLAND (6/1/71 - 5/31/72)
TABLE X	COMPARISON OF PRAIRIE ISLAND 40-FOOT WIND SPEED DISTRIBUTION DATA
TABLE XI	COMPARISON OF PRAIRIE ISLAND 40-FOOT σΘ DATA
TABLE XII	PRAIRIE ISLAND PROBABILITY AT EXCLUSION DISTANCE (715m) (6/1/72 - 5/31/72)
TABLE XIII	METEOROLOGICAL MODEL - DESIGN BASIS ACCIDENT
TABLE XIV	PRAIRIE ISLAND - SITE ACCIDENT DISPERSION FACTORS (sec/m3)

TABLE OF CONTENTS [Continued]

LIST OF FIGURES

FIGURE 1 PRAIRIE ISLAND DATA RECOVERY SUMMARY (6/1/71 - 5/31/72)

FIGURE 2 PRAIRIE ISLAND 40′ WIND DIRECTION FREQUENCY ROSES (%) (6/1/71 - 5/31/71)

FIGURE 3 PRAIRIE ISLAND 40′ WIND SPEED DIRECTION (6/1/71 - 5/31/72)

FIGURE 4 PRAIRIE ISLAND 40′ WIND DIRECTION PERSISTENCE (6/1/71 - 5/31/72)

FIGURE 5 PRAIRIE ISLAND 40′ PERSISTENCE WIND ROSE (MAX. NO. OF HOURS WIND BLOWD FROM EACH DIRECTION) (6/1/71 - 5/31/72)

FIGURE 6 PRAIRIE ISLAND ANNUAL AVERAGE DISPERSION ISOPLETHS BASED ON 40′ LEVEL WIND DATA (6/1/71 - 5/31/72)

FIGURE 7 PRAIRIE ISLAND 0 - 8 HOUR HYPOTHETICAL ACCIDENT (DATA SAMPLE: 6/1/71 - 5/31/72)

FIGURE 8 PRAIRIE ISLAND HYPOTHETICAL ACCIDENT METEOROLOGY (BUILDING WAKE FACTOR - 0.5 X 1500M2)

THIS PAGE IS LEFT INTENTIONALLY BLANK

APPENDIX H

I. SUMMARY

(This report contains historical information. USAR Section 2.3 describes how this report was used and indicates where further information on Prairie Island’s current meteorological monitoring program can be found.) 01120339

This report summarizes and analyzes the meteorological data collected at the Prairie Island site over a one-year period extending from June 1, 1971, through May 31, 1972. The data were analyzed to develop parameters appropriate to dispersion estimates for the Design Basis Accident, and for evaluation of the average dispersion conditions which would govern normal gaseous releases from the Prairie Island Power Station.

One year of 40-foot wind data and ΔT 140′-40′ measurements indicated an average wind speed of 6.7 mph, and the prevalence of stable vertical stability conditions. On an annual basis, 75% of the total hours were categorized as stable on the basis of the temperature difference classifications used. The high incidence of ΔT stable conditions has ramifications with respect to the annual average dispersion meteorology, and the accident meteorology at the site.

The maximum annual χ/Q value at the site boundary is 6.94×10^{-6} sec/m^3, occurring about 1200 m northwest of the release point. This χ/Q factor is about two times higher than the corresponding value reported in the Prairie Island Environmental Report.

The results of the hypothetical accident analysis indicated that a χ/Q value of 6.50×10^{-4} sec/m^3 at the 715 m exclusion distance (which can be associated with “F” 0.89 m/s dilution conditions) is warranted for the short-term accident postulated for Prairie Island. The short-term dilution factor at the same exclusion distance reported in the FSAR was 3.85×10^{-4} sec/m^3.

THIS PAGE IS LEFT INTENTIONALLY BLANK

II. SITE METEOROLOGICAL PROGRAM

The on-site data collection system at Prairie Island consists of temperature and wind instrumentation mounted on a 140-foot tower at levels of 40 feet and 140 feet above grade. The meteorological tower is located approximately 1800 feet northwest of the reactor building. The data recorders and an NUS Variance Computer are housed in a thermostatically controlled shelter at the base of the tower.

The on-site instrumentation includes:

1. Wind

   a. Two sets of Belfort type "M" wind speed and direction sensors and transmitters (starting speed about 2 mph), located at the 40-foot and 140-foot levels, and two Belfort recorders.

   b. One Weather Measure low threshold recording wind system with a 6 cup anemometer (starting speed, 0.45 mph), located at the 40-foot level, and a Weathermeasure recorder.

   c. One Climet low threshold recording wind system (starting speed, 0.5 mph), located at the 40-foot level, and an Esterline-Angus recorder.

   d. One NUS Variance Computer. Wind speed, direction, and directional variance are averaged over 15 minute periods, and recorded on punched paper tape for the 40-foot level.

2. Temperature

   Two Rosemount 4 wire platinum bulbs mounted in Geotech aspirated radiation shields at the 40-foot and 140-foot levels. The output is transmitted to an Esterline-Angus 2 channel strip chart recorder. Temperature difference measurements between the two levels have an accuracy of ± 0.1°F.

   The Weather Measure low threshold wind system was installed in August, 1971 to investigate more thoroughly the percentage of calms occurring on-site. However, because of operational problems with this system, a Climet low threshold wind system was procured and installed as a back-up instrument in January, 1972.

   At the suggestion of the Division of Reactor Licensing of the AEC, temperature sensors were installed at the two levels in February, 1971 to assess the vertical stability distribution.

THIS PAGE IS LEFT INTENTIONALLY BLANK

III. METEOROLOGICAL DATA REDUCTION

Wind data from the Belfort instruments at the 40 foot level were reduced on a real-time basis by an NUS Variance Computer to provide four 15-minute averages per hour of wind speed, wind direction, and variance of wind direction (defined by applying the statistical definition of variance to wind direction). Manually reduced strip chart data were used to supplement periods of missing computer data. During the 12 month period from 6/1/71 to 5/31/72, about 26% of the recoverable 40 foot wind data were reduced by the variance computer, and 74% of the data were reduced by hand.

The analog strip chart data were reduced to determine variance of wind direction ($\sigma\Theta^2$), average wind direction, and speed. For any mean wind direction, the standard deviation of wind direction ($\sigma\Theta$) is estimated by observing the range (in degrees) of wind direction variations from the chart over a 15-minute period and dividing by six, according to methods described by Slade.(1)

The NUS Variance Computer calculates the mean wind direction and the square of the standard deviation of wind direction. These results, together with the average wind speed, are recorded in digital form on punch tape for a given level every 15 minutes.

Variance Computer data were put on magnetic tape, and manually-reduced data were punched on cards for input to a CDC 6600 computer. Manually-reduced wind and temperature data were obtained for only one 15-minute period per hour, while four 15-minute samples were obtained for the Variance Computer per hour. Therefore, when both manually-reduced and chart data are utilized, the data are weighted in order to compensate for the differences in data sampling frequency. Computer codes developed by NUS operate on this data to determine significant meteorological statistics and distributions for further analysis. This output includes the following information on a seasonal and annual basis:

a. Total number of observations used for calculations

b. Hourly stability index (defined both on the basis of wind variance and also by temperature lapse measurements) distribution in percent of total observations and in percent of total observations of each hour

c. Distributions for each stability index in percent of total observations

d. Average wind speed for each stability index

e. Distribution of stability indices for each of 16 wind directions

f. Distribution of wind directions (16) for each stability index

g. Dilution factors χ/Q (sec/m^3) as a function of release height, wind direction, and downwind distance weighted by stability class and wind rose frequencies

h. Wind persistence frequency calculations for various ranges of wind direction, and a listing of persistence episodes greater than five hours

i. Joint frequency distribution of wind variance and temperature lapse rate categories for discrete wind speed categories

In assessing the meteorology of a nuclear reactor site, the purpose is to ascertain the dilution capacity of the atmosphere to disperse radioactive material releases. Wind direction and speed are obvious factors, since the direction determines the trajectory of the material and the speed is a measure of the flow into which the discharge is diluted. However, wind turbulence progressively spreads the plume as it is transported from its source, resulting in a conical configuration.

By definition, a stable atmosphere is non-turbulent and an unstable one is quite turbulent. A low degree of wind turbulence and, consequently, relative unfavorable diffusion conditions can be expected for stable conditions. During periods of instability, a high degree of wind turbulence associated with favorable diffusion conditions can be expected. Since atmospheric turbulence is a measure of the dilution capability of the atmosphere, the dilution capacity is estimated by the classification of stability into categories proposed by Pasquill.(2) The stability classes proposed by Pasquill range from “A”, the most unstable, to “F”, the most stable. An additional classification category, “G”, has been recognized by the Atomic Energy Commission to facilitate a more complete classification system.

Wind direction variance, or standard deviation ($\sigma\Theta$), based on range of wind direction as formulated by Slade (1), is an established method to classify data into horizontal diffusion categories (a measure of the horizontal growth rate of the plume). Table I describes the various $\sigma\Theta$ stability classes. Vertical temperature lapse rate (ΔT) data (i.e., a measure of the temperature change with height) can be used to classify data into vertical diffusion categories (an indication of the vertical grown rate of the plume). Table II describes the various ΔT stability classes as defined by the Atomic Energy Commission in Safety Guide 23.(5)

The operation of the meteorological facility at Prairie Island enables a realistic definition of the diffusion climatology for the site. The continued use of the Prairie Island meteorological data facility when the power station becomes operational will enable constant monitoring of atmospheric diffusion conditions. Hence, in the event of accidental radioactive releases, it will be possible to evaluate dosages for the surrounding area and take corrective measures, if required.

TABLE I HORIZONTAL $\sigma\Theta$ STABILITY CATEGORIES

			Range of Standard Deviation, Degrees					**Turbulence Type**
A	=	Extremely Unstable			$\sigma\Theta$	$\geq$	22.5	High Atmospheric Turbulence
B	=	Unstable	22.5	>	$\sigma\Theta$	$\geq$	17.5	
C	=	Slightly Unstable	17.5	>	$\sigma\Theta$	$\geq$	17.5	
D	=	Neutral	12.5	>	$\sigma\Theta$	$\geq$	7.5	Moderate Atmospheric Turbulence
E	=	Slightly Stable	7.5	>	$\sigma\Theta$	$\geq$	3.8	Low Atmospheric Turbulence
F	=	Stable	3.8	>	$\sigma\Theta$	$\geq$	1.3	
G	=	Extremely Stable			$\sigma\Theta$	$\geq$	1.3	

TABLE II VERTICAL STABILITY ΔT CLASSIFICATIONS

			Range of Vertical Temperature Gradient (°F/1000′)	**Turbulence Type**
A	=	Very Unstable	$\Delta T < -10.4$	High Atmospheric Turbulence
B	=	Moderately Unstable	$-10.4 \leq \Delta T < -9.3$	
C	=	Slightly Unstable	$-9.3 \leq \Delta T < -8.2$	
D	=	Neutral	$-8.2 \leq \Delta T < -2.7$	Moderate Atmospheric Turbulence
E	=	Slightly Stable	$-2.7 \leq \Delta T < 8.2$	Low Atmospheric Turbulence
F	=	Moderately Stable	$8.2 \leq \Delta T < 22.0$	
G	=	Very Stable	$22.0 \leq \Delta T$	

IV. METEOROLOGICAL DATA RECOVERY

The data recovery rates for the Prairie Island meteorological program (6/1/71 - 5/31/72) are listed in Table III. The distribution of data loss and recovery are depicted graphically in Figure 1. Generally, periods of data loss were associated with recorder malfunctioning, such as inking or chart advance problems. About twelve days of ΔT data in July and 8 days of ΔT data in March were lost because of these problems.

Three weeks of wind, temperature and Variance Computer data from 10/7/71 to 10/27/72 were lost in the mail en route from NSP to NUS. As shown in Table III, data recovery during the last half of the study year (December, 1971 - May, 1972) improved significantly.

Unsatisfactory performance of the Weather Measure instruments invalidated much of the data obtained from this system. Many of the problems were traced to faulty recorder and transmitter component parts supplied by the manufacturer. The wind data generated by this system were not used in this analysis because of the low data recovery rate.

Climet low threshold wind data obtained between 1/8/72 - 6/8/72 were analyzed for this report. Over this five month period the percent recovery of Climet wind data was 92.7%.

TABLE III METEOROLOGICAL DATA RECOVERY RATE
PRAIRIE ISLAND
(6/1/71 – 5/31/72)

	40-Foot Wind Data*	**ΔT 140′-40′**	**Joint 40-Foot Wind Data & ΔT 140-40′**
SPRING (March, April, May)	91%	86%	77%
SUMMER (June, July, August)	94%	69%	64%
FALL (September, October, November)	73%	73%	69%
WINTER (December, January, February)	98%	92%	92%
ANNUAL	89%	80%	76%

* Recoverable data consists of the joint occurrence of valid wind speed, wind direction, and wind direction variance for a given 15-minute sample.

V. METEOROLOGICAL DATA ANALYSIS

A. Wind Direction and Speed

Wind direction and wind speed are important considerations in evaluating the site climatology for a nuclear power plant. Wind direction determines the trajectory of any potential radioactive release, and the amount of dilution is directly proportionally to the wind speed.

Seasonal and annual wind direction frequency roses are presented in Figure 2 for the 40-foot level at Prairie Island for the period 6/1/71 - 5/31/72.

The seasonal and annual wind roses show the influence of the Mississippi River Valley, which is oriented along a northwest-southeast axis at the plant site. The high incidence of northwest and southeast winds indicates that winds are frequently channeled by the valley. During the summer, winds from the southeast quadrant predominate (prevailing wind from southeast, occurring 14.04% of the total summertime hours), while during the colder months, winds from the northwest quadrant predominate (during December-January-February, prevailing wind from west-northwest, occurring 13.83% of the total hours).

Figure 3 shows the annual wind speed distribution at the 40-foot level from 6/1/71 to 5/31/72. Table IV summarizes the seasonal and annual average wind speeds and frequencies of calms recorded by the 40-foot Belfort instrument. (Calms are defined as <0.5 mph, commensurate with data reduction accuracy.) Seasonally, average wind speeds vary from 6.2 mph during the summer to 7.2 mph during the fall with an annual average of 6.7 mph, indicative of good natural ventilation conditions. The incidence of calm conditions, as indicated by the Belfort instrument, is quite high at the site, averaging 5.9% of the total annual hours. However, the frequent occurrence of calms is partly attributable to the high starting speed (about 2 mph) of the Belfort wind sensor. This is examined further in Section VII.

TABLE IV PRAIRIE ISLAND 40-FOOT WIND SPEED DATA

	Average Wind Speed (mph)	Frequency of Calms *5)
SPRING (March, April, May)	7.0	5.84
SUMMER (June, July, August)	6.2	7.54
FALL (September, October, November)	7.2	4.68
WINTER (December, January, February)	6.6	5.12
ANNUAL	6.7	5.88

B. Wind Direction Persistence

Wind persistence is important when considering possible dosages from a contaminant release. Wind persistence is a continuous flow from a given direction or range of directions. Figure 4 shows the probability of occurrence, based on 40-foot site data, of wind flow persistence in a 22 1/2° sector direction range greater than a time period, “t”. There is approximately a five percent chance of continuous persistence periods greater than 10 hours, and only a one percent chance of periods greater than 16 hours.

The maximum 22 1/2° range persistence episode recorded during the period of record was a 29 hour wind from the northwest. Wind turbulence was moderate during the period (neutral stability), and was associated with a high average wind speed of 18 mph. In general, persistence periods at Prairie Island are associated with quite high winds and relatively high or moderate turbulence.

Episodes of maximum wind persistence in 22 1/2° sectors are presented in Figure 5. No persistence episode greater than 15 hours associated with calm conditions was observed during the period of record.

Persistence episodes greater than, or equal to 12 hours occur most often with winds from the northwest through the west-northwest, and from the east-southeast through the south.

C. Atmospheric Stability

Atmospheric stability is important in describing the diffusive capacity of the atmosphere. Stable conditions are associated with low turbulence and poor atmospheric diffusive capacity. Unstable conditions are associated with high turbulence and favorable diffusive characteristics. Atmospheric stability, as used in this report, is classified into horizontal and vertical categories. The degree of wind turbulence (i.e., $\sigma\Theta$) is used to determine horizontal stability, and the vertical thermal structure (i.e, ΔT) is used to determine vertical stability. The classification used to categorize $\sigma\Theta$ and ΔT data have been presented in Tables I and II, respectively.

The annual frequency of various $\sigma\Theta$ and ΔT stability classes for Prairie Island and associated wind speeds are presented in Tables V and VI, respectively. It can be seen that a higher incidence of stable classes E, F, and G is indicated by the temperature difference data than by the $\sigma\Theta$ data (75.4% for the $\Delta T_{140'-40'}$ data, compared to 18.0% for the $\sigma\Theta$ data). This results from the frequent occurrence of surface-based inversions monitored at the site.

The seasonal and annual distributions of horizontal and vertical atmospheric stability are presented in Tables VII and VIII, respectively.

TABLE V PRAIRIE ISLAND 40-FOOT σΘ DATA (6/1/71 – 5/31/72) ANNUAL HORIZONTAL STABLITY AND WIND SPEED DISTRIBUTIONS

	A	**B**	**C**	**D**	**E**	**F**	**G**
Percent	4.01	6.73	23.28	47.92	14.46	1.20	0.38
Wind Speed (MPH)	3.4	4.4	7.6	8.1	3.3	2.9	6.1

TABLE VI PRAIRIE ISLAND $\Delta T_{140' - 40'}$ DATA (6/1/71 – 5/31/72) ANNUAL VERTICAL STABLITY AND WIND SPEED DISTRIBUTIONS

	A	B	C	D	E	F	G
Percent	2.76	1.40	1.18	19.23	54.62	15.24	5.67
Wind Speed (MPH)	6.7	8.4	8.2	8.5	7.6	4.0	2.5

TABLE VII PRAIRIE ISLAND 40-FOOT $\sigma\Theta$ DATA (6/1/71 – 5/31/72) ATMOSPHERIC HORIZONTAL STABILITY (%)

	UNSTABLE (A-C)	**NEUTRAL (D)**	**STABLE (E-G)**
SPRING (March, April, May)	30.46	50.91	18.64
SUMMER (June, July, August)	45.55	37.69	16.75
AUTUMN (September, October, November)	40.21	45.38	14.41
WINTER (December, January, February)	21.79	57.03	21.19
ANNUAL	34.05	47.92	18.04

TABLE VIII PRAIRIE ISLAND $\Delta T_{140' - 40'}$ DATA (6/1/71 – 5/31/72) ATMOSPHERIC VERTICAL STABILITY (%)

	UNSTABLE (A-C)	**NEUTRAL (D)**	**STABLE (E-G)**
SPRING (March, April, May)	12.11	27.61	60.27
SUMMER (June, July, August)	4.80	24.16	71.04
AUTUMN (September, October, November)	2.59	13.85	83.55
WINTER (December, January, February)	2.06	12.61	85.34
ANNUAL	5.34	19.23	75.43

It can be seen that σΘ unstable and neutral conditions, and ΔT stable conditions predominate at the site. The high incidence of ΔT stable conditions during the winter (85.3%) results from strong nighttime inversions which often persist into the day, presumably due to the deep snow cover.

The joint distributions of σΘ and ΔT classes on an annual basis are summarized in Table IX.

TABLE IX JOINT FREQUENCY OF σΘ (40′) AND $\Delta T_{140' - 40'}$ DATA (%)
PRAIRIE ISLAND (6/1/71 – 5/31/872)

σΘ Stability Classifications	**ΔT Stability Classifications**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
A	0.27	0.08	0.11	1.22	1.84	0.74	0.11
B	0.51	0.30	0.16	1.73	2.24	0.85	0.35
C	1.06	0.70	0.48	6.27	12.78	2.50	0.73
D	0.88	0.38	0.42	9.24	32.13	6.15	2.33
E	0.11	0.02	0.02	1.33	6.01	3.43	1.12
F	0.02	0.00	0.02	0.08	0.49	0.45	0.27
G	0.00	0.00	0.00	0.00	0.05	0.04	0.00

THIS PAGE IS LEFT INTENTIONALLY BLANK

VI. AVERAGE ATMOSPHERIC DILUTION

Annual average atmospheric dilution factors (χ/Q) have been determined for the Prairie Island site based on site 4-foot wind speed, wind direction, and temperature ($\Delta T_{140'-40'}$) data (temperature data were utilized to determine vertical dispersion parameters). The following standard Pasquill-Gifford diffusion equation for a ground-level release (neglecting the building wake) was utilized to determine sector-average concentrations:

$$X / Q = \sqrt{\frac{2}{\pi}} \left(\frac{8}{\pi}\right) \sum_{i}^{n} \frac{F_i f_i}{\sigma_z u x}$$

where:

X = concentration, units per cubic meter

Q = source strength, units per second

$\bar{u}$ = mean wind speed, meters per second

σ_z = vertical dispersion parameter based on temperature lapse rate data, meters

i = Pasquill stability categories (A - G) with numerical values (1 - 7)

n = number of stability classes (7, from A - G)

F_i = fraction of time stability conditions “i” exist

f_i = fraction of time wind associated with conditions “i”

x = distance downwind, meters

Dilution factors can be considered as relative concentrations, i.e., concentrations relative to source strength. Figure 6 shows the computed distributions of χ/Q values in sec/m^3 based on 6/1/71 - 5/31/72 site data. The configuration of χ/Q isopleths reflects the annual distribution of wind direction, wind speed, and vertical (ΔT) atmospheric stability. The highest value of χ/Q at the northwest site boundary, 1200 m from the release point, is 6.94×10^{-6} sec/m^3.

The maximum annual χ/Q value presented in the Environmental Report for Units 1 and 2 (3.3×10^{-6} sec/m^3) occurred at the east-southeast offsite boundary.(3) This value was calculated on the basis of wind data collected between 5/69 - 5/70. The increase of the maximum annual χ/Q at the exclusion distance by a factor of 2.1 in this current study is attributable primarily to the high incidence of stable vertical stability conditions monitored by the ΔT system.

VII. HYPOTHETICAL ACCIDENT METEOROLOGY

The on-site (6/1/71 - 5/31/72) meteorological data have been used to evaluate the hypothetical accident model for Prairie Island. A hypothetical accident is postulated to determine the concentrations and dosages that might occur in the event of a contaminant release, and a basic input is the meteorological conditions which determine the dilution capacity of the atmosphere.

As indicated in Table IV, the frequency of calms as measured by the Belfort instruments is quite high. This is attributable primarily to the high starting speed (about 2 mph) of the Belfort wind sensor. To investigate more thoroughly the frequency of calms occurring on-site, a Climet low threshold wind system was procured and installed in January 1972.

Tables X and XI compare wind speed and sQ data monitored by the Climet and Belfort instruments from 1/8/72 - 6/8/72 with the corresponding data monitored by the Belfort instrument from 6/1/71 - 5/31/72. During this five-month period in 1972, the data recovery was 93.9% for the Belfort system and 92.7% for the Climet system. Table X shows a lower incidence of calm conditions monitored by the Climet system than by the Belfort system during the five-month period. Also, the distribution of wind speeds monitored by the Belfort instrument during the five-month period is very similar to the annual wind speed distribution. Table XI shows a good correlation between the Belfort and Climet stability distributions over the five-month period.

The postulated accident conditions for the hypothetical accident period were determined on a quantitative statistical basis. Vertical stability parameters were determined from $\Delta T_{140'-40'}$ measurements, and horizontal stability parameters were determined from $\sigma\Theta$ measurements. The frequency of occurrence of each joint horizontal and vertical stability combination was tabulated (wind direction was not considered) for various wind speed ranges based on the computer printout data included in the Appendix. These meteorological conditions were ranked in order of the magnitude of their associated (χ/Q) values and are presented in Table XII and graphically in Figure 7. Calm conditions (winds ≤ 0.5 mph) occurring during the night were considered to result in the highest χ/Q values and were ranked first (calms during the day would generally be associated with unstable conditions and with meandering winds resulting in relatively low dosages at any given point). As indicated by the analysis of the 6/1/71 - 5/31/72 wind data, nighttime calms occurred for 4.74% of the total hours of the one-year study period. The frequency of nighttime calms as indicated by the Belfort and Climet systems during the 1/8/72 - 6/8/72 period was 4.77% and 0.24%, respectively. If the assumption is made that the 4.77:0.24 ratio of Belfort to Climet nighttime calms prevails throughout the year, than an annual Climet nighttime calm occurrence of 0.24% of the total annual hours can be deduced. This value is used in Table XII.

TABLE X COMPARISON OF PRAIRIE ISLAND 40-FOOT WIND SPEED DISTRIBUTION DATA

	% Occurrence of Indicated Wind Speed Class									
	0-0.5 mph	**0.5-2.5 mph**	**2.5-4.5 mph**	**4.5-6.5 mph**	**6.5-8.5 mph**	**8.5-11.5 mph**	**11.5-14.5 mph**	**14.5-18.5 mph**	**18.5-23 mph**	**>23 mph**
Belfort (6/1/71-5/31/72)	5.88	15.72	16.28	16.13	16.81	13.17	8.38	5.21	1.93	0.49
Belfort (1/8/72-6/8/72)	5.94	14.72	16.18	17.21	15.13	13.73	8.19	5.27	2.69	0.94
Climet (1/8/72-6/8/72)	0.42	8.51	8.51	17.26	17.56	17.53	10.77	7.05	3.90	0.39

TABLE XI COMPARISON OF PRAIRIE ISLAND 40-FOOT $\sigma\Theta$ DATA

	% Occurrence of Indicated Stability Class						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Belfort (6/1/72-5/31/72)	4.04	6.73	23.28	47.92	16.46	1.20	0.38
Belfort (1/8/72-6/8/72)	1.61	5.59	20.25	51.90	19.58	1.26	0.00
Climet (1/8/72-6/8/72)	2.68	4.58	21.17	50.94	17.21	3.22	0.21

TABLE XIV PRAIRIE ISLAND – SITE ACCIDENT DISPERSION FACTORS (SEC/M^3)

Distance (m)	0-8 hr Accident	8-24 hr	1-4 Days	4-30 Days
400	1.00 x 10^{-3}	7.05 x 10^{-4}	1.28 x 10^{-4}	1.92 x 10^{-5}
700	6.61 x 10^{-4}	2.69 x 10^{-4}	4.82 x 10^{-5}	7.16 x 10^{-6}
715	6.49 x 10^{-4}	2.59 x 10^{-4}	4.65 x 10^{-5}	6.90 x 10^{-6}
1,000	4.69 x 10-^{4}	1.47 x 10^{-4}	2.63 x 10^{-5}	3.88 x 10^{-6}
2,000	2.01 x 10^{-4}	4.62 x 10^{-5}	8.25 x 10^{-6}	1.20 x 10^{-6}
4,000	8.37 x 10^{-5}	1.59 x 10^{-5}	2.80 x 10^{-6}	4.07 x 10^{-7}
7,000	4.24 x 10^{-5}	7.26 x 10^{-6}	1.26 x 10^{-6}	1.77 x 10^{-7}
10,000	2.73 x 10^{-5}	4.42 x 10^{-6}	7.62 x 10^{-7}	1.06 x 10^{-7}
20,000	1.24 x 10^{-5}	1.75 x 10^{-6}	2.97 x 10^{-7}	4.04 x 10^{-8}
33,000	6.96 x 10^{-6}	9.17 x 10^{-7}	1.53 x 10^{-7}	2.16 x 10^{-8}
40,000	5.58 x 10^{-6}	7.15 x 10^{-7}	1.19 x 10^{-7}	1.59 x 10^{-8}
42,000	5.30 x 10^{-6}	6.73 x 10^{-7}	1.12 x 10^{-7}	1.50 x 10^{-8}
70,000	3.11 x 10^{-6}	3.54 x 10^{-7}	5.83 x 10^{-8}	7.72 x 10^{-9}
100,000	2.09 x 10^{-6}	2.26 x 10^{-7}	3.69 x 10^{-8}	4.87 x 10^{-9}

A 5th percentile χ/Q of 6.50×10^{-4} sec/m^3 at the exclusion boundary distance of 715 m has been graphically interpolated from Figure 7. This χ/Q value has been used to calculate an equivalent "Class F" wind speed condition of 0.89 m/s. (In NUS-695) was utilized.(4)) The meteorological conditions for a hypothetical accident are summarized in Table XIII for Prairie Island. In Table XIII, F_i and f_i are quantitative estimates of the frequency of occurrence of the meteorological conditions assumed for the accident. Invariant wind conditions refer to winds that do not vary indirection; sector average conditions occur when winds prevail within a 22 1/2° sector as used for this model. For time periods greater than 8 hours, the AEC Standard meteorological model was used.

TABLE XII PRAIRIE ISLAND PROBABILITY AT EXCLUSION DISTANCE (715 m) (6/1/71 – 5/31/72)

χ/Q (sec/m^3) Building Wake = 0.5 x 1500m^2)	σ_y ($\sigma\Theta$)	c_z ($\Delta T_{140'\text{-}40'}$)	$\bar{u}$ (mph)	Freq. (%)	Σ Freq. (%)
- - -	(Night)		Calm	0.24	0.24
1.97 x 10^{-3}	G	G	1.0	0.00	0.24
1.64 x 10^{-3}	F	G	1.0	0.09	0.33
1.64 X 10^{-3}	G	F	1.0	0.04	0.37
1.37 x 10^{-3}	E	G	1.0	0.43	0.80
1.29 x 10^{-3}	F	F	1.0	0.17	0.97
1.27 x10^{-3}	G	E	1.0	0.02	0.99
1.18 x 10^{-3}	D	G	1.0	0.74	1.73
1.04 x 10^{-3}	G	D	1.0	0.00	1.73
1.04 x 10^{-3}	E	F	1.0	0.65	2.38
9.50 x 10^{-4}	F	E	1.0	0.21	2.59
9.21 x 10^{-4}	G	G	2.0	0.00	2.59
8.81 x 10^{-4}	C	G	1.0	0.32	2.91
8.68 x 10^{-4}	D	F	1.0	0.89	3.80
7.67 x 10^{-4}	F	G	2.0	0.02	3.82
7.67 x 10^{-4}	G	F	2.0	0.00	3.82
7.51 x 10^{-4}	F	D	1.0	0.00	3.82
7.35 x 10^{-4}	E	E	1.0	0.85	4.67
7.03 x 10^{-4}	B	G	1.0	0.11	4.78
6.55 x 10^{-4}	G	G	3.0	0.00	4.78
6.42 x 10^{-4}	E	G	2.0	0.14	4.92
6.28 x 10^{-4}	G	C	1.0	0.00	4.92
6.23 x 10^{-4}	C	F	1.0	0.74	5.66
6.05 x 10^{-4}	F	F	2.0	0.10	5.76
5.99 x 10^{-4}	D	E	1.0	1.40	7.16
5.96 x 10^{-4}	G	E	2.0	0.00	7.16
5.68 x 10-^{4}	E	D	1.0	0.16	7.32
5.56 x 10^{-4}	A	G	1.0	0.04	7.36
5.52 x 10^{-4}	D	G	2.0	0.41	7.77
5.45 x 10^{-4}	F	G	3.0	0.03	7.80
5.45 x 10^{-4}	G	F	3.0	0.00	7.80
4.87 x 10^{-4}	G	D	2.0	0.00	7.80
4.86 x 10^{-4}	E	F	2.0	0.41	8.21
4.84 x 10^{-4}	B	F	1.0	0.37	8.58
4.60 x 10^{-4}	G	G	4.0	0.00	8.58

TABLE XIII METEOROLOGICAL MODEL – DESIGN BASIS ACCIDENT

Time Period	Stability Class	Wind Speed (m/s)	Fi[a]	fi[b]	Wind Conditions
0 - 8 hours	F	0.89	1.0	1.0	Invariant
8 - 24 hours	F	1	1.0	1.0	Sector Averaged
1 - 4 days	D	3	0.4	0.5	Sector Averaged
	F	2	0.6	0.5	Sector Averaged
4 - 30 days	C	3	0.333	0.111	Sector Averaged
	D	3	0.333	0.111	Sector Averaged
	F	2	0.333	0.111	Sector Averaged

(a) Fi is the fraction of the time stability category “i” occurs.

(b) fi is the fraction of the time when the wind is directed toward the sector of interest for stability category “i”.

Dilution factors (χ/Q) were calculated using Equation 1 for invariant winds and Equation 2 for sector averages. A correction term to account for the additional initial diffusion resulting from the building wake effect is included for invariant wind conditions.

Equation 1

$$\frac{\chi}{Q} = \frac{1}{\left(\pi\sigma_y\sigma_z + cA\right)\bar{u}}$$

Equation 2

$$\frac{\chi}{Q} = \left(\frac{2}{\pi}\right)^{1/2} \frac{8}{\pi} \sum_i \frac{F_i f_i}{\left(\sigma_{z_i}\right) x\bar{u}}$$

x = downwind distance, meters

χ = concentration, units per cubic meter

Q = source strength, units per second

$\bar{u}$ = mean wind speed, meters per second

$\sigma_{y'}$ σ_z = lateral and vertical dispersion parameters, meter

c = building shape factor, dimensionless (0.5 for this study)

A = smallest cross sectional area of the containment structure, (1500 cm^2)

i = Pasquill stability categories (A-G (numerically 1-7)

F_i = fraction of time stability condition “i” exists

f_i = fraction of time winds occur from sector of interest with condition “i”

The diffusion is assumed to be Gaussian, i.e., horizontal and vertical distributions perpendicular to the plume centerline have Gaussian properties.

A graph depicting dilution factors based on the meteorological model for a hypothetical accident is presented in Figure 8, with discrete data given in Table XIV.

Short-term accident dilution factor values (χ/Q) are larger (indicative of poorer diffusion conditions) than those based on conditions postulated in the Prairie Island FSAR. This increase is due to the utilization of ΔT data in this current study, which indicates a high incidence of stable conditions at the site.

VIII. REFERENCES

1. Slade, D. H., “Dispersion Estimates From Pollutant Releases of a Few Seconds to Eight Hours in Duration,” Technical Note 2 - ARL - 1, ESSA, 1965.

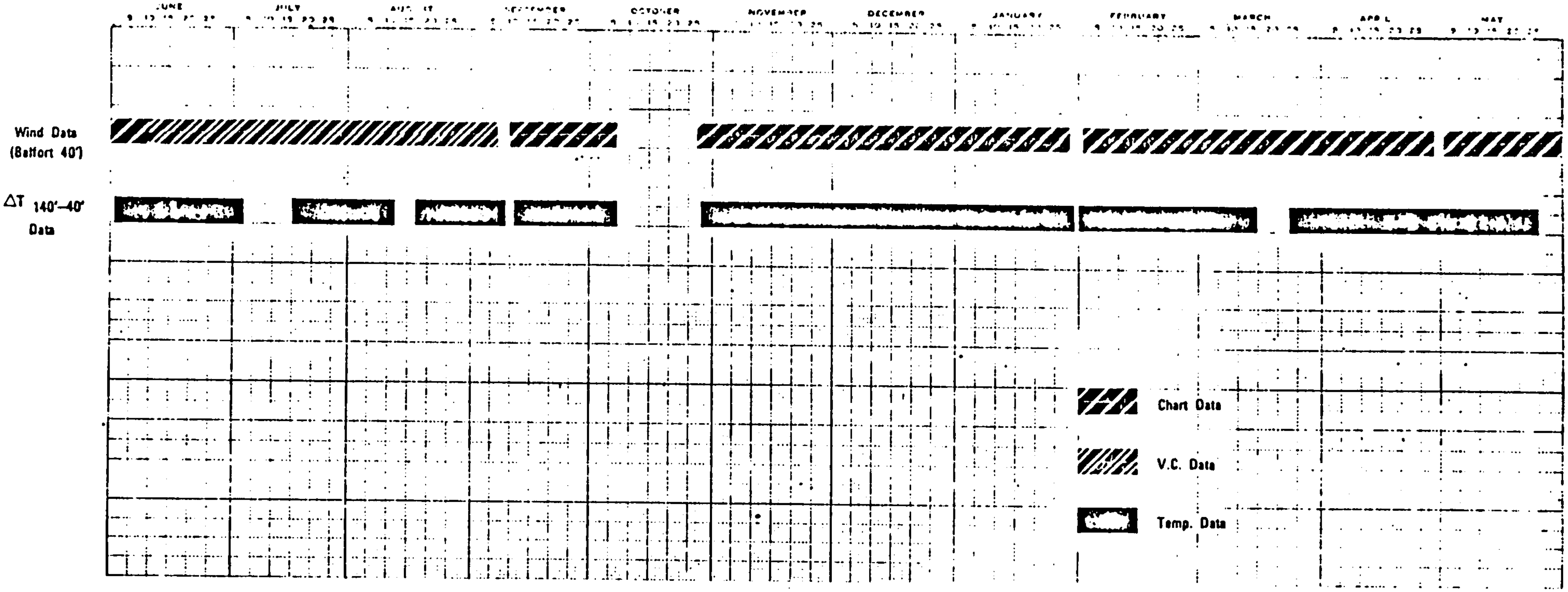
2. Pasquill, F., “Estimates of the Dispersion of Windborne Material,” Meteorology Magazine, (96), 1961.

3. Calley, Harry W., Jr., Fontecilla, Herbert M., and Goodwin, E., “Estimation of the Population Doses Resulting From Radioactive Effluents From the Prairie Island Nuclear Plant,” NUS-841, October 1971. Appearing as Appendix H of the NSP Prairie Island Nuclear Generating Plant Environmental Report, Volume II.

4. Muschett, F. Douglas, “The Meteorological Program at the Prairie Island Nuclear Power Station Site, October 1967 - May 1970,” NUS-695, July 1970.

5. Safety Guide 23, Onsite Meteorological Programs, Atomic Energy Commission, February, 1972.

THIS PAGE IS LEFT INTENTIONALLY BLANK



*Recoverable wind data is defined as simultaneous valid wind speed, wind direction, and wind variance.

**Graph indicates periods of missing data for duration ≥ one day.

Figure 1 PRAIRIE ISLAND DATA RECOVERY*SUMMARY**
(6/1/71 – 5/31/72)

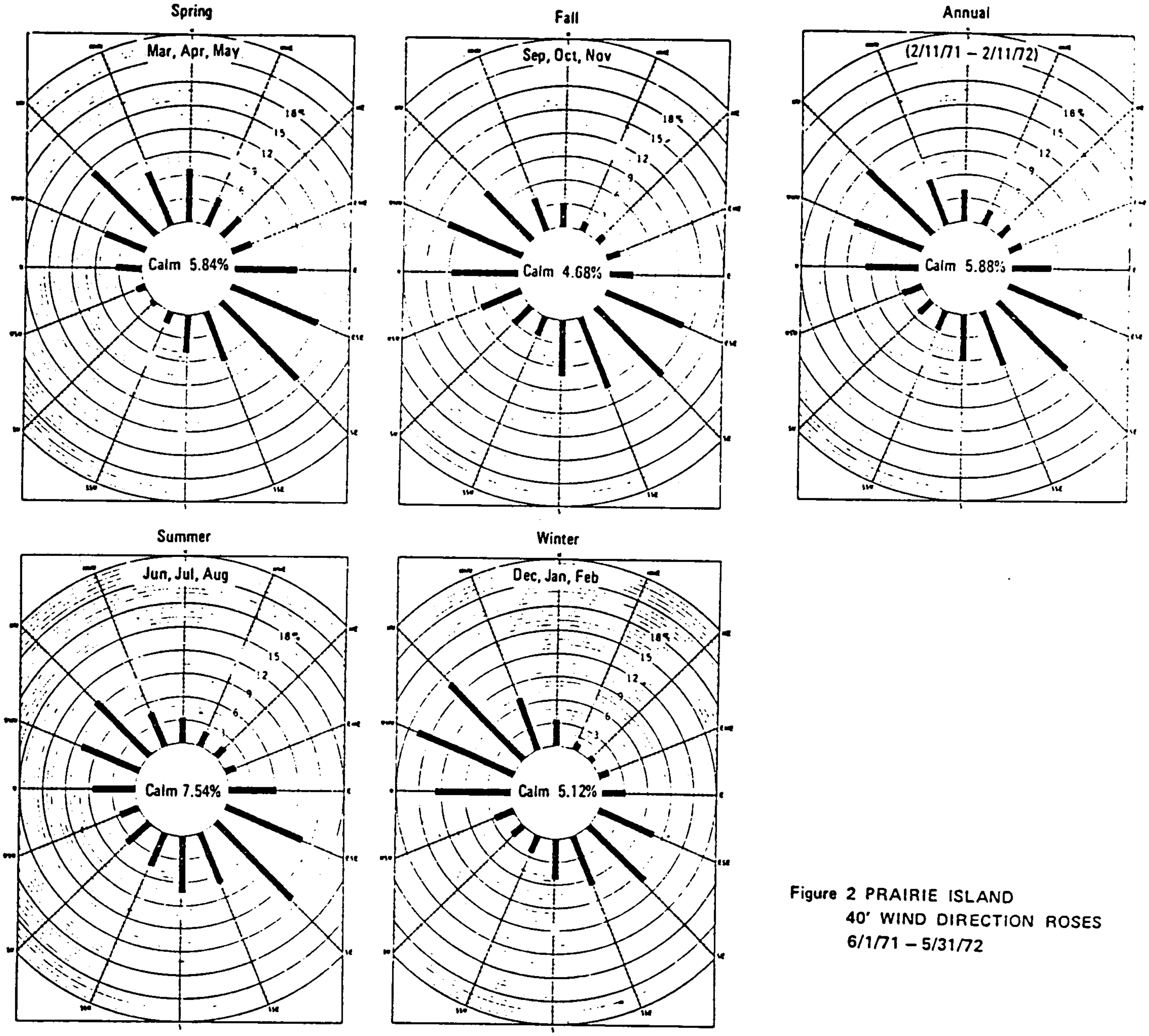


Figure 2 PRAIRIE ISLAND
40' WIND DIRECTION ROSES
6/1/71 – 5/31/72

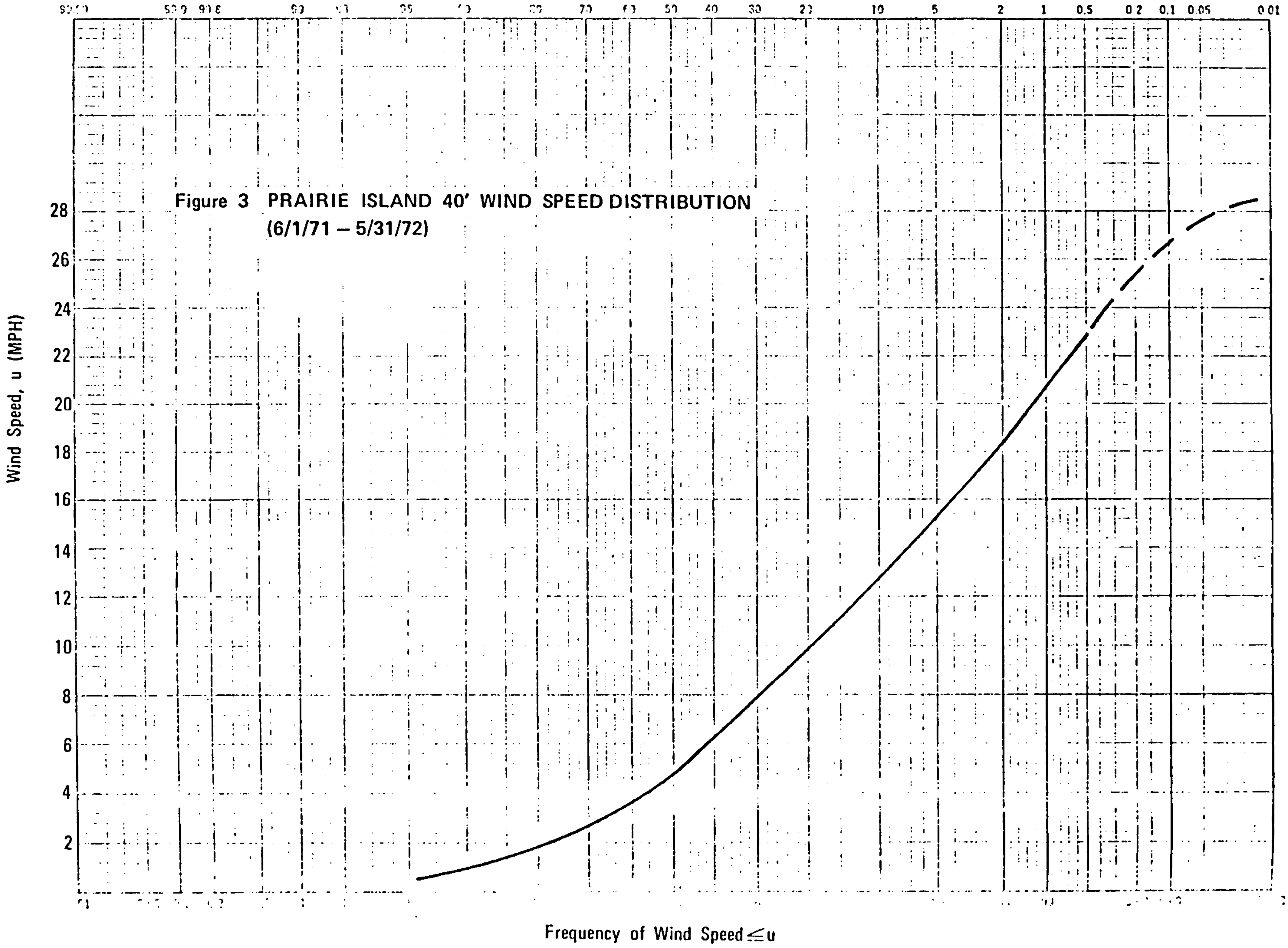
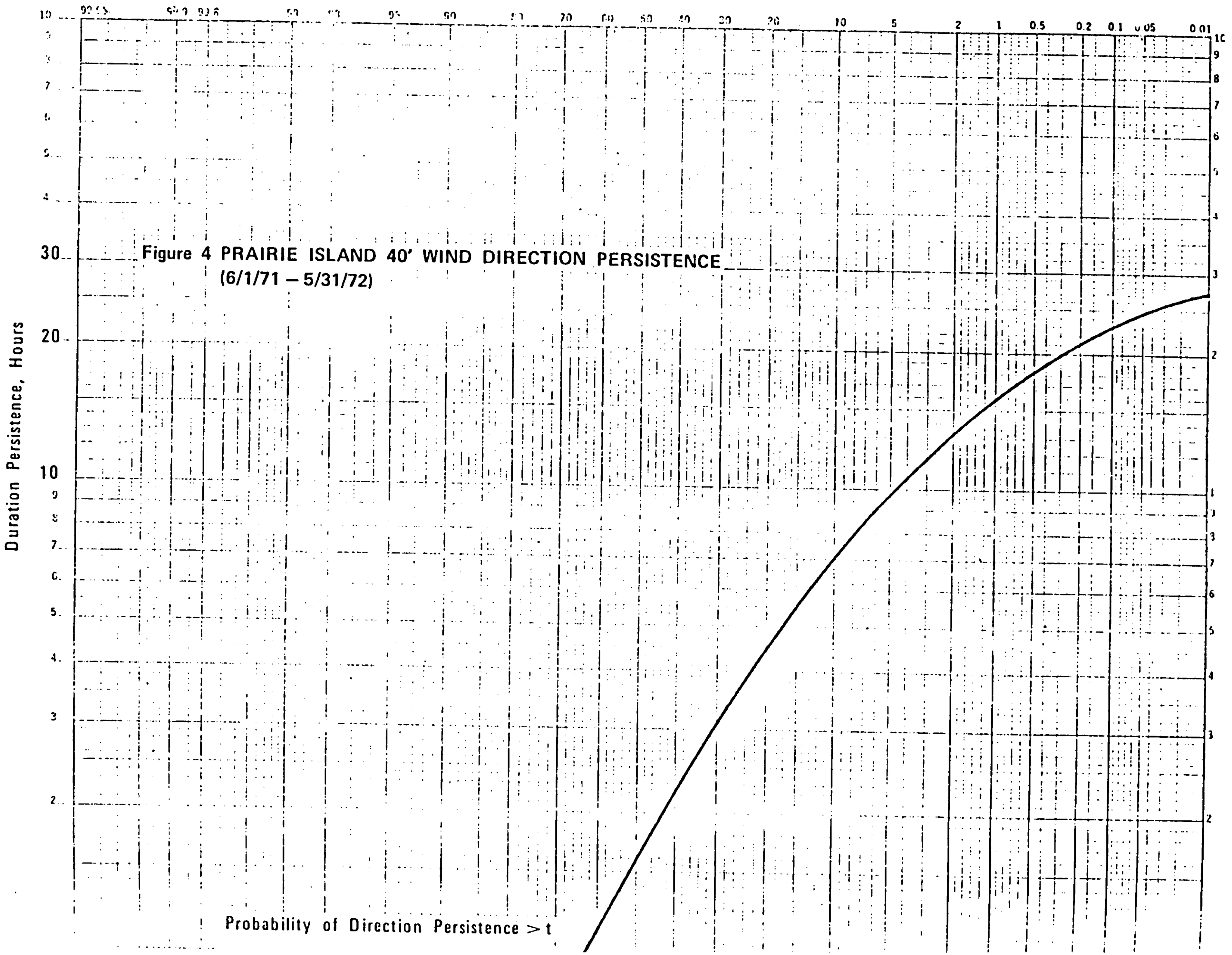


Figure 3 PRAIRIE ISLAND 40' WIND SPEED DISTRIBUTION
(6/1/71 – 5/31/72)



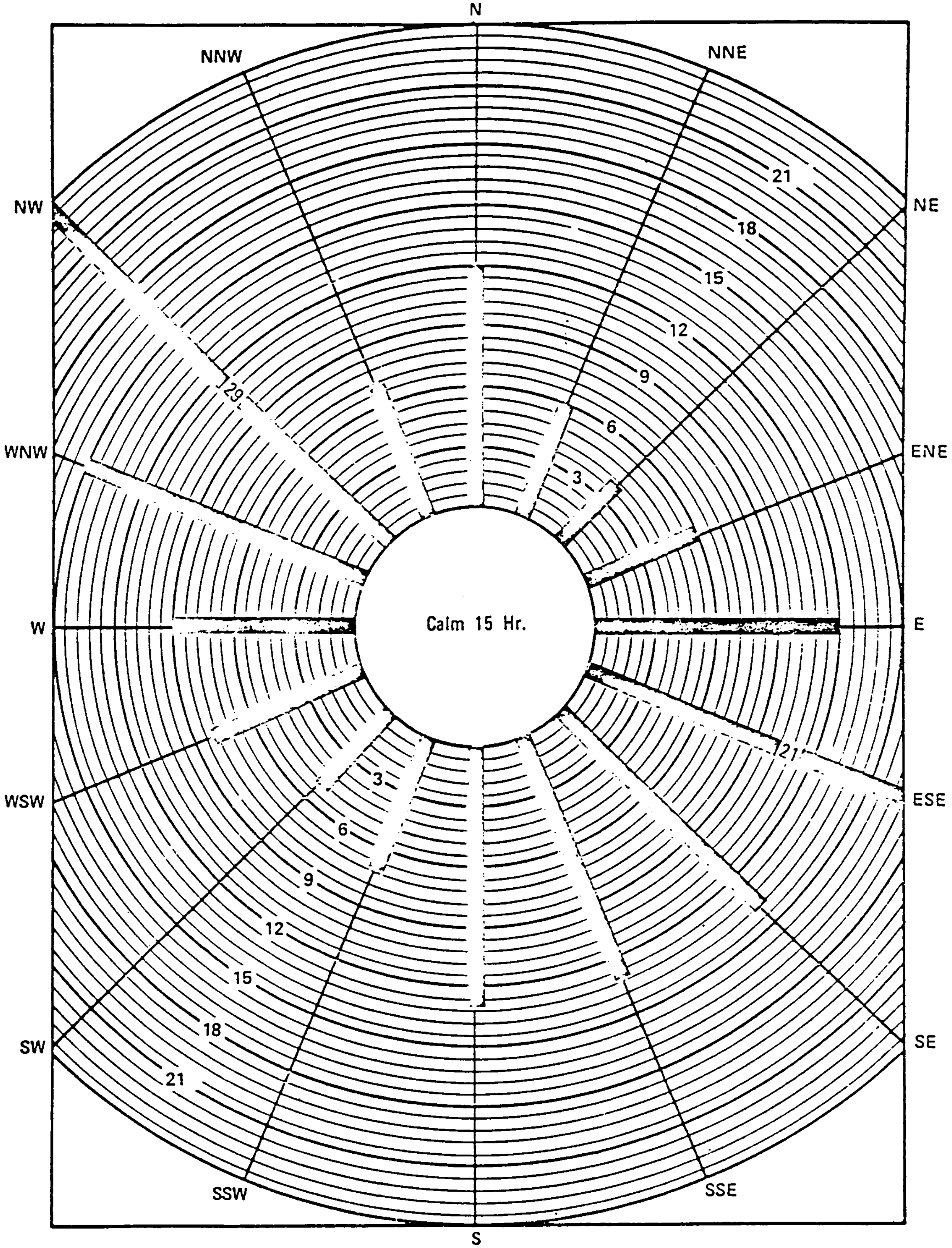


Figure 5 PRAIRIE ISLAND 40 FT. PERSISTENCE WIND ROSE
(Max. No. of Hours Wind Blows from Each Direction)
6/1/71 – 5/31/72

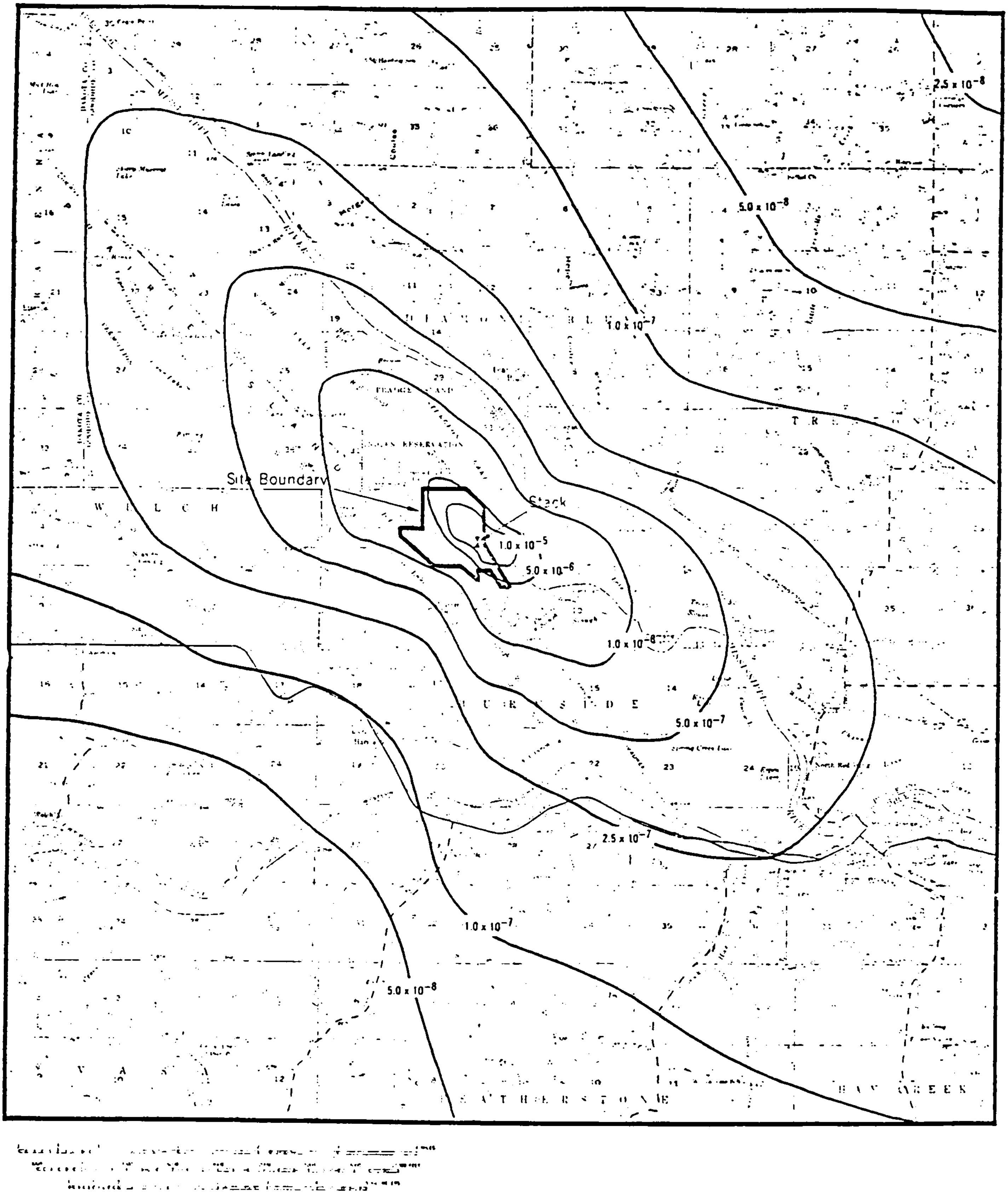


Figure 6 PRAIRIE ISLAND AVERAGE DISPERSION ISOPLETHS (sec/m^3)
BASED ON 40′ LEVEL WIND DIRECTIONAL DATA
AND 140′ – 40′ ΔT DATA (6/1/71 – 5/31/72)

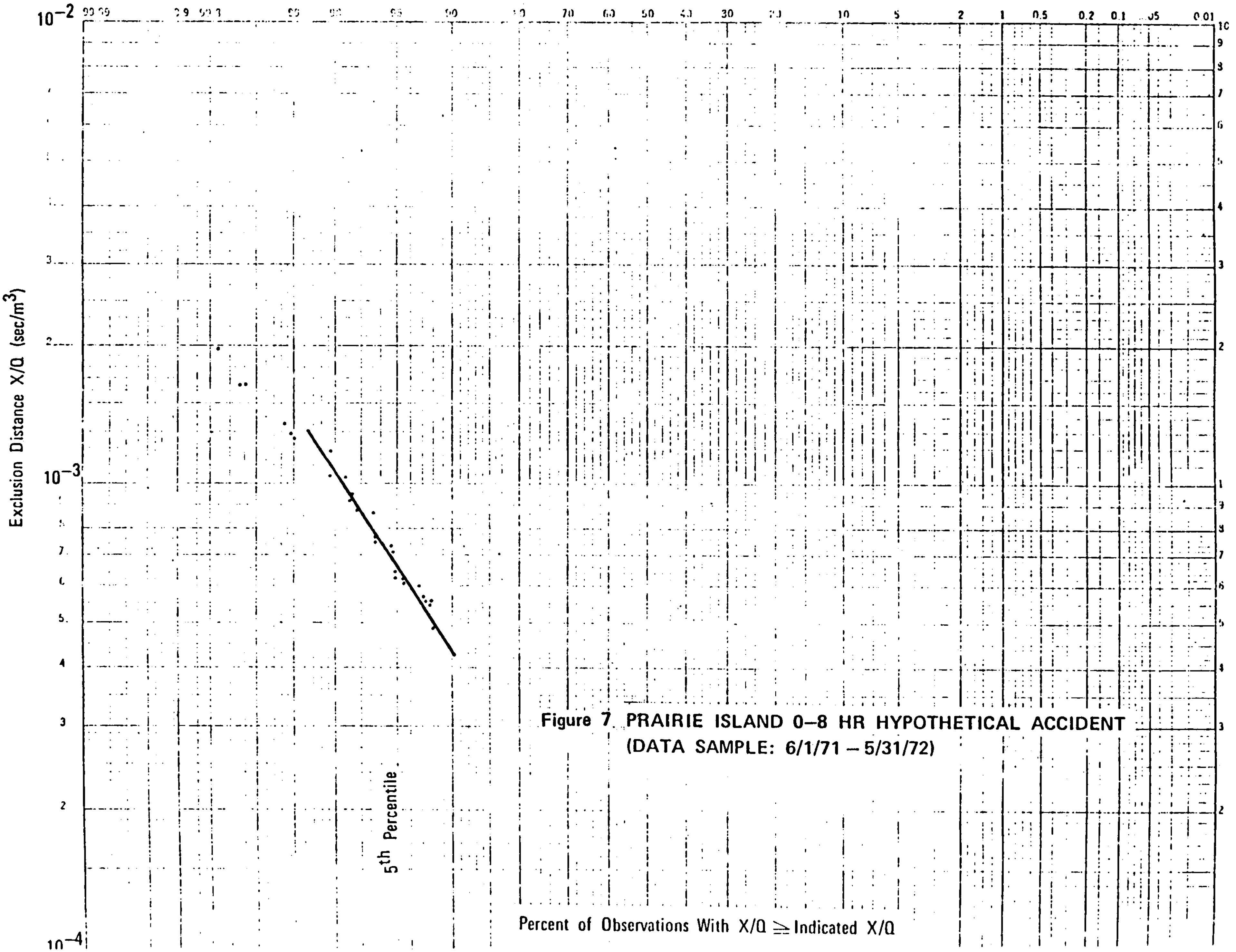


Figure 7 PRAIRIE ISLAND 0–8 HR HYPOTHETICAL ACCIDENT
(DATA SAMPLE: 6/1/71 – 5/31/72)

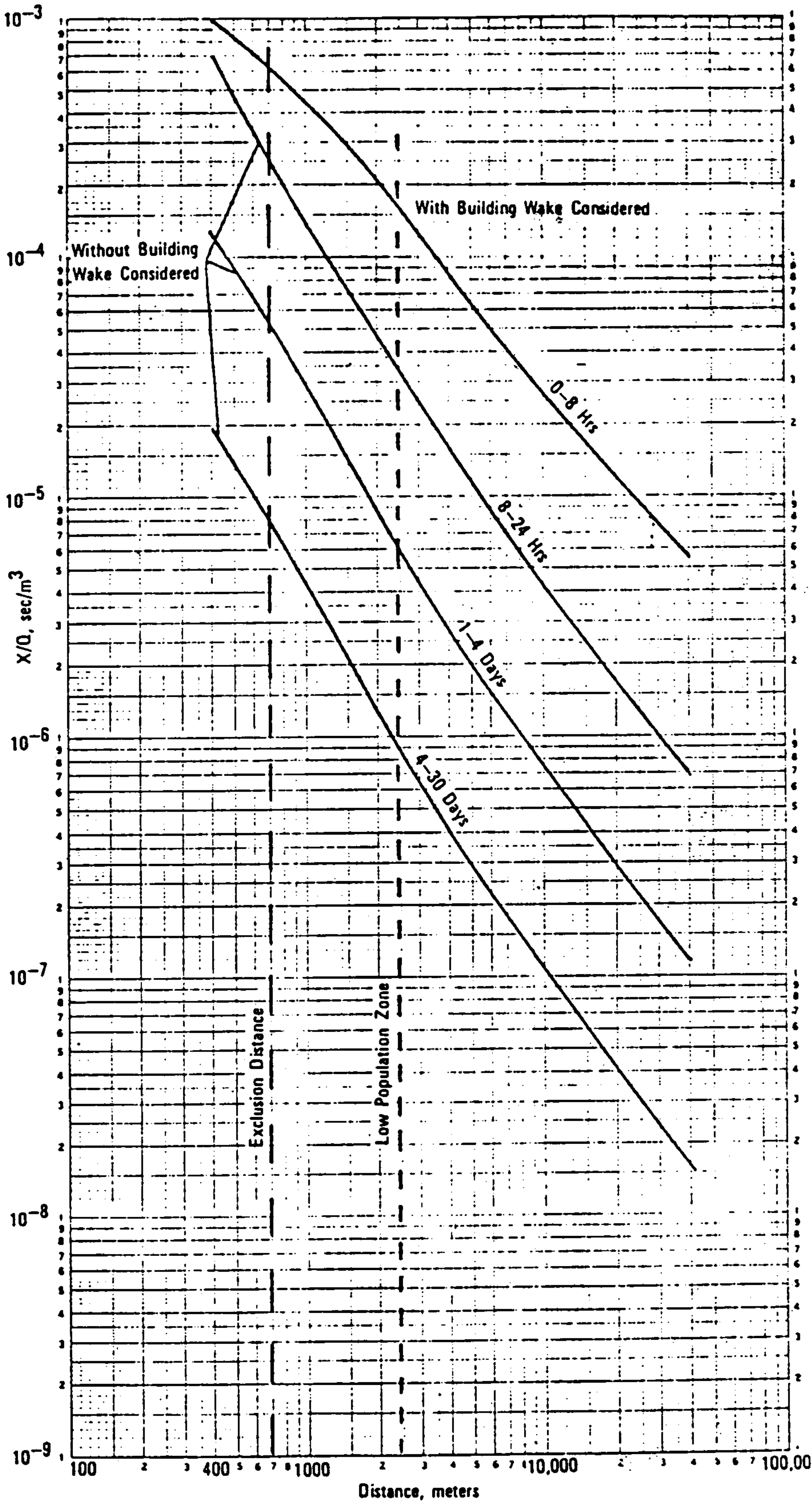


Figure 8 PRAIRIE ISLAND HYPOTHETICAL ACCIDENT METEOROLOGY (Building Wake Factor = 0.5 x 1500 m²)