APPENDIX 2.3A

THE BERKLEY TOWNSHIP TORNADO: A REASSESSMENT OF THE TORNADO HAZARD PROBABILITY FOR OYSTER CREEK NUCLEAR GENERATING STATION

THE BERKLEY TOWNSHIP TORNADO:
A REASSESSMENT OF THE TORNADO HAZARD
PROBABILITY FOR OYSTER CREEK NUCLEAR GENERATING STATION

By

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October 1982

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EXECUTIVE SUMMARY

The purpose of this report is to document the weather conditions associated with the Berkeley Township tornado and also evaluate whether the occurrence of the tornado is consistent with the tornado hazard probability discussed in the Oyster Creek Generating Station Environmental Report.

The tornado struck Berkeley Township between 7:15 P.M. and 7:30 P.M. (EDT) on June 29, 1982. The storm path was 50 to 75 feet wide and about 1.5 miles long. One hundred homes sustained damage and several people were injured. Wind speeds were estimated between 113 and 157 mph.

At about the time of the tornado, one-half to one inch of rain fell at the Oyster Creek site meteorological tower. Maximum wind speeds were 13 mph at the lower level of the tower and 31 mph at the upper level.

An evaluation of whether this tornado is consistent with the tornado hazard probability discussed in the Oyster Creek Environmental Report revealed that the Oyster Creek report hazard probabilities are outdated, but not because of the occurrence of the Berkeley Township tornado. Rather, they are outdated because of the availability of more recent high quality, computerized tornado data and the use of more refined statistical methods, neither of which were available prior to 1972, the year the Oyster Creek Environmental Report was published.

The Environmental Report based the computation of tornado hazard probability at Oyster Creek in part on data from 225 Iowa and Kansas tornados that occurred during the years 1953-1962. Iowa and Kansas tornados, however, are much more severe than New Jersey tornados. More recent technical reports based the tornado hazard probability at Oyster Creek on 110 tornados that occurred in New Jersey and neighboring states during the years 1971-1978.

The use of Iowa and Kansas tornados made the tornado hazard probabilities in the Environmental Report extremely conservative. Using New Jersey area tornados, the mean recurrence interval of a tornado occurring at a point is no shorter than 10,000 years, as compared with 2170 years stated in the Environmental Report. Six to seven tornados per year are expected to occur in an area of land within approximately 125 miles of the Oyster Creek Nuclear Plant. Both this report and the Oyster Creek SEP indicate almost identical tornado hazard probabilities. Reg. Guide 1.76 and WASH 1300, however, indicate slightly greater tornado hazard probabilities.

This report represents six man weeks of effort.

1. INTRODUCTION

At 7:30 P.M. (EDT) on June 29, 1982, a tornado touched down in Berkley Township, N. J., about 10 miles north of the Oyster Creek Nuclear Power Plant.

The purpose of this brief report is to, first, describe the weather conditions associated with this storm, and second, to evaluate whether the occurrence of this tornado is consistent with the tornado hazard probability discussed in the Oyster Creek Environmental Report.

Weather conditions are discussed in Section 2 of this report and the tornado hazard probability is discussed in Section 3.

2. WEATHER CONDITIONS PRECEDING AND ACCOMPANYING TORNADO

2.1 General Weather Conditions and Forecasts for N. J. and Vicinity

On June 29, 1982 a warm, humid air mass covered the middle Atlantic states with a cold front passing through central Pennsylvania in mid-afternoon. Temperatures ranged from the mid 70's to low 80's under partly cloudy to cloudy skies. Winds were either variable or southerly at 5-10 mph.

Rain showers and thunderstorms were scattered in New Jersey, New York, Pennsylvania and Delaware. Some areas of Pennsylvania received 1 to 2 inches of rain during the day in locally heavy downpours. During the mid-afternoon and evening hours, National Weather Service weather radar in Atlantic City showed rainfall of "light" to "very heavy" intensity falling from showers and thunderstorms in eastern Pennsylvania and New Jersey. At 7:30 P.M. on June 29, when the tornado struck Berkley Township, the Atlantic City weather radar showed rainfall of "unknown, but probably heavy" intensity in central and southern New Jersey. (Rainfall intensity is a gross measure of thunderstorm severity; severe thunderstorms can spawn tornados.)

Forecasts for eastern Pennsylvania and New Jersey, issued at 5 P.M. EDT on June 29, called for showers and thunderstorms during the evening. The possibility of severe thunderstorms and tornados was not mentioned in the forecasts. After the Berkley Township tornado was reported, however, the National Weather Service Office in Atlantic City issued a severe thunderstorm and tornado warning for Ocean County and adjacent coastal waters.

2.2 Weather Conditions at the Oyster Creek Meteorological Tower

Aside from the 1/2 to 1 inch of rain that fell at the met tower between 6:30 and 9:30 P.M. (EDT) on June 29, nothing at the tower indicated severe weather. The met tower continued to function. The highest 15-minute average wind speed was 13 mph at the 33-ft. level and 31 mph at the 380-ft. level,

both measured during the onset of the rain. Winds before the rain were from the south-southwest and from the west-southwest thereafter. The temperature remained near 70 degrees and the relative humidity near 100% through the late afternoon and evening hours.

2.3 Eyewitness Accounts and National Weather Service Description of Tornado

The tornado touched down in the west section of Silver Ridge Park in Berkley Township between 7:15 P.M. and 7:30 P.M. (EDT), moving in an easterly-northeasterly direction. The storm path was 50 to 75 feet wide and about 1.5 miles long.

An eyewitness reported two "tubes" hanging down from the clouds that merged into one and hit the house next to his home, which was destroyed. Other people interviewed reported seeing only one funnel. Much of the time, the tornado was apparently at roof-top level; most damage was to roofs and TV antennas. The most severe damage occurred where the tornado reached ground level.

One hundred homes sustained damage - 15 homes were totally damaged, 40 homes were seriously damaged. Seven automobiles were damaged; four were totally damaged. Damage estimates were $1.5 million. From 2 to 30 people suffered injuries (depending on the source of the report).

2.4 Estimate of Wind Speeds in the Tornado

Direct measurements of wind speeds in the Berkley Township tornado were not available. As is usually, if not always, the case with tornados, wind speeds must be estimated indirectly from a general damage description of tornado destruction. The wind speeds in the Berkley Township tornado were estimated using the method of Fujita (1971).

Fujita (1971) proposed a rating system, now widely recognized, whereby tornado intensity (i.e., wind speed) is judged on the basis of damage appearence. Six intensity levels of the Fujita scale, or F-scale, were defined. Each intensity classification has an associated wind speed range. Table 1 presents a general damage description of the destruction expected within each F-scale classification. The intensity assigned to a tornado is based on the worst damage within the tornado path.

TABLE 1

F-SCALE CLASSIFICATION OF TORNADO INTENSITY BASED ON DAMAGE (FUJITA, 1973)

(F0) LIGHT DAMAGE 40-72 mph

This speed range corresponds to Beaufort 9 through 11. Some damage to chimneys or TV antennae; breaks branches off trees; pushes over shallow-rooted trees; old trees with hollow inside break or fall; sign boards damaged.

(F1) MODERATE DAMAGE 73-112 mph

73 mph is the beginning of hurricane wind speed or Beaufort 12. Peels surface off roofs; windows broken; trailer houses pushed or overturned; trees on soft ground uprooted; some trees snapped; moving autos pushed off the road.

(F2) CONSIDERABLE DAMAGE 113-157 mph

Roof torn off frame houses leaving strong upright walls standing; weak structure or outbuildings demolished; trailer houses demolished; railroad boxcars pushed over; large trees snapped or uprooted; light-object missiles generated; cars blown off highway; block structures and walls badly damaged.

(F3) SEVERE DAMAGE 158-206 mph

Roofs and some walls torn off well-constructed frame houses; some rural buildings completely demolished or flattened; trains overturned; steel framed hangar-warehouse type structures torn; cars lifted off the ground and may roll some distance; most trees in a forest uprooted, snapped, or leveled; block structures often leveled.

(F4) DEVESTATING DAMAGE 207-260 mph

Well-constructed frame houses leveled, leaving piles of debris; structure with weak foundation lifted, torn, and blown off some distance; trees debarked by small flying debris; sandy soil eroded and gravels fly in high winds; cars thrown some distances or rolled considerable distance finally to disintegrate; large missiles generated.

(F5) INCREDIBLE DAMAGE 261-318 mph

Strong frame houses lifted clear off foundation and carried considerable distance to disintegrate; steel-reinforced concrete structures badly damaged; automobile-sized missiles fly through the distance of 100 yds. or more; trees debarked completely; incredible phenomena can occur.

For the Berkley Township tornado, a comparison of both newspaper photographs of the damage and written descriptions of the damage with the descriptions in Table 1 suggests that the tornado was a category F2. An F2 tornado is characterized by winds between 113 and 157 miles per hour. Please note that these winds were sustained only in the area where the worst damage occurred, not the entire length of the tornado path.

3. REASSESSMENT OF THE TORNADO HAZARD PROBABILITY FOR OYSTER CREEK NUCLEAR GENERATING STATION

The Oyster Creek Environmental Report (March 6, 1972) only briefly addresses the question of tornado hazard probability. It states that the recurrence interval of a tornado is 2170 years, and that the calculation of this number is based on the method of Thom (1963).

Although Thom's method has served as the basis for many tornado probability studies since 1963, the methodology, by today's standards, is at best crude, and the data, which was tornado data for Iowa and Kansas, not applicable to New Jersey.

The Oyster Creek Environmental Report also does not address the expected intensity of the tornado, or equivalently, the expected wind speeds in the tornado, which can vary anywhere from 40 to 318 miles per hour.

This section updates the tornado hazard probability for Oyster Creek using more refined methods and more recent and applicable tornado data. The refined methods and more recent data described herein were originally presented in an NRC sponsored report entitled Tornado and Straight Wind Hazard Probability for Oyster Creek Nuclear Power Reactor Site, New Jersey (MacDonald, 1982). This section condenses and simplifies the contents of that report.

3.1 Methodology

In basic terms, the probability, P, of a tornado striking a point is given by the relation (Abbey, 1976):

$$P = \begin{matrix}\text{Number of tornados per year} \\ \text{in geographical region}\end{matrix} \times \frac{\text{Tornado path area}}{\text{Total area of geographical region}}$$

To compute the probability of a tornado striking a point, the geographical region must be defined first. For Oyster Creek, obviously, the geographic region should include the Oyster Creek site. The geographic region should also be as large as possible and still give a reasonably homogeneous condition for tornado formation, i.e., the conditions for tornado formation anywhere in the region should remain fairly representative of the Oyster Creek site.

A region that satisfies the above criteria is a rectangular area bounded by latitude 38°N to the south, latitude 42°N to the north, longitude 73°W to the east, and longitude 77°W to the west. The geographical region is shown in Figure 1.

To compute the probability of a tornado striking a point within this region, the number of tornados per year and the tornado path area must be known. These parameters are discussed in the next two sections.

3.2 <u>Tornado Frequency</u>

Figure 2 illustrates the historical trend of tornado frequency for N. J. and also for an area within 125 nautical miles of the Oyster Creek Nuclear Plant. This data is presented for illustrative purposes only. Similar data for the rectangular geographic region described above was not readily available. Nevertheless, note that the annual number of tornados for the 8-year period beginning in 1973 is much higher than for the previous 23 years. Apparently, a campaign in the early 1970's to encourage tornado reporting and documentation by the National Weather Service, Red Cross, and civil defense officials accounts for most of the increase (Abbey, 1982). Natural climatic variability is not a factor in the increase.

To compute the probability of a tornado striking a point within the rectangular region, the number of tornados per year must be known. Figure 3 shows the annual average number of tornados that have occurred during the 29-year period 1950-1978. The annual average number of tornados is shown as a function of tornado intensity. (See Table 1 in Section 2.4 for a description of tornado intensities). As can be seen in the figure, slightly over 6 tornados annually have occurred in the 29-year period. F1 tornados were most frequent, occurring 3-4 times per year. All tornados reported had an intensity of F3 or less, i.e., wind speeds of 206 mph or less.

A statistical analysis of the data in Figure 3 gives the number of tornados expected to occur during any given year. This is the number that will be inserted in the above relation (Section 3.1). The number of tornados expected to

FIGURE -. THE GEOGRAPHICAL REGION FOR WHICH TORNADO HAZARD PROBABILITIES WERE CALCULATED
(Geographical region is within dashed lines)

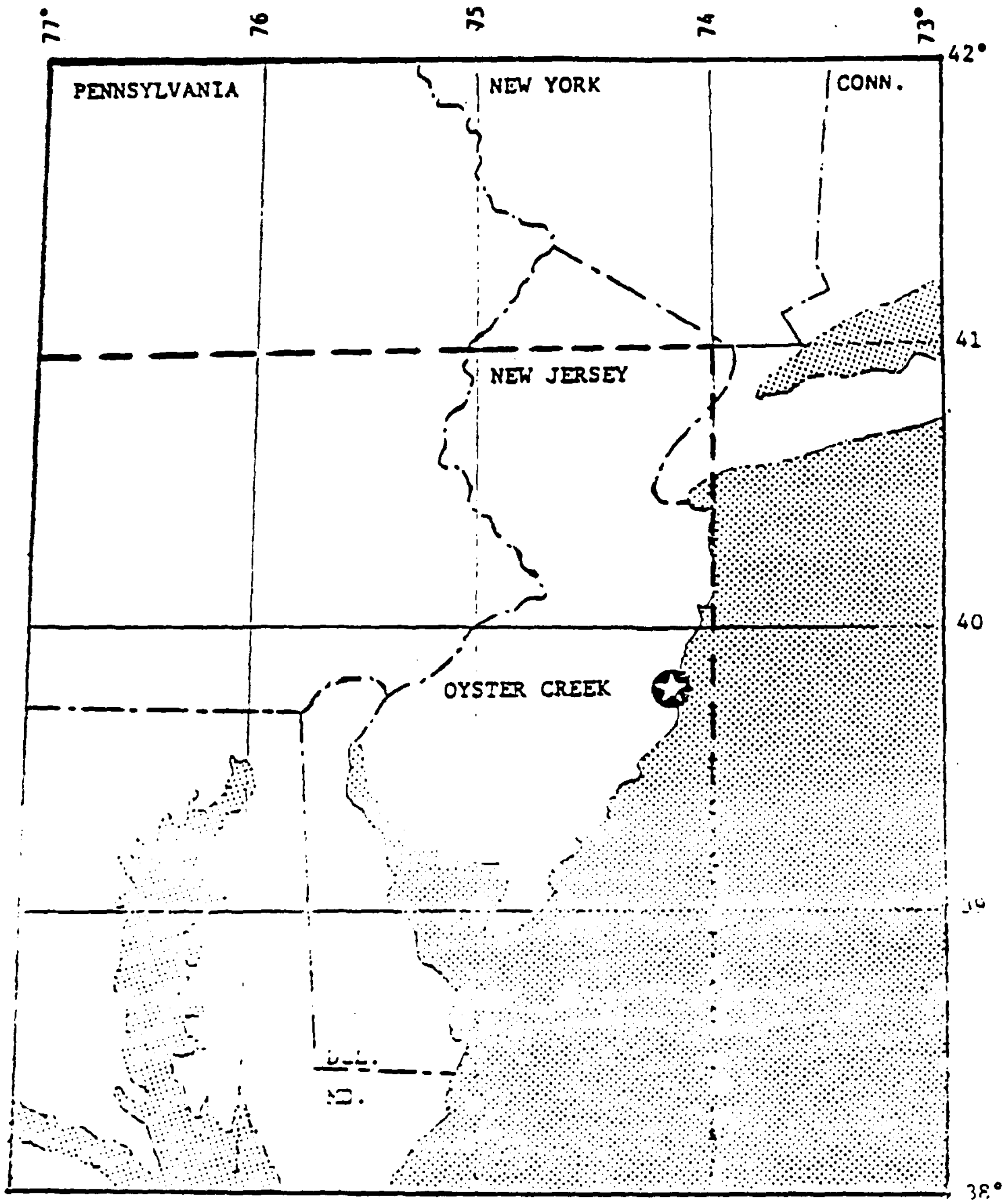


FIGURE 2: ANNUAL COUNT OF TORNADOES
WITHIN 125 NAUTICAL MILES OF THE OYSTER CREEK NUCLEAR PLANT
(COMPILED FROM THE NATIONAL SEVERE STORMS FORECAST CENTER)

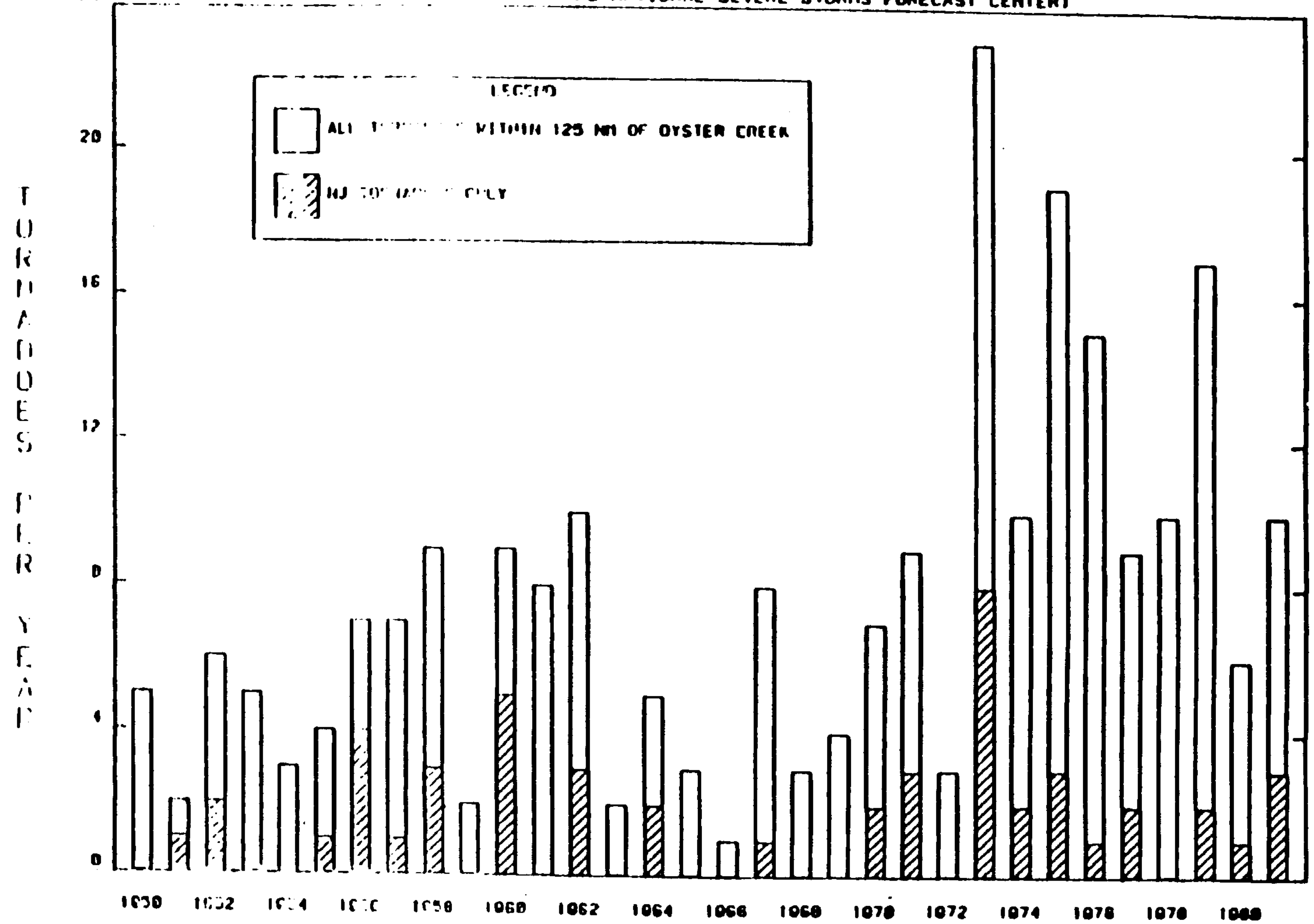
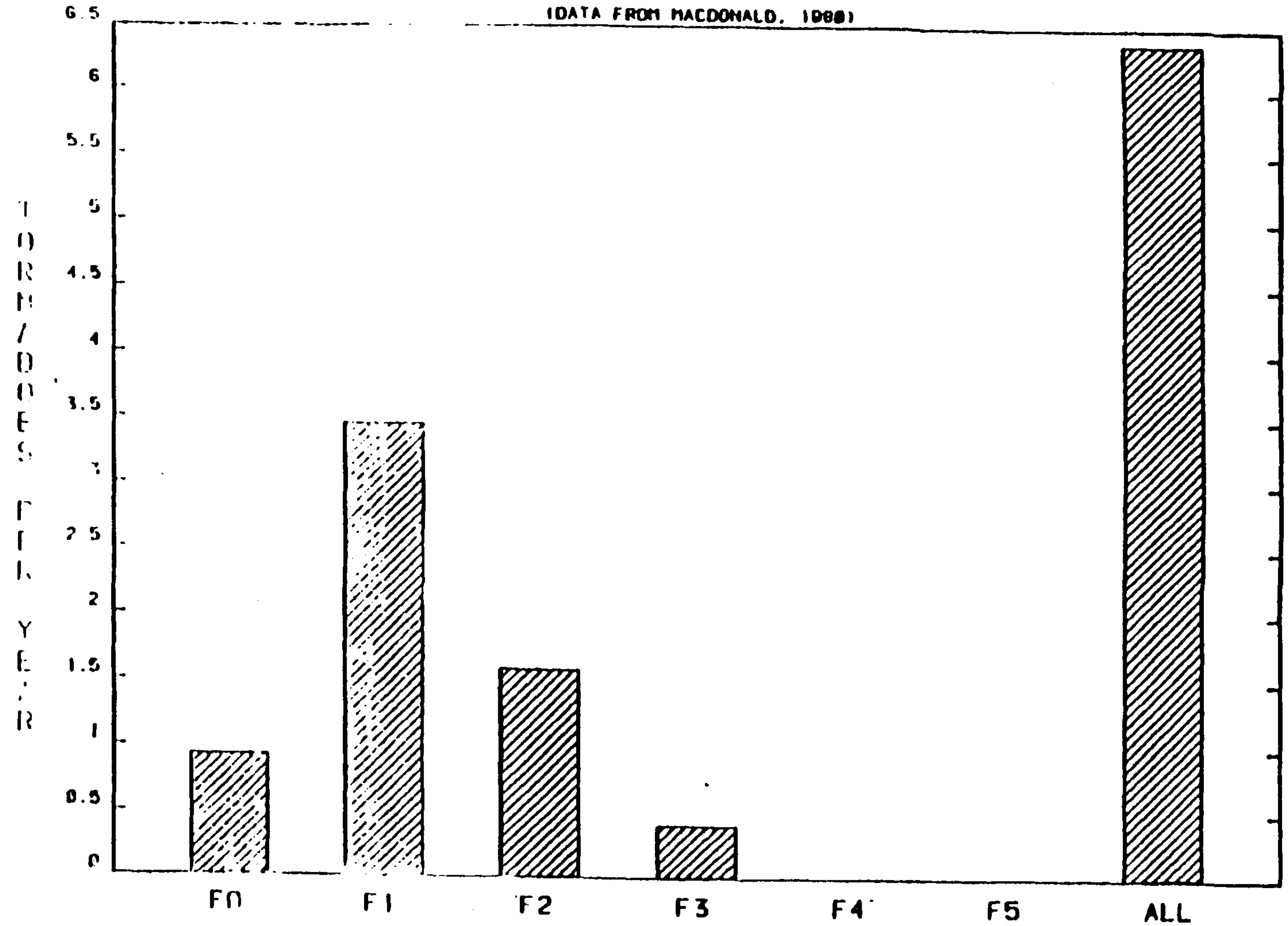


FIGURE [illegible]: AVERAGE NUMBER OF TORNADOES PER YEAR
AS A FUNCTION OF TORNADO INTENSITY



occur during any given year are shown in Figure 4A. The upper limit of the number of tornados expected during any year are shown in Figure 4B.

As can be seen from Figure 4A, between 6 and 7 tornados can be expected to occur each year. In any given year, it is unlikely there will be more than 8 tornados (Figure 4B). The tornado most likely to occur will have winds between 73 and 112 mph and will occur 3-4 times per year (Figure 4A). A tornado with winds between 261 and 318 mph is expected to occur once every 100 years (Figure 4A), but not more than every 20 years (Figure 4B).

3.3 Tornado Path Area

The last parameter needed to compute the probability of a tornado striking a point is the tornado path area. The tornado path area is the damage path area (path length times path width) of the tornado. Figure 5 shows the mean damage path area, as a function of tornado intensity, of all tornados that occurred during the 9-year period 1971-1978. (Accurate damage path area statistics were not generally available prior to 1971.)

As Figure 5 illustrates, the mean damage path area of the most intense tornado reported (F3 intensity) is smaller than the mean damage path area of the less intense F2 tornado. This may be due more to differences in sample size than in the physics of tornados. For example, the sample size of F3 tornados is only 1/4 the sample size of the F2 tornados.

The bias of sample size is minimized in Figure 6, which is a statistical analysis of the data in Figure 5. Figure 6 shows the expected damage path area as a function of tornado intensity. Not surprisingly, the expected damage path area increases with tornado intensity.

3.4 Tornado Hazard Probabilities

The tornado hazard probabilities are computed by substituting both the expected damage path area (as a function of tornado intensity) and the expected number of tornados per year (as a function of intensity) into the relation in Section 3.1. The tornado hazard probabilities computed in this way are shown

FIGURE 4A: EXPECTED NUMBER OF TORNADOES PER YEAR
AS A FUNCTION OF TORNADO INTENSITY

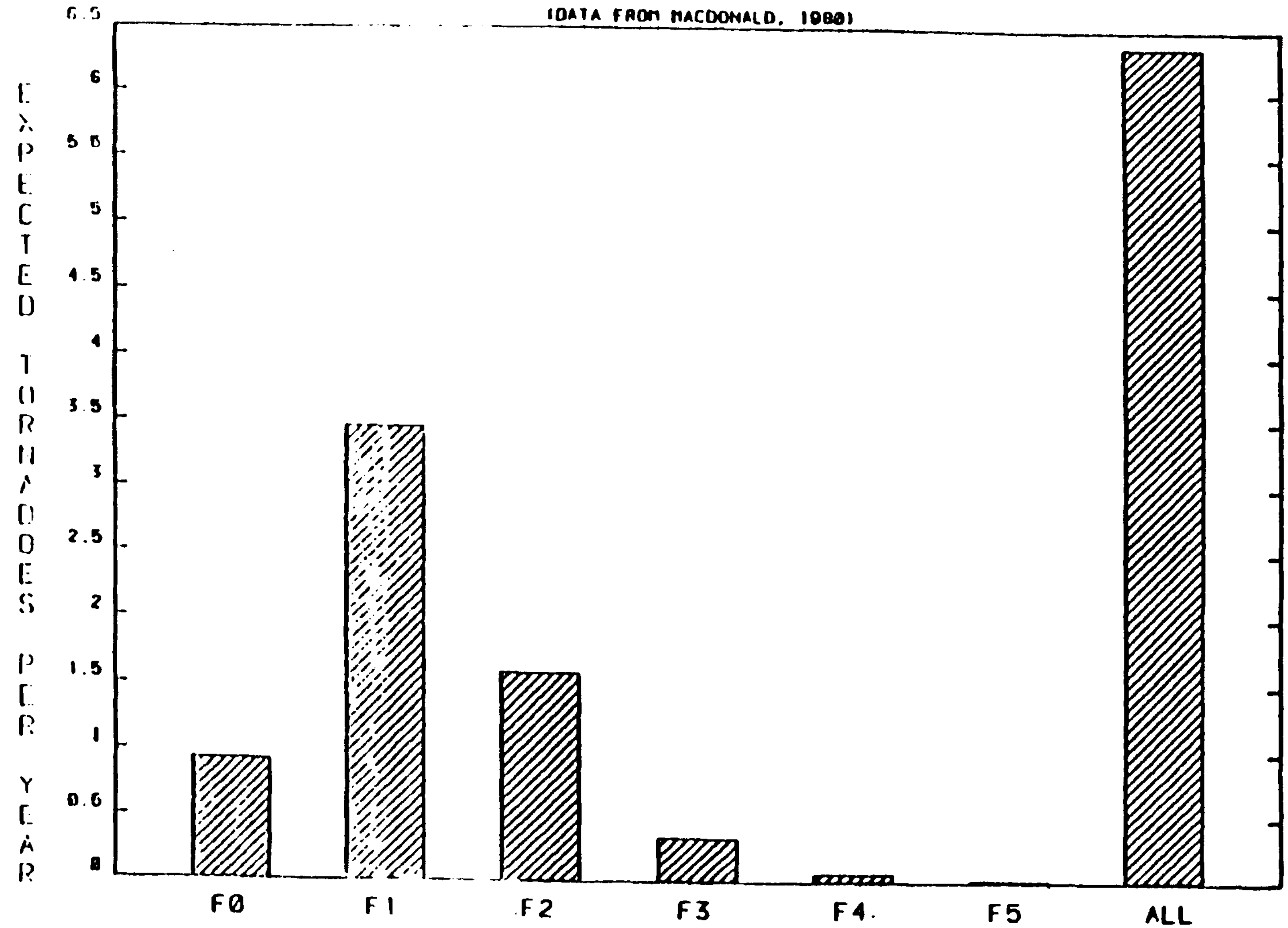


FIGURE 4B: THE UPPER LIMIT OF THE EXPECTED NUMBER OF TORNADOES PER [YEAR] AS A FUNCTION OF TORNADO INTENSITY

(DATA FROM MACDONALD, 1980)

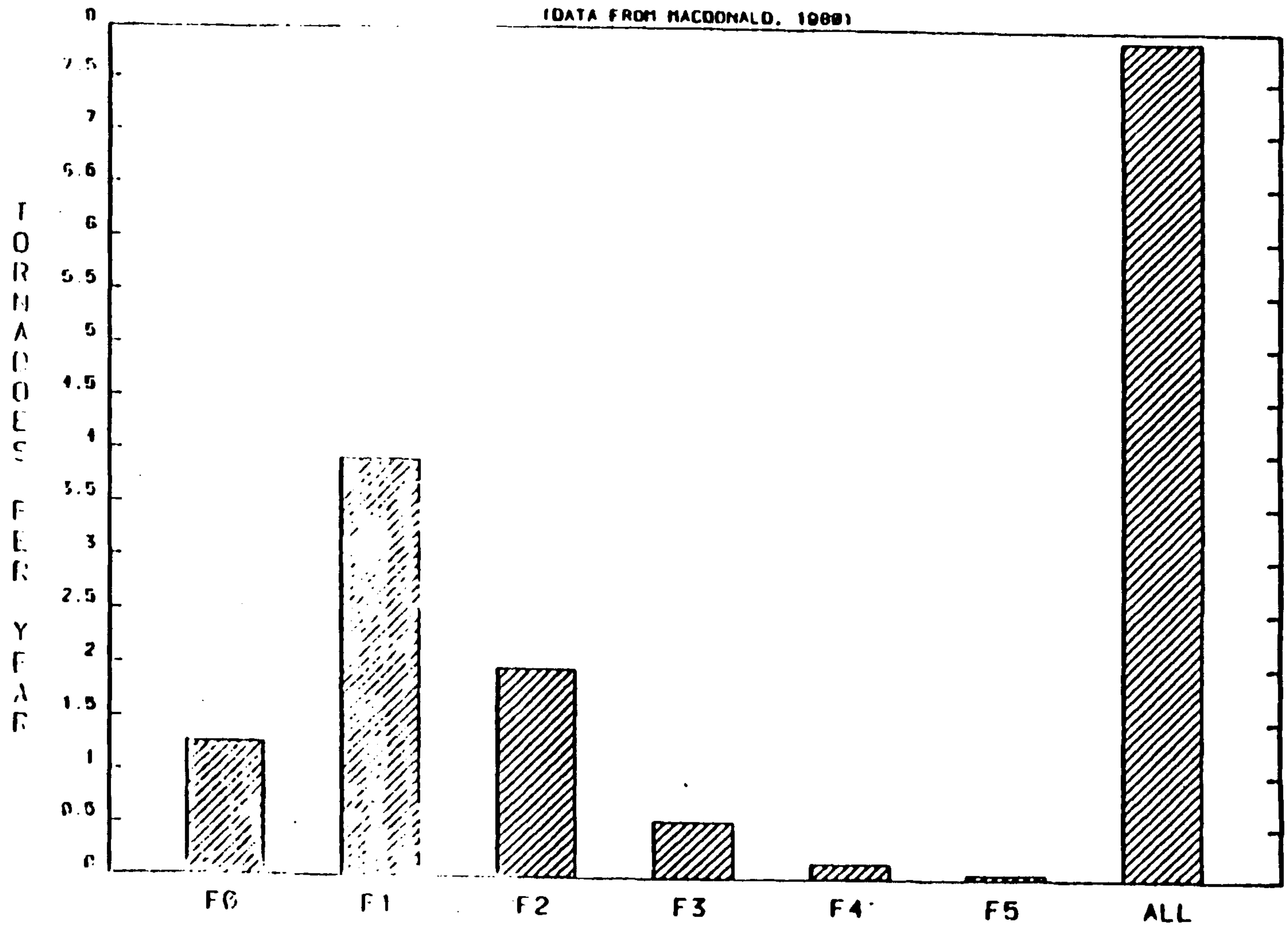
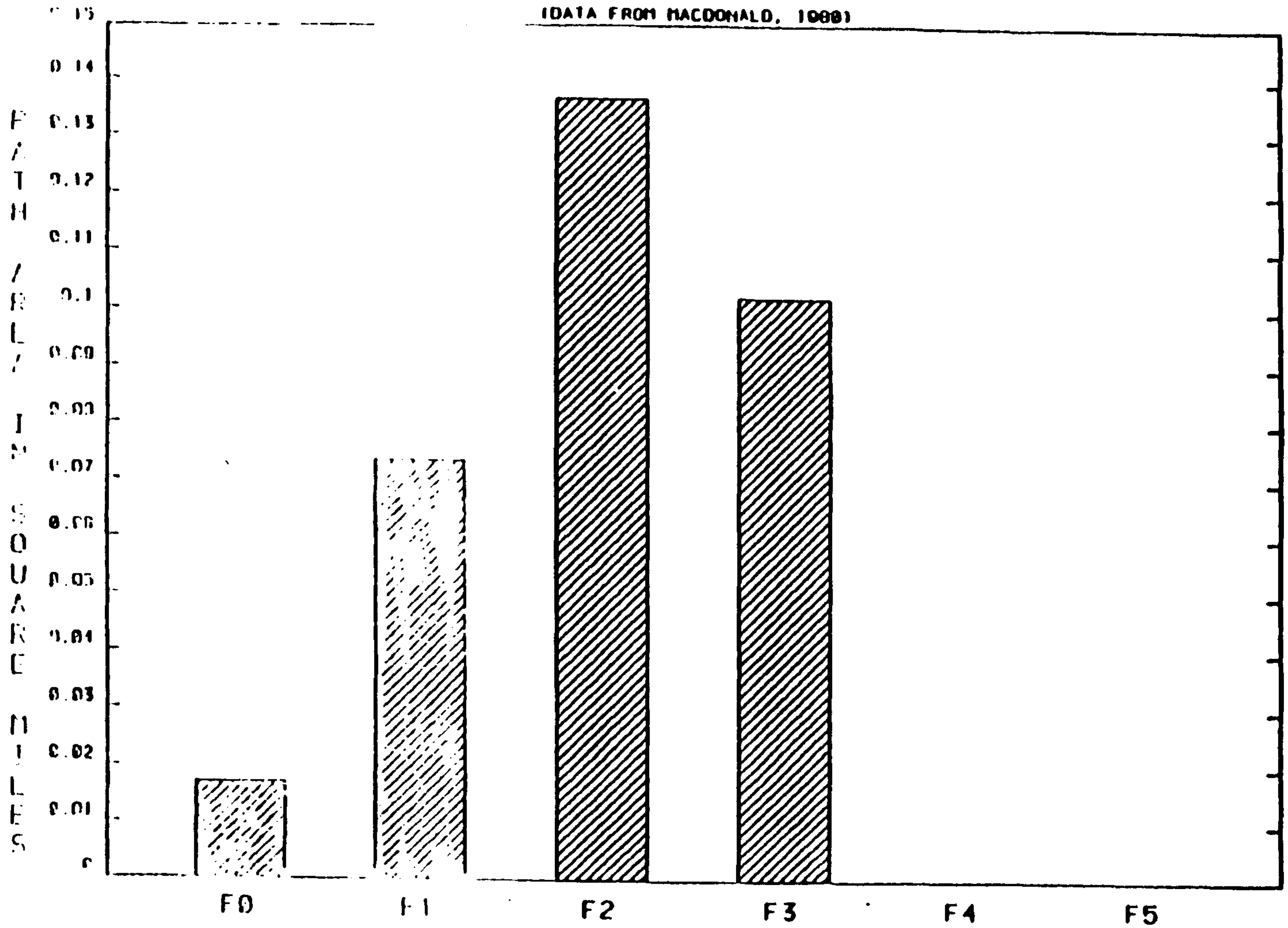


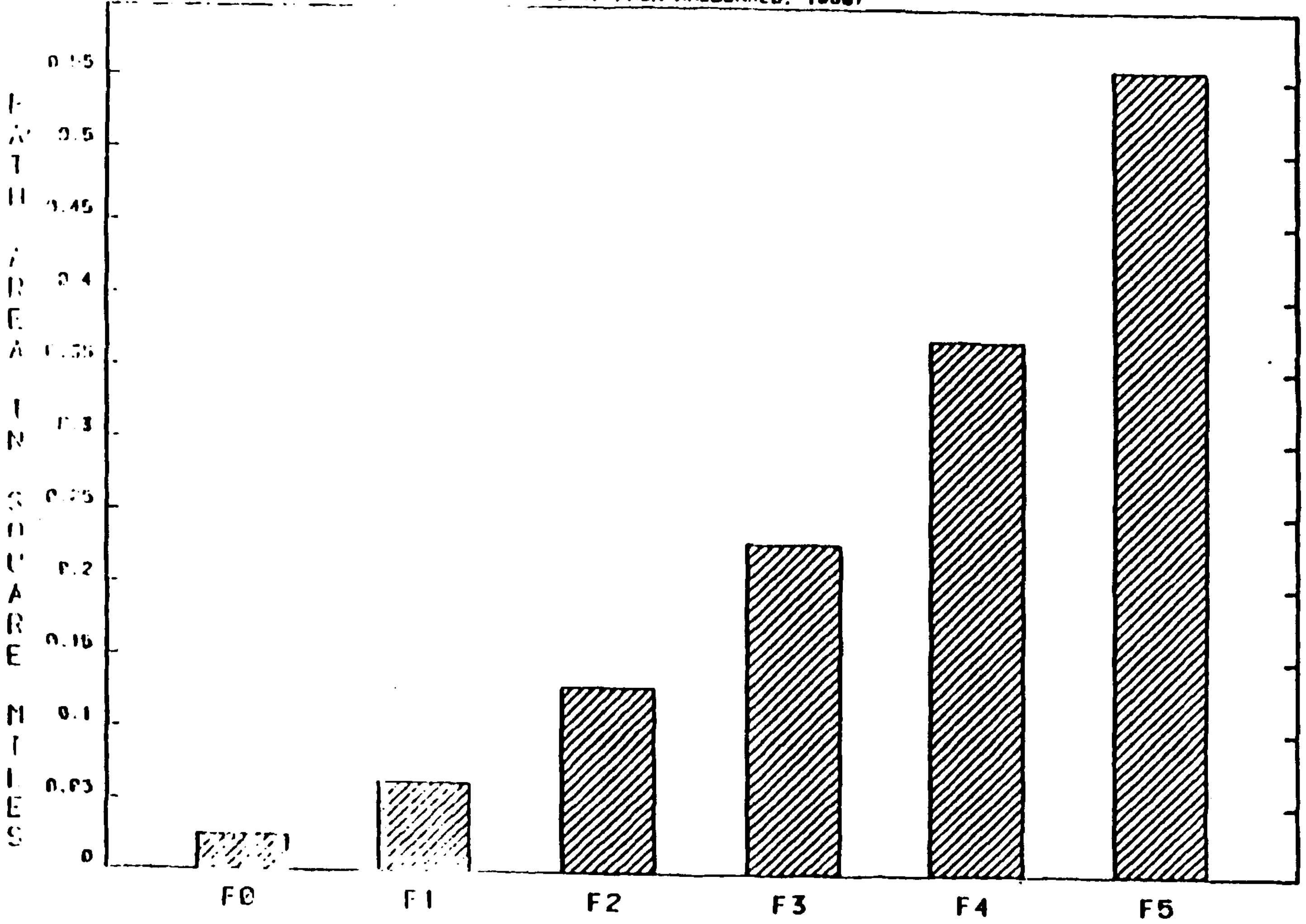
FIGURE 5: MEAN DAMAGE PATH AREA AS A FUNCTION OF TORNADO INTENSITY

(DATA FROM MACDONALD, 1988)



EXPECTED DAMAGE PATH AREA
FUNCTION OF TORNADO INTENSITY

(DATA FROM MACDONALD, 1980)



in the second column of Table 2. The first column of Table 2 shows the mean recurrence interval, which is the inverse of the tornado hazard probability.

It is obvious from Table 2 that the hazard probability decreases as the tornado intensity increases. Also note that the recurrence interval for the weakest tornado is 10,000 years, which is 5 times longer than the recurrence interval calculated using the method and data of Thom (1963).

It should be emphasized that the probability of observing a specific tornado wind speed in a span equal to its recurrence interval is not 1. Rather, the probability is 0.63, and this value is approached asymptotically as the recurrence interval approaches infinity (Crutcher, et. al., 1975).

The tornado hazard probabilities in Table 2 are graphed in Figure 7. For purposes of comparison, the straight wind hazard probabilities are also shown. Note that for wind speeds less than 110 mph, the hazard probability for straight winds is much greater than the hazard probability for tornado winds. Thus, for wind speeds up to 100 mph, the hazard is not likely to be from a tornado. For wind speeds over 110 mph, however, the hazard is likely to be from a tornado.

A summary of wind speed hazard probabilities for Oyster Creek is presented in Table 3. The table summarizes what has just been mentioned. That is, for wind speeds less than 110 mph, straight winds are the hazard. For wind speeds greater than 110 mph, tornado winds are the hazard. In determining the hazardous effects of a tornado, however, the atmospheric pressure change and missiles must be taken into account in addition to the high wind speeds.

The tornado hazard probabilities in this report are compared with the tornado hazard probabilities of three other documents in Table 4. As can be seen from Table 4, both this report and the Oyster Creek SEP indicate almost identical tornado hazard probabilities. Reg. Guide 1.76 and WASH 1300, however, indicate slightly greater tornado hazard probabilities.

TABLE 2

TORNADO HAZARD PROBABILITIES WITH 95 PERCENT CONFIDENCE LIMITS

Mean Recurrence Interval	Hazard Probability Per Year	Tornado Intensity: Expected Wind Speed (mph)	Lower Limit of Wind Speed (mph)	Upper Limit of Wind Speed (mph)
10,000	1.0×10^{-4}	<40	<40	<40
100,000	1.0×10^{-5}	84	56	118
1,000,000	1.0×10^{-6}	152	123	186
10,000,000	1.0×10^{-7}	209	174	255

FIGURE 7: TORNADO AND STRAIGHT WIND HAZARD PROBABILITY MODEL FOR OYSTER CREEK POWER REACTOR SITE, NEW JERSEY

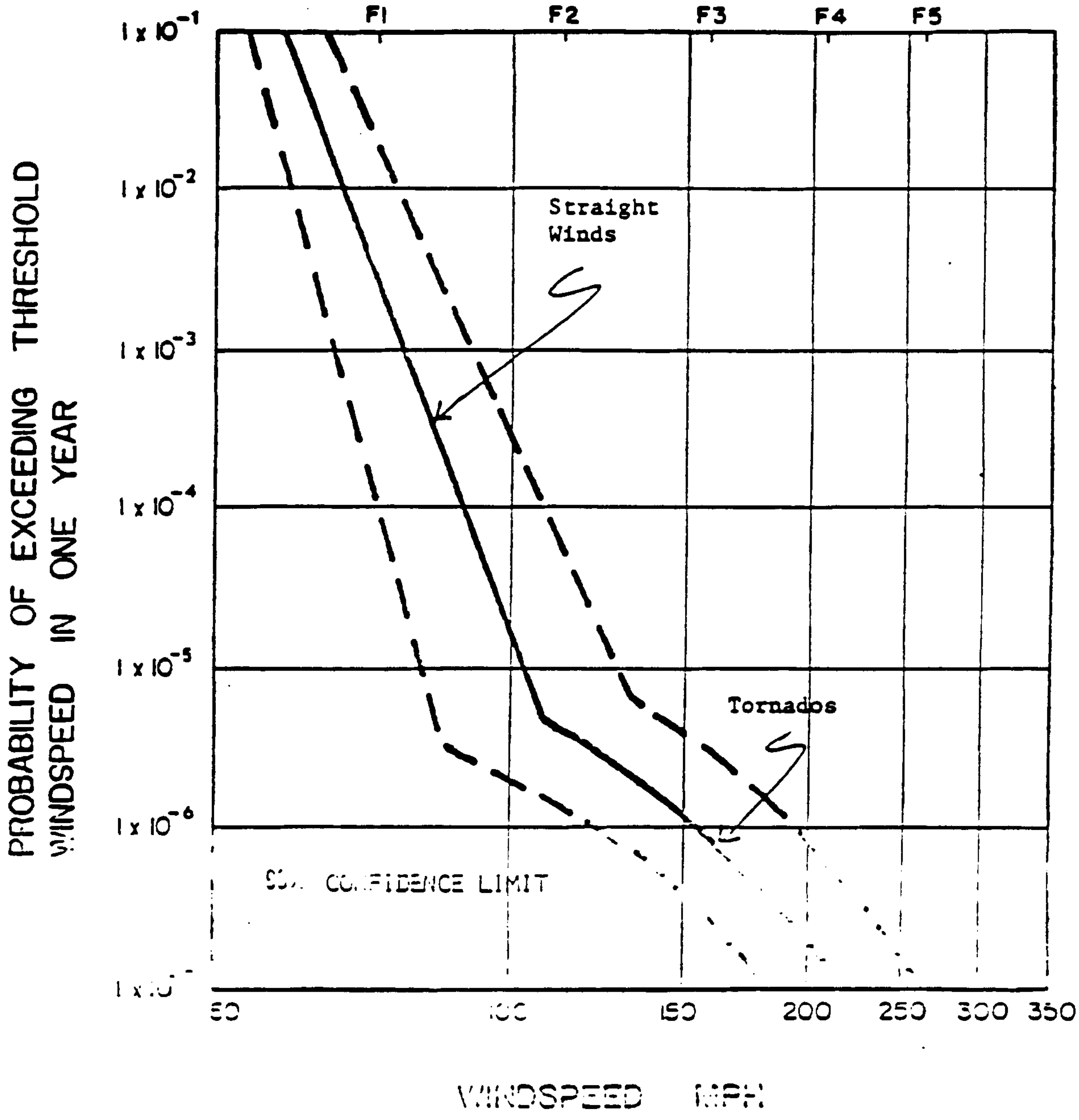


TABLE 3

SUMMARY OF WINDSPEED RISKS WITH 95 PERCENT CONFIDENCE LIMITS FOR OYSTER CREEK

Recurrence Limit	Probability Per Year	Windspeeds, mph: Expected Value	Windspeeds, mph: Lower Limit	Windspeeds, mph: Upper Limit	Type of Storm
100	1.0×10^{-2}	69	60	78	Straight Wind
1,000	1.0×10^{-3}	80	66	93	Straight Wind
10,000	1.0×10^{-4}	91	73	109	Straight Wind
100,000	1.0×10^{-5}	102	80	124	Straight Wind
1,000,000	1.0×10^{-6}	152	123	188	Tornado
10,000,000	1.0×10^{-7}	209	174	255	Tornado

3.5 Summary

An evaluation of whether the occurrence of the Berkley Township tornado is consistent with the tornado hazard probability discussed in the Oyster Creek Environmental Report revealed that the Oyster Creek Report hazard probabilities are outdated, but not because of the occurrence of the Berkley Township tornado. Rather, they are outdated because of the availability of more recent high quality, computerized tornado data and the use of more refined statistical methods, neither of which were available prior to 1972, the year the Oyster Creek Environmental Report was published.

As a result, the mean recurrence interval of a tornado is no shorter than 10,000 years, as compared with 2170 years stated in the Environmental Report. Six to seven tornados per year are expected to occur in an area of land within approximately 125 miles of the Oyster Creek Nuclear Plant. Both this report and the Oyster Creek SEP indicate almost identical tornado hazard probabilities. Reg. Guide 1.76 and WASH 1300, however, indicate slightly greater tornado hazard probabilities.

TABLE [illegible] COMPARISON OF TORNADO CHARACTERISTICS AS COMPILED FROM FOUR DOCUMENTS

	DOCUMENT NAME			
	REG. GUIDE 1.76 (DESIGN BASIS TORNADO)	WASH 1300 (TECHNICAL BASIS FOR INTERIM REGIONAL TORNADO CRITERIA)	OYSTER CREEK SEP	TEXAS TECH/NRC TORNADO HAZARD PROBABILITIES
GEOGRAPHICAL REGION TO WHICH TORNADO CHARACTERISTICS APPLY	All of U.S. east of Rocky Mountains	All of U.S. east of Rocky Mountains	Within 60 mile radius of Oyster Creek	N.J., Eastern 1/3 of Pa., Del., Md.
ANNUAL PROBABILITY OF OCCURRENCE	Not specified	10^{-7}	10^{-7}	10^{-7}
MAXIMUM WIND SPEED (MPH)	360	360	310	250+
MAXIMUM ROTATIONAL SPEED (MPH)	290	300	250	250
TRANSLATIONAL SPEED (MPH)	70	60	60	Not addressed
PRESSURE DROP (PSI)	3	3	2	Not addressed
RATE OF PRESSURE DROP (PSI/SEC)	2	2	1	Not addressed

WH:AMR
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APPENDIX 2.3B

AN INVESTIGATION OF THE SEA BREEZE AT THE OYSTER CREEK NUCLEAR GENERATING STATION

AN INVESTIGATION OF THE

SEA BREEZE AT THE

OYSTER CREEK NUCLEAR GENERATING STATION

By

GPU Nuclear Corporation

Environmental Controls Department

Werner Heck

June 1983

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1. SUMMARY

This study was undertaken in response to NUREG 0654, Rev. 1, and Reg. Guide 1.23, Rev. 1, and also in response to an NRC meteorologist who specifically requested the study be performed during his onsite evaluation of the Oyster Creek meteorological program in January 1982.

The results of this study showed that during the months of May through August, the sea breeze at Oyster Creek occured one day in four, or an average of about 30 days between May and August.

On days when Oyster Creek had sea breezes, the Atlantic City wind direction was within 45° of the Oyster Creek wind direction 56% of the time. In contrast, the Lakehurst wind direction was within 45° of the Oyster Creek wind direction only 35% of the time. This made Atlantic City wind directions more representative of Oyster Creek than Lakehurst. The better representativeness of Atlantic City also held true for the May - August period in general, when Atlantic City winds were within 45° of Oyster Creek winds 63% of the time, as opposed to 50% of the time for Lakehurst.

Meteorological conditions conducive to sea breeze fumigation at Oyster Creek occured on 1/3 of the Oyster Creek sea breeze days, or an average of about 10 days between May and August.

The Oyster Creek sea breeze often penetrated to 16 km inland and occasionally to 21 km inland, but this conclusion was based on somewhat tenuous assumptions.

The analysis described in this report required the processing of 900,000 pieces of meteorological data. The data processing and analysis culminated in the generation of 425 tables and figures, which, in part, consisted of 1590 daily time series plots of meteorological parameters. All tables, figures and time series plots were included in this report.

2. INTRODUCTION

NRC meteorologists have expressed concern about the effects of the sea breeze on effluent plume transport and diffusion at Oyster Creek. They are concerned about abrupt changes in plume direction and diffusion that would occur during a sea breeze at Oyster Creek.

To alleviate these concerns, GPUN Corporate Environmental Controls committed to do a sea breeze analysis at a meeting with NRC meteorologist Joe Levine, who specifically requested the study be performed during his on-site evaluation of the Oyster Creek meteorological program in January 1982.

The need to address the sea breeze is also discussed in NUREG 0654, Rev. 1, in the section entitled "Atmospheric Transport and Diffusion Assessment". This section states:

"The Class A model shall provide calculations or relative concentrations (X/Q) and transit times within the plume exposure EPZ. Atmospheric diffusion rates shall be based on atmospheric stability as a function of site-specific terrain conditions. Site-specific local climatological effects on the trajectories, such as seasonal, diurnal, and terrain-induced flows shall be included."

The need for supplemental meteorological towers in a sea breeze regime is discussed in REG. GUIDE 1.23, REV. 1. Section C.1 of REG. GUIDE 1.23 states:

"Supplemental towers or masts, special meteorological instrumentation, data analysis techniques for field studies, may be needed for the pre-operation and/or operational programs when airflow and diffusion conditions within the vicinity of the site cannot be represented by a single measurement location. An example would be in non-uniform terrain or a land-water interface".

More recently, in December 1982, the NRC promulgated SUPPLEMENT 1 TO NUREG 737 - REQUIREMENTS FOR EMERGENCY RESPONSE CAPABILITY, which states under Section 6.1.b (Control Room):

"No changes in existing meteorological monitoring systems are necessary if they have historically provided reliable indication of these variables that are representative of meteorological conditions in the vicinity (up to about 10 miles) of the plant site".

The purpose of this report is to analyze the sea breeze at Oyster Creek. The sea breeze analysis is divided into the following four parts:

1. Determination of the frequency of the sea breeze at Oyster Creek.

2. Evaluation of the representativeness of the Oyster Creek wind direction during the sea breeze season

3. Evaluation of the implication of (1) and (2) on effluent plume transport.

4. Evaluation of the need for supplementary meteorological towers.

3. CONCLUSIONS

The results of this study showed that during the months of May through August, the sea breeze at Oyster Creek occured one day in four, or an average of about 30 days between May and August.

On days when Oyster Creek had sea breezes, the Atlantic City wind direction was within 45° of the Oyster Creek wind direction 56% of the time. In contrast, the Lakehurst wind direction was within 45° of the Oyster Creek wind direction only 35% of the time. This made Atlantic City wind directions more representative of Oyster Creek than Lakehurst. The better representativeness of Atlantic City also held true for the May - August period in general, when Atlantic City winds were within 45° of Oyster Creek winds 63% of the time, as opposed to 50% of the time for Lakehurst.

Meteorological conditions conducive to sea breeze fumigation at Oyster Creek occured on 1/3 of the Oyster Creek sea breeze days, or an average of about 10 days between May and August.

The Oyster Creek sea breeze often penetrated to 16 km inland and occasionally to 21 km inland, but this conclusion was based on somewhat tenuous assumptions.

4. RECOMMENDATIONS

In the context of the sea breeze, the usefulness of a supplemental met tower located to the east of the plant would be greatly enhanced if it could be shown that the data is useful for revealing not only what is happening at the supplemental tower but also what will happen downwind of the supplemental met tower. This premise leads to two recommendations:

1. It is recommended that the Oyster Creek data serve as a prototype data for testing its usefulness as a predictor of sea breezes at Oyster Creek. If the tower data can be used to predict the sea breeze at Oyster Creek, it is likely, but by no means certain, that data from a supplemental met tower can be used to predict sea breeze occurrences at the supplementary met tower and at points in between the supplementary met tower and the Oyster Creek tower. This would help to define the sea breeze boundary.

2. Pending the completion of the study in Recommendation #1, Corporate Environmental Controls in conjunction with Oyster Creek Environmental Controls and Oyster Creek Emergency Preparedness, should develop an interim plan for compensating actions to be taken during sea breeze regimes

5. THE FREQUENCY OF THE SEA BREEZE AT OYSTER CREEK

5.1 Site Geography

The Oyster Creek Nuclear Plant site is located in the coastal pine barrens of New Jersey about nine miles south of Toms River (see Figure 5-1). Six miles east of the site is the Atlantic Ocean; two miles east of the site is the western edge of Barnegat Bay (see Figure 5-2).

Barnegat Bay is a shallow bay bounded by the mainland on the west and by a barrier beach on the east. The barrier beach, which separates the bay from the Atlantic Ocean, stretches 30 miles from Point Pleasant on the north and Manahawkin Causeway on the south. The only break in the barrier beach in this area is at Barnegat Inlet about 20 miles south of Point Pleasant.

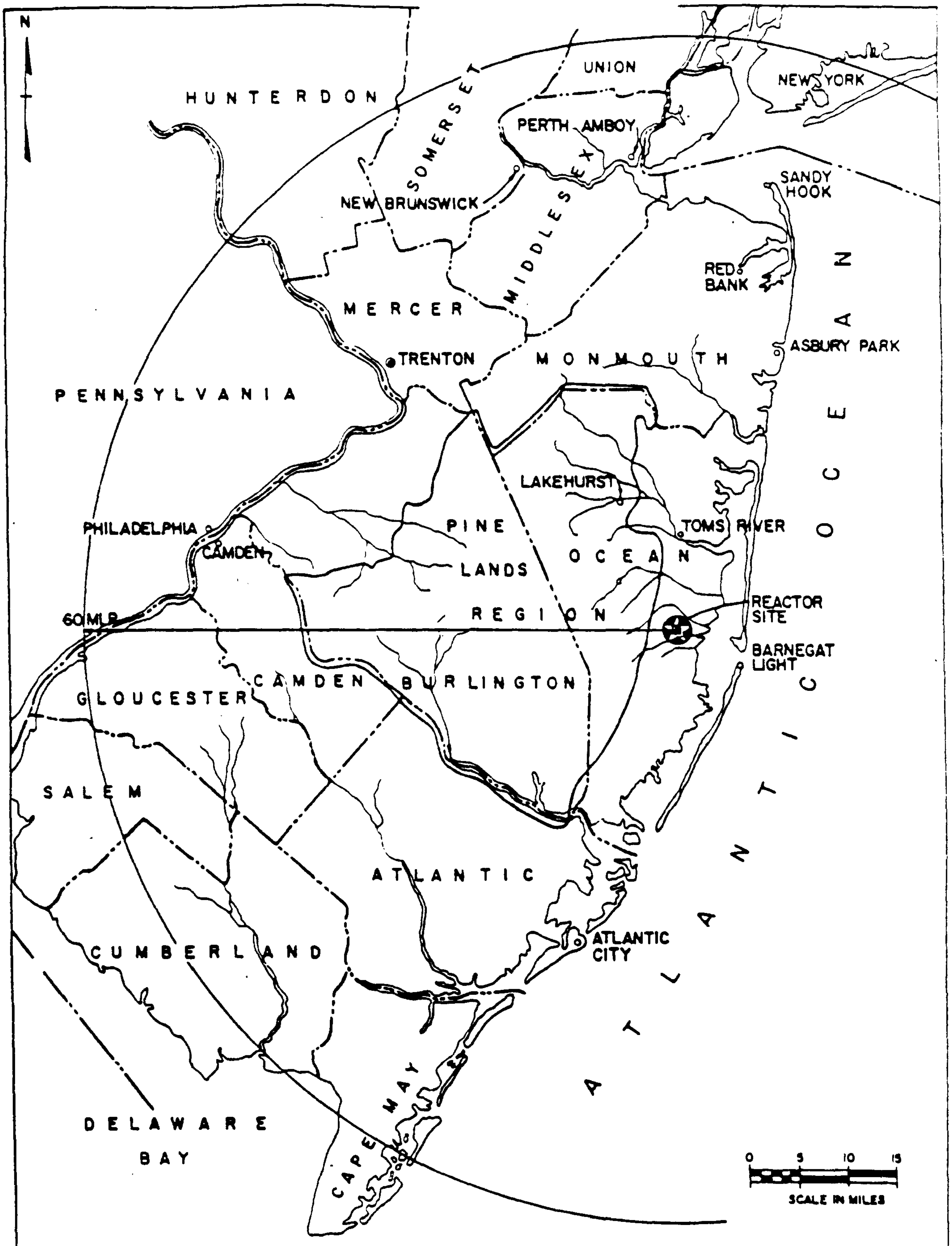
The maximum width of Barnegat Bay is about four miles. The average depth of the Bay is under five feet; large areas are less than one foot deep at local mean low tide.

5.2 Definition of the Sea Breeze

A sea breeze is normally thought of as a cool wind blowing from the ocean. A cool wind blowing from the ocean, however, is not necessarily a sea breeze.

In meteorological terms, a sea breeze is an onshore wind caused specifically by the land heating up more quickly than the adjacent waters (Pielke, 1981; Ryznar and Touma, 1981). An onshore wind caused by something other than the land heating up more quickly than the adjacent waters is, therefore, not a sea breeze.

This definition of the sea breeze implies that the sea breeze is a diurnal phenomenon, i.e., there are cyclical day-to-night variations in one or more meteorological variables, in this case, most notably wind direction and temperature.



JERSEY CENTRAL POWER AND LIGHT COMPANY OYSTER CREEK NUCLEAR GENERATING STATION	AREA MAP: 60 Mile Radius	FIGURE 5-1

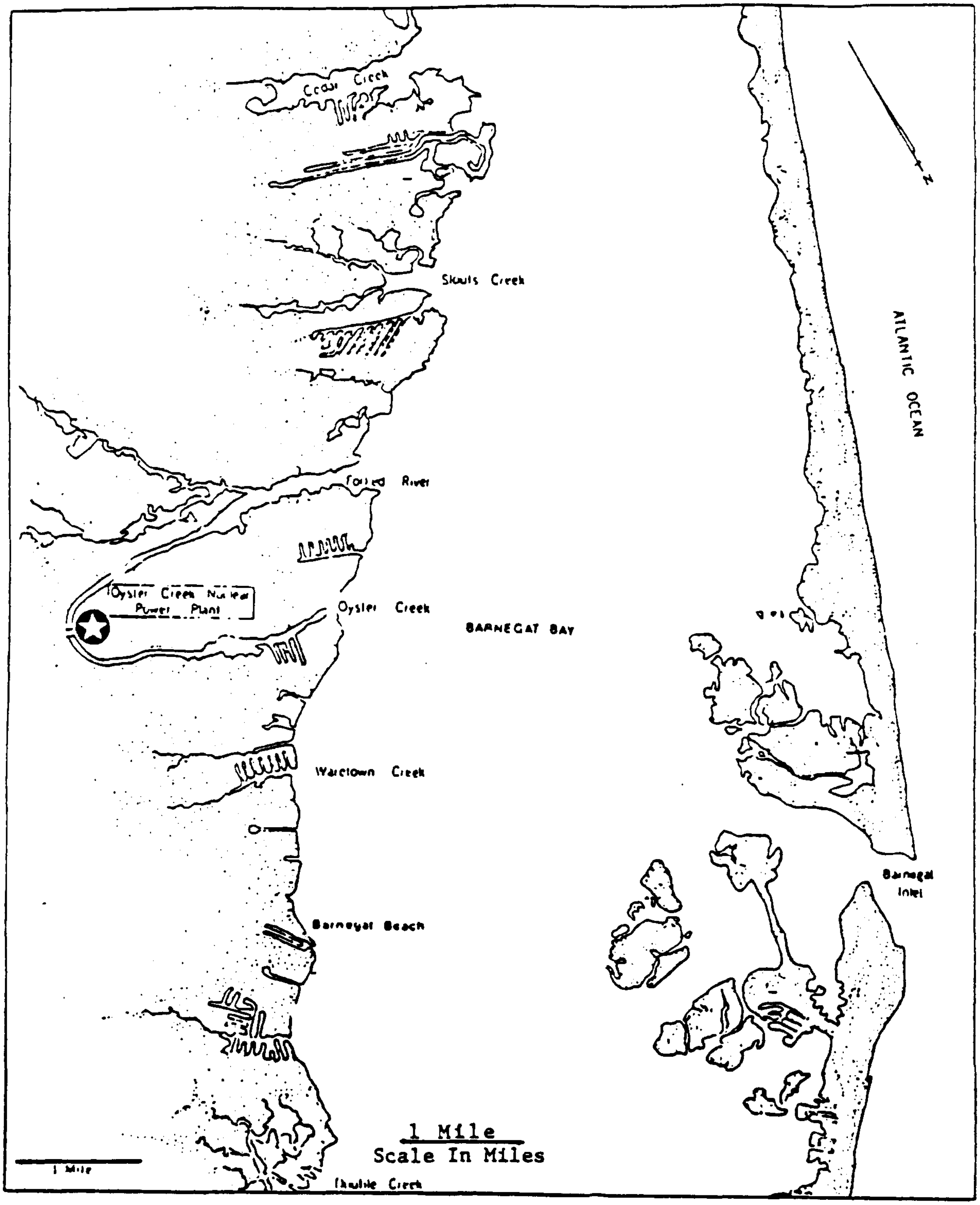


Figure 5-2

AREA MAP: BARNEGAT BAY & BARRIER ISLANDS

Over a 24-hour period, the sea breeze is characterized by the evolution of the following sequence of events (Pielke, 1981; Angell and Pack, 1965):

1. Winds at night or early morning are calm or offshore.
2. Winds shift from offshore to onshore in the late morning or early afternoon.
3. With the onset of onshore winds, the air temperature holds steady or falls.
4. Winds shift back to offshore in the late evening or night.

The sequence of events listed above served as the primary criteria for establishing the existence of the sea breeze at Oyster Creek. Although changes in other meteorological parameters, such as atmospheric stability, may also be associated with the onset of the sea breeze, the changes in wind direction and temperature were expected to be much more pronounced than changes in these other parameters.

In some cases, however, temperature changes by themselves may be insufficient to prove the presence of a sea breeze. In these cases, changes in atmospheric stability served as secondary criteria. Changes in atmospheric stability are reflected by changes in the temperature difference between the 150-ft and 33-ft level of the Oyster Creek met tower. If a sea breeze is present, the temperature difference should be positive or slightly negative at night and negative during the day. This is because the sea breeze cycle is characterized by relatively stable conditions at night and relatively unstable conditions during the day in the layer of air near the ground (Pielke, 1981; Ryznar and Touma, 1981).

The next section describes the meteorological data that was used to implement the primary and secondary criteria above for sea breeze determination.

5.3 Data

Data from the Oyster Creek meteorological tower were used to establish the existence of the sea breeze at Oyster Creek.

The Oyster Creek meteorological tower is instrumented at three levels: 380-ft, 150-ft and 33-ft above ground. The meteorological variables measured at each level are shown in Table 5-1. The variables are measured every 10 seconds and are averaged for 15-minute periods before being archived on computer tape.

The 15-minute averages, centered on the hour, for the five-year period 1977-1981 were used in the analysis.

5.4 Method of Data Analysis

A preliminary estimate of sea breeze occurrences at Oyster Creek was obtained from an analysis of Oyster Creek wind roses. This method of analysis is described in Section 5.4.1

A more accurate and complete picture of the sea breeze at Oyster Creek was obtained by searching the meteorological data for sea breeze days and analyzing in detail the hourly meteorological data on these days. This method of analysis is described in Section 5.4.2

5.4.1 Analysis of Wind Roses

An overview of sea breeze occurrences at Oyster Creek was obtained by examining Oyster Creek wind roses. These wind roses served as a screening procedure for making a preliminary estimate of the frequency of the sea breeze at Oyster Creek.

To determine the extent of sea breeze occurrences at Oyster Creek, wind roses were generated for each season. For this purpose, the year was divided into two seasons: (1) the season from May-August, and (2) the season from September-April. The period from May-August was called the sea breeze season. According to Raynor (1977), sea breezes on Long Island occur most frequently during the months of May, June and July. Peck and Smith (1980) showed from an analysis of Atlantic City area meteorological data that most of the days with sea breezes occurred during the months of May-August. There is no reason why this should not also be true for the Oyster Creek area. Sea breezes are most likely to occur when land-water temperature differences are greatest, and this typically happens during the months of May, June, July and August.

TABLE 5-1

OYSTER CREEK METEOROLOGICAL TOWER:

PARAMETERS RECORDED DURING THE YEARS 1977-1981

APPROXIMATE HEIGHT ABOVE TOWER BASE (ft)	RECORDED METEOROLOGICAL PARAMETERS
380	Wind speed & direction Temperature ΔT 380-33 ft. Dew point témperature Dew point ambient temperature
150	Wind speed & direction Temperature ΔT 150-33 ft.
33	Wind speed & direction Temperature Dew point temperature Dew point ambient temperature
Ground Level	Rainfall

For each of the two seasons of the year, wind roses were also generated for the daytime and nighttime periods. Daytime included the hours from 9 AM to 7PM LST; nighttime included the hours from 8 PM to 8 AM LST.

If the sea breeze occured often at Oyster Creek, the daytime wind rose for the months May-August would show onshore winds occurring more frequently than the nighttime wind rose would show. The nighttime wind rose would show a relatively high frequency of calm and offshore winds if the sea breeze occured often enough. During the months September-April, however, when few sea breezes were expected to occur, differences between the daytime and nighttime wind roses should be negligible.

The analysis of wind roses revealed whether sea breezes occurred frequently at Oyster Creek, but it revealed nothing about the dates they occurred, or whether they in fact were true sea breezes. True sea breezes must meet the criteria outlined in Section 5.2 of this report, and up to this point, the data have not been analyzed to determine when and how often the criteria were met. The method for determining when and how often the criteria were met is described in Section 6.4.2, the next section.

5.4.2 Analysis of Sea Breeze Days

Before the data could be compared against the criteria in Section 5.2, the analysis required more precise definitions of terms used in criteria 1-4 of Section 5.2.

The terms which needed more precise definition were "daytime", "nighttime", "onshore winds", "offshore winds" and "calm winds". These terms are defined below.

"Daytime" - 9 AM to 7 PM, LST

"Nighttime" - 7 PM to 9 AM, LST

"Onshore winds" - Winds blowing from the northeast through southerly directions. Specifically, winds blowing from a sector having as its most counterclockwise boundary a compass direction of 34 degrees and its most clockwise boundary a compass direction of 180 degrees.

"Offshore winds" - Winds that are not onshore

"Calm winds" - Wind speed less than 3.50 mph (about 3 knots).

With these more precise definitions, criteria 1, 2 and 4 of Section 5.2 were easily incorporated into an automated procedure that searched the meteorological data for dates when these criteria were met.

Implementing these three criteria into an automated procedure required more objective and quantitative standards than were contained in the criteria themselves.

Criteria 1, 2 and 4 describe wind direction characteristics during the daytime and nighttime hours during sea breeze conditions. A set of objective standards that satisfy the sense of criteria 1, 2 and 4 are the following:

1. At least 4 of the 11 daytime hours must have onshore winds with speeds greater than 3.49 mph. This allows seven hours of calm winds and offshore winds. Since this allows so many hours of calm and offshore winds during the daytime hours, it is a conservative constraint because it would overestimate the number of sea breeze days.
2. At least 7 of the 13 nighttime hours must have offshore or calm winds. This allows six hours of onshore winds caused by random shifts in direction during a light wind regime, or temporary onshore winds for other reasons. This is also considered a conservative constraint which would result in an overestimate in the number of sea breeze days.

If a daytime period characterized by (1) above was both preceded and followed by a nighttime period characterized by (2) above, the date was classified as a possible or potential sea breeze date.

To determine which of the possible or potential sea breeze dates had true sea breezes, temperature and stability trends were examined. If the temperature held steady or fell during the onset of the onshore wind, then the on-shore wind was classified as a sea breeze. If, however, the temperature trends were not clear cut, the trend of the temperature difference between the 150-ft and the 33-ft level was examined. The temperature difference served as an indicator of atmospheric stability. Since the sea breeze is characterized

by relatively stable conditions at night and relatively unstable conditions during the day (Pielke, 1981; Ryznar and Touma, 1981), a positive or slightly negative temperature difference at night and a negative temperature difference during the day were supplementary evidence that sea breeze conditions existed.

Atmospheric stability can also be estimated from the wind direction range, which is also part of the meteorological data base. The wind direction range can be divided by 6 to approximate sigma theta (Van der Hoven, 1967; Pendergast and Crawford, 1974). Sigma theta is the standard deviation of the horizontal wind direction and can be used as an indicator of atmospheric stability (Slade, 1968; Reg. Guide 1.21, Table 4B; Reg. Guide 1.23, Rev. 1, Table 2)

5.5 Results of Data Analysis

5.5.1 Results of Wind Rose Analysis

Figure 5-3 shows a 5-year average of the annual wind rose for the 33-ft level of the Oyster Creek met tower. Over the 5-year period, SSW through NNW winds blew 50% of the time. Calm winds (i.e., winds with speeds less than 3.5 mph) occurred 11% of the time. All other wind directions occurred 39% of the time. Note that NE through S winds (i.e., onshore winds) occurred 25% of the time.

Figure 5-4 shows the annual wind rose for the 380-ft level. The 380-ft level wind rose shows a similar distribution of winds as the 33-ft level annual wind rose. Because calm winds occur less often at the 380-ft level (only 1.2% of the time), the winds blow more frequently from all directions except the WSW direction when compared to the 33-ft level.

Seasonal wind roses were also generated. For seasonal wind roses, as was discussed in Section 5.4.1, the year was divided into the sea breeze season (May-August) and the non-sea breeze season (September-April). Figure 5-5 shows the seasonal wind roses for the 33-ft level. For ease of comparison, the annual wind rose from Figure 5-3 is also shown. As can be seen from Figure 5-5, the wind rose for September-April shows a predominantly NW through SW flow. During these months, the wind blows from the NW through SW directions

FIGURE 5-3

OYSTER CREEK ANNUAL WIND ROSE: FIVE-YEAR AVERAGE
YEARS: 1977-1981
33-FT LEVEL

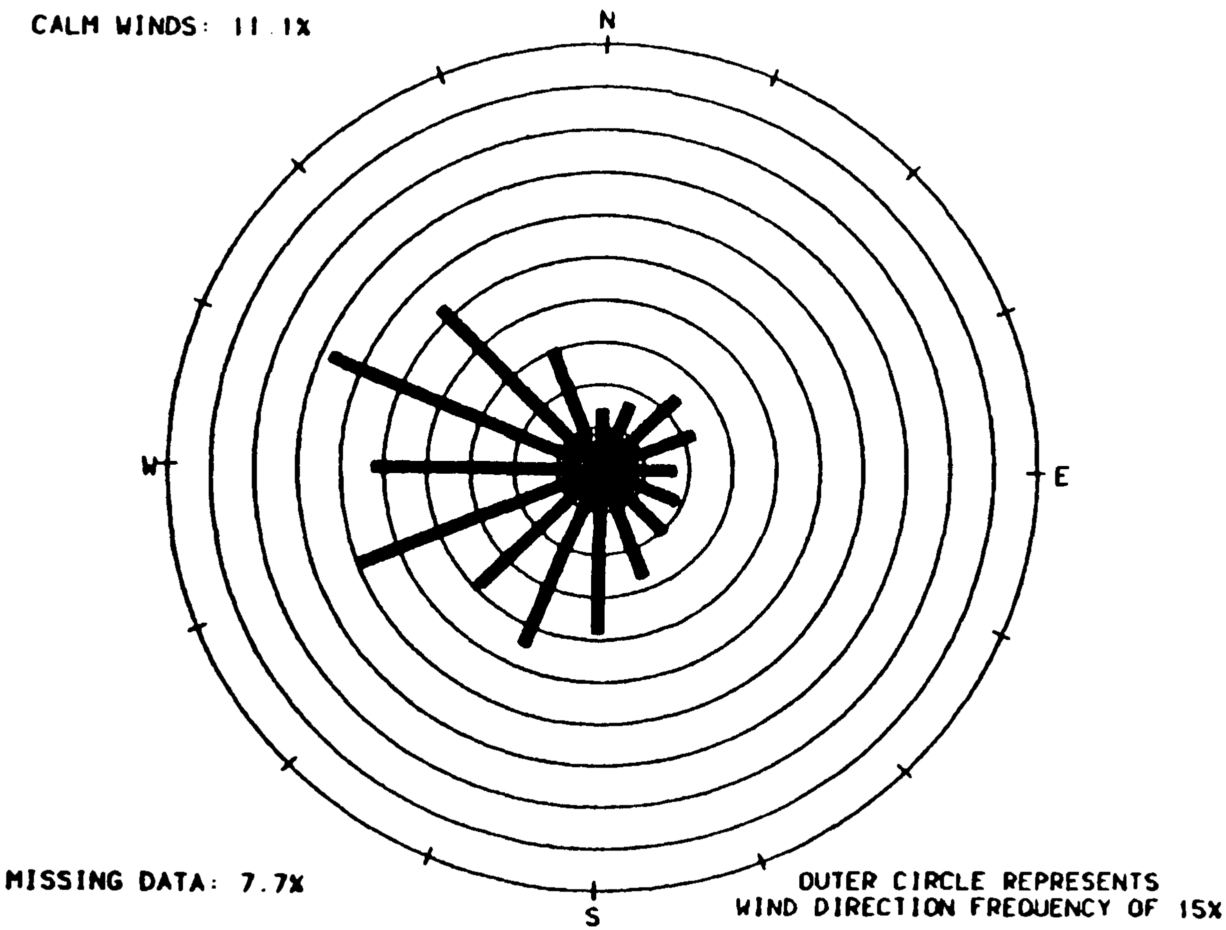


FIGURE 5-4

OYSTER CREEK ANNUAL WIND ROSE FIVE-YEAR AVERAGE
YEARS: 1977-1981
380-FT LEVEL

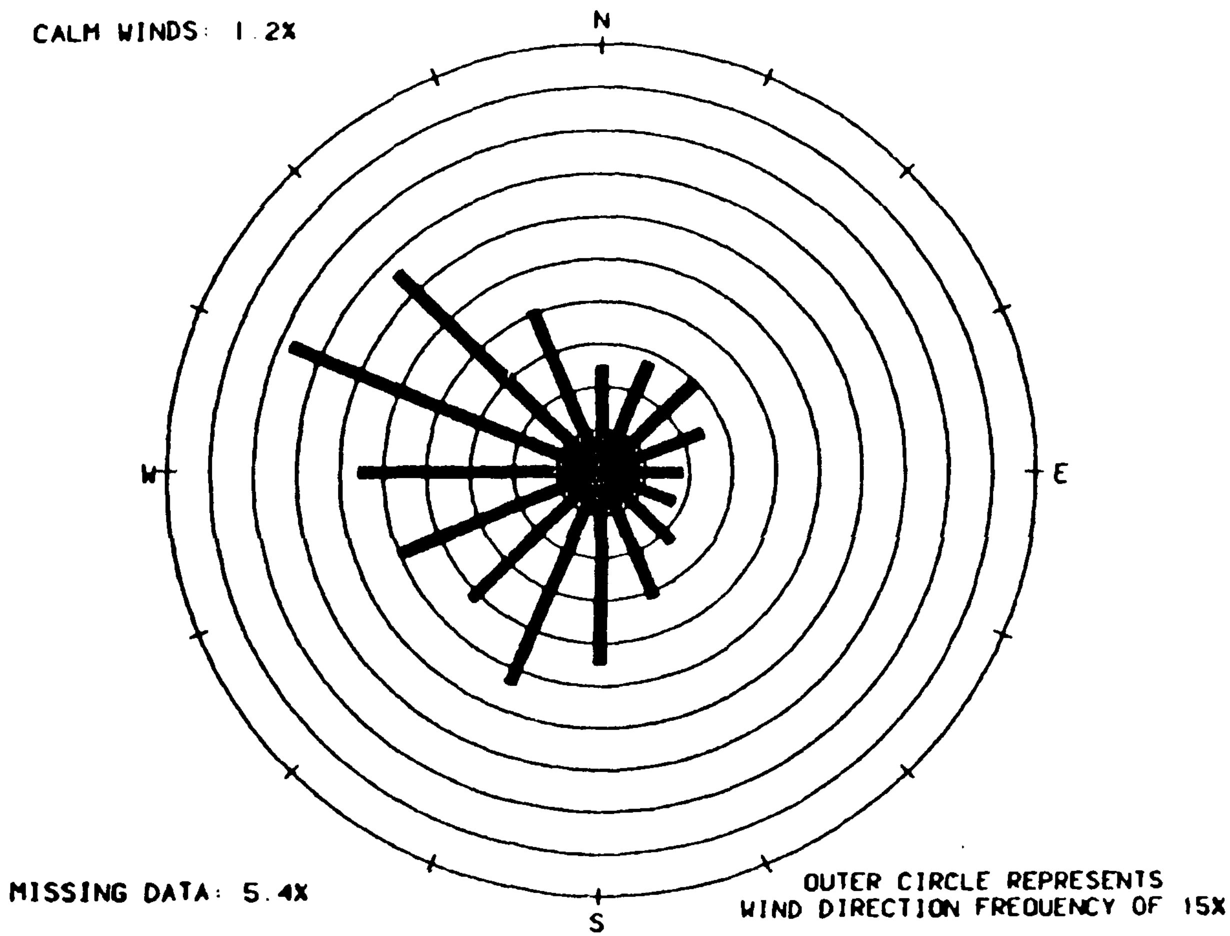
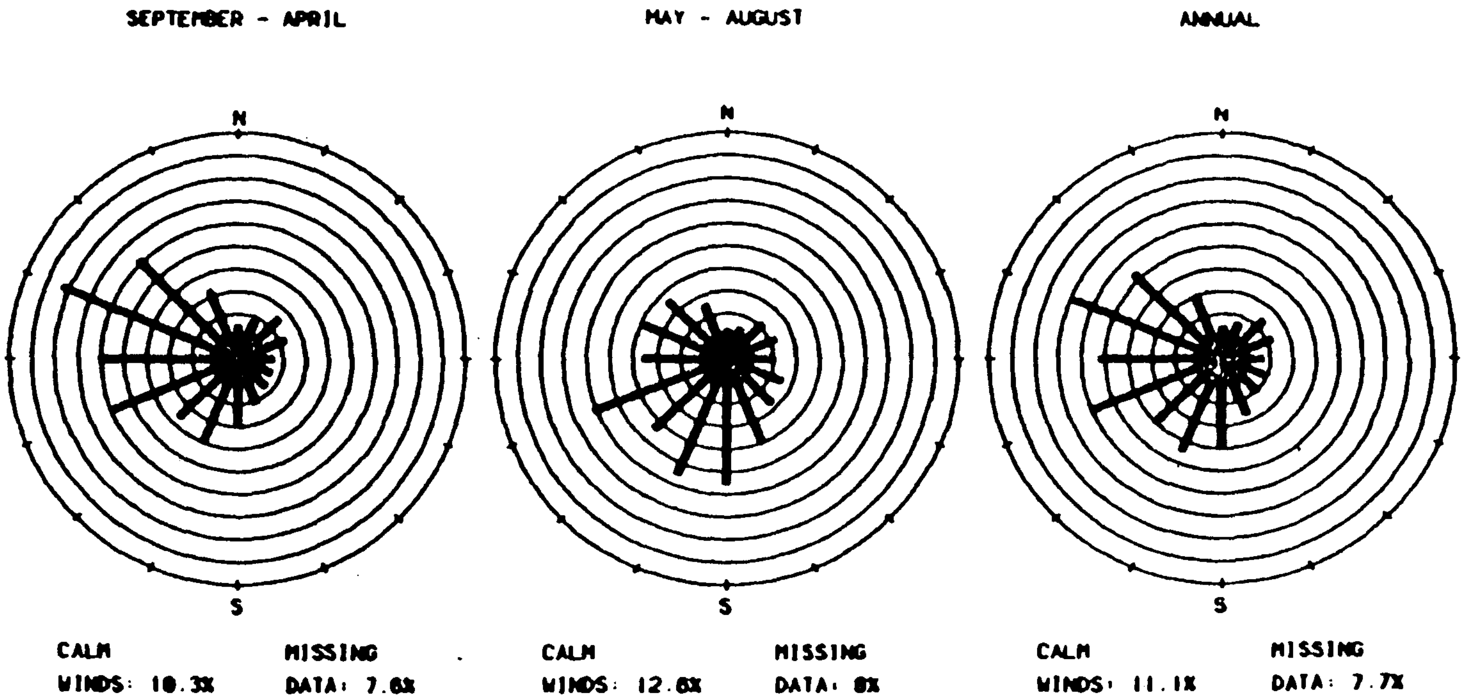


FIGURE 5-5

OYSTER CREEK WIND ROSES: FIVE-YEAR AVERAGE
YEARS: 1977-1981
33-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

approximately 45% of the time. The wind blows from the NE through S directions only about 22% of the time. During May-August, however, the predominant winds blow from a W through S direction, which represents a shift of 45° from the September-April mean direction. The frequency of winds blowing from the NE through S direction is now about 32%, as opposed to 22% for September-April. Note that for both the September-April and May-August periods, calm winds occur about 10-13% of the time.

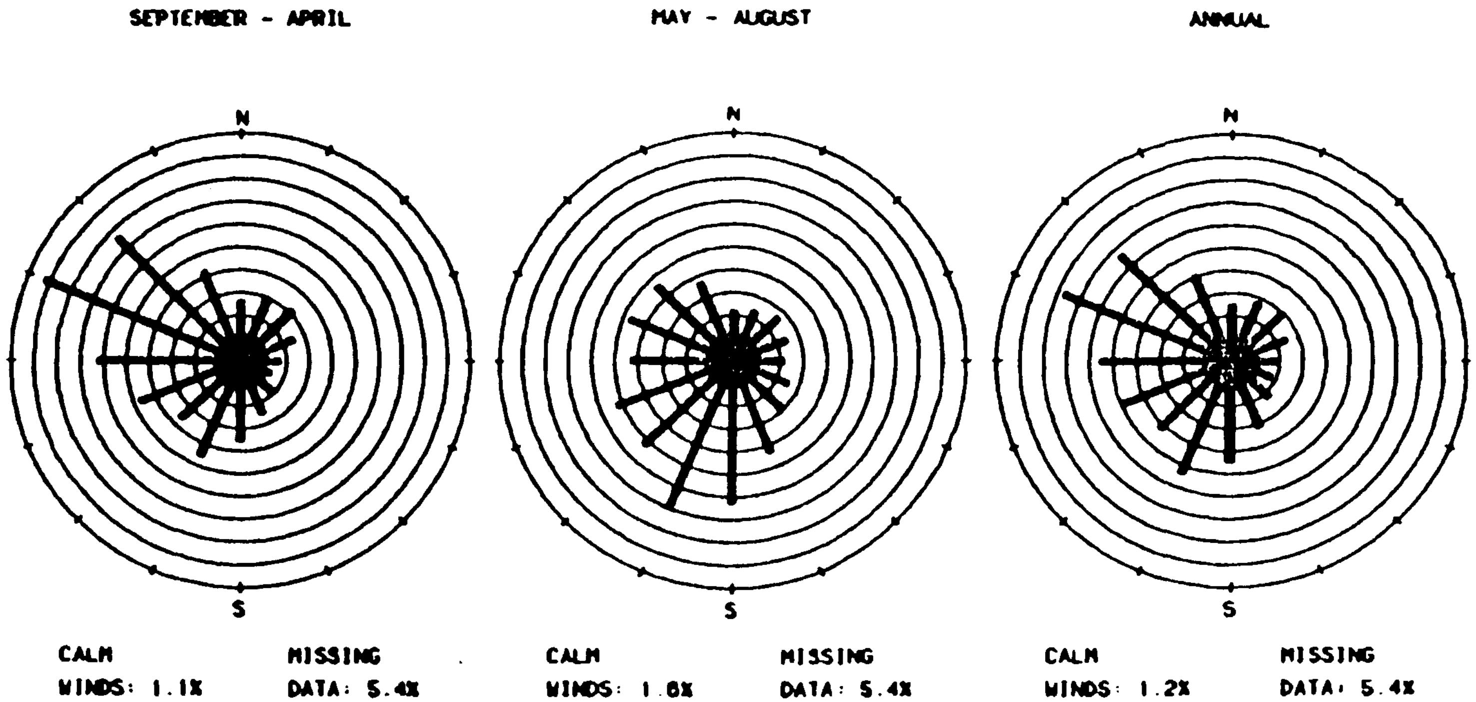
The preceding discussion applied to the 33-ft level wind directions. Seasonal wind roses for the 380-ft level are shown in Figure 5-6. Note that calm winds occur only about 1% of the time, as opposed to 10-13% for the 33-ft level. Because calm winds occur less often at the 380-ft level, the wind direction frequencies equal or exceed the corresponding wind direction frequencies at the 33-ft level.

As mentioned in Section 5.2, the sea breeze is a diurnal phenomenon with onshore winds during the day and offshore or calm winds at night. This diurnal variation in wind direction can be seen in Figure 5-7, which shows the wind roses for both the daytime and nighttime periods during the sea breeze season (May-August) at the 33-ft level. The figure shows a pronounced diurnal variation of W to SW winds at night and NE to S winds during the day. During the daytime, winds from the NE through S directions blow about 48% of the time. During the nighttime, however, winds from the NE through S directions blow only 18% of the time, or about 1/3 as often as during the daytime. Over one-half of the nighttime winds have a westerly component. In addition, 20% of the nighttime winds are calm as opposed to 4% of the daytime winds. Note that the "All Hours" wind rose in Figure 5-7 masks the diurnal variation in that it does not show dual peaks for the daytime and nighttime mean wind directions.

A conservative ball park estimate of the frequency of the sea breeze can be obtained by subtracting the nighttime frequency of NE through S winds from the daytime frequency of NE through S winds. This method of subtraction assumes that all nighttime NE through S winds are synoptically forced, and that this synoptic forcing also operates through the daytime. For the 33-ft

FIGURE 5-6

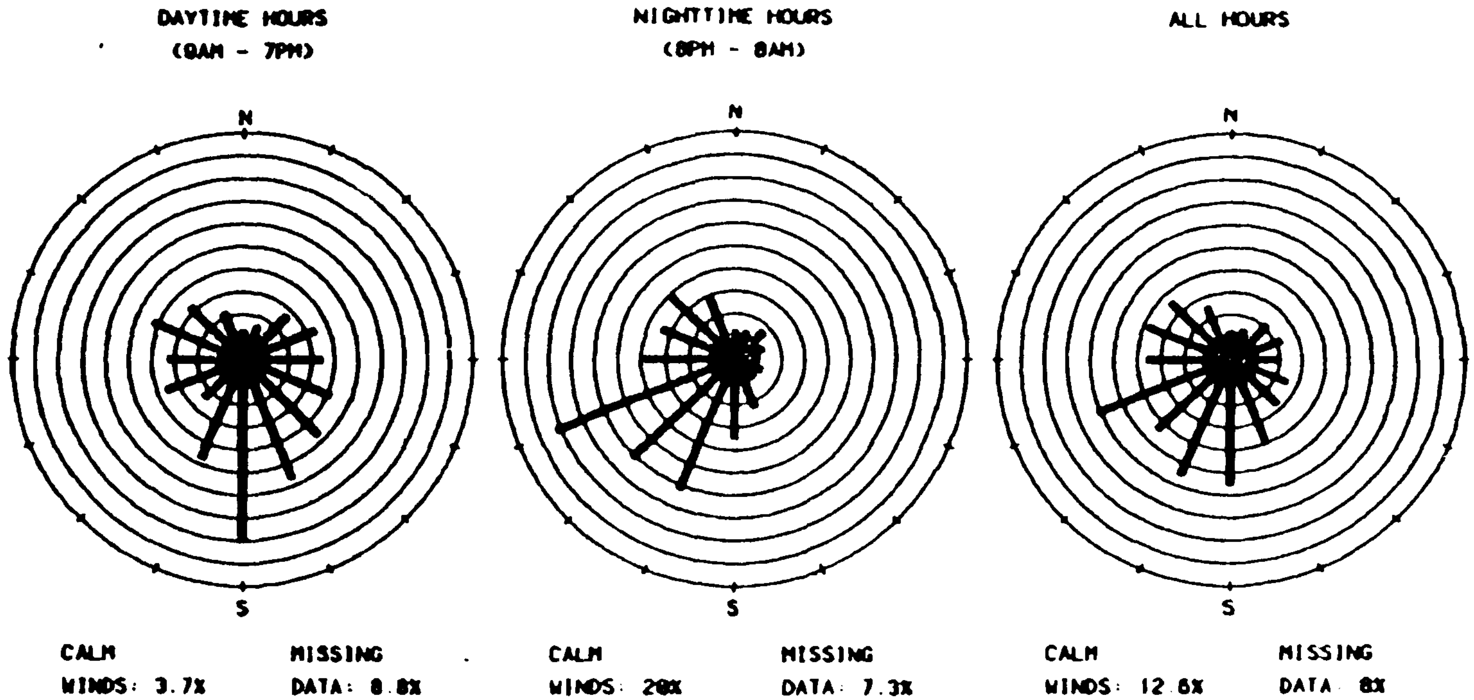
OYSTER CREEK WIND ROSES: FIVE-YEAR AVERAGE
YEARS: 1977-1981
380-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 5-7

OYSTER CREEK WIND ROSES: MAY - AUGUST
FIVE YEARS: 1977-1981
33-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

level of the May-August period, this method of subtraction gives a sea breeze frequency of about 30%. This estimate will be refined in Section 5.5.2.

Daytime and nighttime wind roses for the September-April period are shown in Figure 5-8. Figure 5-8 shows that while there is a difference in wind direction frequencies from daytime to nighttime, there is no pronounced shift of wind direction from onshore during the day to offshore at night, as is shown in Figure 5-7.

Wind roses for the 380-ft level of the met tower are shown in Figures 5-9 and 5-10. Figure 5-9 shows the daytime and nighttime wind roses for the May-August period, and Figure 5-10 shows the daytime and nighttime wind roses for the September-April period.

A comparison of the 380-ft (Figure 5-9) and 33-ft level (Figure 5-7) winds for the May-August period shows that the daytime, nighttime and all hours wind roses are similar for both levels. There is no systematic shift in wind direction with height. The 380-ft level winds blow from same directions as the 33-ft level winds only more frequently; the 380-ft winds blow more frequently because there are only 1/4 as many calm winds at this level.

A comparison of the 380-ft (Figure 5-10) and 33-ft level winds (Figure 5-8) for the September-April period also shows that the daytime, nighttime and all hours wind roses are similar for both levels. The winds at the 380-ft level show the same directional distribution as the winds at the 33-ft level except that the 380-ft level winds blow more frequently because of fewer calm winds at that level.

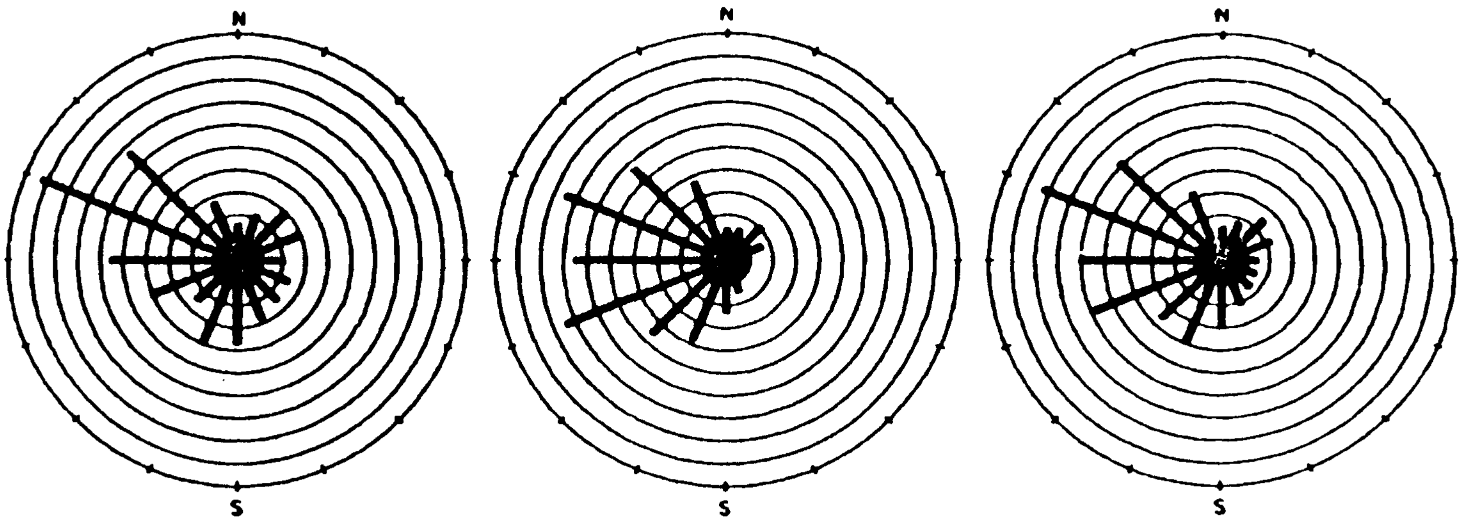
5.5.2 Results of Sea Breeze Days Analysis

The analysis of wind roses in the preceding section gave an estimate of the frequency of the sea breeze at Oyster Creek, but it revealed nothing about the dates they occurred, or whether in fact they were true sea breezes. True sea breezes must meet, at a minimum, the two conditions outlined in Section 5.4.2. That is, a daytime period characterized by condition (1) must be both preceded and followed by a nighttime period characterized by condition (2). Only then was the day classified as a potential sea breeze day.

FIGURE 5-8

OYSTER CREEK WIND ROSES SEPTEMBER - APRIL
FIVE YEARS 1977-1981
33-FT LEVEL

DAYTIME HOURS (9AM - 7PM) | NIGHTTIME HOURS (8PM - 8AM) | ALL HOURS

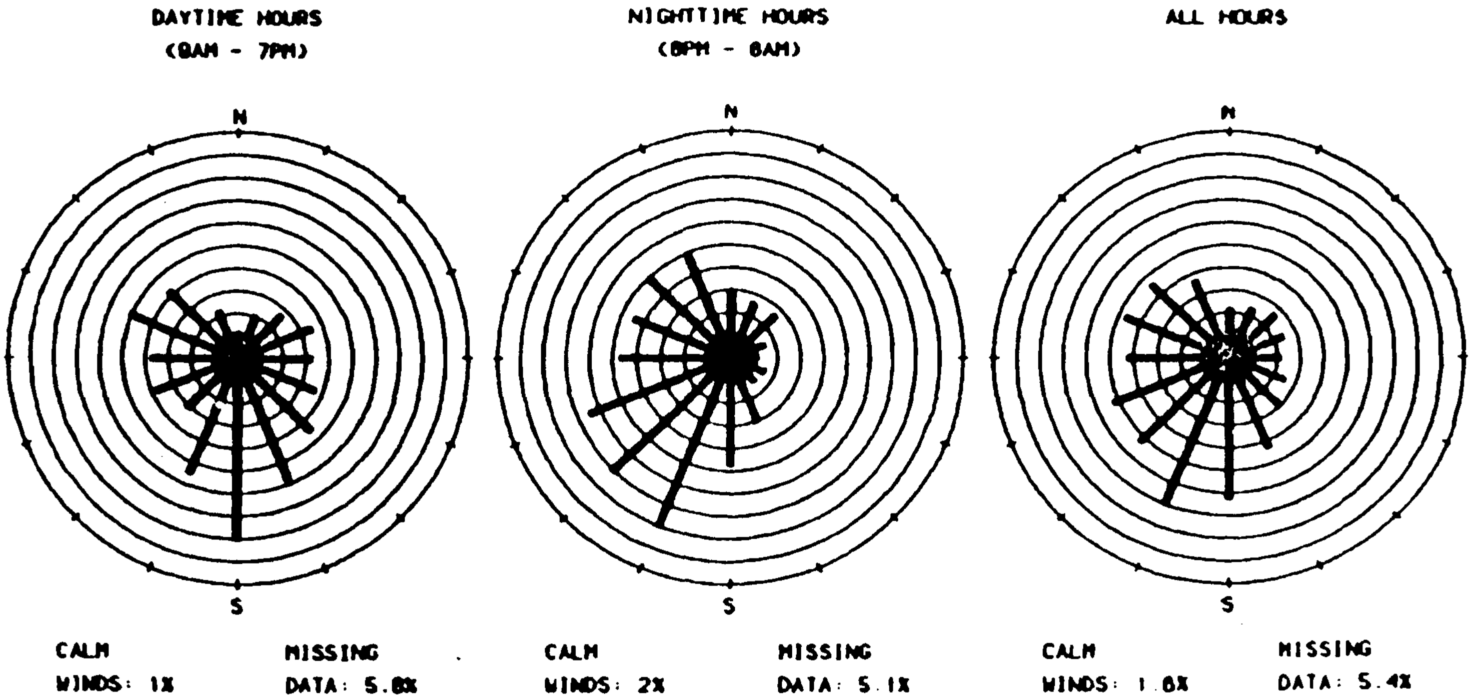


DAYTIME HOURS		NIGHTTIME HOURS		ALL HOURS	
CALM WINDS: 4.9%	MISSING DATA: 8.3%	CALM WINDS: 14.9%	MISSING DATA: 7%	CALM WINDS: 10.3%	MISSING DATA: 7.6%

NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 5-9

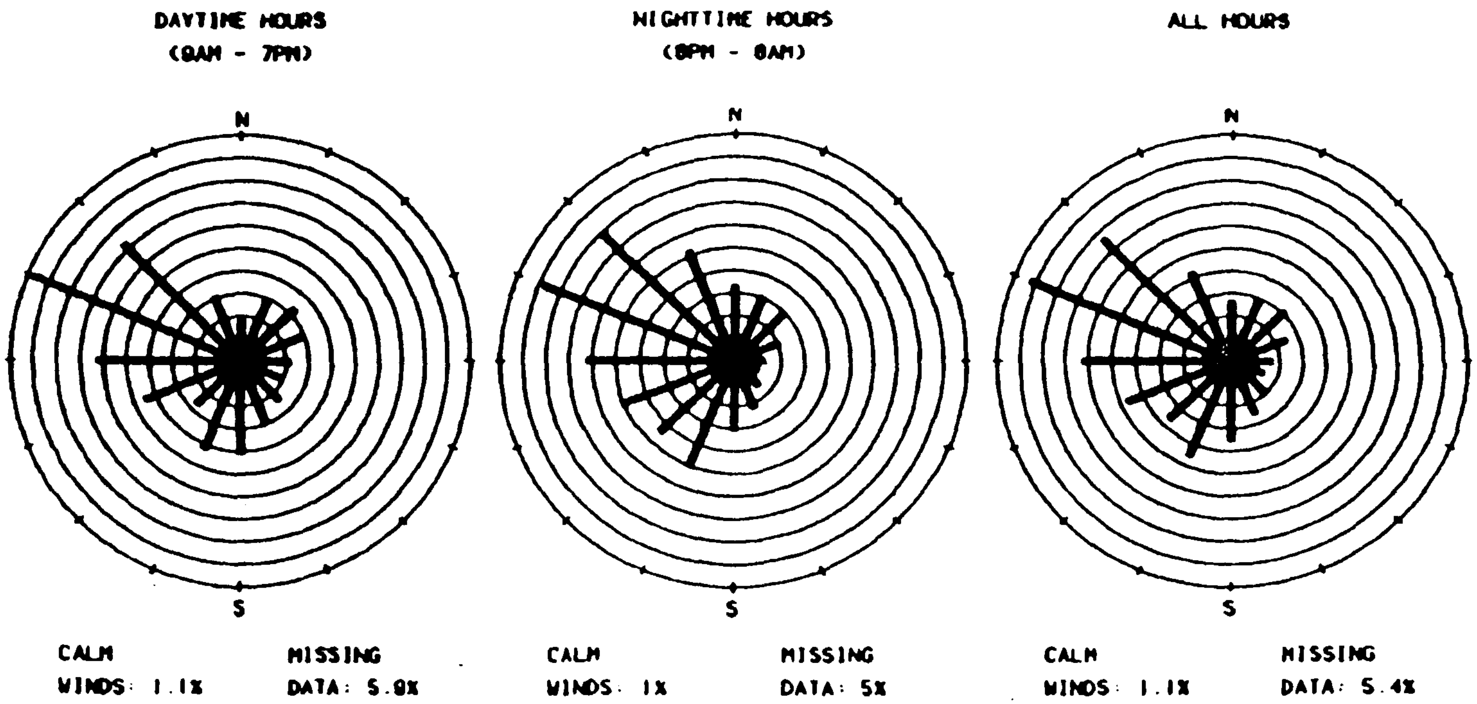
OYSTER CREEK WIND ROSES: MAY - AUGUST
FIVE YEARS: 1977-1981
380-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 5-10

OYSTER CREEK WIND ROSES SEPTEMBER - APRIL
FIVE YEARS: 1977-1981
380-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

As a first step in determining dates with a true sea breezes, the 33-ft level wind data for May-August for 1977-1981 was searched (i.e., computerized search) for days satisfying the above sequence of conditions. The days satisfying this sequence of conditions are listed in Table 5-2. The table lists a total of a 190 potential sea breeze days during May-August for the five-year period. Note that the number of sea breeze days ranges from 28 in 1980 to 45 in 1977 and 1981.

For all potential sea breeze days, hourly winds were plotted for both the 33-ft level and the 380-ft level. Samples of these plots are shown in Figure 5-11 for the 33-ft level and in Figure 5-12 for the 380 ft level. Plots of hourly winds for all dates listed in Table 5-2 are shown in Appendix A1 for the 33-ft level and Appendix A2 for the 380-ft level. The 380-ft level winds are presented to show that in general they blow in the same direction as the 33-ft level winds, even on potential sea breeze days.

Figure 5-11 indicates that the winds on all dates shown look characteristic of the sea breeze cycle with the exception of May 8, which shows an abrupt wind shift at the end of the day. Note also the strong S to SSW winds preceding the wind shift. Neither the strong S to SSW winds nor the abrupt wind shift to a strong WNW flow at the end of the day are typical parts of the sea breeze cycle. May 8 may have started out with a sea breeze regime but it did not end with one. Synoptic-scale effects began dominating the winds later in the day. For this reason May 8, based on wind considerations alone, was not a true sea breeze day.

To verify that the days listed in Table 5-2 were true sea breeze days, hourly temperature and stability data for these days were also examined. Hourly temperature and stability data were plotted for all potential sea breeze days. Plots for all potential sea breeze dates are shown in Appendices B1 through B5. Samples of these plots are shown in Figures 5-13, 5-14 and 5-15. For ease of comparison, the hourly winds shown in previous graphs are also presented. On the left side of the graphs the labels TEMP, DELTA T, and DEL THETA are abbreviations for temperature, delta temperature, and delta theta, respectively. Temperature is the temperature (°F) at the 33-ft level of the tower. Delta temperature is the temperature difference

TABLE 5-2:

POTENTIAL SEA BREEZE DAYS DURING MAY-AUGUST

	1977	1978	1979	1980	1981
	5/03	5/02	5/12	5/02	5/06
	5/08	5/07	5/18	5/06	5/07
	5/15	5/11	6/20	5/12	5/18
	5/19	5/23	6/21	5/15	5/19
	5/20	5/24	6/26	5/16	5/20
	5/21	5/30	6/27	5/19	5/21
	5/22	5/31	6/28	5/24	5/22
	5/23	6/02	6/29	5/25	5/23
	5/26	6/03	7/07	5/28	5/26
	5/27	6/06	7/08	6/07	5/30
	5/31	6/10	7/09	6/11	6/08
	6/06	6/11	7/10	6/13	6/12
	6/09	6/16	7/17	6/14	6/16
	6/12	6/20	7/18	6/17	6/18
	6/13	6/23	7/19	6/22	6/24
	6/14	6/24	7/20	6/23	6/25
	6/23	6/25	7/21	7/04	6/27
	6/24	6/26	7/22	7/07	6/28
	6/27	6/27	7/23	7/24	7/04
	6/28	7/05	7/24	7/26	7/10
	7/03	7/06	7/25	8/10	7/11
	7/06	7/11	7/28	8/11	7/12
	7/07	7/12	8/01	8/17	7/17
	7/08	7/18	8/02	8/22	7/18
	7/09	7/21	8/03	8/23	7/19
	7/15	8/13	8/05	8/24	7/22
	7/16	8/14	8/06	8/25	7/23
	7/18	8/15	8/07	8/26	7/26
	7/19	8/16	8/09		7/28
	7/23	8/19	8/16		7/30
	7/27	8/21	8/17		7/31
	7/28	8/22	8/18		8/01
	7/29	8/23	8/19		8/02
	8/02	8/25	8/20		8/09
	8/03	8/26	8/22		8/10
	8/04		8/26		8/11
	8/10		8/28		8/14
	8/13				8/15
	8/14				8/16
	8/15				8/18
	8/16				8/21
	8/19				8/22
	8/21				8/25
	8/23				8/26
	8/25				8/28
TOTAL NUMBER OF DAYS	45	35	37	28	45

Figure 5-11:

Sample plot of hourly winds at the 33-ft. level. Wind speeds are indicated by barb length: one-half barb equals 5 mph, one full barb equals 10 mph, etc.

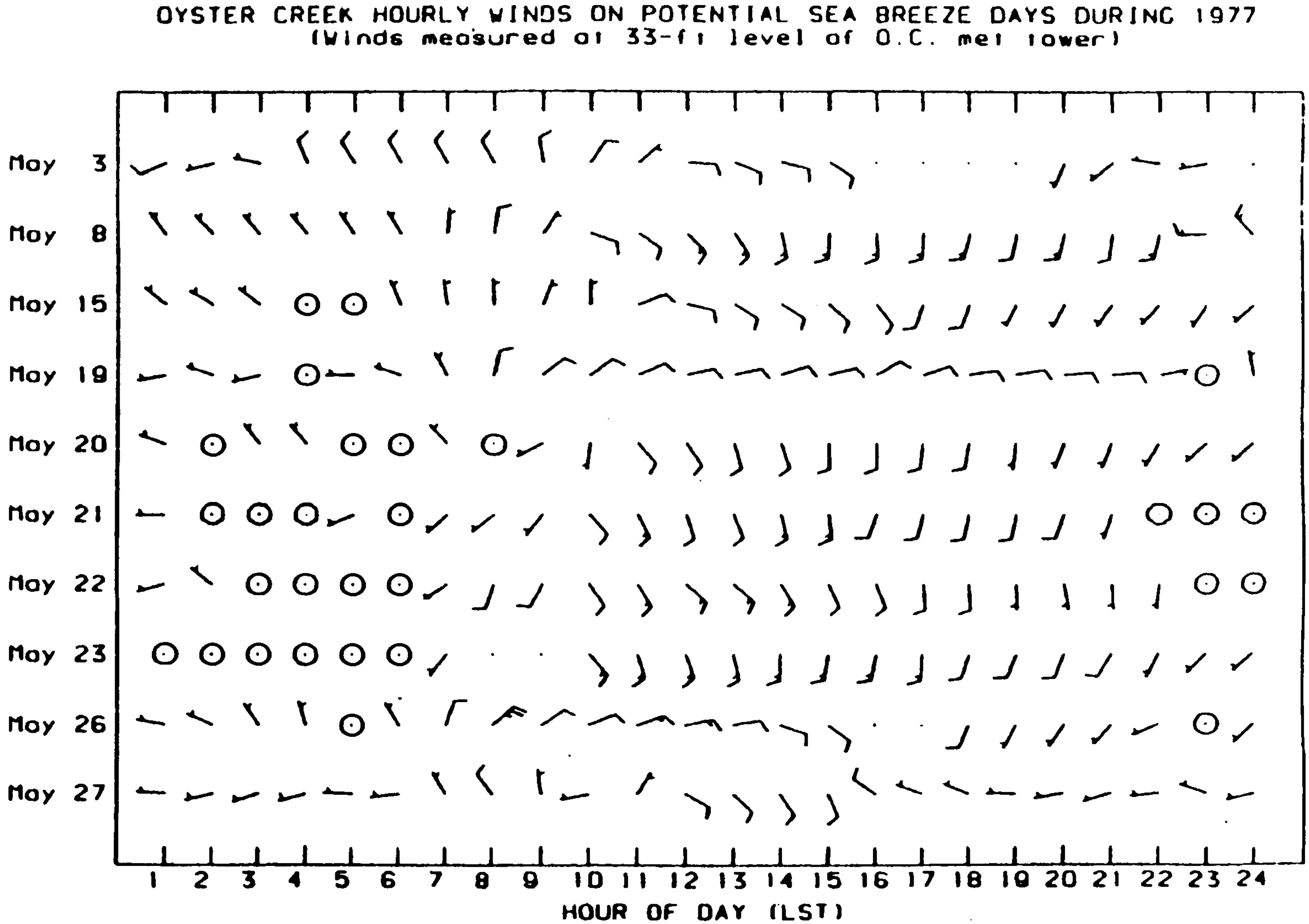


Figure 5-12:

Sample plot of hourly winds at the 380-ft. level. Wind speeds are indicated by barb length: one-half barb equals 5 mph, one full barb equals 10 mph, etc.

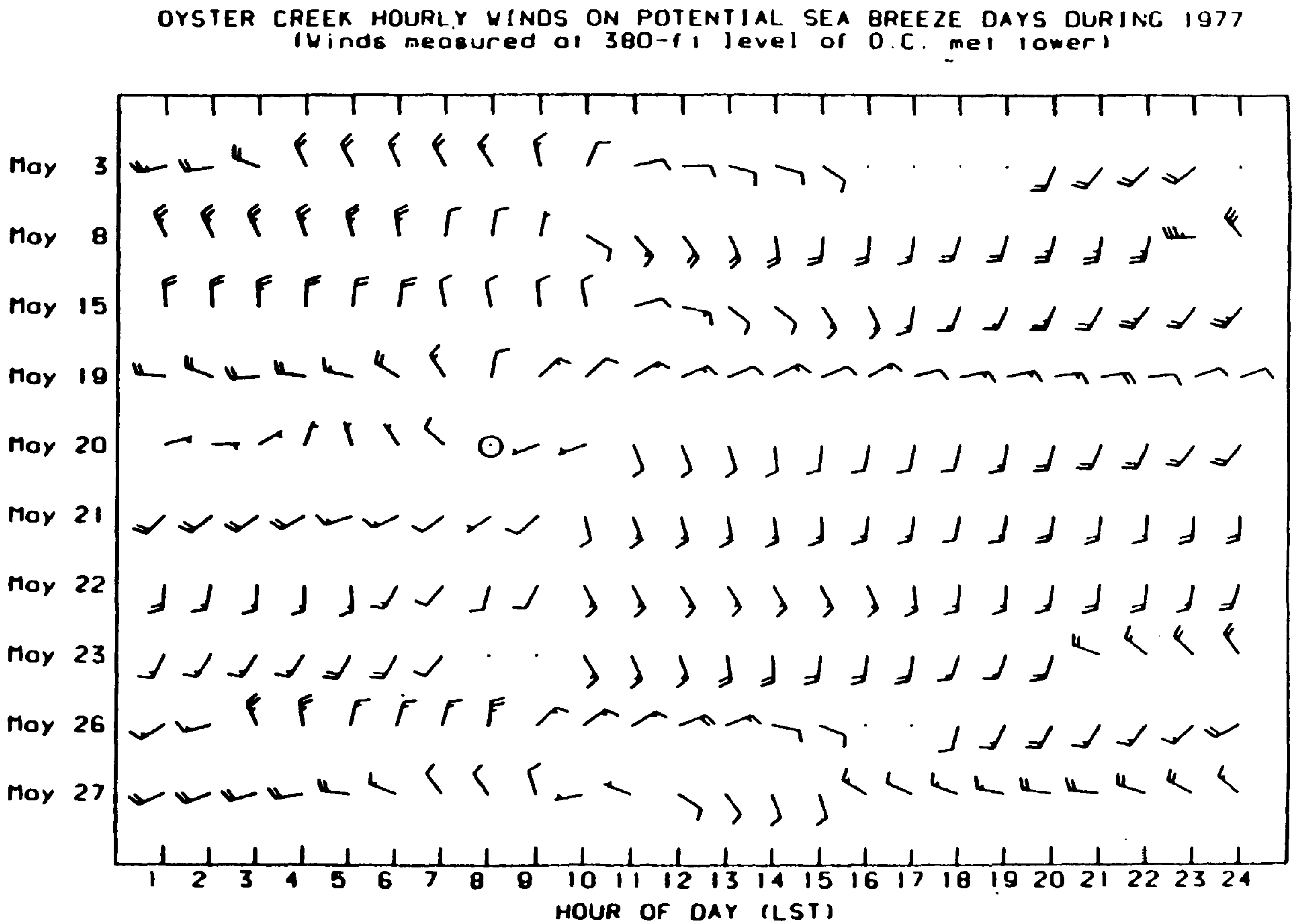


Figure 5-13:

Sample plot of meteorological parameters during true sea breeze conditions. Winds shift through the north during onset of sea breeze.

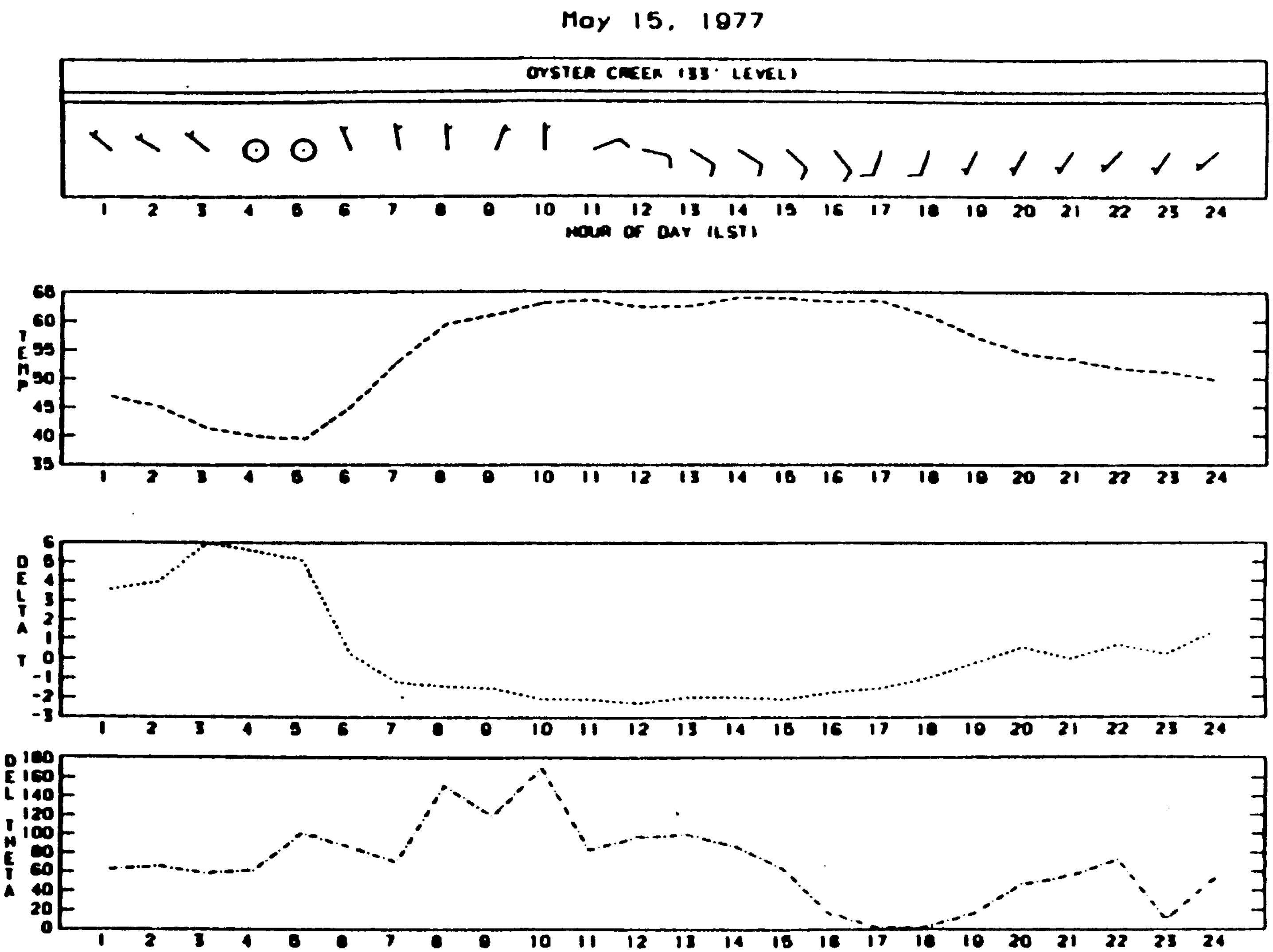


Figure 5-14:

Sample plot of meteorological parameters during true sea breeze conditions. Winds shift through the south during onset of sea breeze.

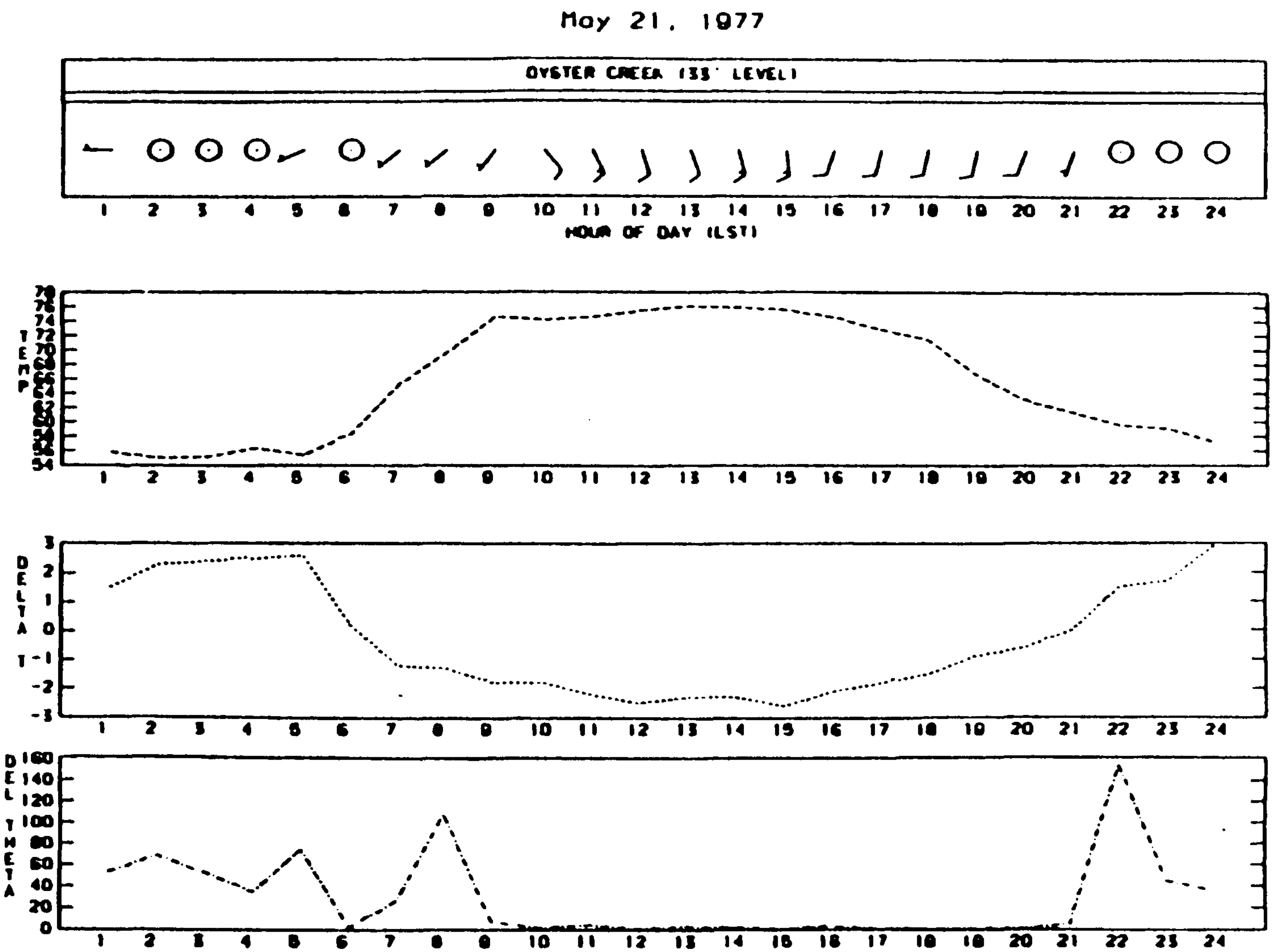
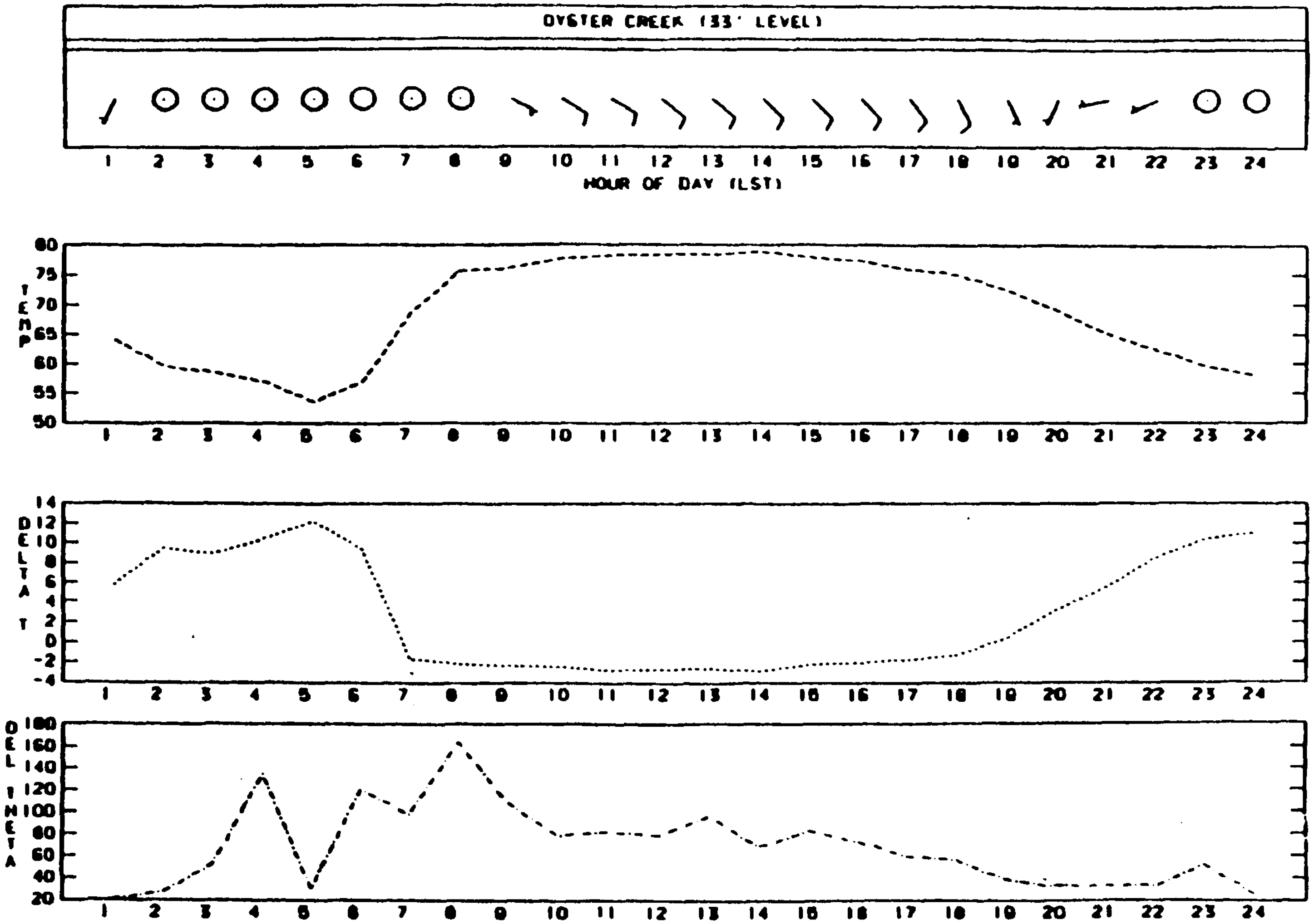


Figure 5-15:

Sample plot of meteorological parameters during true sea breeze conditions. Winds shift from calm to SE during onset of sea breeze.

July 31, 1981



(°F) between the 150-ft level and 33-ft level (T_{150} - T_{33}). Delta theta is the wind direction range (degrees) during any given hour.

The 33-ft and 150-ft levels were chosen for plotting because the sea breeze is a surface based phenomenon that is forced by differential surface heating, and it is at the lower levels where meteorological changes associated with the sea breeze would be most pronounced.

Figures 5-13, 5-14 and 5-15 show different days with classic sea breeze features evident in the winds, temperature and delta temperature. Weak westerly or calm winds blow in the early part of the day, the temperature reaches its minimum value and the atmosphere is extremely stable (large positive delta temperature). As the day progresses, the atmosphere becomes more unstable, the winds shift to easterly, the temperature stops rising and levels off with the onset of the easterly wind, and the atmosphere becomes more unstable. In the early evening, the winds die down and become more westerly, the temperature falls and the atmosphere becomes more stable.

Although Figures 5-13, 5-14, and 5-15 all show classic sea breeze features, there are interesting differences in the morning shift in wind direction on the three days shown in the figures. Figure 5-13 shows the wind in the morning shifting from the NW to the N to the E and finally SE. Figure 5-14 shows the wind in the morning shifting from the SW to the SE. Figure 5-15 shows the wind in the morning shifting from calm to the SE.

Whether the wind shifts through the N or S would have important implications on emergency preparedness, since the direction of evacuation during these two different mornings with sea breezes would have been in opposite directions. This point will be discussed in greater detail in Section 7.1.

Not all the potential sea breeze days showed the classic sea breeze features illustrated in Figures 5-13, 5-14 and 5-15. In some cases, the temperature and delta temperature did not verify the existence of the sea breeze. Of the 190 potential sea breeze days, only 150 had sea breezes that met the adopted criteria. The remaining 40 dates were rejected for various reasons. A list of final sea breeze dates is shown in Table 5-3.

TABLE 5-3:

SEA BREEZE DAYS DURING MAY-AUGUST

	1977	1978	1979	1980	1981
	5/03	5/23	6/20	5/02	5/07
	5/15	5/30	6/21	5/06	5/18
	5/19	5/31	6/26	5/12	5/20
	5/20	6/02	6/27	5/15	5/21
	5/21	6/06	6/28	5/16	5/23
	5/22	6/16	7/07	5/19	5/26
	5/23	6/20	7/08	5/24	5/30
	5/26	6/23	7/09	5/28	6/08
	5/27	6/24	7/17	6/07	6/12
	5/31	6/25	7/18	6/11	6/16
	6/12	6/27	7/19	6/13	6/18
	6/13	7/05	7/20	6/14	6/27
	6/14	7/06	7/21	6/17	6/28
	6/23	7/11	7/22	6/22	7/04
	6/24	7/12	7/23	6/23	7/10
	6/27	7/18	7/24	7/04	7/11
	7/03	7/21	7/25	7/07	7/12
	7/06	8/13	8/01	7/24	7/17
	7/09	8/14	8/02	7/26	7/18
	7/15	8/15	8/03	8/17	7/19
	7/16	8/16	8/05	8/23	7/22
	7/18	8/19	8/06	8/24	7/23
	7/19	8/21	8/07	8/25	7/30
	7/23	8/22	8/09	8/26	7/31
	7/27	8/23	8/16		8/01
	7/28	8/26	8/17		8/02
	8/02		8/19		8/09
	8/03		8/20		8/10
	8/04		8/22		8/11
	8/10		8/28		8/14
	8/13				8/16
	8/14				8/18
	8/15				8/21
	8/25				8/25
					8/26
					8/28
TOTAL NUMBER OF DAYS	34	26	30	24	36

It should be noted that the del theta parameter plotted at the bottom of Figures 5-13, 5-14 and 5-15 has not been included in the discussion. Del theta is the hourly wind direction range. Under certain meteorological conditions, del theta is a gross approximation of sigma theta (Van der Hoven, 1967; Pendergast and Crawford, 1974). Raynor et al. (1980) have suggested that sigma theta, which is the standard deviation of the horizontal wind direction, maybe a more appropriate measure of atmospheric stability than temperature lapse rate, which has been adopted by the NRC as more or less the standard for indicating atmospheric stability. For this reason and as a matter of interest, del theta was plotted in the figures though it was not used in the analysis. Note from Figures 5-13, 5-14 and 5-15, that del theta is largest when the hourly wind changes direction. When this occurs, del theta is not a valid approximation of sigma theta.

6. THE REPRESENTATIVENESS OF THE OYSTER CREEK WIND DIRECTIONS

6.1 Regional Geography

The Oyster Creek site is located on the eastern margin of the Atlantic Coastal Plain. Characteristic topography of the Atlantic Coastal Plain includes gentle rolling plains and flat lowlands at a general elevation of from 0 to 120 feet above mean sea level, although elevations exceed +250 feet locally. General relief in the coastal plain ranges from 20 to 100 feet.

Local topographic features surrounding the site are part of a broad (two to three miles wide) lowland (0 to 25 feet elevation) and tidal marsh area flanked on the east by Barnegat Bay and a sand dune barrier beach. These features typify the eastern margin of the New Jersey Coastal Plain from the vicinity of Manasquan 23 miles NNE of the site to Cape May 70 miles SSW of the site.

The barrier beaches of the New Jersey coast are evident in Figure 5-1.

6.2 Definition of Representativeness

The representativeness of on-site meteorological data can be defined in terms of two types of analyses. The first type of analysis involves developing frequency distributions of parameters measured at each meteorological station and comparing these distributions. The second type of analysis involves comparing the measured parameters at each meteorological station on an hour-by-hour basis.

The first method is a good screening procedure, but the method requires considerable caution when the results are interpreted. For example, the first method may show identical frequency distributions for a given parameter from two meteorological stations, but this should not be interpreted as meaning that one station is representative of the other for that parameter.

To conclusively substantiate representativeness, the second type of analysis must be employed in addition to the first. The second method compares individual hourly values from each meteorological station. With

this second method, however, determining whether a meteorological station is representative or not depends on the resolution of two questions:

1. What is an acceptable level of difference in the measured meteorological parameters at one location versus another?
2. What is an acceptable percentage of time that the meteorological parameter differs by more than this acceptable difference?

In answer to the first question, the acceptable level of difference in the meteorological parameters between locations depends on the intended application of the representativeness study. Suppose, for example, the purpose of the representativeness study was to aid the development of an evacuation plan. If the evacuation plan were based on evacuating a 90° sector, greater differences in wind directions could be tolerated than if the evacuation plan were based on evacuating a 45° sector.

The answer to the second question depends on policy and philosophy. It is almost impossible to have a meteorological measurement program that will assure 100% of the time that the hourly differences in a parameter measured at two locations always fall within a pre-specified range of acceptability. The obvious exception, of course, is the case where the pre-specified range of acceptability is so large that the hourly parameter differences always fall within the range.

Defining quantitative criteria for substantiating representativeness is the subject of considerable debate. What is certain, however, is that of all the meteorological parameters involved in the representativeness issue, wind direction is probably the single most important parameter because it defines the direction in which potential emissions will travel in the event of a radiological emergency and thus constitutes a major factor in developing, for example, evacuation plans. Therefore, it is crucial that the degree of representativeness of this parameter is known. The representativeness of wind direction is the focus of the following sections.

In the absence of objective criteria for establishing representativeness for wind direction between stations, the results of the two types of analyses described above are evaluated subjectively in Section 6.5. The results are

presented in sufficient detail so that individuals with different backgrounds and philosophies will find enough data in this report to form their own conclusions of the representativeness of the Oyster Creek wind direction data.

6.3 Data

For the representativeness study, the closest stations available were the Lakehurst Naval Air Station 14 miles northwest and the National Weather Service Atlantic City station (NAFEC) 33 miles to the southwest. These stations are shown in Figure 6-1.

Although Atlantic City is a considerable distance from Oyster Creek, indications that a sea breeze is occurring simultaneously at Atlantic City and Lakehurst, for example, could suggest that a sea breeze is acting all along the southern New Jersey coast, and not just at Oyster Creek. This information could prove invaluable and argues for including Atlantic City in the representativeness study.

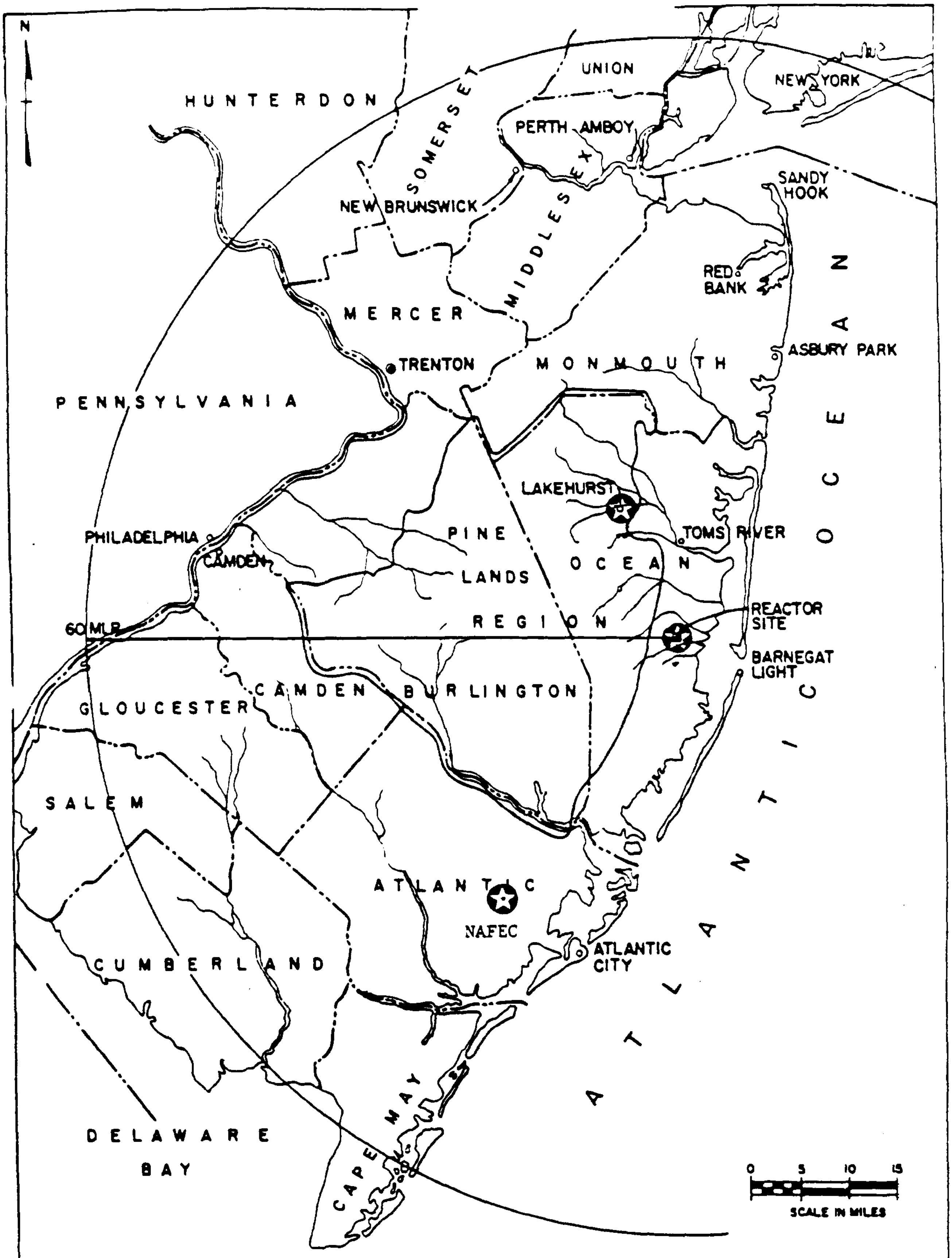
The wind data available at these stations are shown in Table 6-1. Observations are reported every 3 hours. Note that the years of record for Lakehurst and Atlantic City are not identical. Also note Lakehurst does not report observations at 1 AM and 4 AM LST.

6.4 Method of Data Analysis

In the discussion of the definition of representativeness in Section 6.2, two methods of substantiating the on-site representativeness of meteorological data were discussed. The first method consisted of comparing frequency distributions and the second method consisted of comparing hourly values.

For wind direction, the first method entails comparing wind roses and the second method entails comparing hourly values using contingency tables.

With the first method, similar wind roses (i.e., similar wind direction frequency distributions) does not imply one station's winds are representative of the other station's. For example, the wind roses for two stations can show identical averge wind directions, yet for any given hour or sequence of hours,



JERSEY CENTRAL POWER AND LIGHT COMPANY OYSTER CREEK NUCLEAR GENERATING STATION	AREA MAP: NEW JERSEY	FIGURE 6-1

TABLE 6-1

WEATHER STATIONS USED IN
WIND DIRECTION REPRESENTATIVENESS STUDY

	STATION NAME	
	LAKEHURST	ATLANTIC CITY
Years of record readily available	1977, 1978, 1979 1980	1977, 1978, 1980, 1981
Hours of day when observations were reported (LST)	0700, 1000, 1300 1600, 1900, 2200	0100, 0400, 0700, 1000, 1300, 1600, 1900, 2200
Height of anemometer above ground (ft.)	15	20
Wind direction	16 point compass	16 point compass
Wind speed	Nearest whole knots	Nearest whole knots

they can have completely different wind directions. The average for two stations can be the same because the constituent hourly values are the same, or because the constituent hourly values are different and just happen to average out the same over the course of a week, month or year.

The second method, however, which is an hourly comparison of wind direction, will show conclusively the degree of representativeness.

Section 6.4.1 discusses the methodology for the wind rose analysis. Section 6.4.2 discusses the methodology for the hourly comparisons.

6.4.1 Methodology for Wind Rose Analysis

As a preliminary screening procedure for representativeness, wind roses for Lakehurst and Atlantic City were compared to the Oyster Creek wind rose. Since the Lakehurst and Atlantic City wind roses were generated from 3-hourly data, Oyster Creek wind roses were also generated from 3-hourly data. (Note that the Oyster Creek wind roses in Section 5 were generated from hourly data.)

Oyster Creek wind roses included all 3-hourly values for the five year period 1977-1981 (8 values/day). Lakehurst wind roses included 3-hourly values for the four year period 1977-1980 (6 values/day; 1 AM and 4 AM data were not reported at Lakehurst). Atlantic City wind roses included all 3-hourly values for the four year period 1977, 1978, 1979 and 1981 (8 values/day). Thus the data bases differed slightly but not appreciably.

Daytime and nighttime wind roses for the period May-August were generated for all three stations. Daytime and nighttime wind roses for sea breeze days only were also generated for all three stations. Daytime included the hours 1000, 1300, 1600 and 1900; nighttime included the hours 0100, 0400, 0700 and 2200. Note that since Lakehurst did not report data at 0100 and 0400, Lakehurst contained only the hours of 0700 and 2200 in its nighttime data base.

For Lakehurst and Atlantic City, wind speeds 3 knots or less were considered calm. For Oyster Creek, wind speeds 3.4 mph or less were considered calm.

6.4.2 Methodology for Hourly Comparison

The data base used in this analysis is identical to the one described in Section 6.4.1.

In this analysis, hourly differences in wind direction between Oyster Creek and Lakehurst and between Oyster Creek and Atlantic City were computed. These hourly differences in wind direction were then summarized as a function of Oyster Creek wind direction. Contingency tables summarizing the hourly differences were generated for both the May-August period and sea breeze days only.

6.5 Results of Data Analysis

A comparison of wind roses is presented in Section 6.5.1. An hour-by-hour comparison of wind direction is presented in Section 6.5.2.

6.5.1 Results of Wind Rose Analysis

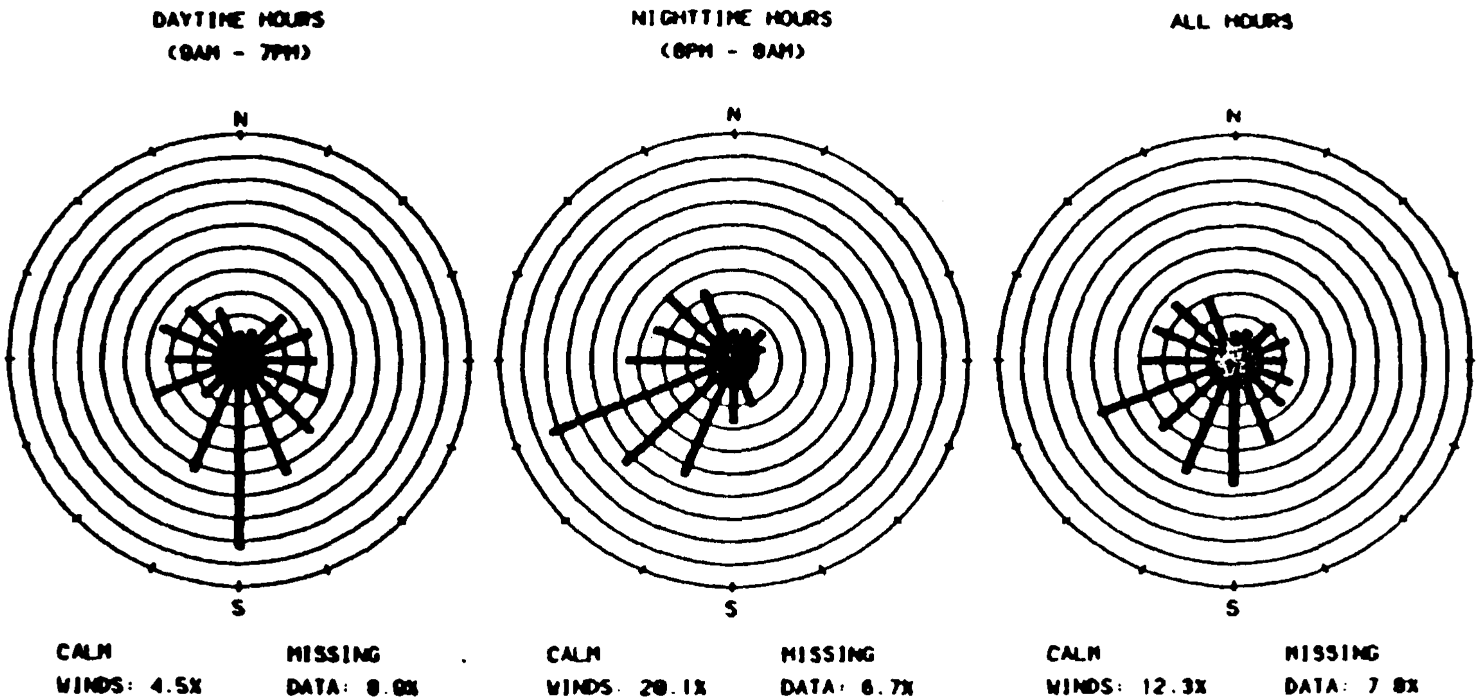
Figure 6-2 shows the daytime and nighttime Oyster Creek wind roses for the May-August period. Note that even though they are generated from 3-hourly data, they are remarkably similar to the wind roses in Figure 5-7 which were generated from hourly data. Thus the use of 3-hourly data rather than 1-hourly data does not distort the wind rose.

Figure 6-2 shows that during the daytime at Oyster Creek, winds from the NE through S directions blow about 50% of the time. During the nighttime winds have a westerly component. In addition, 20% of the nighttime winds are calm as opposed to about 5% of the daytime winds.

Figure 6-3 shows the daytime and nighttime Lakehurst wind roses for the May-August period. From the figure, two things are immediately obvious: (1) calm winds occurred during over one-half the nighttime hours, and (2) daytime winds, when compared with the nighttime winds, show an increase in both westerly and southeasterly winds. Comparing Lakehurst nighttime hours with Oyster Creek nighttime hours shows Lakehurst does not have the predominant W to SW winds that Oyster Creek shows. This is due of course to Lakehurst having calm

FIGURE 6-2

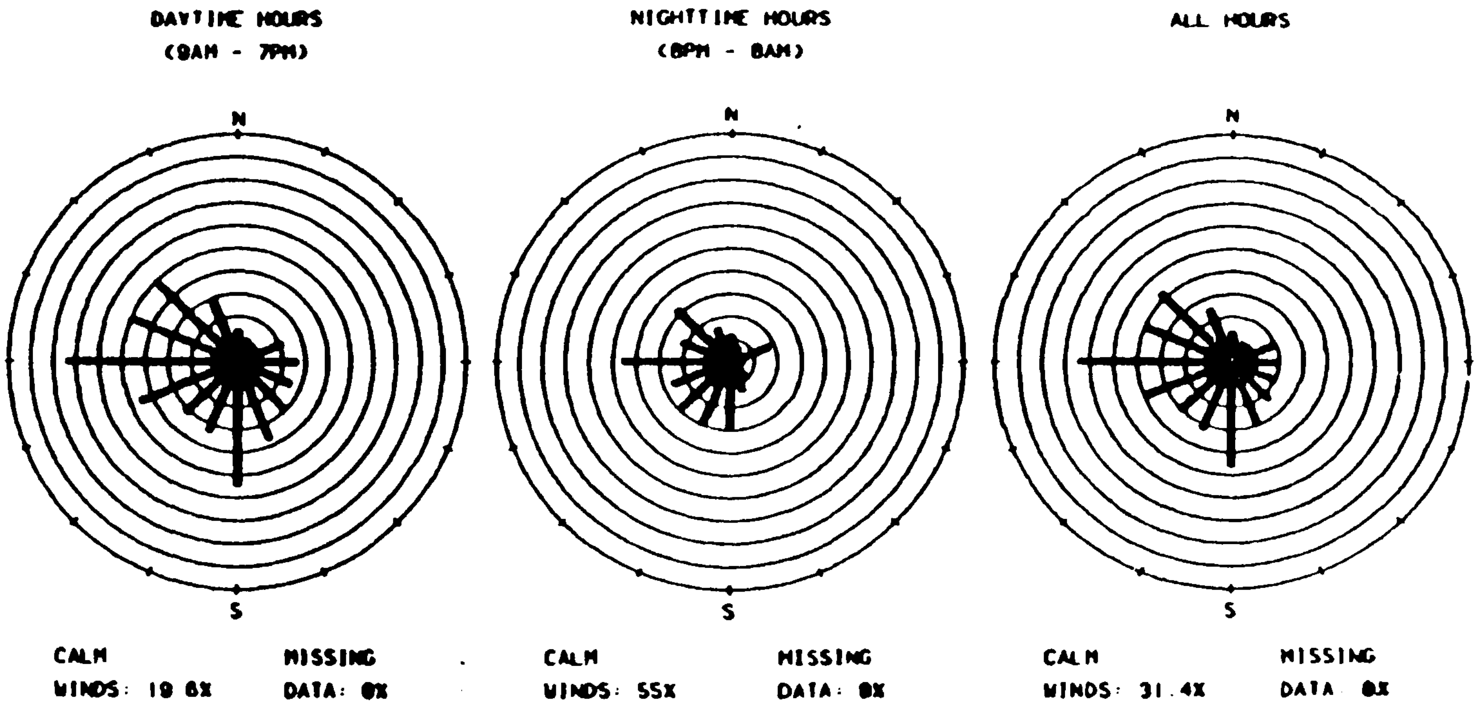
OYSTER CREEK WIND ROSES: MAY - AUGUST
FIVE YEARS (3-HOURLY): 1977-1981
33-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 6-3

LAKEHURST WIND ROSES: MAY - AUGUST
FOUR YEARS (3-HOURLY): 1977-1980



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

nighttime winds over one-half the time. Comparison of daytime winds shows that Lakehurst has westerly winds occurring more frequently than Oyster Creek and southeasterly winds blowing less often than Oyster Creek. Note that for All hours, Lakehurst has almost three times as many calm winds (winds less than 3 knots) as does Oyster Creek.

A conservative estimate of the frequency of the sea breeze at Lakehurst can be obtained by subtracting the nighttime frequency of NE through S winds from the daytime frequency of NE through S winds. For Lakehurst this method of subtraction gives a sea breeze frequency of about 18%, or between 1/2 to 2/3 of the estimate for the Oyster Creek sea breeze frequency using a similar procedure.

Figure 6-4 shows the daytime and nighttime Atlantic City wind roses for the May-August period. Comparison of the daytime and nighttime wind roses shows that onshore winds are much more frequent during the day, but SSW through NNW winds also dominate. The frequency of calm winds at Oyster Creek and Atlantic City are almost identical for the three averaging periods shown. Oyster Creek has more frequent onshore breezes during the day than Atlantic City and about the same frequency of westerly component winds at night.

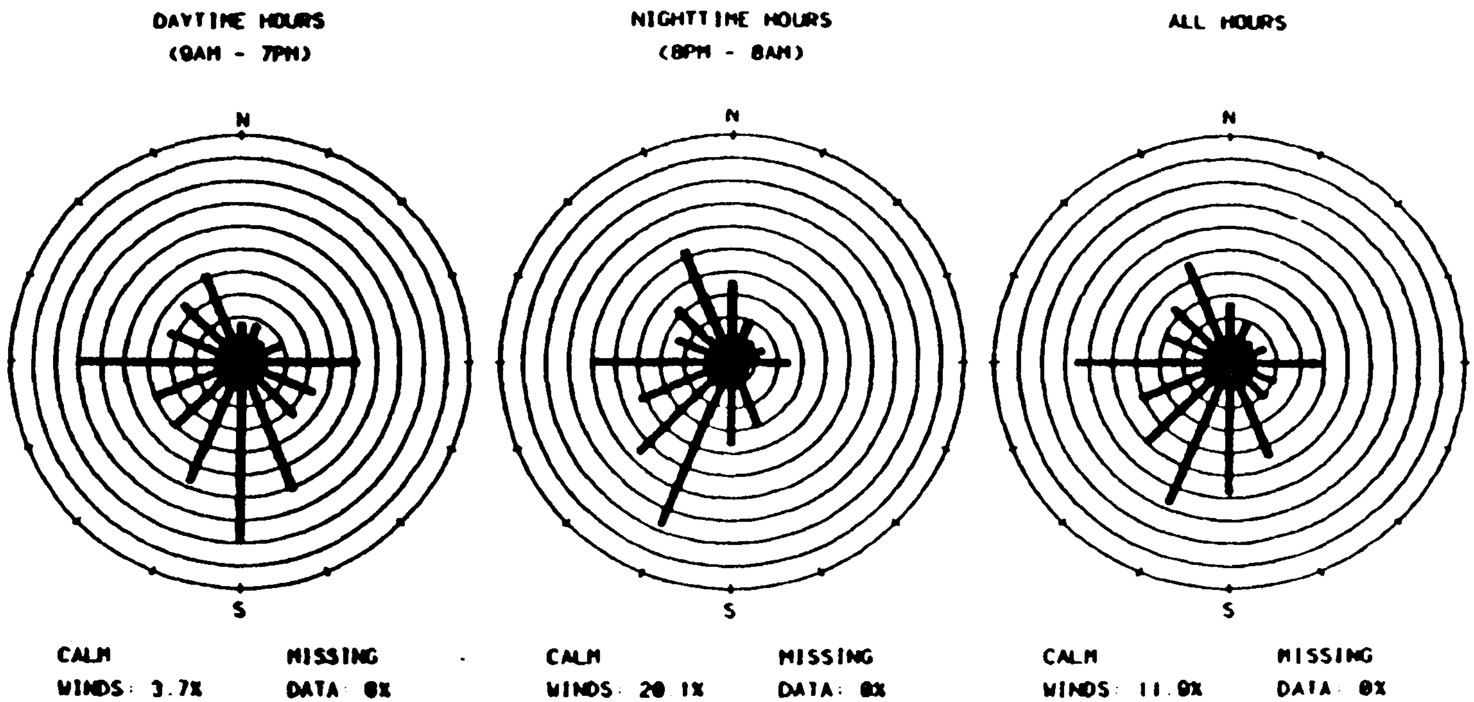
Subtracting nighttime from daytime gives a sea breeze frequency of about 24% at Atlantic City, or about 3/4 of the sea breeze frequency at Oyster Creek, using an identical method.

Figure 6-5 shows the daytime and nighttime Oyster Creek wind roses for sea breeze days only (150 days as listed in Table 5-3). Since the wind roses are for sea breeze days only, it is no surprise that the nighttime wind rose in Figure 6-5 shows only calm winds and winds with westerly components, and that the daytime wind rose shows almost all onshore winds.

Figure 6-6 shows the daytime and nighttime Lakehurst wind roses for sea breeze days only. During the nighttime, 75% of the Lakehurst winds are calm and almost all remaining winds have westerly components. During the daytime,

FIGURE 6-4

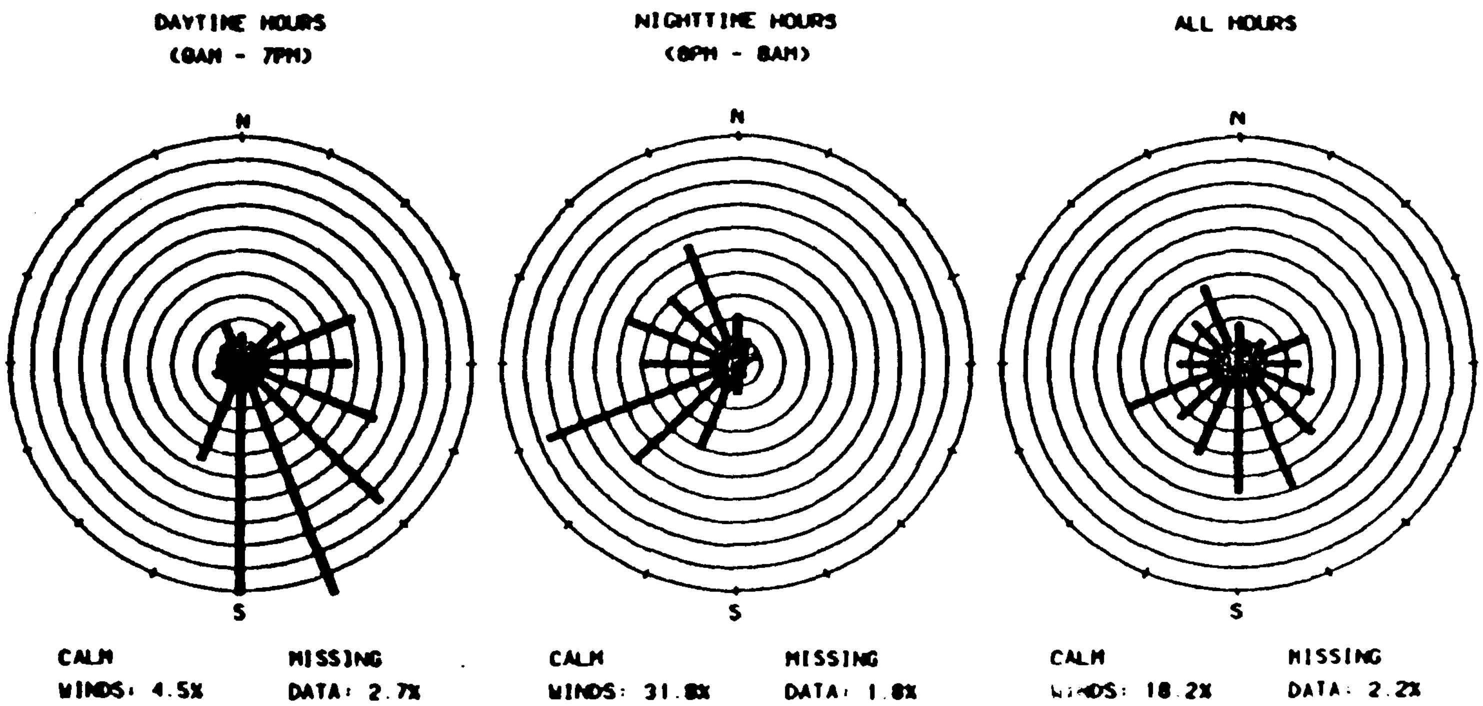
ATLANTIC CITY WIND ROSES MAY - AUGUST
FOUR YEARS (3-HOURLY) 1977, 1978, 1980, 1981



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 6-5

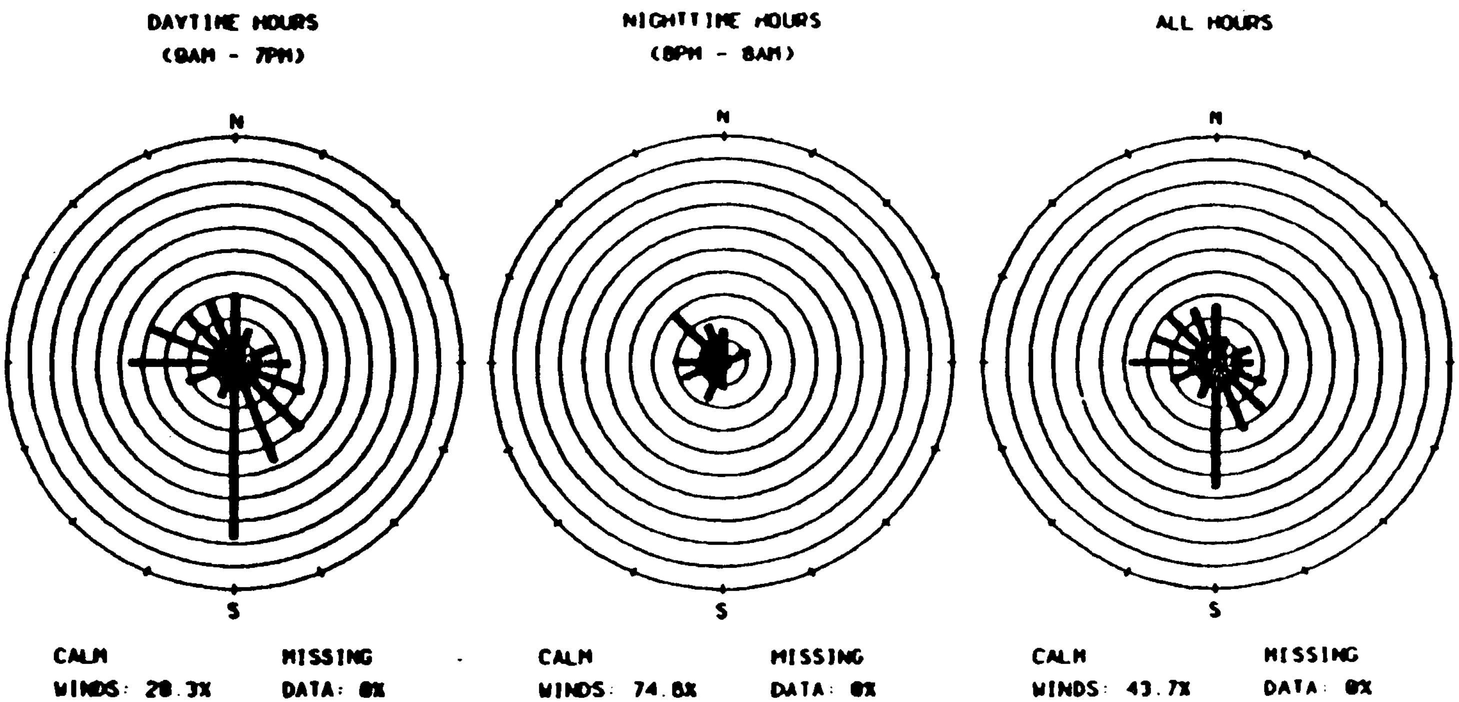
OYSTER CREEK WIND ROSES: SEA BREEZE DAYS ONLY
FIVE YEARS (3-HOURLY): 1977-1981
33-FT LEVEL



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

FIGURE 6-6

LAKEHURST WIND ROSES SEA BREEZE DAYS ONLY
FOUR YEARS (3-HOURLY): 1977-1980



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

only about one-half of the non-calm winds are onshore. Thus at least half the time during the day (not taking into account calm winds) Lakehurst winds would not be representative of Oyster Creek winds.

Figure 6-7 shows the daytime and nighttime Atlantic City wind roses for sea breeze days only. Atlantic City daytime and nighttime wind roses show the classic shift in direction associated with the sea breeze, even though the data are for Oyster Creek sea breeze days. Comparing the Atlantic City nighttime rose with the Oyster Creek nighttime rose shows more NNW to N winds at Atlantic City even though at both locations the frequency of offshore winds is identical. During the daytime Atlantic City shows about the same frequency of onshore winds and only slightly more frequent offshore winds. For both daytime and nighttime, Atlantic City and Oyster Creek have about the same frequency of calm winds.

6.5.2 Results of Hourly Comparisons

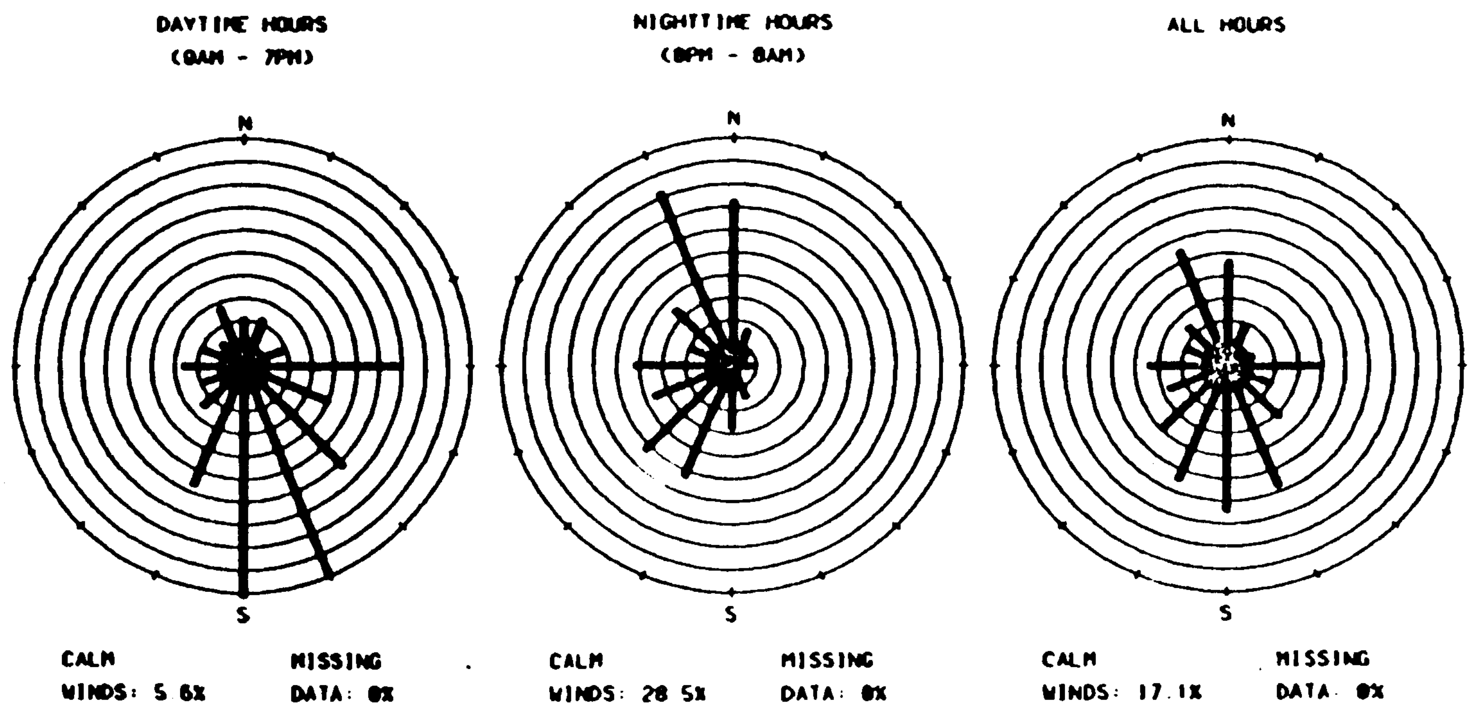
Table 6-2 lists for the May-August period the percentage of hours that the hourly wind direction differences between Oyster Creek and Lakehurst are less than 45° and also less than 90°. These hourly wind direction differences are listed as a function of Oyster Creek wind direction. Also shown are the frequency of these differences as a percentage of total hours in the data sample.

For example, Table 6-2 shows that when a northerly wind blows at Oyster Creek, the Lakehurst wind direction was within 45° of the Oyster Creek wind direction about 56% of the time. But this 56% frequency represents only 1.19% of all hours in the four May-August periods. Looking further at Table 6-2, we see that the percentage of the time that Lakehurst wind is within 90° of the Oyster Creek wind is about 62%, when the wind at Oyster Creek is northerly. This 62% represents 1.33% of all hours in the May-August period.

An analysis of Table 6-2 reveals that the Lakehurst winds were within 45° of Oyster Creek winds about 50% of all hours. Lakehurst winds were within 90° of Oyster Creek winds 56% of all hours, which is not much of an increase from 50% with the 45° angle.

FIGURE 6-7

ATLANTIC CITY WIND ROSES: SEA BREEZE DAYS ONLY
FOUR YEARS (3-HOURLY) 1977, 1978, 1980, 1981



NOTE: OUTER CIRCLE REPRESENTS WIND DIRECTION FREQUENCY OF 15%

Table 6-2: Oyster Creek vs. Lakehurst
Hourly Wind Direction Comparison
for May - August
for the Years 1977, 1978, 1979 & 1980

Oyster Creek 33-ft Level Wind Direction	Percentage of Hours Lakehurst Wind is Coincident Within ±45°		Percentage of Hours Lakehurst Wind is Coincident Within ± 90°	
	Hours (%)	Total Hours (%)	Hours (%)	Total Hours (%)
N	55.56	(1.19)	61.91	(1.33)
NNE	56.52	(1.32)	65.22	(1.52)
NE	66.02	(2.30)	76.70	(2.67)
ENE	55.86	(2.10)	67.57	(2.54)
E	44.04	(1.63)	56.89	(2.10)
ESE	43.33	(1.76)	46.66	(1.89)
SE	41.13	(1.96)	47.52	(2.27)
SSE	51.83	(3.35)	57.58	(3.73)
S	59.53	(6.03)	73.91	(7.50)
SSW	61.97	(5.96)	70.42	(6.77)
SW	63.86	(3.59)	68.67	(3.86)
WSW	59.64	(4.51)	62.78	(4.74)
W	77.92	(4.07)	79.22	(4.13)
WNW	73.10	(3.59)	77.24	(3.79)
NW	73.65	(3.69)	79.73	(4.00)
NNW	60.15	(2.71)	69.92	(3.15)
Subtotal		(49.76)		(55.99)
Oyster Creek or Lakehurst Wind Calm		(30.49)		(30.49)
Oyster Creek Wind Missing		(8.77)		(8.77)
All Other Winds		(10.98)		(4.75)
Grand Total		(100.00)		(100.00)

The winds at Oyster Creek and Lakehurst were most often coincident when the winds at Oyster Creek were W through NW. They were least often coincident when the Oyster Creek winds were E though SE. E though SE winds, of course, are associated with the sea breeze and this suggests that Lakehurst winds are least likely to coincide with Oyster Creek winds during these condtions. We shall see this later in Table 6-4.

When either the Lakehurst or Oyster Creek winds are calm (i.e., winds less than 3.5 mph), hourly wind direction differences cannot be computed. Winds at Oyster Creek and Lakehurst were calm about 30% of the time, as can be seen from the bottom part of Table 6-2. Oyster Creek winds were missing about 9% of the time.

Table 6-3 is the same as Table 6-2 except it compares Oyster Creek with Atlantic City. Atlantic City winds are within 45° of Oyster Creek winds 63% of the time. Oyster Creek or Atlantic City winds are calm only 18% of the time. Comparing these percentages with the corresponding percentages with the Lakehurst shows that the Atlantic City wind is coincident more often with the Oyster Creek wind than is the Lakehurst wind. This greater coincidence of Atlantic City winds is due to Atlantic City having fewer calm winds than Lakehurst. Atlantic City has an especially better coincidence of winds with Oyster Creek during onshore flow than does Lakehurst during onshore flow. Onshore flow, of course, includes sea breeze conditions. Note that in neither the case of Atlantic City or Lakehurst does a 90° angle dramatically increase the percentage of coincident winds over the 45° angle case.

Tables 6-4 and 6-5 list for Lakehurst and Atlantic City respectively the percentage of hours of coincident winds on sea breeze days only. Table 6-4 shows Lakehurst winds are 45° coincident with Oyster Creek winds about 1/3 the time, compared with 1/2 the time for all days in May-August in Table 6-2. The frequency of coincidence for all directions is less on sea breeze days than for all days in May-August. On sea breeze days, 45% of hours have calm winds at either Oyster Creek or Lakehurst, compared to 30% for all days in May-August.

Table 6-3: Oyster Creek vs. Atlantic City
Hourly Wind Direction Comparison
for May - August
for the Years 1977, 1978, 1980 & 1981

Oyster Creek 33-ft Level Wind Direction	Percentage of Hours Atlantic City Wind is Coincident Within ±45°		Percentage of Hours Atlantic City Wind is Coincident Within ± 90°	
	Hours (%)	Total Hours (%)	Hours (%)	Total Hours (%)
N	84.42	(1.65)	93.51	(1.83)
NNE	79.22	(1.55)	92.20	(1.80)
NE	75.86	(2.24)	89.65	(2.64)
ENE	73.38	(2.59)	85.61	(3.02)
E	63.25	(1.88)	73.51	(2.18)
ESE	70.00	(2.67)	74.66	(2.85)
SE	66.46	(2.72)	77.02	(3.15)
SSE	82.59	(4.22)	89.56	(4.57)
S	88.66	(6.55)	94.84	(7.00)
SSW	86.69	(7.11)	92.26	(7.58)
SW	79.01	(5.26)	90.37	(5.65)
WSW	75.53	(7.29)	81.32	(7.86)
W	76.79	(4.62)	89.45	(5.39)
WNW	80.53	(4.62)	93.36	(5.35)
NW	79.36	(4.40)	88.08	(4.88)
NNW	73.60	(3.33)	87.08	(3.94)
Subtotal		(62.70)		(69.69)
Oyster Creek or Atlantic City Wind Calm		(17.89)		(17.89)
Oyster Creek Wind Missing		(8.43)		(8.43)
All Other Winds		(10.98)		(3.99)
Grand Total		(100.00)		(100.00)

Table 6-4: Oyster Creek vs. Lakehurst
Hourly Wind Direction Comparison
for Sea Breeze Days
for the Years 1977, 1978, 1979 & 1980

Oyster Creek 33-ft Level Wind Direction	Percentage of Hours Lakehurst Wind is Coincident Within ±45°		Percentage of Hours Lakehurst Wind is Coincident Within ± 90°	
	Hours (%)	Total Hours (%)	Hours (%)	Total Hours (%)
N	33.33	(1.02)	38.09	(1.17)
NNE	42.86	(.88)	42.86	(0.88)
NE	58.33	(1.02)	83.33	(1.46)
ENE	44.74	(2.49)	60.52	(3.37)
E	27.78	(1.46)	47.23	(2.49)
ESE	25.00	(1.61)	27.27	(1.76)
SE	35.59	(3.07)	40.67	(3.50)
SSE	39.02	(4.67)	45.12	(5.40)
S	55.00	(6.43)	61.25	(7.15)
SSW	36.84	(3.07)	43.86	(3.64)
SW	40.00	(1.75)	40.00	(1.75)
WSW	26.47	(1.32)	29.41	(1.47)
W	52.94	(1.32)	52.94	(1.32)
WNW	33.33	(0.88)	38.89	(1.03)
NW	64.71	(1.61)	70.59	(1.76)
NNW	48.28	(2.05)	51.73	(2.20)
Subtotal		(34.65)		(40.35)
Oyster Creek or Lakehurst Wind Calm		(45.18)		(45.18)
Oyster Creek Wind Missing		(2.78)		(2.78)
All Other Winds		(17.39)		(11.69)
Grand Total		(100.00)		(100.00)

Table 6-5: Oyster Creek vs. Atlantic City
Hourly Wind Direction Comparison
for Sea Breeze Days
for the Years 1977, 1978, 1980 & 1981

Oyster Creek 33-ft Level Wind Direction	Percentage of Hours Atlantic City is Coincident Within ±45°		Percentage of Hours Atlantic City Wind is Coincident Within ± 90°	
	Hours (%)	Total Hours (%)	Hours (%)	Total Hours (%)
N	83.33	(2.60)	93.33	(2.91)
NNE	94.44	(1.77)	100.00	(1.87)
NE	76.19	(1.67)	80.95	(1.77)
ENE	62.50	(3.13)	85.41	(4.28)
E	42.11	(1.67)	60.53	(2.40)
ESE	62.00	(3.23)	68.00	(3.54)
SE	59.02	(3.75)	77.05	(4.90)
SSE	76.71	(5.83)	89.04	(6.77)
S	90.91	(7.28)	94.81	(7.61)
SSW	80.00	(5.42)	90.77	(6.15)
SW	60.42	(3.02)	64.58	(3.22)
WSW	60.81	(4.69)	66.21	(5.10)
W	57.89	(2.29)	78.94	(3.12)
WNW	63.27	(3.23)	83.68	(4.27)
NW	63.89	(2.40)	75.01	(2.82)
NNW	76.79	(4.48)	85.72	(5.00)
Subtotal		(56.46)		(65.73)
Oyster Creek or Atlantic City Wind Calm		(25.73)		(25.73)
Oyster Creek Wind Missing		(2.29)		(2.29)
All Other Winds		(15.52)		(6.25)
Grand Total		(100.00)		(100.00)

Table 6-5 shows Atlantic City winds are 45° coincident with Oyster Creek winds about 56% of the time, compared with 63% for all days in May-August in Table 6-3. The frequency of coincidence for the NNW though the NE directions and the southerly direction is greater on sea breeze days than for all days in May-August. On sea breeze days, 26% of hours at either Oyster Creek or Atlantic City have calm winds, compared with 18% for all days in May-August.

Tables 6-2 through 6-5 showed the percentage of hours that the wind at Oyster Creek is coincident with the wind at Lakehurst and Atlantic City. Tables 6-2 through 6-5 did not reveal, however, whether there was a bias to the hourly wind direction differences. The tables contained insufficient information to show, for example, whether the hourly wind direction differences were consistently positive or negative.

To show possible biases, new tables were generated. Tables 6-6 through 6-9 show the bias in hourly wind direction differences. These four tables correspond to the stations and averaging periods for Tables 6-2 through 6-5, respectively. Note that the hourly wind direction differences are listed to the nearest 22.5° so that, for example, "-45°" includes a wind direction difference anywhere from -56° to -34.5°. Positive biases indicate that the Lakehurst or Atlantic City wind direction is more clockwise from the Oyster Creek wind direction.

An examination of Tables 6-6 through 6-9 shows no obvious biases in wind direction differences in any of the stations for any of the averaging periods.

Graphs of the 3-hourly winds for Oyster Creek, Lakehurst and Atlantic City on sea breeze days only (Table 5-3) are presented in Appendix C.

Table 6-6: Oyster Creek vs. Lakehurst
Hourly Wind Direction Comparison
for May - August
for the Years 1977, 1978, 1979 & 1980

Oyster Creek 33-ft Level Wind Direction	Differences in Wind Direction to the Nearest 22.5° Sector				
	-45°	-22.5°	0°	22.5°	45°
	Percent Occurrence				
N	7.94	14.29	19.05	12.70	1.59
NNE	1.45	8.70	21.74	14.49	13.04
NE	5.83	5.83	14.56	29.13	17.48
ENE	3.60	4.50	24.32	21.62	6.31
E	1.83	3.67	16.51	18.35	9.17
ESE	3.33	6.67	17.50	11.67	5.00
SE	5.67	9.22	17.73	7.80	5.67
SSE	2.62	12.04	23.04	13.61	2.62
S	3.68	11.04	26.09	14.38	6.69
SSW	4.23	20.77	17.25	14.79	9.15
SW	3.61	10.84	23.49	19.28	9.04
WSW	1.35	6.73	15.25	33.18	3.59
W	0.00	6.49	44.16	20.78	7.14
WNW	0.69	22.76	25.52	22.07	6.21
NW	9.46	15.54	33.78	18.24	2.70
NNW	9.77	17.29	24.81	11.28	0.75

Table 6-7: Oyster Creek vs. Atlantic City
Hourly Wind Direction Comparison
for May - August
for the Years 1977, 1978, 1980 & 1981

Oyster Creek 33-ft Level Wind Direction	Differences in Wind Direction to the Nearest 22.5° Sector				
	-45°	-22.5°	0°	22.5°	45°
	Percent Occurrence				
N	5.19	29.87	35.06	11.69	3.90
NNE	10.39	15.58	35.06	20.78	3.90
NE	5.17	20.69	18.97	25.00	16.38
ENE	2.88	8.63	21.58	41.01	4.32
E	1.71	9.40	33.33	17.09	3.42
ESE	1.33	24.67	23.33	14.00	7.33
SE	8.70	10.56	26.71	19.25	6.83
SSE	6.47	15.42	34.33	20.40	7.96
S	1.37	19.59	42.61	21.31	5.50
SSW	8.36	30.34	39.94	8.67	2.79
SW	5.73	28.63	30.15	11.45	6.49
WSW	5.26	20.26	27.37	21.05	3.68
W	10.13	9.28	43.04	13.92	5.91
WNW	2.21	24.78	23.01	22.12	14.16
NW	10.09	13.30	26.61	26.61	7.80
NNW	3.93	10.11	38.76	20.22	4.49

Table 6-8: Oyster Creek vs. Lakehurst
Hourly Wind Direction Comparison
for Sea Breeze Days
for the Years 1977, 1978, 1979 & 1980

Oyster Creek 33-ft Level Wind Direction	Differences in Wind Direction to the Nearest 22.5° Sector				
	-45°	-22.5°	0°	22.5°	45°
	Percent Occurrence				
N	0.00	14.29	14.29	4.76	0.00
NNE	0.00	21.43	14.29	7.14	0.00
NE	50.00	0.00	0.00	16.67	16.67
ENE	7.89	2.63	21.05	15.79	5.26
E	2.78	2.78	16.67	5.56	5.56
ESE	6.82	2.27	11.36	4.55	0.00
SE	3.39	10.17	13.56	5.08	6.78
SSE	2.44	10.98	20.73	6.10	0.00
S	5.00	8.75	36.25	6.25	0.00
SSW	5.26	21.05	8.77	1.75	5.26
SW	0.00	13.33	16.67	6.67	3.33
WSW	0.00	2.94	11.76	11.76	0.00
W	0.00	0.00	29.41	23.53	0.00
WNW	0.00	16.67	11.11	5.56	5.56
NW	5.88	11.76	17.65	29.41	5.88
NNW	0.00	17.24	20.69	10.34	3.45

Table 6-9: Oyster Creek vs. Atlantic City
Hourly Wind Direction Comparison
for Sea Breeze Days
for the Years 1977, 1978, 1980 & 1981

Oyster Creek 33-ft Level Wind Direction	Differences in Wind Direction to the Nearest 22.5° Sector				
	-45°	-22.5°	0°	22.5°	45°
	Percent Occurrence				
N	3.33	26.67	46.67	6.67	0.00
NNE	22.22	22.22	27.78	22.22	5.56
NE	0.00	33.33	9.52	23.81	14.29
ENE	4.17	6.25	4.17	50.00	8.33
E	2.63	5.26	21.05	13.16	2.63
ESE	2.00	18.00	16.00	16.00	10.00
SE	4.92	4.92	27.87	19.67	9.84
SSE	8.22	15.07	27.40	23.29	4.11
S	2.60	24.68	40.26	18.18	5.19
SSW	12.31	29.23	38.46	6.15	3.08
SW	10.42	16.67	31.25	2.08	4.17
WSW	9.46	14.86	18.92	16.22	1.35
W	15.79	10.53	21.05	10.53	7.89
WNW	2.04	10.20	14.29	24.49	20.41
NW	8.33	2.78	8.33	33.33	19.44
NNW	7.14	7.14	32.14	32.14	0.00

7. THE EFFECT OF THE SEA BREEZE ON PLUME TRANSPORT AND DIFFUSION

The sea breeze can affect the plume in two ways: It can change the direction of travel (transport) of the plume, and it can also change the rate of dilution (diffusion) of the plume.

The effect of the sea breeze on plume transport is discussed in Section 7.1, and the effect of the sea breeze on plume difusion is discussed in Section 7.2.

7.1 The Effect of the Sea Breeze on Plume Transport

It is generally recognized that a sea breeze is part of a three-dimensional flow (Van der Hoven, 1967; Lyons, 1975; Pielke, 1981). This flow can be described as a cellular circulation from the colder water to the warmer land at the surface but with a return circulation aloft. The sea breeze extends inland to as much as several tens of kilometers and has a vertical extent varying from a few hundred to a few thousand feet. The nighttime land breeze reverses the cycle but usually as a less vigorous offshore flow. Air trajectories under these conditions, when extended beyond the time period of the daily heating cycle or to distances greater than the dimensions of the localized flow, will show trajectory reversals and complicated patterns.

An example of a trajectory reversal is the morning transition of offshore to onshore winds. As was mentioned in Section 5.5.2, the transition from offshore to onshore winds can be characterized by a shift of the wind through the northerly direction then to onshore, or by a shift through the southerly direction then to onshore. A visual inspection of the Oyster Creek hourly wind directions for the 150 sea breeze days showed that the morning transition from offshore to onshore winds is characterized by a shift through the northerly direction about 2/3 of the time. The morning shift of wind through the southerly direction occurs about 1/6 of the time. The shift of wind for the remaining 1/6 of the time could not be determined from the hourly data.

It is beyond the scope of this report to hypothesize about the details of the three dimensional flow associated with the sea breeze at Oyster Creek. A less ambitious but equally useful task is to determine the maximum inland penetration, or western boundary, of the Oyster Creek sea breeze. The western boundary is the maximum western position the plume would reach before retreating seaward again in the late afternoon or evening. This is of interest for X/Q and dose calculations because beyond this boundary the doses and effluent concentrations would fall off sharply.

Pinpointing the inland penetration of the sea breeze is difficult. For example, Angell and Pack (1965) could not definitively locate the sea breeze boundary even with National Weather Service radar following the track of individual constant volume balloons (tetroons) at Atlantic City on six sea breeze days. Gaynor (1977) documented an average of 70 sea breeze occurrences per year at the Brookhaven National Laboratory on Long Island, 16 km inland from the ocean; the maximum inland extent of these sea breezes was not known, however. Ryznar and Touma (1981) used a network of 25 meteorological stations on the eastern shore of Lake Michigan to show that almost half of 187 lake breezes observed over a six year period penetrated as far as 19 km inland.

Distance of inland penetration is also usually greater in more southern latitudes. But even in England, which is at a latitude 13 degrees north of Oyster Creek, sea breezes have penetrated as far as 85 km (Gaynor, 1977).

The inland penetration of the Oyster Creek sea breeze can be estimated by comparing the Oyster Creek wind rose with the Lakehurst and Atlantic City wind roses for Oyster Creek sea breeze days only. The Oyster Creek, Lakehurst and Atlantic City wind roses for Oyster Creek sea breeze days only are shown in Figures 6-5, 6-6 and 6-7, respectively. Comparing the Oyster Creek daytime wind rose with the Lakehurst daytime wind rose shows that only 1/3 of the winds at Lakehurst are onshore (the remaining 2/3 are offshore or calm), whereas almost all of the Oyster Creek winds are onshore. From this it can be inferred that the sea breeze penetrates as far inland as Lakehurst 1/3 of the time, or an average of about 10 days during May through August. Lakehurst is 21 km from the ocean while Oyster Creek is 6 km from the ocean.

Comparing the Oyster Creek daytime wind rose with the Atlantic City daytime wind rose shows that Atlantic City (16 km inland) has about the same frequency of onshore winds as Oyster Creek. This suggests that the Oyster Creek sea breeze penetrates at least 16 km inland if we assume that the Oyster Creek and Atlantic City sea breezes are part of the same sea breeze front. The validity of this assumption cannot easily be verified. Nevertheless, this tenuous assumption leads to the conclusion that the Oyster Creek sea breeze often penetrates to at least 16 km inland (Atlantic City NAFEC) and occasionally to 21 km inland (Lakehurst).

The inland penetration of the Oyster Creek sea breeze is only one aspect of a complex three dimensional flow. Effluent trajectory reversals and complicated patterns associated with this flow make dose modeling and X/Q modeling a formidable task, even with a dense ground based meteorological network. However, if the dose modeling and X/Q modeling is limited to generating seasonal averages, as opposed to hourly or daily averages, the effect of changes in effluent trajectories is probably small enough so that fixed point straight line wind statistics can be used in an appropriate diffusion model (Van der Hoven, 1967). Long term averages of predicted doses and X/Q's would obviate the need for more than one meterological tower.

7.2 The Effect of the Sea Breeze on Plume Diffusion

During a sea breeze, the cool, stable, ocean air becomes heated from below by the land surface and assumes a neutral or superadiabatic lapse rate in the lower levels while remaining stable aloft. With increased time and distance from the shoreline, the heated zone, or mixing level, grows vertically until the last remnant of the stable layer has been burned off.

If a tall stack located near the shore discharges into the stable layer, the effluent plume disperses very little and holds together in a steady cone as it moves downwind. At some point inland the mixing layer extends upward to the plume level. At this point, material in the plume mixes rapidly downward to cause fumigation and high concentrations of stack effluent at ground level. As the mixing layer continues to grow upward, vertical mixing also takes place above the plume, and gradually normal diffusion conditions take over and ground-level concentrations decrease.

For the case of the Oyster Creek stack, it is not immediately obvious whether, during sea breezes, the 380-ft high stack discharges into the stable layer. To answer this question, the atmospheric stability near stack height must be determined. The atmospheric stability near stack height can be easily determined using met tower data.

Figure 5-1 on page 5-6 shows the Oyster Creek met tower data which were recorded. As can be seen from the table, temperature was measured at all three levels of the tower. Temperature differences were measured between the lower and upper level, and between the lower and middle level. Note that temperature differences were not measured between the middle and upper level. This is the layer of air nearest the level of the stack and it is the stability of this layer which needs to be determined.

In line with NRC guidance, temperature differences between levels served as an indicator of the stability of the layer of air between the levels (Table 7-1). Since the measured temperature difference between the upper and middle levels was not available, the temperature difference for these two levels was instead calculated.

Table 7-1: Classification of Atmospheric Stability

Stability Classification	Pasquill Categories	Temperature Change With Height (a) (°C/100 m)
Extremely unstable	A	<-1.9
Moderately unstable	B	-1.9 to -1.7
Slightly unstable	C	-1.7 to -1.5
Neutral	D	-1.5 to -0.5
Slightly stable	E	-0.5 to +1.5
Moderately stable	F	+1.5 to +4.0
Extremely stable	G	$>+4.0$

Notes to Table:

(a) For the purpose of computing stability classification, the expression "-1.9 to -1.7", for example, was interpreted as meaning "greater than -1.9 and less than or equal to -1.7". This convention was adopted for stability classes B through F.

To make sure the calculated temperature differences did not contain systematic errors, the calculated temperature differences were compared to the measured temperature differences for those levels where measured temperature differences were available. The results of the comparison are shown in Tables 7-2 and 7-3 for the 150 ft - 33 ft and 380 ft - 33 ft levels, respectively. The tables show that the stability class based on measured temperature differences agreed with the stability class based on calculated temperature differences about 93% of the time for the 150 ft - 33 ft layer and about 88% f the time for the 380 ft - 33 ft layer. The remainder of the time, the agnitude of the discrepancy between the measured and calculated value was small, but still large enough to cause the measured temperature difference to fall into one stability class and the calculated temperature difference into another.

Since Tables 7-2 and 7-3 showed that there was no systematic error in the stability class based on calculated temperature differences, the calculated temperature differences were used for determining the atmospheric stability for both the 380 ft - 150 ft and 150 ft - 33 ft layers of the met tower.

For sea breeze fumigation to occur, three conditions must be met simultaneously:

1. The wind blows onshore
2. The atmospheric stability of the layer of air near the ground downwind of the stack is neutral or unstable.
3. The atmospheric stability of the layer of air containing the plume is initially stable downwind of the stack.

Although these three conditions make sea breeze fumigation likely, they do not guarentee that sea breeze fumigation will occur.

To determine the time the winds began blowing onshore during sea breeze days at Oyster Creek, the hourly winds time series illustrated in Appendix C were visually inspected. From this visual inspection it was obvious that

Table 7-2: Comparison of Calculated Temperature Differences with Measured Temperature Differences for the 150 ft - 33 ft Level (May-August, 1977-1981)

Percent of hours when either the measured temperature difference or temperature was missing	26.7%[a]
Percent of hours (missing hours excluded) when the stability class based on measured temperature difference agreed with the stability class based on calculated temperature difference	93.3%
Percent of hours (missing hours excluded) when stability class based on calculated temperature difference was more stable than the stability class based on measured temperature difference	3.2%
Percent of hours (missing hours excluded) when stability class based on measured temperature difference was more stable than the stability class based on calculated temperature difference	3.5%
Total (missing hours excluded)	100%

Notes to Table:

(a) According to M. Abrams of PLG, this percentage is high because in the early part of the five year period 1977-1981, the temperature was not digitized from strip charts when it was missing from the real-time computer data base. Thus, this high percentage is due to the temperature being missing rather than the measured temperature difference being missing. His assertion is borne out by the data which shows that the Rosemount temperature was missing 14% of the time even though the measured temperature difference was available during these same hours. Temperature and measured temperature differences were missing simultaneously 12.5% of the time.

Table 7-3: Comparison of Calculated Temperature Differences with Measured Temperature Differences for the 380 ft - 33 ft Level (May-August, 1977-1981)

Percent of hours when either the measured temperature difference or temperature was missing	26.7%[a]
Percent of hours (missing hours excluded) when the stability class based on measured temperature difference agreed with the stability class based on calculated temperature difference	88.1%
Percent of hours (missing hours excluded) when stability class based on calculated temperature difference was more stable than the stability class based on measured temperature difference	7.7%
Percent of hours (missing hours excluded) when stability class based on measured temperature difference was more stable than the stability class based on calculated temperature difference	4.2%
Total (missing hours excluded)	100%

Notes to Table:

(a) According to M. Abrams of PLG, this percentage is high because in the early part of the five year period 1977-1981, the temperature was not digitized from strip charts when it was missing from the real-time computer data base. Thus, this high percentage is due to the temperature being missing rather than the measured temperature difference being missing. His assertion is borne out by the data which shows that the Rosemount temperature was missing 19.5% of the time even though the measured temperature difference was available during these same hours. Temperature and measured temperature differences were missing simultaneously 7% of the time.

onshore winds usually began blowing sometime after 8 AM LST. Thus the first condition necessary for sea breeze fumigation is typically met sometime after 8 AM. To determine whether the second and third conditions were met, the atmospheric stability of the air near the ground and in the plume was determined. The atmospheric stability near the ground was determined from the stability of the 150 ft - 33 ft layer. The atmospheric stability at plume height was determined from the atmospheric stability of the 380 ft - 150 ft layer. Implicit in this approach was the assumption that the 380 ft - 150 ft layer is representative of the atmospheric stability at plume height.

As a side note, the height of the non-buoyant plume from the Oyster Creek stack is about 25-30 meters above stack top for stable conditions and about 140-150 meters above stack top for unstable and neutral conditions. These plume rises are the maximum possible plume rises because they were computed assuming a maximum stack gas exit velocity of 19.2 m/s and a stack top wind speed of 1 m/s. Actual plume rises are certain to be much lower. The plume rises were calculated from Equations 5.2 and 4.28 in Briggs (1969).

The average hourly stability of the layer near the ground and the layer near stack top are shown in Table 7-4. From the table two things are obvious: First, at night the upper layer is always less stable than the lower layer; during the day the upper layer is more stable than the lower layer . Second, the upper layer from mid morning to mid afternoon is neutral while the lower layer is unstable. Thus the averages do not suggest that there is a fumigation problem, but the averages do not tell the whole story.

To further investigate the possibility of fumigation, a comparison was made of the atmospheric stability at the upper and lower layers for each hour, without averaging. The results of the comparison are shown in Table 7-5. As can be seen from the table, the upper and lower layer were neutral or unstable simultaneously about 2/3 of the time during the hours of 8 AM to 3 PM LST. Fumigation is unlikely to occur under these conditions. The remaining 1/3 of the time during these same hours, however, conditions were favorable for fumigation because the upper layer was stable and the lower layer was neutral or unstable.

Table 7-4: A Comparison of the Hourly Average Atmospheric Stability Near Stack Top with the Hourly Average Atmospheric Stability Near the Ground During Sea Breeze Days[a]

Hour (LST)	Average Calculated Lapse Rate Between the 380-ft and 150-ft Level (°C/100 m)	Stability Class of this Layer	Average Calculated Lapse Rate Between the 150-ft and 33-ft Level (°C/100 m)	Stability Class of this Layer
1	4.85	G	2.38	F
2	5.36	G	2.55	F
3	5.66	G	2.76	F
4	5.74	G	2.54	F
5	5.71	G	2.78	F
6	2.58	F	2.58	F
7	-1.25	D	0.44	E
8	-1.79	B	-0.72	D
9	-2.71	A	-0.60	D
10	-2.97	A	-0.67	D
11	-3.18	A	-0.81	D
12	-3.26	A	-0.79	D
13	-3.51	A	-0.50	D
14	-2.52	A	-0.85	D
15	-2.89	A	-0.52	D
16	-2.51	A	-0.38	E
17	-1.75	B	-0.37	E
18	-0.95	D	-0.56	D
19	-0.25	E	0.20	E
20	1.14	E	0.79	E
21	2.20	F	1.32	E
22	3.04	F	1.68	F
23	3.79	F	2.02	F
24	4.18	G	2.30	F

Notes to Table

(a) The atmospheric stability near stack top is the atmospheric stability of the 380-ft to 150-ft layer (upper layer). The atmospheric stability near the ground is the atmospheric stability of the 150-ft to 33-ft layer (lower layer).

Table 7-5: A Comparison of the Atmospheric Stability Near Stack Top with the Atmospheric Stability Near the Ground for Each Hour During Sea Breeze Days[a]

Hour (LST)	Percent of Hours With Missing Data	Percent of Hours When Upper and Lower Layers Are Neutral or Unstable Simultaneously[b] (Missing Hours Exclud.)	Percent of Hours When Upper Layer is Stable & Lower Layer is Neutral or Unstable[b] (Missing Hours Exclud.)	Percent of Hours With Other Stability Combinations (Missing Hours Exclud.)	Total Percent (Missing Hours Excluded)
1	16.7	1.6	9.6	88.8	100.0
2	16.7	0.8	8.0	91.2	100.0
3	16.7	0.0	5.6	94.4	100.0
4	15.3	0.0	8.7	91.3	100.0
5	15.3	0.0	6.3	93.7	100.0
6	15.3	2.4	20.5	77.1	100.0
7	14.7	25.0	60.1	14.9	100.0
8	18.7	54.1	42.6	3.3	100.0
9	16.7	67.2	32.8	0.0	100.0
10	16.7	66.4	32.8	0.8	100.0
11	15.3	66.1	32.3	1.6	100.0
12	16.0	65.1	34.9	0.0	100.0
13	17.3	64.5	35.5	0.0	100.0
14	16.7	66.4	32.8	0.8	100.0
15	16.0	64.3	34.9	0.8	100.0
16	20.7	58.0	41.2	0.8	100.0
17	22.0	54.7	40.2	5.1	100.0
18	20.7	37.0	51.3	11.7	100.0
19	20.7	10.9	38.7	50.4	100.0

Table 7-5: (continued)

Hour (LST)	Percent of Hours With Missing Data	Percent of Hours When Upper and Lower Layers Are Neutral or Unstable Simultaneously[b] (Missing Hours Exclud.)	Percent of Hours When Upper Layer is Stable & Lower Layer is Neutral or Unstable[b] (Missing Hours Exclud.)	Percent of Hours With Other Stability Combinations (Missing Hours Exclud.)	Total Percent (Missing Hours Excluded)
20	20.7	2.5	18.5	79.0	100.0
21	19.3	0.8	9.9	89.3	100.0
22	19.3	0.8	5.8	93.4	100.0
23	19.3	0.8	5.0	94.2	100.0
24	22.7	0.9	9.5	89.6	100.0

NOTES TO TABLE:

(a) The atmospheric stability near stack top is the atmospheric stability of the 380-ft. to 150-ft. layer (upper layer). The atmospheric stability near the ground is the atmospheric stability of the 150-ft. to 33-ft. layer (lower layer).

(b) For purposes of this table, the neutral and unstable stability categories are treated as a single stability category.

The relative infrequency of fumigation cases is not surprising in view of the local geography. As was mentioned in Section 5.1, the Oyster Creek plant is two miles west of Barnegat Bay. The maximum width of Barnegat Bay is about four miles. The average depth is under five feet and large areas are less than one foot deep at local mean low tide.

Because Barnegat Bay is so shallow and because of its generally non-turbulent nature, the water temperature is more responsive to air temperatures than a deeper, more turbulent bay. To illustrate the relative warmth of the bay, the daily range of the Oyster Creek intake temperature is listed below. (The intake temperature of the water at Oyster Creek was used as a gross indicator of the Barnegat Bay water temperature.) For the months of May, June, July and August, the daily intake temperature ranged over the following values (OC & FRNGS Report #316, 1978, Table A2-6(a)):

Month	Temperature Range (°F)	Years of Record
May	60 - 75	1976
June	65 - 90	1975,1976
July	70 - 85	1975,1976
August	70 - 90	1975,1976,1977

Thus the shallow bay acts more like a warm land surface than a cold water surface. This appears to explain the relative infrequency of fumigation at Oyster Creek.

8. EVALUATION OF THE NEED FOR A SUPPLEMENTARY METEOROLOGICAL TOWER

Before discussing the need for a supplementary meteorological tower, let us list the conclusions of this report up to this point:

1. During the months of May through August, the sea breeze at Oyster Creek occured one day in four, or an average of about 30 days between May and August.

2. On days when Oyster Creek had sea breezes, the Atlantic City wind direction was within 45° of the Oyster Creek wind direction 56% of the time. In contrast, the Lakehurst wind direction was within 45° of the Oyster Creek wind direction only 35% of the time. This made Atlantic City wind directions more representative of Oyster Creek than Lakehurst. The better representativeness of Atlantic City also held true for the May - August period in general, when Atlantic City winds were within 45° of Oyster Creek winds 63% of the time, as opposed to 50% of the time for Lakehurst.

3. Meteorological conditions conducive to sea breeze fumigation at Oyster Creek occured on 1/3 of the Oyster Creek sea breeze days, or an average of about 10 days between May and August.

4. The Oyster Creek sea breeze often penetrated to 16 km inland and occasionally to 21 km inland, but this conclusion was based on somewhat tenuous assumptions.

In light of these conclusions and in light of the regulatory guidance discussed in Section 2 (Introduction) of this report, there appears to be some justification for concern about the representativeness of the Oyster Creek met tower.

If it is assumed that the sea breeze is the primary factor affecting the representativeness of the tower, then the representativeness issue reduces to two questions: (1) Is a sea breeze occurring? (2) If a sea breeze is occurring, how far inland is it?

The first question can be answered easily by locating a met tower on one of the barrier islands to the east of Oyster Creek. The barrier island met tower would show whether a sea breeze was setting up. It is expected that this met tower would show sea breezes occurring much more often than the Oyster Creek met tower because sea breeze frequency and duration increase with proximity to the coastline (Raynor, 1977).

The barrier island met tower, however, would not answer the second question of how far inland the sea breeze was. A sea breeze at the barrier island would not insure its inland penetration to Oyster Creek or even to the western side of Barnegat Bay. Some sea or lake breezes penetrate only a small distance inland and then remain stationary or retreat seaward again (Ryznar and Touma, 1981). This makes locating sea breezes difficult.

One approach to answering the second question is to apply to Oyster Creek a lake breeze index developed by Biggs and Graves (1962). This index was used successfully by Biggs and Graves to distinguish between lake breeze and non-lake breeze days at the Enrico Fermi Nuclear Reactor site on the western shore of Lake Erie. Biggs and Graves also suggested that the probable strength of the lake breeze could be inferred from the magnitude of the lake breeze index. The strength of the lake breeze, and hence the magnitude of the lake breeze index, determines the inland penetration of the breeze.

The lake breeze index as applied to Oyster Creek would consist of the land-ocean temperature difference and the 33-ft level met tower wind speed. The land-ocean temperature difference would be obtained by subtracting the ocean temperature from the 33-ft level met tower temperature. The daily ocean temperature for Sandy Hook, Long Branch, Atlantic City and Cape May for the years 1976 through 1981 are already in the GPUN data base. The data, which were obtained from NOAA National Ocean Survey, have not yet been quality assured, however.

By computing the sea breeze index for Oyster Creek from this historical data, it can be determined whether there exists an empirical relationship between the size of the sea breeze index and the inland penetration of the

sea breeze to as far west as Oyster Creek and also Lakehurst, for example. If a simple relationship between the index and inland sea breeze penetration can be found, the result could prove invaluable in locating the sea breeze front based on sea breeze strength.

In summary, it appears unwise to consider a supplementary met tower before exploring the relationship between the sea breeze index and inland penetration of the sea breeze. If a sea breeze index/inland penetration distance relationship can be established, a supplementary met tower could serve as a warning beacon for an advancing sea breeze. If a relationship between sea breeze index and inland penetration distance does not exist, however, the data from a supplementary met tower would have little predictive value because it could not be used to establish whether the sea breeze at the supplementary tower, for example, would remain stationary, advance or retreat seaward. In the absence of a sea breeze index/inland penetration distance relationship, the tower would be an indicator of where the sea breeze has been, not where it is going. The usefulness of a supplementary met tower would be greatly diminished if the data has no predictive value for sea breeze movement.

The need to analyze existing data before proceeding with additional measurement programs is echoed in NUREG/CR-2754, Critical Review of Studies on Atmospheric Dispersion in Coastal Regions (September, 1982), which states in part:

> "A great potential exists for further analysis of existing data, and this may alleviate the need for establishing additional measurement programs." (page 26, paragraph 4)

> "It goes without saying that the fulfillment of information gaps through analysis of existing data will enable NRC to achieve program objectives at a substantial saving of both time and money." (page 27, paragraph 1)

While there always seems to be a need for more data in resolving representativeness issues, a thorough, thoughtful analysis of existing data will go a long way for answering many of today's questions and also for building the foundation for tomorrow's supplementary measurement program.

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APPENDIX 2.3C

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APPENDIX 2.3D

METEOROLOGICAL INFORMATION AND DIFFUSION ESTIMATES BASED ON OYSTER CREEK METEOROLOGICAL TOWER DATA

INTRODUCTION

Information in this Appendix is extracted from the following Reference.

METEOROLOGICAL INFORMATION AND DIFFUSION ESTIMATES TO CONFORM WITH APPENDIX I REQUIREMENTS

This Appendix contains all of the information from that Reference with the exception of Tables 1.1-2 through 1.1-5 and text related to these particular Tables. The omitted Tables provided joint frequencies of stability, wind direction and wind speed for various tower levels on a monthly basis. This voluminous set of Tables provided the meteorological input data to the dispersion and deposition model and is available in the referenced document.

Section 1.0 Meteorological Diffusion Calculations

1.1 Meteorological Data Used for Analysis

Section 1.1 contains information relative to the data bases available from the site measurement programs and a description of the meteorological tower configuration. Tables in this section contain the measured meteorological data requested as well as discussions of representativeness and terrain effects.

1.1.1 Tower Configuration at the Site

The Oyster Creek tower configuration and instrumentation used to measure data included in this report are described in Table 1 of the FSAR, Amendment No. 13, Docket No. 50-219.

1.1.2 Available Data from the Site

Table 1.1-1 summarizes data bases available from the site monitoring program. The data periods used for the detailed Regulatory Guide 1.111 diffusion calculations are indicated in the right hand column of the table. The 1968 site data were used for the detailed diffusion estimates for the Oyster Creek plant. Calculations were also made using a composite three-year period from 1966-1968 data. Wind roses for years of data 1966-1975 were used to demonstrate that the data used in the analysis were representative of longer term conditions at the site.

1.1.3 Summary of Available Data

Data which were used in the analyses are presented in this section as joint frequency tables. For the Oyster Creek site these tables were com-

piled for two levels over a three year period of record. Table 1. 1-2 is a joint frequency table of wind speed, wind direction and stability group for the 400 ft level using delta-T between 400 ft and 12 ft. These data are used for evaluations of stack effluents. A logarithmic adjustment is made to the delta-T to be representative of temperature difference between 400 ft and 33 ft. Table 1. 1-3 is a joint frequency table for the 75 ft data. Speeds are adjusted to a 33 ft level for ground release calculations and 200 ft-12 ft delta-T is adjusted to be representative of temperatures between 200 ft and 33 ft. Table 1. 1-4 is a 400 ft level joint frequency table similar to Table 1. 1-2 for each of the 12 months and Table 1. 1-5 is a 75 ft level joint frequency table similar to Table 1. 1-3 for each of the 12 months.

Figures 1. 1-1 through 1. 1-10 represent wind roses for each year of data collected to date from both levels on the tower. These will be discussed further in Section 1. 1. 4 below.

1. 1. 4 Representativeness of the Year of Data Used in Analysis

Meteorological data have been collected continuously for 10 years at the Oyster Creek site. The tower instrumentation conforms with most of the Regulatory Guide 1.23 requirements. However, the aerovane anemometers do not comply with the specified threshold speed of 1. 0 mph. Since winds are relatively high at the site and since most plant releases are at a high elevation, it is believed that the aerovane has provided data which can be used to make accurate diffusion estimates at this site.

Inspection of the available records showed that the 1968 data were most appropriate for analyses at the site. Data from 1966 and 1967 were also

considered adequate. Therefore, detailed hourly calculations were made using the 1968 data and the results were compared with a calculation using three year composite joint frequency data. Results were similar as shown in Tables 1.3-6 and 1.3-10. Thus, from a diffusion standpoint the 1968 data are considered representative of the three year period 1966-1968. To demonstrate longer term representativeness wind roses for a ten year period at the site, Figures 1.1-1 through 1.1-10 were compared. They showed similarity with respect to predominant winds which further supports the conclusion that the 1968 data were representative of longer term conditions.

1.1.5 Airflow Trajectory and Terrain Influences

The general flow in the Oyster Creek site region, as indicated in the wind roses shown in Figures 1.1-1 through 1.1-10, is from the northwest through southwest. During the fall and winter months the east coast of the U. S. is generally dominated by high pressure centers from Canada and the Pacific. These high pressure systems with their clockwise flow of air around them produce west and northwest winds when they are west of the plant region, and south and southwest winds when they are east of the plant region. During the spring and summer months the predominant flow across the U. S. is from west to east resulting in winds from the northwest to the southwest. Many low pressure systems move up the east coast producing easterly winds in the site region. However, they move rapidly and their duration of influence is short in comparison to high pressure systems.

During periods of light winds, the proximity of Barnegat Bay and the Atlantic Ocean results in the formation of land and sea breezes. This is particularly true in the summer months when large temperature

differences exist between the land and the sea. During such conditions a circulation cell can be set up which may produce sea breezes during the day or land breezes at night. Inspection of the wind roses from the meteorological tower at the site, however, shows only a small percentage of low wind speeds from directions that would indicate the presence of land or sea breezes. Since the plant is located considerably inland (at least two miles from Barnegat Bay and six miles from the ocean) land or sea breeze situations may not have a significant influence on the local average annual flow patterns.

Terrain in the site region is nonvarying and should not significantly influence flow patterns. Since it is not considered practical at the present time to compute estimates using particle-in-cell or puff trajectory diffusion models, correction factors suggested in Regulatory Guide 1.111 for open terrain are used in this analysis. This is considered to result in very conservative estimates at distances near the plant.

1.2 Description of Atmospheric Diffusion Models

Models described in this section generally follow Regulatory Guide 1.111 (previously 1.DD). Subsections below describe the model used in these evaluations with references to Regulatory Guide 1.111 since most assumptions are identical to those in the guide. These models are used to determine routine (average) X/Q and D/Q values applicable to the site.

1.2.1 Atmospheric Diffusion Model

Average atmospheric dispersion evaluations are made using the straight line airflow model shown below:

$$(\overline{X/Q'})_D = 2.032 \sum_{ij} n_{ij}[N x \bar{u}_i \Sigma_{zj}(x)]^{-1} \exp[-h_e^2/2\sigma_{zj}^2(x)] \qquad (1)$$

where

h_e	is the effective release height
n_{ij}	is the length of time (hours of valid data) weather conditions are observed to be at a given wind direction. windspeed class, i, and atmospheric stability class, j;
N	is the total hours of valid data;
$\bar{u}_i$	is the geometrical mean of all speeds in the windspeed class, i, at a height representative of release, calms are one-half the threshold anemometer speed or less:
$\sigma_{zj}(x)$	is the vertical plume spread without volumetric correction at distance, x, for stability class, j (see Figure 1 of Regulatory Guide 1.111) based on vertical temperature difference (ΔT) and Regulatory Guide 1.23 categorization of Pasquill Groups by ΔT;
$\Sigma_{zj}(x)$	is the vertical plume spread with a volumetric correction for a release within the building wake cavity, at a distance, x, for stability class, j; otherwise $\Sigma_{zj}(x) = \sigma_{zj}(x)$;
$(\overline{X/Q'})_D$	is the average effluent concentration, X, normalized by source strength, Q', at distance, x, in a given downwind direction, D; and
2.032	is $(2/\pi)^{1/2}$ divided by the width in radians of a 22.5^o sector.

For sites where hourly data were available on tape the summation over i and j in the above equation was deleted and the summation was accomplished for all hours at all distances for each direction. Hourly calculations are considered to be more accurate since the actual wind speeds at the vent location are available rather than the extrapolation of an average from a lower level. Dilution was decreased according to terrain correction factors of Regulatory Guide 1.111 given in Figure 2 of Regulatory Guide 1.111. These factors were multiplied by the results from Equation (1) and varied in accordance with the direction and distance being evaluated.

This general Gaussian diffusion model has been utilized extensively for both nuclear reactor and air pollution diffusion analysis for at least 10 years, therefore, it is considered appropriate for use in this specific application. With regard to model accurancy, the greatest weakness results from determining stability using vertical temperature difference. A more appropriate representation of turbulence and resulting diffusion could be obtained using bivane data or some other measurement of turbulence.

Actual model input assumptions and source term configurations are discussed below.

1.2.2 Source Configuration Considerations

If a release point is elevated and there are no buildings which would obstruct the plume in its normal trajectory, Equation (1) above is used with the height of release defined as follows (from Equation (4) of Regulatory Guide 1.111):

$$h_e = h_s + h_{pr} - h_t - c$$

where

c is the correction for low relative exit velocity (Equation (5) of Regulatory Guide 1.111)

h_e is the effective release height;

h_{pr} is the rise of the plume above the release point based on Briggs (see below);

h_s is the physical height of the release point (the elevation of the stack base should be assumed to be zero); and

h_t is the maximum terrain height between the release point and the point for which the calculation is made.

Values of h_{pr} are computed as follows for a "jet" since nuclear plant vents have an insignificant amount of buoyancy due to heated discharges:

$$h_{pr} = 1.44D \left(\frac{W_o}{u}\right)^{2/3} \left(\frac{x}{D}\right)^{1/3}$$

up to the point where h_{pr} is the minimum of the following two equations:

$$h_{pr_{max}} = 3\left(\frac{W_o}{u}\right)D, \text{ or}$$

$$h_{pr_{max}} = 1.5 \left(\frac{F_m}{u}\right)^{1/3} s^{-1/6}$$

where symbols are as before, and:

D is stack or vent effective inside diameter (m)

W_o is stack or vent exit velocity (m/sec)

u is wind speed at discharge level (m/sec)

F_m is momentum flux (m^4/sec^2)

s is stability parameter (sec^{-2})

If the plume trajectory from a release point (vent) does not remain outside of building wake influences near large structures all or portions of the plume are considered to be entrapped and brought to ground level in the turbulent wake of the building. The criteria for determining the portion of the plume treated as an elevated or ground release follows from Equations (6), (7) and (8) of Regulatory Guide 1.111 and are repeated here for completeness.

If $W_o/\bar{u} > 5.0$ use h_e as calculated above

If $W_o/\bar{u} \leq 1.0$ use $h_e = 0$

If $1 < W_o/\bar{u} \leq 1.5$ $\qquad E_t = 2.58 - 1.58 \left(\frac{W_o}{\bar{u}}\right)$

If $1.5 < W_o/u \leq 5.0$ $\qquad E_t = 0.3 - 0.06 \left(\frac{W_o}{\bar{u}}\right)$

The appropriate diffusion estimate is then computed by assuming an elevated release 100 $(1 - E_t)$ percent of the time and by assuming ground release 100 E_t percent of the time.

A building wake correction is computed for all ground releases near structures in accordance with the following general equation:

$$\Sigma = \sqrt{\sigma_z^{\,2} + \frac{cH^2}{\pi}} \leq 1.73\,\sigma_z$$

where

Σ	effective dispersion coefficient for use in Equation (1) (m)
c	building wake coefficient (c = 0.5)
H	height of the tallest structure in the nuclear plant power block (m)

1.2.3 Removal Mechanisms

As radioactive effluent in a plume travels downwind, it is subject to several removal mechanisms including radioactive decay, dry deposition, and wet deposition (during rain). Corrections for radioactive decay are not made in the estimates reported in this section.

Dry deposition which results in depletion of halogen and particulate isotopes from the plume is considered only to the extent suggested in Regulatory Guide 1.111, Figures 3 through 6. Depletion factors in these curves are a function of height and distance, therefore, for sites where elevated releases occur the terrain must be subtracted from the plume height before entering the curves at the appropriate distance. Each elevated or ground level X/Q is multiplied by the depletion and the terrain correction factors before combining to give the final depleted X/Q value.

To determine relative deposition rate as a function of distance and stability the curves given in Figures 7 through 10 of Regulatory Guide 1.111 are used. Again terrain heights are subtracted before the table look-up is made. Terrain correction factors, if any, multiply each D/Q value. Values from the curves are divided by the sector cross width (arc) at the point of calculation.

Dry depostion is believed to adequately represent overall deposition rates, since seasonal rainfall is fairly uniform, therefore, wet deposition has not been considered.

1.3 Diffusion Model Inputs and Results

Computer runs have been made using site data in the diffusion models given in 1.2 above. A list of runs made, input parameters and assumptions and results are given in the following sections.

1.3.1 List of Computer Runs

Table 1.3-1 tabulates computer runs made using the diffusion models described in Section 1.2 above. Separate runs were made for the grazing seasons and annual periods. The grazing season was assumed to be May through October.

1.3.2 Summary of Plant Discharges

A summary of plant vent information for each discharge point is given in Tables 1.3-2 and 1.3-3. Only vents used during routine operation are considered in this evaluation. Inspection of Tables 1.3-2 and 1.3-3 showed that two calculations were required to determine diffusion conditions applicable for each vent.

1.3.3 Input Assumptions

Table 1.3-4 tabulates all pertinent input information utilized in making the model calculations. Table 1.3-5 gives terrain elevations for all distances out to 10 miles. Terrain height is conservatively not allowed to decrease with increasing distance in accordance with Regulatory Guide 1.111.

1.3-4 Results

Resulting X/Q, depleted X/Q and D/Q values are listed in Tables 1.3-6 through 1.3-10 for each direction sector for ten distances. These results are used as input for the dose calculations described in the appropriate section. Tables 1.3-11 through 14 summarize the resulting diffusion factors for each of the receptor locations. Each table represents model results for one stack for each season being evaluated. One set of calculations was made for the stack through which most effluents are discharged. A second set of calculations was

made for the liquid radwaste building vent and all effluents were assumed to be entrapped in the building wake. This vent was assumed to represent all other plant vents because there was little or no vertical exit velocity associated with the other vents (see Table 1.3-1), thus it is appropriate to assume a ground level release in the building wake.

Table 1.1-1

Oyster Creek Site

Period of Record	Speed and Direction Level (ft)	Temperature Difference Between (ft)	Combined % Recovery	Comment
2/66-12/66	400 75	400-12 200-12	Not Determined "	Used for comparative purposes only
1/67-12/67	400 75	400-12 200-12	" "	Used for comparative purposes only
1/68-12/68	400 75	400-12 200-12	91.9 83.6	Used for hourly diffusion calculations
Composite including above 3 years of record	400 75	400-12 200-12	83.8 61.0	Joint frequency tables used for diffusion calculations
1/69-12/75	400 75	400-12 200-12	Not Determined "	Used wind roses for comparative evaluations

TABLES 1.1-2 through 1.1-5

(OMITTED FROM APPENDIX)

Table 1.3-.

List of Computer Runs

Site: Oyster Creek

Run Number	Vent Identification	Data Used	Type of Run	Hourly or Joint Frequency Data Used	Grazing Season or Annual Data	To Be Used for Evaluation Releases from the Following Vents	Location of Results in the Report
OX-1	Stack	68 Oyster Creek	Elevated Source	Hourly	Grazing	Stack	Tables 1.3-6 & 1.3-12
OX-2	Stack	68 Oyster Creek	Elevated Source	Hourly	Annual	Stack	Tables 1.3-7 & 1.3-11
OX-3	Radwaste Bldg Vent	68 Oyster Creek	Ground Source in bldg wake	Hourly	Grazing	Radwaste vent, turbine bldg vent	Tables 1.3-8 & 1.3-14
OX-4	Radwaste Bldg vent	68 Oyster Creek	Ground source in bldg wake	Hourly	Annual	Radwaste vent, turbine bldg vent	Tables 1.3-9 & 1.3-13
OX-5	Stack	Oyster Creek 3 yr composite 66, 67, 68	Elevated Source	Joint Frequency	Grazing	Stack	Table 1.3-10

Table 1.3-2

Gaseous Discharge Points

Oyster Creek

System	Vent Number
Turbine building ventilation	1
Auxiliary building ventilation	1
Radwaste building ventilation	2
Containment building ventilation	1
Main condenser offgas system	1
Turbine gland sealing system	1
Mechanical vacuum pumps	1

Table 1.3-3
Vent Design Information
Oyster Creek

ent	Location	Discharge Elevation Above Grade (m)	Height of Discharge Above Maximum Building Elevation (m)	Effective Vent Diameter (m)	Velocity at Point of Discharge (m/sec)
1	Main stack	112	-	2.5	15.2
2	Liquid radwaste building	15	Vents on sidewall assumed trapped in building wake	N/A	N/A

Table 1.3-4

Tabulation of Input Assumptions for Calculations

Site: Oyster Creek

r	Assumed Value or Characteristic
meteorological instruments runs	400 ft speed and direction, ΔT 400-12 ΔT adjusted to represent 400-33 ft
meteorological instruments d level releases	75 ft speed and direction, ΔT 200-12 75 ft speed adjusted to 33 ft, ΔT adjusted to represent 200-33 ft
or determining stability and coefficients	Temperature difference using Regulatory Guide 1.23 and Pasquill curves
eatment	Assumed 1.0 mph (threshold for aerovane is about 2.5 mph). Assumed to have same direction as measured.
mit for σ_z (m)	1000
f tallest structure for tion of Σ effective (m)	15.2
it conditions	From Tables 1.3-3
emperature correction	For ΔT 200-12 = 0.64 For ΔT 400-12 = 0.71
nts for exponential speed tion with height (Stability A-G)	0.25, 0.25, 0.25, 0.33, 0.5, 0.5, 0.5
n height	See Table 1.3-5
n correction factors	Figure 2 of Regulatory Guide 1.111

Table 1. 3-5

Maximum Topographic Elevations for Oyster Creek (ft-MSL)

(Plant Grade is 20 ft)

DISTANCE IN MILES									
1	2	3	4	5	6	7	8	9	10
30	30	60	60	60	60	70	60	70	70
10	20	40	40	60	60	60	40	40	40
10	10	10	10	10	0	0	0	0	0
10	10	0	0	0	0	0	0	0	0
20	10	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
10	10	0	0	0	0	0	0	0	0
20	20	20	0	0	0	0	0	0	0
10	40	50	30	30	30	20	10	10	10
20	50	90	120	130	120	110	110	100	90
10	60	90	140	150	145	169	150	140	130
40	40	90	80	130	160	172	169	160	164
40	50	70	117	140	158	179	187	202	202
30	50	100	100	180	176	174	187	195	200
30	30	90	110	120	120	120	130	130	152
30	40	80	80	80	80	60	70	109	85

Table 1.3-6

ATMOSPHERIC DISPERSION FACTORS FOR- OYSTER CREEK VENT- STACK SEASON- GRAZING RLO- OX-1 68 HRLY FLE

RUN TYPE- X/Q SEC/M3 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.29E-08	3.54E-08	3.44E-08	3.36E-08	2.92E-08	1.90E-08	7.65E-09	3.71E-09	2.46E-09	1.77E-09
NNE	7.72E-09	2.24E-08	2.42E-08	2.44E-08	2.35E-08	1.71E-08	7.62E-09	3.49E-09	2.64E-09	1.94E-09
NE	3.40E-08	2.52E-08	1.42E-08	1.44E-08	1.48E-08	1.02E-08	4.80E-09	2.57E-09	1.79E-09	1.34E-09
ENE	2.53E-08	2.73E-08	2.22E-08	1.84E-08	1.67E-08	1.13E-08	5.07E-09	2.64E-09	1.41E-09	1.34E-09
E	7.46E-08	3.70E-08	2.47E-08	1.99E-08	1.73E-08	1.12E-08	4.38E-09	2.52E-09	1.72E-09	1.27E-09
ESE	1.21E-07	4.47E-08	2.43E-08	2.10E-08	1.05E-08	1.24E-08	5.55E-09	2.82E-09	1.48E-09	1.47E-09
SE	8.29E-08	2.41E-08	1.45E-08	1.18E-08	1.05E-08	7.23E-09	3.44E-09	1.88E-09	1.33E-09	1.00E-09
SSE	9.47E-08	1.85E-08	1.08E-08	9.20E-09	8.50E-09	6.27E-09	3.04E-09	1.64E-09	1.15E-09	8.65E-10
S	4.80E-08	1.47E-08	9.02E-09	7.62E-09	6.86E-09	4.96E-09	2.54E-09	1.44E-09	1.04E-09	7.97E-10
SSW	2.23E-08	1.86E-08	1.45E-08	1.46E-08	1.30E-08	7.78E-09	3.23E-09	1.67E-09	1.15E-09	8.60E-10
SW	2.63E-08	2.64E-08	3.26E-08	3.04E-08	2.75E-08	1.59E-08	5.50E-09	2.65E-09	1.90E-09	1.37E-09
WSW	1.79E-08	4.60E-08	4.19E-08	3.46E-08	2.93E-08	1.92E-08	7.00E-09	3.33E-09	2.19E-09	1.58E-09
W	2.36E-08	4.96E-08	4.23E-08	3.78E-08	3.50E-08	2.27E-08	8.71E-09	4.18E-09	2.77E-09	2.00E-09
WNW	2.88E-08	4.36E-08	4.12E-08	3.47E-08	3.23E-08	2.02E-08	7.87E-09	3.79E-09	2.51E-09	1.82E-09
NW	7.97E-08	4.59E-08	3.56E-08	3.17E-08	2.70E-08	1.55E-08	6.22E-09	2.94E-09	1.98E-09	1.43E-09
NNW	1.55E-08	4.11E-08	4.45E-08	4.00E-08	3.39E-08	2.04E-08	6.36E-09	3.99E-09	2.62E-09	1.88E-09

RUN TYPE- DEPLETED X/Q SEC/M3 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.25E-08	3.49E-08	3.50E-08	3.24E-08	2.80E-08	1.78E-08	6.96E-09	3.29E-09	2.15E-09	1.54E-09
NNE	7.59E-09	2.20E-08	2.30E-08	2.39E-08	2.32E-08	1.65E-08	7.17E-09	3.61E-09	2.43E-09	1.79E-09
NE	3.36E-08	2.45E-08	1.66E-08	1.55E-08	1.42E-08	9.71E-09	4.45E-09	2.36E-09	1.63E-09	1.22E-09
ENE	2.49E-08	2.65E-08	2.17E-08	1.42E-08	1.61E-08	1.07E-08	4.66E-09	2.39E-09	1.63E-09	1.20E-09
E	7.32E-08	3.58E-08	2.40E-08	1.92E-08	1.65E-08	1.05E-08	4.42E-09	2.23E-09	1.51E-09	1.11E-09
ESE	1.19E-07	4.30E-08	2.53E-08	2.01E-08	1.76E-08	1.15E-08	5.09E-09	2.60E-09	1.77E-09	1.30E-09
SE	8.14E-08	2.31E-08	1.40E-08	1.13E-08	9.98E-09	6.81E-09	3.19E-09	1.73E-09	1.21E-09	9.13E-10
SSE	9.36E-08	1.78E-08	1.06E-08	8.36E-09	8.15E-09	5.95E-09	2.84E-09	1.51E-09	1.05E-09	7.83E-10
S	4.73E-08	1.41E-08	8.88E-09	7.32E-09	6.56E-09	4.71E-09	2.38E-09	1.35E-09	9.66E-10	7.41E-10
SSW	2.19E-08	1.53E-08	1.60E-08	1.49E-08	1.22E-08	7.11E-09	2.89E-09	1.47E-09	1.01E-09	7.51E-10
SW	2.60E-08	2.62E-08	3.18E-08	2.94E-08	2.55E-08	1.44E-08	5.12E-09	2.42E-09	1.54E-09	1.15E-09
WSW	1.75E-08	4.53E-08	[illegible]	3.27E-08	2.72E-08	1.70E-08	5.94E-09	2.78E-09	1.80E-09	1.29E-09
W	2.32E-08	4.88E-08	4.12E-08	3.59E-08	3.25E-08	2.04E-08	7.60E-09	3.58E-09	2.34E-09	1.69E-09
WNW	2.83E-08	4.26E-08	3.99E-08	3.29E-08	2.94E-08	1.81E-08	6.87E-09	3.25E-09	2.13E-09	1.54E-09
NW	7.83E-08	4.44E-08	3.43E-08	3.00E-08	2.50E-08	1.40E-08	5.41E-09	2.54E-09	1.66E-09	1.19E-09
NNW	1.53E-08	4.04E-08	4.35E-08	3.95E-08	3.22E-08	1.90E-08	7.43E-09	3.44E-09	2.22E-09	1.58E-09

RUN TYPE- DEPOSITION D/Q M-2 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	2.65E-09	1.90E-09	7.85E-10	4.43E-10	2.94E-10	1.33E-10	3.25E-11	1.14E-11	6.12E-12	3.85E-12
NNE	1.20E-09	7.94E-10	3.28E-10	1.87E-10	1.25E-10	5.75E-11	1.42E-11	5.00E-12	2.69E-12	1.69E-12
NE	2.01E-09	8.61E-10	3.25E-10	1.79E-10	1.19E-10	5.43E-11	1.36E-11	4.93E-12	2.71E-12	1.71E-12
ENE	2.95E-09	1.31E-09	4.44E-10	2.72E-10	1.80E-10	8.23E-11	2.06E-11	7.43E-12	4.07E-12	2.59E-12
E	7.74E-09	2.28E-09	7.71E-10	4.09E-10	2.67E-10	1.19E-10	3.62E-11	1.13E-11	6.41E-12	4.15E-12
ESE	1.15E-08	2.96E-09	[illegible]	5.01E-10	3.25E-10	1.42E-10	3.65E-11	1.40E-11	8.03E-12	5.23E-12
SE	7.80E-09	1.88E-09	5.69E-10	3.04E-10	1.96E-10	8.53E-11	2.21E-11	8.55E-12	4.95E-12	3.25E-12
SSE	3.47E-09	8.53E-10	[illegible]	1.40E-10	9.01E-11	3.93E-11	1.02E-11	3.96E-12	2.31E-12	1.52E-12
S	2.21E-09	5.13E-10	1.60E-10	8.20E-11	5.27E-11	2.24E-11	5.95E-12	2.14E-12	1.37E-12	8.97E-13
SSW	1.40E-09	5.39E-10	2.07E-10	1.14E-10	7.56E-11	3.26E-11	8.07E-12	2.93E-12	1.61E-12	1.03E-12
SW	1.11E-09	1.24E-09	5.54E-10	3.17E-10	2.15E-10	9.04E-11	2.15E-11	7.42E-12	[illegible]	2.49E-12
WSW	2.23E-09	2.14E-09	9.03E-10	5.10E-10	3.42E-10	1.48E-10	3.52E-11	1.22E-11	6.51E-12	4.09E-12
W	2.94E-09	1.60E-09	6.36E-10	3.59E-10	2.43E-10	1.04E-10	2.51E-11	8.64E-12	4.79E-12	3.04E-12
WNW	2.62E-09	1.36E-09	[illegible]	3.13E-10	2.12E-10	9.01E-11	2.17E-11	7.65E-12	4.16E-12	2.63E-12
NW	5.72E-09	2.10E-09	7.50E-10	4.05E-10	2.66E-10	1.14E-10	2.83E-11	1.05E-11	5.83E-12	3.73E-12

Table 1.

ATMOSPHERIC DISPERSION FACTORS FOR- OYSTER CREEK VENT- STACK SEASON- ANNUAL REQ- OX-2 68 HRLY ELE

RUN TYPE- X/Q SEC/M3 DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	7.06E-09	2.39E-08	2.58E-08	2.43E-08	2.15E-08	1.45E-08	6.13E-09	3.07E-09	2.06E-09	1.51E-09
NNE	4.34E-09	1.51E-08	1.75E-08	1.93E-08	1.83E-08	1.35E-08	6.15E-09	3.19E-09	2.19E-09	1.62E-09
NE	1.62E-08	1.57E-08	1.34E-08	1.27E-08	1.19E-08	8.72E-09	4.23E-09	2.29E-09	1.60E-09	1.20E-09
ENE	1.46E-08	1.40E-08	1.63E-08	1.48E-08	1.37E-08	9.81E-09	4.65E-09	2.47E-09	1.72E-09	1.28E-09
E	3.55E-08	3.05E-08	2.37E-08	2.07E-08	1.88E-08	1.31E-08	5.92E-09	3.07E-09	2.10E-09	1.55E-09
ESE	7.44E-08	3.45E-08	2.67E-08	2.59E-08	2.36E-08	1.63E-08	7.24E-09	3.74E-09	2.55E-09	1.87E-09
SE	5.57E-08	2.56E-08	1.91E-08	1.64E-08	1.55E-08	1.09E-08	5.00E-09	2.60E-09	1.79E-09	1.33E-09
SSE	5.54E-08	1.74E-08	1.25E-08	1.12E-08	1.06E-08	7.60E-09	3.62E-09	1.93E-09	1.34E-09	1.09E-09
S	3.00E-08	1.38E-08	1.15E-08	1.05E-08	9.71E-09	7.07E-09	3.44E-09	1.67E-09	1.32E-09	9.94E-10
SSW	1.42E-08	1.55E-08	1.73E-08	1.79E-08	1.69E-08	1.06E-08	4.37E-09	2.20E-09	1.49E-09	1.10E-09
SW	1.01E-08	1.97E-08	2.41E-08	2.56E-08	2.39E-08	1.44E-08	5.46E-09	2.68E-09	1.80E-09	1.31E-09
WSW	1.25E-08	3.09E-08	3.10E-08	2.77E-08	2.46E-08	1.71E-08	6.30E-09	3.00E-09	1.97E-09	1.42E-09
W	1.23E-08	3.04E-08	2.85E-08	2.78E-08	2.72E-08	1.65E-08	7.10E-09	3.37E-09	2.22E-09	1.60E-09
WNW	2.12E-08	2.76E-08	2.75E-08	2.52E-08	2.49E-08	1.64E-08	6.53E-09	3.17E-09	2.11E-09	1.53E-09
NW	4.33E-08	3.08E-08	2.73E-08	2.61E-08	2.29E-08	1.37E-08	5.64E-09	2.72E-09	1.81E-09	1.31E-09
NNW	7.73E-09	2.52E-08	2.83E-08	2.59E-08	2.21E-08	1.37E-08	5.90E-09	2.93E-09	1.97E-09	1.43E-09

RUN TYPE- DEPLETED X/Q SEC/M3 DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	6.92E-09	2.34E-08	2.53E-08	2.35E-08	2.06E-08	1.37E-08	5.66E-09	2.79E-09	1.86E-09	1.35E-09
NNE	4.27E-09	1.49E-08	1.74E-08	1.90E-08	1.78E-08	1.30E-08	5.84E-09	3.00E-09	2.05E-09	1.51E-09
NE	1.60E-08	1.54E-08	1.35E-08	1.24E-08	1.15E-08	8.37E-09	4.00E-09	2.14E-09	1.49E-09	1.12E-09
ENE	1.38E-08	1.76E-08	1.60E-08	1.44E-08	1.33E-08	9.42E-09	4.38E-09	2.31E-09	1.59E-09	1.19E-09
E	3.88E-08	2.97E-08	2.32E-08	2.00E-08	1.81E-08	1.24E-08	5.53E-09	2.83E-09	1.92E-09	1.41E-09
ESE	7.35E-08	3.74E-08	2.89E-08	2.51E-08	2.27E-08	1.55E-08	6.79E-09	3.43E-09	2.32E-09	1.70E-09
SE	5.47E-08	2.48E-08	1.65E-08	1.53E-08	1.49E-08	1.04E-08	4.71E-09	2.42E-09	1.65E-09	1.22E-09
SSE	5.47E-08	1.69E-08	1.22E-08	1.09E-08	1.01E-08	7.27E-09	3.40E-09	1.80E-09	1.24E-09	9.26E-10
S	2.95E-08	1.34E-08	1.12E-08	1.02E-08	9.38E-09	6.78E-09	3.26E-09	1.76E-09	1.23E-09	9.30E-10
SSW	1.40E-08	1.52E-08	1.69E-08	1.72E-08	1.61E-08	1.00E-08	4.05E-09	2.01E-09	1.36E-09	1.00E-09
SW	9.92E-09	1.96E-08	2.55E-08	2.44E-08	2.24E-08	1.32E-08	4.89E-09	2.36E-09	1.57E-09	1.15E-09
WSW	1.22E-08	3.05E-08	3.02E-08	2.64E-08	2.31E-08	1.57E-08	5.60E-09	2.61E-09	1.70E-09	1.22E-09
W	1.20E-08	3.02E-08	2.78E-08	2.66E-08	2.57E-08	1.71E-08	6.42E-09	3.01E-09	1.97E-09	1.41E-09
WNW	2.09E-08	2.70E-08	2.71E-08	2.41E-08	2.34E-08	1.51E-08	5.90E-09	2.83E-09	1.87E-09	1.35E-09
NW	4.25E-08	2.59E-08	2.65E-08	2.48E-08	2.14E-08	1.26E-08	5.01E-09	2.38E-09	1.56E-09	1.12E-09
NNW	7.59E-09	2.48E-08	2.78E-08	2.50E-08	2.11E-08	1.27E-08	5.33E-09	2.60E-09	1.72E-09	1.25E-09

RUN TYPE- DEPOSITION D/Q M-2 DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.59E-09	1.36E-09	5.70E-10	3.22E-10	2.14E-10	9.65E-11	2.35E-11	8.22E-12	4.39E-12	2.76E-12
NNE	7.02E-10	6.17E-10	2.57E-10	1.47E-10	9.89E-11	4.52E-11	1.11E-11	3.87E-12	2.07E-12	1.30E-12
NE	1.32E-09	6.14E-10	2.34E-10	1.30E-10	8.58E-11	3.93E-11	9.81E-12	3.53E-12	1.93E-12	1.22E-12
ENE	1.85E-09	9.10E-10	3.48E-10	1.93E-10	1.28E-10	5.84E-11	1.46E-11	5.22E-12	2.84E-12	1.80E-12
E	4.43E-09	1.85E-09	6.77E-10	3.68E-10	2.43E-10	1.16E-10	2.74E-11	9.93E-12	5.47E-12	3.49E-12
ESE	7.23E-09	2.56E-09	9.01E-10	4.85E-10	3.18E-10	1.42E-10	3.58E-11	1.32E-11	7.34E-12	4.72E-12
SE	5.75E-09	1.82E-09	6.22E-10	3.31E-10	2.16E-10	9.62E-11	2.43E-11	9.06E-12	5.09E-12	3.28E-12
SSE	2.68E-09	8.51E-10	2.64E-10	1.57E-10	1.03E-10	4.59E-11	1.16E-11	4.34E-12	2.45E-12	1.58E-12
S	1.53E-09	5.01E-10	1.80E-10	9.66E-11	6.32E-11	2.83E-11	7.14E-12	2.65E-12	1.48E-12	9.56E-13
SSW	9.14E-10	4.46E-10	1.83E-10	1.02E-10	6.84E-11	2.96E-11	7.25E-12	2.59E-12	1.41E-12	8.94E-13
SW	5.87E-10	9.12E-10	4.16E-10	2.34E-10	1.63E-10	6.84E-11	1.62E-11	5.57E-12	2.96E-12	1.85E-12
WSW	1.45E-09	1.46E-09	6.22E-10	3.51E-10	2.36E-10	1.02E-10	2.43E-11	8.39E-12	4.49E-12	2.63E-12
W	1.63E-09	1.05E-09	4.23E-10	2.40E-10	1.63E-10	6.98E-11	1.67E-11	5.86E-12	3.19E-12	2.04E-12
WNW	1.73E-09	9.08E-10	3.69E-10	2.04E-10	1.38E-10	5.88E-11	1.41E-11	5.00E-12	2.73E-12	1.73E-12
NW	3.78E-09	1.35E-09	5.07E-10	2.79E-10	1.84E-10	7.93E-11	1.95E-11	7.09E-12	3.91E-12	2.49E-12
NNW	[illegible]	[illegible]	4.62E-10	2.60E-10	1.72E-10	7.69E-11	1.87E-11	6.55E-12	3.51E-12	2.21E-12

IN RUN TYPE-

DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.46E-05	1.86E-06	4.75E-07	2.39E-07	1.59E-07	5.74E-08	[illegible]			
NNE	2.05E-05	2.83E-06	7.43E-07	3.77E-07	2.52E-07	1.09E-07	3.41E-08	[illegible]		
NE	1.86E-05	2.59E-06	6.82E-07	3.46E-07	2.32E-07	1.00E-07	3.17E-08	1.33E-08	9.08E-09	[illegible]
ENE	2.35E-05	3.34E-06	8.52E-07	4.56E-07	3.07E-07	1.39E-07	4.30E-08	1.90E-08	1.25E-08	9.15E-09
E	2.45E-05	3.80E-06	1.02E-06	5.23E-07	3.52E-07	1.55E-07	5.00E-08	2.22E-08	1.46E-08	1.07E-08
ESE	2.33E-05	3.37E-06	9.10E-07	4.49E-07	3.15E-07	1.40E-07	4.58E-08	2.04E-08	1.35E-08	9.53E-09
SE	3.57E-05	5.25E-06	1.42E-06	7.36E-07	4.94E-07	2.20E-07	7.27E-08	3.24E-08	2.15E-08	1.59E-08
SSE	2.42E-05	3.62E-06	9.80E-07	5.13E-07	3.46E-07	1.55E-07	5.16E-08	2.31E-08	1.54E-08	1.14E-08
S	1.02E-05	1.48E-06	3.40E-07	2.05E-07	1.34E-07	6.13E-08	2.01E-08	8.95E-09	5.91E-09	4.34E-09
SSW	6.15E-06	8.45E-07	2.23E-07	1.14E-07	7.62E-08	3.29E-08	1.04E-08	4.59E-09	2.98E-09	2.15E-09
SW	8.35E-06	1.13E-06	2.99E-07	1.51E-07	1.01E-07	4.36E-08	1.39E-08	6.04E-09	3.92E-09	2.93E-09
WSW	8.89E-06	1.10E-06	2.81E-07	1.41E-07	9.33E-08	3.89E-08	1.18E-08	5.07E-09	3.22E-09	2.27E-09
W	1.14E-05	1.47E-06	3.78E-07	1.93E-07	1.28E-07	5.31E-08	1.63E-08	7.02E-09	4.49E-09	3.19E-09
WNW	9.08E-06	1.17E-06	3.02E-07	1.51E-07	1.00E-07	4.24E-08	1.30E-08	5.62E-09	3.59E-09	2.55E-09
NW	1.07E-05	1.42E-06	3.49E-07	1.86E-07	1.24E-07	5.28E-08	1.65E-08	7.17E-09	4.62E-09	3.30E-09
NNW	1.38E-05	1.65E-06	4.82E-07	2.43E-07	1.62E-07	6.92E-08	2.15E-08	9.35E-09	6.04E-09	4.34E-09

IN RUN TYPE- DEPLETED X/Q SEC/M3 DISTANCE (METERS)

DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.19E-05	1.40E-06	3.36E-07	1.59E-07	1.02E-07	3.92E-08	1.00E-08	3.65E-09	2.04E-09	1.31E-09
NNE	1.75E-05	2.15E-06	5.26E-07	2.51E-07	1.61E-07	6.32E-08	1.65E-08	6.08E-09	3.44E-09	2.23E-09
NE	1.58E-05	1.96E-06	4.83E-07	2.31E-07	1.49E-07	5.84E-08	1.53E-08	5.66E-09	3.22E-09	2.09E-09
ENE	2.00E-05	2.54E-06	6.31E-07	3.05E-07	1.95E-07	7.80E-08	2.08E-08	7.73E-09	4.42E-09	2.90E-09
E	2.26E-05	2.84E-06	7.21E-07	3.49E-07	2.25E-07	8.99E-08	2.42E-08	9.03E-09	5.18E-09	3.41E-09
ESE	1.96E-05	2.56E-06	6.46E-07	3.13E-07	2.02E-07	8.13E-08	2.22E-08	8.29E-09	4.78E-09	3.15E-09
SE	3.04E-05	3.94E-06	1.01E-06	4.91E-07	3.17E-07	1.28E-07	3.52E-08	1.32E-08	7.61E-09	5.04E-09
SSE	2.06E-05	2.74E-06	7.00E-07	3.42E-07	2.21E-07	9.01E-08	2.50E-08	9.39E-09	5.44E-09	3.61E-09
S	8.70E-06	1.12E-06	2.83E-07	1.37E-07	8.85E-08	3.56E-08	9.72E-09	3.64E-09	2.09E-09	1.39E-09
SSW	5.25E-06	6.42E-07	1.56E-07	7.58E-08	4.87E-08	1.91E-08	5.05E-09	1.86E-09	1.06E-09	6.85E-10
SW	7.11E-06	8.61E-07	2.11E-07	1.01E-07	6.47E-08	2.54E-08	6.68E-09	2.45E-09	1.39E-09	8.99E-10
WSW	7.40E-06	8.34E-07	1.99E-07	9.38E-08	5.97E-08	2.27E-08	5.73E-09	2.06E-09	1.14E-09	7.19E-10
W	9.67E-06	1.11E-06	2.67E-07	1.26E-07	8.06E-08	3.09E-08	7.87E-09	2.85E-09	1.59E-09	1.01E-09
WNW	7.73E-06	8.90E-07	2.14E-07	1.01E-07	6.43E-08	2.47E-08	6.29E-09	2.28E-09	1.27E-09	8.10E-10
NW	9.11E-06	1.08E-06	2.61E-07	1.24E-07	7.90E-08	3.07E-08	7.98E-09	2.91E-09	1.64E-09	1.05E-09
NNW	1.19E-05	1.41E-06	3.41E-07	1.62E-07	1.04E-07	4.03E-08	1.04E-08	3.80E-09	2.14E-09	1.38E-09

IN RUN TYPE- DEPOSITION D/Q M-2 DISTANCE (METERS)

DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	8.46E-08	9.54E-09	2.16E-09	9.99E-10	6.05E-10	2.29E-10	5.23E-11	1.71E-11	8.66E-12	5.39E-12
NNE	8.89E-08	1.00E-08	2.27E-09	1.05E-09	6.35E-10	2.41E-10	5.49E-11	1.79E-11	9.09E-12	5.65E-12
NE	7.14E-08	8.05E-09	1.83E-09	8.43E-10	5.10E-10	1.93E-10	4.41E-11	1.44E-11	7.31E-12	4.54E-12
ENE	9.45E-08	1.07E-08	2.42E-09	1.12E-09	6.75E-10	2.56E-10	5.84E-11	1.91E-11	9.67E-12	6.00E-12
E	1.06E-07	1.20E-08	2.72E-09	1.26E-09	7.60E-10	2.88E-10	6.57E-11	2.15E-11	1.09E-11	6.76E-12
ESE	1.08E-07	1.22E-08	2.76E-09	1.27E-09	7.72E-10	2.92E-10	6.67E-11	2.18E-11	1.10E-11	6.86E-12
SE	1.26E-07	1.42E-08	3.22E-09	1.49E-09	9.01E-10	3.41E-10	7.79E-11	2.54E-11	1.29E-11	8.01E-12
SSE	6.42E-08	7.24E-09	1.64E-09	7.58E-10	4.59E-10	1.74E-10	3.97E-11	1.30E-11	6.57E-12	4.08E-12
S	2.96E-08	3.34E-09	7.57E-10	3.50E-10	2.12E-10	8.02E-11	1.83E-11	5.98E-12	3.03E-12	1.88E-12
SSW	1.81E-08	2.04E-09	4.63E-10	2.14E-10	1.29E-10	4.90E-11	1.12E-11	3.65E-12	1.85E-12	1.15E-12
SW	3.59E-08	4.05E-09	9.17E-10	4.24E-10	2.56E-10	9.71E-11	2.22E-11	7.24E-12	3.67E-12	2.28E-12
WSW	7.47E-08	8.42E-09	1.91E-09	8.82E-10	5.34E-10	2.02E-10	4.62E-11	1.51E-11	7.65E-12	4.75E-12
W	8.23E-08	9.28E-09	2.10E-09	9.71E-10	5.88E-10	2.23E-10	5.09E-11	1.66E-11	8.42E-12	5.23E-12
WNW	6.58E-08	7.42E-09	1.68E-09	7.77E-10	4.71E-10	1.78E-10	4.07E-11	1.33E-11	6.74E-12	4.18E-12
NW	6.29E-08	7.09E-09	1.61E-09	7.42E-10	4.49E-10	1.70E-10	3.89E-11	1.27E-11	6.43E-12	4.00E-12
	[illegible]	8.31E-09	1.88E-09	8.70E-10	5.27E-10	2.00E-10	4.56E-11	1.49E-11	7.55E-12	4.69E-12

Table [illegible]

ATMOSPHERIC DISPERSION FACTORS FOR- OYSTER CREEK VENT- RADWASTE BLDG SEASON- ANNUAL REU- OX-4 68 HRLY GND

IN DIRECTION SECTOR — RUN TYPE- X/Q SEC/M3 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.41E-05	1.99E-06	4.95E-07	2.50E-07	1.67E-07	7.13E-08	2.21E-08	9.64E-09	5.23E-09	4.49E-09
NNE	1.45E-05	2.54E-06	6.74E-07	3.42E-07	2.23E-07	9.87E-08	3.10E-08	1.36E-08	8.85E-09	6.41E-09
NE	2.02E-05	2.87E-06	7.47E-07	3.92E-07	2.64E-07	1.15E-07	3.69E-08	1.64E-08	1.07E-08	7.65E-09
ENE	2.81E-05	4.02E-06	1.06E-06	5.51E-07	3.71E-07	1.62E-07	5.21E-08	2.31E-08	1.52E-08	1.11E-08
E	2.85E-05	4.06E-06	1.09E-06	5.54E-07	3.73E-07	1.63E-07	5.23E-08	2.32E-08	1.52E-08	1.11E-08
ESE	2.74E-05	3.86E-06	1.03E-06	5.24E-07	3.52E-07	1.53E-07	4.92E-08	2.17E-08	1.42E-08	1.04E-08
SE	3.22E-05	4.65E-06	1.25E-06	6.42E-07	4.32E-07	1.90E-07	6.19E-08	2.75E-08	1.81E-08	1.33E-08
SSE	2.22E-05	3.22E-06	8.68E-07	4.47E-07	3.01E-07	1.33E-07	4.33E-08	1.93E-08	1.27E-08	9.34E-09
S	1.13E-05	1.60E-06	4.27E-07	2.19E-07	1.47E-07	6.42E-08	2.07E-08	9.15E-09	6.00E-09	4.39E-09
SSW	7.07E-06	9.61E-07	2.52E-07	1.27E-07	8.51E-08	3.64E-08	1.14E-08	4.98E-09	3.22E-09	2.32E-09
SW	8.47E-06	1.14E-06	2.97E-07	1.49E-07	9.95E-08	4.26E-08	1.32E-08	5.76E-09	3.71E-09	2.65E-09
WSW	1.02E-05	1.33E-06	3.43E-07	1.71E-07	1.14E-07	4.80E-08	1.47E-08	6.32E-09	4.03E-09	2.86E-09
W	1.13E-05	1.49E-06	3.86E-07	1.94E-07	1.29E-07	5.47E-08	1.69E-08	7.30E-09	4.68E-09	3.33E-09
WNW	8.05E-06	1.07E-06	2.76E-07	1.39E-07	9.27E-08	3.95E-08	1.22E-08	5.31E-09	3.42E-09	2.45E-09
NW	9.73E-06	1.31E-06	3.41E-07	1.72E-07	1.15E-07	4.94E-08	1.55E-08	6.75E-09	4.16E-09	3.14E-09
NNW	1.11E-05	1.52E-06	3.96E-07	2.00E-07	1.34E-07	5.74E-08	1.80E-08	7.45E-09	5.09E-09	3.67E-09

IN DIRECTION SECTOR — RUN TYPE- DEPLETED X/Q SEC/M3 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	1.20E-05	1.44E-06	3.51E-07	1.67E-07	1.07E-07	4.15E-08	1.07E-08	3.92E-09	2.21E-09	1.42E-09
NNE	1.57E-05	1.94E-06	4.77E-07	2.26E-07	1.47E-07	5.74E-08	1.50E-08	5.53E-09	3.14E-09	2.04E-09
NE	1.72E-05	2.18E-06	5.43E-07	2.62E-07	1.69E-07	6.70E-08	1.79E-08	6.64E-09	3.80E-09	2.49E-09
ENE	2.39E-05	3.05E-06	7.61E-07	3.68E-07	2.37E-07	9.43E-08	2.52E-08	9.39E-09	5.38E-09	3.53E-09
E	2.43E-05	3.08E-06	7.67E-07	3.70E-07	2.38E-07	9.47E-08	2.53E-08	9.41E-09	5.34E-09	3.53E-09
ESE	2.33E-05	2.93E-06	7.27E-07	3.50E-07	2.25E-07	8.93E-08	2.38E-08	8.83E-09	5.04E-09	3.29E-09
SE	2.75E-05	3.53E-06	8.85E-07	4.29E-07	2.77E-07	1.11E-07	2.99E-08	1.12E-08	6.42E-09	4.22E-09
SSE	1.89E-05	2.44E-06	6.14E-07	2.98E-07	1.92E-07	7.72E-08	2.09E-08	7.83E-09	4.50E-09	2.96E-09
S	9.63E-06	1.22E-06	3.03E-07	1.46E-07	9.39E-08	3.74E-08	1.00E-08	3.72E-09	2.13E-09	1.39E-09
SSW	6.02E-06	7.29E-07	1.78E-07	8.49E-08	5.44E-08	2.12E-08	5.51E-09	2.02E-09	1.14E-09	7.37E-10
SW	7.22E-06	8.64E-07	2.10E-07	9.97E-08	6.37E-08	2.48E-08	6.41E-09	2.34E-09	1.31E-09	8.43E-10
WSW	8.68E-06	1.01E-06	2.43E-07	1.14E-07	7.29E-08	2.79E-08	7.10E-09	2.57E-09	1.43E-09	9.07E-10
W	9.59E-06	1.13E-06	2.73E-07	1.29E-07	8.24E-08	3.18E-08	8.16E-09	2.97E-09	1.66E-09	1.05E-09
WNW	6.86E-06	8.09E-07	1.95E-07	9.28E-08	5.93E-08	2.30E-08	5.91E-09	2.16E-09	1.21E-09	7.76E-10
NW	8.26E-06	9.92E-07	2.42E-07	1.15E-07	7.36E-08	2.87E-08	7.44E-09	2.74E-09	1.55E-09	9.96E-10
NNW	9.45E-06	1.15E-06	2.80E-07	1.34E-07	8.56E-08	3.34E-08	8.68E-09	3.19E-09	1.80E-09	1.16E-09

IN DIRECTION SECTOR — RUN TYPE- DEPOSITION D/Q M-2 — DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	7.35E-08	8.30E-09	1.88E-09	8.49E-10	5.26E-10	1.99E-10	4.55E-11	1.48E-11	7.53E-12	4.69E-12
NNE	7.54E-08	8.50E-09	1.93E-09	8.90E-10	5.39E-10	2.04E-10	4.66E-11	1.52E-11	7.71E-12	4.79E-12
NE	6.58E-08	7.42E-09	1.68E-09	7.77E-10	4.70E-10	1.78E-10	4.07E-11	1.33E-11	6.73E-12	4.18E-12
ENE	1.04E-07	1.18E-08	2.67E-09	1.23E-09	7.46E-10	2.83E-10	6.45E-11	2.11E-11	1.07E-11	6.63E-12
E	1.28E-07	1.45E-08	3.28E-09	1.51E-09	9.16E-10	3.47E-10	7.92E-11	2.59E-11	1.31E-11	8.15E-12
ESE	1.48E-07	1.66E-08	3.77E-09	1.74E-09	1.06E-09	4.00E-10	9.12E-11	2.98E-11	1.51E-11	9.39E-12
SE	1.29E-07	1.46E-08	3.31E-09	1.53E-09	9.25E-10	3.51E-10	8.00E-11	2.61E-11	1.33E-11	8.23E-12
SSE	7.39E-08	8.33E-09	1.89E-09	8.72E-10	5.28E-10	2.00E-10	4.57E-11	1.49E-11	7.56E-12	4.70E-12
S	3.57E-08	4.02E-09	9.11E-10	4.21E-10	2.55E-10	9.65E-11	2.20E-11	7.19E-12	3.65E-12	2.27E-12
SSW	2.37E-08	2.67E-09	6.05E-10	2.79E-10	1.69E-10	6.41E-11	1.46E-11	4.77E-12	2.42E-12	1.50E-12
SW	3.92E-08	4.42E-09	1.00E-09	4.63E-10	2.80E-10	1.06E-10	2.42E-11	7.91E-12	4.01E-12	2.49E-12
WSW	6.55E-08	7.38E-09	1.67E-09	7.73E-10	4.68E-10	1.77E-10	4.05E-11	1.32E-11	6.70E-12	4.16E-12
W	6.85E-08	7.73E-09	1.75E-09	8.09E-10	4.90E-10	1.86E-10	4.24E-11	1.39E-11	7.02E-12	4.36E-12
WNW	4.94E-08	5.57E-09	1.26E-09	5.83E-10	3.53E-10	1.34E-10	3.05E-11	9.97E-12	5.06E-12	3.14E-12
NW	5.20E-08	5.87E-09	1.33E-09	6.14E-10	3.72E-10	1.41E-10	3.21E-11	1.05E-11	5.32E-12	3.31E-12
NNW	5.46E-08	6.16E-09	1.40E-09	6.45E-10	3.90E-10	1.48E-10	3.37E-11	1.10E-11	5.59E-12	3.47E-12

ATMOSPHERIC DISPERSION FACTORS FOR- OYSTER CREEK   VENT- STACK   SEASON- GRAZING   REO- OX-S

RUN TYPE- X/Q SEC/M3   DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	3.30E-08	4.72E-08	4.07E-08	3.61E-08	3.12E-08	1.99E-08	7.93E-09	3.83E-09	2.53E-09	1.82E-09
NNE	4.11E-09	2.24E-08	2.43E-08	2.40E-08	2.13E-08	1.65E-08	7.24E-09	3.69E-09	2.51E-09	1.85E-09
NE	2.35E-09	2.61E-08	2.06E-08	1.92E-08	1.66E-08	1.15E-08	5.30E-09	2.80E-09	1.93E-09	1.44E-09
ENE	2.82E-09	2.37E-08	1.90E-08	1.70E-08	1.51E-08	1.03E-08	4.70E-09	2.49E-09	1.73E-09	1.29E-09
E	5.24E-09	2.94E-08	2.08E-08	1.49E-08	1.49E-08	9.85E-09	4.41E-09	2.32E-09	1.60E-09	1.19E-09
ESE	7.48E-09	3.07E-08	2.05E-08	1.47E-08	1.46E-08	9.69E-09	4.32E-09	2.26E-09	1.56E-09	1.16E-09
SE	7.24E-09	2.59E-08	1.47E-08	1.15E-08	1.00E-08	6.68E-09	3.09E-09	1.66E-09	1.16E-09	8.79E-10
SSE	5.57E-09	1.57E-08	1.08E-08	9.23E-09	8.37E-09	5.91E-09	2.78E-09	1.49E-09	1.04E-09	7.81E-10
S	3.55E-09	1.29E-08	1.07E-08	9.70E-09	8.06E-09	6.53E-09	3.19E-09	1.75E-09	1.24E-09	9.41E-10
SSW	1.97E-09	1.77E-08	1.04E-09	1.99E-08	1.86E-08	1.14E-08	4.66E-09	2.35E-09	1.59E-09	1.17E-09
SW	2.65E-09	2.72E-08	3.20E-08	3.06E-08	2.81E-08	1.67E-08	6.28E-09	3.05E-09	2.03E-09	1.48E-09
WSW	2.11E-09	3.44E-08	3.21E-08	2.78E-08	2.43E-08	1.66E-08	6.08E-09	2.89E-09	1.89E-09	1.36E-09
W	2.53E-09	3.87E-08	3.24E-08	2.91E-08	2.70E-08	1.73E-08	6.63E-09	3.13E-09	2.06E-09	1.48E-09
WNW	2.62E-09	3.53E-08	3.71E-08	3.23E-08	3.07E-08	1.88E-08	7.10E-09	3.33E-09	2.18E-09	1.55E-09
NW	4.66E-09	3.95E-08	3.70E-08	3.54E-08	3.04E-08	1.74E-08	6.77E-09	3.18E-09	2.09E-09	1.49E-09
NNW	2.37E-09	3.53E-08	3.82E-08	3.32E-08	2.77E-08	1.64E-08	6.61E-09	3.15E-09	2.07E-09	1.49E-09

RUN TYPE- DEPLETED X/Q SEC/M3   DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	3.25E-09	4.21E-08	3.08E-08	3.50E-08	2.98E-08	1.86E-08	7.15E-09	3.36E-09	2.19E-09	1.56E-09
NNE	3.04E-09	2.21E-08	2.40E-08	2.34E-08	2.26E-08	1.59E-08	6.79E-09	3.42E-09	2.31E-09	1.70E-09
NE	2.31E-09	2.36E-08	2.02E-08	1.77E-08	1.60E-08	1.10E-08	4.94E-09	2.57E-09	1.76E-09	1.31E-09
ENE	2.77E-09	2.33E-08	1.95E-08	1.65E-08	1.46E-08	9.70E-09	4.33E-09	2.26E-09	1.55E-09	1.16E-09
E	5.17E-09	2.85E-08	2.01E-08	1.44E-08	1.42E-08	9.25E-09	4.02E-09	2.07E-09	1.42E-09	1.05E-09
ESE	7.34E-09	2.97E-08	1.99E-08	1.41E-08	1.40E-08	9.08E-09	3.93E-09	2.02E-09	1.37E-09	1.02E-09
SE	7.11E-09	2.49E-08	1.41E-08	1.10E-08	9.50E-09	6.25E-09	2.83E-09	1.50E-09	1.04E-09	7.83E-10
SSE	5.82E-09	1.52E-08	1.05E-08	8.93E-09	8.04E-09	5.60E-09	2.58E-09	1.36E-09	9.41E-10	7.04E-10
S	3.50E-09	1.25E-08	1.05E-08	9.49E-09	8.63E-09	6.24E-09	3.01E-09	1.64E-09	1.15E-09	8.74E-10
SSW	1.94E-09	1.74E-08	1.04E-08	1.92E-08	1.76E-08	1.07E-08	4.27E-09	2.12E-09	1.43E-09	1.05E-09
SW	2.60E-09	2.65E-08	3.12E-08	2.91E-08	2.63E-08	1.53E-08	5.57E-09	2.66E-09	1.76E-09	1.27E-09
WSW	2.07E-09	3.38E-08	3.12E-08	2.64E-08	2.27E-08	1.50E-08	5.32E-09	2.44E-09	1.60E-09	1.14E-09
W	2.88E-09	3.80E-08	3.15E-08	2.76E-08	2.51E-08	1.56E-08	5.77E-09	2.67E-09	1.73E-09	1.24E-09
WNW	2.58E-09	3.47E-08	3.61E-08	3.08E-08	2.86E-08	1.70E-08	6.19E-09	2.84E-09	1.83E-09	1.30E-09
NW	4.58E-09	3.87E-08	3.49E-08	3.36E-08	2.84E-08	1.58E-08	5.88E-09	2.68E-09	1.72E-09	1.22E-09
NNW	2.32E-09	3.85E-08	3.72E-08	3.18E-08	2.62E-08	1.51E-08	5.83E-09	2.70E-09	1.74E-09	1.24E-09

RUN TYPE- DEPOSITION D/Q M-2   DISTANCE (METERS)

IN DIRECTION SECTOR	804	2413	4022	5631	7240	12067	24135	40225	56315	72405
N	4.45E-09	2.41E-09	9.56E-10	5.33E-10	3.53E-10	1.58E-10	3.80E-11	1.38E-11	7.49E-12	4.73E-12
NNE	1.22E-09	1.02E-09	4.19E-10	2.39E-10	1.60E-10	7.30E-11	1.79E-11	6.26E-12	3.35E-12	2.10E-12
NE	2.19E-09	5.41E-10	3.50E-10	1.03E-10	1.32E-10	6.04E-11	1.51E-11	5.44E-12	2.48E-12	1.89E-12
ENE	2.74E-09	1.21E-09	4.57E-10	2.52E-10	1.67E-10	7.51E-11	1.90E-11	6.87E-12	3.77E-12	2.40E-12
E	4.74E-09	1.55E-09	5.41E-10	2.90E-10	1.90E-10	8.54E-11	2.16E-11	8.01E-12	4.49E-12	2.92E-12
ESE	7.29E-09	2.02E-09	6.40E-10	3.52E-10	2.29E-10	1.02E-10	2.59E-11	9.81E-12	5.58E-12	3.62E-12
SE	6.32E-09	1.56E-09	4.04E-10	2.56E-10	1.65E-10	7.22E-11	1.86E-11	7.19E-12	4.16E-12	2.72E-12
SSE	2.91E-09	8.52E-10	2.87E-10	1.52E-10	9.90E-11	4.40E-11	1.12E-11	4.22E-12	2.39E-12	1.55E-12
S	1.82E-09	5.75E-10	2.04E-10	1.09E-10	7.13E-11	3.17E-11	8.02E-12	2.98E-12	1.68E-12	1.08E-12
SSW	1.63E-09	7.06E-10	2.78E-10	1.53E-10	1.02E-10	4.39E-11	1.08E-11	3.87E-12	2.12E-12	1.34E-12
SW	3.12E-09	1.54E-09	6.21E-10	3.44E-10	2.31E-10	9.71E-11	2.35E-11	8.32E-12	4.52E-12	2.85E-12
WSW	2.56E-09	1.58E-09	6.30E-10	3.56E-10	2.38E-10	1.03E-10	2.47E-11	8.65E-12	4.67E-12	2.95E-12
W	2.44E-09	1.37E-09	5.35E-10	3.01E-10	2.03E-10	8.69E-11	2.09E-11	7.38E-12	4.02E-12	2.56E-12
WNW	2.50E-09	1.33E-09	5.41E-10	3.01E-10	2.04E-10	8.66E-11	2.08E-11	7.34E-12	3.99E-12	2.54E-12
NW	4.15E-09	1.73E-09	6.77E-10	3.77E-10	2.59E-10	1.08E-10	2.64E-11	9.48E-12	5.19E-12	3.29E-12
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.41E-12

TABLE 1.3-11 A

Diffusion and Deposition Estimates for All Receptor Locations

Site: Oyster Creek Release Point: Stack Season: Annual • Computer Run ID OX-2 603-5

Direction	Distance to Nearest Milk Cow (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Distance to Nearest Meat Animal (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Distance to Nearest Milk Goat (sec/m³)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NNE												
NE												
ENE												
E												
ESE												
SE												
SSE												
S												
SSW												
SW												
WSW												
W												
WNW												
NW												
NNW												

NOTE: • N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.

• (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE 1.3-11 B

Diffusion and Deposition Estimates for All Receptor Locations (cont'd)

Site: Oyster Creek   Release Point: Stack   Season: Annual   Computer Run ID: OX-2 603-5

Direction	Distance to Nearest Residence (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Distance to Nearest Veg. Garden (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Nearest Site Boundary (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})
N	1710	1.5E-08	1.5E-08	1.8E-09	N/A	N/A	N/A	N/A	610	6.8E-09	6.7E-09	1.7E-09
NNE	940	5.2E-09	5.0E-09	7.3E-10					731	3.8E-09	3.7E-09	7.3E-10
NE	1170	1.4E-08	1.4E-08	1.1E-09					957	1.6E-08	1.5E-08	1.2E-09
ENE	1780	1.5E-08	1.5E-08	1.3E-09					1500	1.4E-08	1.4E-08	1.4E-09
E	1340	3.3E-08	3.2E-08	3.2E-09					914	3.8E-08	3.7E-08	4.3E-09
ESE	1040	5.7E-08	5.6E-08	6.0E-09					914	6.8E-08	6.6E-08	6.9E-09
SE	890	4.9E-08	4.8E-08	5.5E-09					731	6.2E-08	6.2E-08	6.1E-09
SSE	1150	3.3E-08	3.2E-08	2.0E-09					625	7.4E-08	7.4E-08	2.9E-09
S	2380	1.4E-08	1.3E-08	5.1E-10					610	3.3E-08	3.3E-08	1.7E-09
SSW	2350	1.5E-08	1.5E-08	4.7E-10					625	1.8E-08	1.8E-08	9.8E-10
SW	2710	2.4E-08	2.4E-08	8.0E-10					731	1.1E-08	1.1E-08	5.8E-10
WSW	6250	2.6E-08	2.4E-08	2.9E-10					1000	1.4E-08	1.4E-08	1.7E-09
W	7160	2.7E-08	2.6E-08	1.7E-10					1000	1.4E-08	1.4E-08	1.6E-09
WNW	5180	2.6E-08	2.5E-08	2.4E-10					838	2.1E-08	2.1E-08	1.7E-09
NW	7580	2.2E-08	2.0E-08	1.7E-10					646	4.4E-08	4.4E-08	4.1E-09
NNW	2680	2.7E-08	2.7E-08	9.4E-10					610	6.3E-09	6.3E-09	1.6E-09

NOTE: • N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.

• (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE 1.3-12 A

Diffusion and Deposition Estimates for All Receptor Locations

Site: Oyster Creek   Release Point: Stack   Season: Grazing   Computer Run ID: OX-1 G03-6

Direction	Distance to Nearest Milk Cow (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Distance to Nearest Meat Animal (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Distance to Nearest Milk Goat (sec/m^3)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})
N	-	2.7E-08	N/A	2.5E-10	-	2.7E-08	N/A	2.5E-10	-	2.7E-08	N/A	2.5E-10
NNE	7400, 10600	2.4E-08		6.9E-11	5790, 7400	2.4E-08		1.8E-10	6440, 7500	2.4E-08		1.5E-10
NE	-	1.4E-08		1.0E-10	-	1.4E-08		1.0E-10	-	1.4E-08		1.0E-10
ENE	-	1.6E-08		1.6E-10	-	1.6E-08		1.6E-10	-	1.6E-08		1.6E-10
E	-	1.6E-08		2.3E-10	-	1.6E-08		2.3E-10	-	1.6E-08		2.3E-10
ESE	-	1.7E-08		2.8E-10	-	1.7E-08		2.8E-10	-	8.1E-08		7.6E-09
SE	-	9.9E-09		1.7E-10	-	9.9E-09		1.7E-10	-	1.0E-08		1.7E-10
SSE	-	8.2E-09		7.8E-11	-	8.2E-09		7.8E-11	1200	4.5E-08		2.3E-09
S	-	6.6E-09		4.5E-11	2410	1.5E-08		8.6E-10	2570, 2770	1.3E-08		4.4E-10
SSW	9490	1.0E-08		4.8E-11	8210	1.2E-08		1.8E-10	15300	5.9E-09		2.2E-11
SW	-	2.5E-08		1.8E-10	-	2.5E-08		1.8E-10	3380	3.3E-08		7.2E-10
WSW	-	2.8E-08		2.9E-10	-	2.8E-08		2.9E-10	-	2.8E-08		2.9E-10
W	-	3.3E-08		2.1E-10	-	3.3E-08		2.1E-10	-	3.3E-08		2.1E-10
WNW	-	3.3E-08		1.8E-10	-	3.3E-08		1.8E-10	-	3.3E-08		1.8E-10
NW	-	2.5E-08		2.3E-10	9650	2.0E-08		1.7E-10	-	2.5E-08		2.3E-10
NNW	-	3.1E-08		2.2E-10	-	3.1E-08		2.2E-10	-	3.1E-06		2.2E-10

NOTE:
- N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.
- (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE 1.3-12 B

Diffusion and Deposition Estimates for All Receptor Locations (cont'd)

Site: Oyster Creek   Release Point: Stack   Season: Grazing   Computer Run ID: OX-1 603 6

Direction	Distance to Nearest Residence (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Distance to Nearest Veg. Garden (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Nearest Site Boundary (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)
N	1710	2.3E-08	N/A	9.6E-10	12400	1.8E-08	N/A	1.2E-10	610	1.3E-08	N/A	2.8E-09
NNE	940	9.5E-09		1.2E-09	8850	2.2E-08		9.5E-11	731	7.0E-09		1.2E-09
NE	1170	2.7E-08		1.6E-09		1.4E-08		1.0E-10	957	3.0E-08		1.8E-09
ENE	1780	2.5E-08		1.9E-09		1.6E-08		1.6E-10	1500	2.4E-08		2.1E-09
E	1340	5.5E-08		4.8E-09		1.6E-08		2.3E-10	914	7.1E-08		7.3E-09
ESE	1040	9.3E-08		8.8E-09		1.7E-08		2.8E-10	914	1.1E-07		1.1E-08
SE	890	7.0E-08		7.3E-09		9.9E-09		1.7E-10	731	9.2E-08		8.2E-09
SSE	1150	4.9E-08		2.4E-09	2570	1.7E-08		7.3E-10	625	1.3E-07		3.8E-09
S	2380	1.5E-08		5.2E-10	7080	6.9E-09		5.5E-11	610	5.7E-08		2.4E-09
SSW	2350	1.9E-08		5.6E-10	4510, 7560	1.5E-08		7.1E-11	625	2.7E-08		1.5E-09
SW	2710	3.1E-08		1.1E-09		2.5E-08		1.8E-10	731	2.1E-08		1.1E-09
WSW	6250	3.2E-08		4.3E-10	9170	2.6E-08		2.4E-10	1000	2.2E-08		2.5E-09
W	7160	3.5E-08		2.5E-10		3.3E-08		2.1E-10	1000	2.7E-08		2.7E-09
WNW	5180	3.7E-08		3.6E-10		3.3E-08		1.8E-10	838	3.0E-08		2.6E-09
NW	7580	2.6E-08		2.5E-10	9650	2.0E-08		1.6E-10	646	8.4E-08		8.8E-09
NNW	2680	4.4E-08		1.4E-09		3.1E-08		2.2E-10	610	1.3E-08		3.3E-09

NOTE:
- N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.
- (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

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TABLE I.3-13 A

Diffusion and Deposition Estimates for All Receptor Locations

Site: Oyster Creek

Release Point: Radwaste Bldg. Vent
Assumed Ground Release

Season: Annual

Computer Run ID OX-4
603-3

Direction	Distance to Nearest Milk Cow (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^-2)	Distance to Nearest Meat Animal (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^-2)	Distance to Nearest Milk Goat (sec/m^3)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^-2)
N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NNE												
NE												
ENE												
E												
ESE												
SE												
SSE												
S												
SSW												
SW												
WSW												
W												
WNW												
NW												
NNW												

NOTE: • N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.

• (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE I - 15 B

Diffusion and Deposition Estimates for All Receptor Locations (cont'd)

Site: Oyster Creek — Release Point: Radwaste Bldg. Vent, Assumed Ground Release — Season: Annual — Computer Run ID: OX-4 603-3

Direction	Distance to Nearest Residence (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Distance to Nearest Veg. Garden (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Nearest Site Boundary (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})
N	1710	4.3E-06	3.4E-06	1.0E-08	N/A	N/A	N/A	N/A	610	2.3E-05	2.0E-05	1.2E-07
NNE	940	1.5E-05	2.3E-05	5.7E-08					731	2.2E-05	1.9E-05	9.0E-08
NE	1170	1.1E-05	9.6E-06	3.6E-08					957	1.6E-05	1.3E-05	4.9E-08
ENE	1780	8.0E-06	6.3E-06	2.5E-08					1500	1.1E-05	8.8E-06	3.8E-08
E	1340	1.3E-05	1.1E-05	5.6E-08					914	2.4E-05	2.0E-05	1.0E-07
ESE	1040	1.8E-05	1.6E-05	1.0E-07					914	2.3E-05	1.9E-05	1.2E-07
SE	890	2.7E-05	2.3E-05	1.0E-07					731	3.8E-05	3.2E-05	1.5E-07
SSE	1150	1.3E-05	1.1E-05	4.2E-08					625	3.3E-05	2.8E-05	1.1E-07
S	2380	1.6E-06	1.3E-06	4.1E-09					610	1.8E-05	1.5E-05	6.0E-08
SSW	2350	9.9E-07	7.8E-06	2.9E-09					625	1.0E-05	9.2E-06	3.7E-08
SW	2710	8.1E-07	6.2E-07	3.1E-09					731	1.0E-05	8.6E-06	4.7E-08
WSW	6250	1.4E-07	9.4E-07	7.1E-10					1000	7.2E-06	6.0E-06	4.5E-08
W	7160	1.3E-07	8.4E-08	5.0E-10					1000	8.0E-06	6.7E-06	4.7E-08
WNW	5180	1.6E-07	4.2E-07	6.2E-10					838	7.7E-06	6.5E-06	4.7E-08
NW	7580	1.0E-07	6.8E-07	3.4E-10					646	1.4E-05	1.2E-05	7.6E-08
NNW	2680	1.1E-06	8.5E-07	4.5E-09					610	1.8E-05	1.6E-05	9.2E-08

NOTE:
- N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.
- (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE 1.3-14 A

Diffusion and Deposition Estimates for All Receptor Locations

Site: Oyster Creek Release Point: Radwaste Bldg. Vent Assumed Ground Release Season: Grazing * Computer Run ID OX 3 603-4

Direction	Distance to Nearest Milk Cow (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Distance to Nearest Meat Animal (m)	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)	Distance to Nearest Milk Goat	X/Q (sec/m³)	Depleted X/Q (sec/m³)	D/Q (m⁻²)
N	-	1.3E-07	N/A	5.0E-10	-	1.3E-07	N/A	5.0E-10	-	1.3E-07	N/A	5.0E-10
NNE	7401, 10600	2.4E-07		6.2E-10	5790, 7400	3.7E-07		1.0E-09	6440, 7500	3.0E-07		8.0E-10
NE	-	2.0E-07		4.2E-10	-	2.0E-07		4.2E-10	-	2.0E-07		4.2E-10
ENE	-	2.6E-07		5.6E-10	-	2.6E-07		5.6E-10	-	2.6E-07		5.6E-10
E	-	3.0E-07		6.3E-10	-	3.0E-07		6.3E-10	-	3.0E-07		6.3E-10
ESE	-	2.7E-07		6.4E-10	-	2.7E-07		6.4E-10	-	2.7E-07		6.4E-10
SE	-	4.2E-07		7.5E-10	-	4.2E-07		7.5E-10	-	4.2E-07		7.5E-10
SSE	-	3.0E-07		3.8E-10	-	3.0E-07		3.8E-10	1200	1.3E-05		3.4E-08
S	-	1.2E-07		1.8E-10	2410	1.5E-06		3.4E-09	2570, 2770	1.2E-06		2.7E-09
SSW	9490	4.9E-08		7.6E-11	8210	6.2E-08		1.0E-10	15,300	2.3E-08		8.1E-11
SW	-	8.6E-08		2.1E-10	-	8.6E-08		2.1E-10	3380	4.3E-07		1.4E-09
WSW	-	7.9E-08		4.4E-10	-	7.9E-08		4.4E-10	-	7.9E-08		4.4E-10
W	-	1.1E-07		4.9E-10	-	1.1E-07		4.9E-10	-	1.1E-07		4.9E-10
WNW	-	8.5E-08		3.9E-10	-	8.5E-08		3.9E-10	-	8.5E-08		3.9E-10
NW	-	1.0E-07		3.7E-10	9650	7.7E-08		2.5E-10	-	1.0E-07		3.7E-10
NNW	-	1.4E-07		4.4E-10	-	1.4E-07		4.4E-10	8000	1.4E-07		4.4E-10

NOTE: • N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.

• (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

TABLE 1.3-14 B

Diffusion and Deposition Estimates for All Receptor Locations (cont'd)

Site: Oyster Creek | Release Point: Radwaste Bldg. Vent | Season: Grazing | Computer Run ID: OX-3 603-4

Assumed Ground Release

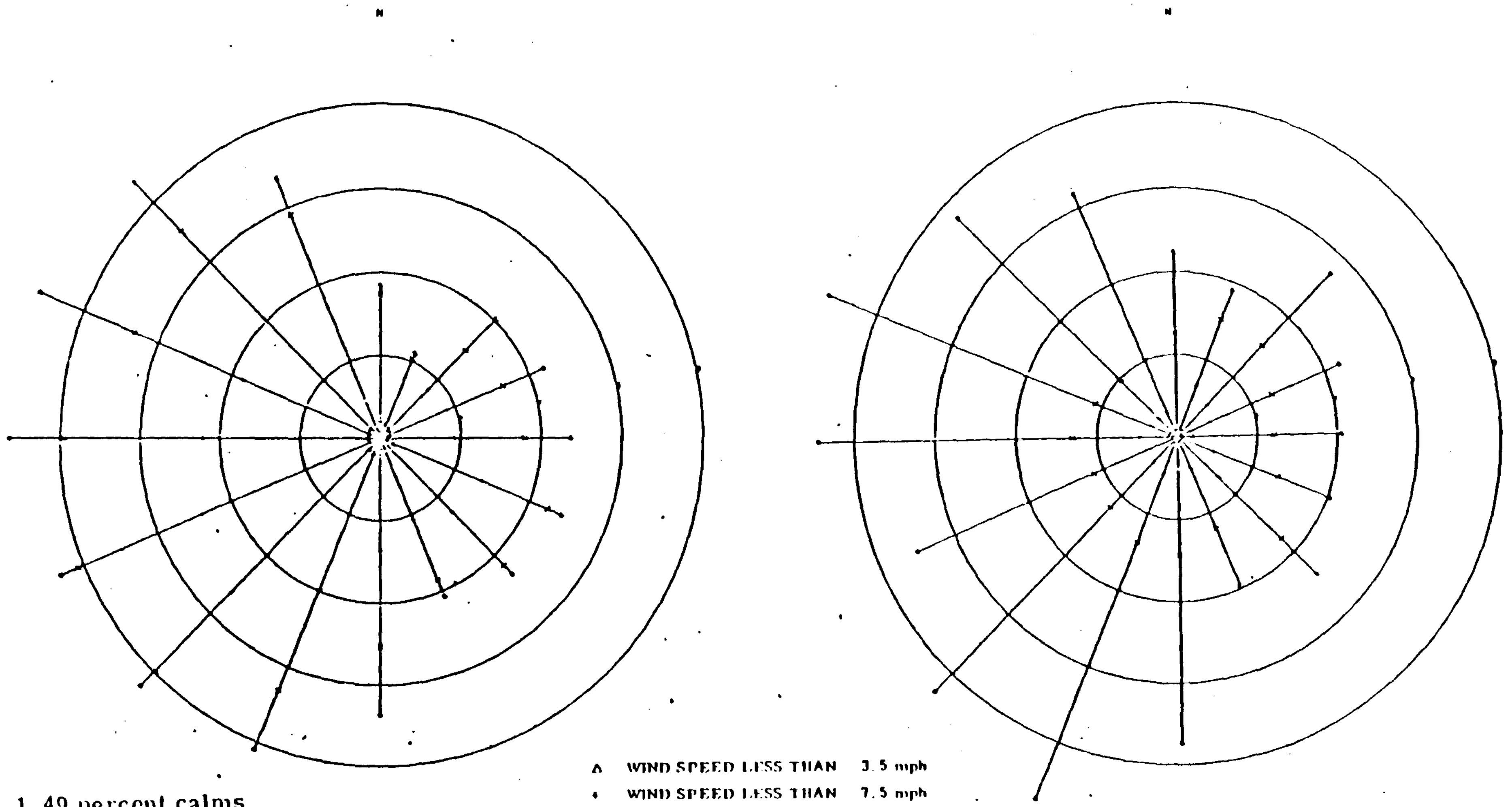
Direction	Distance to Nearest Residence (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Distance to Nearest Veg. Garden (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})	Nearest Site Boundary (m)	X/Q (sec/m^3)	Depleted X/Q (sec/m^3)	D/Q (m^{-2})
N	1710	4.2E-06	N/A	2.4E-08	12,400	6.4E-08	N/A	2.2E-10	610	2.3E-05	N/A	1.4E-07
NNE	940	1.6E-05		6.7E-08	8850	1.8E-07		4.3E-10	731	2.4E-05		1.0E-07
NE	1170	1.1E-05		4.0E-08	-	2.0E-07		4.2E-10	957	1.4E-05		5.3E-08
ENE	1780	6.7E-06		2.5E-08	-	2.6E-07		5.6E-10	1500	9.1E-06		3.5E-08
E	1340	1.2E-05		4.7E-08	-	3.0E-07		6.3E-10	914	2.2E-05		8.2E-08
ESE	1040	1.6E-05		6.9E-08	-	2.7E-07		6.4E-10	914	2.0E-05		8.4E-08
SE	890	3.0E-05		1.0E-07	-	4.2E-07		7.5E-10	731	4.1E-05		1.4E-07
SSE	1150	1.4E-05		3.6E-08	2570	3.0E-06		5.8E-09	625	3.5E-05		1.0E-07
S	2380	1.5E-06		3.4E-09	7080	1.4E-07		2.2E-10	610	1.6E-05		5.0E-08
SSW	2350	8.9E-07		2.1E-09	4510, 7560	1.7E-07		3.3E-10	625	9.3E-06		2.9E-08
SW	2710	8.2E-07		2.8E-09	-	8.6E-08		2.1E-10	731	1.0E-05		4.1E-08
WSW	6250	1.2E-07		7.1E-10	9170	6.3E-08		3.4E-10	1000	6.1E-06		5.1E-08
W	7160	1.3E-07		5.9E-10	-	1.1E-07		4.9E-10	1000	8.0E-06		5.6E-08
WNW	5180	1.8E-07		9.3E-10	-	8.5E-08		3.9E-10	838	8.3E-06		5.9E-08
NW	7580	1.1E-07		4.1E-10	9650	7.8E-08		2.6E-10	646	1.5E-05		1.0E-07
NNW	2680	1.4E-06		6.0E-09	-	1.4E-07		4.4E-10	610	2.2E-05		1.2E-07

NOTE:
- N/A indicates that diffusion information for this run was not used in dose calculations for receptors in this column.
- (-) indicates receptor distance is greater than 8000m, diffusion values given are for 8000m.

Figure 1. 1-1

Oyster Creek Wind Roses

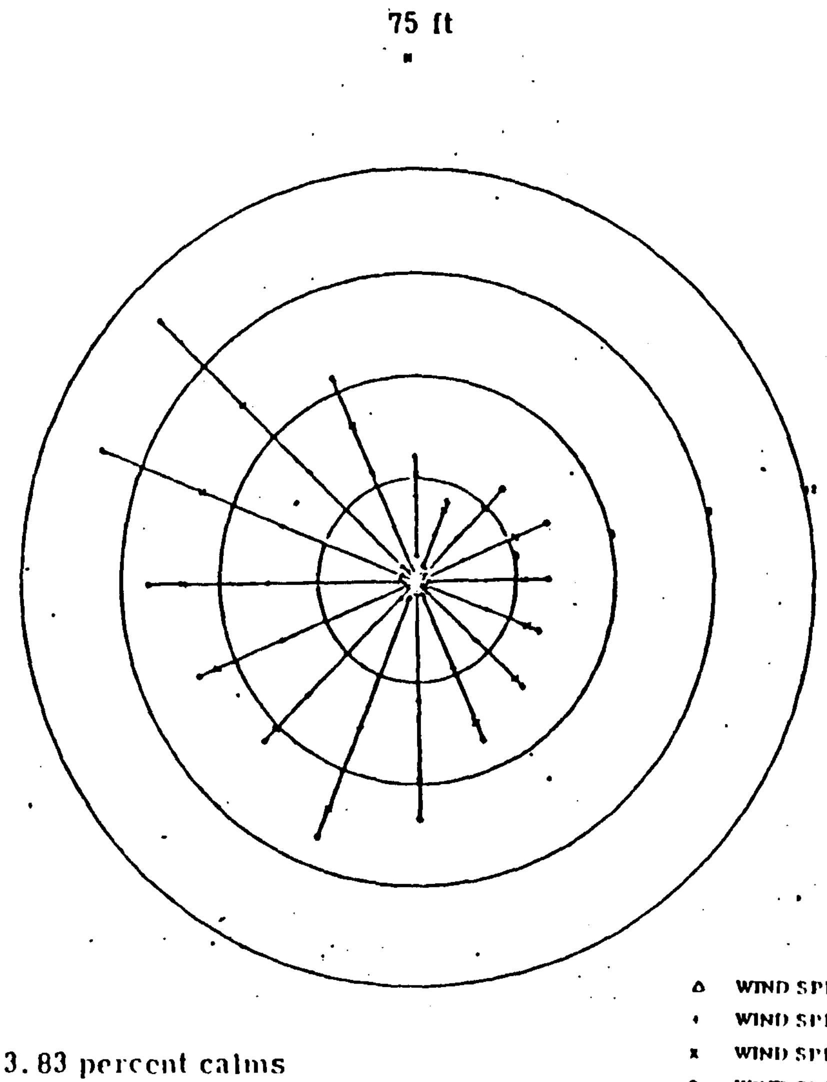
1966

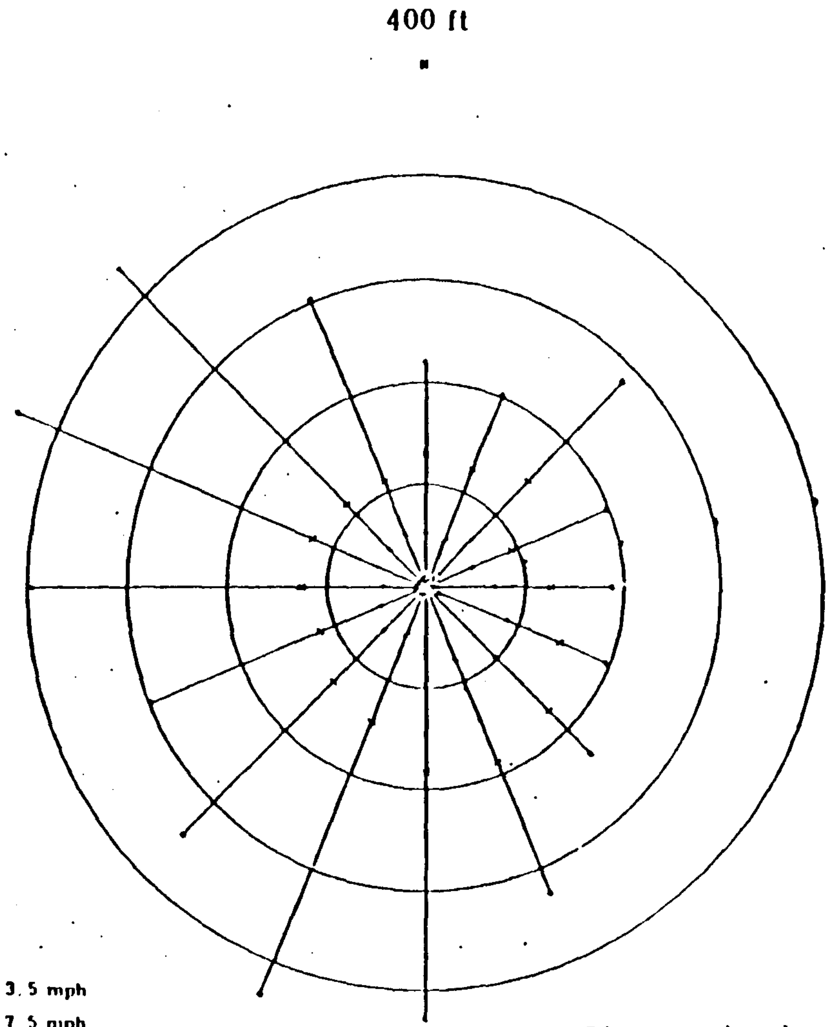


1.49 percent calms

.36 percent calms

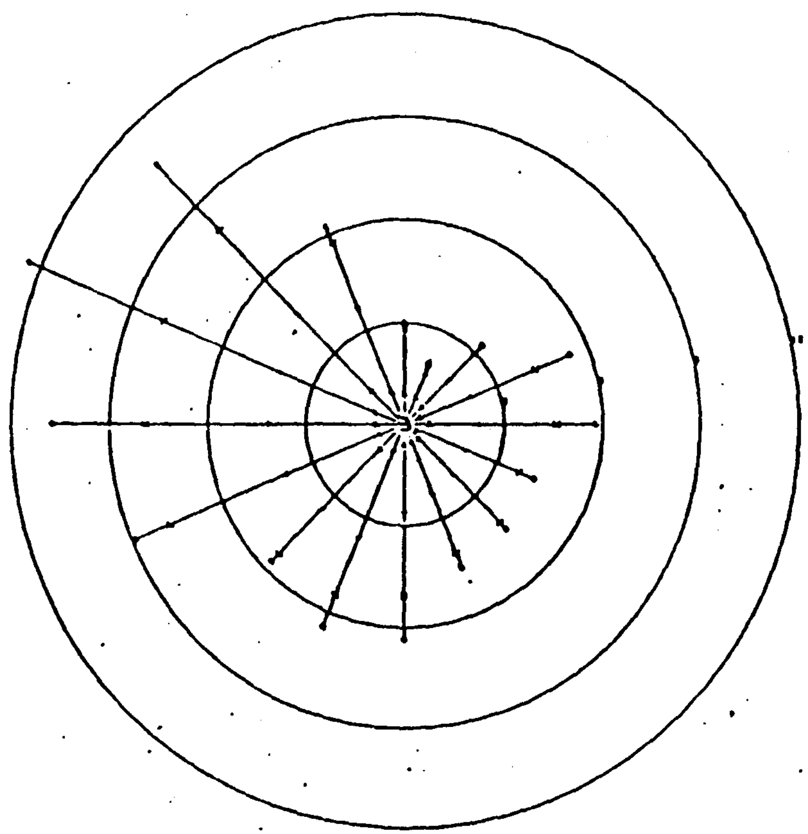
Figure 1. 1-2
Oyster Creek Wind Roses
1967



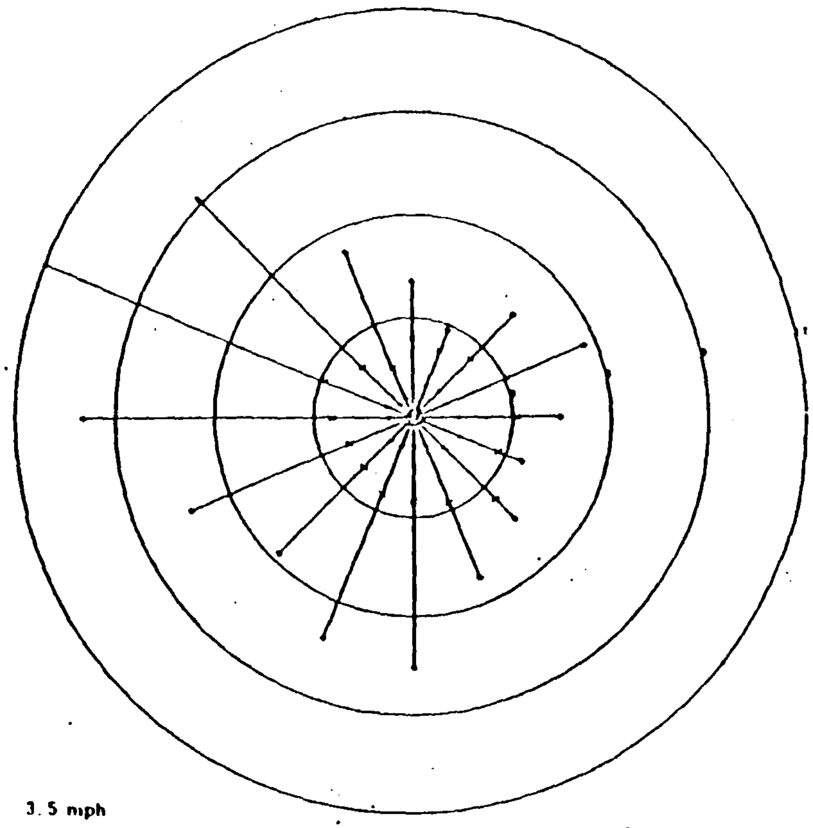


△ WIND SPEED LESS THAN 3. 5 mph
+ WIND SPEED LESS THAN 7. 5 mph
x WIND SPEED LESS THAN 12. 5 mph
◇ WIND SPEED LESS THAN 999. 0 mph

Figure 1. 1-
Oyster Creek Wind Roses
1968



1.7 percent calms

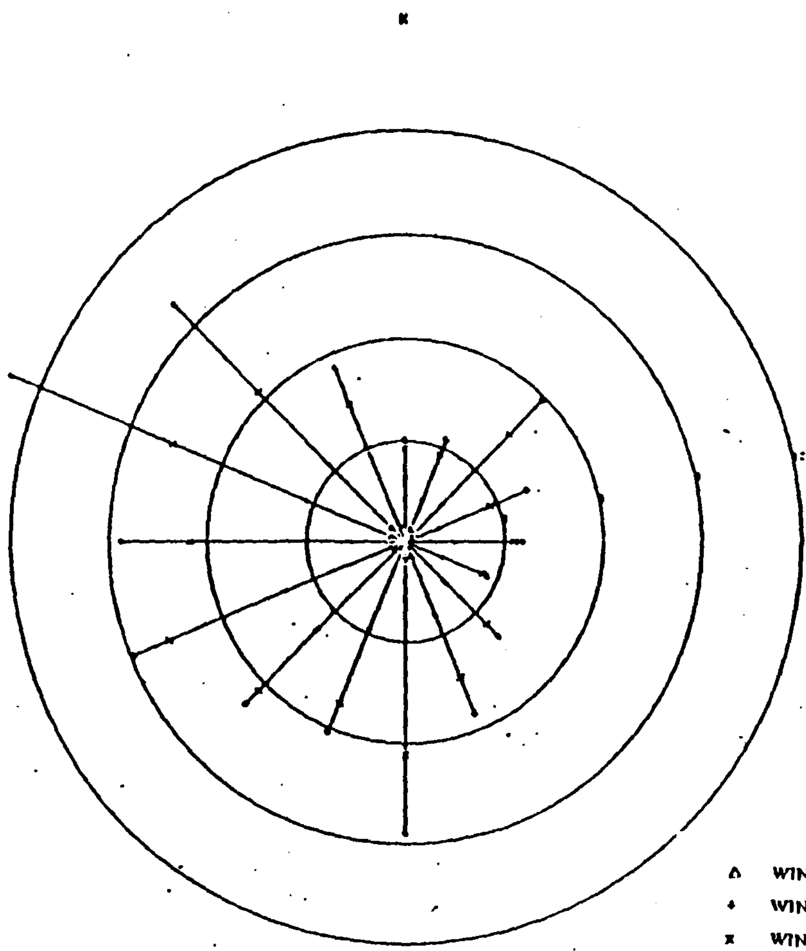


1.52 percent calms

Δ WIND SPEED LESS THAN 3.5 mph
+ WIND SPEED LESS THAN 7.5 mph
x WIND SPEED LESS THAN 12.5 mph
○ WIND SPEED LESS THAN 999.0 mph

Figure 1. 1-4
Oyster Creek Wind Roses
1969

75 ft



. 6 percent calms

Δ WIND SPEED LESS THAN 3.5 mph
+ WIND SPEED LESS THAN 7.5 mph
x WIND SPEED LESS THAN 12.5 mph
O WIND SPEED LESS THAN 999.0 mph

Figure 1.1
Oyster Creek Wind Roses
1970

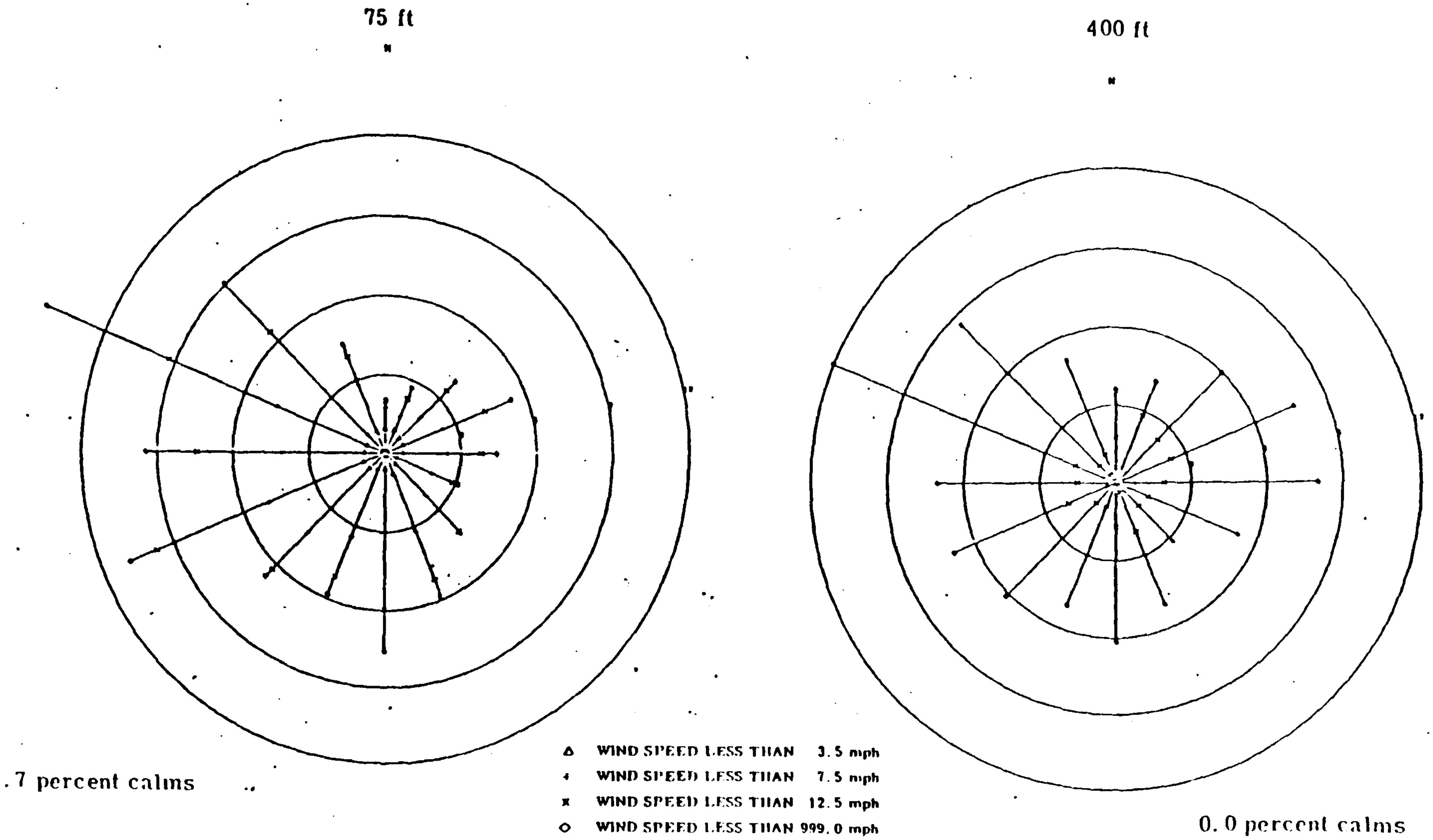


Figure 1. 1-6
Oyster Creek Wind Roses
1971

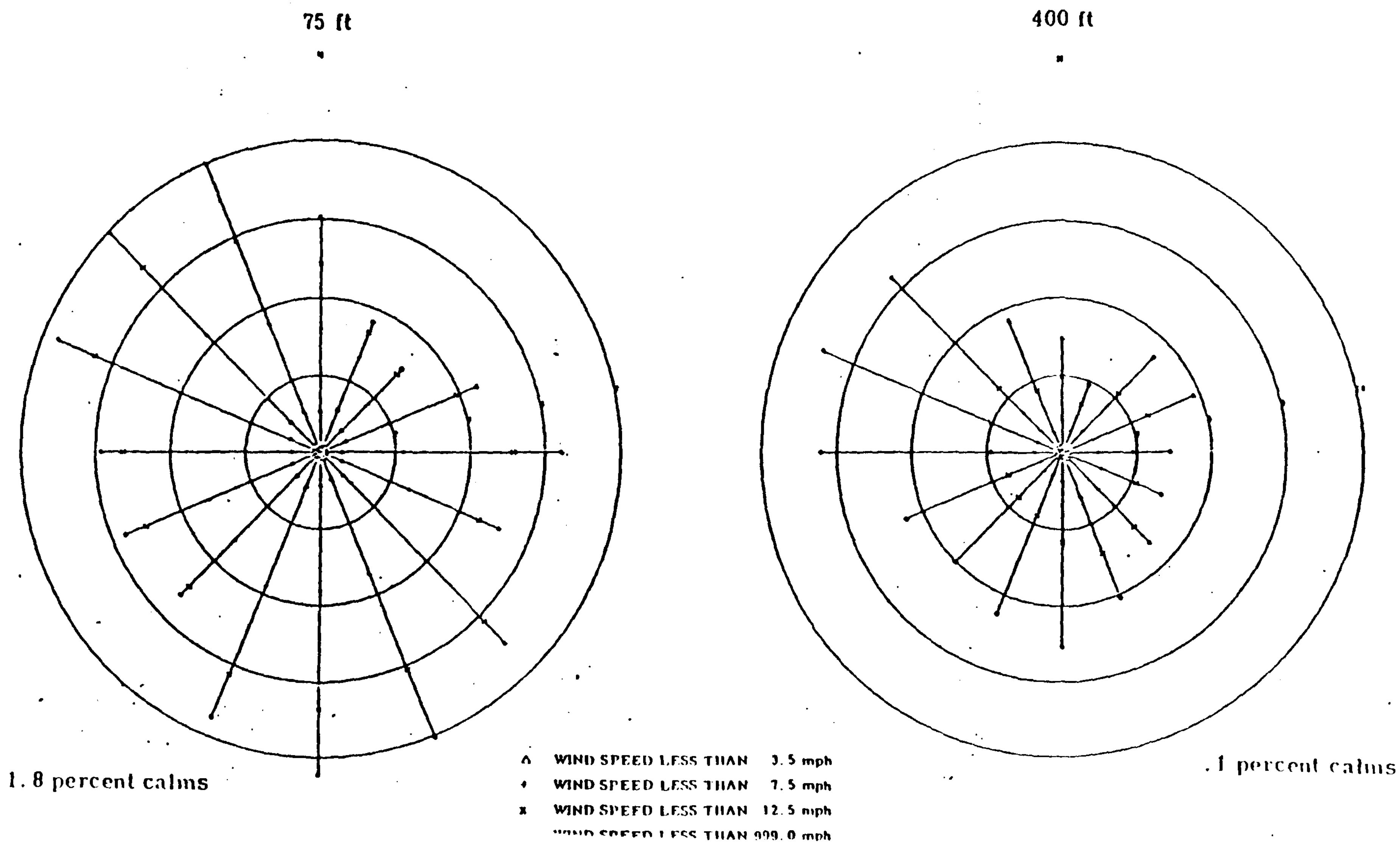


Figure 1.
Oyster Creek Wind Roses
1972

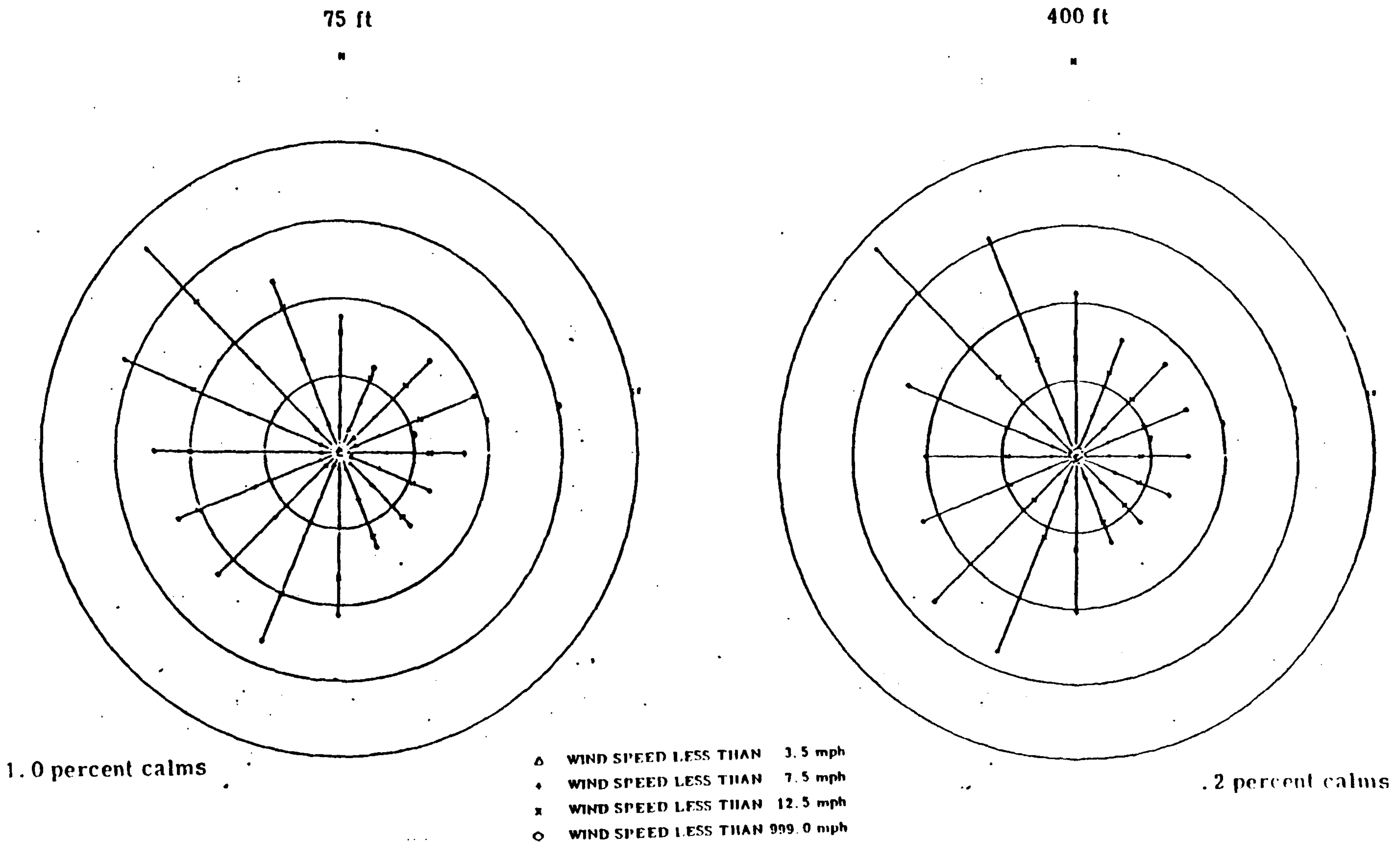
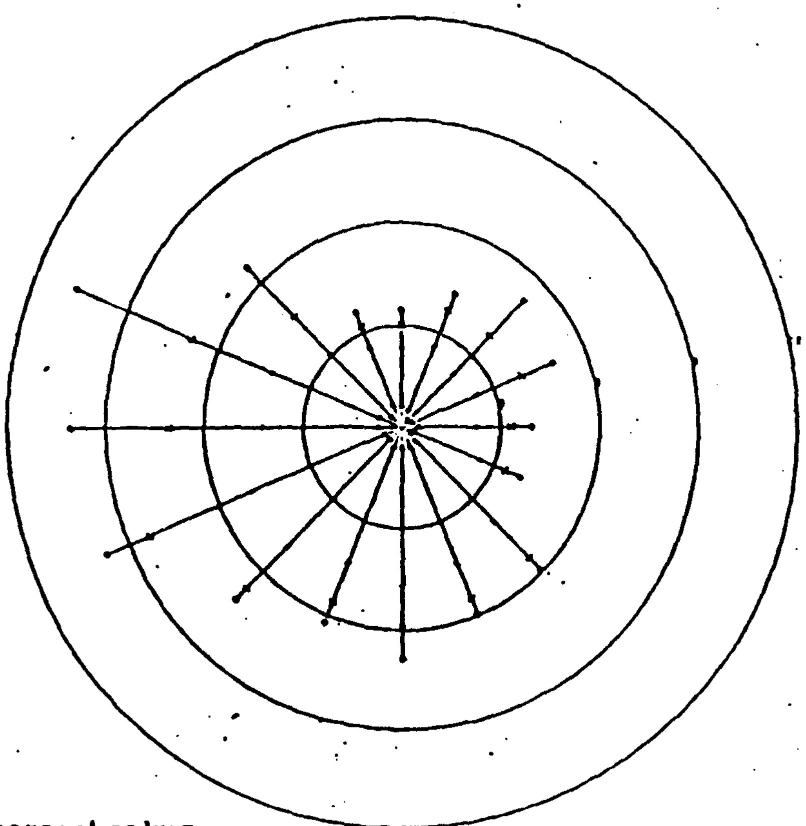
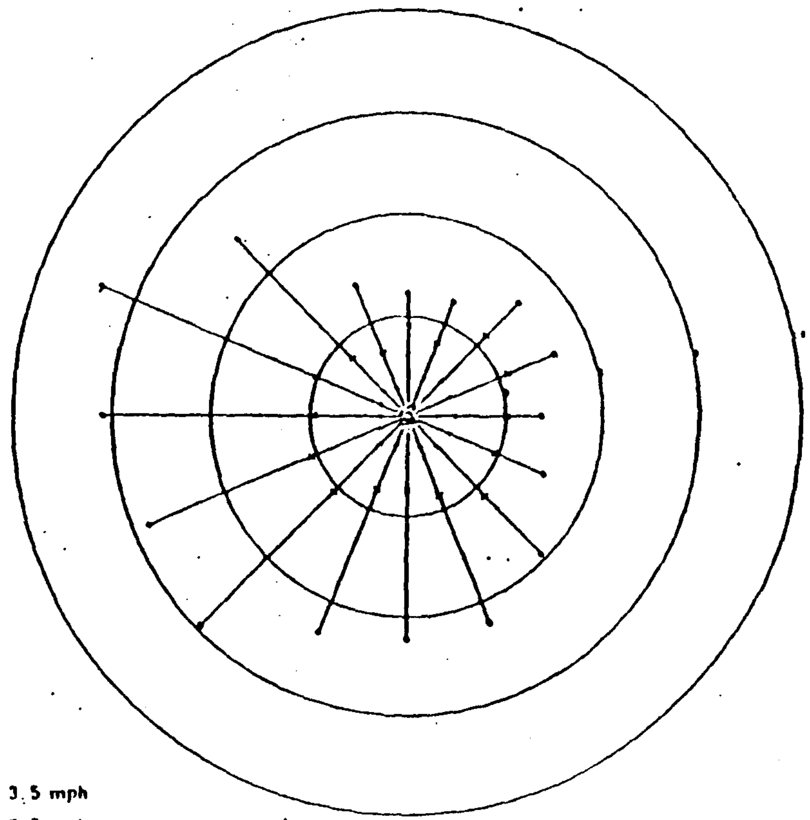


Figure 1.1-8
Oyster Creek Wind Roses
1973

75 ft



400 ft



1.49 percent calms

.2 percent calms

Δ WIND SPEED LESS THAN 3.5 mph
♦ WIND SPEED LESS THAN 7.5 mph
x WIND SPEED LESS THAN 12.5 mph
WIND SPEED LESS THAN 999.0 mph

Figure 9
Oyster Creek Wind Roses
1974

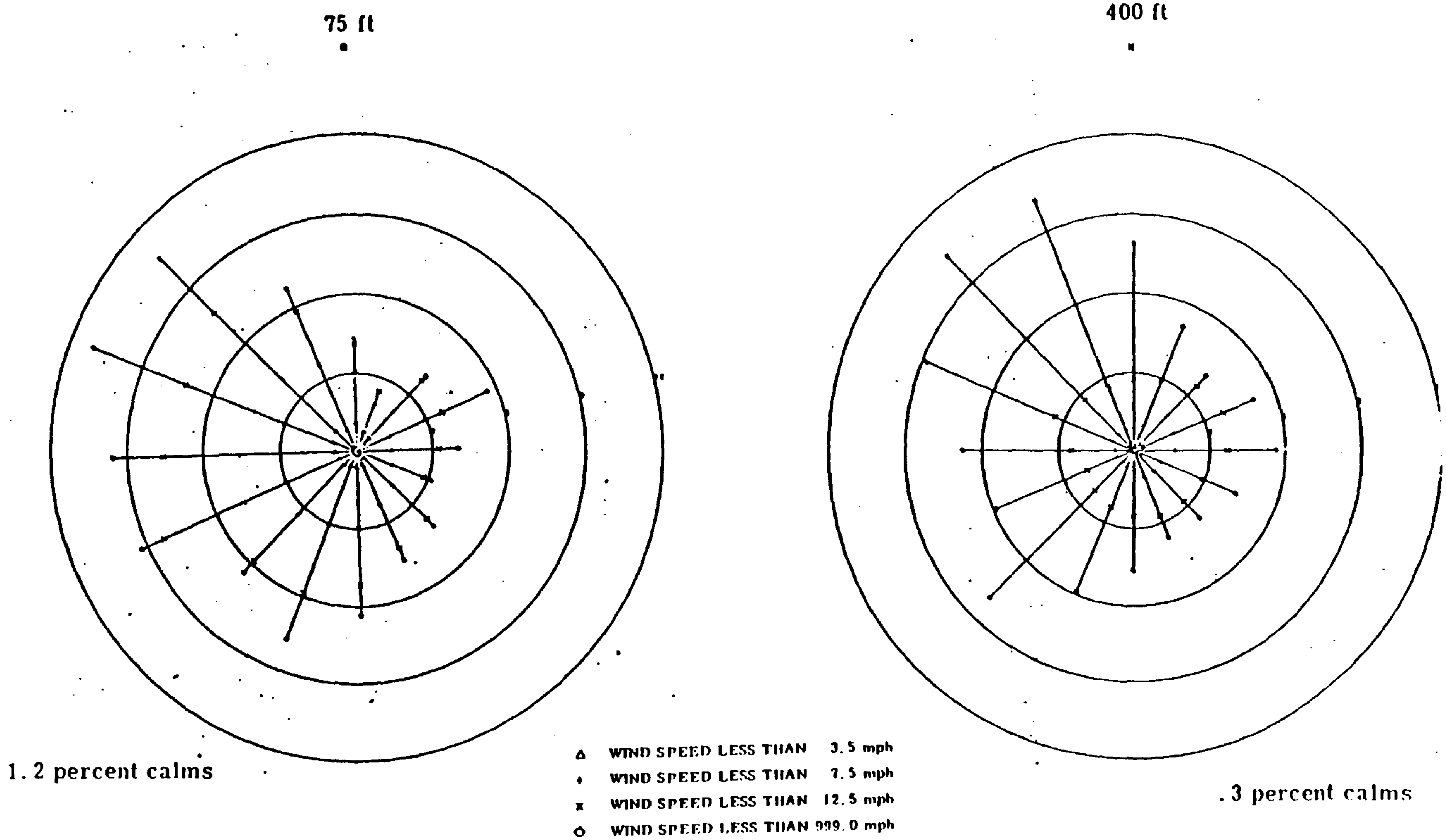
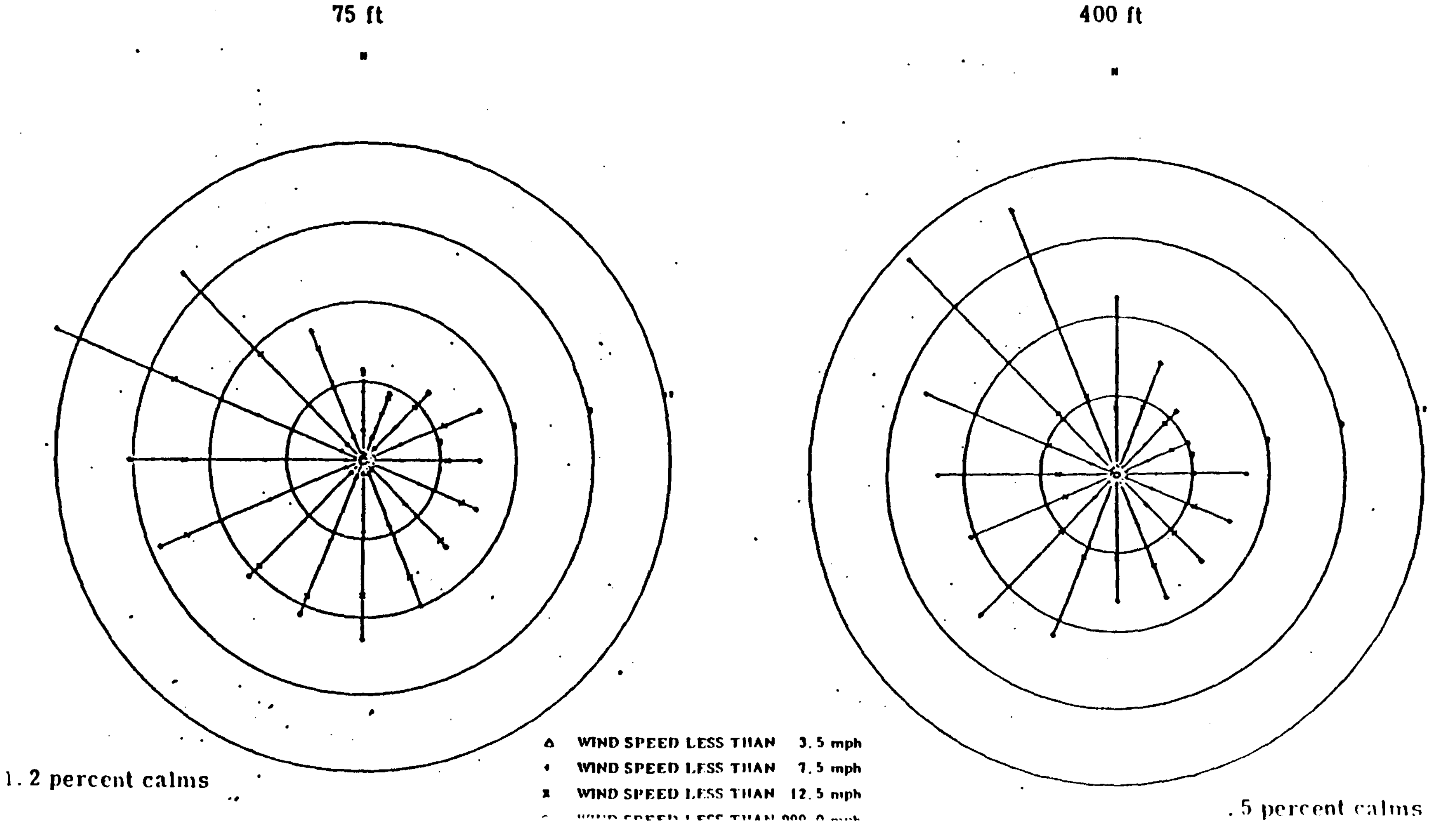


Figure 1. 1-10
Oyster Creek Wind Roses
1975



APPENDIX 2.4A

FLOOD LEVEL STUDIES

10812 ADMIRALS WAY
POTOMAC, MARYLAND 20854

MAILING ADDRESS
P O BOX 1246
ROCKVILLE, MARYLAND 20850

RICHARD O. EATON, P. E.
CONSULTING ENGINEER

REFER TO: 2700-03
RPG 4/28

April 27, 1970

Subject:
W.O. 2700-03
Jersey Central Power & Light Company
Forked River Nuclear Station-Unit 1
Report on Probable Maximum Hurricane Flood Level

Mr. R. P. Giloth, Project Manager
Burns and Roe, Inc.
700 Kinderkamack Road
Oradell, New Jersey 07649

Dear Mr. Giloth:

In response to your letter April 16, 1970, we have elected to completely rewrite our earlier report on the above subject. Because of our now rather long experience in debating this general subject with AEC Consultants we have fallen into the habit of analyzing and writing more for their perusal than that of our clients who are perhaps not as likely to be familiar either with terminology or the basis of reasoning with which the numbers we propose are supported.

We have done our best to rectify this in the new version of our report. If anything remains unclear please inform me and we will do what we can to provide additional clarification.

It will doubtless be evident to you, as well as to other reviewers, that a substantial factor in the validity of our analysis is the extent of overtopping which will occur over the barrier beach at the maximum water stage on the open coast. While the report by my Associate could be interpreted to imply that our reasoning is based upon experience along the Florida coasts (both Atlantic and Gulf), I must explain that our reasoning applies also to careful analyses which I have made over many years of storm overtopping of the barrier beaches of the Carolinas, Virginia, Maryland, New Jersey and New York.

In all of my experience in the studies which could be made on the basis of data available I have reached a firm conclusion that the overtopping which occurs at the extreme height of ocean level, while it creates small fissures through the beach, does not produce major breaches. These occur when the transit of the storm produces a rapid lowering of ocean sea level and impounded bay waters, seeking exit under substantial head, scour new channels through the beach. This is amply born out by such data as have been obtained after storms and by elder fishermen on the Carolina Banks who are quite astute observers of coastal phenomena.

What I have said above is simply in support of our method of analysis of extreme tidal flooding conditions. I believe that we have been sound and properly conservative and we would be pleased to defend the numbers we have presented if need should arise.

Also enclosed are instructions for correcting exhibits previously submitted which your draftsmen will find quite easy to follow. We are submitting a revised version of the 1/250 year event which will presumably be used for non-critical plant elements and for construction planning. We regret this but it appeared to be the simplest procedure.

Sincerely yours,

Richard O. Eaton

Richard O. Eaton, P.E.
Consulting Engineer

ROE:w
Encls. Revised Report-TEH-4/25/70
Exhibits Instructions
Hurricane Tide Estimate;1/250 year event

cc Mr.J.V.Neely,JCP&L w/out enclosures

FOREWORD

DEFINITION OF A PROBABLE MAXIMUM HURRICANE

This report postulates an occurrence of a probable maximum hurricane at the Forked River Unit 1 Nuclear Power Plant and stipulates a set of conditions associated with its occurrence which, in combination, is considered to be critical and will result in a probable maximum hurricane surge elevation. The definition of that storm, as contained in Appendix A - Glossary of Terms, of the U.S. Army Coastal Engineering Research Center Technical Report No. 4, is as follows:

> PROBABLE MAXIMUM HURRICANE - "A hypo-hurricane that might result from the most severe combination of hurricane parameters that is considered reasonably possible in the region involved, if the hurricane should approach the point under study along a critical path and at optimum rate of movement."

Each of the basic parameters defining the characteristics of a probable maximum hurricane, and its derivation is contained in U.S. Department of Commerce, ESSA, Weather Bureau, Memorandum HUR 7-97A. A definition and/or description of each of those basic parameters, as contained in those reports is as follows:

CENTRAL PRESSURE INDEX (CPI) - The central pressure index (p_o) is the minimum surface pressure in the eye (approximate center) of a particular hurricane. For the probable maximum hurricane the CPI was determined on a probability basis to represent a minimum pressure in each of various zones along the Atlantic and Gulf coasts

having a return frequency of near 1 in 1,000 years.

PERIPHERAL PRESSURE (p_n) - The peripheral pressure in a probable maximum hurricane is the surface pressure at the outer limits of the hurricane where the hurricane circulation ends. It is, in effect, a "real" pressure normally found in the periphery of a hurricane where the cyclonic isobars give way to straight or anti-cyclonic isobars.

ASYMPTOTIC PRESSURE (p_m) - The asymptotic pressure of a probable maximum hurricane is a parameter for defining the intensity of the pressure gradient and wind in the inner portion of the storm and, as such, has no real physical counterpart in the pressure field of the storm. The asymptotic pressure is a theoretical pressure at "infinite distance" and can exceed the peripheral pressure by a considerable margin.

RADIUS OF MAXIMUM WINDS (R) - The radius of maximum winds in all hurricanes is the distance from the eye of the storm, where surface wind velocities are zero, to the locus of maximum surface wind velocities.

FORWARD SPEED (T) - The forward speed of the hurricane is the rate of forward movement of the eye (center) usually averaged over several hours.

MAXIMUM WIND (V_x) - The absolute highest surface wind speed in the zone of maximum winds occurring at a 30 foot level above the surface of the water and averaged over a 10-minute period generally defines the term V_x. Its derivation is mathematical based on the equation $V_x = 0.865 \quad V_{gx} + 0.5T$, where V_{gx} is the maximum gradient wind in

the storm as defined by the pressure gradient and other meteorological considerations.

ISOVEL PATTERN - The isovel or wind pattern in a hurricane is a graphical representation of the 30-foot overwater wind speeds at a particular instant. Wind directions are indicated thereon by arrows or deflection angles. Standard procedures are used for deriving an isovel pattern, as contained in HUR 7-97.

DETERMINATION OF P.M.H. FLOOD HEIGHT
FOR FORKED RIVER UNIT 1 NUCLEAR POWER PLANT
BARNEGAT BAY, NEW JERSEY

HISTORIC STORMS AND TIDES

Storm Occurrence and Characteristics

Historic accounts of early hurricanes affecting the New Jersey-New York area date back to the 17th Century. Early chronologies of tidal flooding from such extreme events have been reported in References 1 and 2 in some detail. From the latter report it is noted that at least 80 tropical hurricanes or their remnants have affected the coastal area of New Jersey in the 75 year period since 1889. In recent years, some of the more severe storms to have passed over or near the area, whose paths are shown in Reference 3, have been hurricanes "Hazel" in October, 1954, "Connie" and "Diane" in August, 1955, and "Donna" in September 1960. The "Great Atlantic Hurricane" of September, 1944 passed directly over the New Jersey shoreline in its northward movement. The relative storm frequency for the area, noted in Table 1 of Reference 4, is roughly one occurrence every 1.8 years. In general, record hurricanes passing over the general study area have had central pressures of from 27.8 to 28.5 inches and peak wind speeds over the ocean approaching 100 mph. The forward speed of the more severe hurricanes, following recurvature in the middle latitudes, has ranged from 15 to 40 knots. Northeast storms also affect the area, the most severe

in recent years has been the March, 1962 Northeaster which lasted for several days and resulted in a recorded high tide of 7.20 ft. MSL at Atlantic City, New Jersey. Numerous accounts of that storm, its tides, and the resulting beach erosion and tidal damage have been reported.

TIDES AND STORM SURGES

Normal Tides in Barnegat Bay are semidiurnal having two highs and lows roughly every 23½ hours, with a higher high and lower low as a daily occurrence. Information contained in Reference 5 shows normal and spring tide ranges at Barnegat Inlet along the oceanfront and at various locations in Barnegat Bay. Data for Barnegat Inlet, Oyster Creek Channel (off Sedge 1) and for Waretown (1.5 miles south of Oyster Creek mouth) are given below:

	Mean Range (ft.)	Spring Range (ft.)	MTL
Barnegat Inlet	3.1	3.8	1.5
Oyster Creek Channel	0.6	0.7	0.3
Waretown	0.6	0.7	0.3

The time difference between the occurrence of high water at Sandy Hook and Waretown gage is +2 hours and 33 minutes; between low water occurrence it is +2 hours and 49 minutes.

Storm Surges and Extreme High Tides. The March 1962 Northeaster generated the highest tide ever recorded along the beachfront of Barnegat Bay, 7+ ft. MSL, higher than that observed during passage of the more severe hurricanes of record. Recorded tide data for Barnegat Inlet gage, or gages in Barnegat Bay, were not available to the writer, however, some indication of the peak tides observed

at Atlantic City, New Jersey can be found in References 3 and 4. In general, it appears that surges on the order of 2 to 3 feet have been about the highest observed at that station. This would be correct inasmuch as most of the major hurricanes have passed inland of the New Jersey area, have lost intensity rapidly and have not occurred on the most critical path for tidal surge generation.

PROBABLE MAXIMUM HURRICANE

General

Detailed analyses have been made, as described below, of the height of flooding to be expected at the Forked River Unit 1 Nuclear Power Plant site during an occurrence of the Probable Maximum Hurricane. Basic parameters defining that hurricane were selected from Reference 6, ESSA Memorandum HUR 7-97. The effect of alternate forward speeds of storm movement on the generation and magnitude of peak hurricane tide in the ocean at shore was evaluated; the occurrence of that storm was on the most critical path for tide generation and with concurrence of peak hurricane tide and spring astronomical tide; procedures used for hourly hurricane surge computations were those given in CERC Technical Report No 4, Reference 7; estimates of tidal overflow of the beach island and tidal inflow to Barnegat Bay were made to establish the resultant bay elevation; the effect of additional wind setup in the bay was calculated; simultaneous occurrence of rainfall and runoff associated with the storm was evaluated as to their effects on flood level at the plant site; a routing of tidal inflows into the plant intake and discharge channels was included and, an

estimate made of associated wave action to be expected in those channels. The results of those studies are given below.

PROBABLE MAXIMUM HURRICANE PARAMETERS

Selection of the basic parameters defining the probable maximum hurricane for the Forked River area was made from Table 1 of ESSA Memorandum HUR 7-97. Those parameters are as follows:

a. C.P.I. (p_o). The latitude of the plant site is approximately 39° and 49' N.; that at the point of entry (landfall) selected for this hurricane is 39° 10' N. Interpolation of C.P.I. values for latitudes 39° and 40° from Table 1 of the reference memorandum results in a C.P.I. value of 27.10 inches.

b. Radius of maximum winds (R). Table 1 of ref. Memo. HUR 7-97 lists three possible radii for each C.P.I. ..... RS, RM, and RL. For latitude 39° N. the values given range from 7 to 39 nautical miles. A moderately large-radius storm is required in order to have sufficient horizontal extent of peak hurricane tide along the coastal reach opposite Barnegat Bay. A storm radius R of 30 nautical miles (34.50 statute miles) was therefore selected as being reasonable for that purpose.

c. Asymptotic pressure (p_m). Clarification and definition of the asymptotic pressure associated with the P.M.H., as derived on Figure 6 of ref. Memo. HUR 7-97, was contained in a memorandum to the Corps of Engineers dated December 3, 1968, Reference 8. In accordance with that memorandum and ref. Figure 6, the value of the asymptotic pressure p_m for the P.M.H. at latitude 39° is

30.70 inches. A peripheral pressure, pn, of 30.08 inches was selected to define the P.M.H. pressure at the outer limits of the storm where hurricane circulation ends. Use of that pressure and the C.P.I. value of 27.10 inches was used to define the maximum pressure effect at or near the center of the storm.

d. Maximum wind speed - V_x. Table 1 of Memo. HUR 7-97 shows a maximum gradient wind speed of 134 mph and a maximum 10-minute average 30 ft.-overwater wind speed on the order of 120 mph. Those values are for a stationary storm; for a moving storm half the forward speed must be added to the latter value to obtain the maximum wind at radius R.

e. Forward speed of the storm - T. The speed of translation affects the shape and duration of the resulting storm surge hydrograph at the coast, as well as the maximum intensity of the storm and the peak tide height. For fast moving storms a slightly higher surge height will result but for a much briefer duration of time. Also, a rapid shift in wind direction can occur during passage of such storms which, in turn, can affect the tide buildup potential at a given location. An evaluation of the importance of forward speed with respect to tidal flood conditions at the plant site was therefore necessary. Table 1 of Memo. HUR 7-97 lists alternate forward speeds possible of use, ST, MT, and HT. Values of 11, 20, and 49 knots were selected; conditions related to the use of each of those speeds were evaluated for applicability and maximum effect in the

analysis to determine the critical hurricane speed:surge relationship.

f. Path. In order to generate critical tides along the open coast the path of the hurricane was selected so that the wind direction of the maximum isovel would be oriented normal to the offshore depth contours and to shore. The storm would approach the New Jersey coastline from the southeast on an azimuth of about 135° from North. The storm center would pass inland some 36 statute miles south of Forked River, as shown on Exhibit 1.

g. Parametric relationships describing the stationary storm in terms of a wind speed profile, the pressure profile within the area of hurricane circulation, the probable pressure effect profile, and basic data used in constructing isovel patterns for the hurricane were derived using a computer program developed and employed by personnel of the Jacksonville District, Corps of Engineers, and run on a G.E. 415 Computer. The output of that program for the three alternate speeds of translation is given on Exhibit 2 through 6. Methods used conform to those presented in Memo. HUR 7-97. Graphical presentation of the overwater wind profile for the stationary storm can be seen on Exhibit 7; the pressure and pressure effect profiles are shown on Exhibit 8.

HURRICANE TIDE COMPUTATIONS

General. The problem of accurately predicting the height of tide to be expected at the plant site can be divided into two basic areas of

concern:

1. Those factors which affect the peak open-coast surge, and
2. Those which affect the peak bay tide elevation at the plant site.

With regard to the former, they can best be described as:

a. Storm intensity.
b. Forward speed.
c. Path.
d. Offshore depth configuration.
e. Coincidence with normal high (or spring) tide.
f. Added wave and pressure effects.

Evaluation of those factors can be accomplished with a high degree of accuracy. Factors affecting bay tide elevation are primarily a function of the amount and duration of tidal overflow of the beach island, of tidal inflow through the inlet contributing to the main water level of the bay, hurricane rainfall and runoff, and the extent of wind setup across the bay to include any local wave effects. The occurrence and magnitude of wind setup across the bay is also a function of the available fetch length, plus the requirement that fairly unidirectional winds are maintained over the fetch to permit a steady state setup condition to occur on the mainland shore. In evaluating those factors consideration must be given to the following:

a. The shape of the coastal wind-tide hydrograph inasmuch as it affects the duration of wave and tide attack.

b. The peak value of the hurricane surge, with respect to the beach island profile.

c. The configuration and topography of the coastal beach island with respect to height and lateral extent of the dune, the presence or absence of urban development, roads, and the like which would obstruct erosion and tidal overflow.

d. The area of Barnegat Inlet and the extent and degree of subsequent erosion during tidal inflow.

e. The creation of secondary small inlets resulting from coastal breakthrough of the low areas along the beach island.

While some of the above noted factors are predictable and subject to accurate definition and resolution, a highly accurate determination of others would require detailed field study with possible corroborative model tests. Perhaps the most critical factor affecting and, to a large extent, controlling the predicted peak hurricane tide elevation at the plant site is the condition of dune erosion with time during hurricane passage and the consequent extent and volume of tidal overflow. Recognition must also be given to the probability of physical changes that will most assuredly occur along the beach island, not only with respect to development, but also with regard to the consequences of those changes on any basic assumptions made in this analysis. Those assumptions must necessarily be "reasonable" in that they should reflect the extent and scope of available knowledge, particularly with regard to beach erosion as observed in past events of this nature.

<u>Procedures</u>. The following is a discussion and description of the

procedures used in this analysis with regard to the P.M.H. tide computations.

a. Hurricane tide computations. The procedures used to compute the peak surge and shape of the surge hydrograph at the open coast are those described in CERC Technical Report No.4. Surge heights were determined at hourly intervals using Formula 1-65 from that report. Offshore depth profiles were obtained and averaged from U.S.C.& G.S. Map No. 1108. The critical fetches for tide generation were selected and generally paralleled the path of approach of the storm in the area of highest winds. Computations were made for both slow and high speeds of translation to define the extreme range in peak tide and the shape of the tide hydrograph along the open coast for each event. Changes in pressure effect were added to the offshore depth with change in fetch length. One foot of wave effect was added at shore to the hourly surge height. The resulting hydrographs are shown on Exhibit 9 together with the spring tide hydrographs for ocean and bay. Peak values are 21.56 ft. MLW (20.06 ft. MSL) for the high speed storm and 18.25 ft. MLW (16.75 ft. MSL) for the slow speed storm. The difference in peak tide heights is 3.31 feet. However, the difference in the shape of the resulting hydrographs is even more significant as is indicated by the tide-duration curves shown on Exhibit 10. As can be seen from that exhibit not only is the duration of tide for the slow moving storm, at all elevations except above 18 feet MLW, approximately two to three times that of the high

speed storm but also the height of tide exceeds that of the high speed storm by as much as 10 feet for nearly two hours. Of even greater importance however is the fact that a rapid shift in wind direction will occur in the high speed storm immediately following its landfall. Wind directions will shift from an easterly component across the bay at the time of peak ocean tide to southerly, thus precluding sufficient time for a steady-state surge condition to be fully developed across the bay. It is therefore concluded that a slow moving storm with a forward speed on the order of 13 to possibly 20 mph generating a peak surge height of from 18 to 19+ feet MLW at the open coast represents the most critical P.M.H. condition for the area.

b. Tidal overflow and inflow computations. (1) Basic Data. Available U.S.G.S. quad sheets for the area were used to plot a beach profile for the reach between Manahawkin Bridge on the south and Thomas Mathis Bridge on the north. Those were considered to be the limits of the bay (and beach) area affected by tidal overflow and inflow. The total reach length is 22 statute miles. Dune elevation was plotted against accumulated distance, or length, to obtain basic relationship for use in determining tidal overflow. Curves were established for the reaches between Manahawkin Bridge and the south side of the inlet, from the north side of the inlet to Thomas Mathis Bridge and for the total reach encompassed by those two reaches. Those relations are shown on Exhibit 11. Cross sections of the beach

island were also plotted by 1-mile average reaches to obtain an indication of the width of beach area at certain elevations for use in evaluation of the probable rate of erosion with both time and increase in tide height at shore. An area-volume relation was determined for Barnegat Bay between the two bay bridges using available U.S.G.S. quad sheets and navigation maps. The area-capacity relation was extended inland to the 20 ft. MLW contour. Those relations are shown on Exhibit 12. The cross-sectional area of Barnegat Inlet was also obtained by averaging several limiting sections to arrive at a "basic" area-elevation relation. That relation is shown on Exhibit 13. Also shown on that exhibit is the total accumulative area-elevation relation that was assumed to exist during storm occurrence as a result of beach erosion at the inlet and from the creation of small secondary inlets (breakthroughs in the beach island) which would add to the total available inlet area with time. As shown on that exhibit the existing inlet area at elevation 8 feet MSL would be assumed to increase from 24,000 ft.^{2} to a maximum of 97,000 ft.^{2} when the ocean tide reaches elevation 17 ft. MSL.

(2) Erosion, breakthrough, and overflow assumptions. The assumptions made regarding the time - history and extent of erosion and subsequent overflow to Barnegat Bay are probably the most significant part of this entire analysis. Available information, including personal observations of beach erosion in major hurricanes affecting similar beach and shore installations in the Florida area provided some knowledge of the time

sequence of erosion and resultant effects. Wave action in advance of actual storm passage attacks coastal beaches in varying degrees depending on both offshore and onshore beach slopes, the proximity (or existance) of dunes, type of underlying material, wave characteristics, and other factors. As the hurricane tide at shore rises, the area of beachfront exposed to wave attack and possible overtopping increases with elevation. The horizontal extent of beach erosion can vary; in major hurricanes some 10 to 20 feet horizontal loss of beach has been observed. In long-duration northeast storms, which occur in late winter and early spring, tide heights do not approach the maximum values observed in hurricanes; however, the repeated occurrence of four to five much-above-normal tides plus abnormally high seas and wave action has caused horizontal erosion of beachfront areas of as much as 50 to 100 feet. Such storms also have associated severe wave action lasting from 36 to 48 hours and longer. The March 1962 Northeaster had 5 successive high tides with wave action of nearly 60 hours duration. From Exhibits 9 and 10 the tide hydrograph of the slow moving storm (considered applicable for the P.M.H.) and the tide-duration curve indicate that the beach island fronting the plant site will be subject to joint tide and wave attack for about a 6 to 8 hour period. Exhibit 11 indicates that some 5,000 feet of beachfront is at or below elevation 10 ft. MSL and about 18,000 feet is at or below 15 feet MSL. The duration of tide height above 10 ft. MSL, as shown on Exhibit 10, is approximately 4 hours; that

above 15 ft. MSL is about 2+ hours. Based on those data and the general width of dune and beach in the area an erosion rate of 1 foot per hour vertically was postulated, beginning at time T_{-6} for beach areas at or below elevation 6 ft. MLW. For those areas the maximum erosion depth in the total storm would be on the order of a 7-foot vertical reduction. Comparable hourly rates were assumed to occur with increase in beach elevation and with hourly increase in tide height at shore. In this manner a final "eroded" profile relation was established, as shown on Exhibit 11, which was assumed to exist at time T_{+1} hours. The progressive hourly changes in beach elevation provided a basis for computation of hourly overflow volumes (as described later in this report). The total inlet area relation shown on Exhibit 13 was based on an estimated total 7,500 linear feet of breakthrough of the beach, occurring at about 7 locations within the 2-mile reach south of the inlet and in the first 1½ miles north of the inlet. A total erosion depth of about 10+ feet was assumed to occur in those specific locations, down to about mean low water. This assumption depends in large measure on the type of material underlying the beach, ie., whether entirely sand or composed of limerock or some other non-erodable material. In view of this unknown the assumption is considered to be extreme.

(3) Overflow and inflow computations. These computations were made simultaneously to evaluate hourly changes in bay volume and stage. Hourly computations of the volume of overflow of the beach island were based on a series of hourly erosion pro-

files which were related to tide elevation and were planimetered to obtain a "mean" depth and area of overflow. Mannings formula for turbulent flow in open channels was used to compute tidal overflow of the constantly changing beach profile. As such the flow is non-uniform through the various cuts and troughs which comprise the eroding sections along the reach of beachfront considered.

$$Q = aV = \frac{1.486}{n} r^{2/3} s^{1/2} \qquad \text{where}$$

Q = discharge in cubic feet per second
a = hourly area of overflow in square feet
V = flow velocity in feet per second
r = hydraulic radius, assumed to be equal to the mean hourly depth of overflow.
s = water surface slope, estimated as the hourly average head across a 1,000 foot width of beach
n = roughness coefficient, assumed as 0.03 which is noted on page 7-17 of King's Handbook of Hydraulics as applicable for natural stream channels, with no rifts or deep pools, but containing some obstructions such as stones.

The maximum hourly overflow rate of 1,775,000 cfs was reached in the hour T_{-1} to T_0. The maximum average hourly velocity, based on slope, was 12.25 feet per second and occurred in the period T_{-2} to T_{-1}. The total volume contribution to the bay from tidal overflow would be 405,074 acre feet. The orifice formula was used to compute inflow. As defined in King's Handbook of Hydraulics, an orifice is an opening with a closed perimeter and of regular form through which water flows. The movement of tidal inflow through Barnegat Inlet during the P.M.H. under both relatively high head conditions and the influence of

winds in excess of 100 mph was considered best represented hydraulically as flow through an orifice. That formula is:

$$Q = CA\sqrt{2gh} \qquad \text{where}$$

Q = discharge in cubic feet per second
C = empirical constant (used 0.64 based on similar computations made by the Jacksonville District, Corps of Engineers in design hurricane-protection studies)
A = inlet area (from Exhibit 13)
g = gravitational constant (32.186)
h = average hourly head across the inlet.

The maximum hourly inflow rate through Barnegat Inlet and the various breakthroughs was computed to be 1,050,000 cfs in the period T_{-1} to T_0. The maximum hourly average velocity was 16.2 feet per second from T_{-2} to T_{-1}. The total volume contribution to the bay from tidal inflow would be 310,010 acre feet, making a grand total volume of 765,084 acre feet added to the bay. Graphs of the hourly inflow, overflow, and total volume added to the bay are shown on Exhibit 14. The rise in mean hourly bay level (stage) from that inflow can be seen on Exhibit 15. The peak stage reached in the bay would be 15.8 ft. MLW, and would occur at time T_{+1} hours.

c. Hurricane rainfall. As noted on page 7 of U.S.W.B. Technical Paper No. 48, Reference 9 --- "hurricanes may dump as much as 12 inches of rainfall in 24 hours over large areas and even more over areas of a few square miles". In general, the amount of rain resulting from any given storm is a function of several factors --- the moisture content of the storm and influence of surrounding air masses, its path, ie., whether over relatively

flat terrain or mountainous areas, where the effect of orographic lifting can result in torrential and widespread downpours, and other meteorologic conditions. Examination of rainfall records associated with the passage of intense hurricanes over or near the northeastern seaboard indicates that rainfall distribution in those storms has been light along the coast, with heavier amounts noted inland due to rise in topography. The heaviest reinfall has been found to occur in the area slightly ahead of the center, this being the area of maximum moisture inflow and convergence, and that most affected by orographic lifting. For the P.M.H. a total pre-peak tide rainfall is postulated, ranging from 3 inches along the coast over the Barnegat Bay area, to a maximum 12 inches some 25 to 30 miles inland. The total contribution of storm rainfall over Barnegat Bay (0.25 ft.) within a 24-hour period prior to peak tide occurrence in the bay would be small in terms of its normal average depth, and even smaller with respect to the added volume of tidal inflow and overflow noted above.

d. Runoff. Little or no contribution to the bay from upland runoff from such streams as Toms River, Cedar Creek, Forked River, Oyster Creek, Gunning River, or Manahawkin Creek is expected at the time of peak bay tide occurrence because of the normal 3 to 6 hour lag between rainfall occurrence and the time of concentration in peak runoff from those watersheds. In this regard it has been observed that the effect of hurricane winds plus high water levels in coastal bays and rivers can and has

delayed or caused a further lag in the time of occurrence of peak runoff owing to reversals in slope upstream.

e. Barnegat Bay wind set-up computations. During the period of P.M.H. surge occurrence along the oceanfront the water level in Barnegat Bay will have risen up to a peak at time T_{+1}. At that time peak hurricane winds are directed across the east-west axis of the bay causing an additional rise in water level along the mainland shore from wind and wave setup. Following passage of the hurricane center inland wind directions gradually begin to shift to the southeast. For the available 4 to 5 miles of fetch distance across the bay a minimum duration of at least ½ hour is considered necessary for average winds to be effective in creating a theoretical "steady-state" setup condition along shore. Accordingly, a mean ½ hourly bay level of 15.35 ft. MLW (from time $T_{+\frac{1}{2}}$ to T_{+1}) was used to compute the additional bay tide. The formula

$$S = \frac{\lambda T_s \, L \, N}{\gamma \, D}$$

was used to compute the slope S, in feet per mile, across the bay. After several successive approximations a node line was established and setup and setdown computations were made. The water area in the vicinity of the beach island will "setdown" because of the shallower water depths. A half-hourly average wind speed of 120 mph was used, based on a slight reduction in storm winds due to the effect of overland friction and normal

storm filling following landfall. A geographical sketch of conditions used in the computation can be seen on Exhibit 16. The peak computed tide elevation at shore, including the effects of wind, rainfall, and wave action, was determined to be 19.83 ft. MLW (19.5 ft. MSL). That tide elevation is considered applicable at the plant site.

f. Wave runup at the plant site. 1. General. Location of the plant site is approximately 1½ miles inland from the western shore of Barnegat Bay and about 2,000 feet east of Highway 9. Topographic data for the area fronting the plant site was taken from Topographic Survey "Baywood Farms" dated January 23, 1970, sheets 1 through 7, prepared for Jersey Central Power and Light Company. Those data supplement the U.S.G.S. Quadrangle Sheet-Forked River, N.J. 1953, a portion of which is reproduced on Exhibit 17 with the plant site location indicated thereon. Four ground profiles for the area fronting the plant site are shown on Exhibit 18, one extending north-south along the base of the plant fill and three east-west profiles bracketing the wave approach area to the plant site.

2. Wave heights in Barnegat Bay. Evaluation of wave generation conditions in the bay was based on an available east-west fetch length across the bay of approximately 3.5 statue miles, an average beach-mainland depth under the wind tide profile (Exhibit 16) of approximately 18 feet, and an average wind speed from the east-southeast of 120 mph. Wave height and period were obtained with the above data from Figures 1-35 and 1-36 (extended for wind

speed) of ETL-1110-2-8, dated 1 August 1966, interpolated for an average depth of 18 feet. From those curves a wave height Hs = 8 to 8.5 feet and wave period T = 7 seconds were obtained.

3. Wave heights and characteristics in the vicinity of the plant site will be a function of available depth of water some distance eastward of the plant embankment. Water depth decreases progressively with distance inland from the mainland shore. The higher waves will break on moving inland as their breaking depth is reached. For example, an 8.5 ft. wave will break in approximately 11 feet of water, or about 0.9 mile inland from the western bay shore, barring the effect of any physical obstruction to its forward progress inland. The wave height that can be sustained without breaking in crossing the area in front of the plant site fill and that will break on and run up the fill slope was determined using the topographic profiles A-D shown on Exhibit 18. If the effect of the dense woods extending north-south for over half a mile east of the plant site can be ignored, ground elevations of 15+ to 17 feet will control the wave height reaching the plant fill embankment. Using an average tide elevation of 19+ ft. and a controlling ground elevation of 15+ ft. the maximum non-breaking depth of water for waves reaching the embankment will be about 4 feet. For that depth a 3.1 ft. wave will break (H_b = 0.78 x 4 = 3.12 ft.), indicating that the height of the wave breaking on the embankment will be about 3 feet.

4. Wave runup on the plant embankment. An embankment slope of

one vertical on 3 horizontal is planned for the bay side of the plant site fill. Wave runup for that slope was computed. Generalized relationships between water depth, wave height, and wave length were derived, as given below; equivalent deep water relations and runup criteria were obtained from Techanical Report No. 4, "Shore Protection Planning and Design" by BEB, OCE. Wave runup and wave runup elevation (non-overtopping) for determining plant fill elevation were computed for two conditions: 1. A smooth 1 on 3 embankment slope, and 2. A rubble (riprap) coated 1 on 3 embankment slope. Determinate data for each are as follows:

General

$d = d_b = 4$ feet	$H_s = H_b = 3$ feet
$T = 7$ seconds	$L = 5.12T^2 = 251$ feet
$d/L = 4/251 = 0.0159$	$d/L_o = 0.00160$
$H/H_o' = 2.238$	$H_o' = 1.35$
$H_o'/T = 0.0276$	$d/H_o' = 2.96$

Condition 1 - Smooth 1 on 3 slope: (Figure 3-2)

Cot a = 3.08	$d/H_o' = 3$
$R/H_o' = 3.9$	$R = 5.3$ feet

(Correction for Model Scale Effect - Fig. 3-11 = 12%)

$R_{corr.} = 5.9$ feet

Runup elevation = 19.5 + 5.9 = 25.4 ft. MSL

Condition 2 - Rubble 1 on 3 slope: (Figure 3-12)

Cot a = 3.08	$d/H_o' = 3$
$R/H_o' = 0.96$	$R = 1.3$ feet

$R_{corr.} = 1.47$, say 1.5 feet

Runup elevation = 19.5 + 1.5 = 21.0 ft. MSL

PROBABILITY OF OCCURRENCE

The return frequency of the probable maximum hurricane has been defined on a probability basis in ESSA Memorandum HUR 7-97 wherein the frequency of C.P.I. occurrence was derived for various coastal zones at a 1,000-year return period. Numerous factors, both singly and in combination, influence and comprise the return frequency of this storm and its associated maximum water level at the Forked River Unit 1 Nuclear Power Plant site. They include storm intensity (central pressure index), the selected radius of maximum wind and forward speed, the requirement that the P.M.H. occur on an exact critical path for peak ocean surge generation, and the further requirement that the time of peak storm surge occurrence at the coast coincide with the high monthly astronomical tide level. The absence, omission, or failure of any one or more of the above conditions and requirements will result in a less-than-critical event than that predicated in this report. For example, assuming all other conditions met if the peak storm surge occurs coincident with low astronomical tide at the coast the resulting peak surge elevation would be over 4 feet lower than predicated. If all other conditions are met but the storm path is to the north of the plant site the resultant surge height would be minimal. An exact determination of the probable return frequency of the peak P.M.H. surge elevation predicated for the plant site would be extremely difficult at best and would have to represent the composite probability of occurrence of each of the conditions and combinations of conditions stipulated. As such it would be an

extremely rare event with a return frequency estimated to be on the order of once in a million years, or possibly more.

EXTREME LOW TIDE ANALYSIS

Various factors affect and to a large extent control the value of the probable minimum water level elevation, or extreme low tide condition, to be expected at the intake canal of Forked River Unit 1 nuclear power plant. They are essentially as follows:

1. Hurricane wind direction, duration and intensity in a P.M.H. occurence passing either a sufficient distance offshore or a sufficient distance to the north of the site area so as to prevent the buildup of tides alongshore and in Barnegat Bay. Winds in the bay area opposite the plant site must be directed toward the east so as to create a setdown in bay level along the western bay shore.

2. The occurrence of the storm, with applicable winds over the bay, on a normal low astronomical tide condition in the bay.

3. The location of the plant site with respect to the principal axis of the bay.

4. The average depth of the bay with respect to wind-tide generation and,

5. The general orientation of the bay with respect to anticipated hurricane wind direction.

An occurrence of the P.M.H. is postulated on a path generally parallel to shore at a distance some 35 to 40 statue miles offshore. Peak offshore winds (corrected for offland friction) in the left rear quadrant of the storm would be on the order of 90-95 mph (100-110 mph x 0.89)

over the bay. For the Forked River Unit 1 plant site tide-generating conditions in Barnegat Bay are minimal. The available east-west wind-tide generating fetch across the bay would be of some 3 miles maximum length. The plant site is located at or near the nodal point for north-south tide generation and water levels would be affected the least under those conditions. An assumed normal low tide condition in the bay of -0.1 ft. MLW (-0.4 ft. MSL) would exist in the bay coincident with the time of maximum setdown along the western bay shore. The formula used to compute wind setdown in the bay within the plant intake and discharge channels is that described in Reference 10. That formula is:

$$S = \frac{L \lambda T_s N}{\gamma D} \qquad \text{where}$$

S = total setup over the respective fetch, in feet.

L = fetch distance, in feet.

λT_s = tangential wind shear stress (lbs./ft.^{2}).

γ = specific weight of water (62.4 lbs/ft.^{3}).

D = average depth of water over fetch L, in feet.

N = ratio of setup to depth (after

An average bay bottom profile (west to east) was constructed for a 2-mile wide bay section, shown on Exhibit 19. From that bay profile, shown on Exhibit 20, average bay bottom elevations were obtained to determine average depths and bay volumes. The nodal point in the bay was estimated initially and subsequently finalized by a volumetric check of setup and setdown volumes. Outflow from

the bay was considered negligible, assuming the condition of normal low tide plus wind setup against the eastern bay shore would be acting against a rising normal ocean tide condition. Basic computations and data all shown in tabular form on Exhibit 20. An Extreme Low Tide elevation of -3.1 ft. MLW (-3.4 ft. MSL) was computed in the bay at the intake canal.

CONCLUSIONS

Based on the above analysis the undersigned has drawn the following conclusions:

1. That attainment of the maximum flood level in Barnegat Bay at the plant site is a function of the maximum volume of inflow to the bay.

2. That that volume is primarily dependent upon the P.M.H. tide duration curve at the coast.

3. That a P.M.H. with a moderately slow speed of translation is required to provide the most critical combination of conditions for Conclusions 1 and 2.

4. That such a storm, as described above in this report, will generate a peak tide elevation of 19.83 ft. MLW (19.5 ft. MSL) at the plant site.

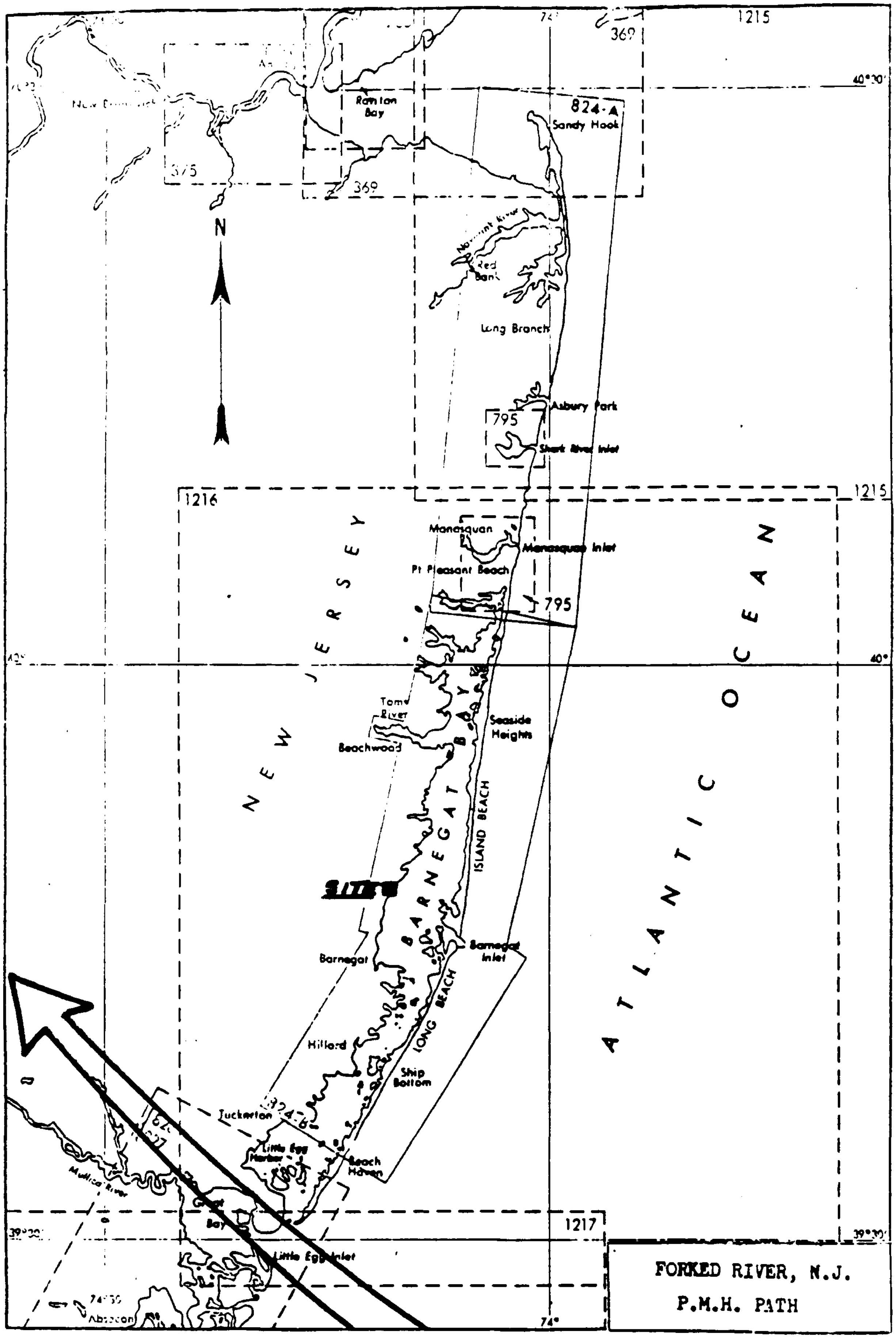
5. That an added wave runup can be expected to occur on the planned 1 on 3 embankment fronting the plant ranging from 5.9 feet (elevation 25.4 ft. MSL) for a smooth slope, to 1.5 feet (elevation 21.0 ft. MSL) for a rubble (riprap) slope.

6. That the Extreme Low Tide elevation to be expected in the bay at the plant intake and discharge channels is on the order of -3.1 ft. MLW (-3.4 ft. MSL).

Submitted by

Theodore E. Haeussner
Hydraulic Engineer Consultant
Jacksonville, Florida
April 25, 1970

EXHIBITS



FORKED RIVER, N.J.
P.M.H. PATH

EXHIBIT 1

PROBABLE MAXIMUM HURRICANE PARAMETERS

P_o = 27.10 inches

P_n = 30.08 inches

P_a = 30.70 inches

R = 34.50 statute miles

ST = 13 miles per hour

MT = 23 miles per hour

HT = 56 miles per hour

EXHIBIT 2

BASIC INFORMATION

DISTANCE FROM CENTER	OVERWATER WIND PROFILE	PRESSURE
8.6	39.88	27.17
17.3	76.97	27.59
25.9	106.05	28.05
34.5	118.03	28.42
44.5	104.61	28.76
54.5	91.80	29.01
64.5	84.38	29.21
74.5	78.46	29.37
84.5	72.22	29.49
94.5	67.05	29.60
114.5	60.78	29.76
134.5	55.50	29.89
154.5	50.77	29.98
174.5	46.48	30.05
194.5	42.55	30.11
214.5	38.91	30.17
234.5	35.51	30.21
254.5	32.32	30.24

EXHIBIT 3

OVERWATER WIND SPEED DATA

SLOW SPEED TRANSLATION

ANGLES MEASURED FROM LINE OF FORWARD MOTION

DIST.	25	55	85	115	145	175	205	235	265	295	325	355
8.6	39.9	43.1	45.5	46.4	45.5	43.1	39.9	36.6	34.3	33.4	34.3	36.6
17.3	77.0	80.2	82.6	83.5	82.6	80.2	77.0	73.7	71.3	70.5	71.3	73.7
25.9	106.1	109.3	111.7	112.6	111.7	109.3	106.1	102.8	100.4	99.6	100.4	102.8
34.5	118.0	121.3	123.7	124.5	123.7	121.3	118.0	114.8	112.4	111.5	112.4	114.8
44.5	104.6	107.9	110.2	111.1	110.2	107.9	104.6	101.4	99.0	98.1	99.0	101.4
54.5	91.8	95.1	97.4	98.3	97.4	95.1	91.8	88.6	86.2	85.3	86.2	88.6
64.5	84.4	87.6	90.0	90.9	90.0	87.6	84.4	81.1	78.8	77.9	78.8	81.1
74.5	78.5	81.7	84.1	85.0	84.1	81.7	78.5	75.2	72.8	72.0	72.8	75.2
84.5	72.2	75.5	77.8	78.7	77.8	75.5	72.2	69.0	66.6	65.7	66.6	69.0
94.5	67.1	70.3	72.7	73.6	72.7	70.3	67.1	63.8	61.4	60.6	61.4	63.8
114.5	60.8	64.0	66.4	67.3	66.4	64.0	60.8	57.5	55.2	54.3	55.2	57.5
134.5	55.5	58.7	61.1	62.0	61.1	58.7	55.5	52.2	49.9	49.0	49.9	52.2
154.5	50.8	54.0	56.4	57.3	56.4	54.0	50.8	47.5	45.1	44.3	45.1	47.5
174.5	46.5	49.7	52.1	53.0	52.1	49.7	46.5	43.2	40.8	40.0	40.8	43.2
194.5	42.5	45.8	48.2	49.0	48.2	45.8	42.5	39.3	36.9	36.0	36.9	39.3
214.5	38.9	42.2	44.5	45.4	44.5	42.2	38.9	35.7	33.3	32.4	33.3	35.7
234.5	35.5	38.8	41.1	42.0	41.1	38.8	35.5	32.3	29.9	29.0	29.9	32.3
254.5	32.3	35.6	37.9	38.8	37.9	35.6	32.3	29.1	26.7	25.8	26.7	29.1

EXHIBIT 4

OVERWATER WIND SPEED DATA

MODERATE SPEED TRANSLATION

ANGLES MEASURED FROM LINE OF FORWARD MOTION

DIST.	25	55	85	115	145	175	205	235	265	295	325	355
8.6	39.9	45.6	49.8	51.4	49.8	45.6	39.9	34.1	29.9	28.4	29.9	34.1
17.3	77.0	82.7	86.9	88.5	86.9	82.7	77.0	71.2	67.0	65.5	67.C	71.2
25.9	106.1	111.8	116.0	117.6	116.0	111.8	106.1	100.3	96.1	94.6	96.1	100.3
34.5	118.0	123.8	128.0	129.5	128.0	123.8	118.0	112.3	108.1	106.5	108.1	112.3
44.5	104.6	110.4	114.6	116.1	114.6	110.4	104.6	98.9	94.7	93.1	94.7	98.9
54.5	91.8	97.6	101.8	103.3	101.8	97.6	91.8	86.1	81.8	80.3	81.8	86.1
64.5	84.4	90.1	94.3	95.9	94.3	90.1	84.4	78.6	74.4	72.9	74.4	78.6
74.5	78.5	84.2	88.4	90.0	88.4	84.2	78.5	72.7	68.5	67.0	68.5	72.7
84.5	72.2	78.0	82.2	83.7	82.2	78.0	72.2	66.5	62.3	60.7	62.3	66.5
94.5	67.1	72.8	77.0	78.6	77.0	72.8	67.1	61.3	57.1	55.6	57.1	61.3
114.5	60.8	66.5	70.7	72.3	70.7	66.5	60.8	55.0	50.8	49.3	50.8	55.0
134.5	55.5	61.2	65.5	67.0	65.5	61.2	55.5	49.7	45.5	44.0	45.5	49.7
154.5	50.8	56.5	60.7	62.3	60.7	56.5	50.8	45.0	40.8	39.3	40.8	45.0
174.5	46.5	52.2	56.4	58.0	56.4	52.2	46.5	40.7	36.5	35.0	36.5	40.7
194.5	42.5	48.3	52.5	54.0	52.5	48.3	42.5	36.8	32.6	31.0	32.6	36.8
214.5	38.9	44.7	48.9	50.4	48.9	44.7	38.9	33.2	28.9	27.4	28.9	33.2
234.5	35.5	41.3	45.5	47.0	45.5	41.3	35.5	29.8	25.6	24.0	25.6	29.8
254.5	32.3	38.1	42.3	43.8	42.3	38.1	32.3	26.6	22.4	20.8	22.4	26.6

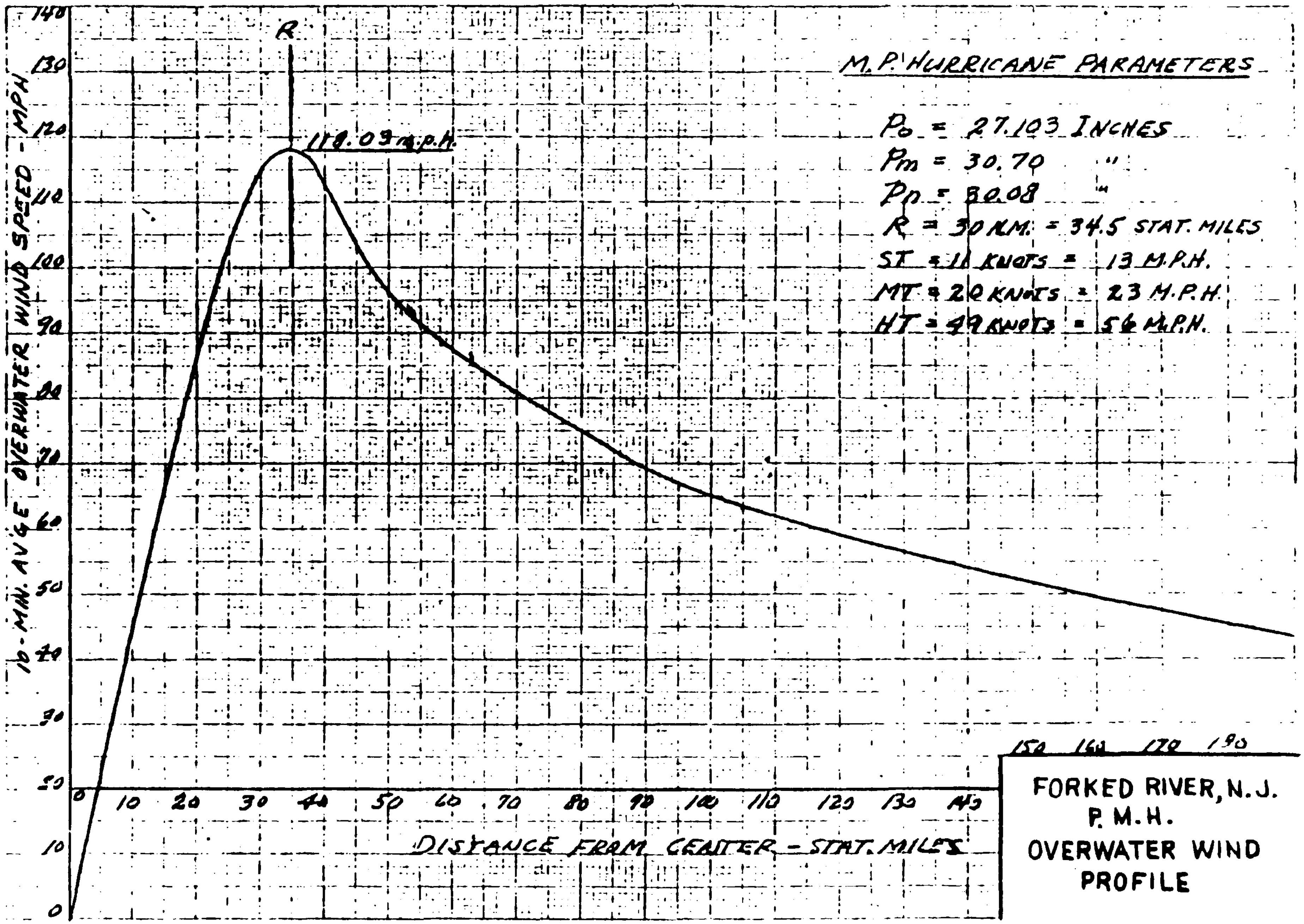
EXHIBIT 5

OVERWATER WIND SPEED DATA

HIGH SPEED TRANSLATION

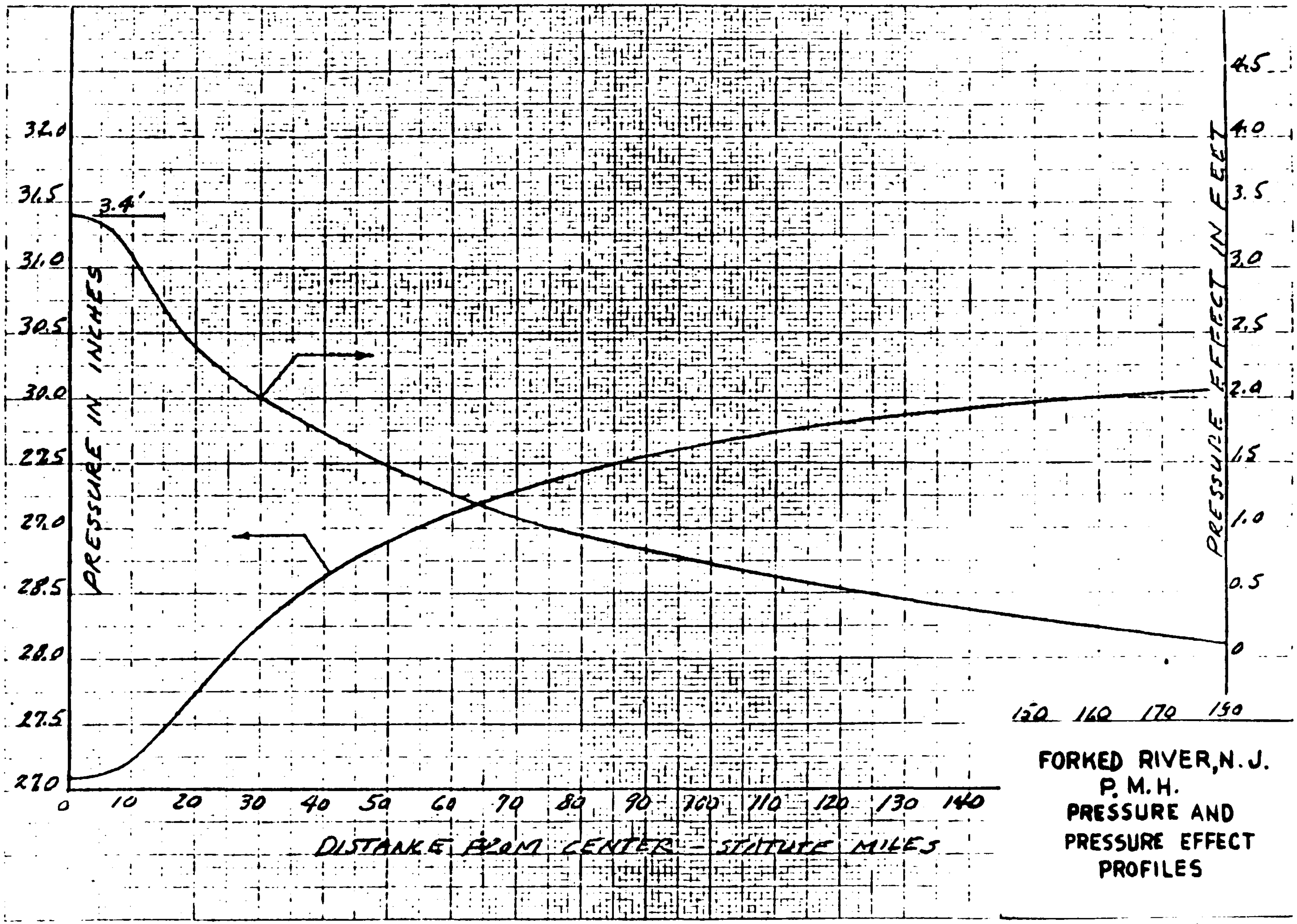
ANGLES MEASURED FROM LINE OF FORWARD MOTION

DIST.	25	55	85	115	145	175	205	235	265	295	325	355
8.6	39.9	53.9	64.1	67.9	64.1	53.9	39.9	25.9	15.6	11.9	15.6	25.9
17.3	77.0	91.0	101.2	105.0	101.2	91.0	77.0	63.0	52.7	49.0	52.7	63.0
25.9	106.1	120.1	130.3	134.1	130.3	120.1	106.1	92.1	81.8	78.1	81.8	92.1
34.5	118.0	132.0	142.3	146.0	142.3	132.0	118.0	104.0	93.8	90.0	93.8	104.0
44.5	104.6	118.6	128.9	132.6	128.9	118.6	104.6	90.6	80.4	76.6	80.4	90.6
54.5	91.8	105.8	116.1	119.8	116.1	105.8	91.8	77.8	67.6	63.8	67.6	77.8
64.5	84.4	98.4	108.6	112.4	108.6	98.4	84.4	70.4	60.1	56.4	60.1	70.4
74.5	78.5	92.5	102.7	106.5	102.7	92.5	78.5	64.5	54.2	50.5	54.2	64.5
84.5	72.2	86.2	96.5	100.2	96.5	86.2	72.2	58.2	48.0	44.2	48.0	58.2
94.5	67.1	81.1	91.3	95.1	91.3	81.1	67.1	53.1	42.8	39.1	42.8	53.1
114.5	60.8	74.8	85.0	88.8	85.0	74.8	60.8	46.8	36.5	32.8	36.5	46.8
134.5	55.5	69.5	79.7	83.5	79.7	69.5	55.5	41.5	31.3	27.5	31.3	41.5
154.5	50.8	64.8	75.0	78.8	75.0	64.8	50.8	36.8	26.5	22.8	26.5	36.8
174.5	46.5	60.5	70.7	74.5	70.7	60.5	46.5	32.5	22.2	18.5	22.2	32.5
194.5	42.5	56.5	66.8	70.5	66.8	56.5	42.5	28.5	18.3	14.5	18.3	28.5
214.5	38.9	52.9	63.2	66.9	63.2	52.9	38.9	24.9	14.7	10.9	14.7	24.9
234.5	35.5	49.5	59.8	63.5	59.8	49.5	35.5	21.5	11.3	7.5	11.3	21.5
254.5	32.3	46.3	56.6	60.3	56.6	46.3	32.3	18.3	8.1	4.3	8.1	18.3

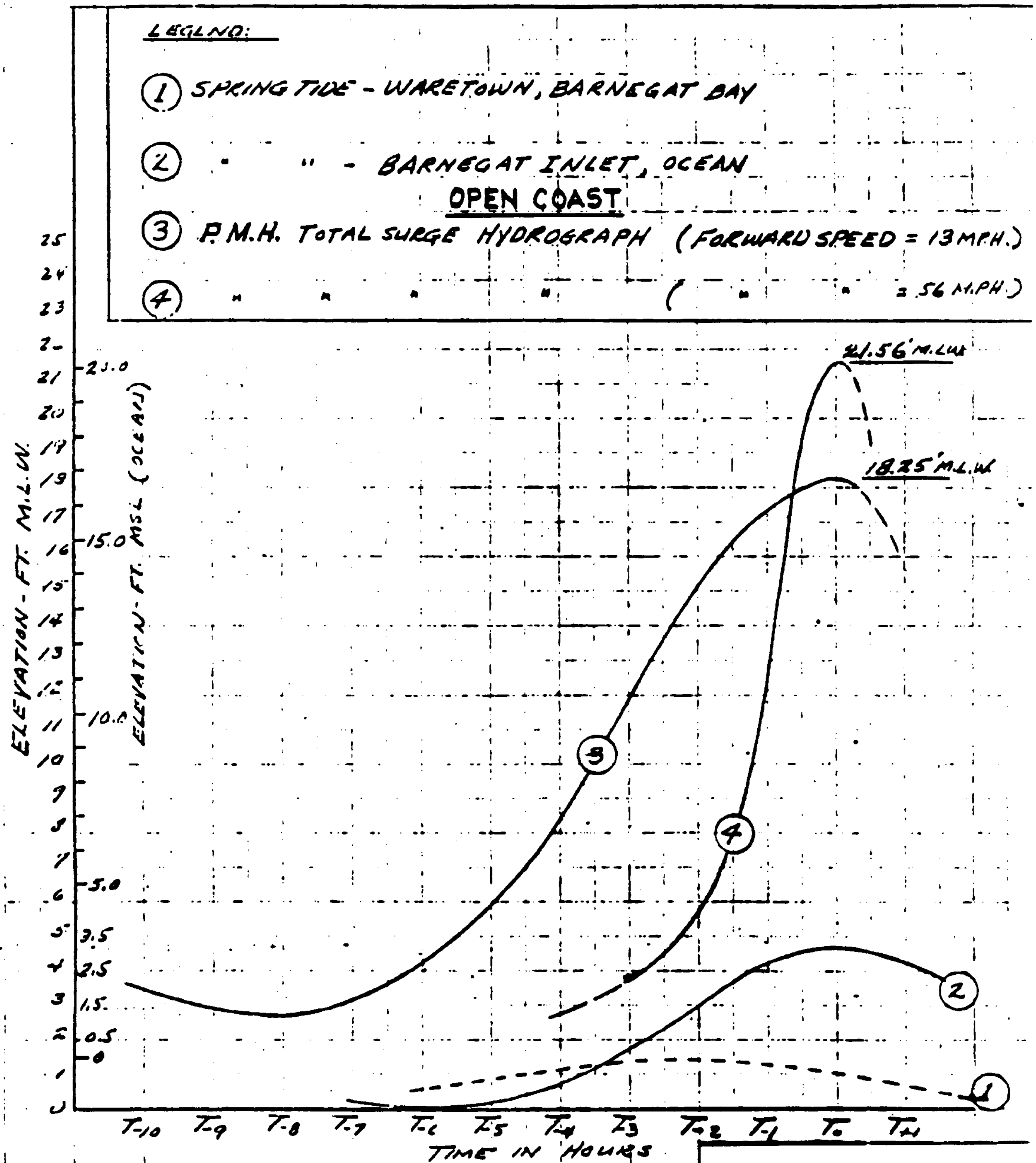


M.P. HURRICANE PARAMETERS
Po = 27.103 INCHES
Pm = 30.70 "
Pn = 30.08 "
R = 30 N.M. = 34.5 STAT. MILES
ST = 11 KNOTS = 13 M.P.H.
MT = 20 KNOTS = 23 M.P.H.
HT = 49 KNOTS = 56 M.P.H.
R
118.09 m.p.h.
10-MIN. AVGE OVERWATER WIND SPEED - MPH
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
150 160 170 190
DISTANCE FROM CENTER - STAT. MILES
FORKED RIVER, N.J.
P. M. H.
OVERWATER WIND
PROFILE

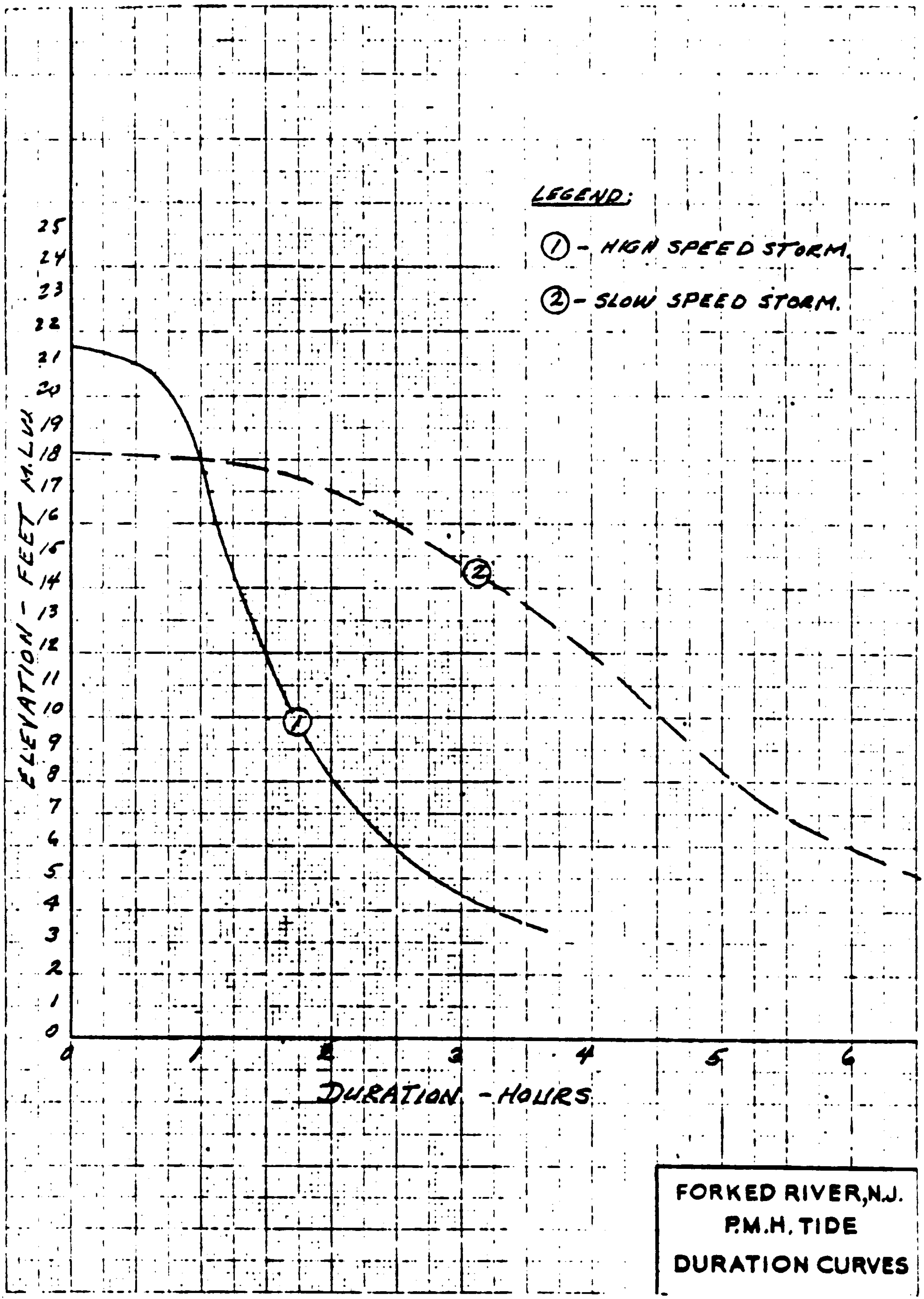
EXHIBIT 7



FORKED RIVER, N.J.
P. M. H.
PRESSURE AND
PRESSURE EFFECT
PROFILES

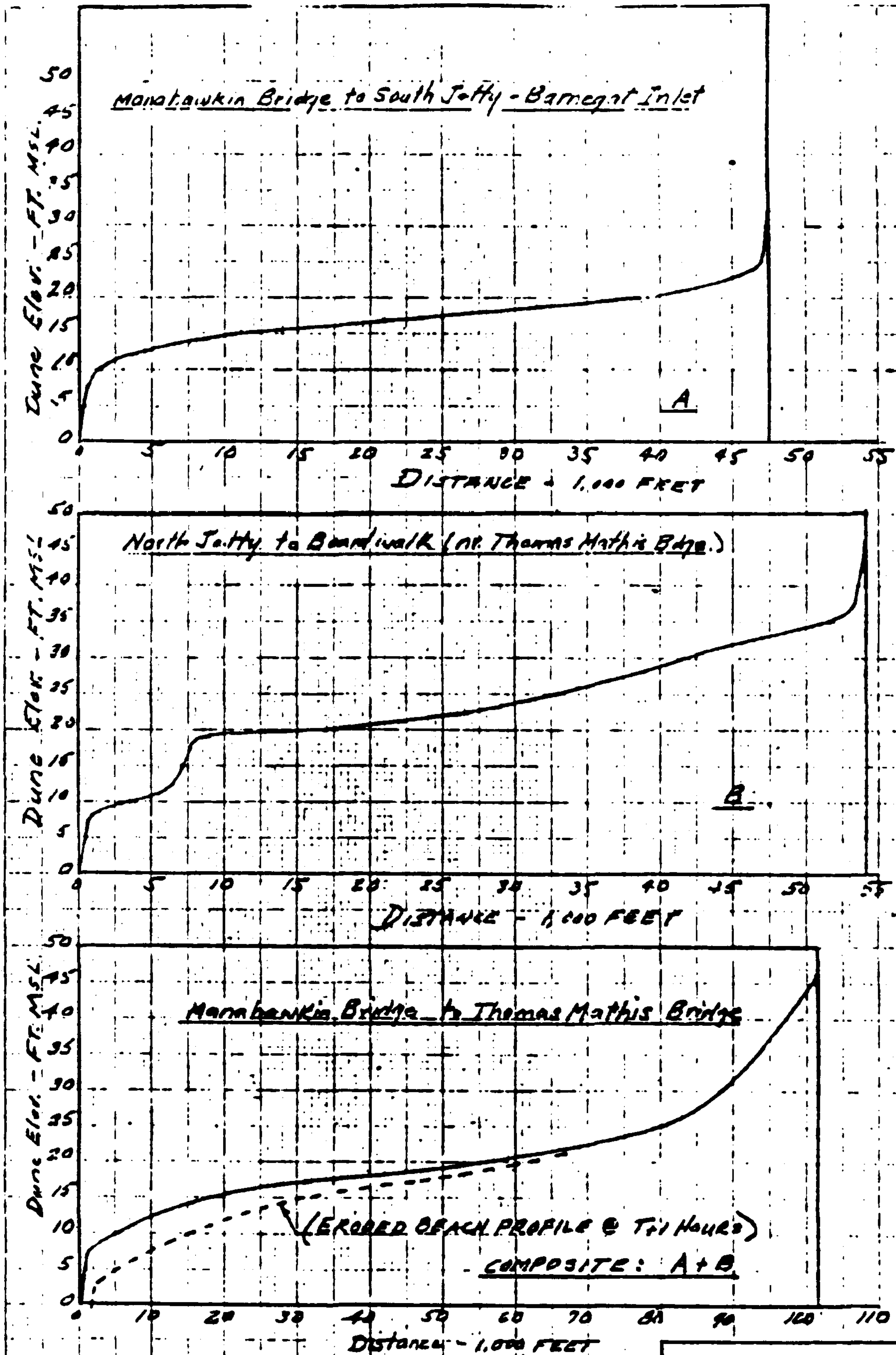


NORMAL & P.M.H. TIDE HYDROGRAPHS

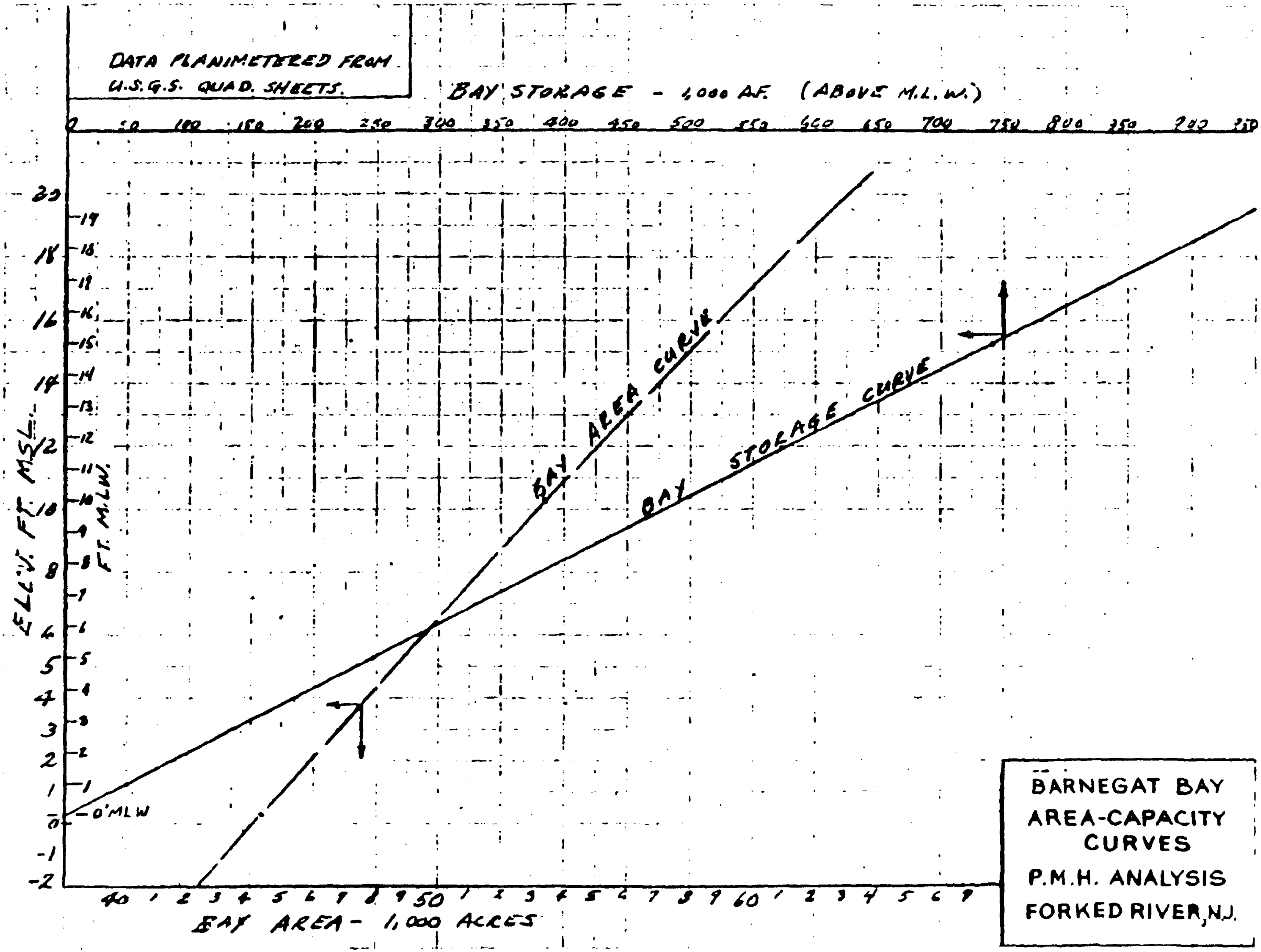


FORKED RIVER, N.J.
P.M.H. TIDE
DURATION CURVES

EXHIBIT 10

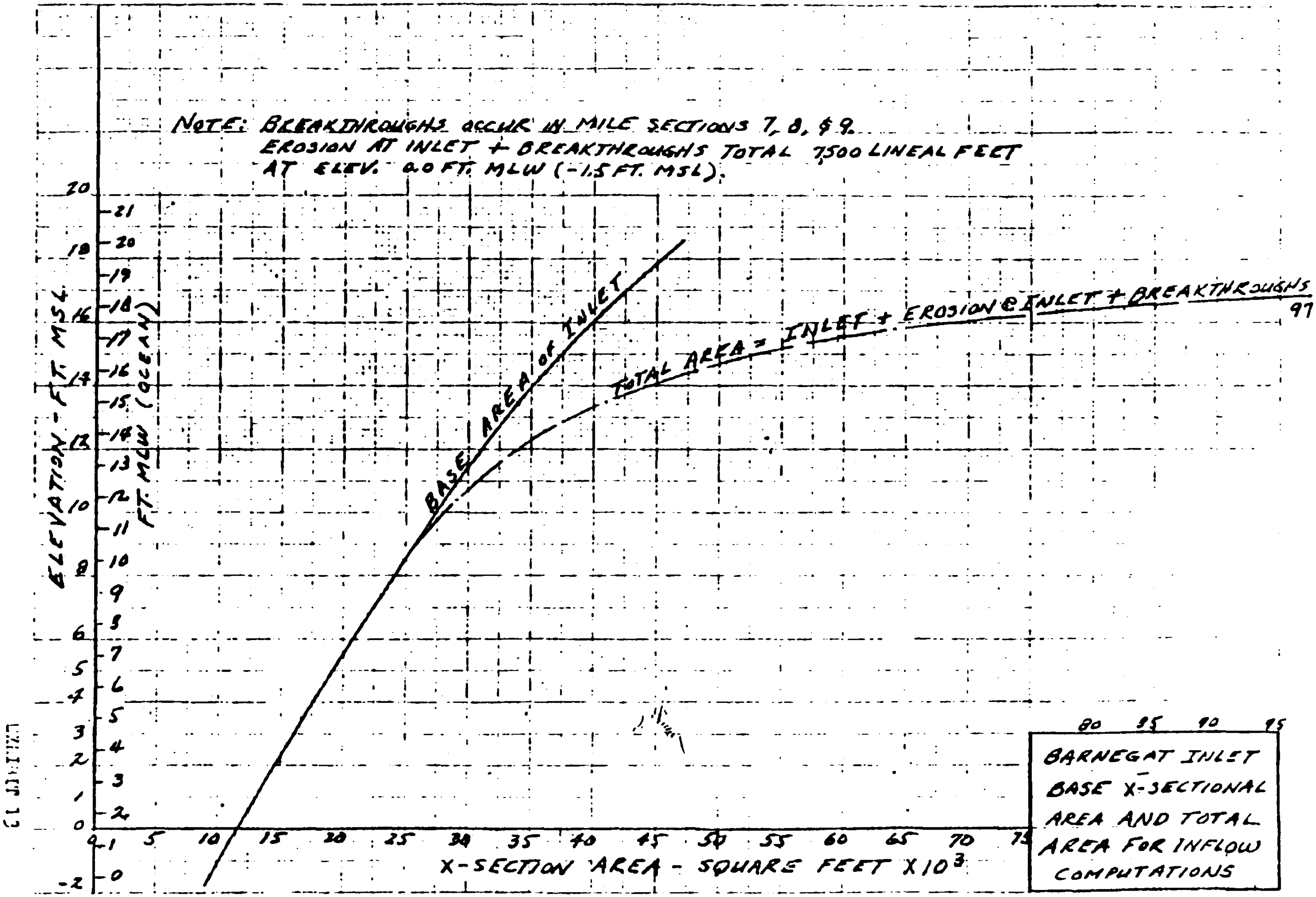


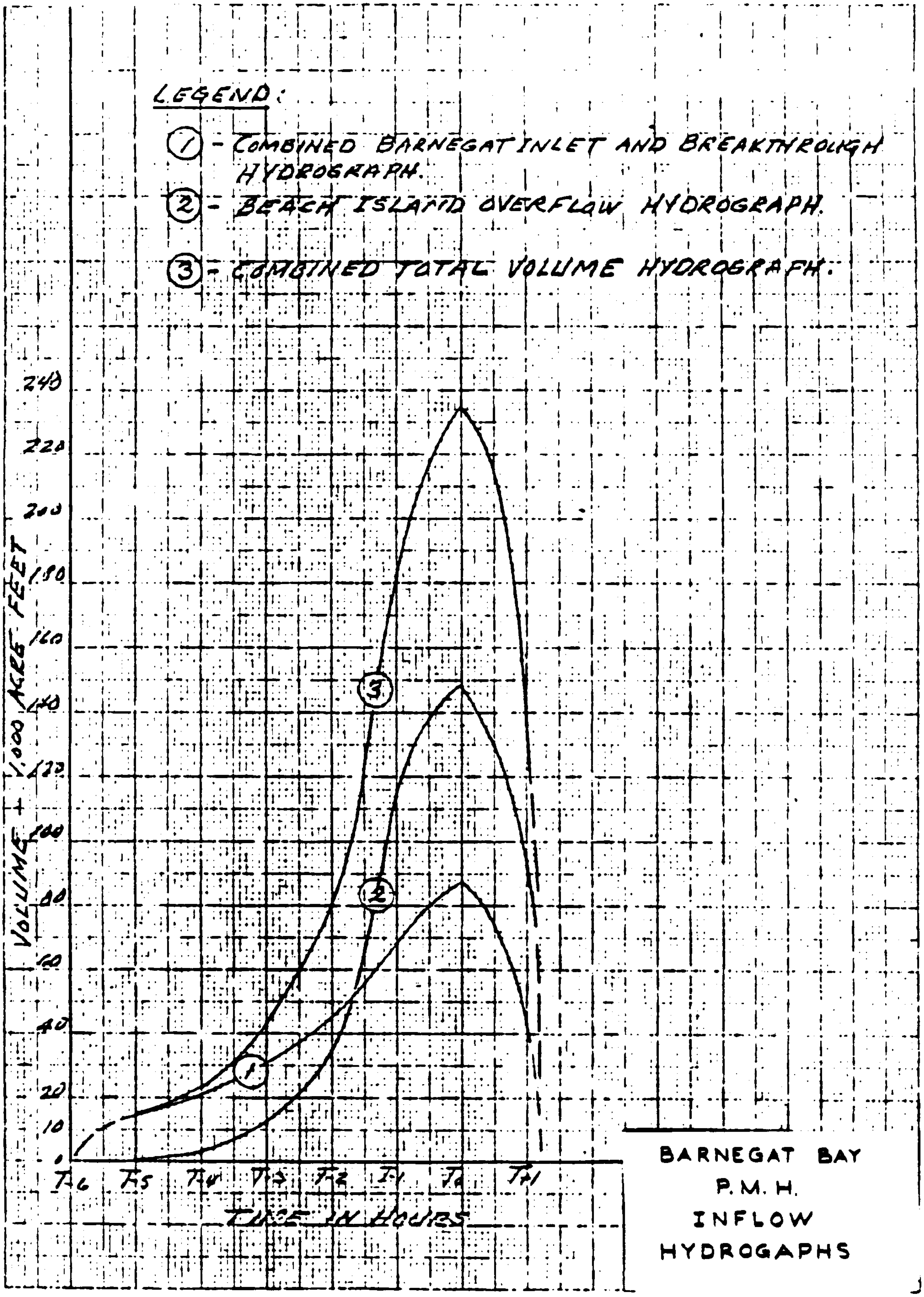
DUNE ELEVATION VS. DISTANCE



DATA PLANIMETERED FROM
U.S.G.S. QUAD. SHEETS.
BAY STORAGE - 1,000 A.F. (ABOVE M.L.W.)
BAY AREA CURVE
BAY STORAGE CURVE
ELEV. FT. M.S.L.
FT. M.L.W.
0'MLW
BAY AREA - 1,000 ACRES
BARNEGAT BAY
AREA-CAPACITY
CURVES
P.M.H. ANALYSIS
FORKED RIVER, N.J.

EXHIBIT 12


NOTE: BREAKTHROUGHS OCCUR IN MILE SECTIONS 7, 8, & 9.
EROSION AT INLET + BREAKTHROUGHS TOTAL 7,500 LINEAL FEET
AT ELEV. 0.0 FT. MLW (-1.5 FT. MSL).
ELEVATION - FT. MSL
FT. MLW (OCEAN)
BASE AREA of INLET
TOTAL AREA = INLET + EROSION @ INLET + BREAKTHROUGHS.
X-SECTION AREA - SQUARE FEET X 10³
BARNEGAT INLET
BASE X-SECTIONAL
AREA AND TOTAL
AREA FOR INFLOW
COMPUTATIONS



BARNEGAT BAY
P.M.H.
INFLOW
HYDROGAPHS

EXHIBIT 14

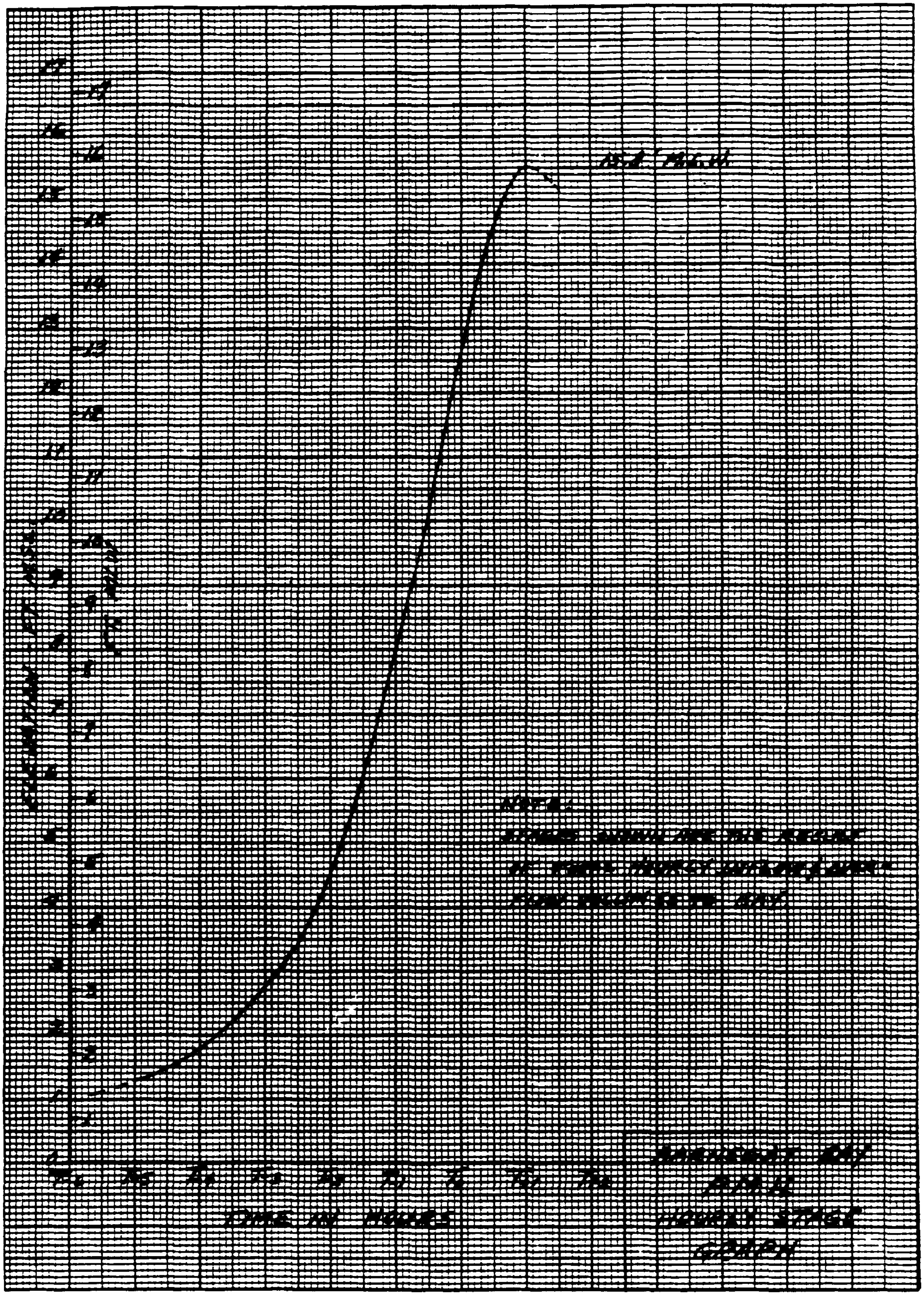
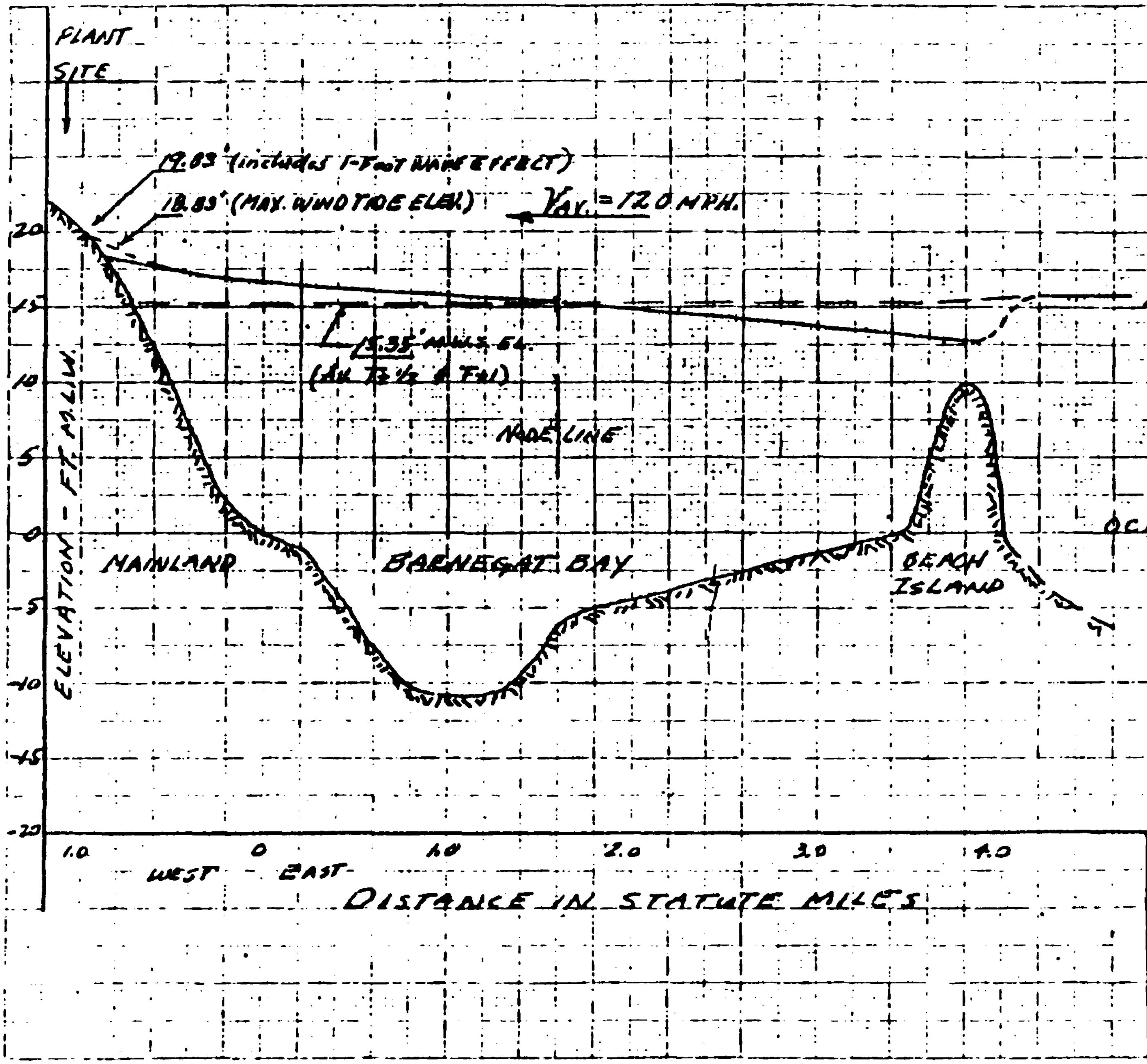


EXHIBIT 15



FORKED RIVER, N.J.
P. M. H.
TIDE PROFILE
ACROSS
BARNEGAT BAY

EXHIBIT 15

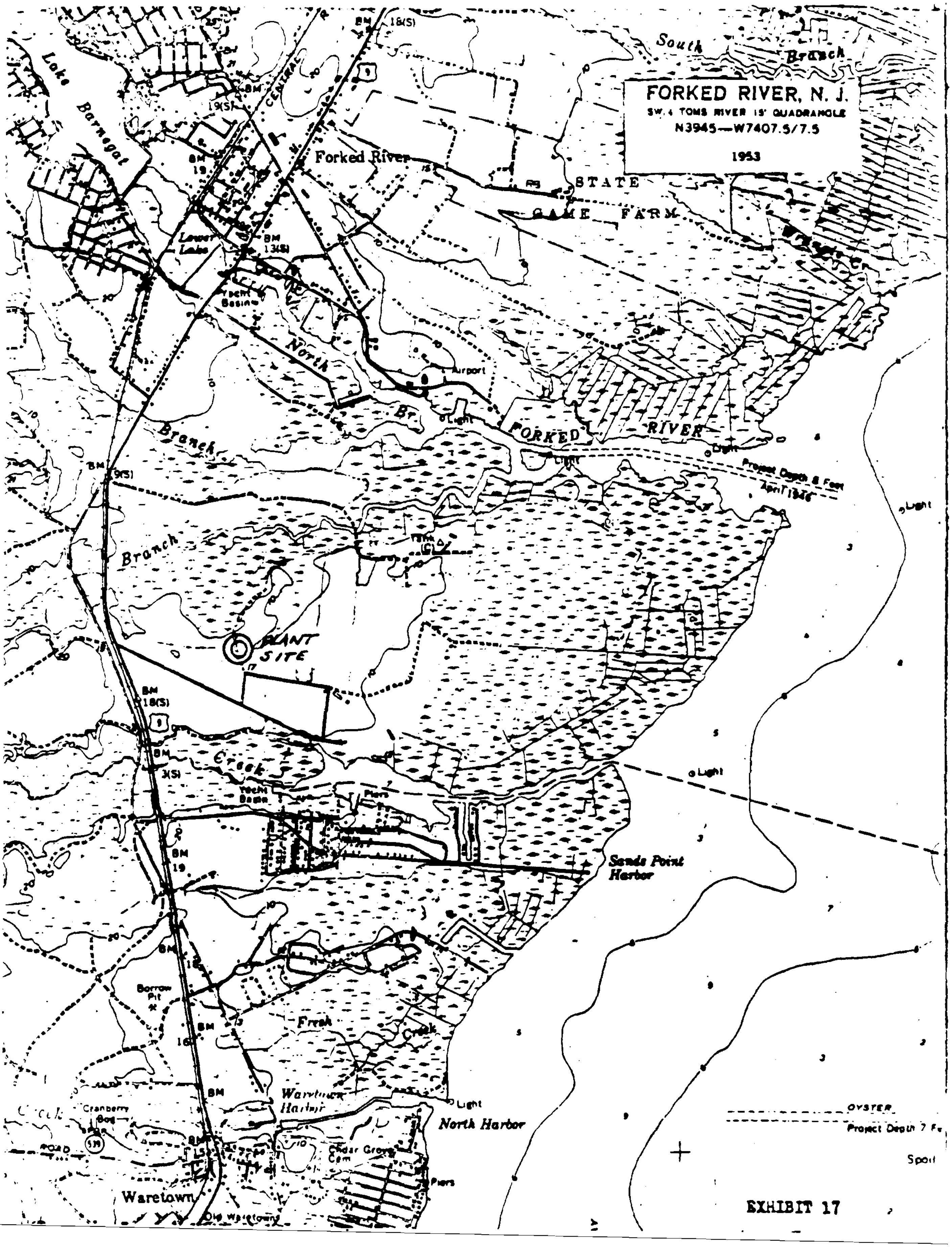

FORKED RIVER, N. J.
SW/4 TOMS RIVER 15' QUADRANGLE
N3945—W7407.5/7.5
1953
South Branch
Lake Barnegat
Forked River
STATE GAME FARM
Lower Lake
Yacht Basin
North Br.
Airport
Light
FORKED RIVER
Project Depth 6 Feet
Branch
PLANT SITE
Creek
Piers
Sands Point Harbor
Borrow Pit
Fresh Creek
Waretown Harbor
North Harbor
Cranberry Bog
Cedar Grove Cem
Waretown
Old Waretown
OYSTER
Project Depth 7 Fe
Spoil

EXHIBIT 17

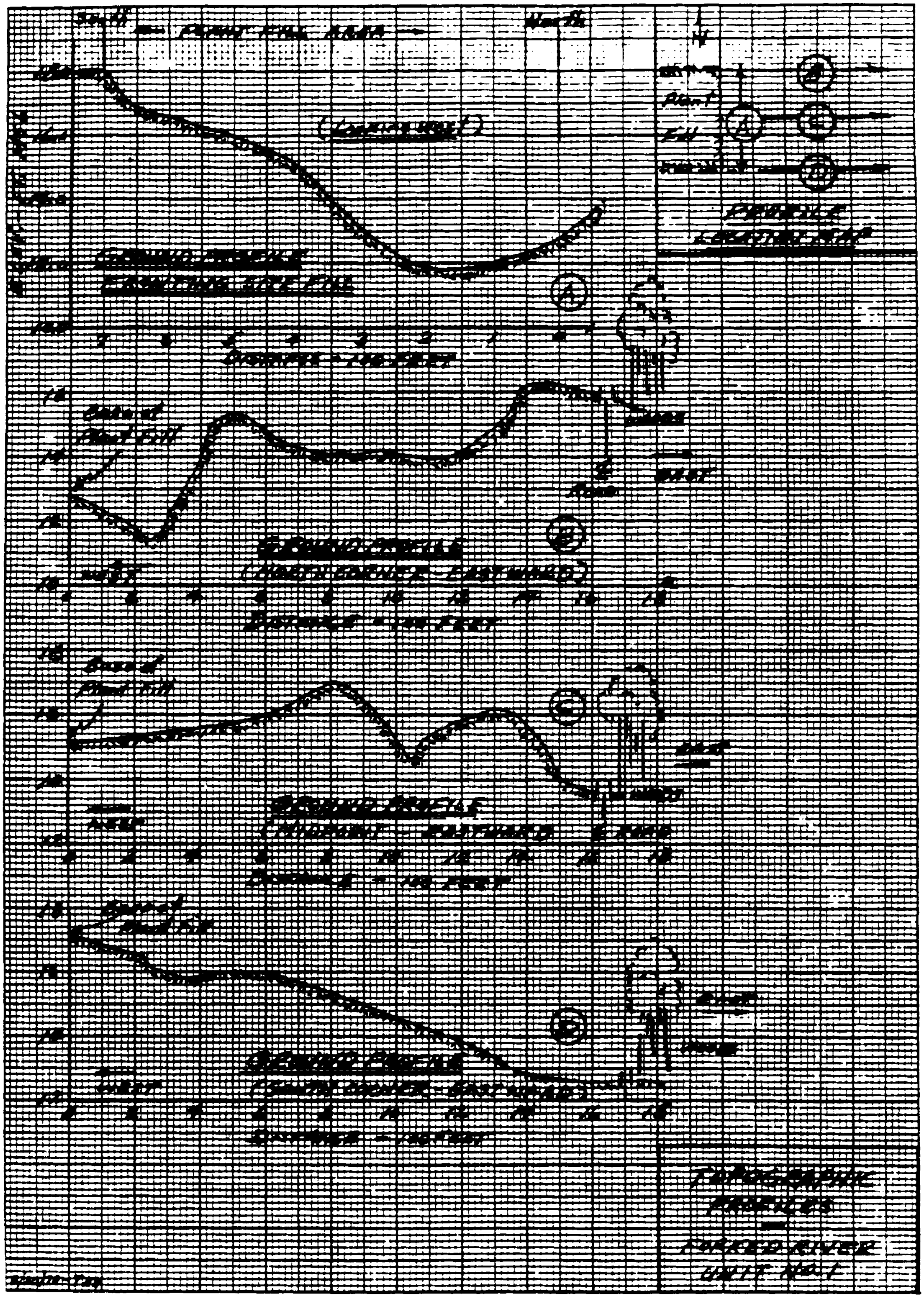


EXHIBIT 18

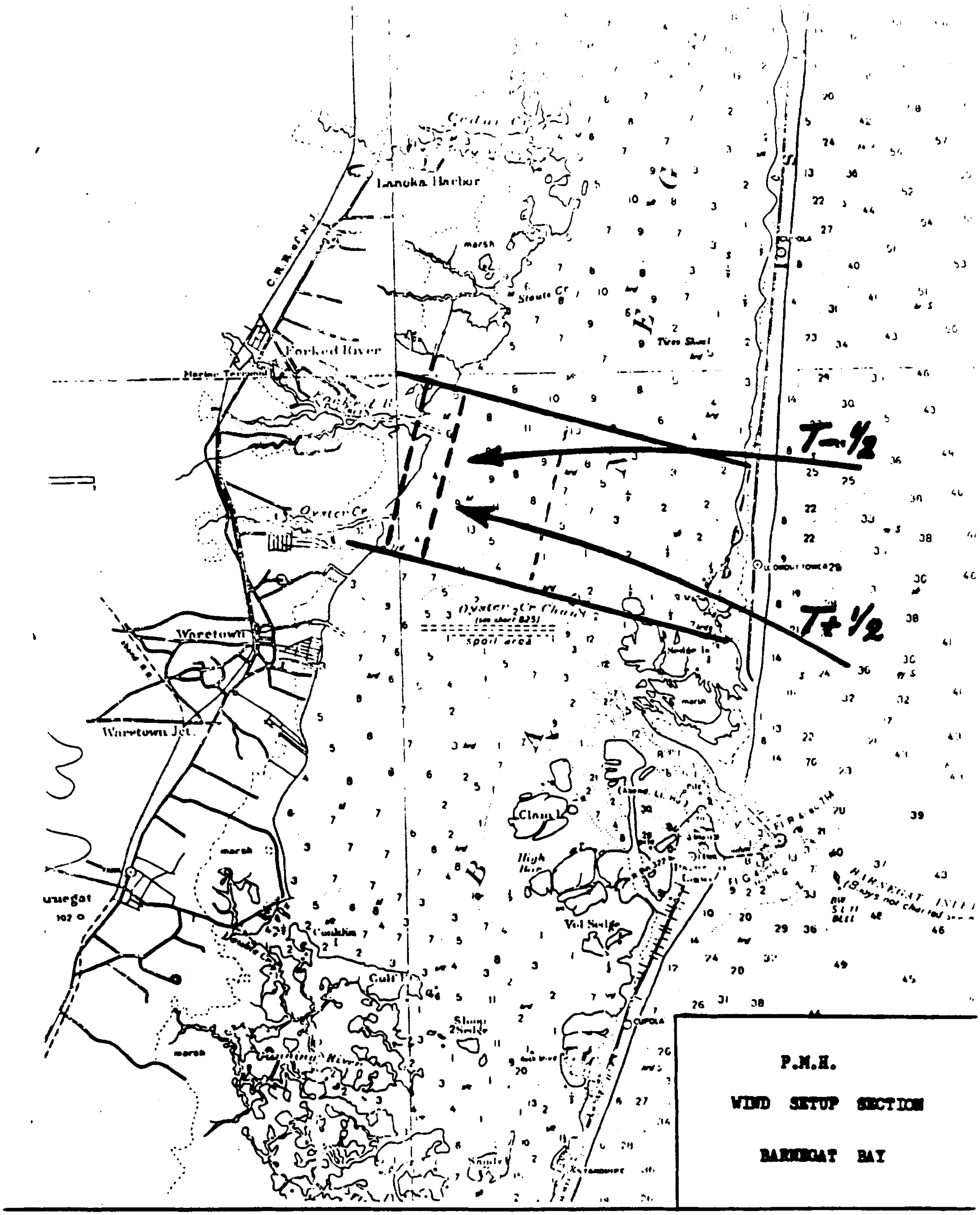

Lanoka Harbor
Forked River
Marine Terminal
Oyster Cr.
Oyster Cr. Chan.
spoil area
Waretown
Waretown Jct.
Clam I.
High Bar
Vol Sedge
Gulf Pt.
Sloop Sedge
Barnegat Inlet
Stouts Cr
Three Shoal
Cupola
Lookout Tower
marsh
T – 1/2
T + 1/2
P.M.H.
WIND SETUP SECTION
BARNEGAT BAY

EXHIBIT 19

Mile Section	Fetch (ft.)	Vav. (mph)	λ Ts	Dav. (ft.)	S (ft.)	Σ S (ft.)	Elev. (ft. MLW) -0.01 (node line)	
SETUP PORTION								
2.1 to 2.6	2,640	93.5	0.0995	3.4	1.18	1.18	+1.17	
2.6 to 3.2	3,168	94+	0.10037	3.3	1.45	2.63	+2.62	
3.2 to 3.5	1,584	95	0.1014	3.3	0.71	3.34	+3.33	
3.5 to 3.6+	550	95	0.1014	2.3	3.31	6.65	+6.64	Max.
SETDOWN PORTION								
1.6 to 2.1	2,640	92.5	0.0988	3.6	1.11	1.11	-1.12	
1.4 to 1.6	1,056	92	0.0982	5.7	0.29	1.40	-1.41	
0.6 to 1.4	4,224	91.5	0.0978	8.3	0.78	2.18	-2.19	
0.33 " 0.6	1,430	90.5	0.0963	2.3	0.93	3.11	-3.12	Min.

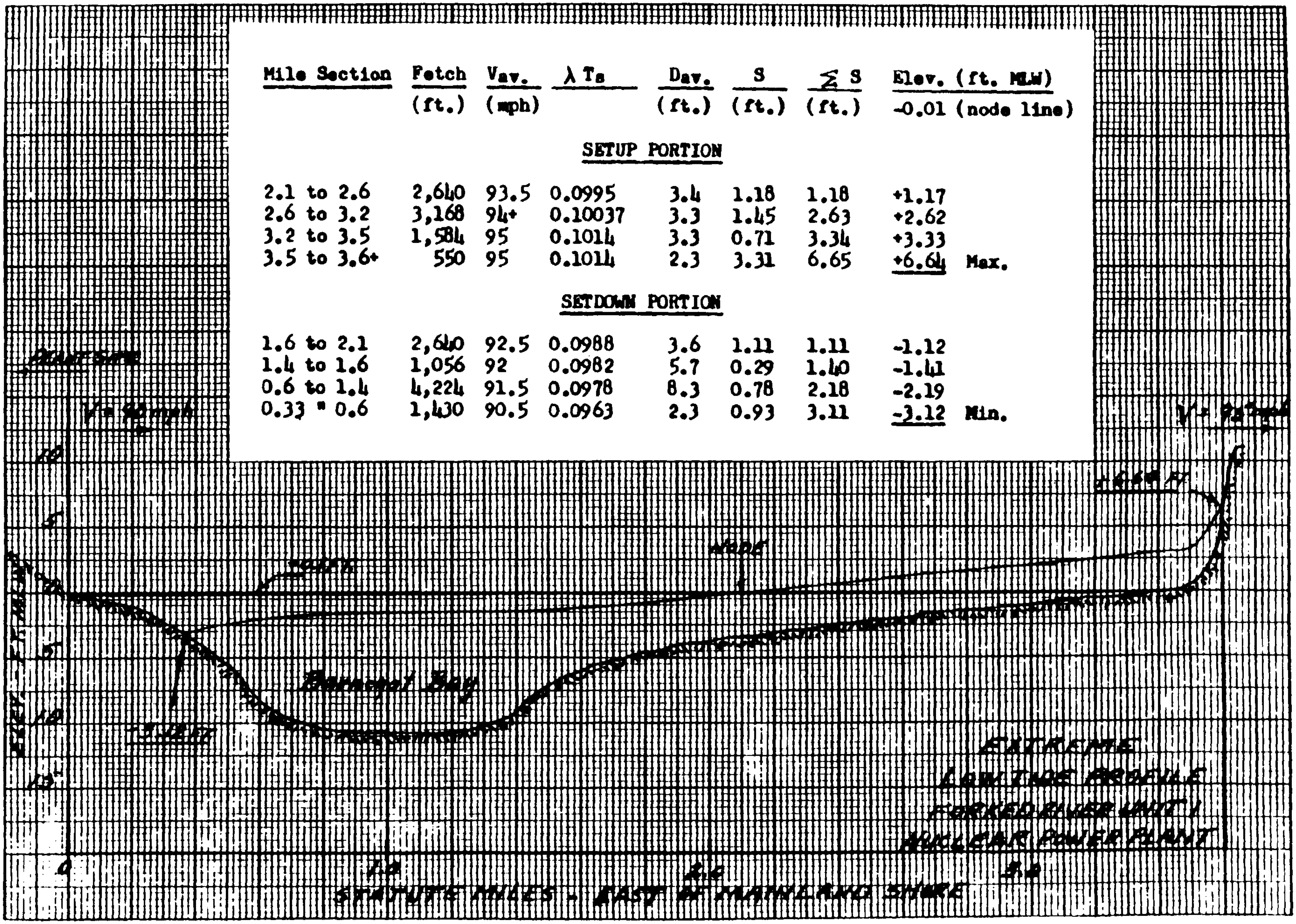


EXHIBIT 20

HURRICANE TIDE ESTIMATE - 1/250 YEAR EVENT

FORKED RIVER UNIT 1 NUCLEAR POWER PLANT

GENERAL

A preliminary estimate was made of the tide height to be expected in the vicinity of the Forked River Unit 1 nuclear power plant during an occurrence of a hurricane with a C.P.I. having a return frequency on the order of once in 250 years. Basic parameters describing the storm were taken from ESSA Memorandum HUR 7-97; a critical path for peak tide generation in both the ocean and bay was selected; available topographic and oceanographic data utilized in the P.M.H. tide report were employed where possible; basic tide computation procedures discussed in that report were used; tidal inflow and overflow estimates to the bay were calculated to obtain a mean bay level for wind tide generation across the bay to the plant site area. Those data and the criteria selected as well as procedures employed and results obtained are described in the following paragraphs.

HURRICANE PARAMETERS

As noted above, selection of the basic parameters describing the once in 250 year hurricane were taken from ESSA Memorandum HUR 7-97. They are as follows:

a. C.P.I. (p_o). Interpolation of values from Figure 4 of the memorandum relating central pressure to latitude at the point of storm landfall (approximately 39 degrees 10 minutes north)

resulted in a CPI value of 28.05 inches.

b. Radius of maximum winds (R). A moderate radius of maximum winds of 30 statute miles was selected as being representative of storms in this area (see Table A, Zone 4 of HUR 7-97).

c. Peripheral pressure (p_n). A peripheral pressure of 30.08 inches was selected from Figure 6 of HUR 7-97. Use of that value and the C.P.I. of 28.05 inches results in a maximum pressure effect of 2.31 feet at or near the center of the storm.

d. Maximum wind speed (V_x). From Figure 9, extrapolated to a C.P.I. of 28.05 inches, a maximum 30-foot overwater wind speed for a stationary storm of 75 miles per hour was determined.

e. Forward speed of the storm (T). A forward speed of 20 miles per hour was selected for this storm based essentially on results of the P.M.H. study. Adding half the forward speed to the maximum wind for the stationary storm results in a peak storm wind speed of 85 miles per hour.

f. Path. The path of this storm would be generally that selected for the P.M.H. as being critical for tide generation in the area. The storm would approach the New Jersey coastline from the southeast on an azimuth of about 135° from North. The storm center would pass inland some 30-32 statue miles south of Forked River.

HURRICANE TIDE COMPUTATIONS

General. Factors affecting the height of tide to be expected in

Barnegat Bay in the vicinity of the plant site were discussed at some length in the P.M.H. Tide report dated April 25, 1970. In general they relate to the height of peak tide reached along the oceanfront; the duration of tide above the beach dune elevations alongshore; the duration and volume of dune overtopping and overflow as well as the amount of inflow through Barnegat Inlet which affects the mean water level of the bay at the time of bay tide occurrence.

Procedures. The procedures used to compute the peak surge elevation along the oceanfront are those described in CERC Technical Report No. 4. A complete surge hydrograph for this storm was not computed; a theoretical hydrograph was approximated patterned generally after the shape of the P.M.H. tide hydrograph for a slow moving storm. As will be shown later in the report the duration and volume of tidal overflow is small compared to that of the P.M.H.; the primary contribution to bay volume increase is from inflow through the inlet.

Peak ocean tidal-surge elevation. Computations were made for the peak ocean tide at shore with the storm in a critical position at shore at time T_0. A total fetch of some 70 statute miles was used generally defining the limit of applicable wind directions over the fetch. Average wind speeds ranging from 70 mph at shore to a peak of 85 mph in the zone of maximum winds were used. The initial elevation at the ocean end of the fetch was 4.70 ft. MLW (astronomical tide) + 1.4 ft. (pressure effect) or 6.10 ft. MLW. One foot of wave

effect was added to the computed peak tide elevation at shore. The total peak tide elevation was determined to be 12.66 ft. MLW (11.16 ft. MSL).

Tidal overflow and inflow to Barnegat Bay. Area-elevation relationships for the reach of beachfront exposed to tidal overflow as derived in the P.M.H. tide report were used in this analysis. Based on an estimated tide hydrograph for this storm the total duration of overflow would be less than 4½ hours and would involve less that a 2-mile total overflow section of beachfront. Total overflow volume would be on the order of 48,000 acre feet, or about a 1-foot contribution to increased bay levels. Total tidal inflow volume through the inlet would be roughly 100,000 acre feet. With an initial bay elevation of 1.0 ft. MLW the added effect of tidal inflow and overflow, plus a one foot added height for pressure effect, will result in a mean bay level at time T_0 of approximately 4.0 ft. MLW.

Barnegat Bay wind tide computations. Procedures and formula for computing wind setup in the bay for the P.M.H. were employed in this analysis. An average half-hourly wind speed of 70-75 mph was used; average bottom elevations were obtained over a 3½ mile fetch across the bay for a two mile wide section of bay fronting the plant site. A wind tide elevation of 5.21 ft. MLW was determined; an added wave effect of from 0.3 to 0.5 ft. can be assumed to occur along the mainland shore which would result in a total peak tide elevation in the vicinity of the plant site of about 5.6 ft. MLW (5.3 ft. MSL).

CONCLUSIONS

Based on the above analysis the undersigned concludes that:

1. An occurrence of a hurricane having a return frequency on the order of once in 250 years on a critical path concurrent with high astronomical tide in the ocean will result in a peak tide level of 12.66 ft. MLW (11.16 ft. MSL) along the beachfront opposite the plant site.

2. Minimal tidal overflow and inflow to Barnegat Bay will raise bay levels to approximately 4.0 ft. MLW.

3. Wind effect in Barnegat Bay occurring on that bay level will result in a peak tide elevation on the order of 5.6 ft. MLW (5.3 ft. MSL) on the mainland shore.

Submitted by

Theodore E. Haeussner
Hydraulic Engineer Consultant
Jacksonville, Florida
April 25, 1970

RICHARD O. EATON - JUNE 22, 1970
CIRCULATING WATER SYSTEM
ENVIRONMENTAL CONSIDERATIONS

10812 ADMIRALS WAY
POTOMAC, MARYLAND 20854

MAILING ADDRESS
P. O. BOX 1246
ROCKVILLE, MARYLAND 20850

RICHARD O. EATON, P. E.
CONSULTING ENGINEER

TELEPHONE 299-9603
AREA CODE 301

June 22, 1970

Re: Oyster Creek Nuclear Station Unit 1
Forked River Nuclear Station Unit 1
Circulating Water System
Environmental Considerations

REFER TO: 2700-...
RPG 7/15

Mr. R. T. Richards, Project Engineer
Burns and Roe, Inc.
700 Kinderkamack Road
Oradell, New Jersey 07649

Dear Mr. Richards:

Pursuant to your letter June 5, 1970, we have reviewed the tidal flooding characteristics at the new Forked River Site. The enclosed report by my Associate, in which I concur, presents our conclusions in this regard.

Please inform me if any additional information is desired.

Sincerely,

Richard O. Eaton

ROE:w
Encl. TEH Report 6/18/70

cc Richard W. Haward, Jr.
Project Manager
Jersey Central Power & Light Co.

T. E. Haeussner

ADDENDUM

GENERAL

This Addendum is supplemental to the report "Determination of Probable Maximum Hurricane Flood Height-Forked River Unit 1 Nuclear Power Plant", dated April 25, 1970. The purpose of this addendum is to provide an evaluation of the tidal flood potential at a plant site located approximately 7,000 feet westward of that shown on Exhibit 17 of the above referenced report. The exact location of the relocated site can be seen on the enclosed Attachment, a reproduced portion of U.S.G.S. Quadrangle Sheet - Forked River, N.J. 1953. The evaluation postulates an occurrence of a Probable Maximum Hurricane identical in all aspects to and occurring under the same stipulated conditions as those described in the reference report.

TOPOGRAPHIC FEATURES

The relocated plant site is to be situated on a plateau within a 30 ft. MSL ground contour, as can be seen on the Attachment. The site is some 2½ to 3 statute miles inland from the west shore of Barnegat Bay. It is flanked north and south by the South Branch Forked River and Oyster Creek, respectively.

P.M.H. TIDAL FLOOD POTENTIAL

The peak Probable Maximum Hurricane tidal flood level that would

be attained along the western shore of Barnegat Bay, as determined in the above referenced report, is 19.5 ft. MSL occurring at time T+1 hours, or 1 hour after storm landfall. Because of the close proximity of the proposed site area to the bay shore little or no reduction in that flood level can be expected to occur in its movement up the Oyster Creek and South Branch Forked River channels to the site area. Wave action, including wave runup, is not expected to be a problem in the plant site area. Waves generated in Barnegat Bay were previously calculated to reach a maximum of 8 to 8.5 feet in height during the P.M.H. occurrence. The higher waves would break in moving inland when reaching State Road No. 9, the railroad, and other secondary roads which range in grade from 10 ft. up to 19 ft. MSL. The lesser waves would break progressively with distance westward as natural ground and river bank elevations north and south of the plant site gradually rise to the 20 ft. MSL contour (see Attachment for topography). Ground slope between the 20 and 30 ft. MSL contours in the site area ranges from 1 on 20 to 1 on 50. For those flat slopes wave runup resulting from wave heights on the order of 3 to 4 feet would be limited to values of approximately 1 to 2 feet above the peak tidal flood level of 19.5 ft. MSL. The maximum flood level including wave runup would therefore be on the order of 21.5 ft. MSL in the site area.

CONCLUSIONS

Based on the above evaluation the undersigned has drawn the following conclusions.

1. That the peak tidal flood level, including wave runup, that would result from the postulated Probable Maximum Hurricane occurrence would be on the order of 21.5 ft. MSL in the vicinity of the relocated Forked River Unit 1 nuclear power plant site.

2. That since the plant site is to be located on natural ground at elevation 30+ ft. MSL the resultant plant grade would be approximately 9 feet above the maximum probable flood level and therefore the plant site would not be subject to any flooding effects during a Probable Maximum Hurricane occurrence.

Submitted by

Theodore E. Haeussner
Theodore E. Haeussner
Hydraulic Engineer Consultant
Jacksonville, Florida
June 18, 1970

Attachment - Site Map

REPORT

PROBABLE MAXIMUM HURRICANE FLOOD ANALYSIS
OYSTER CREEK NUCLEAR UNIT NO.1

OYSTER CREEK, NEW JERSEY
FOR JERSEY CENTRAL POWER & LIGHT COMPANY.

March 2, 1972

EO (2)
NY (3)

2455-005-10

10812 ADMIRALS WAY
POTOMAC, MARYLAND 20854

TELEPHONE 299-5803
AREA CODE 301

RICHARD O. EATON, P. E.
CONSULTING ENGINEER

March 10, 1972

Mr. Philip Sherlock
Dames & Moore
14 Commerce Drive
Cranford, N. J. 07016

Dear Mr. Sherlock:

I have reviewed the report transmitted with your letter March 2, 1972, addressed to GPU Service Corporation re "Probable Maximum Flood Analysis, Oyster Creek Nuclear Unit No. 1". My comments follow:

a. Maximum Storm Surge Still Water Level. I am in accord with the analysis of maximum still water of +22' MSL at the western shore of Barnegat Bay as derived by AEC Consultants with the exception that I know of no justification for the factor of 1.1' ascribed as "initial tidal rise". Otherwise the analysis meets current AEC criteria for maximizing all of the variables, assuming simultaneous occurrence which is truly a fantastically remote occurrence. The addition of 1.1' to values thus derived ascribed to "initial rise" is, in my opinion, completely unsupported by any technical evaluation of which I am aware. In my judgment, the maximum still water level on the west side of Barnegat Bay cannot exceed +21' MSL by the most extreme logical reasoning.

b. Effect of Waves at the Plant Site. With respect to wave runup it is quite obvious that this will be governed primarily by topography between the western shore of Barnegat Bay and the plant site. A prime factor in this respect is the stabilized "Highway 9", at elevation 18' to 19' MSL, which traverses the land between the bay and the plant site. While detailed topography has not been presented it is apparent by inspection that the highway grade is only slightly higher than the adjacent terrain. Along the gently sloping gradient between Highway 9 and the plant site, while somewhat inadequately portrayed on Plate 10 but obvious from personal inspection, the wave heights of 3' to 4' passing over the highway embankment will progressively break and reform as the plant is approached. Runup of 1' above maximum SWL is considered to be a conservative estimate as expressed in relation to maximum SWL. This would result in no overtopping at plant grade of +23' MSL and freeboard of 1' for my preferred elevation of 21' for maximum SWL.

> Excavated areas for intake and discharge canals will present no hazard insofar as runup is concerned because of their alignment.

Summarizing, I believe that the report maximizes each parameter relating to total flooding and adds an unsupported factor of 1.1' described as "initial rise". The result, in my judgment, represents a maximum possible condition plus a factor of safety of at least 1'. Probability of occurrence is so remote as to be almost inconceivable. Wave runup, when governed by topography as in this case, is quite accurately determinable. Effects of wave stresses, either impact or uplift, become nominal in a site of this character. I therefore regard the results of our study to be ultra-conservative.

Sincerely yours,

Richard O. Eaton
Consulting Engineer

ROE:w

REPORT

PROBABLE MAXIMUM HURRICANE FLOOD ANALYSIS

OYSTER CREEK NUCLEAR UNIT NO.1

OYSTER CREEK, NEW JERSEY

FOR

JERSEY CENTRAL POWER & LIGHT COMPANY

INTRODUCTION

This report presents the results of our flood analysis for the Oyster Creek Nuclear Unit No.1 , Oyster Creek, New Jersey. The Oyster Creek Plant is located at approximately Latitude 39°49' on the eastern coastline of New Jersey 1.5 nautical miles inland from the western shoreline of Barnegat Bay as shown on Plate 1.

All elevations unless otherwise indicated are in feet and refer to Mean Sea Level Datum as Zero.

PURPOSE

The purpose of our study was to perform flood analyses to establish design criteria for suitable flood protection of Class 1 structures. The Oyster Creek Nuclear Unit No.1 plant layout is shown on Plate 2.

SCOPE

The scope of our analysis included an evaluation of the following:

1.. Wind-generated waves.

2. Flood levels.

3. Wave forces.

Work pertinent to this analysis conducted prior to this report included:

1. Hurricane storm surge analyses resulting in a probable maximum hurricane (PMH) stillwater level of +22 feet Mean Sea Level (MSL) at the western side of Barnegat Bay fronting the Oyster Creek Unit No. 1 during a high astronomical tide condition.* (Reference 1)
2. Procedure for routing the open coast surge into Barnegat Bay.** (Reference 2)

BASIC DATA AND ASSUMPTIONS

Basic data and assumptions for our analysis included:

1. The PMH stillwater level at the western side of Barnegat Bay was taken at +22 feet MSL as requested by the AEC.
2. A surge hydrograph giving maximum stillwater levels at the western side of Barnegat Bay was developed by using the Barnegat Bay surge hydrograph of Reference 2.
3. A wind field for the PMH parameters was developed for use in calculating wind-generated waves.
4. The calculation methods for wave generation of Coastal Engineering Research Center (CERC), "Shore Protection, Planning, and Design," Technical Report No. 4, 1966, were used.

---

* D. J. Skovolt, AEC letter to R. H. Sims dated 12-29-71.

** Theodore E. Haeussner, Report-Determination of M.P.H. Flood Height for Oyster Creek, Units 1 and 2, Copy No. 1, December 21, 1968.

PROBABLE MAXIMUM STILLWATER LEVELS AT THE PLANT SITE

The open coast surge was calculated in References 1 and 2. Its effects were routed into Barnegat Bay to determine the probable maximum stillwater levels at the plant site. The PMH parameters used by the AEC (Reference 1) in calculating the open coast surge were:

1. A central pressure index of 27.10 inches of mercury.
2. An asymptotic pressure of 30.70 inches of mercury.
3. A radius of maximum winds of 39 nautical miles.
4. A maximum gradient wind speed of 133.0 miles per hour.
5. A forward translational speed of 12 knots and 23 knots.
6. A bottom friction factor of 0.008.
7. An initial rise in water level of 1.1 feet.
8. An astronomical high spring tide of 4.2 feet above Mean Low Water (MLW).

In evaluating the stillwater levels at the plant site on the western shore of Barnegat Bay, the following were considered:

1. The amount and duration of tidal overflow of Island Beach (the beach island).
2. The amount and duration of tidal inflow through Barnegat Inlet and through the eroded sections of the beach island.
3. The extent of wind setup across Barnegat Bay.
4. Local wave setup.

These four items were analyzed in Reference 2 for an open coast PMH stillwater elevation of 16.75 feet MSL. The result was a maximum stillwater elevation of 19.5 feet MSL at the plant site that occurred one hour after the maximum open coast stillwater elevation.

The approximate stillwater hydrograph was developed at the plant site as shown on Plate 3 by considering the following:

1. The open coast surge hydrographs of the AEC (Reference 1) and of Reference 2.
2. The surge hydrograph for Barnegat Bay of Reference 2.
3. The inflow-overflow curves of Reference 2.
4. The hurricane wind field developed using the PMH parameters of the AEC.

By using the AEC open coast surge hydrograph in conjunction with the open coast surge hydrograph and inflow-overflow curves of Reference 2, an approximate time history of additional inflow-overflow was determined for use in adjusting the Barnegat Bay surge hydrograph of Reference 2 upward to a peak value of +22 feet MSL. This stillwater hydrograph also includes the effects of wind and wave setup, and is, therefore, used as the plant site stillwater hydrograph. The hurricane wind field developed using the PMH parameters was adjusted for nearshore land effects and was then propagated across Barnegat Bay. Component wind velocities were calculated along the storm traverse as shown on Plate 4 in order to consider wind setup and wind-generated waves. The time history of these component winds is shown on Plate 5. This wind profile and the stillwater hydrograph, shown on Plate 3, including the effects of wind and wave setup, at the plant site, were used in the following analyses.

WIND-GENERATED WAVES

GENERAL

Wave characteristics are dependent upon wind speed, wind duration, water depth and fetch length. Generated waves were calculated coincidental with the maximum surge hydrograph to determine the maximum flood elevation.

FETCH

Deepwater fetches were not considered because the larger deep-water-generated waves would break on reaching Island Beach. The elevation of the island, ranging from 0 to +40 feet, as shown on Plate 4, would be reduced by approximately five feet along its lower elevations by wave erosion. Most of the erosion would occur primarily during the surge recession when wave direction would be offshore rather than onshore. Therefore, the critical wave conditions would be the shallow water waves generated within Barnegat Bay. The fetch distance would be approximately five nautical miles (along the hurricane traverse) across Barnegat Bay from Island Beach to the Oyster Creek Plant Unit No.1 as shown on Plate 6.

WIND

As hurricanes move towards the coast, wind speeds and directions are dependent upon location and time. In order to prepare a wind distribution for the purpose of wave forecasting, the wind vectors along the storm traverse were calculated using the hurricane wind field. A component wind profile was then plotted as shown on Plate 5 using the time history of average wind vectors over the fetch length.

WAVE CHARACTERISTICS

Shallow water waves were generated by using Fig.1-32 of CERC, T.R. No.4*. These significant shallow water wave heights and periods, based on the fetch length, component wind profile and average water depth are plotted on Plate 7. The generated wave height and period profiles have a phase shift in time of +0.5 hour over the wind profile to allow for the generation and travel of waves to the site. The maximum significant wave height and period is 8.7

*U.S.Army Coastal Engineering Research Center (1966). Shore Protection Planning and Design, Technical Report No.4, 3rd Edition.

feet and 6.3 seconds, respectively. This significant wave occurs during stillwater level of +21.3 feet Mean Sea Level as shown on Plate 7 at the site location.

The significant wave height was obtained from statistical analysis of synoptic weather charts. Approximate relationships of the significant wave height to other parameters of the normal wave spectra were defined. The maximum wave height curve*, as shown on Plate 7 is based on the significant wave height curve. The maximum wave height is 14.5 feet but will not occur at the site because of insufficient water depth.

DESIGN WAVES

Selection of design waves depends on the offshore waves at the site, the structures being considered, and the available water depths fronting the structures. Generated wave conditions during the PMH occurrence were propagated shoreward to the plant structures. Topographic data indicate that the elevation of Highway 9 to the east of the plant site is about 18 to 19 feet MSL. As shown on Plate 8 the top of fill elevation surrounding the plant site will be at least +23 feet MSL, and this fill will be graded towards Highway 9, east of the plant. Therefore, as land elevations rise abruptly to the west, waves would break progressively westward and would not reach the plant site area. The only wave action that could reach the plant site would result from possible waves traveling up the 100 to 140 feet wide intake and discharge channels. This wave action would be small because of channel friction, trees, vegetation, and other obstructions adjacent to the channels, the two bridges in the intake and discharge channels, the 90 degree curvature of the channels in the plant area, and the fact that the intake and discharge structures are located on the westward side of the power plant. Therefore the largest wave

*Considered as the one percent wave in this analysis as requested by the AEC.

that could possibly reach the intake and discharge structures is on the order of one foot.

FLOOD LEVELS

The generated waves coming from the east, break far eastward of the site because the minimum top of levee elevation at the plant is +23. Maximum waves that might break in the area of Highway 9 will depend on the available water depth. Time histories of the maximum wave heights without breaking (H_b) that might reach and runup on the graded plant fill are shown on Plate 7. Using these data, the maximum design wave height was computed as 3.1 feet during a stillwater elevation of +22 feet MSL. Runup would be less than one foot; therefore, there will be no wave overtopping of the +23 feet MSL top of plant fill.

The top of both the intake and discharge structures is at elevation 15 feet MSL. Because these structures are located on the western side of the plant, they will not experience as high a stillwater level as the eastern side of the plant which is directly exposed to the wave and wind setup. Maximum stillwater levels against the intake and discharge structures would be less than +20 feet MSL. However, during maximum stillwater levels, a one-foot wave could pass across the intake and discharge structures and runup on the 2;1 backfilled slope in front of the turbine building. Maximum runup would be about 2.2 feet for a smooth slope and about one foot for a rough slope such as rip-rap, resulting in a maximum flood elevation of 22.2 feet MSL. Therefore, the +23 feet top of backfill elevation in front of the turbine building would not be overtopped.

The maximum flood level for plant structures would be caused by the maximum stillwater level, or +22 feet MSL. Plate 10 illustrates the boundaries

of flooded land in the vicinity of the Oyster Creek Nuclear Unit No.1 during a stillwater level of +22 feet MSL.

WAVE FORCES

There will be no wave forces against plant structures except for the intake and discharge structures because the plant grade elevation of 23 feet MSL protects plant strucutres from wave action. As wave action is small at the intake and discharge structures, the maximum wave forces against these structures will essentially be the hydrostatic pressures resulting from a stillwater elevation of +22 feet MSL. The generated waves will break to the east of the plant site against the graded fill during the higher water levels. For design purposes the maximum significant wave height that may break against this graded fill is 3.1 feet.

CONCLUSIONS

Based on the above discussions and analyses the following is concluded:

1. The maximum stillwater elevation at the site, as determined by the AEC, is +22 feet MSL.
2. With the surrounding top of the plant site fill to at least Elevation +23 feet MSL, plant structures are protected against wave runup.
3. The maximum flood elevation for plant structures is +22 feet MSL.
4. Plant structures are protected against wave forces.

The following Plates are attached and complete this Report:

Plate 1	-	Site Location
Plate 2	-	Plot Plan
Plate 3	-	PMH Stillwater Level at Oyster Creek Nuclear Unit No.1
Plate 4	-	Storm Traverse
Plate 5	-	Component Wind Profile
Plate 6	-	Storm Traverse Depth Profile
Plate 7	-	Wave Characteristics and Stillwater Levels versus Time.
Plate 8	-	Site Plan
Plate 9	-	Intake & Turbine Area Excavation and Backfill Plan and Sections.
Plate 10	-	Boundaries of Flooded Land during the PMH Occurrence.

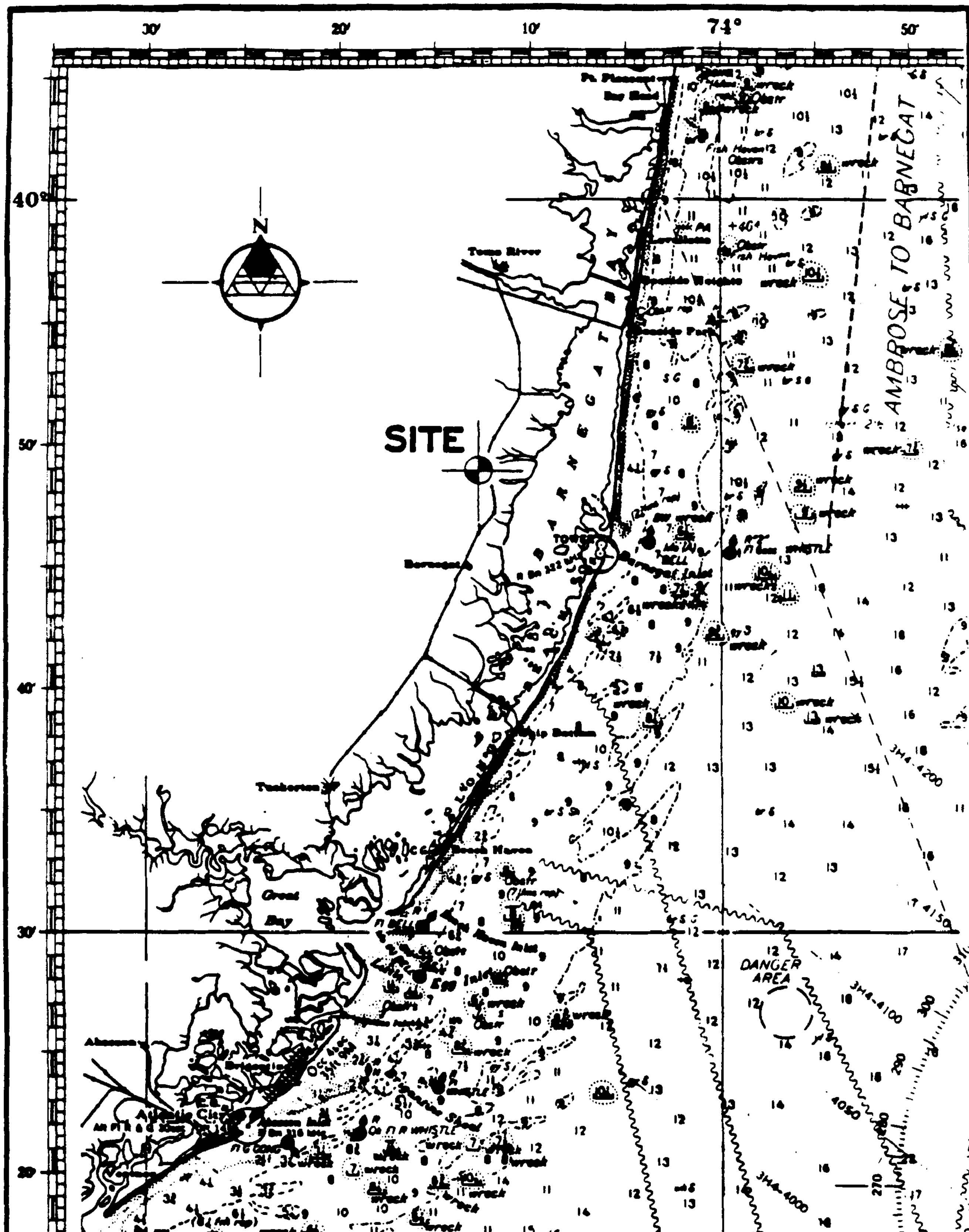
Respectfully submitted,

DAMES & MOORE

(for)

Philip Sherlock

PS-UK-bak
(5 copies submitted)



REFERENCE:

SITE LOCATION

C & G S 1108

(Approaches to New York)

SOUNDINGS IN FATHOMS - SCALE 1:400,000

Published at Washington, D. C.
U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

DAMES & MOORE

PLATE 1

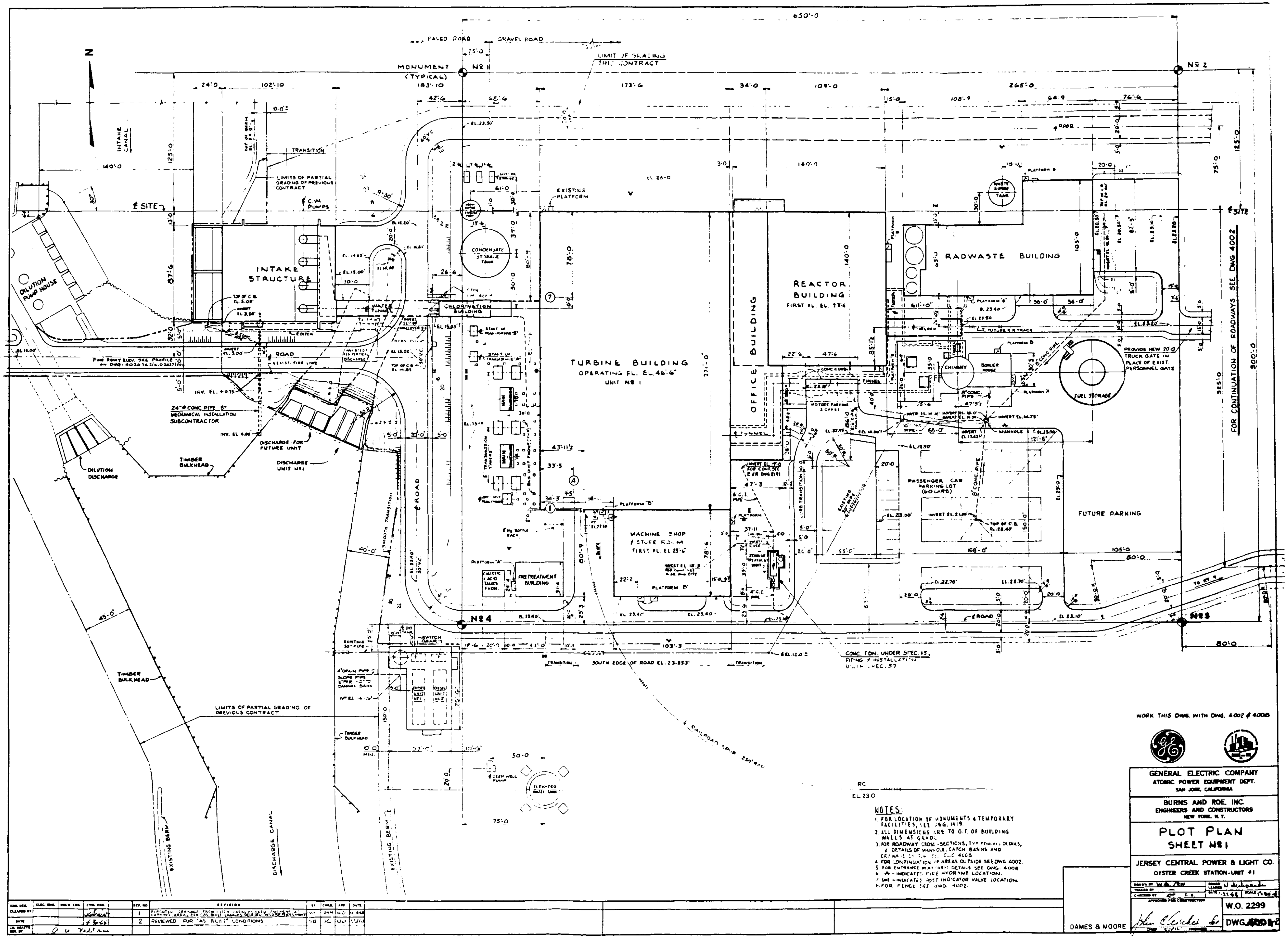
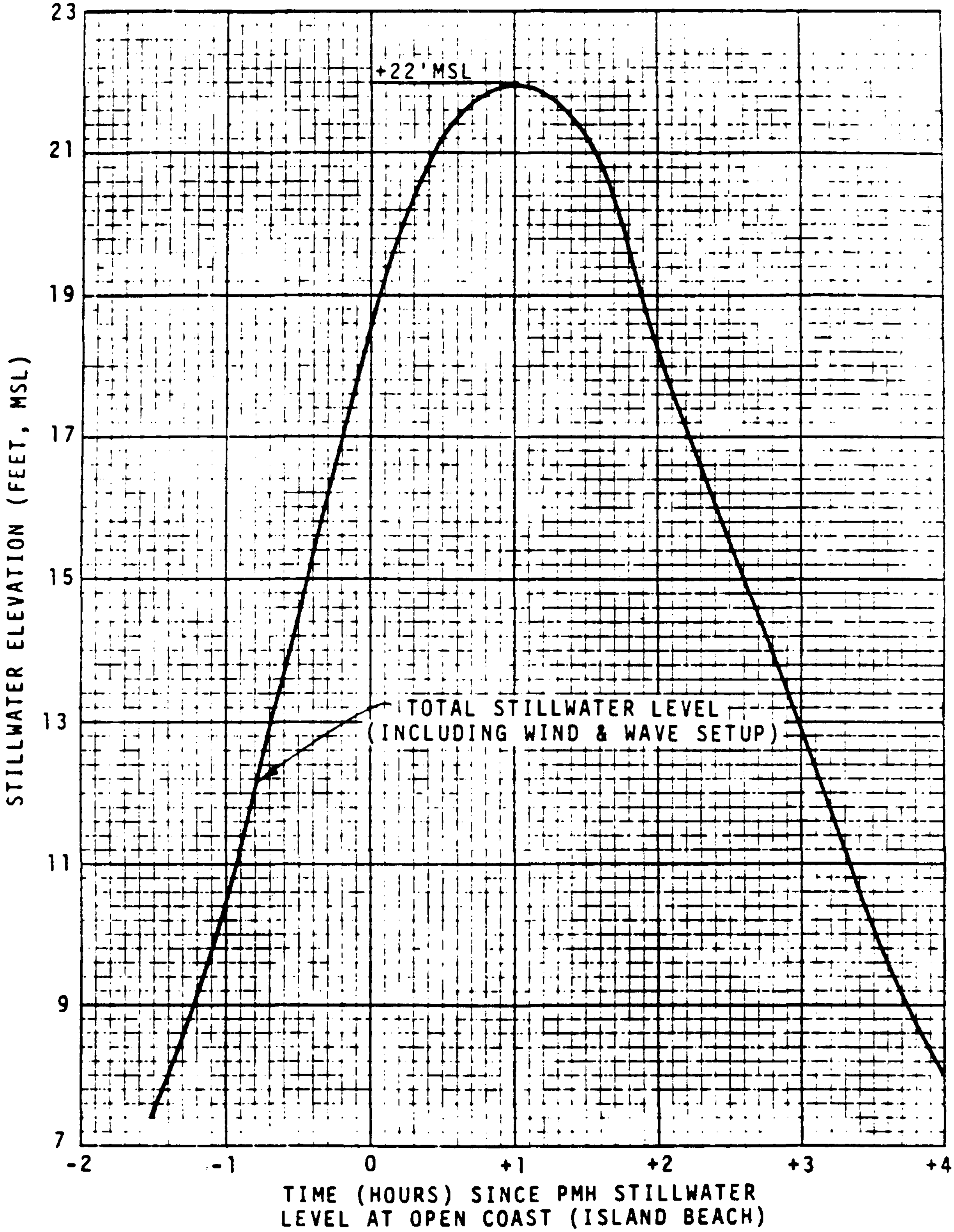

N
MONUMENT (TYPICAL)
Nº 1
Nº 2
Nº 3
Nº 4
650'-0
PAVED ROAD
GRAVEL ROAD
LIMIT OF GRADING THIS CONTRACT
INTAKE CANAL
TRANSITION
LIMITS OF PARTIAL GRADING OF PREVIOUS CONTRACT
℄ C.W. PUMPS
℄ SITE
DILUTION PUMP HOUSE
INTAKE STRUCTURE
WATER TUNNEL
EXISTING PLATFORM
CONDENSATE STORAGE TANK
CHLORINATION BUILDING
TURBINE BUILDING
OPERATING FL. EL. 46'-6"
UNIT Nº 1
OFFICE BUILDING
REACTOR BUILDING
FIRST FL. EL. 23'-6
RADWASTE BUILDING
CHIMNEY
BOILER HOUSE
FUEL STORAGE
PROVIDE NEW 20'-0 TRUCK GATE IN PLACE OF EXIST. PERSONNEL GATE
FOR CONTINUATION OF ROADWAYS SEE DWG 4002
24"⌀ CONC PIPE BY MECHANICAL INSTALLATION SUBCONTRACTOR
DISCHARGE FOR FUTURE UNIT
DISCHARGE UNIT Nº1
TIMBER BULKHEAD
DILUTION DISCHARGE
MACHINE SHOP & STORE ROOM
FIRST FL. EL. 23'-6"
PRETREATMENT BUILDING
PASSENGER CAR PARKING LOT (60 CARS)
FUTURE PARKING
SWITCH GEAR
SOUTH EDGE OF ROAD EL. 23.353'
CONC. FDN. UNDER SPEC. 15, PIPING & INSTALLATION UNDER SPEC. 57
LIMITS OF PARTIAL GRADING OF PREVIOUS CONTRACT
℄ RAILROAD SPUR
DEEP WELL PUMP
ELEVATED WATER TANK
EXISTING BERM
DISCHARGE CANAL
WORK THIS DWG. WITH DWG. 4002 & 4008
RC
EL 23.0
NOTES:
1. FOR LOCATION OF MONUMENTS & TEMPORARY FACILITIES, SEE DWG. 1419.
2. ALL DIMENSIONS ARE TO O.F. OF BUILDING WALLS AT GRADE.
3. FOR ROADWAY CROSS-SECTIONS, TYP. FENCING DETAILS, & DETAILS OF MANHOLE, CATCH BASINS AND DRAINAGE SYSTEM SEE DWG 4005
4. FOR CONTINUATION OF AREAS OUTSIDE SEE DWG 4002.
5. FOR ENTRANCE PLATFORM DETAILS SEE DWG. 4008
6. -INDICATES FIRE HYDRANT LOCATION.
7. -INDICATES POST INDICATOR VALVE LOCATION.
8. FOR FENCE SEE DWG. 4002.
REVIEWED FOR "AS BUILT" CONDITIONS
GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPT.
SAN JOSE, CALIFORNIA
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
NEW YORK, N.Y.
PLOT PLAN
SHEET Nº1
JERSEY CENTRAL POWER & LIGHT CO.
OYSTER CREEK STATION-UNIT #1
APPROVED FOR CONSTRUCTION
W.O. 2299
DAMES & MOORE

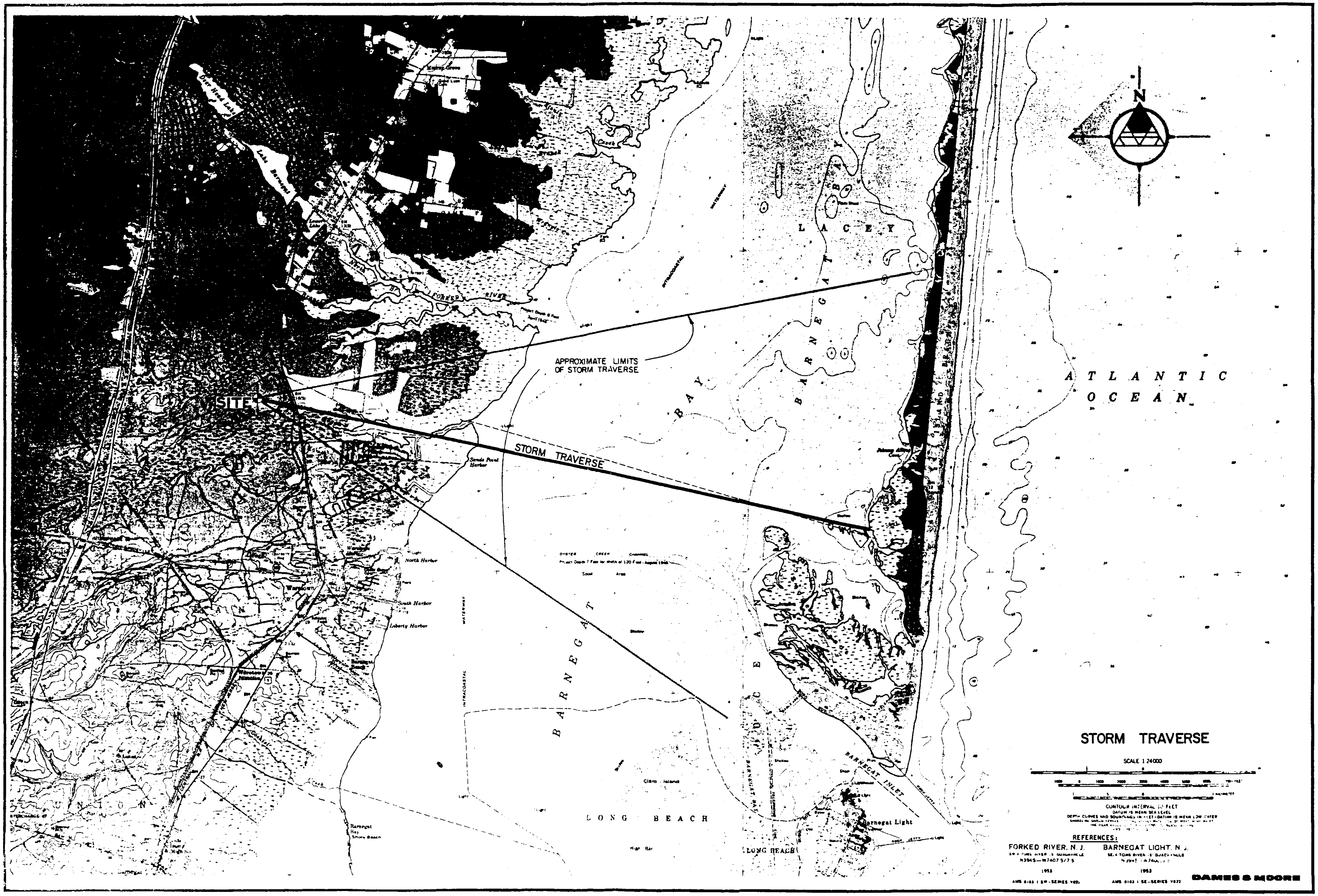
PLATE 2



PMH STILLWATER LEVEL

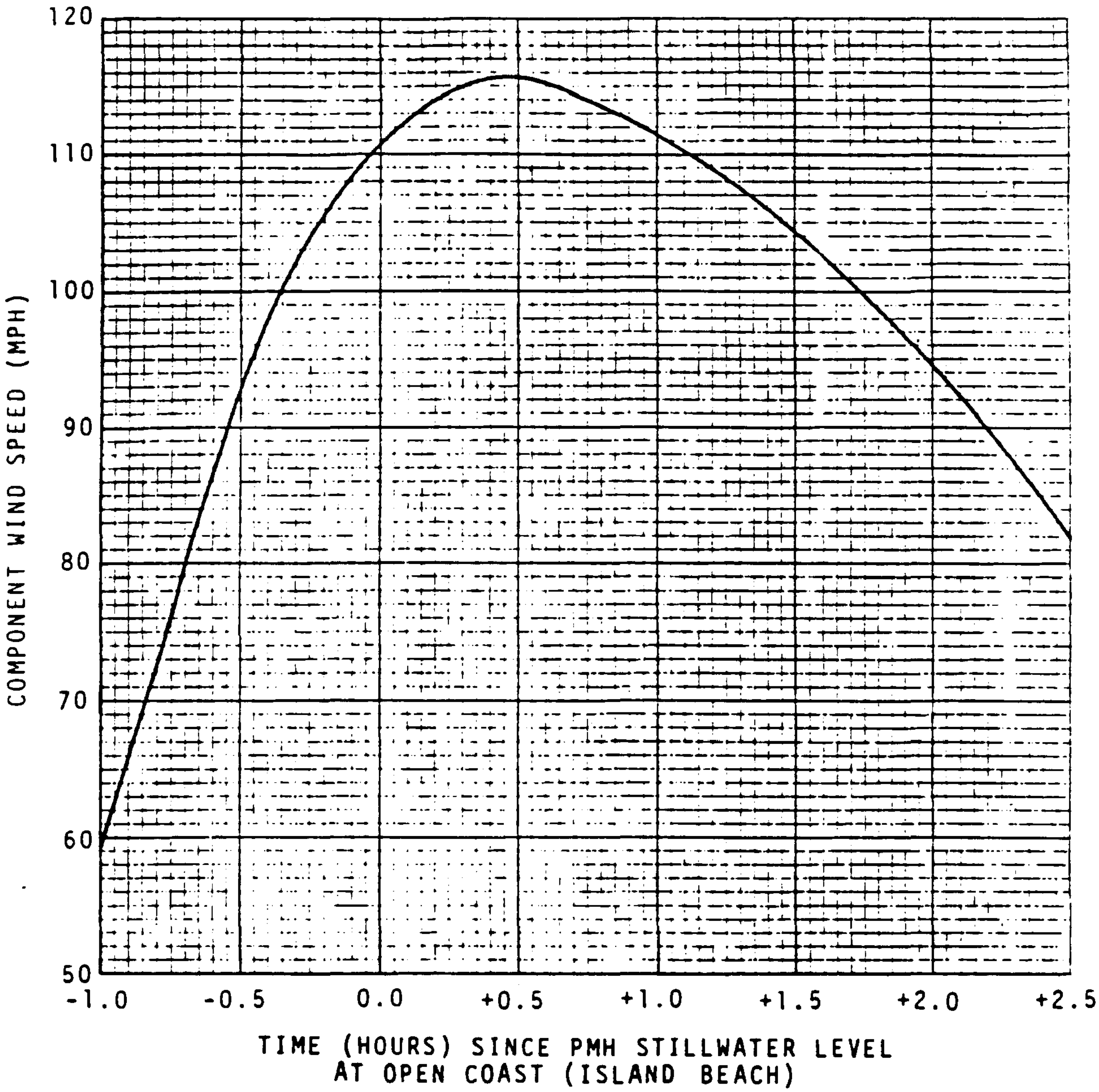
AT OYSTER CREEK NUCLEAR UNIT I

DAMES & MOORE



N
ATLANTIC OCEAN
APPROXIMATE LIMITS OF STORM TRAVERSE
SITE
STORM TRAVERSE
LACEY
BARNEGAT BAY
BARNEGAT
FORKED RIVER
Sands Point Harbor
North Harbor
South Harbor
Liberty Harbor
OYSTER CREEK CHANNEL
INTRACOASTAL WATERWAY
BARNEGAT INLET
Barnegat Light
LONG BEACH
OCEAN
UNION
STORM TRAVERSE
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
REFERENCES:
FORKED RIVER, N. J.
BARNEGAT LIGHT, N. J.
1953
1953
DAMES & MOORE

PLATE 4

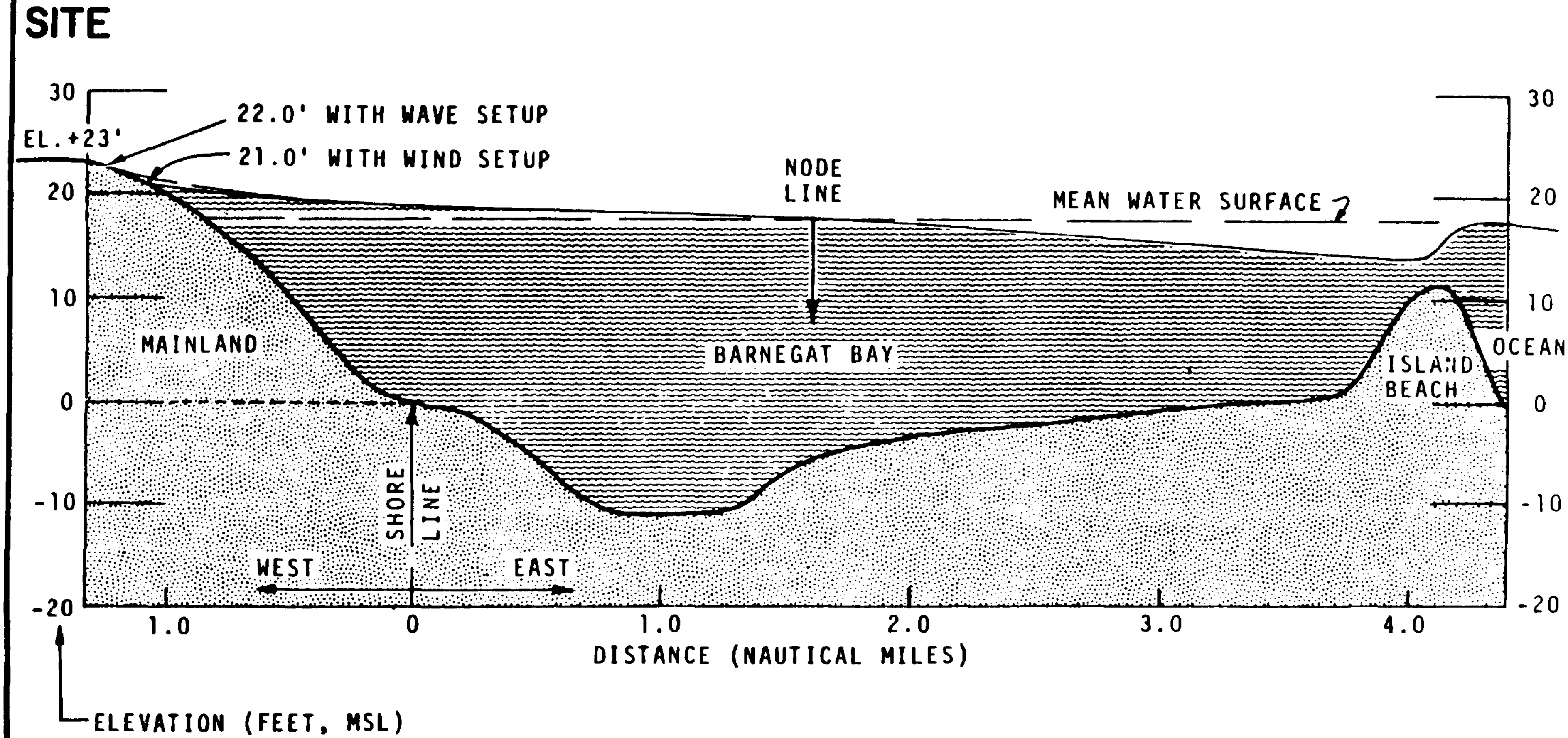


COMPONENT WIND PROFILE

FOR 5 NAUTICAL MILE FETCH

(FETCH SHOWN ON PLATES 4 & 6)

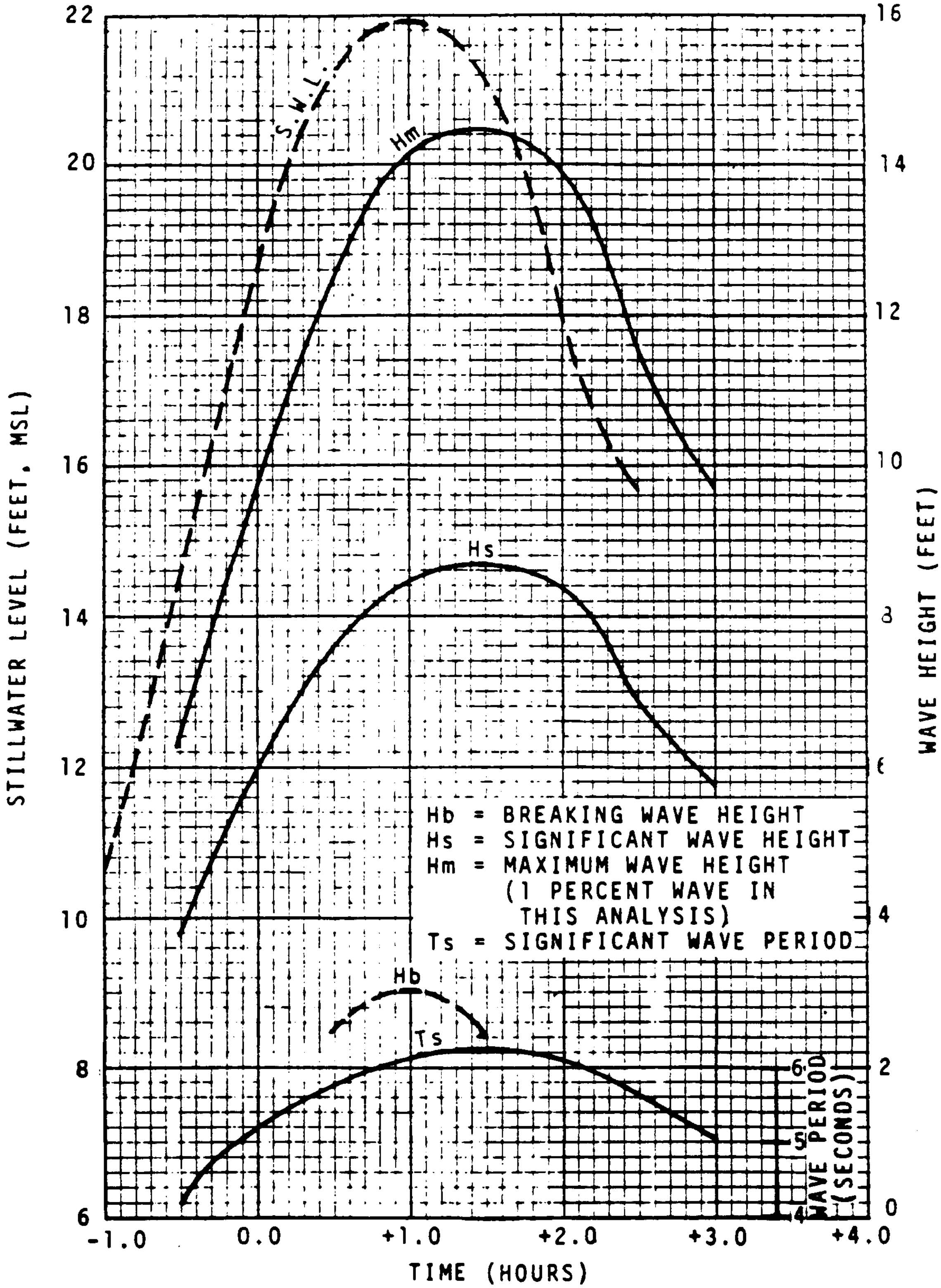
DAMES & MOORE



STORM TRAVERSE DEPTH PROFILE

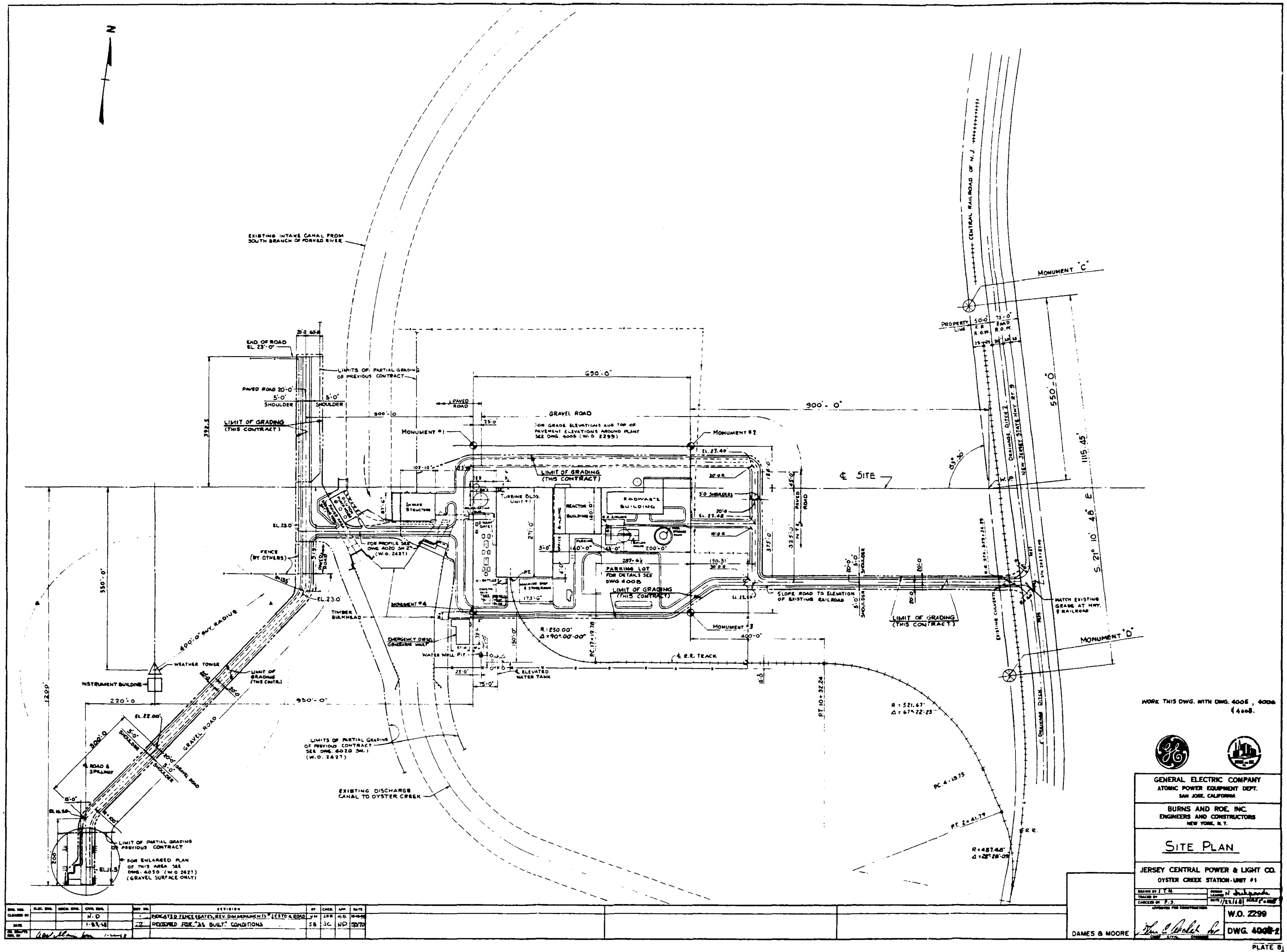
DAMES & MOORE

PLATE 6



WAVE CHARACTERISTICS & STILLWATER LEVELS VS. TIME

DAMES & MOORE


N
EXISTING INTAKE CANAL FROM SOUTH BRANCH OF FORKED RIVER
CENTRAL RAILROAD OF N.J.
MONUMENT "C"
MONUMENT "D"
PROPERTY LINE
R.R. R.O.W.
ROAD R.O.W.
DRAINAGE DITCH
NEW JERSEY STATE HWY. RT. 9
550'-0"
1115.45'
S 21° 10' 48" E
900'-0"
650'-0"
℄ SITE
END OF ROAD EL. 23'-0"
LIMITS OF PARTIAL GRADING OF PREVIOUS CONTRACT
PAVED ROAD 20'-0"
5'-0" SHOULDER
LIMIT OF GRADING (THIS CONTRACT)
GRAVEL ROAD
FOR GRADE ELEVATIONS AND TOP OF PAVEMENT ELEVATIONS AROUND PLANT SEE DWG. 4005 (W.O. 2299)
MONUMENT #1
MONUMENT #2
MONUMENT #3
MONUMENT #4
INTAKE STRUCTURE
TURBINE BLDG. UNIT #1
REACTOR BUILDING
RADWASTE BUILDING
OFFICE BUILDING
PARKING LOT FOR DETAILS SEE DWG. 4005
SLOPE ROAD TO ELEVATION OF EXISTING RAILROAD
MATCH EXISTING GRADE AT HWY. & RAILROAD
EXISTING CULVERTS
FENCE (BY OTHERS)
FOR PROFILE SEE DWG. 4020 SH. 2 (W.O. 2627)
TIMBER BULKHEAD
EMERGENCY DIESEL GENERATOR VAULT
WATER WELL PIT
ELEVATED WATER TANK
℄ R.R. TRACK
R = 250.00'
Δ = 90°-00'-00"
R = 521.67'
Δ = 67°-22'-23"
R = 487.46'
Δ = 28°-28'-05"
400'-0" GUY RADIUS
WEATHER TOWER
INSTRUMENT BUILDING
220'-0"
950'-0"
1200'
350'-0"
℄ ROAD & SPILLWAY
LIMITS OF PARTIAL GRADING OF PREVIOUS CONTRACT SEE DWG. 4020 SH. 1 (W.O. 2627)
EXISTING DISCHARGE CANAL TO OYSTER CREEK
LIMIT OF PARTIAL GRADING OF PREVIOUS CONTRACT
FOR ENLARGED PLAN OF THIS AREA SEE DWG. 4030 (W.O. 2627) (GRAVEL SURFACE ONLY)
WORK THIS DWG. WITH DWG. 4005, 4006 & 4008.
INDICATED FENCE (GATES), REV. DIM. MONUMENTS ... & ROAD
REVISED FOR "AS BUILT" CONDITIONS
GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPT.
SAN JOSE, CALIFORNIA
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
NEW YORK, N.Y.
SITE PLAN
JERSEY CENTRAL POWER & LIGHT CO.
OYSTER CREEK STATION - UNIT #1
DRAWN BY I.T.M.
CHECKED BY P.S.
DATE 1/22/68
APPROVED FOR CONSTRUCTION
W.O. 2299
DWG. 4008-2
DAMES & MOORE
PLATE 8

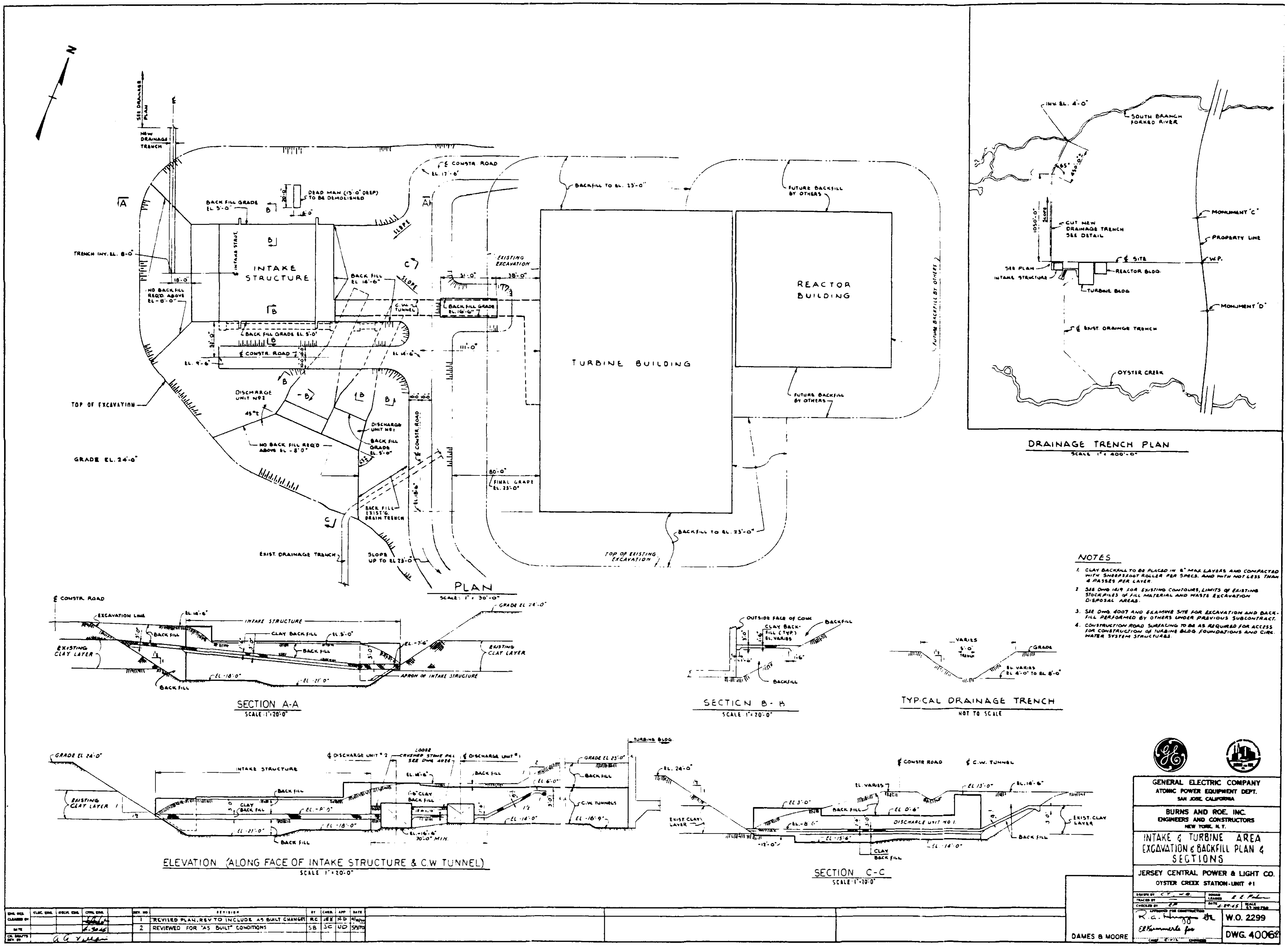
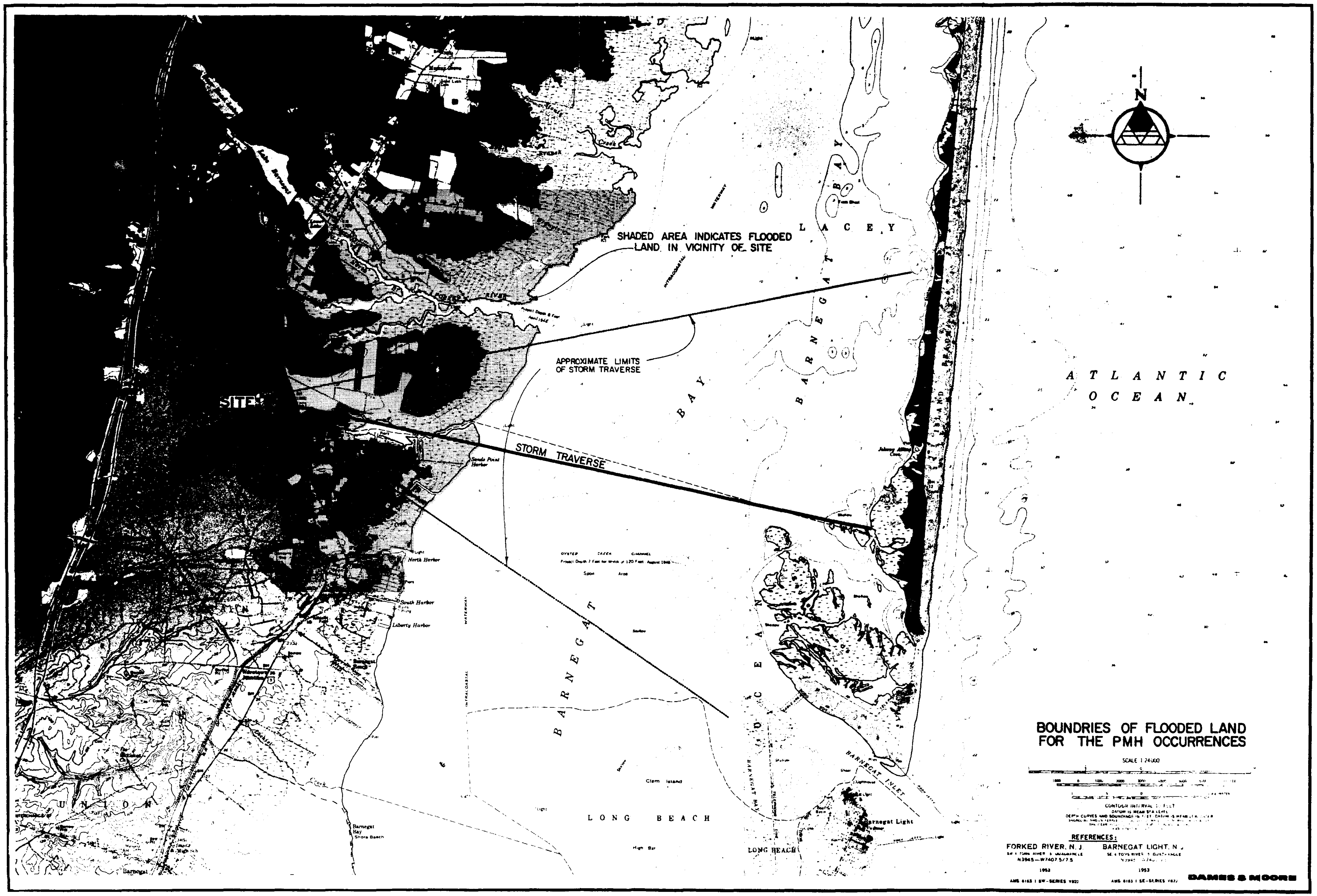

PLAN
SCALE: 1" = 30'-0"
N
INTAKE STRUCTURE
TURBINE BUILDING
REACTOR BUILDING
TOP OF EXCAVATION
GRADE EL. 24'-0"
TRENCH INV. EL. 8'-0"
NO BACK FILL REQ'D. ABOVE EL - 8'-0"
BACK FILL GRADE EL 5'-0"
DEAD MAN (15'-0" DEEP) TO BE DEMOLISHED
DISCHARGE UNIT NO 2
DISCHARGE UNIT NO 1
NO BACK FILL REQ'D ABOVE EL - 8'-0"
BACKFILL TO EL. 23'-0"
FUTURE BACKFILL BY OTHERS
FINAL GRADE EL. 23'-0"
TOP OF EXISTING EXCAVATION
EXISTING EXCAVATION
EXIST. DRAINAGE TRENCH
SLOPE UP TO EL 23'-0"
C.W. TUNNEL
℄ CONSTR. ROAD
DRAINAGE TRENCH PLAN
SCALE 1" = 400'-0"
SOUTH BRANCH FORKED RIVER
OYSTER CREEK
MONUMENT "C"
MONUMENT "D"
PROPERTY LINE
CUT NEW DRAINAGE TRENCH SEE DETAIL
REACTOR BLDG.
TURBINE BLDG
INTAKE STRUCTURE
℄ EXIST. DRAINAGE TRENCH
SECTION A-A
SCALE 1" = 20'-0"
SECTION B-B
SCALE 1" = 20'-0"
TYPICAL DRAINAGE TRENCH
NOT TO SCALE
ELEVATION (ALONG FACE OF INTAKE STRUCTURE & C.W. TUNNEL)
SCALE 1" = 20'-0"
SECTION C-C
SCALE 1" = 20'-0"
NOTES
1. CLAY BACKFILL TO BE PLACED IN 8" MAX LAYERS AND COMPACTED WITH SHEEPSFOOT ROLLER PER SPECS. AND WITH NOT LESS THAN 4 PASSES PER LAYER.
2. SEE DWG 1419 FOR EXISTING CONTOURS, LIMITS OF EXISTING STOCKPILES OF FILL MATERIAL AND WASTE EXCAVATION DISPOSAL AREAS.
3. SEE DWG. 4007 AND EXAMINE SITE FOR EXCAVATION AND BACK-FILL PERFORMED BY OTHERS UNDER PREVIOUS SUBCONTRACT.
4. CONSTRUCTION ROAD SURFACING TO BE AS REQUIRED FOR ACCESS FOR CONSTRUCTION OF TURBINE BLDG. FOUNDATIONS AND CIRC. WATER SYSTEM STRUCTURES.
GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPT.
SAN JOSE, CALIFORNIA
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
NEW YORK, N.Y.
INTAKE & TURBINE AREA
EXCAVATION & BACKFILL PLAN & SECTIONS
JERSEY CENTRAL POWER & LIGHT CO.
OYSTER CREEK STATION-UNIT #1
W.O. 2299
DWG. 4006
DAMES & MOORE
REV. NO. 1 REVISED PLAN, REV TO INCLUDE AS BUILT CHANGES
REV. NO. 2 REVIEWED FOR "AS BUILT" CONDITIONS

PLATE 9


SHADED AREA INDICATES FLOODED LAND IN VICINITY OF SITE
APPROXIMATE LIMITS OF STORM TRAVERSE
STORM TRAVERSE
SITE
L A C E Y
B A Y
B A R N E G A T
ATLANTIC OCEAN
North Harbor
South Harbor
Liberty Harbor
Clam Island
LONG BEACH
BARNEGAT INLET
Barnegat Light
U N I O N
BOUNDRIES OF FLOODED LAND FOR THE PMH OCCURRENCES
SCALE 1:24000
REFERENCES:
FORKED RIVER, N.J.
BARNEGAT LIGHT, N.J.
1953
1953
DAMES & MOORE

APPENDIX 2.5-A
INVESTIGATION OF STABILITY CHARACTERISTICS OF SOILS IN THE CANAL BANKS

CASAGRANDE REPORT - APRIL 21, 1972

FORKED RIVER NUCLEAR STATION

INVESTIGATION OF STABILITY CHARACTERISTICS

OF SOILS IN THE CANAL BANKS

Arthur Casagrande
Leo Casagrande
Dirk R. Casagrande

April 21, 1972

Mr. R. P. Giloth
Project Manager
Burns and Roe, Inc.
700 Kinderkamack Road
Oradell, New Jersey 07649

Subject: Forked River Nuclear Station
Investigation of Stability Characteristics of Soils in the Canal Banks

Dear Mr. Giloth:

The purpose of this letter-report is to describe the investigations which were carried out recently for the purpose of defining more accurately the stability characteristics of the sands in the canal banks, with special attention to the sensitivity of these sands to liquefaction.

In accordance with recommendations which I made during our meeting on April 3, 1972, ten exploratory trenches were excavated in the canal banks which extended from the top of the slope down to the water surface. In the higher banks the trenches were excavated by means of a dragline, and by means of a backhoe further north where the banks are low. These trenches were inspected and in situ penetration tests were carried out on April 7, 1972. In the following week the trench profiles were surveyed and the profiles were extended into the canal by soundings.

40 Massachusetts Avenue/Arlington, Massachusetts 02174/Telephone: (617) 648-3630
Pierce Hall, Harvard University/Cambridge, Massachusetts 02138/Telephone: (617) 495-2843

The following persons participated in the field inspection and testing on April 7, 1972:

W. G. Thorpe, Burns and Roe	B. L. Smith, Consultant
R. C. Macken, Burns and Roe	A. Casagrande, Consultant
T. Hannen, Oyster Creek Plant	D. R. Casagrande, Consultant

Stratigraphy as Disclosed by Exploratory Trenches

In Figs. 1 to 10, the trench profiles are plotted and the description of the soil layers is given. Also shown are the locations where in situ penetration tests were carried out. The locations of the trenches are shown in plan in Fig. 11.

In general, an upper sand stratum is clearly identified which extends from the ground surface down to the surface of a layer of clay or peat and which varies from about El. +9 at the southern end to El. +6 at the northern end, near the bridge.

The clay layer was found in trenches 1 and 2 on the west side, and 9 and 10 on the east side, i.e. along the southern portion of the canal. Further north the clay layer changes into a peat layer which lies approximately at the same elevation, but which almost disappears in trench 6, i.e. at the north end near the bridge. Some peat lenses with a thickness of a few inches were found at several locations within the upper sand stratum.

Although the upper part of the clay or peat layer is generally massive, in the lower zone the clay or peat is usually stratified with sand layers.

The more massive sand layers consisted generally of clean, fine to medium sands, without any distinct stratification. Cross-bedding was not observed. Directly overlying the clay was usually found a layer of gravelly sand, sometimes sandy gravel, with the gravel consisting of well-worn beach pebbles. At some locations a layer of gravelly sand or sandy gravel was observed below the peat layer.

The lower end of the trenches, close to the water level, ended in sand, except in trench 6. In trench 6, hand excavation behind a small "cofferdam" disclosed the surface of another clay layer a few inches below the water surface.

All sand and clay layers showed extensive color stratification. In fact, the colors varied so greatly that they could not be described in detail.

In general, the portions of the bank slopes within the massive sand layers were standing at approximately the angle of repose of sand, whereas in the clay and peat layers the slope was usually much steeper.

Immediately above the water surface, and to the extent one could see the bottom through the water, a flat "beach" had formed, probably by erosion caused by discharging groundwater which always develops high discharge velocities at the elevation of the open water level. The extent of this beach formation can be seen in the profiles, Figs. 1 to 10.

Static Cone Penetration Tests

The penetration tests in sand were made by means of a cone penetrometer with a base area of one square inch and a 30 degree angle at the apex, which is patterned after a design that was developed by the U.S. Waterways Experiment Station about 20 years ago. The dimensions of the cone are shown in an inset in Fig. 12. This device is equipped with (1) a dial gage which measures the applied pressure, (2) a handle and (3) extension rods for deep penetration. Extension rods were not needed for the measurements at this site. The maximum load P that was applied in these tests was limited by the weight (220 lb) of the man who pushed the penetrometer into the ground. In sands, the penetration resistance close to ground surface rapidly increases with depth of penetration. Therefore, it was intended to perform all these tests to a

constant depth d of penetration. However, because of the high resistances encountered (and partly because of inclement weather - a cold rain fell all day)this could not be controlled within the desired limits. In retrospect, it is recognized that in these dense sands it would have been better to use a penetrometer with a much smaller area, e.g. 0.5 sq in.

The results of the penetration tests in sand layers are plotted in Fig. 12. The locations of these tests are shown in the trench profiles, Figs. 1 to 10. In Fig. 12 it can be seen that the test results fall clearly into two areas as described below:

Area I, which is bounded by lines A and B,covers all tests performed at locations deeper than 3 ft below the original ground surface. Most of these tests were made at depths of 4 to 6 ft measured vertically from the sloping canal-bank surface,(i.e. before the exploratory trenches were excavated). At these locations the depths below the original ground surface, i.e. before the canal was dredged, were of course much greater. If these tests had all been performed with the same depth of penetration, the results would lie within a relatively narrow range of pressure. E.g., if consistently a depth of penetration of about 3 in. had been used, the applied pressure would

have ranged between about 150 and 200 lb (or lb/sq in.). All tests between lines A and B are indicative of very dense sands. The high density was reflected also qualitatively by the effort required in excavating by means of a shovel horizontal shelves into the back of the trenches for performing the penetration tests. Normally one can excavate with a shovel even in fairly dense sands without much effort. However, while excavating the shelves into undisturbed sand, the required effort left not the slightest doubt that the sand layers for which the test results fall between lines A and B, are indeed very compact.

Area II - The test results, which in Fig. 12 fall within or on the elliptical curve C, were all performed at locations which were less than 3 ft from the original ground surface. On an average they yielded pressures approximately one-half of those in the other group which were performed at locations substantially deeper than 3 ft below the original ground surface. The test results which fall in Area II indicate loose to medium dense sands, and which was also reflected by the ease with which excavation by hand shovel could be performed. At depths of less than 3 ft beneath original ground surface even a sand which was originally deposited in a dense state, would have been loosened by alternate freezing and thawing. But it is

also possible that close to the ground surface the sand was relatively loose, man-made fill.

Comparison of Standard (Dynamic) Penetration Measurements (N-values) Measured in Borings, with Static Cone Penetration Values Measured in Trenches, for Sand Stratum Above the Clay

Among the many standard penetration borings which were made for the Oyster Creek Nuclear Power Plant, the borings B4, B10, B11, B12 and C25 are located in the vicinity of test trenches 1, 2 and 10. Therefore, a meaningful comparison could be made between these two sets of test data.

In Table I are compared for the sand above the clay layer the N values from Boring C25 with the P values determined in trenches 1 and 2.

TABLE I

Boring C25		Trench 1			Trench 2		
El.	N	El.	P(lb)	d(in.)	El.	P(lb)	d(in.)
+20	21						
+14	48	+14	190	4			
		+14	174	4			
					+10	190	5
					+10	177	4.5
+9	58						
					+8	193	5
					+8	223	6.5
Sand Layer Below Clay		+2	180	4.5			
		+2	183	4.5			

For Trench 1 is also included penetration tests determined on sand below the clay stratum (probably a sand layer within the clay stratum), which showed the same high P values as the sand above the clay. Comparing the N values from boring C25 with the P values determined in Trenches 1 and 2, one may conclude that in the sand stratum above the clay N values in the range between 21 and 50 correspond to P values falling in Area I of Fig. 12. It should be noted that the relatively low N value of 21 was at a shallow depth for which such a value also indicates dense sand.

In the following Table II are compared for the sand above the clay the P values from trench 10 with the N values from four nearby borings.

TABLE II

Trench 10

El.	P(lb)	d(in.)
+16	158	2.5
+11	158	3

Boring B4		Boring B10		Boring B11		Boring B12	
El.	N	El.	N	El.	N	El.	N
+17	63	+18	60	+20	37	+18	24
+12	51	+13	43	+15	37	+12	50
		+8	47				

Comparing the P values from trench 10 with the N values from the four nearby borings, it is concluded that P values falling in Area I of Fig. 12 correspond to N values ranging between 24 and 63.

On the basis of the foregoing data the following conclusions are justified:

1. In the area represented by the borings and trenches which are listed in Tables I and II, the sand stratum overlying the clay is dense to very dense.
2. Whenever penetration tests at the locations of other trenches gave results falling within Area I of Fig. 12, such sands are dense to very dense.

Pocket Penetrometer Measurements on Clay

A pocket penetrometer was used to measure the in situ strength of typical clay. The penetrometer readings are expressed as equivalent unconfined compressive strength, in ton/sq ft. The results are summarized below.

Trench 1

Elevation +12 to +13

Compressive strength, ton/sq ft, 1.8; 2.2; 3.0; 3.6; 2.2.

Trench 4

Elevation +1.5

Compressive strength, ton/sq ft, 1.5; 1.3; 1.0; 1.2; 1.0; 1.2.

Remolding changed the consistency of the clay into the range of soft to very soft.

No penetration tests were made in the peat layers because of the spongy consistency.

Discussion and Conclusions

The 10 trenches which were excavated in both canal banks, permitted an excellent opportunity to inspect and test in situ the soil strata from the ground level adjacent to the excavated canal prism down to the water surface.

By comparing the results of static cone penetration tests in the sand above the clay with the results of standard penetration tests (N values) obtained in nearby borings, the cone penetrometer tests could be used to establish that the sand overlying the clay or peat layers along both canal banks is dense to very dense, with the exception of a surface layer not exceeding 3 ft in thickness which ranges between medium loose to medium dense.

The detailed inspection of all soil strata in the canal banks and test results convinced the writer that there is no possibility that the banks could experience liquefaction slides. The worst that could happen during a severe earthquake would be slumping of oversteepened slopes. Most of the slumped material

would collect on the flat beach-like berm which has formed within the range of normal tidal fluctuations (see Figs. 1 to 10), and the volume of material that might move into the canal prism below El. zero would be of no consequence.

Sincerely yours,

A. Casagrande

AC:sm

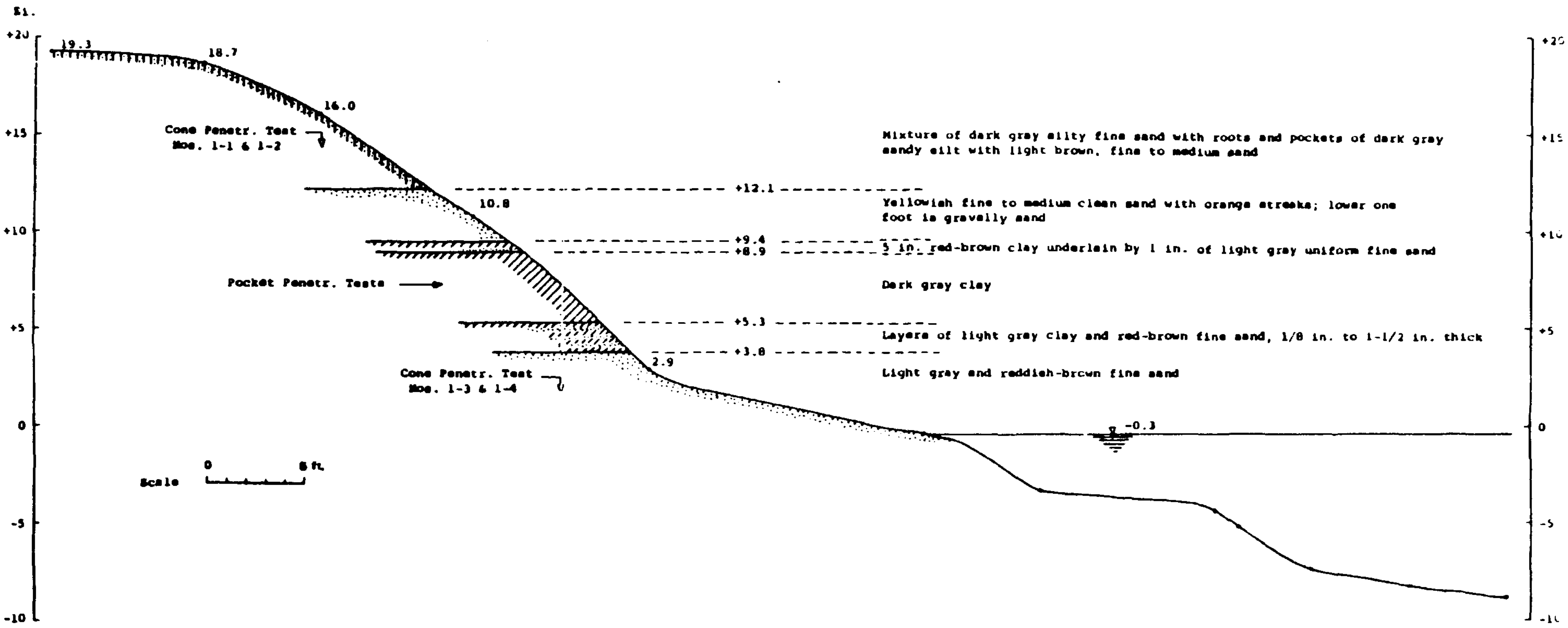


FIG. 1: SOIL PROFILE AT TRENCH NO. 1
(Revised June 30, 1972)

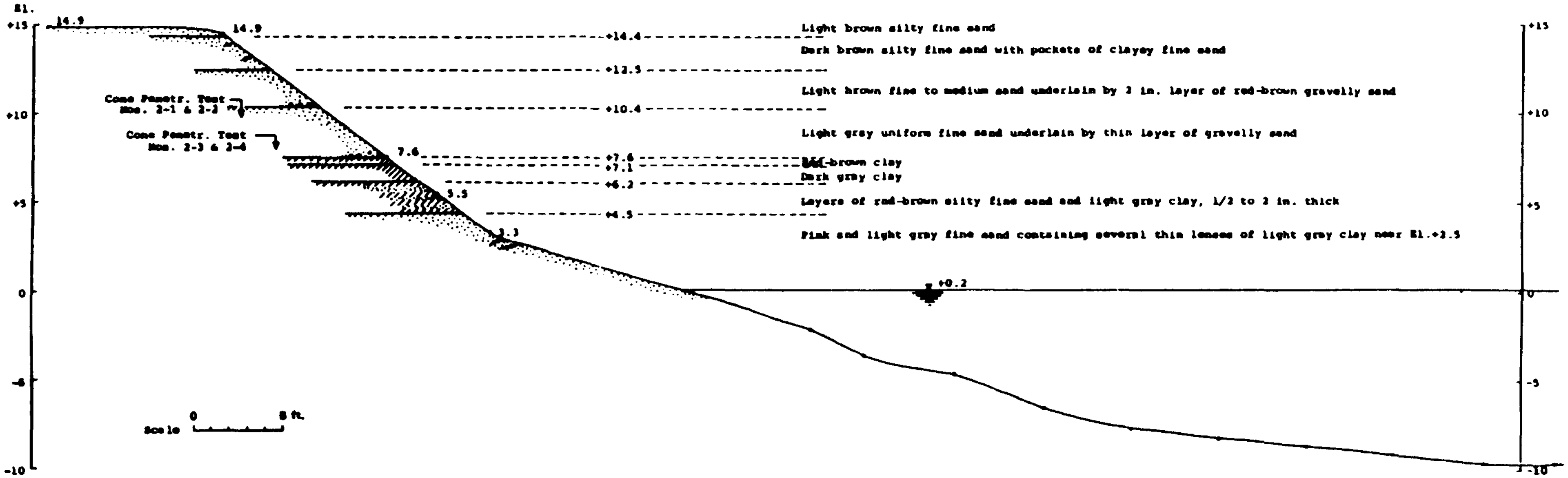


FIG. 2: SOIL PROFILE AT TRENCH NO. 2
(Revised June 30, 1972)

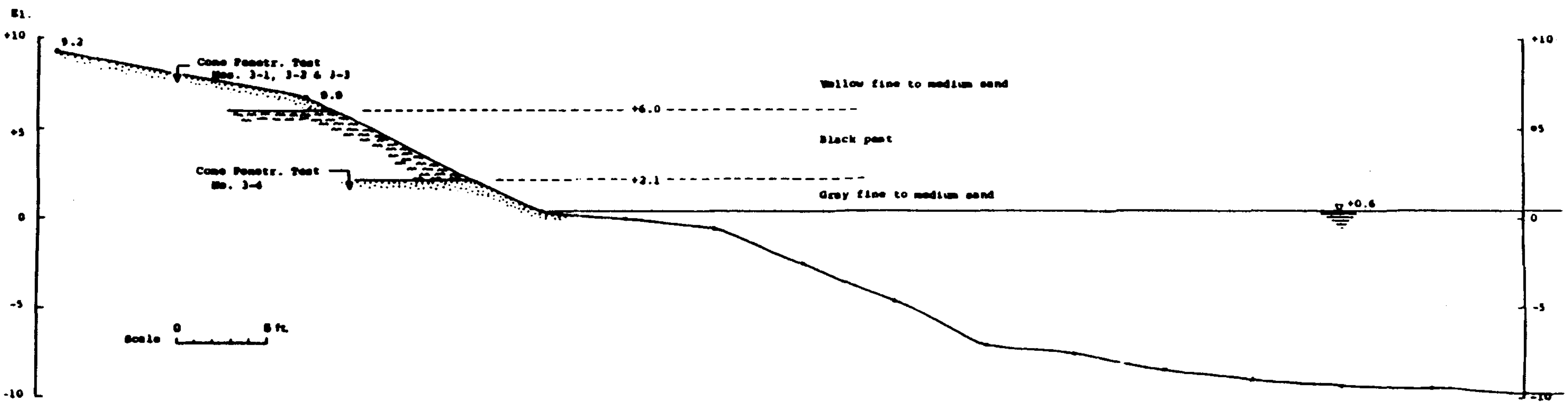


FIG. 3: SOIL PROFILE AT TRENCH NO.
(Revised June 30, 1972)

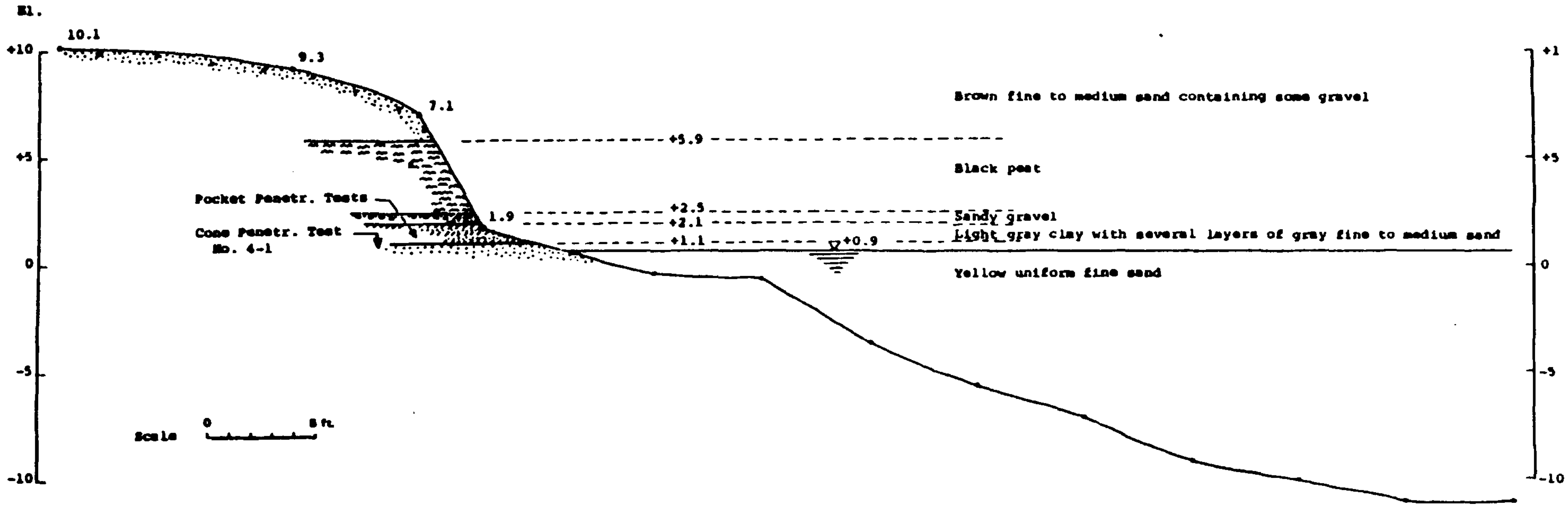


FIG. 4: SOIL PROFILE AT TRENCH NO. 4
(Revised June 30, 1972)

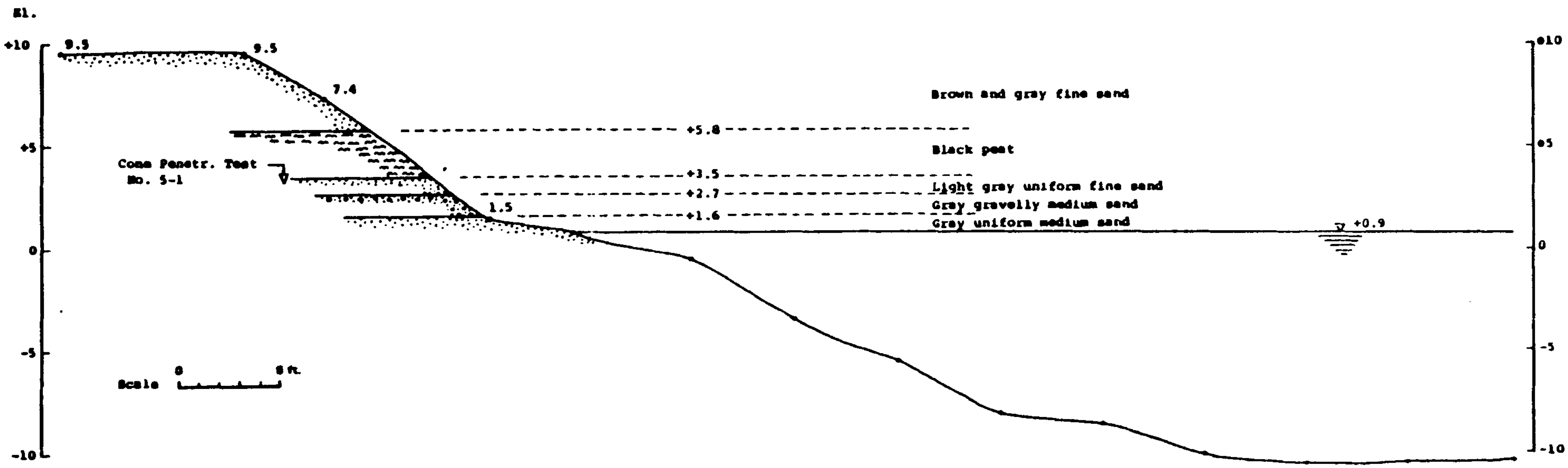


FIG. 5: SOIL PROFILE AT TRENCH NO. 5
(Revised June 30, 1972)

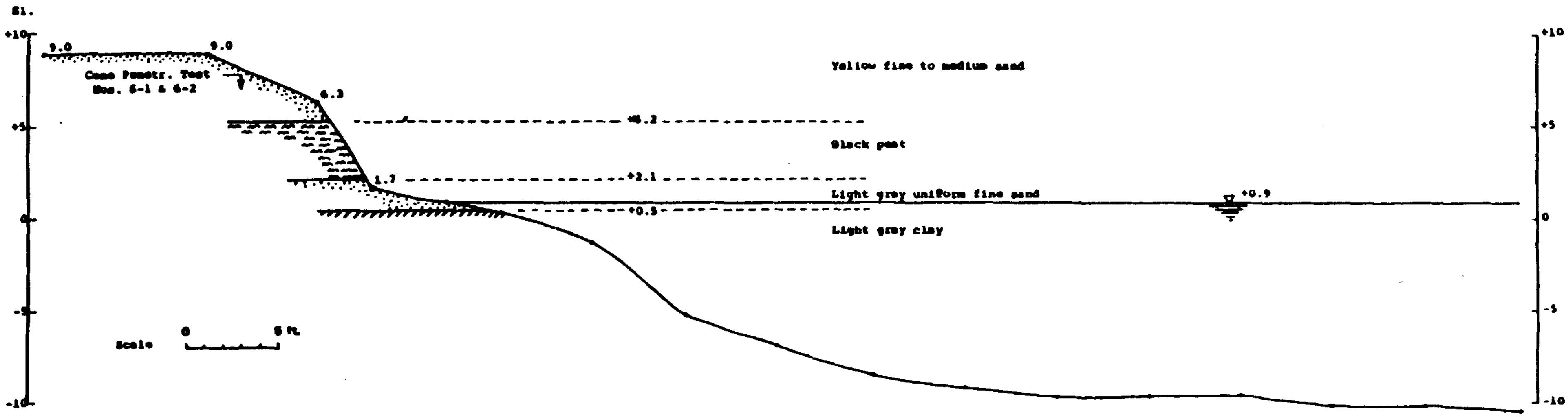


FIG. 6: SOIL PROFILE AT TRENCH NO. 6
(Revised June 30, 1972)

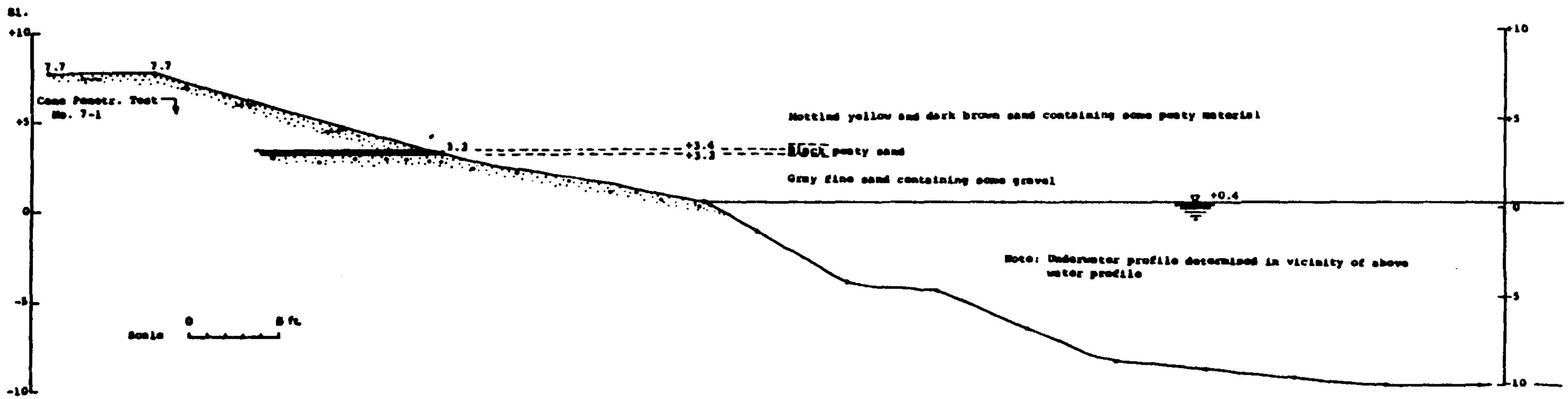


FIG. 7: SOIL PROFILE AT TRENCH NO. 7
(Revised June 30, 1972)

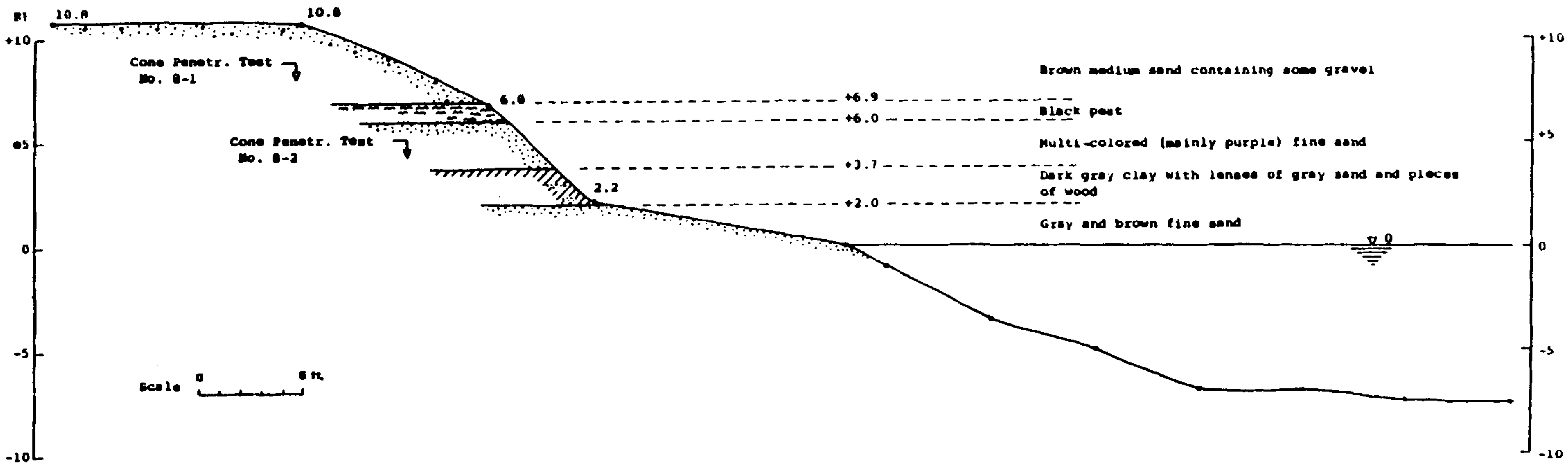


FIG. 8: SOIL PROFILE AT TRENCH NO. 8

(Revised June 30, 1972)

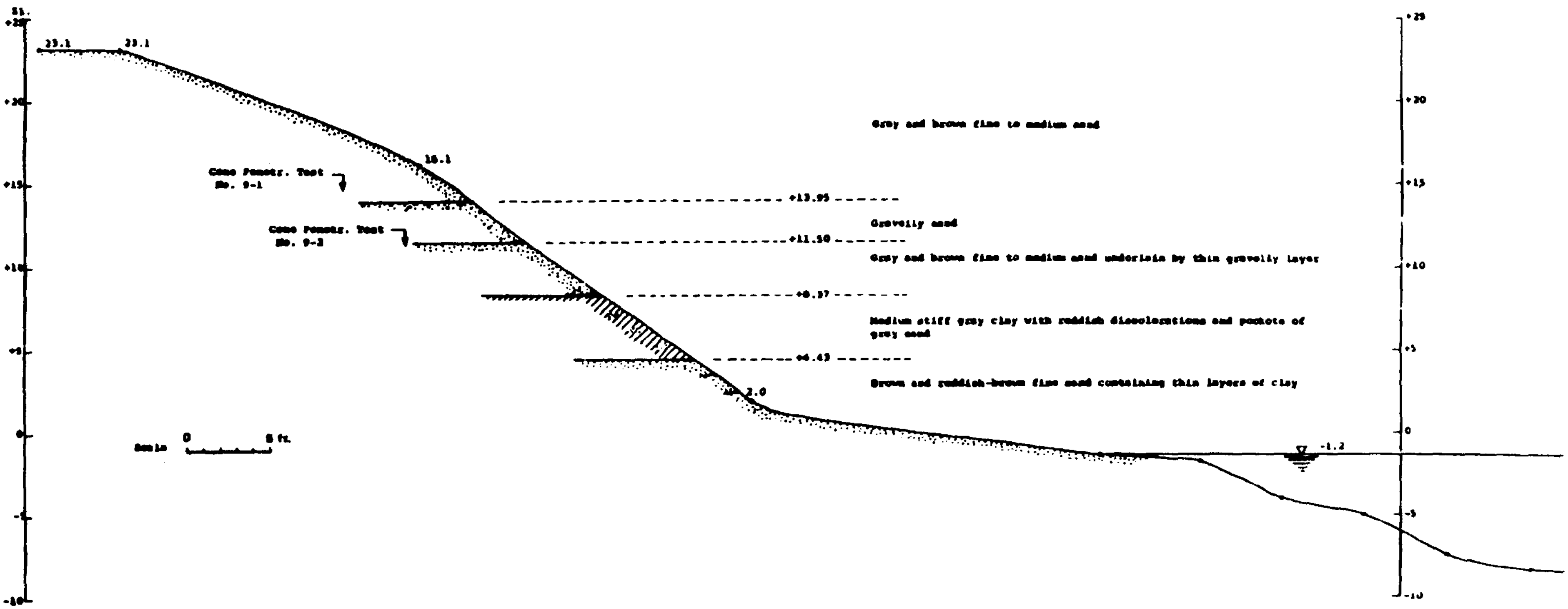


FIG. 9: SOIL PROFILE AT TRENCH NO. 9
(Revised June 30, 1972)

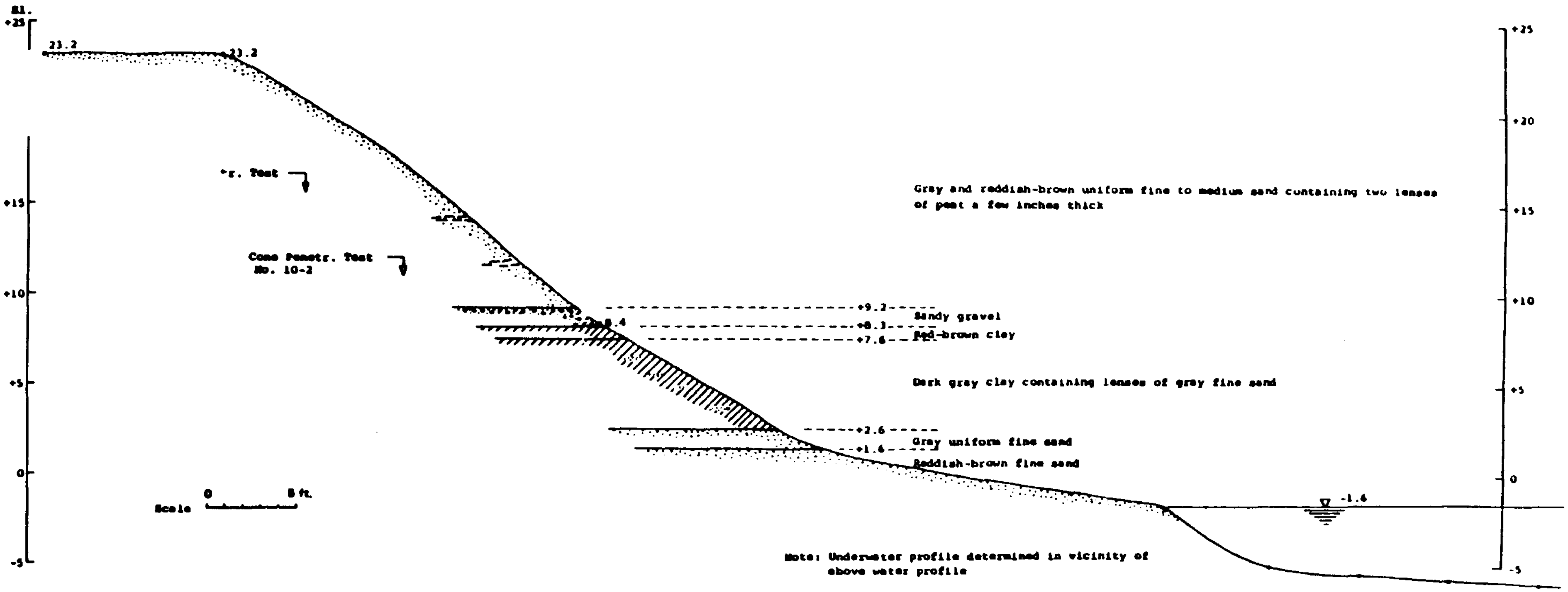


FIG. 10: SOIL PROFILE AT TRENCH NO. 10
(Revised June 30, 1972)

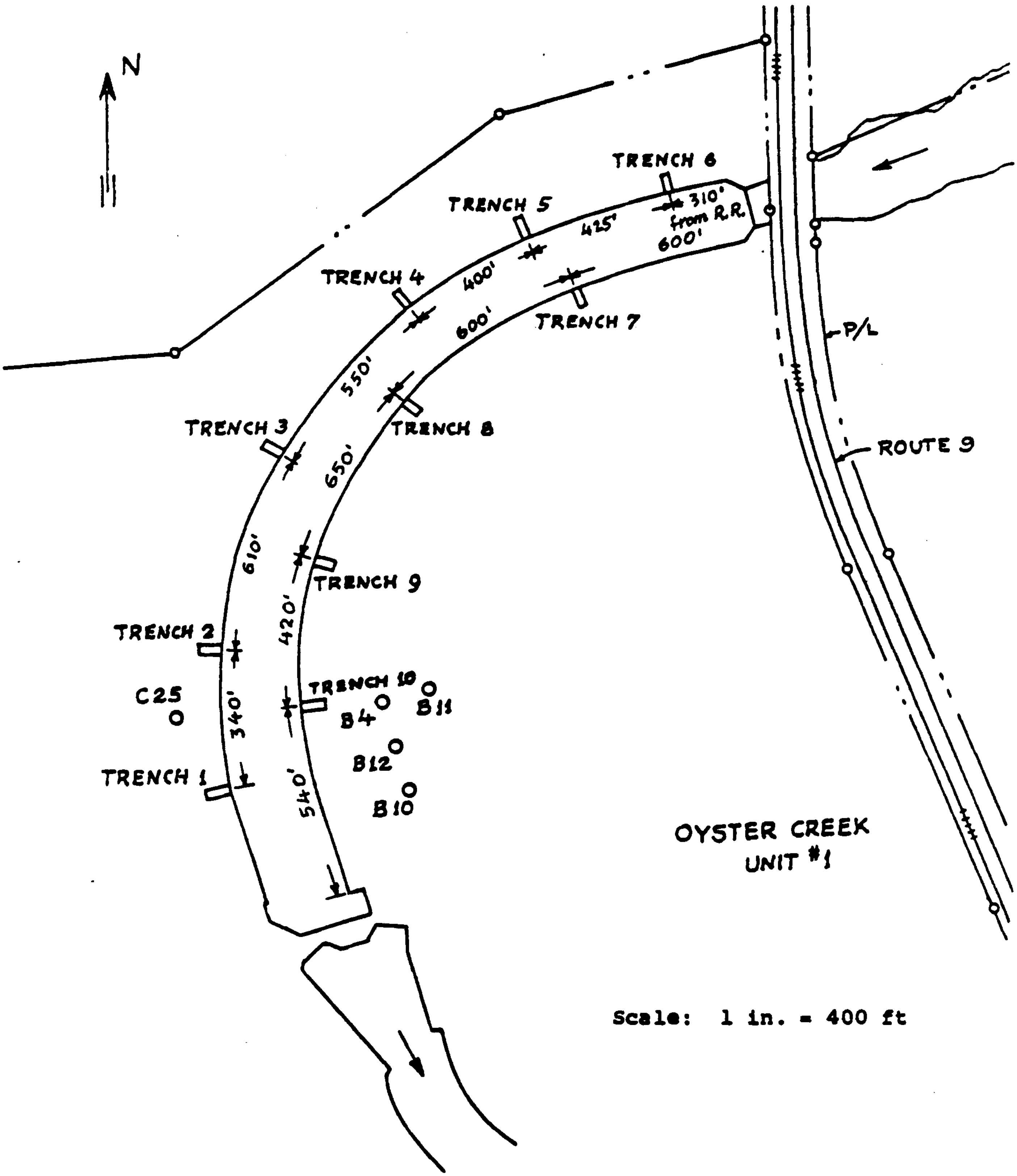


Fig. 11: LOCATIONS OF EXPLORATORY TRENCHES AND NEIGHBORING BORINGS ALONG INTAKE CANAL

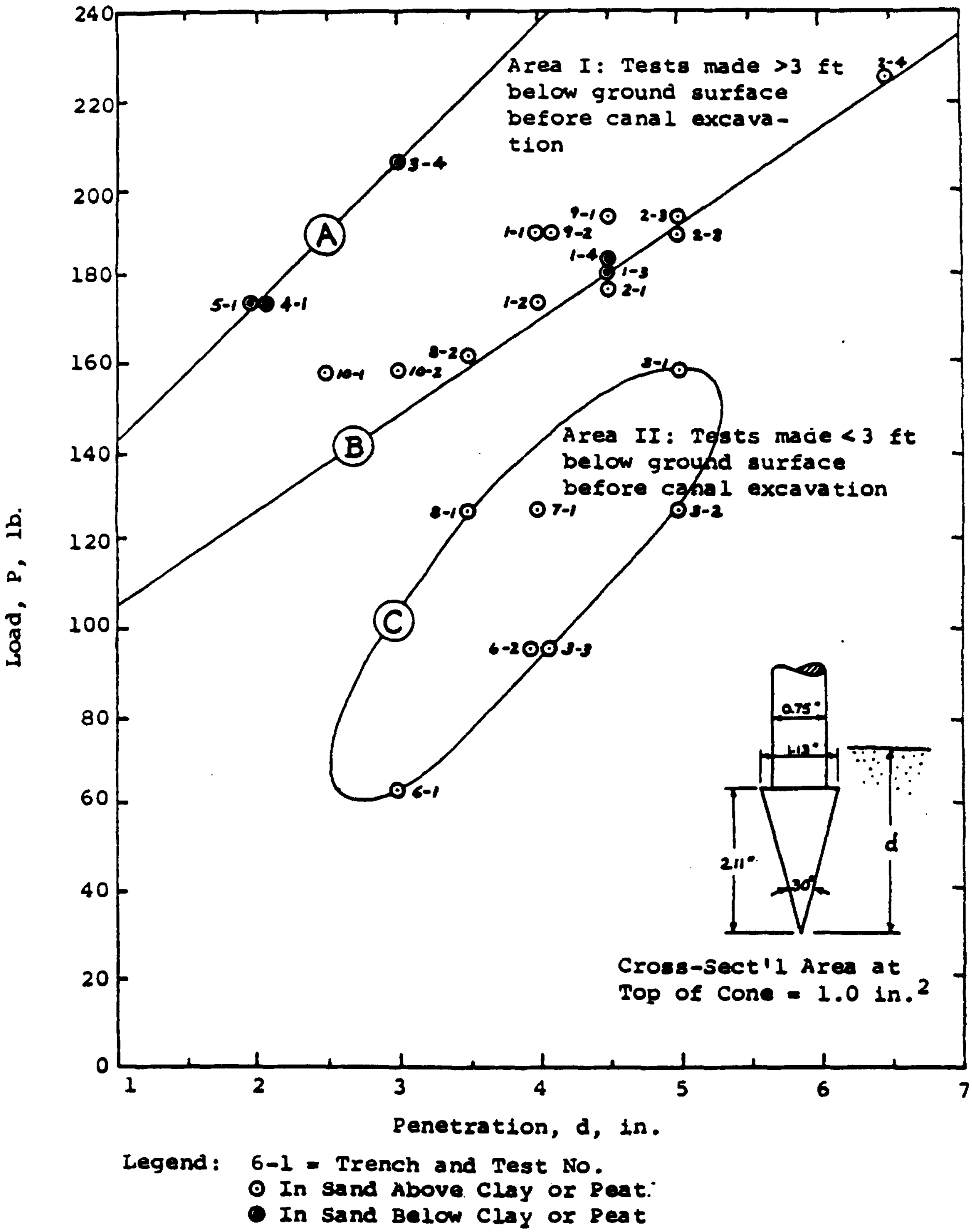


Fig. 12: CONE PENETRATION TESTS IN INTAKE CANAL SLOPES