2.0 SITE AND ENVIRONMENT

2.1 SITE DESCRIPTION

2.1.1 Summary

The site is located in a region devoted primarily to agriculture. There are no continuously occupied residences within 2160 feet of the reactor containment structures. The distances from the reactor containment structures to the areas defined in the Rules and Regulations Title 10 Chapter I Part 100 are as follows:

Exclusion area	650 acres
Minimum distance to exclusion area	2000 feet
Outer boundary of low population zone	2 miles
Population center distance	8 miles

The closest population center is the twin cities of Benton Harbor-St. Joseph, Michigan. The site, therefore, provides excellent isolation as well as low population densities over a wide area.

2.1.2 Location

The site is located in Lake Township, Berrien County, Michigan, about 11 miles south-southwest of the center of Benton Harbor, Michigan. The axis point of the Cook Nuclear Plant is latitude 41°58'32.07" and longitude 86°33'54.87." Figure 2.1-1 shows the regional features of the area up to 60 miles from the site, while Figure 2.1-2 indicates the features within about 15 miles of the facility.

The site consists of about 650 acres along the eastern shore of Lake Michigan, with approximately 4350 feet of Lake frontage, and extends an average of about one and one quarter miles eastward from the lake.

The entire site, with the exception of the right of way for Interstate Route 94, about 400 feet from the eastern site boundary, is controlled by the Indiana Michigan Power Company (I&M). No residence is permitted inside the site boundaries.

Figure 2.1-3 shows a map of the plant site defining the plant property lines.

1. The boundary lines inside of which I&M exercises exclusive control of access are the property lines which are to the west of the Interstate 94. These property lines are also the boundary lines at which gaseous effluent limits apply. The line in the area of Lake Michigan is the shore line El 580'-0" extended by 100 feet toward the lake, up to which I&M exercises rights, besides those obtained to install, maintain and operate the condenser cooling water intake and discharge pipes. Riparian rights extend to the low water line which in consideration of the lake bottom movement is approximately 100 feet outward from the elevation 580' line.
2. The points on the plant structure from which gaseous effluent containing, or potentially containing, radioactivity will be released; and the distance of each from the nearest boundary line have been shown and tabulated on the map (see Figure 2.5-1a.) Points 3, 4, 5 and 6 may release radioactivity effluents only during conditions of primary to secondary leakage.
3. There will be no residential housing on site. Only Plant personnel in the conduct of their duties are permitted along the beach in front of the plant.

There are no military installations, missile sites, or industrial facilities located beyond the Donald C. Cook Nuclear Plant Site boundaries at which an accident might cause interaction with the plant so as to affect public health and safety.

The plant is located along the lakeshore approximately midway between the northern and southern boundaries of the site. The distance from either of the reactor containment structures to the nearest site boundary is 2000 feet.

Figure 2.1-3 indicates the topographical details of the site and the location of the plant. Figure 2.1-4 is an aerial photograph of the site and its immediate environs before plant construction began.

2.1.3 Topography

The site consists primarily of heavily wooded rugged sand dunes. A sandy beach slopes gently upwards for about 200 feet from the lake before rising sharply into the dunes. The peaks of the highest dunes reach an elevation of about 120 feet above the lake's surface; depressions between the dunes are as low as 10 feet above lake level.

Figure 2.1-4a shows modifications in the site topography due to plant structures. Figure 2.1-4b shows views of the site from the minimum exclusion radius to major plant structures showing the topography of the site in relation to major plant structures.

2.1.4 Access

The site area is accessible by air, rail, and road.

The Pere Marquette Line, runs in an approximately north-south direction about 1600 feet east of the site's eastern boundary. A corridor between the site and the railroad has been purchased to permit construction of a rail spur, and a bridge spanning Thorton Drive and Interstate Route 94 has been erected to provide direct rail access to the plant.

Interstate Route 94 runs through the eastern portion of the site in a north-south direction, while the Red Arrow Highway runs along the eastern boundary in the same general direction. Thorton Drive, a local roadway, runs parallel to Interstate 94 and slightly to the west of it, while Livingston Road, also a local thoroughfare, forms the southern site boundary.

Within the 15-mile vicinity of the Donald C. Cook Nuclear Plant there are two airports: Southwest Michigan Regional Airport located approximately 12 miles NE of the plant on the NE edge of Benton Harbor and Andrews University Airport located approximately 10 miles East of the plant near Berrien Springs. For airports beyond this 15-mile radius, the orientation of runways and normal flight patterns are not in the direction of the plant or the normal glide path heights are not within the plant vicinity so that aircraft utilizing the facilities of these airports would not normally fly over the plant site.

Southwest Michigan Regional Airport has three runways all 100 feet wide, paved and lighted;

Direction	**Length**
East-West	5100 feet
North-South	3200 feet
NW-SE	3750 feet

For 1971 there were 67,690 operations (take-off or landings) resulting in 33,845 flights or an average of 93 flights per day of which only 9 were scheduled by commercial airplanes.

Weight load of aircraft using this field is limited to 30,000 pounds per single wheel load, which is the design specification for the concrete runways. Three classifications of airplanes utilize the airport facilities: corporate, private and commercial.

Due to the North-Easterly location of the airport and the orientation of the runways, normal glide paths would not approach the vicinity of the plant. There are no specified glide path heights since erection of structures taller than 500 feet are not permitted within a 10-mile radius of the airport. Neither is there a glide slope. However, the East-West runway, which handles most of the traffic because of the prevailing winds, is the only runway having the localizer portion of the Instrument Landing System. This indicates only the aim of the airplane.

Andrews University Airport has two runways:

Direction	Length	Characteristics
310^{o} & 130^{o}	3100 feet	Paved & Lighted
210^{o} & 30^{o}	2500 feet	Sod & Unlighted

There are no records maintained concerning the number of flights. The airport manager has estimated that there are approximately 70 flights some days and none during inclement weather conditions for a yearly total of 4,000 to 6,000.

The maximum weight load allowed is 12,500 pounds. There are no commercial flights; only corporate and private aircraft operate from this field.

There is no height, length, or orientation specified for a normal glide path.

2.1.5 Population

The population data quoted in this section are a mixture of original analysis data, data obtained during an evacuation time estimate study performed during 1991-1992, and the demographic analysis performed during 1993. The evacuation time estimate study also provided updated information regarding schools and businesses near the Cook Nuclear Plant site. The demographic analysis projected future population in the Cook Nuclear Plant for the years 2000 and 2037.

Some of the population projections for individual sectors near the plant are greater than were anticipated in the original analysis. However, the referenced evacuation time estimate study shows that the population living near the plant could leave the area in a reasonable amount of time in the unlikely event of an ordered evacuation. Therefore, the combination of these time estimates and the fact that the total 10 mile emergency planning zone (EPZ) population has not exceeded projections indicate that there is no adverse impact on the EPZ population.

The area within 60 miles of the site, which encompasses portions of Southwestern Michigan, Northwestern Indiana, and Northeastern Illinois, is a region of moderate population that contained approximately 4,073,369 people in 1990. The population of this area from 1975 to 1990 has declined 12%. This decline in total population is attributed to the steady decline of the Chicago area. It is projected from the year 1990 to 2000, the population will increase approximately 3.3%. From 2000 to 2037, it is expected the population will increase by another 3.9%. The projected population distribution information for the years 1990, 2000, and 2037 is located in Tables 2.1-6 and 2.1-6a, 2.1-7 and 2.1-7a, and 2.1-8 and 2.1-8a, respectively.

The closest population center is the twin cities of Benton Harbor-St. Joseph with a combined 1990 population of 22,032. The closest population center boundary is the southern edge of St. Joseph, about eight miles north-northeast of the plant. All population centers within 60 miles of the site are indicated in Table 2.1-3.

The closest continuously occupied residence to the plant lies about 2160 feet to the north.

Figures 2.1-6, -6a, and -6b shows the 1990 population distribution around the site up to a distance of 60 miles. The Low Population Zone is identified in Figure 2.1-6 as the zone included within the 2-mile radius. Figure 2.1-6 divides the region from 0 to 5 miles from the plant into concentric circles and sectors of 22½°, where as Figure 2.1-6a and -6b divides the region from 5 to 60 miles and 10 to 60 miles, respectively. Similar data for the years 2000 and 2037 are included in Figures 2.1-7, -7a, -7b and 2.1-8, -8a, -8b. Population data are presented in tabular form in Tables 2.1-1 through 2.1-8b.

Thirty-four public and parochial schools exist within a ten-mile radius with 625 teachers and a student population of 11,621. (1992)

Data collection to provide forecasts for the 21 counties entirely or partially within the 60-mile radius of the Donald C. Cook Nuclear Plant site was performed. This data was processed with the U.S. Census TIGER digital maps to apportion population forecasts for the years 2000 and 2037 for the radial distances and sectors as presented in the tables and figures. This analysis included the assignment of population forecasts for cities and towns within Berrien County, Michigan by one mile increments for the 0 to 5 mile area, and a five mile increment for the 5 to 10 mile area for forecast years 2000 and 2037. Similar forecasts were developed for the 10 to 60 mile area by ten mile increments for the sixteen 22 1/2° compass sectors.

The "best available data" regarding population growth during this study was obtained from the following sources:

- For the State of Michigan, initial population forecast data was obtained through telephone conversations with the State Demographer, State of Michigan, Department of State Planning and Commerce. (It should be noted that the existing State forecasts are based on pre-1990 census data and are subject to change when new projections are released.) Based on highly variable trends in population growth over the past few decades, it was suggested that it is difficult to determine what the long-range growth to the year 2037 will be. Thus, for the purposes of this analysis, population forecasts for the years 2000 and 2037 were derived using adjusted growth factors based on 1990 census data. More detailed local data for cities and towns in Berrien County was obtained through numerous informal communications with the Southwestern Michigan Commission.

- For the State of Indiana, county population forecasts were obtained through telephone conversations and from subsequent data provided by the State of Indiana reporting the results of the Business Research Center estimates for population growth through 2030.
- For Cook County Illinois, population forecasts were obtained through telephone conversations with the Northeast Illinois Planning Commission, which cited pre-1990 forecasts from the Illinois Bureau of the Budget, Illinois Population Trends - 1900.

In addition to the permanent resident population, Berrien County experiences an influx of approximately 3000 to 4000 summer residents each year. The great majority of the summer homes and cottages are located along the Lake Michigan Beach and in the Paw Paw Lake region in the north-eastern portion of the county.

The closest summer colony to the plant is the Rosemary Beach Association just north of the site boundary. Rosemary Beach is virtually uninhabited during the Fall, Winter and Spring and has a population of up to 150 during the peak of the summer season.

During the late summer and fall fruit harvest, substantial numbers of migrant farm workers are employed in Berrien County. The maximum number recorded in 1976 was 6,800.

Table 2.1-8b and Figure 2.1-10 represent the seasonal transient population out to the Population Center Distance of 8 miles with the 0-2 mile population figures representing the Low Population Zone.

The Work Employment Security Commission supplied data for total migrant workers in Berrien County in 1971 working as transient crop pickers. This total, consisting of 8355 workers, was uniformly averaged over the entire county rural area resulting in an average total of 1263 migrants within the Population Center Distance distributed evenly over the rural area. Some migrant workers arrive in the Spring to cut asparagus but most of them begin to arrive in the latter part of August, building up to a peak in the Fall during the peach and apple crop-picking periods. After the crops have been harvested, they leave the area.

The number of summer homes were supplied by the Twin Cities Chamber of Commerce (St. Joseph - Benton Harbor) and the Berrien County Clerks Office, and the number of people occupying the various beach areas were estimated from visual observations in 1971. Most of the summer vacationists begin to arrive in June when school ends and leave in late August when school recommences; although, a few remain into the Fall as long as favorable weather conditions exist. These vacationists are located mostly along the lakeshore front.

Although, there is an overlapping of the seasonal transient population towards the end of summer; in general, there are two reasons: the summer months consisting of vacationists and the fall months consisting of migrant crop pickers.

The trend is towards a decreasing number of transients within Berrien County and hence within the Population Center Distance.

The migrant workers in the county decreased from a total of 11,100 in 1966 to 8,355 in 1971. This decline is attributed mainly to automation in the crop-picking industry and to a reduced apple market since the cost of picking will not support the apple market price.

Warren Dunes State Park lies along the lake about six miles south of the site. On a peak summer day in 1992, an attendance of 20,881 was recorded at the park of which 1,600 were overnight campers. In 1969, the park was enlarged somewhat to accommodate more daily visitors with increased camping facilities.

While the Warren Dunes State Park has changed from a 1976 summer peak of 23,958 days visitors of which 1300 were overnight campers to a 1992 day peak of 20,881 visitors of which 1600 were overnight campers, there has been a decline in the number of people occupying summer homes over the years with a decrease from 4,000 in 1964 to 3,000 in 1971 due to the high cost of home maintenance. Hence, the potential for a significant increase in transient population over the life of the plant does not seem probable especially within the Low Population Zone which comprises about 3 miles of lake shore front already containing four beach areas.

2.1.6 Land Use

The area surrounding the site is devoted primarily to agricultural pursuits. Over 60% of the land in the three counties, Berrien, Cass, and Van Buren, surrounding the site is devoted to farming. The major crops produced are apples, cherries, grapes, peaches, feed grains, livestock and dairy products. Agricultural statistics are summarized in Table 2.1-9.

Figure 2.1-9 illustrates the number of farms with dairy cattle, the number of dairy cattle per farm, and their distance from the plant within a 10-mile radius (as of 1972).

In 1990, the low population zone contained approximately 764 permanent residents with no more than 174 in any 22½° sector. Industrial activities in the area are centered around Benton Harbor and Niles, Michigan. The primary industries are home appliances, metal casting and electronic and audio equipment. Updated information on Local Schools and Hospitals is given in Table 2.1-12.

Lake Michigan water in the vicinity of the plant site is not used for irrigation. Lake Michigan is however used for swimming, fishing, boating, domestic water supply and sewage. Only crab fishing in water over 30 fathoms is permitted commercially in Michigan waters. The Rickman-Jameson 1971 Sport Fishing Survey for Berrien County (Lake Michigan) indicates the following species and number caught:

Perch	748,800
Walleye	640
Northern Pike	2,120
Lake Trout	6,960
Rainbow & Steelhead Trout	15,120
Brown Trout	3,160
Coho	94,680
Chinook	3,540

In 1971, 24,200 anglers fished 203,260 angler days. There are 4,850 registered boats within a 50-mile radius of the plant site. About 3½ million people use the lake annually within the 50-mile radius.

2.2 METEOROLOGY

Due to the extreme importance of site meteorology, particularly with regard to safety considerations, an extensive meteorological study program was initiated at the site during the summer of 1966.

The meteorological features of the plant site were evaluated primarily on the basis of three years data obtained from the 200-foot tower which was installed on the site in 1966. Satellite aerovane stations at inland and on-site locations were used to complement the main tower data. Data from the original meteorological study can be found in the original FSAR. Recently, the meteorological features have been further evaluated on the basis of five consecutive years of data from 2001 to 2005. These data were obtained from the 60-meter primary tower and 10-meter shoreline tower.

According to the original meteorological study, in most respects, the meteorological patterns were those of a typical open mid-latitude exposure. The wind speeds were strong, variations in direction were frequent and the overall wind rose showed no marked favoritism for any particular direction. The only unusual feature was the low frequency of stable conditions. Both the lapse rate and turbulence class analyses indicate far fewer stable cases than originally anticipated, reaching only 7% over the three year period. Even in the late spring and early summer when the lake was relatively cold, the frequency of stable cases reached only 20 to 25%. According to the recent data from 2001 to 2005, extremely stable conditions (i.e., Pasquill class G) occurred 9.1% of the five year period, and moderately stable conditions (i.e., Pasquill class F) occurred 7.9% of the five year period.

According to the original meteorological study, even more favorable was the very low frequency of the combination of light winds and stable, on-shore flow. Less than 1% of the 200-foot data and only 2.5% of the satellite data were in this category. According to the recent data from 2001 to 2005, less than 1% of the 60-meter data (0.4% during Pasquill class G and 0.2% during Pasquill class F) and only 2.2% of the shoreline data were in this category (1.0% during Pasquill class G and 1.2% during Pasquill class F).

The only major meteorological hazard expected in the site area is the tornado, which has recurrence frequency of over 5000 years at the site itself. Ice storms, which would be expected with greater frequency, are not likely to damage essential facilities, but have been considered in developing certain criteria.

2.2.1 Sources Of Data

Old Site Meteorological Tower

The main source for the initial site meteorological data was a 200-foot meteorological tower, which was erected at the site during the summer of 1966 and equipped with meteorological instrumentation (Fig. 2.2-1). This tower remained in continuous operation from October 1966 until 1978. The tower instruments consisted of the following:

200 ft. level	Aerovane and aspirated resistance thermometer.
150 ft. level	Climet Bivane (the extremely strong winds at the site had damaged the Bivane, but some data had been obtained).
50 ft. level	Aerovane and aspirated resistance thermometer.
Ground-level	Resistance thermometer, Dewcell, recording rain gage and recording barometer.

In the Unit 1 Control Room there was instrumentation and a recorder for wind speed, direction and temperature.

Old Satellite Aerovane

In addition to the measurements taken directly at the site, a third aerovane was located inland in the summer of 1966 on a short pole in the flat terrain about 2 miles east of the tower. This instrument was transferred to a pole on the site near the beach in the Spring of 1969 to measure unobstructed wind speed. It was replaced in December 1969 by a more sensitive RAIM wind instrument to obtain better response in the low-speed range. Construction progress made it necessary to make an adjustment to the location of the pole, and it was accordingly moved a short distance in July 1970 to a point where it still measured unobstructed wind speed. The detectors at these satellite locations were about 50 feet above the ground level. The elevations of the aerovane detectors are listed below.

	Elevation USGS
200 feet level on main tower	892'
50 feet level on main tower	742'
Inland satellite	701'
Beach satellite (previous location)	696.3'
Beach satellite (present location until 1978)	656'
Plant grade	608'
Average lake water level	580.4'

The inland satellite and the beach satellite are also no longer in operation.

Meteorological System Description

The tower locations for the meteorological system are shown in Figure 2.2-23. The system includes primary, backup, and shoreline towers tied into a central computer via microprocessors. Readouts of data are provided in both control rooms. Data is recorded at each tower site. Each tower measures wind speed and wind direction. The primary tower and the shoreline tower measure temperature. The primary tower also measures precipitation. The instruments are made by Climatronics Corporation. The specifications for the instruments are as follows:

	F460 Wind Speed	F460 Wind Direction
Accuracy	±0.07 m/s (0.15 mph) or 1.0% of true air speed (whichever is greater)	±2°
Threshold	±0.22 m/s (0.5 mph)	0.22 m/s (0.5 mph)
Distance Constant	Vinyl: 1.5 m (5 ft.) of air max. Stainless Steel: 2.4m (8.0 ft.) of air max.	.9 m (2.95 ft.) of air max
Damping Ratio		0.4 at 10° initial angle of attack
Operating Range	0-56 m/s (0-125 mph)	0° to 360°

Temperature Sensor Specifications

Accuracy	±0.15°C (±0.27°F) over full range
Range	-30.0° to 50.0°C (-22.0° to 122.0°F)
Time Constant	3.6 s
Interchangeability	±0.15°C (±0.27°F)
Linearity	±0.16°C (±0.29°F)
Leads	3
Size	0.64 cm dia x 11.4 cm long (1/4" x 4 1/2")

Precipitation Monitor Specification Sensor Specifications

	8" Tipping Bucket
Accuracy	±1% up to 7.5 cm/hr (3 inch/hr)
	±5% up to 25 cm/hr (10 inch/hr)
Resolution (Sensitivity)	0.025 cm (0.01 in)

The primary site is a 60-meter tower on plant property. The base of the tower is at approximately 650' above sea level. The tower and its instruments are located in an area relatively free of interfering structures and vegetation, and are within the thermal internal boundary layer (TIBL) during on-shore flow. By being within the TIBL, the tower measurements are representative of the meteorology in the emergency planning zone.

The primary tower has the following instrumentation:

1. Wind Direction at the 10m and 60m levels.
2. Wind Speed at the 10m and 60m levels.
3. Temperature at the 10m and 60m levels.
4. Precipitation at the 1m level.

The primary tower is not equipped with redundant instrumentation. A back-up tower is used to maintain the ability to monitor wind speed and wind direction when the primary tower is unavailable. The back-up tower site is a siren pole located across from the plant entrance on Red Arrow Highway. The back-up tower has the following instruments at 10 meters above the base of the pole:

- Wind Direction
- Wind Speed

The shoreline tower monitors representative conditions of unmodified marine air. The shoreline instruments are located on a siren pole on the shoreline. The base of the tower is at approximately 600' above sea level. The shoreline tower has the following instruments:

Wind Direction at the 10m level.

Wind Speed at the 10m level.

Temperature at the 10m and 2m level.

Each site has a microprocessor to calculate 15 minute averages and this information is transmitted to a central computer.

The central computer to collect meteorological data is located on the plant property. It polls the meteorological tower site microprocessor for the 15-minute averages for each instrument. The central computer has software to calculate 10 CFR 50, Appendix I dose estimates. The central computer provides meteorological data to the PPC system. Meteorological data from the PPC display is entered into a stand-alone PC running the accident dose assessment program. This program provides dose estimates for emergency planning.

Special Studies

Phenomena having relatively long recurrence intervals, such as tornadoes and ice storms, in the area cannot be studied directly from site observations and estimates have been derived from special reports. (References 1, 2, 3, 4, and 6)

Analysis

The initial meteorological data from the Donald C. Cook Nuclear Plant site were abstracted, processed and analyzed on a monthly basis by Maynard E. Smith, Inc., Meteorologists, Inc. The computer output from which the analysis is made is too extensive to include as a part of this report. The summaries given here are derived from it. Table 2.2-1 is a sample of the original (1969) hourly records in the computer data file. Table 2.2-2 is a sample of the meteorological tower system's data output (1992).

2.2.2 General Meteorology

Southwestern Michigan is typical of the northern lake regions of the United States in most respects. The flat terrain and the frequent passage of well-developed extra-tropical storms create a consistently strong wind flow, as well as rapid changes in both dispersion conditions and wind direction. Some of the meteorological statistics are useful primarily for general planning of the facilities and are therefore reported with a minimum of description. Other data are important in the assessment of safety and these are discussed fully.

High Winds

Strong winds are the most important meteorological hazard to the facilities. The region is frequented by relatively strong, gusty winds, usually accompanying the passage of squall lines or thunderstorms and the maximum wind associated with these phenomena is 90 mph on a 100 year recurrency interval.

The tornado presents a very specialized type of hazard involving both violent winds and extremely large, rapid changes in barometric pressure.

The storms are small, unpredictable in detail and rather infrequent, but they undoubtedly represent one of the few environmental factors that could, if ignored in plant design, inflict direct major damage on the facility. Typically, the tornado is a narrow funnel, often only a few hundred yards wide, in which winds may briefly reach 300 mph. Almost instantaneous changes in barometric pressure occur, reaching 3 psi and causing explosion of vulnerable structures. Because of the severity of the phenomena, very few reliable measurements of tornado intensities exist. It is therefore difficult to dissociate wind and pressure effects, but the estimates given above are considered fairly reliable maximum values. This portion of Michigan has a significant tornado probability, as is apparent in the map shown in Figure 2.2-2. Berrien County has had 25 tornadoes between 1950 and 1989.

Ice Storms

Far less destructive, but far more probable, are the ice storms that frequent the north central states. Michigan lies in the belt where such storms are common and in the years from 1970 to 1989, 6 significant ice storms have been reported in this area.

2.2.3 Dispersion Meteorology

According to the original meteorological study, the micrometeorology of the site seemed fairly typical of the northern lake regions. The sand dunes in the immediate vicinity caused some aberration of wind flow at low levels for short distances, but, in general, the wind was vigorous, turbulent and uncomplicated over the entire area. The thermal stability showed approximately the seasonal variation expected close to large lakes, exhibiting almost no stable cases during the winter months, contrasted with a slightly greater frequency in inversions in the late spring and summer when the air temperature was usually warmer than that of the lake surface. According to the original meteorological study, even in the least favorable month, however, the inversion frequency was only 22%. According to the recent data from 2001 to 2005, the inversion frequency was 56% in the least favorable month. There were almost no instances in which stable lapse rates were accompanied by winds toward the heavily populated Chicago areas.

2.2.3.1 Turbulence Classification

According to the original meteorological study, the four turbulence classes employed in the analysis follow closely the system developed and used extensively by Smith and Singer. Turbulence class I was clearly related to unstable lapse rates. Turbulence class II was also primarily related to unstable lapse rates, but a significant portion of the cases were associated with stable lapse rates. Turbulence class III was related to lapse rates between classes II and IV. Turbulence class IV was related to stable lapse rates.

In the distribution of the four Smith-and-Singer turbulence classes on an annual basis, individual monthly variations among the three years were small, and the overall summary was a good representation of the typical distribution. Turbulence class I represented a very small percentage (4%) of the total observational period. Turbulence class II dominated the distribution throughout the year, accounting for 81% of all hours. Turbulence class III included a small percentage (8%) of the overall hours. The surprisingly small frequency of turbulence class IV conditions was apparently a genuine feature of the site, since its annual occurrence was only 7% of the total. But this frequency was more significant because of the relatively poor dispersion conditions associated with this turbulence class. At all of the locations, the distributions were surprisingly uniform.

Currently, the seven Pasquill turbulence classes A, B, C, D, E, F and G are used and represent extremely unstable, moderately unstable, slightly unstable, neutral, slightly stable, moderately stable and extremely stable, respectively. Joint frequency distributions of wind speed and wind direction by atmospheric stability class are presented in Tables 2.2-3 through 2.2-9 for the shoreline tower for the year 2005. Pasquill turbulence class A represented 23% of all hours. Pasquill turbulence class D occurred 33% of the time. The annual average occurrence of Pasquill turbulence classes F and G were 6% and 7%, respectively. (Smith-and-Singer turbulence class IV encompassed Pasquill turbulence classes F and G.)

According to the original meteorological study, there was considerable seasonal variability in wind roses, but nothing was exceptionally significant from the point of view of dispersion problems. The most marked tendency for stable conditions occurred in the summer when the general wind flow in the area became relatively light. There was a tendency for an increase in the number of stable hours during the spring, when the lake water was cold compared to the air temperature, but it was not especially marked.

2.2.3.2 Representativeness of Wind Speeds

After the original main tower installation and inland satellite were in operation for the first full year, it became evident that there was some tendency for restriction of the low-level wind speeds as exemplified by the 50-foot level on the main tower. In particular, it was noted that the mean winds at the 50-foot level were much lower than those at the inland satellite, which were actually closer to the ground surface. Table 2.2-10 shows the problem very clearly: the wind speeds at the 50-foot level on the main tower were significantly lower than those at the satellite in all but the stable conditions. Furthermore, the comparison of the 50-foot speeds with those obtained from the 200-foot instrument on the main tower indicated an unreasonably rapid increase of wind speed with height, whereas the comparison between the satellite and the 200-foot levels were more in accord with typical results.

This restriction apparently was associated with the vegetation nearby and with the rugged dune structure. Since the terrain was being altered locally for construction purposes, it was felt that a wind instrument located nearer the beach would be more representative, and the 50-foot aerovane on the inland satellite was moved in the Spring of 1969. The instrument was replaced by a RAIM Associates cup and vane in December 1969 to provide greater sensitivity and accuracy at low speeds.

The recent data from 2001 to 2005 were similarly compared, as shown in Table 2.2-10. Mean wind speeds at the 10-meter level of the primary tower were significantly lower than those at the shoreline tower for all conditions (Pasquill turbulence classes A through G). In addition, the comparison of the 10-meter and 60-meter speeds from the primary tower indicated an unreasonably rapid increase of wind speed with height, whereas the comparison between the 10-meter speed from the shoreline tower and the 60-meter speed from the primary tower were more in accord with typical results. Therefore, the 10-meter speed from the shoreline tower was more representative.

2.2.3.3 Onshore Winds During Stable Conditions

An important factor in safety analyses is the frequency of onshore winds accompanied by stable atmospheric conditions, and the speed of such winds when such a condition occurs. The data from the original beach instrument were reviewed from this standpoint. The frequency of onshore winds associated with stable conditions were reviewed for the five months in which the beach instrument operated satisfactorily. The data were further broken down according to wind speeds in the 0 to 3 mph class and those exceeding 3 mph. “Onshore” was defined as any wind ranging from 180 to 010 degrees on the westerly side of the compass rose. Except for the month of August 1969, in which stable conditions were common, the combination of onshore winds of low speeds in stable conditions was very unusual. Based on this data, an annual frequency of occurrence of less than 1% of the 200-foot data and only 2.5% of the satellite data were anticipated.

According to the recent data from 2001 to 2005, an annual frequency of occurrence of less than 1% of the 60-meter data (0.4% during Pasquill class G and 0.2% during Pasquill class F) and only 2.2% of the shoreline data were anticipated (1.0% during Pasquill class G and 1.2% during Pasquill class F).

2.2.3.4 Atmospheric Dispersion Models

Utilization of meteorological data in the assessment of safety requires selection of appropriate mathematical models for emissions and building characteristics, and the computation of concentrations. For design basis accident calculations, to ensure that the health and safety of the public is protected, one establishes the least favorable conditions that might be reasonably expected to accompany a release over a given period. The least favorable conditions according to the original meteorological study were Smith-and-Singer turbulence class IV, which encompassed Pasquill turbulence classes F and G.

Currently, the offsite atmospheric dispersion factor model is based on Regulator Guide 1.145, and the control room atmospheric dispersion factor model is based on the ARCON96 computer code. According to the original meteorological study, Smith and Singer derived horizontal and vertical atmospheric dispersion coefficients for the four turbulence classes partially from the aerovane records of wind direction and partially from general considerations of mid-latitude dispersion. The contribution of the horizontal and vertical atmospheric dispersion coefficients for the stable turbulence class IV gave results very close to Pasquill turbulence class F within the first kilometer from the source.

The resulting off-site and control room atmospheric dispersion factors (χ/Q values) used in radiological consequence calculations for design basis accidents are presented in Tables 2.2-11 and 2.2-12, respectively.

2.2.3.5 Normal Operation

Meteorological data used to compute non-accident doses to a member of the public is maintained current within the Off-site Dose Calculation Manual (ODCM). Other data contained herein is historical information.

Atmospheric dispersion factors for normal operation are calculated from data from the primary tower's 10 meter instruments using the MIDAS computer code. Joint frequency distributions of wind speed and wind direction from the primary tower are shown in Tables 2.2-13 through 2.2-20 for 1992 (historical data – sample of a typical year).

Wind speeds were moderate in 1992 (historical data - sample from a typical year). The predominant wind speed range is 4-7 mph category. The wind speed exceeded 14 mph less than 4% of the time. The wind direction at the main tower varied, with the largest frequencies occurring both from the North and from the South. This can be observed in the wind roses shown in Figures 2.2-3 through 2.2-7. There was a slight tendency for winds from the West (onshore flow) to occur. The second quarter of the year produced winds mostly from the North, while during the fourth quarter they were from the South.

The wind at the shoreline (measured by the shoreline tower) shows a large contrast. The winds are mostly from the South East. This directional preference can be seen in all four quarters for 1992, as shown on the wind roses in Figures 2.2-8 through 2.2-12.

2.2.4 References for Section 2.2

1. Fawbush, Miller and Starrett: "An Empirical Method of Forecasting Tornado Development," Bulletin, AMS, 32, 1951.
2. Spohn et. al.: "Tornado Climatology," Monthly Weather Review, Wash., D.C., 1962.
3. Thom: "Tornado Probabilities," Monthly Weather Review, Wash., D.C., 1963.
4. Thom: "Distributions of Extreme Winds in the United States," Journal, Struct. Div. ASCE, April, 1960.
5. Singer and Smith: "Relation of Gustiness to Other Meteorological Variables," Journal of Met., 1953.
6. Michigan Emergency Management Division, "Michigan Hazard Analysis," September 1992.

2.3 GEOLOGY

The geology of the site and surrounding areas is basically simple. Although bedrock in the area is concealed beneath thick glacial deposits, variable data indicate that the bedrock beneath the site conforms to the regional structural and stratigraphic system. The overlying glacial deposits are typical of those found in the vicinity of Lake Michigan. No anomalous geologic condition is known or suspected. A complete report of site geology is included in Appendix A to the Preliminary Safety Analysis Report.

2.3.1 Regional Geology

Physiography

The southern peninsula of Michigan lies within the Central Lowland Physiographic Province. The topography is typical of areas of regional glaciation. As a consequence of glaciation, land forms are of low to moderate relief and generally smoothly contoured. Bedrock exposures are rare. Reaches of the Lake Michigan shoreline are characterized by extensive sand dunes and ancient shoreline features of Glacial Lake Chicago. Regional drainage in southwest Michigan is toward Lake Michigan on the west.

Stratigraphy

The regional bedrock geology is relatively simple. The southwest part of Michigan is located on the flank of a very large synclinal basin, the Michigan Basin. Bedrock consists of a mixed sequence of sedimentary strata including shale, limestone, sandstone and dolomite. The strata range in age from Cambrian to Pennsylvanian. This sequence is underlain by a basement complex of Precambrian igneous and metamorphic rocks.

Bedrock formations in the vicinity of the site include shale and sandstones of Devonian and Mississippian age. The Precambrian basement is estimated to occur at a depth of 3,500 feet. In southwest Michigan, the surficial glacial deposits exceed 350 feet in thickness in places and overlie a moderately irregular bedrock surface. Valleys in the bedrock surface represent pre-glacial stream channels modified to a certain extent by glacial erosion. In the site area, the bedrock surface slopes generally north or northwest.

Structure

The Michigan Basin is a remarkably symmetrical dish-shaped structure bounded on the north by the Canadian Shield and on the west by the La Salle Anticline and Wisconsin Arch. On the south side, it is bounded by the Cincinnati-Kankakee-Findlay Arch System. A number of large faults have been mapped in areas surrounding the Michigan Basin. All but one lie well beyond the borders of the state. The principal geologic structures in the region are shown in Figure 2.3-l, Regional Tectonic Map.

In southwest Michigan, the bedrock formations dip at low angles to the northeast. Subsurface data indicated the presence of deeply buried folds and possible faults at a number of locations. These structures are related to ancient crustal movements. The relatively minor folds do not carry through to succeeding younger formations, and no recent faulting can be identified. No fault or other geologic structure is evident within 50 miles of the site. One named structure, the Howell Anticline, is located in southeast Michigan. Some indirect evidence exists of a possible concealed subsurface fault tending in a northwest direction from Hillsdale County to Allegan County. At its closest approach, this postulated structural trend is located approximately 50 miles northeast of Benton Harbor. Evidence for this possible fault includes a negative gravity anomaly, structure contour steepening, an earthquake epicenter, and the occurrence of oil fields along the trend.

History

The Michigan Basin was a basin of deposition and subsidence throughout most of the Paleozoic Era. The strata decrease in thickness away from the center of the basin and much of southwest Michigan appears to have been a submarine platform or shelf. Absence of Mesozoic and Cenozoic Strata indicate that the area was above sea level during this long period of time. The glacial deposits which fill irregularities in the eroded bedrock surface reveal a complex history of repeated advances and retreats of the Pleistocene glaciers. The last glacier, which extended south into Illinois and Ohio completely covered the State of Michigan. In the site area, it eroded or buried all evidence of earlier glacial stages. A series of end moraines parallel to the shore of Lake Michigan define the lobate character of the ice front and represent halts in the retreat of the last glacier. Some shoreline features adjacent to Lake Michigan are related to different stages in the level of ancient Glacial Lake Chicago which fluctuated in response to alternate damming of outlets by glaciers and opening of outlets at different elevations as the ice melted.

2.3.2 Site Geology

Physiography

The site is located within a local physiographic area known as the Grand Marais Embayment. This area extends l6 miles parallel to the lake and has an average width of one mile. On the Lake Michigan side, it is characterized by high sand dunes and shoreline features of several glacial lake stages. The area is bounded on the east by a glacial moraine known as Covert Ridge. This ridge is a drainage divide. The westward draining catchment area is limited and there are only a few, very small, intermittent streams on the west side of the ridge. At the site, the sand dunes rise abruptly from the narrow beach and extend inland about 6,000 feet. The shoreline in this area is stable.

Surficial Geology

The western part of the site is covered by large coalescing sand dunes more than 150 feet high. The eastern portion of the site is characterized by scattered lower dunes with broad intervening basins, some of which contain shallow ponds. Old shoreline features such as beaches, bars and spits occur at different elevations and are related to former lake levels.

Subsurface Geology

The details of the subsurface geology were investigated by means of 19 test borings and geophysical studies. The borings reveal a simple sequence of deposits consisting of a surface deposit of dune sand which overlies older beach sand which in turn is underlain by glacial lake clays, glacial till and shale bedrock. In the eastern half of the property, the beach sands are absent and the dunes rest directly on glacial lake deposits. The subsurface conditions are illustrated on Figure 2.3-2, Geologic Cross Section. The dune sand is generally loose at and near the surface and grades to moderately compact with depth. The underlying beach sands are generally compact and commonly range from about 25 to 35 feet in thickness in the west-central portion of the property.

The surface of the lake deposits slopes upward gradually from elevations of about 555 to 560 feet along the beach to about Elevation 590 feet in the southeast corner of the site. These deposits comprise an irregularly interbedded series of clayey sediments 80 to 90 feet in thickness. The upper portion tends to be organic and, in places, a very thin layer of peat is encountered. The lake sediments exhibit varying strength characteristics. Commonly, the uppermost zone is firm to very firm and grades with increasing depth to layers that are generally firm to moderately firm. The higher strength of the upper zone is probably due to desiccation. Below about Elevation 500 feet, the deposit is very firm.

In the deepest boring, a stratum of compact glacial till about 22 feet in thickness was encountered immediately overlying the bedrock. This stratum probably extends throughout the site and fills in irregularities in the bedrock surface. The bedrock consists of thin bedded shale with thin interbeds of shally limestone. Seismic refraction surveys indicate that the bedrock beneath the site has a relatively smooth, gently sloping surface. It occurs at elevations ranging from 420 feet to 460 feet above sea level along the beach. Inland, the bedrock surface lies at elevations ranging from 400 feet to 420 feet above sea level.

2.3.3 Summary of Conclusions

Based on the geologic studies, the following conclusions have been reached:

- The geology of the site and surrounding area is basically simple. A thick sequence of sand dunes, beach sands and glacial lake and till deposits conceals the underlying shale bedrock.
- Shoreline erosion is not evident at the site.
- The bedrock characteristics and geologic features at the site conform to the regional conditions.
- No fault or other adverse geologic phenomenon is known or suspected in the vicinity of the site.
- Adequate foundation support for major structures is available from the lake clays and deeper glacial soils.
- The geologic conditions at and in the vicinity of the site are satisfactory for the construction and operation of the nuclear power facility.

2.4 HYDROLOGY

The surface drainage characteristics of the area are controlled by the glacial and sand dune topography and the nature of the surficial soils. The groundwater characteristics of the area are governed by the nature and distribution of the glacial deposits. A complete report of site hydrology was included in Appendix A to the Preliminary Safety Analysis Report.

2.4.1 Surface Water Hydrology

Regional

The gently undulating glacial terrain controls the surface drainage pattern. Regional drainage is westward into Lake Michigan. The drainage system is for the most part, very irregular and poorly developed. Small lakes and local swampy areas are abundant. The site is located within the Grand Marais Embayment drainage basin which is separated from the St. Joseph River drainage basin to the east by a glacial moraine known as Covert Ridge. A regional water budget analysis of the St. Joseph River drainage basin (the closest basin for which data are available) indicates an annual average precipitation of 34 inches, 41 percent of which is runoff and 59 percent of which recharges ground-water reservoirs and/or is lost as evapotranspiration. Precipitation is fairly uniformly distributed throughout the year.

Local

Only a few minor intermittent streams occur west of Covert Ridge. Thornton Valley, situated between the dunes area and Covert Ridge, contains a small intermittent stream, which traverses the eastern portion of the site via a man-made drain. Run-off from the eastern portion of the site drains north via Thornton Valley into the Grand Marais Lakes. Run-off is limited due to rapid infiltration of rainfall into the sandy soils.

Surface water run-off in the dune-covered western part of the site is negligible. Swampy areas are found within some of the closed depressions in the east-central portion of the site.

2.4.2 Ground-Water Hydrology

Regional

Ground-water supplies in the region are obtained primarily from shallow wells, which terminate in the more granular glacial deposits. The predominantly shale bedrock in southwest Michigan is not recognized as an aquifer. The deeper bedrock strata are known to contain brines and are not used as sources of ground water. Some larger towns near the lake, such as Benton Harbor, obtain their water supplies directly from Lake Michigan.

The water sources, as of December, 1999, for Parks, Public Facilities and Communities within ten (10) miles of the site are given in the following table:

Place	Distance From Plant In Miles	Source of Drinking Water	Capacity in gpd	Number of People	Storage Capacity In Gallons
St. Joseph	9.0	Lake Michigan 1500 ft. Offshore	16,000,000	27,500	4,850,000
City of Bridgman	2.5	Crib 300 ft. Offshore	1,400,000	2,000	600,000
Lake Township*	0.6	Lake Michigan 2400 ft. Offshore	2,000,000	10,000	1,000,000

There are a large number of private domestic wells (estimated 4000) in the area within the ten (10) mile radius. The nearest is 2,160 feet from the plant. There are no residences on the site property.

Covert Ridge is a ground-water barrier as well as a watershed boundary between the glacial plain to the east and the Grand Marais Embayment to the west.

Static ground-water levels east of the ridge are generally at Elevation 650 feet above sea level. In contrast, static water levels west of the ridge occur generally at elevations of 580 to 490 feet above sea level. The chemical characteristics of the ground water on each side of the ridge are also different.

Local

Three existing wells are located within 1,500 feet of the southern boundary of the site, and approximately 20 wells are found within 1,500 feet of the northern site boundary. In addition, 25 residences are supplied by a number of the shallow wells in Thornton Valley approximately one mile northeast of the property. These wells are generally 20 to 30 feet deep and have a static water level of 586 feet above sea level. No wells are located between the site and Convert Ridge to the east. At the site, the water table occurs within the dune and beach sands which overlie impermeable lake deposits. Recharge of ground water by infiltration of precipitation through the

* Lake Township serves Warren Dunes State Park and is interconnected with the City of Bridgman and the Township of Chicaming.

permeable sandy surficial soils is rapid. Static water table elevations observed inside perforated plastic pipe installed in 19 test borings at the site ranged from 582 to 609 feet above sea level. Slightly higher levels probably occur beneath the higher dunes, particularly after rainy periods.

The overall gradient of the water table, except in the eastern-most part of the site, is toward the west. The direction of ground-water flow for most of the site is, therefore, westward to Lake Michigan. The ground-water divide between Thornton Valley and the dunes area is close to the topographic divide, some 3,500 feet east of the lake. Consequently, only minor ground-water seepage escapes into Thornton Valley, and this seepage originates from the extreme eastern part of the site. The water table gradient is very flat with typical values of 0.5 to 0.7 percent in the dune area and 1 to 4 percent close to the lake front. Consequently, the rate of ground-water flow under these conditions is extremely slow. Inplace field permeability tests indicate an average permeability of the upper sands on the order of one to two feet per day with a maximum measured value of three feet per day. The deposits beneath the sands are impermeable. Since the water table gradient is small and since the ground-water flow from the west and central portions of the site is not in the direction of existing ground-water supplies but is toward the lake, the possibility of accidental spillage of liquids in the plant area affecting ground-water supplies is remote.

2.4.3 Summary of Conclusions

Based on the hydrologic studies conducted at the site, the following conclusions have been reached:

a. The site is located within the Grand Marais Embayment and is distinctly separated from the area to the east by Covert Ridge which is a surface drainage divide and a groundwater barrier.

b. The hydrologic study, as part of the application for a permit for the initial construction of the plant, found that infiltration of rainfall into the sandy surficial soils at the site was rapid and flooding conditions were non-existent.

c. Surface runoff is minor and is restricted to the eastern portion of the site. The minor runoff discharges into Lake Michigan via Thorton Valley and the Grand Marais Lakes. The rest of the site is characterized by basins of interior drainage and is devoid of streams. Shallow swampy areas occupy depressions between coalescing sand dunes in the eastern part of the site.

d. The ground-water table generally rises gradually eastward away from Lake Michigan. The water table is less than 30 feet above the level of the lake and occurs within the dune sand or beach sand which overlies impermeable glacial lake clays. Local mounding of the water table occurs beneath some of the higher dunes and beneath the turbine room absorption pond.

e. Beneath most of the site, including the plant areas, the overall direction of ground-water flow is toward Lake Michigan. East of the topographic divide, some 3,500 feet east of the lake, the direction of ground-water flow trends northeast into Thornton Valley.

f. The water table gradients are very flat and the rate of ground-water movement consequently is slow.

g. The possibility of affecting wells or the available ground-water resources in the site area by construction and operation of a nuclear facility located in the west-central portion of the site is extremely improbable.

h. The hydrologic characteristics of the site are, therefore, favorable for the location of a nuclear power plant.

2.5 ENGINEERING SEISMOLOGY

The site lies in a region which has experienced very little earthquake activity. No major earthquakes have had epicenters closer than about 400 miles to the plant site. There has been some minor earthquake activity closer to the site; however, no shocks within 50 miles of the site have been large enough to cause significant structural damage. A complete report of site seismology is included in Appendix A to the Preliminary Safety Analysis Report.

2.5.1 Seismicity

The epicentral locations of all reported earthquakes with Modified Mercalli Intensities of V or greater in the region surrounding the site are shown on Figure 2.5-1, Epicentral Location Map. The closest Intensity IV shock is also shown. Only three recorded earthquakes with epicentral intensities of V or greater have occurred within approximately 100 miles of the plant site. These were of relatively low intensity, barely strong enough to cause even slight structural damage. The two largest earthquakes in the vicinity of the site had maximum intensities of VI. The first occurred near Fort Dearborn (Chicago) Illinois, about 70 miles from the site, in 1804. The second occurred in south-central Michigan about 75 miles from the site, in 1947. An Intensity V earthquake occurred near Milwaukee, Wisconsin in 1947. A weak earthquake with a maximum intensity of IV occurred in 1938 on the south shore of Lake Michigan about 30 miles from the site. This earthquake did no damage but was felt over a relatively large area.

A possible earthquake occurred in 1883 near Kalamazoo, Michigan about 50 miles northeast of the site. The maximum intensity for this event is listed as VI since there is a record of some minor damage in Kalamazoo. However, information is available which indicates that the damage may have been caused by an explosion and not an earthquake.

It is likely that most of the minor earthquake activity in the Michigan Basin is related to readjustments along zones of weakness in the bedrock, probably caused by glacial rebound. This same mechanism probably caused the minor earthquakes reported in northern Ohio, Lake Erie and western New York State. The 1947 earthquake in south-central Michigan may be related to a possible northwest trending fault located 50 miles northeast of Benton Harbor. Other seismic activity is related to fault systems bordering the Michigan Basin such as the Findlay Arch System in western Ohio. Some of the larger shocks from this area have been felt in southern Michigan.

In summary, it may be stated that the seismicity of the region is low. Although no major earthquake has originated closer than about 400 miles to the plant site, several damaging shocks have occurred close enough to be of significance. A list of the closest significant earthquakes in the region is presented in Table 2.5-1, Earthquakes with Epicenters located within 200 miles of Plant Site.

While several of these shocks were possibly felt in the vicinity of the site, no damaging effect would have been experienced from them. In the event of a recurrence of an historical earthquake, no damage would be experienced at the site by reasonably well-designed structures.

2.5.2 A Seismic Design

Foundation Materials

The site is underlain by a simple sequence of formations consisting of a surface stratum of dune sand underlain by dense beach sands, a stiff clay stratum and, glacial till resting on shale-bedrock. Major plant structures are supported on mat foundations installed on the overlying compact sand, recompacted sand, or stiff clay deposits.

Available data from past earthquakes indicate that compact glacial till and competent bedrock perform well under dynamic loading. Dynamic laboratory testing on samples of the compact beach sand and the upper lake bed deposits of silty clay indicates that these materials would experience no significant loss in strength during any potential earthquake.

Operating Basis Earthquake

On the basis of the seismic history of the area, it appears extremely likely that the site will not experience any significant earthquake motion during the life of the plant. Based on the history of previous earthquake activity in the area, it is estimated that the maximum ground motion to which the site may be subject during its life would be due to a shock similar to the 1947 south-central Michigan earthquake. It is estimated that the magnitude of this shock was no greater than about 4½ on the Richter Scale. This earthquake possibly may be related to a postulated fault structure trending northwest-southeast through southwest Michigan. The closest approach of this postulated structure to the site is about 50 miles to the northeast. It is estimated that the ground acceleration at the site due to a magnitude 4½ earthquake at a distance of 50 miles would be barely perceptible at the site. The largest earthquake in the region occurred near Lima, Ohio, in 1937. It has an epicentral Intensity of VII to VIII and was felt over an area of about 150,000 square miles. The magnitude of this earthquake has been estimated at about 5½. This earthquake was related to local faulting associated with the Findlay Arch. The closest approach of the Findlay Arch or any related structure to the site is about 130 miles. An earthquake of magnitude 5½ at an epicentral distance of 130 miles would be barely perceptible at the site. On a historical basis, it does not appear necessary to incorporate a seismic factor in the elastic design of the power plant. However, in view of the nature of the facility, the major structures are conservatively designed for a maximum horizontal ground acceleration of 10 percent of gravity and a maximum vertical acceleration of 6.66 percent of gravity. The seismic design requirements of the reactor containment structure are given in Chapter 5 and the requirements for other structures and equipment are given in Sub-Chapter 2.9. The dynamic analysis of the containment structure for seismic loading is in Appendix F to the Original Safety Analysis Report.

Design Basis Earthquake

The maximum potential earthquake for this site is considered to be a recurrence of the largest recorded earthquake in a nearby region at the closest epicentral distance consistent with geologic structure. A number of earthquakes in the region have not been related to known tectonics. These shocks may have their origin in the crystalline basement rock where the structure is complex. They may occur along zones of weakness, triggered by glacial rebound. Historically, such shocks have been minor, with estimated magnitudes not exceeding 4½. However, an earthquake in 1943 with its epicenter in Lake Erie may have had a magnitude as great as 5. The geology of Lake Erie is similar to that of southwest Michigan in that the bedrock is essentially a stable platform with little or no seismic history and no known faulting. Shocks in the Lake Erie area are probably related to glacial rebound, as we believe the shocks to be in the area of the site.

Based on the foregoing, it has been conservatively assumed that the maximum potential earthquake could be as large as Magnitude 5 and might occur relative to some yet unknown geologic structure in the bedrock near the site, perhaps triggered by glacial rebound. Assuming such a shock might have a focal depth as shallow as 10 kilometers, it is estimated that the maximum ground acceleration at foundation level (within the lake or beach sand deposits) at the site would be about 15 percent of gravity. However, additional margin has been provided for by designing the engineered safety features to be operative under a maximum horizontal ground acceleration of 20 percent of gravity and maximum vertical acceleration of 13.33 percent of gravity.

The seismic design requirements of the containment are given in Chapter 5, and the requirement for other structures and equipment are given in Sub-Chapter 2.9.

Response Spectra

Recommended response spectra showing responses for typical percent of critical damping for the operating basis and the design basis earthquakes, corresponding to horizontal ground accelerations of 10 and 20 percent of gravity, are presented on Figures 2.5-2 and 2.5-3. These response spectra represent the maximum amplitudes of motion in structures having a range of natural frequencies subjected to earthquake ground motion.

The use of the average (El-Centro) response spectra as presented in TID 7024, normalized to the recommended ground accelerations, was deemed appropriate for this site since the average spectra are based on site conditions consisting of a deep thickness of overburden soil over bedrock. The subsurface conditions at the Cook Plant site consists of soils which are comparable in compactness to El-Centro and it was therefore felt that the normalized El-Centro spectra are appropriately conservative for this site.

In order to show that the response spectra generated, using four earthquakes, are as conservative as the spectra generated using a synthetic earthquake, which falls above the site spectra, a comparison was made for the Auxiliary Building, between existing floor spectra and the spectra generated using the modified El-Centro Earthquake (N-S-components - 1934).

The El-Centro earthquake was modified such that at all frequencies its response spectrum falls above the site response spectrum. (See Figure 2.5-3a.)

Figures 2.5-3b through 2.5-3e show this comparison for various elevations in the structure for an OBE. Curve - A represents the spectrum used in design and curve - B represents the spectrum generated using the synthetic time history motion. Since curve - A envelopes curve - B in all cases the response spectra used in design are conservative.

Figures 2.5-3f through 2.5-3j show this comparison for the DBE with 5% structural damping.

For the Dry Cask Storage Project, the Maximum Critical Load (MCL) rating of the east auxiliary building crane was increased to 145 tons. For this specific effort, new ground response spectra for the auxiliary building were developed using the guidance in Regulatory Guide 1.60, Revision 1. Spectra shapes from this Regulatory Guide were anchored at 0.lg OBE and 0.2g SSE zero period ground acceleration. In addition, the original real time histories from the four historical earthquakes were replaced with synthetic time-histories which were developed in three directions (two horizontal and one vertical). The design artificial time history function enveloped the Regulatory Guide 1.60, Revision 1 design ground response spectrum for all damping values from Regulatory Guide 1.61, Revision 1.

Supplemental Data

Subsequent to the detailed studies of the site and its surroundings described in the Appendix A, additional work was performed to confirm the validity of the seismic accelerations proposed as design bases for the plant.

An investigation was made of the logs of a series of gas and oil wells drilled in the site vicinity to depths of up to 2500 feet and the results were plotted. Although fifteen logs were studied, eleven lay along a southwest-northeast axis about 35 miles long, roughly parallel to the lake shore and passing about two to three miles from the plant location. The remaining five were located along an axis perpendicular to the first and intersecting it in the site vicinity.

The results of this study demonstrated that there is a complete absence of geologic structure in the immediate site area which could be related to past or future seismic events.

In addition, a large number of references were studied to determine the seismic characteristics of the region surrounding the site. This included eastern Wisconsin, northern Illinois and Indiana, and northwestern Ohio as well as Michigan.

Further information relating to the selection of seismic parameters can be found in the reports of the results of foundation investigations conducted at the site, by A. & L. Casagrande:

- Report on Foundation Investigation for Donald C. Cook Nuclear Power Plant", 2/20/68
- "Donald C. Cook Nuclear Power Plant Settlement Analyses of Containment Units Based on Investigation of Undisturbed Samples from Boring No. 105", 5/4/68
- "Report on Foundation Investigations for the Donald C. Cook Nuclear Power Plant", 8/26/68
- "Supplement to Report of August, 1968 on Report on Foundation Investigation for the Donald C. Cook Nuclear Power Plant", 4/69

2.5.3 Conclusions

It is anticipated that the site will not experience any significant earthquake motion during the life of the nuclear facility. Historically, there is no basis for expected ground motion of more than a few percent of gravity. However, as a conservative basis, an earthquake horizontal ground acceleration of 10 percent of gravity was adopted for plant design where applicable.

For safe shutdown of the reactor, and operability of engineered safety features a maximum horizontal ground acceleration of 20 percent of gravity was assumed. This ground acceleration is in excess of that estimated on the basis of an occurrence of a shallow focus Magnitude 5 earthquake close to the site. On the basis of the seismic history and the known tectonics of the area, the possibility of such an occurrence is extremely remote.

2.6 LIMNOLOGY AND ECOLOGY

2.6.1 Limnology and Ecology Introduction

Lake Michigan is the condenser cooling water, component cooling water, and service water for Cook Nuclear Plant. Lake Township Fire Hydrant System is the back-up fire protection source water for Cook Nuclear Plant. Radioactive liquid wastes generated by the plant are processed in the liquid radioactive waste system and the processed stream is discharged within the plant to the circulating water system discharge stream. All effluent streams from the liquid radioactive waste system are sampled and analyzed prior to the discharge and monitored during the discharge in accordance with the regulations in 10 CFR Parts 20 and 50.

The Cook Nuclear Plant withdraws 1,645,000 gpm for cooling water and plant process water from Lake Michigan. Heat with small amounts of chlorine used for biofouling control, radioactivity in the liquid radioactive waste system outfalls, and blowdown from the steam generators are the primary additions to the plant effluent water. Heat rejection rates for Units 1 and 2 are - subject to variations depending on plant efficiency. The maximum allowed heat rejection rate for plant total is 16.8×10^9 Btu/hr.

Potential impacts to the limnological and ecological features of the region from the operation of Cook Nuclear Plant include thermal stress to lake biota, fish and macrobenthos impingement on traveling water screens, entrainment of planktonic biota through the plant and into the thermal plume, alterations to local water and sediment chemistry, thermal plume induced shore ice melts, meteorological changes, bathymetric changes, biocide toxicity, and increases in water and sediment radioactivity.

Research programs to determine the interactions between the Cook Nuclear Plant and the Lake Michigan environs were begun in 1966 and continue to the present. These research studies were conducted in three phases. From 1966 until 1973, the limnological investigations were conducted primarily to provide information for the environmental impact statement. Research conducted from 1973 through 1982 was required by the Nuclear Regulatory Commission license Appendix B Technical Specifications and was needed for certain provisions of the State of Michigan issued National Pollution Discharge Elimination System (NPDES) Permit. The last phase of research, which continues to date, is mostly monitoring of certain baseline conditions established in the first two phases and new conditions, specifically the introduction to the Cook Nuclear Plant vicinity of Lake Michigan of the biofouling molluscs, Asiatic clams (Corbicula fluminea) and zebra mussels (Dreissena polymorpha). The results of the first and second phase studies were compiled in reports prepared by the consultant or were reports placed in the Donald C. Cook Nuclear Plant Annual Environmental Operating Reports starting in 1974 through the present.

The three phases of studies were conducted in numerous segments and were reported on in numerous reports but they can be grouped in general categories and the results of these studies will be grouped by category within the three phases of study. The following sections identify the category groupings of the studies by phases. Within the category grouping is a brief identification of the types of studies within the grouping, the purpose of doing the studies, and the significant results and conclusions of the studies within the category group.

2.6.2 Initial Studies

2.6.2.1 Study Groupings

Physical Limnology

Physical limnological studies conducted in Lake Michigan near the Cook Nuclear Plant included lake bathymetry, sediment stability and physical characteristics, ice formation and melting patterns, seiches, and a special subset of the physical limnology that dealt with thermal plume dispersion. Thermal plume dispersion studies included wind, wave, and lake current studies, dye dispersion studies; mathematical and scale modeling of the thermal plume dispersion; and locating potable water intakes and determining the possibility of the thermal plume reaching those intakes.

Biological Studies

Biological studies covered periphyton, phytoplankton, zooplankton, benthic invertebrate, and psammolitoral fauna community composition and abundance and benthic invertebrate and sediment chemistry interactions.

Sediment Chemistry

Sediment chemistry studies included determination of the baseline concentrations of radioactive and non-radioactive elements in the Lake Michigan sediments.

Water Chemistry

Water chemistry studies include determinations of radioactive and non-radioactive element concentrations in Lake Michigan.

Table 2.6-1 is a list of the references used to compile the initial phase studies summary.

2.6.2.2 Purpose of Initial Phase Studies

Physical Limnology

The physical limnological studies were conducted for many reasons. Bathymetry and sediment size composition and distribution was studied to determine the baseline lake bottom contour conditions and use this information to determine if plant operation would alter the bottom contours near the intake and discharge structures. Sediment stability determinations were made using sediment particle size, composition and distribution. This gave the intake and discharge design engineers information on the scour potential of the lake sediments. Sediment size can also be used to correlate benthic macroinvertebrate population distribution and density to physical characteristics.

Ice formation and ice melting of the floating and shore ice was important in determining the potential for ice damage to plant equipment. These studies also provided the baseline data to determine if the thermal discharge would cause shoreline erosion by melting the shoreline that protects the beaches from wave erosion during winter storms.

Seiches were studied to determine the possible effect on equipment and the potential for flooding of equipment.

Thermal plume dispersion studies were conducted to determine the direction the thermal plume would curve, whether the thermal plume would impinge on the beach, the area within thermal isopleths, and the distance the heated water would travel in the lake.

Biological Studies

Biological studies were conducted to determine the effect of the thermal discharge on algae growth and on zooplankton populations. Benthic macroinvertebrate studies were conducted to determine the effect of chemical discharges from the plant on this organism group.

Sediment Chemistry

Sediment chemistry studies were conducted to determine if the Cook Nuclear Plant vicinity in particular and Lake Michigan in general were contaminated from anthropogenic trace element sources and to establish the background levels of the radioactive and non-radioactive elements so these concentrations could be compared with levels measured after plant operation began.

Water Chemistry

Water chemistry studies were conducted to determine if the Cook Nuclear Plant vicinity in particular and Lake Michigan in general were contaminated from anthropogenic trace element sources and to establish the background concentrations of radioactive and non-radioactive elements so these concentrations could be compared with levels measured after plant operation began.

2.6.2.3 Initial Study Results

Physical Limnology

Figure 2.6-1 is a plot of the bottom of the lake adjacent to the site. It is characterized by gentle and regular topography. The 100-foot depth isopleth lies about six miles from shore. Isopleths are generally regular and parallel to the shoreline. Two sand bars lie close to shore along the entire length of the site property. The inner bar averages about 500 feet from the shoreline while the outer bar runs approximately 1000 feet from the shoreline. Maximum water depth of five to six feet is present between the inner bar and the shore. Twelve to thirteen feet of depth is the greatest measured between the bars. The depth over the crest of the inner bar is about four feet, while the outer bar peaks at eight to nine feet beneath the surface.

A number of studies of bottom stability along the east shore of Lake Michigan have been made in the past decade or two. Lake Michigan has what appears to be very stable conditions near shore despite severe storms and winter icing. Present evidence indicates that the nearshore sandbars fluctuate in position but maintain a fairly consistent average position, with fairly consistent water depths over their crests. Though bottom contours remain relatively stable, the littoral transport of sand has been estimated to be 100,000 cubic yards per year moving generally southward along the Michigan shore.

Although all of the currents of Lake Michigan are not thoroughly understood, certain of the larger features have been found with a surprising degree of constancy. There is a general outflow current along the Michigan shore from Little Sable Point northward toward the Straits of Mackinac, and there is a large eddy near the eastern shore near Benton Harbor, Michigan. Figure 2.6-2 indicates the results of several studies made of lake currents. In addition to the gross current features, there appears to be a thin, elongated, counterclockwise eddy close to the shore between Michigan City, Indiana and Benton Harbor (indicated by X on Figure 2.6-2). Some discussion on natural cyclic lake level fluctuation is warranted.

The speed and direction of local water currents in the site vicinity control the movement and dispersal of plant thermal plume. Studies (Reference 4) indicated that alongshore currents are established and controlled by interactions between local winds and the regional current pattern. Local winds are the dominant factors in establishing alongshore currents.

Lake levels tend to follow cycles. Over the past fifty years, periods of high lake levels and erosion were experienced from 1951-55, 1969-1975, and 1983-1987. The all-time maximum (monthly mean) high water level during this period was recorded in 1986 at 583.1 (NGVD)*. The lowest recorded (monthly mean) level of the lake was 576.8 feet above mean sea level (NGVD) during the 1964-65 winters; the highest (monthly mean) high lake level was 583.6 feet above mean sea level (NGVD) during the summer of 1886.

An Illinois State Geological Survey report (Reference 3) cites that where lake levels are rising above the 579 ft. IGLD level, well-developed beaches will delay the onset of maximum bluff erosion until they are depleted. After beaches have been depleted, bluff erosion from wave attack progresses fairly rapidly. Bluff erosion generally does not immediately decrease with decreasing lake levels, even when they fall below the 579 ft. level. Commonly, there is a lag effect by which recession rates are maintained or accelerated because slopes remain exposed until vegetation can become firmly established.

The Cook Nuclear Plant is protected by a sheet piling wall which runs the entire length of its lake frontage from the north to south property lines. A second row of sheet piling runs parallel and 35 ft. west of the first line of piling and spans the length of the protected area.

Figure 2.6-3 is a plot of surface water temperatures in Lake Michigan during the relatively cool year of 1965 and the relatively warm year of 1966. Temperatures rise abruptly from a 32°F icing condition in winter to a peak in July and August and then decrease linearly to ice-water temperatures by late December.

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* Cook Nuclear Plant elevations are expressed in National Geodetic Vertical Datum (NGVD).

A number of southwestern Michigan municipalities use Lake Michigan as their potable water source. These intakes and their approximate distances from the plant discharge are as follows:

Northward

South Haven	32 miles
Benton Harbor	11 miles
St. Joseph	9 miles

Southward

Lake Township	0.6 miles
Bridgman	2.5 miles
New Buffalo	16 miles
Grand Beach	18 miles
Michigan	19 miles
Unknown	22 miles
Michigan City, Indiana	25 miles

To the north, the outflow of the St. Joseph River interposes a physical and dynamic barrier to further progress of effluent northward along the shore. The plant effluent plume could reach the water intakes to the south at Lake Township and Bridgman. These intakes are also of the infiltration type. However, the prevailing winds of summer, when the worst dilution conditions (minimum wind and wave section) exist, are expected to carry the plume north from the plant and away from these water intakes.

Seiches are oscillations in the level of lakes and similar bodies of water caused by the passage of squall lines across the body of water. In Lake Michigan, these squalls have their fronts oriented NE to SW and are accompanied by an abrupt increase in barometric pressure and local high winds. Although seiches occur frequently in the Great Lakes, the great majority are only a few inches in amplitude. A large seiche occurred on June 26, 1954 and caused water level increases of up to 10 feet at North Avenue in Chicago, Illinois. The greatest level increase recorded on the lake's eastern shore was 6 feet at Michigan City, Indiana.

The maximum recorded amplitude of an open lake seiche was 4.2 feet observed at the Wilson Avenue Crib in Chicago on July 6, 1954. A previous seiche on June 26, 1954, which resulted in a rise of 3.2 feet at Wilson Avenue Crib, caused the rise estimated at less than 6 feet in the Michigan City yacht basin, a point approximately 25 miles south of the plant site in an area where seiche effects are considered more severe than those farther to the north. Taking these values in proportion, one can postulate the maximum seiche producing a water level increase of as much as 8 feet in the Michigan City yacht basin.

To determine the plant elevation necessary to protect the plant from flooding due to seiches, the characteristics of the lake shore at the plant, historical meteorological conditions, and mathematical modeling were used to determine a maximum seiche of 11 feet. This equates to a plant elevation of 594.6 feet above mean sea level (NGVD).

The plant is flood protected from the maximum (monthly mean) high lake water level; however, a design basis seiche occurring when the lake is at its maximum recorded level will cause flooding in the Turbine Building Screen-house. Safety-related components located in the Turbine Building Screen-house have been evaluated for the condition and flood sensitive components have been protected. Therefore protection has been provided for safety-related equipment from flooding, waves, ice storms and other lake related hazards.

Wind generated waves are limited in their dimensions by wind velocity, duration and fetch. The greatest Lake Michigan fetch for the plant site is 265 miles to the north. The maximum deep waterwave is approximately 23 feet, and would require a sustained north wind of about 26 knots for over 19 hours. The runup of such a wave on the site shore, discounting the effects of the off-shore sandbars, has been calculated as 3.7 feet. This figure is overly conservative, however, since the large wave approaching the beach would be tripped by each of the sand bars.

The coincidental occurrence of maximum wave and maximum seiche was evaluated and determined not to be a possible event.

Seiches are produced by squall-line weather and maximum waves by many hours of sustained wind.

Biological Studies

The Lake Michigan flora and fauna (excluding fish) were studied during the initial phase and was found to be similar to other very large, oligotrophic North American lakes. Phytoplankton, zooplankton and benthic macroinvertebrate communities were diverse. The psammolitoral community was fairly diverse, and several taxa were at times very abundant. The environment of the psammolitoral community is very harsh and unstable. Population fluctuations were large over short time intervals.

Phytoplankton in Lake Michigan was dominated by diatoms followed by green algae. Densities of total cells ranged from 20,000 to over 8 million cells per liter, depending upon station, water depth and season.

Periphyton, attached algae, was sparse near Cook Nuclear Plant. The lack of substrate was a major cause. Most periphyton were diatoms with green algae making up a minor portion of the standing crop.

Zooplankton in the Cook Nuclear Plant vicinity were abundant and fairly diverse. Early samples were collected with a net that was too coarse. Collections using the proper net mesh produced samples with at least 24 taxa of copepods, cladocerans and rotifers with total densities between 5,000 and 90,000 animals per liter.

Benthos studies in the early stages were descriptive and date interpretation was intuitive rather than statistical. Pontoporeia affinis, tubifex sp., Limnodridus sp., and Pisidium were the dominant taxa. Abundance and species composition varied greatly with station (water depth) and season.

The concentration of trace elements in the biota showed no specific pattern. The levels of mercury in phytoplankton, zooplankton, benthos and fish were quite low compared to Lake St. Clair and Lake Erie. Selenium was slightly elevated in three zooplankton samples but not in benthos or phytoplankton from the safe station. Estimates made of the concentration of radioisotopes in invertebrates of Lake Michigan, at the highest, will reach values equal to 8% of the upper limiting concentration normally applied to fish.

Sediment Chemistry

Sediment chemistry study results showed the sediments to be comparable to sediments in water bodies of the world. There were no trace elements or radioisotopes present in concentrations higher than values obtained from uncontaminated water bodies.

Water Chemistry

Water chemistry studies showed the concentrations of trace elements, both radioactive and non-radioactive, to be very similar to concentrations measured in uncontaminated water bodies around the world except for chromium and zinc concentrations near the Grand River. Trace element concentrations in water near the Cook Nuclear Plant were at background levels for the Great Lakes.

2.6.3 NRC Technical Specification, Appendix B Phase Studies (1973-1982)

This study phase was predominately research and monitoring required by the Technical Specifications, Appendix B of the plant operating license issued by the Nuclear Regulatory

Commission, but not exclusively. Some studies were conducted under requirements of the National Pollution Discharge Elimination System Permit issued to the plant by the Michigan Water Resources Commission. The majority of the research was conducted by the University of Michigan with the private consulting firm ETA Engineering, Inc. and the Cook Nuclear Plant staff conducting the thermal plume mapping and bathymetric surveys.

Many studies begun during the initial phase were continued during this phase. These studies provide the plant operational data to compare with the pre-operational data gathered during the initial phase studies. Table 2.6-2 is a bibliography of the reports published during this phase of study at the Cook Nuclear Plant.

2.6.3.1 Study Groupings

Physical Limnology Studies

These studies include the shore ice formation and melt studies, the lake current and temperature study using in situ monitors, the study of the effects of the thermal plume on local meteorology, the thermal plume mapping studies and the bathymetric studies.

Biological Studies

These studies include continuations of the periphyton, phytoplankton, zooplankton and benthos studies of species composition and abundance. Fish studies of population size and species composition were initiated.

Sediment Chemistry Studies

Sediment chemistry studies included the non-radiological elemental composition of the sediments. Radiological elements were also monitored for the increase in certain radioactive isotopes.

Water Chemistry Studies

The water chemistry studies included analyses for pH, hardness, conductivity, phosphorous, total nitrogen, sulfate, ammonia and trace metals.

2.6.3.2 Purpose of Technical Specification, Appendix B Studies

The Technical Specification Appendix B is part of the Cook Nuclear plant operating license that regulated the radiological and non-radiological environmental monitoring, aquatic ecological studies of the post-startup impacts to Lake Michigan, and regulated plant effluents, both radiological and non-radiological. Radiological issues are now addressed in the Off-site Dose

Calculation Manual. The non-radiological issues remain in the Appendix B Technical Specifications, whose objectives are to:

- Verify that the station is operated in an environmentally acceptable manner, as established by the FES and other NRC environmental impact assessments.
- Coordinate NRC requirements and maintain consistency with other Federal, State, and local requirements for environmental protections.
- Keep NRC informed of the environmental effects of facility construction and operation and of actions taken to control those effects.

Environmental concerns identified in the FES, which relate to water quality matters are regulated by way of the Plant's NPDES permit.

Physical Limnological Studies

The ice studies were continued to determine how the thermal discharge affected the shore ice and the floating ice in front of the plant. Winter storms could potentially cause severe beach erosion if the thermal plume melted the floating ice and the ice foot (the ice frozen to the bottom at the water/substrate interface) exposing the beach to winter storm generated waves.

A five-year meteorological study was conducted at Cook Nuclear Plant to determine if the operation of the once-through lake water cooling system would significantly effect the natural temperature, moisture, precipitation and fog conditions inland from the plant and, if so, how and to what extent these climatic conditions are affected. This investigation was undertaken because of the absence of quantitative information on the meteorological effects of near-shore warm water plumes. The local economy is heavily dependent on agriculture, especially fruit crops. Changes to the local weather conditions could have a serious impact on the local economy.

Thermal plume mapping studies were conducted to determine the aerial extent of the 3F° and 1F° isotherms and the 3F° plume volume. This information was needed to determine if the plume would impact potable water intakes north and south of the plant, if the thermal plume would sink in the winter and impact the benthos and if the thermal discharge would comply with the 570-acre areal limit imposed by the state issued NPDES Permit. The lake current and temperature studies were used to help interpret the thermal plume mapping studies and evaluate the accuracy of the mathematical plume dispersion model. Knowing the size of the thermal plume also helped aquatic biologists determine how much aquatic habitat was impacted by the plume. Knowing the plume dimensions and location also helped the research team from the University of Michigan evaluate causes of changes in fish populations near the plant.

The bathymetric studies were conducted to determine if the lake water intake and discharge structures caused sediment erosion outside of the rip-rap aprons around these structures.

Biological Studies

The biological studies of the abundance and distribution of periphyton, phytoplankton, zooplankton and benthos were continued from the initial phase studies to provide the pre-operational and operational data comparisons. Fish studies were initiated in 1973 and were fully implemented in 1974. These studies were conducted to determine the impact of the Cook Nuclear Plant from construction and operation. Construction related impacts include the habitat alteration resulting from increased silt run-off from the construction site, placement of rip-rap around the intake and discharge structures and burying of the intake and discharge tunnels in the lake bed. Operational impacts could result from oil and chemical spills, thermal discharges, the impingement of fish and benthos (crayfish) on traveling screens and the entrainment of planktonic organisms (phytoplankton, zooplankton, benthos and fish eggs and larvae) through the cooling water system. The combined impacts of the plant construction and operation were studied by analyzing the biological community structure for changes in species diversity and abundance. Primary production was estimated using the C-14 method; a measure of the effect of plant effluents on algae cell function. The health of algae cells entrained through the plant was assessed by measuring chlorophyll to phaeophytin ratios. Zooplankton could be impacted by the Cook Nuclear Plant thermal plume or by entrainment through the cooling system. Heat and mechanical damage caused by turbulent water flow through the system are the major effects.

Benthos were studied to determine the impacts of heat, habitat alteration, impingement on travelling water screens and plant entrainment caused by Cook Nuclear Plant operation. Changes in species composition and abundance was the measure used to determine effects.

Fish were studied to determine the effects of the thermal plume on adult and juvenile fish distributions, the impact of adult and juvenile fish impingement on travelling water screens, and the effects of fish egg and larvae entrainment through the power plant.

Sediment Chemistry Studies

The sediment chemistry studies were conducted to determine the changes in sediment chemical composition due to chemical discharges from the plant and from the possible build-up of organic material due to the settling and decomposition of aquatic biota killed by the Cook Nuclear Plant thermal plume or plant entrainment.

Water Chemistry Studies

Water samples were collected and analyzed for phosphorus, dissolved silica, nitrate, nitrite, chloride, sulfate, oxygen saturation, alkalinity, pH, conductivity and these trace metals: Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Sr and Zn. In addition, a detailed study of the thermal bar was conducted to determine if it is a barrier to mixing of onshore with offshore water and, if so, how great did the chemical gradient become before the thermal bar moved far offshore.

2.6.3.3 Results of Technical Specification, Appendix B Studies

All results reported below are from Publication 22 from the University of Michigan unless noted otherwise.

Physical Limnology Studies

Ice studies were conducted over a ten-year period from the winter of 1969-1970 through 1979-1980. A method of photographing the ice formation and analyzing the photographs was developed so the distance from the camera and the elevation of the object could be determined with reasonable accuracy. The conclusions of the ice study were:

1. The data show that the offshore ice ridges, offshore breakers and breaker zones, three characteristic features of the Lake Michigan shoreline in front of Cook Nuclear Plant, are coincident. Ice ridges appear to be grounded features of the near shore ice complex and they serve a dual role. They protect the beaches from incoming wave energy when present and, during the breakup of the complex, may modify the topography in the offshore bar vicinity.

2. The stages of ice development appear not to be controlled by any single meteorological variable but by a complex interrelationship between ice development and meteorological conditions. Air temperatures below freezing were found to be a necessary condition for initiation of the ice foot. Growth of the ice complex was associated with westerly winds and deterioration with easterly winds.

3. The plant's thermal plume produced a melthole that ranged from 0.1 to 0.5 square miles in size. The melthole was restricted to the vicinity of the discharge area. The ice ridges closest to the shoreline were minimally affected by the melthole and the effectiveness of the "ice ridge" complex as a wave energy dissipator to protect the beach was not significantly altered.

4. North and south of the melthole there was no noticeable change in the normal ice complex of ridges and lagoons and the nearshore ice complex was not discernibly altered due to the presence of the plant thermal plume.

Lake current studies were used to help analyze the thermal plume mapping data. Lake currents near the plant were the single most important physical parameter affecting the position, size and trajectory of the thermal plume. The lake current data were needed to determine the probability of the plume influencing other water intakes, recirculation to the Cook Nuclear Plant intakes and contacting the beaches north or south of the plant. The in situ current meters were moored about 1m from the bottom of the lake in four locations (see Figure 2.6-4). Surface drogues were used on the days thermal plume mapping surveys were conducted to determine surface current direction and speed.

Current speed and direction recorded by the four instrument units were compared by correlation analysis. Current speeds recorded by the four units generally correlated. Better correlations of speed were obtained when the two inshore data sets and the two offshore data sets were compared. Short-term comparisons among the meters showed very poor current speed correlation.

Current direction measurements among the four current meters showed very poor correlation. A typical current correlation is illustrated by the north inshore and offshore meters for the period November 29, 1977 to December 19, 1977. The two meters recorded current direction differences equal to or greater than 105° more than 50% of the time.

Surface current direction measurements made with the drogues too often showed the bottom current and surface current flowing in different directions.

The lack of good correlation between lake current speed and direction illustrates the unpredictability and complexity of the physical forces affecting the thermal plume in the inshore region of Lake Michigan.

Current direction persistence analysis showed more consistent patterns than did current direction analysis. Nonetheless, variability did exist. In 1977, currents persisting less than one day in any direction occurred 68% to 81% of the time at all four meters. Total current persistence was similar for 1-2, 2-3 and 3-4 days at all four meters and with the exception of the north nearshore meter, flows to the north were more frequent and persisted longer than in any other direction. In 1979, however, current persistence in one direction for less than one day ranged from 10% to 55% of the time. North flowing currents at all stations were more frequent and persistent than other directions, but only slightly. Current direction persistence variability was least in 1977 and 1978 and greatest in 1979. Current direction persistence analysis also illustrates the complexity and variability both spacially and temporally of the physical forces of inshore Lake Michigan.

Lake temperature data was collected in situ using three instrument units located north and south of the plant and west of the intake structures (Figure 2.6-4). The instrument units consisted of a thermistor string and a data recorder. Each thermistor string was 5m long and had eleven equally spaced thermistors. The data recorder logged the temperature of each thermistor every half-hour. Data recovery was nearly 100% for the period April 1978 through May 1979. Some anomalous data was recorded due probably to weak batteries in the data-recording unit. For example, the south instrument recorded daily temperature variations of more than 40°F. These temperature changes are not plausible, because the plant discharge ΔT is 20°F and during the time of these fluctuations the current recorder at this temperature station showed persistent current flow to the north.

Daily temperature variations of 2°F to 3°F up to 20°F to 23°F were recorded and are plausible. Temperature variation between late October to early May was small, generally less than 2 to 3°F within a 2 to 4-hour period. Between May and late September, the greatest temperature fluctuations occurred.

The pattern of temperature variation among the three stations at a given depth was very similar. An analysis of the location and depth of the recorder and thermistor string indicates most of the large temperature changes were due to fluctuations in the thermocline elevation. Since all three recorders were well within the zone influenced by the thermal plume, the similarity of temperature change patterns among the stations demonstrates that natural energy inputs to the lake are far greater and cause greater temperature fluctuations than the thermal plume. Thus, the seasonal patterns of temperature change are unaffected by the thermal plume. Impacts of the thermal plume are isolated to the immediate plume discharge points. The position and persistence of the discharge cause localized temperatures and temperature change patterns that do not resemble natural lake conditions. Specifically the upper two meters of the lake within the thermal plume is the impact zone.

Thermal plume maps were produced by recording lake temperatures at one meter intervals from surface to bottom in the thermal plume vicinity and then plotting water temperature isotherms (Reference 3). A thermistor string was towed behind a boat (Figure 2.6-5) in a zigzag pattern through the plume while temperatures at each water depth, time and boat position were recorded on paper punch tape. This information was then used to generate thermal plumes at one meter depth intervals. The plume dimensions in both areas at a given depth and total volume could be calculated within any selected ΔT.

Two problems were encountered that confounded plume dimension estimates. One and a half to two hours were required to complete the field data collection necessary to map plumes. Two plumes a day could be mapped, weather permitting. On occasion, during the 1.5 to 2-hour plume survey, the intake water temperature would increase due to hypolimnion upwelling or plume recirculation. Variable lake currents could drive the plume in one direction and then reverse the direction or stop allowing the plume to spread in different directions. Thus, the plume mapped early in the two-hour period could be abnormally spread out due to the shift in lake current.

Most plumes mapped during two-unit operation were much less than the 570-acre limit allowed in the state issued NPDES Permit. Three plumes were mapped greater than the 570-acre limit. On September 8, 1978, a 740 acre plume was mapped and on November 3, 1978, two plumes of 655 and 634 acres were mapped (Reference 3).

The plume mapped at 740 acres was 35% larger than the plume mapped that same morning. Water intake temperatures, in situ lake temperature monitors and the thermistors on the plume mapping equipment indicate the lake temperature increased between the time the "ambient" temperature survey was made and the end of the plume mapping by 0.5°F to 2°F. If the ambient temperature was assumed to be 1°F higher, then the 4°F isotherm becomes the 3°F isotherm and plume drops from 740 acres to 113 acres. This is an excellent example of how a small change in the definition of ambient temperature makes a great difference in plume mapping results.

The two plumes mapped on November 3, 1978, were larger than the 570 acre limit at the 3°F isotherm due to a combination of several transient factors. The lake currents were variable and shifting from southerly to northerly flows. The plume appears to have been turned back upon its self causing an abnormally high plume recirculation since the Unit 1 and Unit 2 intake water temperatures were 2 to 3°F higher than the previous day and yet the in situ temperature records showed stable temperatures. So these plumes, 655 acres and 634 acres, were most probably the result of short duration transient conditions.

Twenty-nine plumes were mapped from August 23, 1978, through July 28, 1979. Three mapping surveys were made August 23 through September 8, 1978; November 1 through 7, 1978; and July 24 through 28, 1979. A summary of the plumes is presented in Table 2.6-3. The average plume area for all 29 maps was 290 acres. The smallest plume was 21 acres and the largest 740 acres (Reference 3).

The thermal plume at Cook Nuclear Plant was shown to be dynamic and constantly altered by wind and lake currents. Several general observations about shape, size and location of the plume were made. Figure 2.6-6 shows the areas of Lake Michigan occupied by the thermal plume 3% to 25%, 25% to 50%, 50% to 75% and 75% to 100% of the time. The plumes tend to drift to the northwest from the plant outfall structures. Finally, the thermal plume maps were all measured under calm lake conditions, conditions conducive to forming large plumes. Plumes will tend to be smaller during periods of winds and lake waves, which would themselves promote mixing as well as creating lake currents that also promote mixing of the plume with lake water.

The thermal plume mapping, lake current monitoring and lake temperature monitoring studies were evaluated and compared to mathematical model predictions of thermal plume size and shapes under varying lake and meteorological conditions (ETA Engineering, 1980). With the exception of the three plumes that exceeded the 570-acre NPDES Permit limit, the surface area and volume of thermal plumes were over predicted by about two times the measured size of the plume at the 3°F isotherm. Under all but unusual wind and lake current conditions, i.e., light and shifting conditions, the Cook Nuclear Plant thermal plume will not exceed the 570 acre surface area limit.

ETA concluded, "The natural temperature changes represent a rate of change in the energy content of the water that far exceeds anything the Donald C. Cook Nuclear Plant could produce."

Meteorological studies were conducted in the vicinity of the Cook Nuclear Plant to monitor the effects on local climate resulting from the atmospheric heating and relative humidity increases caused by the once-through cooling system. This five-year study began in 1972 and ended in 1977. Figure 2.6-7 shows the location of the 12 meteorological stations used to gather air temperature, relative humidity and precipitation. Two of these stations also had equipment to measure wind speed and direction, visibility and thermal radiation (Reference 4).

This study concluded that

1. Lake Michigan has a large influence on coastal air temperatures and precipitation,
2. wind speed and direction were significantly altered by local terrain, and
3. the 1973 data from the Cook Nuclear Plant meteorological network was different from the 30-year average for spring and autumn precipitation patterns and for total precipitation in winter, summer and spring (Reference 4).

A statistical analysis of the data for air temperature showed that the Cook Nuclear Plant thermal plume would have to increase the air temperature above the background by at least 1°F to detect the change at the α=0.05 level and 1.5°F at the α=0.01 confidence level.

Although not a stated conclusion of the report, it is obvious and can be supported by calculations that the 16.8x109 Btu/hr heat rejection rate is insufficient to increase the air temperature by 1°F inland from the plant property (4).

Bathmetric studies were conducted at the Cook Nuclear Plant as required by the Technical Specifications, Appendix B of the NRC issued operating license. Results were reported in the semi-annual and annual environmental operating reports for the Donald C. Cook Nuclear Plant.

Bathymetry maps were produced by cruising Lake Michigan in a boat equipped with a depth transponder, radar positioning equipment and a real time data logger. The boat would zigzag in a systematic manner north and south in front of the plant and with each pass move farther offshore. A similar east-west pattern was cruised moving farther south at each turn from the north end of the study zone. A baseline map was established in 1976 and diver surveys were used to monitor changes by visual observations for signs of bottom erosion near the intake and discharge structures. In the summer of 1979, diver observations confirmed bottom scour was occurring around the discharge structures. The erosion problems were corrected by pouring a concrete apron around these structures. In 1980, the boat surveys of lake bathymetry were resumed and continued through 1983. No significant bathymetric changes were documented after the problems discovered in 1979.

Biological Studies

Periphyton was sampled in 1970 through 1972 (pre-operational sampling) and then from 1975 through 1981 (operational sampling). The pre-operational samples were collected using high-density styrofoam blocks moored to the bottom with enough line to allow the blocks to float about one meter below the water surface. In the operational studies measured areas of the plant water intake structures were scraped and the periphyton collected. Divers performed sample collections during the pre-operational and operational sampling. Pre-operational periphyton study results were reported in the Great Lakes Research Division, University of Michigan Special Report series and operational study results were reported in the annual environmental operating reports for 1978 through 1983. The results of the surveys showed that 45 taxa of periphyton were identified and the changes in species composition and periphyton standing crop (ash-free dry weight per unit area) was a result of periphyton community succession on new substrate such as the rip-rap artificial reef or the Cook Nuclear Plant water intake structure. The natural habitat in Lake Michigan near Cook Nuclear Plant does not include solid objects for periphytic community development. The periphyton community is an artifact of the plant construction. The studies concluded plant operation has no impact on the periphyton community.

Phytoplankton was sampled from 1966 through 1982 in the Lake Michigan vicinity of the Cook Nuclear Plant. Sampling was conducted in the plant intake and discharge bays from January 1975 through May 1982. The open lake sampling for the Technical Specifications, Appendix B, began in 1973 and continued through May 1982. Lake samples were collected monthly from April through November each year with 36 to 39 stations sampled April, July and October and 9 to 13 stations sampled in May, June, August, September and November. All samples were whole water one-liter samples in either Niskin bottles or brown polyethylene bottles.

Plant entrainment samples were analyzed for cell counts in nine major algae taxanomic groups, chlorophylls, phaeophyton a and primary productivity by the C-14 method. A study was done to determine if the water in the intake forebay was heterogenious over the horizontal face of the trash racks and vertical water depth. The intake was determined to be heterogenious.

Cell counts by nine major groupings were analyzed for group numbers and total cell count were compared statistically between intake and discharge to determine if plant entrainment destroyed algae cells. No statistical differences were found. Chlorophyll a, b and c levels in intake and discharge samples were compared statistically and no difference found. Chlorophyll a to phaeophyton a ratios were compared statistically between the intake and the discharge. No differences were found.

Primary productivity rates were compared statistically between samples collected from the intake and discharge. Statistical differences were found. Primary productivity was reduced 16% to 76% in the discharge samples from rates measured in the intake samples. It was not determined if this reduction in primary productivity was permanent, because chlorophyll concentrations remained unchanged, which allows for possible complete recovery from the productivity reduction.

Lake samples were collected at the stations shown in Figure 2.6-8. Lake samples were analyzed for cell count by lowest practical taxa, which was usually species but occasionally was no lower than major group and for some taxa the variety was identified. Samples were analyzed for chlorophylls and for phaeophyton a. Impact analyses were done by comparing the pre-operational sample results with the operational results and comparing the near field results with the far field results within years. The parameters analyzed included species composition similarity, species abundance, total cell count, diversity indicies, dominant species, species redundancy, chlorophyll content and chlorophyll a: phaeophyton a ratios.

The Lake Michigan phytoplankton community structure in the Cook Nuclear Plant vicinity was highly variable. However, the variability in sample results before operation were the same as variability during operation. Also, changes to the phytoplankton near the power plant paralleled the changes in sampling results from stations distant from the plant effluent. There were no significant differences in phytoplankton sampling results, therefore, it was concluded that the plant has no significant impact on Lake Michigan phytoplankton.

Zooplankton were collected from Lake Michigan from April 1969 through May 1982. From April 1969 through November 1972 samples were collected from 30 stations (Figure 2.6-9). From April 1973 through May 1982, 30 stations were sampled in April, July and October and 14 stations were sampled in May, June, August, September and November. December through March were not sampled.

Lake sampling for zooplankton was conducted by towing vertically from the bottom to the surface a 0.5 m mouth diameter, No. 10 net (156-micron mesh) equipped with a flow meter. Triplicate samples were collected at each station sampled. Zooplankton were identified (usually two species) and counted in the laboratory.

Entrainment samples were collected by pumping water from the intake and discharge bays through a No. 10 plankton net for 30 minutes (water volume was measured during the sampling). Samples were collected monthly from February 1975 through May 1982. Samples were analyzed for live and dead animals and species identifications and counts were conducted. Live/dead samples were held for 24 hours to determine the delayed mortality rate.

Lake sample results were analyzed by comparing species composition and abundance for pre-operational years with operational years. Also, samples collected in reference areas outside the thermal plume effect zone were compared with samples collected within the plume influenced zone. These analyses documented large changes in the zooplankton community from the pre-operational vs. operational data comparisons. There was no consistent pattern of abundances being higher (or lower) from the operational comparisons with the pre-operational data. Thus, there is no support for a conclusion that the Cook Nuclear Plant is having a significant adverse effect on the zooplankton community.

Entrainment samples were analyzed by comparing the survival of zooplankton collected from the plant intake base with survival of zooplankton collected from the discharge bay. An average of

10% of the total zooplankton in the intake bay samples were dead and an average of 12% were dead in the discharge bay samples. Dead zooplankton represented 4,480 kg of zooplankton dry weight per month. This biomass was probably distributed over a lake bottom area of 2.2 km^2 by the thermal plume. The 4,480 kg of dead zooplankton distributed over 2.2 km^2 of lake bottom represents a detritus deposition rate of 67.5 $mg/m^2/day$ compared with a natural detritus deposition rate in Lake Michigan of 2,800 to 4,000 $mg/m^2/day$. Therefore, the Cook Nuclear Plant increases detrital deposition rates of 1.7% to 2.4% over the natural depositional rate.

Neither the loss of 2% of the entrained zooplankton nor a detrital deposition rate of 67.5 $mg/m^2/day$ over and above the natural deposition rate would be a significant impact to the Lake Michigan ecosystem in the Cook Nuclear Plant vicinity was the conclusion expressed by the scientist conducting the zooplankton research.

Benthos studies of Lake Michigan in the Cook Nuclear Plant vicinity began in 1970 and continued through 1978. Samples were collected using a ponar grab sampler from stations established as shown in Figure 2.6-10. The sampling design underwent minor changes during the nine year study, but the majority of the study period included sampling 30 stations in April, July and October and 9 to 13 stations in May, June, August, September and November. Depending upon the sampling design, between one and five replicates were collected at each station. Sediment samples were washed in a custom design sorter to retain all material that would not pass through a 0.500-mm mesh screen. The retained material was preserved and analyzed in the laboratory. Benthos were identified to species where practical and counted.

Benthos entrainment sampling was conducted from mid-1974 through 1978. Weekly samples were collected May through August and semi-monthly September through April. Water was pumped from the intake forebay and discharge bay for 24-hour periods, broken into 4-hour subsamples. The water was filtered through a 0.35-mm mesh plankton net.

Benthos population colonizing the rip-rap were sampled with artificial substrates. Sediment samples were visually classified using the Krumbein scale.

Benthos impingement sampling was conducted in conjunction with the fish impingement sampling. Screen wash baskets were sorted for fish and benthos daily in 1975 and every fourth day from 1976 through 1982 (benthos data through 1978 only were analyzed).

The lake sampling data were analyzed statistically for spatial and temporal population density differences. Five major groups were statistically analyzed - Pontoporeia hoyi (Amphipoda), Pisidium spp. (Pelecypoda), Stylodrilas heringianus (Lumbriculidae, Oligochaeta), Tubificidae

(Oligochaeta) and Chironomidae (Diptera, Insecta) and total benthos. Plant effect was based on density estimates for each zoobenthic component obtained from lake sampling.

The only group to show any significant differences in population density were the Chironomidae. Densities near the plant were higher after the plant began operation than before. It could not be determined if this was a positive or negative effect. While abundance of Chironomidae increased, the species composition shifted from chironomids generally associated with eutrophic conditions (Chironomus spp.) to species more typically associated with mesotrophic conditions (Saetheria tylus, Paracladopelma spp. and Robackio demeijerei). Power plant operation may have helped stimulate a naturally occurring mesotrophic trend in the inner region as indicated by similar, although less intense, changes in the outer region.

The researchers concluded that factor or factors of plant operations 1) resulted in an increased number of chironomids in the inner region disproportionate to that in the outer region, 2) aided in establishing conditions favoring a more homogeneous chironomid population structure in the inner region, and 3) aided in decreasing eutrophy in the inner region. Increases in the number of chironomids most likely reflect alterations of substrates, but increased (or at least more constant) food supply and temperature effects cannot be entirely ruled out. In general, changes in the benthos population structure attributable to the power plant were interpreted as essentially benign, but nevertheless real in terms of ecological changes.

Benthos entrainment samples were analyzed by first grouping the taxa that were entrained in sufficient number to conduct meaningful analyses. These groups were Pontoporeia hoyi, Gammarus spp., Hyalella azteca, Mysis relicta and Asellus spp. Entrainment impacts were evaluated by estimating the annual entrainment rate and then determining how much lake bottom will be required to produce the number or biomass of organisms.

Pontoporeia hoyi annual average entrainment was 1.97×10^8 individuals/yr or an average of 297 kg (285 kg/yr minimum and 315 kg/yr maximum). These numbers and weights were compared to the surface area in the central portion of the lake study area 0.48 km^2 that would be needed to produce 1.97×10^8 individuals or 1.07 to 3.99 km^2 to produce 285 to 315 kg of P. hoyi biomass per year. Since no significant changes in P. hoyi numbers or biomass were evident from the lake surveys of benthos, then it is reasonable to conclude the entrainment losses had no adverse effect on P. hoyi.

Gammarus spp. like crayfish were present only because of the rip-rap habitat; therefore, it is difficult to assign impacts from plant entrainment to an organism that would not be present in the lake if not for the rip-rap apron around the intake.

Hyalella azteca were only 0.1% of the entrainment total. The ecological significance of this entrainment estimate was not evaluated. This small portion of the entrained population impacted would not cause a significant change in the whole population of H. azteca.

Asellus spp. were 0.4% of the total benthos entrainment. The ecological significance of this loss was not evaluated. This small portion of the entrained benthos would not impact the Asellus spp. population.

Mysis relicta entrainment averaged $1.11x10^8$ individuals annually. This represents 0.59 km² of lake bottom near the intakes to produce the number of entrained organisms. Studies show M. relicta are more abundant at the 30 to 50 m depth contours. Comparing 0.59 km² to the enormous profundal zone of Lake Michigan indicates M. relicta entrainment by Cook Nuclear Plant will not cause an ecologically significant impact.

Impingement of benthos was restricted to crayfish, nearly all of which were Orconectes propinquus. Impingement in 1975 was 16,151 and 7,625 in 1978 with a four-year total of 50,256 individuals or 326 kg of biomass. Impingement rates declined steadily during the four years of entrainment study. As with Gammarus spp., crayfish are present only as a result of the rip-rap reef around the intake. Therefore, ascribing an ecological significance to the entrainment losses appears illogical.

Rip-rap colonization by benthos was studied briefly as part of the overall ecological evaluation of Cook Nuclear Plant operation. Concrete artificial substrates were placed at Cook Nuclear Plant rip-rap and at Waugoshance Point. The benthos colonizing the Waugoshance Point artificial substrates were mostly filter feeders and at Cook Nuclear Plant mostly predators. Artificial substrates at Cook Nuclear Plant were colonized by a species assemblage different from that collected in the Ponar grabs taken from surrounding unconsolidated substrates. Comparison of the rip-rap benthos community with the Waugoshance Point community shows the similarity of the two communities. Thus, the community at the Cook Nuclear Plant is representative of benthos colonizing consolidated substrate in Lake Michigan.

Substrate analysis was done visually using the Krumbein scale. Most Ponar grabs less than 30 m were mostly sand. Pure gravels, silts and clays were uncommon except in highly localized, often transitory, patches.

The following is the summary for the effects on benthos chapter of the final report on the Cook Nuclear Plant aquatic ecological studies (Reference 2):

1. Crayfish are the only macrozoobenthos in the vicinity of the Donald C. Cook Nuclear Plant large enough to be impinged on the traveling screens. Though a large number are impinged each year, the population probably is becoming stable. The rip-rap provides the primary habitat.

2. The water intake entrains a wide variety of zoobenthos. The ecological effects of entrainment on lake populations of Pontoporeia hoyi and Mysis relicta are unknown but probably insignificant in comparison with lake populations present in the vicinity of the power plant.

3. Dynamics of the lake bottom zoobenthos populations in the vicinity of the Donald C. Cook Nuclear Plant show the general lake-wide trend toward mesotrophy. Populations in the south region are slightly more mesotrophic due to greater accumulations of organic particulates while populations in the north tend toward oligotrophy, again due to structure of the substrate.

4. While populations of Chironomidae (and other major taxa) show general density increases over all years of the study in all regions, the central or inner region densities have increased more rapidly and toward a more homogeneous species composition. Reasons for increases in the inner region are unknown but may reflect altered current patters near the rip-rap or increased food supplies stimulated by the heated effluent. Most dramatic effects on the benthos are direct and indirect influences of the rip-rap.

5. A wide variety of benthic species have colonized the rip-rap (crayfish, amphipods, mayflies, caddisflies) which would not normally have been present on the open lake bottom.

6. The rip-rap may have altered current and sedimentation patterns in the inner region influencing the distribution and abundance of sediment-dwelling taxa, particularly the Chironomidae.

The fish studies in Lake Michigan near the Cook Nuclear Plant were conducted to 1) document the species of fish which inhabit the Cook Nuclear Plant area, and their distribution, spawning behavior, and nursery grounds, 2) determine the impact of the thermal plume on fish by comparing catch indices between the Cook Nuclear Plant and a reference area, 3) establish the numbers of larval fish and fish eggs that were entrained at the Cook Nuclear Plant, 4) record the number of juvenile and adult fish impinged on Cook Nuclear Plant traveling screens, 5) describe the ecology of the major fish species for which there were adequate data, 6) integrate the various data sets from the phytoplankton, benthos, zooplankton and fish sections of the project to better understand their interactions in the nearshore zone of Lake Michigan, and (7) attempt to establish the significance of the entrainment and impingement losses through production forgone calculations.

Fish studies were conducted in the open lake and within the plant. Adult, juvenile, larvae and fish eggs were collected in both sampling programs. Open lake sampling was conducted monthly from April through November. Adult and juvenile fish were collected with gillnets, trawls and seines. Fish eggs and larvae, ichthyoplankton, were collected with 0.5 m conical plankton nets, 363-micron mesh, equipped with a mouth mounted flow meter. Figure 2.6-11 shows all open lake sampling stations.

Fish data were gathered from the open lake from 1973 through 1982. Adult and juvenile fish collected were identified, weighed, measured, sexed and observations noted for each fish on gonad development, stomach content, parasites and lamprey scars. Larvae and eggs were identified and counted (number/1000 m^3).

Fish data were gathered so that pre-operational data sets could be compared with operational data (among years analyses) and plant influenced station data could be compared with reference station data (within year analyses). Temporal and spacial variations in species diversity and relative abundance were tested statistically using the analysis of variance procedure (ANOVA).

Fish samples collected in the power plant were all gathered in the screenhouse. Adult and juvenile fish impingement samples were collected by gathering all fish wash off from the traveling screens. These samples were gathered from 1975 through 1982. All fish were identified, weighed, measured and sexed. These observations were noted: gonad development, parasites, lamprey scars, and presence of food in the stomach. In 1975, all fish were analyzed from the 365, 24-hour samples. From 1976 through 1982, only fish collected from every fourth 24-hour period were fully analyzed. Fish gathered on the three intervening days were bulk weighed each day. Subsamples were analyzed when large collections of a species were made.

Entrained ichthoplankton were pumped from three locations in the intake bay and one location in the discharge bay. Diaphram pumps were used to draw an average of 208 liters/ min from each location. The sample volume was passed through a 363-micron mesh net suspended in a 208-liter barrel equipped with a metered overflow pipe. Weekly or twice weekly samples were pumped June through August and semi-monthly samples were pumped from September through May. Sampling began in 1975 and ended December 1982.

Ichthyoplankton samples were analyzed for species and number of entrained fish eggs and larvae.

Data analyses were conducted to estimate annually the number and weight of each species of fish impinged and estimate, by species, the number of eggs and larvae entrained. These data were used to calculate the fish flesh (biomass) that would have been produced had larvae, juveniles, and adults of alewife, rainbow smelt, spottail shiner and yellow perch not been impinged or entrained.

Lake studies of adult and juvenile fish were conducted from 1973 to 1982 by gillnetting, seining and trawling at the plant site and at a reference site, Warren Dunes. The primary purpose of this surveillance was to determine the distribution and abundance of fish at the two areas before and during plant operation. For fish species caught in sufficient numbers, statistical tests were employed to establish whether differences between area catches were significant. Data on other species were examined for consistency or trends in annual abundances in the two areas.

Over the 10 years, just over 1,100,000 fish of 59 species were caught (Table 2.6-4). Six of these species were abundant in the study areas. Alewife constituted 61% of the total catch over the 10 years. Spottail shiner contributed 21% of the total, rainbow smelt and yellow perch each contributed 7% and trout-perch and bloater each contributed just under 2%. All other species combined made up 1% of the total.

Fish species annual abundance or distributions that were statistically different from the Cook Nuclear Plant site compared with the Warren Dunes station established that that species was assumed to have been affected by plant operation. In general, four categories of effects in the Cook Nuclear Plant area were noted:

1. There was greater abundance during preoperational and operational years resulting from fish being attracted to the plant rip-rap. Diver observations helped to confirm this. There are no catch data before rip-rap placement, but because the topography and bottom sediments were similar at the Cook Nuclear Plant and Warren Dunes areas, it is probable that the preconstruction distributions of fish were similar.

2. There was greater abundance during operational years resulting from an attraction to the Cook Nuclear Plant rip-rap, structures and currents.

3. There was lesser abundance during preoperational and operational years resulting from fish avoiding the alterations caused by construction, dredging and discharges.
4. There was lesser abundance during operational years resulting from either avoidance of the discharges and their effects or mortality caused by substantial impingement or entrainment.

Based upon lake survey catch data, three of the six most abundance species, alewife, bloater and rainbow smelt, were not affected by plant operation even though these species were abundant in the impingement catch also. These species were also the most abundant and mobile forage species in the lake. Immigrations from other areas could obscure any depletions caused by localized impacts.

In general, the abundance or distribution of 22 out of a total of 59 fish species was altered by the physical structure of the Cook Nuclear Plant or its operation. These alterations varied from a minor change in distribution (for example, the apparent attraction of a few redhorse suckers to the plant's discharges) to decreases in spottail shiner, trout-perch and yellow perch abundances at the plant site. The consequences of these changes to the lake's fish populations were not resolved and may be impossible to determine. For example, the plant's rip-rap attracted fish, thereby increasing their vulnerability to entrainment mortality, consequently diminishing abundance of some species. On the other hand, the rip-rap provided spawning substrate and food organisms which enhanced growth, reproduction and survival of some species.

Community structure may be only locally altered, with no important effect on the lake as a whole. In addition, the ability of the lake's fish populations to compensate for local abundance declines is unknown, and depends on the species, geographical area and population density.

Lake fish larvae data analyses did not show any statistically significant differences between preoperational years and operational years nor between Cook Nuclear Plant stations and reference stations at Warren Dunes State Park except for common carp larvae and rainbow smelt. Common carp larvae were not collected during preoperational sampling and after operation began only two out of 23 samples containing common carp larvae were collected at Warren Dunes. Common carp appeared to be strongly attracted to Cook Nuclear Plant for use as a spawning area. Rainbow smelt were significantly more abundant at Cook Nuclear Plant than at Warren Dunes when the data for preoperational years 1974 and 1975, and operational years 1980-1982, were combined. This was due to unusually high catches of rainbow smelt larvae at the Cook Nuclear Plant 6m and 9m depth stations in 1974. There were no significant differences when the 1974 data set was deleted from the analysis.

Adult and juvenile fish impingement annually at Cook Nuclear Plant were estimated to be from 53,190 in 1977 to 2,307,654 in 1980. Only one unit was operating from 1975 through most of 1978 when the second unit began operating.

Generally, the impingement rates are reflected in the change of water flow from one-unit to two-unit operation. About four times as many fish were impinged after two-unit operation began than when only one unit operated. Table 2.6-5 shows the annual estimated impingement rates. Alewife impingement was higher than all other fish combined in all years except 1978 when alewives were only 38% of the impingement catch.

The percent contribution to total fish impingement over the period 1975 through 1982 was: alewives (68%), spottail shiner (10%), yellow perch (9%), trout-perch (5%), rainbow smelt (4%), slimy sculpin (2%) and others (2%). Figure 2.6-12 shows the annual percentages from 1975-1982.

There were only a few fish species showing any trends in the estimated number impinged annually. Trout-perch comprised 2.4% of the catch during the period 1975-1977 and dropped to 0.5% during the period 1980-1982. Slimy sculpin impingement followed a similar pattern. They were 4% of the impinged fish in 1975-1977 and 0.4% in 1980-1982.

Over 8 years, 61 species were impinged at the Cook Nuclear Plant. Nineteen species were impinged during only one or two years. Fourteen of these species were never collected in lake sampling and 12 species collected in lake sampling were never impinged.

Entrainment of fish eggs and larvae from 1975-1982 resulted in a total annual estimate of 750,000,000 fish larvae and 23 billion eggs. Annual estimates range from 33.5 million in 1977 to 167 million in 1982. Table 2.6-6 shows the annual estimate of fish eggs and larvae for the 13 species, four "undifferentiated genera" and "poor condition" and "unidentifiable" larvae entrained at Cook Nuclear Plant from 1975 through 1982.

Although the scientific literature strongly suggests otherwise, Alewife larvae were between 54% and 92% of the annual estimated larvae entrainment and 74% of the annual average for the 8-year period. Spottail shiners were 9%, rainbow smelt 5%, yellow perch 2% and other 10% of the annual average fish larvae entrainment.

Entrainment rates were strongly diel with night samples containing significantly more than day samples. May through August was the peak larvae density period with the maximum entrainment rate occurring in June or July each year.

the assumption was made at Cook Nuclear Plant that 100% of entrained larvae were killed.

Production forgone calculations from the entrainment and impingement data are estimates of the fish biomass that was not produced in Lake Michigan as a result of fish impingement and entrainment mortalities. Alewife production forgone estimates were 186,024 and 327,964 kg in 1975 and 1976, respectively. Spottail shiner production forgone was 6,011 and 1,736 kg in 1975 and 1976, respectively. Yellow perch production forgone was 1,647 and 1,812 kg in 1975 and 1976, respectively. Actual biomass of impinged fish of these three species in the respective years 1975 and 1976 were 5,203 and 3,003 kg for alewife, 88 and 232 kg for spottail shiner and 395 and 1,096 kg for yellow perch. For alewife and spottail shiner most of the production forgone comes from the entrainment of larvae of these species. Yellow perch larvae were far less abundant than for other species. Most of the production forgone results from the impingement of one-year old fish.

These production forgone estimates, while useful in characterizing fish losses beyond the mortality, present problems that make drawing conclusions about these calculations nearly impossible. A sensitivity analysis done on the production forgone calculations shows that the parameters that are the most poorly estimated, that is, mortality rates at the pro-larvae and post-larvae life states, have the greatest effect on the final estimate. The survival rate estimates used to derive the alewife production forgone were much higher than values reported in the literature. In fact, actual data gathered during the lake studies showed actual survival rates for the Lake Michigan alewife population to be much lower than the survival rates used in the production forgone model. The result is the alewife production forgone estimates are severely biased upward from actual production forgone. Also, fish populations are dynamic. Reproductive success varies greatly from year-to-year due entirely to natural conditions; fish populations, while not demonstrated at the existing alewife population densities to actually occur, do exhibit density-dependent compensation for mortalities; and even after extensive study, the exact figure is elusive - it is generally believed fish populations can compensate for exploitation rates of about 20%. Lacking specific knowledge about compensatory mechanisms, difficulty with estimating correct age specific mortality rates and the difficulty of accounting for year-to-year variability, estimating production forgone becomes an interesting exercise, but not a useful tool. The Cook Nuclear Plant did have impacts to the fish populations near the Cook Nuclear Plant.

The ecological significance of these impacts was judged to be minor enough by the Michigan Water Resources Commission to approve a variance allowing Cook Nuclear Plant to discharge 16.8 x10^9 Btu/hr without specific temperature limits on the discharge and approve the plant intake structures as best available technology. In other words the ecological impact of impingement and entrainment did not justify modifying the plant to reduce the impact.

Sediment Chemistry Studies

Sediment samples were collected from equally spaced intervals on a 10x22 km grid in Lake Michigan offshore from Cook Nuclear Plant. During 1973 and 1975, 158 surficial samples (0 to 3 cm depth) and seven cores were collected and analyzed each year for chemical and physical properties. Sediment particle size ranged from medium sand located generally near shore to silt located generally at lakeward stations. Core samples showed that coarser material was near the surface with finer material deeper in the sediments. Chemically, sediments tend to have higher concentrations of trace elements, heavy metals, nutrients, inorganic carbon, organic carbon and total carbon. Exceptions occurred frequently. High concentrations inshore of carbon, trace elements and heavy metals were generally associated with stream mouth deposits. No distribution patterns of any parameters were attributed to operation of the Cook Nuclear Plant.

Water Chemistry Studies

Water chemistry samples were collected at a depth of one meter from 19 of the same grid points as used to collect sediment samples (10x22 km). Samples were collected every year from 1975 through 1982. In addition, six streams or drainages to Lake Michigan from the St. Joseph River south to and including Galien River were also sampled. The water chemistry associated with the thermal bar was studied.

Streams were consistently higher in nutrients and anions than the near shore lake water. Total phosphorus, dissolved orthophosphate, dissolved silica, nitrates, nitrites, chlorides and sulfates were higher in streams compared to near shore lake water. Chloride and sulfate were higher in streams, oxygen saturation was slightly higher, along with alkalinity and conductivity. pH was slightly lower in streams compared to lake water. All metals except molybdenum was from slightly to greatly higher in streams compared with lake water. Molybdenum concentrations were the same in streams as in the lake. Radiological monitoring of lake water is conducted annually and the results reported in the Cook Nuclear Plant annual radiological environmental operating report. No radionuclide concentrations have been found above natural background levels.

Thermal bar study results were inconsistent. Because of the inter-relationship between nutrients, temperature and phytoplankton densities, differences in nutrient concentrations between inshore and offshore zones were inconsistent. All metals, both as particulate and dissolved metals, were in higher concentrations inshore vs. offshore except chromium and cobalt, which were higher offshore. However, only sodium was statistically higher in the inshore zone compared with offshore.

Water chemistry, chemical inputs and water mass movements were also studied in detail in an attempt to understand phytoplankton species composition and shifts during the study period from one major grouping to another and back again as the dominant group. The observations of this detailed analysis were summarized as follows:

"The observed variation in chemistry of the nearshore waters of southeastern Lake Michigan is complex and derived from a variety of sources. Observed areal variations in chemistry are controlled by the way in which stream and river inputs are incorporated within the nearshore water mass. The mixing of these inputs with nearshore waters gives rise to water masses, which trace their origin to stream, inputs. Other water masses are derived from the occurrence of the thermal bar in spring and upwelling of hypolimetic water during summer. Each water mass is chemically different from others, especially with respect to nutrients and temperature. These differences must be considered in any interpretation of nearshore phytoplankton distributions within any one sampling period or in month-to-month and year-to-year changes in phytoplankton assemblages" (Reference 2).

2.6.4 Ongoing Study Phase (1983 to Present)

Asiatic clams (Corbicula fluminea) and zebra mussels (Dreissena polymorpha) have been introduced to the Cook Nuclear Plant area as well as other locations in Lake Michigan. An Asiatic clam shell was found at the plant in 1983 and zebra mussels were discovered in the plant intake forebay in 1990.

Asiatic clams have caused serious clogging problems in water intake systems in the southern United States over the past 30 years or so. The Nuclear Regulatory Commission issued a bulletin requiring nuclear plants to monitor for Asiatic clam infestation in 1982. Asiatic clams are heat tolerant and cold intolerant. Water temperatures at the plant will prevent this species from becoming a serious biofouling organism at Cook Nuclear Plant.

Monitoring to ensure the Asiatic clam population remained low was begun in 1982 and has been conducted annually since then. Larval Asiatic clams (veligers) are monitored in filtered intake water samples and plant raw water systems are carefully inspected during routine maintenance. One live clam and about a dozen shell halves have been found in eight years of monitoring. No veligers have been collected.

Zebra mussels have been the cause of serious biofouling problems in Europe and Russia for many years (Reference 4). Water intakes for drinking water supplies and power plants have been clogged by zebra mussels in Lake Erie since they were first discovered in the St. Clair River in 1988. Zebra mussels are cold adapted animals and are considered a potentially serious biofouling problem at the Cook Nuclear Plant.

No Asiatic clams have been found since April 1991, when half-shells were found during a Clam-trol flush of the fire protection system. This system has been placed on Lake Township water since the Spring of 1993. No Asiatic clams or zebra mussels have been reported in the Fire Protection System since it has been placed on the Lake Township water system. There is a consensus that Asiatic Clams do not pose a threat to Cook Nuclear Plant as they are a warm water species. They are no longer a part of the monitoring program.

Biocides supplemented by mechanical cleaning and design changes including strainers, filters, screens, and chemical delivery systems, work to protect plant systems. A zebra mussel monitoring program utilizing side-stream and artificial substrate monitors, along with diver and heat exchanger inspections, is used to evaluate the effectiveness of chemical and physical control measures.

2.6.5 References for Section 2.6

1. Donald C. Cook Nuclear Plant, Supplement to Environmental Report, November 8, 1971
2. Monthly Bulletin of Lake Levels for the Great Lakes, March 1997, U.S. Army Corps of Engineers
3. Bluff Erosion, Recession Rates, and Volumetric Losses on the Lake Michigan Shore in Illinois, Richard C. Berg and Charles Collins, Illinois State Geological Survey, Environmental Geology Notes No. 76 July 1976.
4. Baker, D. L. 1993. Report on the 1992 Zebra Mussel Control Program. Letter from D. L. Baker (I&M) to F. P. Morley (Michigan Department of Natural Resources).

2.7 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

2.7.1 Purpose of the Radiological Environmental Monitoring Program (REMP)

The purpose of the REMP is to establish baseline radiation and radioactivity concentrations in the environs prior to reactor operations, to monitor critical environmental exposure pathways, and to determine the radiological impact, if any, caused by the operation of the Donald C. Cook Nuclear Plant upon the local environment.

The first purpose of the REMP was completed prior to the initial operation of either of the two nuclear units at the Cook Nuclear Plant Site. The second and third purposes of the REMP are an on-going operation and as such various environmental media and exposure pathways are examined. A complete and technical representation of the REMP is set forth in the Donald C. Cook Off-site Dose Calculation Manual (ODCM).

2.7.2 Preoperational Study

The preoperational portion of the REMP was started 12 - 18 months before fuel was loaded into Unit 1. During this period, equipment was tested, sampling stations and sample media were determined, analytical procedures were tested, and some data was accumulated and examined for statistical variability. Modifications that were necessary to attain reliable and coherent data were made during this period.

2.7.3 Summary of Preoperational Radiological Environmental Monitoring Program

There were several different types of environmental samples collected and analyzed during the preoperational sampling phase. Results from these samples are listed below.

The average monthly LiF thermoluminescent dosimeter (TLD) readings of August 1971 through December 1971, on-site, varied from 3.9 ±1.3 mrem to 11.7 ±0.8 mrem and off-site from 3.9 ±1.2 mrem to 13.3 ±1.1 mrem.

Initial water samples were taken in Lake Michigan and at water treatment facilities located in Bridgman, St. Joseph, Benton Harbor, and New Buffalo. These showed tritium concentrations of 562 ±36 pCi/l to 583 ±36 pCi/l. Gross beta at the above sampling stations showed 0.0 ±2.0 pCi/l to 6.8 ±1.0 pCi/l.

The determination of gross beta in the on-site airborne particulate samples was 0.01 ±0.01 to 0.24 ±0.1 pCi/m^3. The same values for off-site stations are 0.01 ±0.01 to 0.24 ±0.1 pCi/m^3.

2.8 PLANT DESIGN BASES DEPENDENT UPON SITE AND ENVIRONS CHARACTERISTICS

Information relating to the site and environs for the plant has been summarized in the preceding sections of this chapter. The several design features, which are dependent or affected by the site characteristics, are summarized below.

2.8.1 Unit Vent Gas Effluent

A unit vent located on the outside of the reactor containment is used for the controlled, intermittent dispersal of decayed and diluted radioactive gases to the atmosphere.

2.8.2 Liquid Waste Effluent

Liquid wastes, suitably decayed and diluted, are discharged to the lake intermittently through the circulating water discharge canal and to the turbine room absorption pond. Based upon circulating water dilution, the concentration of such wastes at the point of discharge from the station is in full compliance with 10 CFR 20. Substantial additional dilution and dispersion is provided by the lake thereby reducing concentrations to values far below permissible levels.

2.8.3 Wind Loading Design

Plant building structures are capable of withstanding the effect of 90 mph winds. Although the possibility of a tornado occurring at the site during plant lifetime is remote, the plant can safely shutdown despite the effects of a tornado with a forward progression of 60 mph containing 300 mph winds coincident with an atmospheric pressure drop of 3.0 psi applied within 3 seconds.

2.8.4 Geology

The geology of the region including the site indicates that the strata underlying the site are capable of supporting loads at least as high as those required for plant structures. The foundation design of all structures, and in particular those associated with plant safety, is based on the conditions existing at the site.

2.8.5 Hydrology

Intermittent liquid effluents from the site do not affect ground water supplies in the adjacent area in excess of 10 CFR 20 due to local drainage patterns, release rates, and specific features of the sources of water supplies.

2.8.6 Seismology

The seismic design for structures important to safety is based on a horizontal ground acceleration of 0.10g and a vertical acceleration of two-thirds this value. This is the seismic criteria for the operating basis earthquake. In addition, the design is such that a safe shutdown can be made and the engineered safety features remain operable after the design basis earthquake of 0.20g horizontal ground acceleration and two-thirds this value acting vertically.

2.8.7 Limnology

Plant grade and the design bases of features related to plant safety are established to consider the coincidence of the maximum seiche postulated for the site with the highest recorded lake level.

No consideration is given to the simultaneous occurrence of maximum high water level, maximum deep water waves and maximum seiche water levels because of the differing meteorological conditions required for the wave and seiche generation.

2.9 PLANT DESIGN CRITERIA FOR STRUCTURES AND EQUIPMENT

2.9.1 Definition of Seismic Design Classification

All equipment and structures are classified as Class I, Class II, or Class III as recommended in:

a. TID-7024, "Nuclear Reactors and Earthquakes" August, 1963 and

b. G. W. Housner, "Design of Nuclear Power Reactors Against Earthquakes," Proceedings of the Second World Conference on Earthquake Engineering Vol. I, Japan 1960, pg. 133, 134 and 137.

Class I

Those structures and components including instruments and controls whose failure might cause or increase the severity of a loss-of-coolant accident or result in an uncontrolled release of excessive amounts of radioactivity. Also, those structures and components vital to safe shutdown and isolation of the reactor.

Class II

Those structures and components which are important to reactor operation but not essential to safe shutdown and isolation of the reactor and whose failure could not result in the release of substantial amounts of radioactivity.

Class III

Those structures and components which are not related to reactor operation or containment.

2.9.2 Classification of Structures and Equipment

The classifications presented below are intended, by example, to convey the application of the seismic classification definitions.

Item	Class
Buildings and Structures	
Containment (including all penetrations and airlocks, the concrete shell, and the interior structures)	I
Spent Fuel Pool	I
Control Room	I
Auxiliary Building Structure	I
Circulating water pump screen house structure(as required to make water available to the essential service water pumps)	I
Turbine Room foundation	I
Remainder of Turbine Room structure	III
Buildings containing conventional facilities	III
Ice Condenser	I
Equipment, Piping and Supports	I
Reactor Control and Protection System, and Process Instrumentation (and Controls as required for Class I equipment and systems)	
Reactor	I
Vessel and its supports, Fuel assemblies, RCC assemblies and drive mechanisms, Supporting and positioning members	
Reactor Coolant System	I
Piping and valves (including safety & relief valves), Steam generators, Pressurizer, Reactor coolant pumps and motors, Reactor coolant system supports	

Item	Class
Emergency Core Cooling System	I
Accumulators, Residual heat removal system, Safety injection system, Centrifugal Charging system, Boron Injection Tank, Refueling Water Storage Tank	
Containment Spray System	I
Spray additive tank	
Chemical & Volume Control System	
Letdown and makeup components	I
Seal water system	I
Boric acid storage tanks and transfer pumps	I
Cleanup demineralizers and filters	I
Boric acid recovery equipment	I
Condensate Storage Tank	II
Auxiliary Feedwater System	I
Essential Service Water System	I
Return Lines in Turbine Building	III
Component Cooling System	I
Emergency Power Generation and Distribution System	I

Item	Class
Ventilation Systems	
Engineered Safety Features Ventilation System	I
Control Room Ventilation System	I
Auxiliary Feedwater Pump Enclosure Ventilation System	I
Essential Service Water Pump Ventilation System	I
Emergency Power Ventilation Systems	I
Containment Ventilation System	II & III
Containment Air Recirculation/Hydrogen Skimmer System	I
Turbine Room Ventilation System	III
Waste Disposal System	
Gas decay tanks	I
Liquid waste holdup tanks	II
Waste evaporator	II
Waste condensate tanks	III
Waste evaporator condensate pumps	III
Non-Essential Service Water System	II & III
Primary Water System	
Primary water storage tank	II
Primary water make-up pumps	II
Balance of System	III

Item	Class
Control Air System	
Air compressor and receiver	III
Fire Protection System	III
Weld Pressurization System	III
Spent Fuel Pool Cooling System	
Demineralizers and filters	II
Heat exchanger	II
Spent fuel pit pumps	II
New Fuel Handling Equipment and Racks	III
Spent Fuel Transfer Mechanisms	II
Spent Fuel Storage Racks	I
Refueling Cavity Manipulator Crane	III
Containment Polar Crane	I
Auxiliary Building Crane	I

Item	Class
New and Spent Fuel Crane	I
Radiation Monitoring System	III

2.9.3 Seismic Design Criteria for Seismic Class I and II Piping

In addition to the loads imposed under normal operating conditions, the design of piping and piping supports requires that consideration also be given to abnormal loading conditions such as earthquakes and pipe ruptures.

Two types of seismic loadings are considered: Operational Basis Earthquake (OBE) and Design Basis Earthquake (DBE).

For the OBE loading condition, the nuclear steam supply system is designed to be capable of continued safe operation. Therefore, for this loading condition, structures and equipment needed for this purpose are required to operate within design limits. The seismic design for the DBE is intended to provide a margin in design that assures capability to shutdown and maintain the nuclear facility in a safe condition. In this case, it is necessary to ensure that required critical structures and components do not lose their capability to perform their safety function. This has come to be referred to as the "no-loss-of-function" criteria and the loading condition as the DBE.

The functional requirements of various components differ significantly. Some components must operate within the elastic region, since any significant deformation could result in loss of function. Active components such as rotating equipment, valves, motors etc. fall into this category. On the other hand, some components can experience significant permanent deformation without loss of function. Piping and vessels are examples of the latter where the principal requirement is that they retain their contents and allow fluid flow.

The normal as well as abnormal loads are considered singly and in combination (see Table 2.9-1 and notes thereto), and the allowable stress limits for each of the possible combinations are limited to those specified in Table 2.9-2. Class I piping of 2 1/2 inch nominal diameter and greater, and Class I piping less than 2 1/2 inch nominal diameter with a normal operating temperature in excess of 250°F, are dynamically analyzed, using documented computer programs. The computer programs employ multi-degree-of-freedom modal analysis methods which consider frequency, mode shape and modal participation factors in determining seismic response. Seismic inputs include the appropriate DBE spectra and/or the appropriate OBE spectra. When the OBE spectra are used exclusively for a particular system analysis, the seismic output piping stress and support reactions are multiplied by the conservative factor of 2 for determining DBE system adequacies and for designing support structures.

In the dynamic piping analyses, vertical seismic spectra equal to 2/3 of the pertinent building base horizontal spectra was computer input with the appropriate building floor horizontal seismic spectra. The effects of each seismic spectra input were computed independently and the various modal results were computer combined by the square root of the sum of the squares (SRSS) method. The effects of the vertical and a horizontal seismic run were then computer combined by the SRSS method. The larger resultant value of the vertical and horizontal seismic run [(Y + X), or (Y + Z)] at each node was considered to be the critical load and/or stress.

Class I piping smaller than 2½ inch nominal diameter with operating temperatures less than 250°F, may be qualified by using either a simplified analysis (Alternate Analysis) method or a computer dynamic analysis. The Alternate Analysis method developed for the Cook Nuclear Plant considered gravity loads, seismic loads (based on floor acceleration response spectra) and internal pressure loads. The acceptance criteria were based on pipe stress and pipe displacement. A set of instructions, guidelines, tables and graphs reflecting the above, were issued to establish acceptable spacing of supports.

Class II piping with operating temperatures less than 250°F may be qualified by using this Alternate Analysis method. Class II piping with operating temperatures greater than 250°F are qualified using the computer dynamic analysis method. The seismic inputs are taken from the appropriate OBE spectra.

Where a piping system consists of a combination of Class I and/or Class II, and/or Class III piping, the method of analysis is for the higher-class piping. The piping model may be structurally decoupled, to suit the higher class piping, at an anchor or at a point (or points) encompassing restraints in the 3 orthogonal directions.

2.9.4 Seismic Design Criteria for Class I, Class II and Class III Structures

Class I

A dynamic analysis was performed using Response Spectrum and Modal Analysis Program, as discussed in Appendix F of the original FSAR, "Dynamic Analysis of the Containment Structure for Seismic Loading." Response spectra were generated from information obtained by a full seismological study of the site. The dynamic analysis of the Auxiliary Building superstructure supporting the Auxiliary Building east crane was modified to use spectra which were generated using Revision 1 of NRC Regulatory Guides 1.60 and 1.61. These changes were implemented as part of the Dry Cask Storage project and are further discussed in Section 2.9.5. Stress criteria are those of ACI 318-63 Ultimate Strength Design with the exception of the ice condenser wear slab. The applicable code for the ice condenser wear slab is ACI 318-71.

To address projected increased loading on the spent fuel pool associated with the installation of high capacity racks in 1993, the structural reanalysis of the concrete under the racks was performed using ACI 318-89. This code was reviewed and accepted by the NRC in a license amendment submitted for the re-racking. ACI 318-89 was also used in the structural evaluation of the pool floor slab in the cask loading area in support of spent fuel cask loading operations.

Class II

An analysis using the procedures of the Uniform Building Code (International Conference of Building Officials) was made. Standard working stresses are used.

Values of maximum ground acceleration are those used for Class I criteria. The factor applied to the seismic forces from which the values of shear, bending moments, etc. are computed, is taken as that for Zone 3 of the Uniform Building Code multiplied by the ratio of the maximum ground acceleration to a value of 0.30g. The minimum ratio used is one-fourth.

Class III

An analysis using the procedures of the Uniform Building Code (International Conference of Building Officials) was made. Standard working stresses increased by 33 percent are used. Zonal factors of the Uniform Building Code are used.

For All Structure Seismic Classifications

A vertical component of earthquake acceleration of two-thirds the value of the horizontal component of earthquake is assumed to be acting simultaneously with the horizontal component.

See Section 2.9.5 for a description of the horizontal and vertical acceleration used for analysis of the East Auxiliary Building Crane and Auxiliary Building superstructure supporting the crane.

When Seismic Class II or III structures, systems, and components (SSCs) are located within the interaction zone (where the SSCs are expected to fall, in the event that they fail) of a Seismic Class I SSC, then the subject Seismic Class II or III SSCs are designed and installed in such a way that there is no potential for the subject Seismic Class II or III SSCs to impair the functional capability of the Seismic Class I SSCs by adversely interacting with them during a Design Basis Earthquake (DBE).

Seismic design criteria for combined structures (i.e., structures having Class I and Class II elements, Class I and Class III elements or Class II and Class III elements) are as follows:

1. Equipment is supported by structural elements equal to or higher than the classification of the equipment.
2. Equipment is surrounded by structural elements equal to or higher than the classification of the equipment.
3. Structural elements are supported by, or framed to, elements equal to or higher than its own classification.

The following example illustrates the design criteria stated above.

The auxiliary feed pumps are Class I equipment but are housed in the turbine building which is essentially a Class III structure. In this case, the Class I equipment is supported by the foundation slab which is designed to Class I criteria. The pumps are surrounded by local structural elements designed to Class I criteria which have been designed to withstand potentially adverse effects of lower class structures in the area.

The superstructure for the turbine room, heater bay and main steam pipe enclosure beyond the steam generator stop valve are Class III structures, which are designed for seismic loading in accordance with the seismic criteria of the Uniform Building Code. The maximum deflection for all conditions of loading were computed for these structures.

These deflections plus an allowance for erection and fabrication tolerances and an additional amount for clearance were designed into these structures to prevent rattling (hammering) effect.

The primary water and condensate tanks are functionally Seismic Class II structures located near Seismic Class I structures, namely, the refueling water storage tank and the containment. The condensate and refueling water storage tanks have been seismically analyzed to insure their structural integrity during a seismic event. The primary water tank was analyzed seismically for the OBE. All three tanks are located in excess of 20 feet from the containment wall. The primary water storage tank is approximately 55 feet from the refueling water storage tank. Analysis indicates that the primary water storage tank will not cause structural damage to the refueling water or condensate storage tanks in the unlikely event that it fails. The condensate storage tank, although not required to be a Seismic Class I structure, was designed as such to insure the structural integrity of the refueling water tank.

2.9.5 General Design Considerations for Building Structures

Those structures considered are the auxiliary, containment, circulating water pump screen house and turbine buildings, and the steam generator stop valves and pipe enclosures outside the containment building.

Building structures were designed to withstand wind forces.

Class I building structures were evaluated with reference to tornado conditions to assure that there would be no loss of function.

The wind velocities and tornado model are discussed in Chapter 5 and Sub-Chapters 1.4 and 2.8.

Tornado loading was not considered coincident with earthquake loading. However, a 3 psi ambient pressure drop was considered coincident with tornado velocity pressures.

Pressure and suction forces together with internal pressure or suction was considered in accordance with the procedure in ASCE Paper No. 3269 "Wind Forces on Structures."

Torsional effects due to tornado loading were considered in evaluating Class I structures.

Maximum torsional loading was determined by using varying diameter tornado "funnels."

Reinforcing was placed so that minimum reinforcing cover provisions are as recommended by the Uniform Building Code and ACI Building Code.

1. 3 in. cover where concrete was deposited against the ground (bottom of slab).
2. 2 in. cover at all formed surfaces exposed to the ground or weather (all exterior surfaces of the structure).
3. 1½ in. cover for beams and girders not exposed to the ground or the weather.
4. 1 in. cover for slabs and walls not exposed to the ground or weather.

5. Concrete protection for reinforcement is in all cases at least equal to the diameter of the bars.

Building structures were designed in accordance with the seismic design criteria as stated in Section 2.9.4.

The effects of differential motion between the various buildings were considered. This was necessary both to provide adequate separation between the structures to prevent "banging together" of the structures during a seismic occurrence and to provide for this condition on interconnecting elements.

Both the horizontal and rotational motions of the containment structure due to earthquake were analyzed. A plot of displacement vs height was made.

The magnitude of maximum vertical motion due to the DBE was determined for the structures, considering each structure as a rigid body.

The maximum magnitude of differential motion was considered to be the absolute value of the peaks of motion between the independent structures, considering each motion to occur simultaneously with the others.

The effect of static differential settlement was considered additive to the dynamic effects where this resulted in a more severe condition.

A discussion of the design for the auxiliary and turbine building follows. The design of the containment building is discussed in Chapter 5.

Auxiliary Building

The Auxiliary Building encloses the fuel storage areas (both new and used fuel), the fuel transfer canal, the containment equipment hatches access areas, control facilities and other equipment.

Seismic considerations for the Auxiliary building were based on the 10% and 20% Ground Response Curves as indicated in Figures 2.5-2 and 2.5-3. A dynamic analysis of the building was performed to determine the seismic stresses in Class I portions of the structure. Using a slab-spring model subjected to independent translational excitation in two perpendicular directions, the modal periods, the forces acting on the slabs, the slab displacement and the loads on major lateral load resisting elements were computed. Consideration was also given to the action of water in the spent fuel pool during a seismic occurrence.

The Auxiliary Building was designed using the method of the square root of the sum of the squares (SRSS) of the individual modal forces and stresses.

The superstructure is a Class I structure consisting of a structural steel skeleton with exterior walls and roof of reinforced concrete.

The structural steel was designed in accordance with the "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," adopted April 17, 1963, by the American Institute of Steel Construction.

The roof of the structure is constructed of steel beams and girders supporting a poured concrete roof on steel ribbed decking. The roof varies in thickness, stepped from two feet to seven inches. The thickest portion of the roof is directly over the spent fuel pool area.

The walls are of poured concrete supported, for their vertical load, on the concrete substructure and for their lateral forces by the structural steel columns and struts. The walls vary in thickness from two feet to six inches. The thickest area is the west wall adjacent to the fuel pool and the thinnest portion is at the east end of the structure.

The concrete walls and roof of the auxiliary building were designed to provide protection against potential missiles. The whole structure was designed to withstand the design basis tornado missiles and was also designed to protect the control room and fuel pool against a turbine missile. See Sub-Chapter 1.4 for a discussion on missile protection.

The tornado forces applied to the structure are as outlined in Chapter 5 with the exception that the diameter of the tornado was assumed to vary in the following manner:

a. The diameter is equal to the width of the structure.

b. The diameter is equal to the length of the structure.

c. The diameter is infinite in extent.

In the event of a tornado, the pressure within the structure will not differ from the outside by more than 1/2 psi in three seconds. This low differential is achieved by the installation of vents in the periphery of the roof, which will allow release of internal pressure. However, as an added conservatism, the building roof and walls have been designed to withstand 3/4 psi coincident with tornado wind forces. For forces resulting from tornado winds of 250 mph tangentially and a progression velocity of 50 mph, the auxiliary building steel will not experience stresses in excess of allowable as outlined in the 1963 American Institute of Steel Construction specifications. For tornado winds of 300 mph tangentially with a progression of 60 mph, coincident with internal pressures of 3/4 psi, steel will remain within yield and no permanent deformation will result.

The auxiliary building, as a Class I structure, has been designed for seismic forces as described in this chapter. A dynamic analysis was made for the OBE and DBE. For the OBE, all stresses in the steel superstructure are within allowables as specified by the 1963 code of the "American Institute of Steel Construction for Buildings." For the DBE, the superstructure steel stresses do not exceed yield and no permanent deformations will result.

For the 1988 Steam Generator Replacement Project, the following changes were made to the auxiliary building. An additional 150-ton single failure proof crane was installed and the existing 150-ton crane was upgraded to a single failure proof design. The building was reanalyzed for the following conditions:

a. The two cranes acting in tandem to move steam generator components during the replacement project.

b. The seismic forces, as described in this chapter, resulting from a single crane, or tandem cranes, with a 60-ton live load acting anywhere in the building.

For the OBE, all stresses in the steel superstructure are within Allowable as specified by the code of the "American Institute of Steel Construction for Buildings," adopted November 1, 1978. For the DBE, the superstructure steel stresses do not exceed yield and no permanent deformation will result.

For the Dry Cask Storage Project, the East Auxiliary Building Crane was uprated to a main hoist MCL of 145 tons for all operations. The crane, crane rails and the Auxiliary Building columns supporting the crane rails were reanalyzed utilizing the guidance provided in Regulatory Guide 1.60, Rev. 1 and Regulatory Guide 1.61, Rev. 1.

Specifically:

a. Horizontal Ground Response Spectra anchored to a 0.10g Zero Period Ground Acceleration (ZPGA) for the OBE and 0.20g ZPGA for the DBE.

b. Vertical Ground Response Spectrum anchored to 0.10g ZPGA for the OBE and 0.20g for the DBE.

c. Damping values for DBE and OBE per Regulatory Guide 1.61, Rev. 1.

For the OBE, all stresses in the steel superstructure of the Auxiliary Building are within Allowable, including the 1/3 increase in allowable stresses for seismic loads, as specified by the code of the "American Institute of Steel Construction for Buildings" adopted November 1, 1978, in accordance with the D.C. Cook allowable stress criteria. For the DBE, the stresses in the

Auxiliary Building superstructure steel (supporting the crane) do not exceed yield. As such, no permanent deformation will occur in the superstructure steel supporting the crane.

For the Dry Cask Storage project, the use of East and West Auxiliary Building cranes acting in tandem was not evaluated with the revised spectra based on the guidance provided in NRC Regulatory guides 1.60. As such, additional analysis will be required prior to the use of these two cranes in tandem.

Turbine Building

A structure such as the turbine building, which consists of a Class I foundation and a superstructure, which is Class I in some areas and Class III in other areas, was designed as follows. The superstructure was designed in accordance with the criteria discussed in Section 2.9.4. The reactions at the base of the superstructure were used as input for the foundation design. The foundation was analyzed for lateral earthquake and a simultaneously acting vertical component, considering the effects on the foundations of the superstructure and any equipment supported directly on the foundation.

For seismic or tornado conditions, the mat was designed in accordance with the stress criteria of ACI Code 318-63 "Ultimate Strength Design." The load equations used were those of Sub-Section 5.2.2.3, with the elimination of the pressure and temperature items.

For normal load conditions, the mat was designed using Working Stress Design. Stresses and strains for normal loading were held to the limits of ACI Code 318-63 "Working Stress Design."

In the design of Class I structures by ACI Code 318-63 "Ultimate Strength Design" procedure, load reduction factors (Ø) used for the containment are discussed in Sub-Section 5.2.2.3. However, for structures other than the containment structure and when considering seismic conditions, the load reduction factor for diagonal tension, bond and anchorage in concrete was reduced to 0.75.

Emergency Diesel Generator Ventilation Structures

An analysis was conducted by PLG, Inc. to specifically address the effects of increased tornado wind loading on emergency diesel generator ventilation structures (exhaust silencers, combustion intakes, and room cooling intakes). These structures are located outdoors and are bounded by the containment, auxiliary, and switchgear buildings.

The results of this analysis indicate that the subject ventilation structures will experience tornado winds speeds of approximately 60 percent of the highest assumed incident tornado wind speeds.

This reduction is due to the wind obstruction provided by the structures (buildings) in place around the ventilation structures.

2.9.6 Seismic Design Criteria for Equipment

Typically, all safety-related equipment is designed to Seismic Class I criteria. However, not all Seismic Class I equipment is safety-related. Examples of non-safety-related items which have been designed to Seismic Class I criteria are the new and spent fuel crane, the reactor vessel support cooling system and the steam generator blowdown piping.

Seismic Class I equipment design generally requires that normal plus DBE stresses do not exceed yield, and rotating or sliding equipment functions do not bind. The combination of earthquake plus normal stresses for the OBE condition shall not exceed normal allowable, as defined by applicable code. Refer to Table 2.9-1, and Notes thereto, for the definition of loading conditions. Restraints for both Class I mechanical and electrical equipment were generally designed to accept combined normal plus DBE loading without exceeding 0.9 of the yield stresses.

Class I equipment was designed for earthquake loads represented by the combination of appropriate horizontal and vertical floor responses simultaneously applied. The vertical response was equal to 2/3 of the horizontal response.

New response spectra, based on NRC Regulatory Guide 1.60, Rev. 1 and Regulatory Guide 1.61, Rev. 1, were utilized for a design analysis of the East Auxiliary Building Crane, the crane rails and the Auxiliary Building superstructure supporting the crane. These changes were implemented as part of the Dry Cask Storage Project and are further discussed in Section 2.9 .5.

Depending on the relative structural complexity and relative rigidity of the equipment to be evaluated, one of the following methods of seismic qualification was performed:

1. For structurally complex equipment, with the exception of the spent fuel storage racks and the Dry Cask Storage unrestrained / freestanding stack-up, a dynamic multi-degree-of-freedom modal analysis which considered frequency, mode shape and modal participation factors in determining seismic response.

2. For structurally simple equipment, a dynamic single degree-of-freedom analysis, which considered fundamental frequency response of the equipment as, determined from the floor response spectrum.

3. A simplified dynamic analysis, which utilized the peak of the floor response spectrum to determine seismic loading.

4. Testing of identical or similar components using approved procedures to simulate appropriate seismic loads.

5. For the spent fuel storage racks, a time history integration analysis of motion. The specific analysis that utilized this methodology was reviewed and approved by the NRC (Reference 7).

6. The Dry Cask Storage unrestrained / freestanding stack-up was analyzed using time history integration analysis of motion.

2.9.6.1 Use of Earthquake Experience Data as a Method for Assessing Equipment Seismic Adequacy

Revision 3 of the SQUG Generic Implementation Procedure (GIP-3) as modified and supplemented by the Nuclear Regulatory Commission Supplemental Safety Evaluation Report No. 2 (SSER No.2) and Report No.3 (SSER No.3) may be used as an alternative method for seismic qualification of mechanical and electrical equipment, electrical relays, and cable and conduit raceway systems and portions thereof (References 1 to 6). This alternative seismic qualification method is applicable to re-analysis or modification of existing items and to new or replacement items. This alternative method will not supercede specific commitments that were made for the seismic qualification of Regulatory Guide 1.97 equipment unless justified on a case specific basis.

2.9.6.2 References for Section 2.9.6.

1. Letter from Mr. John F. Stang of Nuclear Reactor Regulation to Mr. Robert Powers of Indiana Michigan Power dated February 3, 2000 on subject, Donald C. Cook Nuclear Plant, Units 1 and 2 – Closure of USI A-46, “Seismic Qualification of Equipment in Operating Plants,” and review of licensee’s USI A-46 implementation program (TAC Nos. M69437 and M69438).

2. NRC (Brian Sheron) letter to SQUG (Neil Smith) dated June 19, 1998. Clarification of the staff’s position regarding incorporation of the GIP Method as a revision to the Plant Licensing Basis.

3. Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, Revision 2, corrected 2/14/92 (GIP-2). Prepared by the Seismic

Qualification Utility Group (SQUG) and sent to the NRC by letter dated February 14, 1992.

4. Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, Revision 3. Prepared by SQUG and sent to the NRC by letter dated May 16, 1997.

5. Implementation Guidelines for Seismic Qualification of New and Replacement Equipment / Parts (NARE) using Generic Implementation Procedure (GIP), Revision 4, dated July 2000.

6. NRC letter to SQUG dated June 23, 1999. Review of Seismic Qualification Utility Group's Report on the use of the Generic Implementation Procedure for New and Replacement Equipment and Parts.

7. NRC SER N93004, Safety Evaluation By The Office of Nuclear Reactor Regulation Related To Amendment No. 169 To Facility Operating License No. DPR-74 Indiana Michigan Power Company.

Qualification of Masonry Block Walls

Masonry block walls have been evaluated for their potential impact on other safety-related or important to safety SSCs. Those walls, whose failures could result in adverse interactions with safety-related or important to safety SSCs have been designated as safety-related walls, and have been evaluated for normal and abnormal loading conditions. Abnormal loading considerations have included, as a minimum, seismic, HELB, and post-accident ventilation system operation as applicable for each wall. Where necessary, masonry block walls were modified to meet the applicable loading conditions. All safety-related masonry block walls are evaluated to ensure that the minimum acceptance criteria as given in "Structural and Geotechnical Engineering Branch (SGEB) Criteria for Safety Related Masonry Wall Evaluation" (NRC, July 1981) have been met. This SGEB criteria is contained within NRC Safety Evaluation Report N83096. This SER was issued following the NRC review of AEP's response to IE Bulletin 80-11, "Masonry Wall Design".

Wall 1-4033-W3 has been modified to utilize a sealed steel barrier in combination with a masonry block wall to perform the overall design function of the wall and to satisfy its design bases criteria. The sealed steel barrier has been evaluated for all normal and abnormal loading conditions in accordance with the "Specification for the Design, Fabrication and Erection of

Structural Steel for Buildings," adopted April 17, 1963, by the American Institute of Steel Construction. The masonry block wall is utilized as a 4 hour rated fire barrier.

2.10 CONCLUSIONS

The previous sections have described the numerous site and environs studies which Indiana & Michigan Electric Company has performed to qualify the site for nuclear plant operation.

The design, construction, and operation of the plant on this site meet the reactor siting criteria of 10 CFR Part 100 and the standards for protection against radiation of 10 CFR Part 20.

This conclusion is based on the following considerations:

a. The approximately 650-acre site provides minimum distance to the exclusion area of about 2000 feet.

b. There are no permanent residences on the site or within about 2160 feet of either containment structure.

c. The population of the area surrounding the site is low and only moderate growth is anticipated over the lifetime of the plant.

d. The use characteristics of the site environs are compatible with safe operation of the plant.

e. As tabulated in Chapter 14, the total radiation doses to an individual at the boundary of the exclusion area, or at the boundary of the "low population zone" under postulated hypothetical accidents, are well within the limits prescribed in 10 CFR 50.67.

f. Access to the site is readily available via road, rail and air. Numerous primary, secondary, and interstate roads provide connection with the surrounding area.

g. The meteorological, geological, hydrological, seismological, and limnological characteristics of the site and environs are suitable for operation of the plant.

POPULATION TRENDS OF THE COUNTIES SURROUNDING THE DONALD C. COOK NUCLEAR PLANT SITE

County	State	1940	1950	1960	1970	1975	1985	1990	2000	2037
Allegan	Michigan	41,839	47,493	57,279	66,575	70,264	70,900	90,509	101,300	123,047
Berrien	Michigan	89,117	115,702	149,865	163,875	165,294	179,900	161,378	172,771	187,556
Cass	Michigan	22,810	28,185	39,932	43,312	42,388	46,700	49,477	54,300	56,520
Kalamazoo	Michigan	100,085	126,707	169,712	201,550	209,678	235,400	223,411	219,700	247,643
Ottowa	Michigan	59,660	73,751	98,719	128,181	139,947	172,600	187,768	204,000	275,055
St. Joseph	Michigan	31,749	35,071	42,332	47,392	50,388	55,100	58,913	68,900	73,235
Van Buren	Michigan	35,111	39,194	48,395	56,173	62,643	75,900	70,060	81,300	87,380
Elkhart	Indiana	72,634	84,512	106,790	126,529	136,900	161,800	156,200	169,600	186,600
Fulton	Indiana	15,577	16,565	16,957	16,984	17,900	19,700	18,800	19,000	19,900
Jasper	Indiana	14,397	17,031	18,842	20,429	23,000	28,000	25,000	25,700	27,300
Kosciosko	Indiana	29,561	33,002	40,373	48,127	52,800	53,700	65,300	70,300	80,900
Lagrange	Indiana	14,352	15,347	17,380	20,890	23,200	29,000	29,500	33,800	48,600
Lake	Indiana	293,195	368,152	513,269	546,253	550,100	569,900	475,600	470,400	490,600
Laporte	Indiana	63,600	76,808	95,111	105,343	105,900	111,000	107,100	108,200	110,400
Marshall	Indiana	25,935	29,468	32,443	34,896	38,500	45,600	42,200	44,300	48,800
Noble	Indiana	22,776	25,075	28,162	31,382	33,100	37,700	37,900	40,200	45,200
Porter	Indiana	27,936	40,076	60,279	87,114	95,800	122,900	128,900	133,000	127,100
Pulaski	Indiana	12,056	12,493	12,837	12,534	12,900	13,600	12,600	12,700	14,500
St. Joseph	Indiana	161,823	205,058	238,614	245,045	241,900	240,500	247,100	254,500	256,900
Starke	Indiana	12,258	15,282	17,911	19,280	21,000	24,100	22,700	23,400	24,800
Cook	Illinois	4,063,342	4,508,792	5,129,725	5,492,369	5,371,897	5,418,100	5,105,067	5,276,875	5,338,749

POPULATION TRENDS OF CITIES AND TOWNSHIPS IN BERRIEN COUNTY, MICHIGAN

City or Township	1940	1950	1960	1970	1975	1980	1990	2000	2037
Benton Harbor City	16,668	18,769	19,136	16,481	15,668	14,707	12,818	13,000	13,185
Buchanan City	4,056	5,224	5,341	4,645	4,722	5,142	4,992	5,152	5,350
Niles City	11,328	13,145	13,842	12,988	13,277	13,115	12,456	13,144	13,957
St. Joseph City	8,863	10,223	11,755	11,042	11,001	9,622	9,214	9,300	9,387
Bainbridge	2,046	2,194	2,503	2,784	2,764	2,879	2,865	2,889	2,931
Baroda	1,433	1,558	1,877	2,167	2,473	2,666	2,731	2,670	2,626
Benton	8,105	16,732	23,658	22,714	23,139	19,120	17,163	20,500	21,606
Berrien	2,122	2,542	3,183	3,905	4,098	4,302	4,697	4,800	4,998
Bertrand	1,072	1,342	1,969	2,259	2,235	2,369	2,228	2,373	2,542
Bridgman City [1]	na	na	na	na	na	2,235	2,140	2,244	2,368
Buchanan	1,237	1,655	2,410	3,182	3,406	3,571	3,402	3,584	3,799
Chickaming	1,711	2,318	3,476	4,051	4,086	4,302	3,717	3,800	3,885
Coloma	2,301	3,308	5,413	6,190	6,089	5,345	5,123	5,361	5,644
Coloma City [(1)]	na	na	na	na	na	1,833	1,679	1,837	2,021
Galien	1,190	1,380	1,685	1,671	1,692	1,786	1,591	1,787	2,018
Hagar	1,429	2,451	3,562	4,088	4,087	4,943	4,113	4,954	6,003
Lake	1,928	2,409	3,470	3,767	3,711	2,212	2,487	2,500	2,513
Lincoln	1,949	2,588	4,462	11,007	11,408	13,520	13,604	14,000	14,408
New Buffalo	2,175	2,879	4,196	5,367	5,358	2,878	2,419	2,500	2,795

[1] New entity since 1980.

POPULATION TRENDS OF CITIES AND TOWNSHIPS IN BERRIEN COUNTY, MICHIGAN

City or Township	1940	1950	1960	1970	1975	1980	1990	2000	2037
New Buffalo City (1)	na	na	na	na	na	2,821	2,317	2,829	3,476
Niles	3,000	5,732	11,934	13,414	13,021	13,165	12,828	13,194	13,653
Oronoko	3,443	4,737	6,397	8,482	8,865	10,761	9,819	10,790	11,927
Pipestone	1,696	1,911	2,174	2,422	2,532	2,364	2,303	2,389	2,495
Royalton	1,188	1,414	1,744	2,513	2,508	3,046	3,135	4,100	6,900
St. Joseph	2,374	1,677	3,674	6,591	6,675	9,961	9,613	10,000	12,587
Sodus	1,626	2,092	2,575	2,504	2,507	2,260	2,065	2,700	3,476
Three Oaks	2,135	2,469	2,856	2,894	3,030	3,045	2,952	3,048	3,168
Watervliet	2,279	3,042	4,344	4,474	4,507	3,275	2,926	3,286	3,713
Watervliet City (1)	na	na	na	na	na	1,867	1,867	1,876	1,897
Weesaw	1,663	1,911	2,229	2,338	2,329	2,164	2,114	2,164	2,230
Total	89,017	115,702	149,865	163,940	165,188	171,276	161,378	172,771	187,556

POPULATION CENTERS OF 25,000 OR MORE WITHIN 60 MILES OF THE DONALD C. COOK NUCLEAR PLANT SITE

City	Distance (mi)	Direction	1975 Population
Benton Harbor - St. Joseph, Michigan	11	NNE	26,925
Michigan City, Indiana	26	SW	38,937
South Bend, Indiana	26	SE	105,511
Mishawaka, Indiana	29	SE	37,133
Elkhart, Indiana	38	ESE	43,152
Gary, Indiana	48	WSW	171,282
Merrillville, Indiana	48	SW	27,174
Highland, Indiana	53	WSW	26,922
Portage, Michigan	54	ENE	39,067
East Chicago, Illinois	55	WSW	43,012
Hammond, Indiana	55	WSW	105,319
Calumet City, Illinois	56	WSW	39,591
Kalamazoo, Michigan	56	ENE	73,644
Lansing, Illinois	56	WSW	30,707
Chicago, Illinois	58	W	3,150,00
Evanston, Illinois	58	W	73,658
Wilmette, Illinois	59	W	32,545
Dolton, Illinois	59	WSW	26,390
Holland, Illinois	60	NNE	28,097
Skokie, Illinois	60	W	70,162

POPULATION DISTRIBUTION (1975)

Direction	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	50-60 Miles	Total
N	0	0	0	0	0	0
NNE	16,425	2,777	13,609	6,462	18,131	57,404
NE	23,866	15,757	10,706	7,356	25,190	82,875
ENE	4,095	5,714	15,752	16,195	169,798	211,554
E	8,153	15,420	6,455	17,092	15,140	62,260
ESE	21,526	11,231	58,577	26,314	13,166	130,814
SE	20,384	176,762	35,853	36,094	15,297	284,390
SSE	5,214	22,132	14,974	21,597	11,718	75,635
S	5,217	7,480	9,844	12,641	12,472	47,654
SSW	6,231	32,134	11,242	9,531	8,475	67,613
SW	3,147	60,820	29,324	195,258	90,764	379,313
WSW	0	0	0	62,630	1,810,927	1,873,557
W	0	0	0	0	1,357,309	1,357,309
WNW	0	0	0	0	0	0
NW	0	0	0	0	0	0
NNW	0	0	0	0	0	0
TOTAL	114,258	350,227	206,336	411,170	3,548,387	4,630,378

POPULATION DISTRIBUTION (1990)

Direction	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	Total
N	3	0	0	0	0	3
NNE	15	11	58	441	977	1,502
NE	12	25	333	1,975	2,460	4,805
ENE	9	111	181	259	348	908
E	0	88	122	163	186	908
ESE	0	75	160	452	903	1,590
SE	3	107	259	161	199	729
SSE	5	169	866	295	234	1,569
S	8	86	937	277	238	1,546
SSW	4	33	104	60	31	232
SW	0	0	0	0	0	0
WSW	0	0	0	0	0	0
W	0	0	0	0	0	0
WNW	0	0	0	0	0	0
NW	0	0	0	0	0	0
NNW	0	0	0	0	0	0
Total	59	705	3,020	4,083	5,576	13,443

POPULATION DISTRIBUTION (1990)

Direction	0-5 Miles	5-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	46-50 Miles	50-60 Miles	Total
N	3	0	0	0	0	0	0	3
NNE	1,502	14,649	16,833	3,297	12,645	8,912	33,593	91,431
NE	4,805	12,634	20,189	16,571	10,659	11,876	30,608	107,342
ENE	908	2,489	4,295	5,618	17,126	27,209	183,270	240,915
E	559	1,302	12,339	14,532	7,322	20,825	16,610	73,489
ESE	1,590	1,318	18,843	18,920	69,710	31,639	16,366	158,386
SE	729	703	11,920	178,696	55,516	44,563	17,581	309,708
SSE	1,569	917	3,081	18,023	11,923	24,797	10,871	71,181
S	1,546	1,350	7,253	6,254	8,626	13.435	12,396	50,860
SSW	232	2,239	4,536	37,033	11,299	9,839	9,297	74,475
SW	0	0	3,993	42,892	25,429	186,622	157,635	416,571
WSW	0	0	0	0	0	17,298	1,182,109	1,199,407
W	0	0	0	0	0	0	1,279,601	1,279,601
WNW	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0
Total	13,443	37,601	103,282	341,836	230,255	397,015	2,949,937	4,073,369

PROJECTED POPULATION DISTRIBUTION (2000)

Direction	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	Total
N	3	0	0	0	0	3
NNE	15	11	58	452	1,003	1,539
NE	12	25	340	2,017	2,518	4,912
ENE	9	111	184	264	356	924
E	0	88	121	156	181	546
ESE	0	75	160	441	871	1,547
SE	3	107	260	160	193	723
SSE	5	171	897	297	235	1,605
S	8	88	978	282	238	1,594
SSW	4	34	108	62	31	239
SW	0	0	0	0	0	0
WSW	0	0	0	0	0	0
W	0	0	0	0	0	0
WNW	0	0	0	0	0	0
NW	0	0	0	0	0	0
NNW	0	0	0	0	0	0
Total	59	710	3,106	4,131	5,626	13,632

PROJECTED POPULATION DISTRIBUTION (2000)

Direction	0-5 Miles	5-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	50-60 Miles	Total
N	3	0	0	0	0	0	0	3
NNE	1,539	14,873	17,912	3.829	14,574	9,981	37,198	99,906
NE	4,912	13.770	22,769	18,275	12,351	13,580	34,091	119,748
ENE	924	3,053	4,699	6,399	19,857	28,604	179,627	243,163
E	546	1,461	13,241	15,985	8,053	24,230	19,133	82,649
ESE	1,547	1,391	19,654	20,340	76,005	34,875	18,568	172,380
SE	723	703	12,280	184,094	58,265	48,499	19,032	323,596
SSE	1,605	922	3,254	18,563	12,349	26,036	11,463	74,192
S	1,594	1,359	7,396	6,320	8,829	13,869	12,762	52,129
SSW	239	2,254	4,634	37,403	11,439	10,056	9,566	75,591
SW	0	0	4,425	43,353	26,184	188,025	156,452	418,439
WSW	0	0	0	0	0	17,125	1,210,464	1,227,589
W	0	0	0	0	0	0	1,317,989	1,317,989
WNW	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0
Total	13,632	39,786	110,264	354,561	247,906	414,880	3,026,345	4,207,374

PROJECTED POPULATION DISTRIBUTION (2037)

Direction	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	Total
N	3	0	0	0	0	3
NNE	15	11	60	464	1,032	1,582
NE	12	26	351	2,075	2,592	5,056
ENE	9	112	189	271	367	948
E	0	88	120	153	180	541
ESE	0	75	160	432	853	1,520
SE	3	108	261	159	190	721
SSE	5	174	943	297	235	1,654
S	8	91	1,033	290	238	1,660
SSW	4	35	115	65	31	250
SW	0	0	0	0	0	0
WSW	0	0	0	0	0	0
W	0	0	0	0	0	0
WNW	0	0	0	0	0	0
NW	0	0	0	0	0	0
NNW	0	0	0	0	0	0
Total	59	720	3,232	4,206	5,718	13,935

PROJECTED POPULATION DISTRIBUTION (2037)

Direction	0-5 Miles	5-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	50-60 Miles	Total
N	3	0	0	0	0	0	0	3
NNE	1,582	16,425	19,095	4,219	16,060	12,120	47,104	116,605.
NE	5,056	16,323	24,306	19,610	13,359	15,364	41,268	135,286
ENE	948	4,619	5,163	6,808	21,391	31,710	203,471	274,110
E	541	1,763	14,307	16,566	8,347	25,677	20,390	87,591
ESE	1,520	1,480	20,671	20,949	82,456	37,994	24,046	189,116
SE	721	724	12,859	186,055	60,449	53,012	21,556	335,376
SSE	1,654	944	3,484	18,743	12,818	28,764	12,747	79,154
S	1,660	1,392	7,617	6,443	9,102	14,759	13,765	54,738
SSW	250	2,308	4,918	38,143	11,582	9,894	9,689	76,784
SW	0	0	5,200	44,112	25,188	188,950	162,045	425,495
WSW	0	0	0	0	0	17,816	1,237,659	1,255,475
W	0	0	0	0	0	0	1,343,581	1,343,581
WNW	0	0	0	0	0	0	0	0
NW	0	0	0	0	0	0	0	0
NNW	0	0	0	0	0	0	0	0
Total	13,935	45,978	117,620	361,648	260,752	436,060	3,137,321	4,373,314

TRANSIENT POPULATION DISTRIBUTION 1 MILE INCREMENTS (1971)

	0-1 Mi	1-2 Mi	2-3 Mi	3-4 Mi	4-5 Mi	5-6 Mi	6-7 Mi	7-8 Mi	Total
NNE	(0)	(108)	(60)	(0)	(0)	(0)	(0)	(0)	(168)
NNE	0	0	0	0	0	0	0	0	0
NE	0	1	9	9	25	31	36	44	155
ENE	0	7	15	22	27	34	41	47	193
E	0	9	16	22	28	35	41	46	197
ESE	0	8	15	20	20	34	41	47	185
SE	0	9	16	22	28	33	41	47	196
SSE	0	4	5	22	28	34	41	47	181
S	0	0	0	3	21	35	41	43	143
SSW	0	0	0	0	0	4	2	7	13
SSW	(53)	(78)	(300)	(2282)	(6505)	(5213)	(162)	(65)	(14,658)
TOTAL MIGRANT	0	38	76	120	177	240	284	328	1,263
TOTAL VACATIONISTS	(53)	(186)	(360)	(2282)	(6505)	(5213)	(162)	(65)	14,826
TOTAL TRANSIENT	(53)	224	436	2402	6682	5453	446	393	16,089

Legend: (No.) Summer Peak Vacationists
No. Yearly Average Migrant Crop Pickers

AGRICULTURAL STATISTICS

(FIGURES TAKEN FROM U. S. CENSUS OF AGRICULTURE - 1974 LATEST DATA)

County:	Berrien	Van Buren	Cass
Total Farm Acreage	199,357	213,131	197,700
Percent of County in Farms	54.0	55.0	63.0
Number of Farms	2,118	1,782	1,179
Average Size of Farms (acres)	94.0	120	168.0
Average Value of Farms	$72,762	$73,519	$90,317
Farm Population	6,884	5,740	3,648
Major Farm Products	Fruits	Fruits	Livestock
	Dairy Products	Dairy Products	Dairy Products
	Livestock	Livestock	
	($ millions)		
Value of Farm Products Sold	$42.3	$45.0	$26.3
Value of Crops Sold	28.0	30.0	9.9
Fruits	28.0	30.0	9.9
Value of Livestock & Livestock			
Products Sold	14.3	15.0	16.4
Livestock	5.1	8.8	9.5
Dairy Products	1.3	2.6	2.6

HOSPITALS IN BERRIEN COUNTY, 1997

Hospital	Location	Distance from Station, miles	Capacity
Lakeland Medical Center	Berrien Center	14	250
Lakeland Medical Center	St. Joseph	10	300
Lakeland Medical Center	Niles	18	174
Community	Watervliet	22	70

DATA SUMMARY SHEET STATION 5-DATE 7/2/69

	WIND VELOCITIES						Bivane Angles		Turbulence Classes		Temperature (F)			Temperature Difference	Not Used				
	30FT		200 FT		SAT.														
Hour	DIR	SP	DIR	SP	DIR	SP	EL.	AZ	Satellite	Local Tower	0 Check	Dew Point	3oft Temp	DEL-T (200-30)	D	S	PCPN	PRES	RH
1	999	99	85	12	80	6	999	999	0	4	1.0	48.9	61.3	5.00	0	0	0.00	29.46	0
2	999	99	100	11	95	5	999	999	0	4	.8	48.2	61.2	4.80	0	0	0.00	29.46	0
3	999	99	120	9	105	5	999	999	0	4	1.5	47.8	61.0	5.13	0	0	0.05	29.46	0
4	999	99	135	10	120	9	999	999	0	4	1.2	46.7	61.3	5.45	0	0	0 00	29.45	0
5	999	99	170	8	130	8	999	999	0	2	1.0	45.5	61.5	5.25	0	0	0.00	29.45	0
6	999	99	195	7	170	4	999	999	0	2	1.0	46.1	61.6	5.50	0	0	0 00	29.45	0
7	999	99	210	6	185	4	999	999	0	2	1.0	45.9	61.6	5.75	0	0	0.00	29.45	0
8	999	99	200	2	185	2	999	999	0	2	1.0	46.0	61.0	.25	0	0	0.00	29.44	0
9	999	99	220	3	203	2	999	999	0	2	.8	51.6	61.9	.20	0	0	0.00	29.43	0
10	999	99	240	3	220	2	999	999	0	2	1.0	54.5	63.5	1.75	0	0	0 00	29.43	0
11	999	99	230	3	220	2	999	999	0	2	.9	55.4	64.4	1.22	0	0	0 00	29.43	0
12	999	99	275	2	250	2	999	999	0	1	1.1	58.0	66.0	3.77	0	0	0.00	29.43	0
13	999	99	310	2	295	2	999	999	0	2	1.0	57.0	65.3	2.75	0	0	0 00	29.43	0
14	999	99	315	3	305	2	999	999	0	2	1.0	59.1	67.9	3.75	0	0	0.00	29.41	0
15	999	99	340	5	330	4	999	999	0	2	1.0	56.8	69.9	5.75	0	0	0.00	29.40	0
16	999	99	345	4	350	4	999	999	0	2	1.0	57.5	69.2	4.50	0	0	0.00	29.39	0

DATA SUMMARY SHEET STATION 5-DATE 7/2/69

	WIND VELOCITIES						**Bivane Angles**		**Turbulence Classes**		**Temperature (F)**			**Temperature Difference**	**Not Used**				
	30FT		200 FT		SAT.														
Hour	DIR	SP	DIR	SP	DIR	SP	EL.	AZ	Satellite	Local Tower	0 Check	Dew Point	3oft Temp	DEL-T (200-30)	D	S	PCPN	PRES	RH
17	999	99	345	2	350	3	999	999	0	2	1.1	58.9	71.6	5.27	0	0	0.00	29.36	0
18	999	99	280	0	350	2	999	999	0	4	1.0	55.6	71.2	4.79	0	0	0.00	29.34	0
19	999	99	230	1	355	2	999	999	0	2	.9	52.3	73.0	2.97	0	0	0.00	29.34	0
20	999	99	280	2	350	2	999	999	0	2	1.1	53.4	73.9	.77	0	0	0.00	29.34	0
21	994	99	230	1	360	1	999	999	0	4	1.0	51.9	73.1	.50	0	0	0.00	29.33	0
22	999	99	125	7	100	5	999	999	0	4	.9	53.4	70.6	3.27	0	0	0.00	29.31	0
23	999	99	135	10	110	6	999	999	0	4	1.2	48.7	70.6	3.95	0	0	0.00	29.30	0
24	999	99	135	12	110	8	999	999	0	4	1.1	51,2	68.4	5.22	0	0	o.00	29.29	0

METEOROLOGICAL DATA FOR JUNE 1, 1992

Hour	DIR1 10 M	S	SPD1 10 M	S	DIR2 60 M	S	SPD2 60 M	S	DIR4 SHOR	S	SPD4 SHOR	S	STAB	TEM2 DEWP	S	TEM1 10 M	S	DTI 60 M	S	RAIN	S
100	308	0	2.2	0	276	0	8.7	0	213	0	3.1	0	6	45.2	0	52.9	0	2.8	0	0.00	0
200	324	0	1.4	0	327	0	10.4	0	51	0	1.6	0	7	44.5	0	52.9	0	7.1	0	0.00	0
300	301	0	2.6	0	320	0	11.8	0	292	0	1.1	0	7	43.2	0	51.8	0	5.4	0	0.00	0
400	316	0	1.4	0	341	0	10.6	0	13	0	3.8	0	7	41.7	0	51.8	0	4.0	0	0.00	0
500	28	0	2.8	0	10	0	11.0	0	38	0	3.7	0	6	42.3	0	51.4	0	1.5	0	0.00	0
600	199	0	2.2	0	37	0	4.7	0	92	0	2.3	0	7	40.7	0	47.9	0	3.9	0	0.00	0
700	285	0	2.9	0	293	0	4.0	0	260	0	2.5	0	7	41.0	0	47.3	0	3.8	0	0.00	0
800	307	0	2.0	0	324	0	5.7	0	0	0	2.7	0	5	44.4	0	51.4	0	0.3	0	0.00	0
900	339	0	1.7	0	26	0	2.1	0	3	0	4.6	0	2	47.4	0	56.9	0	-1.6	0	0.00	0
1000	309	0	3.0	0	319	0	3.8	0	359	0	4.7	0	1	46.9	0	58.3	0	-2.1	0	0.00	0
1100	313	0	3.6	0	318	0	4.0	0	351	0	5.1	0	1	49.3	0	62.8	0	-2.1	0	0.00	0
1200	283	0	5.4	0	308	0	7.0	0	337	0	4.6	0	1	46.8	0	60.2	0	-2.3	0	0.00	0
1300	319	0	5.6	0	318	0	9.7	0	352	0	4.7	0	1	47.3	0	61.3	0	-2.7	0	0.00	0
1400	344	0	4.3	0	326	0	8.0	0	324	0	4.5	0	1	50.0	0	64.2	0	-3.2	0	0.00	0
1500	354	0	5.9	0	336	0	9.5	0	320	0	3.6	0	1	50.1	0	62.4	0	-2.2	0	0.00	0
1600	351	0	5.7	0	344	0	9.6	0	350	0	6.0	0	1	49.7	0	61.9	0	-2.0	0	0.00	0
1700	358	0	6.2	0	351	0	10.5	0	353	0	6.3	0	1	46.7	0	62.0	0	-1.9	0	0.00	0
1800	355	0	4.9	0	357	0	9.7	0	5	0	7.9	0	4	46.2	0	60.5	0	-0.9	0	0.00	0
1900	356	0	3.9	0	4	0	7.6	0	13	0	10.8	0	4	45.5	0	61.2	0	-0.9	0	0.00	0
2000	2	0	3.3	0	18	0	7.4	0	15	0	8.2	0	5	44.2	0	60.7	0	-0.3	0	0.00	0
2100	29	0	2.4	0	28	0	5.9	0	37	0	2.2	0	5	41.4	0	59.0	0	0.4	0	0.00	0

METEOROLOGICAL DATA FOR JUNE 1, 1992

Hour	DIR1 10 M	S	SPD1 10 M	S	DIR2 60 M	S	SPD2 60 M	S	DIR4 SHOR	S	SPD4 SHOR	S	STAB	TEM2 DEWP	S	TEM1 10 M	S	DTI 60 M	S	RAIN	S
2200	32	0	2.7	0	34	0	9.1	0	51	0	2.1	0	6	40.9	0	56.2	0	1.6	0	0.00	0
2300	6	0	1.6	0	37	0	9.0	0	97	0	1.5	0	6	41.1	0	54.5	0	2.0	0	0.00	0
2400	267	0	1.1	0	35	0	8.1	0	162	0	1.2	0	7	41.0	0	51.4	0	6.4	0	0.00	0

Status Code(S) Definition: 0 = Valid, 1 = Questionable, 2 = Invalid, 3 = Unsteady Direction, 5 = Flat Direction

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS A

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	1	3	11	19	37	111	105	180	467
NNE	0	0	0	0	0	2	5	6	15	26	96	150
NE	0	0	0	1	4	7	8	5	1	1	0	27
ENE	0	0	0	0	1	2	5	4	2	0	0	14
E	0	0	0	0	0	6	3	6	1	0	0	16
ESE	0	0	0	0	1	13	11	18	26	14	7	90
SE	0	0	0	0	0	6	27	48	77	43	28	229
SSE	0	0	0	0	1	3	8	13	14	3	1	43
S	0	0	0	0	1	5	3	8	9	2	0	28
SSW	0	0	0	0	0	4	3	4	23	18	0	52
SW	0	0	0	0	2	8	15	34	73	37	16	185
WSW	0	0	0	0	5	28	25	16	22	18	39	153
W	0	0	0	2	16	17	12	7	10	12	41	117
WNW	0	0	1	3	16	6	9	9	18	16	55	133
NW	0	0	2	5	17	13	12	6	22	10	83	170
NNW	0	0	0	3	17	20	17	18	20	28	75	198
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	3	15	84	151	182	239	444	333	621	2072

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS B

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	0	0	3	5	4	3	4	17	36
NNE	0	0	0	0	1	2	2	1	8	5	13	32
NE	0	0	0	0	1	2	4	0	0	0	0	7
ENE	0	0	0	0	2	4	3	0	0	0	0	9
E	0	0	0	0	0	3	2	3	0	0	0	8
ESE	0	0	0	0	2	2	10	7	6	5	3	35
SE	0	0	0	1	1	4	7	14	20	8	2	57
SSE	0	0	0	0	1	3	1	3	4	0	0	12
S	0	0	0	0	0	2	3	3	0	0	0	8
SSW	0	0	0	0	0	0	2	0	8	7	0	17
SW	0	0	0	0	1	1	4	10	16	8	5	45
WSW	0	0	0	1	2	3	4	0	0	0	8	18
W	0	0	0	0	3	0	4	1	1	0	22	31
WNW	0	0	0	0	0	0	2	1	0	1	15	19
NW	0	0	0	0	5	0	1	1	2	3	18	30
NNW	0	0	0	0	6	2	3	0	1	0	17	29
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	2	25	31	57	48	69	41	120	393

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS C

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	0	4	3	1	1	5	2	24	40
NNE	0	0	0	1	2	1	2	4	7	9	24	50
NE	0	0	0	0	3	3	0	1	0	0	1	8
ENE	0	0	0	0	2	4	5	1	0	0	0	12
E	0	0	0	0	1	1	2	1	0	0	0	5
ESE	0	0	0	0	5	5	8	8	3	2	2	33
SE	0	0	0	0	2	4	5	11	17	7	11	57
SSE	0	0	0	0	1	1	5	2	2	0	0	11
S	0	0	0	0	0	0	7	5	2	0	0	14
SSW	0	0	0	0	0	1	2	2	9	3	0	17
SW	0	0	0	0	2	2	4	6	10	5	15	44
WSW	0	0	1	0	2	4	0	0	1	0	23	31
W	0	0	0	0	0	1	0	1	1	2	28	33
WNW	0	0	0	1	0	0	1	0	2	1	27	32
NW	0	0	0	0	2	0	1	1	2	4	26	36
NNW	0	0	0	1	2	0	0	1	2	1	40	47
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	1	3	28	30	43	45	63	36	221	470

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS D

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	1	1	5	7	12	10	7	176	219
NNE	0	0	1	1	9	15	10	18	31	34	65	184
NE	0	0	0	4	27	16	14	8	2	0	1	72
ENE	0	0	1	7	31	26	12	3	2	0	0	82
E	0	0	1	3	20	25	14	8	0	0	0	71
ESE	0	0	0	1	22	49	41	40	39	25	38	255
SE	0	0	0	1	5	13	36	51	81	61	84	332
SSE	0	0	0	0	1	12	12	8	17	9	0	59
S	0	0	0	1	1	6	5	15	20	22	7	77
SSW	0	0	0	0	1	1	7	23	62	33	28	155
SW	0	0	0	1	2	11	7	12	26	24	81	164
WSW	0	0	0	2	4	6	4	4	8	5	91	124
W	0	0	1	0	3	1	1	2	9	9	118	144
WNW	0	0	0	0	1	0	1	3	4	8	136	153
NW	0	0	3	0	0	0	1	1	10	9	179	203
NNW	0	0	1	0	1	3	1	2	4	9	136	157
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	8	22	129	189	173	210	325	255	1140	2451

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS E

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	1	2	6	1	0	2	7	18	43	80
NNE	0	0	0	3	9	16	8	12	26	16	14	104
NE	0	0	0	4	27	25	19	10	5	1	0	91
ENE	0	0	1	6	20	19	5	2	2	0	0	55
E	0	0	3	6	48	26	8	0	0	0	0	91
ESE	0	0	0	2	34	44	56	35	50	36	23	280
SE	0	0	0	3	7	19	42	68	131	85	84	439
SSE	0	0	0	1	5	9	17	12	18	10	1	73
S	0	0	0	0	1	4	5	13	25	13	1	62
SSW	0	0	0	0	3	7	6	22	55	12	4	109
SW	0	0	0	2	3	9	16	14	16	15	11	86
WSW	0	0	2	0	2	1	2	3	10	8	18	46
W	0	0	1	1	0	1	1	1	6	6	23	40
WNW	0	0	0	0	0	1	2	0	5	5	23	36
NW	0	0	0	0	2	1	1	0	7	5	31	47
NNW	0	0	0	0	1	0	1	3	7	6	53	71
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	8	30	168	183	189	197	370	236	329	1710

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS F

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	1	1	1	1	3	3	2	4	16
NNE	0	0	1	2	6	5	4	2	1	2	5	28
NE	0	0	1	1	8	4	2	1	1	0	0	18
ENE	0	0	1	6	9	4	0	1	0	0	0	21
E	0	0	0	4	24	3	1	0	1	0	0	33
ESE	0	0	0	3	36	63	51	39	44	23	10	269
SE	0	0	0	0	8	17	43	56	76	37	12	249
SSE	0	0	0	1	1	3	11	5	2	2	0	25
S	0	0	1	0	1	2	2	3	3	3	0	15
SSW	0	0	1	1	1	2	4	13	11	0	1	34
SW	0	0	1	0	4	4	8	4	2	1	1	25
WSW	0	0	1	0	2	0	0	0	1	1	3	8
W	0	1	0	0	0	0	1	0	1	1	2	6
WNW	0	0	0	1	0	0	0	0	2	1	0	4
NW	0	0	0	0	0	0	0	0	1	2	1	4
NNW	0	0	0	0	0	0	0	0	1	2	4	7
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	1	7	20	101	108	128	127	150	77	43	762

Number of Calms: 0

Number of Missing Hours: 51

ANNUAL JOINT FREQUENCY DISTRIBUTION – 2005 – 10 m SHORELINE TOWER – PASQUILL CLASS G

Compass Direction	<0.5 mph	0.5-1.0 mph	1.1-1.5 mph	1.6-2.0 mph	2.1-3.0 mph	3.1-4.0 mph	4.1-5.0 mph	5.1-6.0 mph	6.1-8.0 mph	8.1-10.0 mph	>10.0 mph	Total
N	0	0	0	1	0	1	1	1	1	0	0	5
NNE	0	0	0	0	5	2	3	0	1	0	0	11
NE	0	0	0	1	1	2	0	0	0	0	0	4
ENE	0	0	0	2	3	2	0	0	0	0	0	7
E	0	1	1	2	9	11	1	0	0	0	0	25
ESE	0	1	0	2	27	46	98	72	75	23	1	345
SE	0	1	0	3	9	31	61	87	109	20	0	321
SSE	0	1	2	2	7	7	18	8	1	0	0	46
S	0	0	0	0	4	5	8	3	1	0	1	22
SSW	0	0	1	2	2	1	4	18	11	0	0	39
SW	0	0	1	0	1	3	5	3	2	0	0	15
WSW	0	0	0	1	1	0	0	0	1	0	0	3
W	0	0	0	2	0	0	0	0	0	0	1	3
WNW	0	1	0	0	0	0	0	0	0	0	0	1
NW	0	1	0	0	0	1	0	0	0	0	0	2
NNW	0	0	1	0	0	0	0	0	0	0	1	2
VARIABLE	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	6	6	18	69	112	199	192	202	43	4	851

Number of Calms: 0

Number of Missing Hours: 51

MEAN WIND SPEEDS

Smith and Singer Turbulence Class	200 foot Level Main Tower (mph)	50 foot Level Main Tower (mph)	50 foot Level Satellite (mph)
I	8	5	8
II	14	6	9
III	18	8	11
IV	8	4	3
Pasquill Turbulence Class	60 meter Level Primary Tower (mph)	10 meter Level Primary Tower (mph)	10 meter Level Shoreline Tower (mph)
A	11.2	6.1	9.2
B	11.8	6.4	9.7
C	13.2	6.7	11.5
D	14.3	6.7	11.8
E	11.7	4.4	7.4
F	10.2	2.5	5.5
G	9.2	1.6	5.2

Offsite Atmospheric Dispersion Factors

Release Point[1]	Receptor Point	0-2 hour *X/Q*	2-8 hour *X/Q*	8-24 hour *X/Q*	1-4 days *X/Q*	4-30 days *X/Q*
U1 Plant Vent	EAB	5.69E-04				
U1 Plant Vent	LPZ	1.13E-04	5.28E-05	3.62E-05	1.64E-05	6.30E-06
U1 Containment Surface	EAB	6.04E-04				
U1 Containment Surface	LPZ	1.13E-04	5.32E-05	3.64E-05	1.66E-05	6.37E-06
U1 Turbine Building	EAB	8.62E-04				
U1 Turbine Building	LPZ	1.16E-04	5.45E-05	3.74E-05	1.74E-05	6.74E-06
West Main Steam Enclosure	EAB	5.87E-04				
West Main Steam Enclosure	LPZ	1.13E-04	5.29E-05	3.63E-05	1.65E-05	6.36E-06
U1 RWST	EAB	6.25E-04				
U1 RWST	LPZ	1.14E-04	5.35E-05	3.67E-05	1.65E-05	6.36E-06
North Auxiliary Building Supply	EAB	6.19E-04				
North Auxiliary Building Supply	LPZ	1.13E-04	5.31E-05	3.64E-05	1.67E-05	6.24E-06

[1] Only the most limiting source and receptor pairs are included.

Control Room Atmospheric Dispersion Factors

Release Point[1]	Receptor Point	0-2 hour *X/Q*	2-8 hour *X/Q*	8-24 hour *X/Q*	1-4 days *X/Q*	4-30 days *X/Q*
U1 Plant Vent	U1 Normal	2.03E^{-03}	1.37E^{-03}	4.89E^{-04}	3.84E^{-04}	2.62E^{-04}
U1 Plant Vent	U1 Emergency	2.17E^{-03}	1.42E^{-03}	5.18E^{-04}	3.99E^{-04}	2.72E^{-04}
U2 Plant Vent	U2 Normal	2.10E^{-03}	1.48E^{-03}	5.52E^{-04}	3.98E^{-04}	3.17E^{-04}
U2 Plant Vent	U2 Emergency	2.28E^{-03}	1.59E^{-03}	5.95E^{-04}	4.46E^{-04}	3.49E^{-04}
U2 Containment Closest Point	U2 Normal	1.02E^{-02}	8.41E^{-03}	2.74E^{-03}	2.66E^{-03}	2.34E^{-03}
U2 Containment Closest Point	U2 Emergency	1.24E^{-02}	1.02E^{-02}	3.32E^{-03}	3.24E^{-03}	2.84E^{-03}
U2 PORV/MSSV	U2 Normal	1.09E^{-02}	8.61E^{-03}	2.87E^{-03}	2.78E^{-03}	2.50E^{-03}
U2 PORV/MSSV	U2 Emergency	1.26E^{-02}	9.72E^{-03}	3.26E^{-03}	3.71E^{-03}	2.80E^{-03}
U2 Turbine Building	U2 Normal	4.57E^{-02}	3.14E^{-02}	1.27E^{-02}	8.30E^{-03}	6.73E^{-03}
U2 Turbine Building	U2 Emergency	2.91E^{-02}	2.02E^{-02}	8.14E^{-03}	5.34E^{-03}	4.32E^{-03}
U2 RWST	U2 Normal	1.74E^{-03}	1.44E^{-03}	5.24E^{-04}	4.42E^{-04}	3.86E^{-04}

[1] Only the most limiting source and receptor pairs are included.
[2] 0-2 hour value is from Unit 1 containment to Unit 1 emergency intake

U2 RWST	U2 Emergency	$1.81E^{-03}$	$1.45E^{-03}$	$5.43E^{-04}$	$4.43E^{-04}$	$3.86E^{-04}$
U2 Containment Surface	U2 Normal	$2.51E^{-03}$	$1.94E^{-03}$	$6.66E^{-04}$	$6.44E^{-04}$	$5.61E^{-04}$
U2 Containment Surface	U2 Emergency	$2.73E^{-03}$ [2]	$2.05E^{-03}$	$7.04E^{-04}$	$6.89E^{-04}$	$5.95E^{-04}$
U1 SJAE	U1 Normal	$8.50E^{-04}$				
South Auxiliary Building Intake	U2 Normal	$7.91E^{-03}$	$5.93E^{-03}$	$2.12E^{-03}$	$1.50E^{-03}$	$1.01E^{-03}$

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: A DT/DZ
ELEVATION: SPEED: SPD10M DIRECTION: DIR10M LAPSE: DT60M
WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	5	161	153	15	0	0	334
NNE	3	21	15	2	0	0	41
NE	0	19	16	0	0	0	35
ENE	5	19	14	0	0	0	38
E	6	44	40	3	0	0	93
ESE	2	59	19	0	0	0	80
SE	10	50	17	0	0	0	77
SSE	5	69	29	0	0	0	103
S	1	75	49	19	1	0	145
SSW	2	17	20	10	1	0	50
SW	3	48	50	6	0	0	107
WSW	4	65	75	2	1	0	147
W	9	96	35	5	0	0	145
WNW	10	119	21	5	0	0	155
NW	12	117	17	1	0	0	147
NNW	15	169	95	6	0	0	285
TOTAL	92	1148	665	74	3	0	1982

Period Of Calm (Hours): 0

Variable Direction: 0

Hours Of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: B DT/DZ
ELEVATION: SPEED:SPD10M DIRECTION:DIR10M LAPSE:DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	12	29	18	6	0	0	65
NNE	2	19	7	0	0	0	28
NE	2	16	0	1	0	0	19
ENE	1	15	5	1	0	0	22
E	6	10	10	0	0	0	26
ESE	4	19	12	0	0	0	35
SE	10	15	6	0	0	0	31
SSE	3	12	5	0	0	0	20
S	4	23	18	4	0	0	49
SSW	3	16	18	3	0	0	40
SW	3	23	14	3	0	0	43
WSW	5	16	13	2	0	0	36
W	3	19	7	2	0	0	31
WNW	4	24	10	4	0	0	42
NW	15	19	20	2	0	0	56
NNW	6	22	15	1	0	0	44
TOTAL	83	297	178	29	0	0	587

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: C DT/DZ
ELEVATION: SPEED:SPD10M DIRECTION:DIR10M LAPSE:DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	6	36	37	3	1	0	83
NNE	2	15	6	1	0	0	24
NE	7	13	3	0	0	0	23
ENE	4	16	4	0	0	0	24
E	4	17	4	0	0	0	25
ESE	12	16	8	0	0	0	36
SE	12	24	9	0	0	0	45
SSE	7	13	12	1	0	0	33
S	4	21	19	4	0	0	48
SSW	2	24	22	6	0	0	54
SW	7	21	25	3	0	0	56
WSW	7	9	15	0	0	0	31
W	9	32	21	5	0	0	67
WNW	6	25	42	7	1	0	81
NW	9	23	29	4	0	0	65
NNW	9	27	15	2	0	0	53
TOTAL	107	332	271	36	2	0	748

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: D DT/DZ
ELEVATION: SPEED: SPD10M DIRECTION: DIR10M LAPSE: DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	37	152	44	4	0	0	237
NNE	29	70	22	3	0	0	124
NE	23	66	20	0	0	0	109
ENE	28	87	27	7	0	0	149
E	38	89	28	12	0	0	167
ESE	36	94	25	5	0	0	160
SE	33	103	51	3	0	0	190
SSE	33	68	48	8	0	0	157
S	40	138	69	22	0	0	269
SSW	18	85	95	23	1	0	222
SW	10	62	94	20	0	0	186
WSW	19	51	71	17	0	0	158
W	28	88	82	14	0	0	212
WNW	36	130	67	7	0	0	240
NW	33	90	40	2	0	0	165
NNW	45	92	45	4	0	0	186
TOTAL	486	1465	828	151	1	0	2931

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: E DT/DZ
ELEVATION: SPEED:SPD10M DIRECTION:DIR10M LAPSE:DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	46	34	2	0	0	0	82
NNE	28	27	0	0	0	0	55
NE	35	27	0	0	0	0	62
ENE	29	50	2	0	0	0	81
E	33	39	2	0	0	0	74
ESE	52	57	3	0	0	0	112
SE	55	47	15	1	0	0	118
SSE	39	52	16	1	0	0	108
S	47	145	23	1	0	0	216
SSW	15	74	28	0	0	0	117
SW	11	67	12	4	0	0	94
WSW	9	41	15	0	0	0	65
W	18	23	9	0	0	0	50
WNW	16	16	4	0	0	0	36
NW	22	11	2	0	0	0	35
NNW	29	21	0	0	0	0	50
TOTAL	484	731	133	7	0	0	1355

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: F DT/DZ
ELEVATION: SPEED: SPD10M DIRECTION: DIR10M LAPSE: DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	17	6	0	0	0	0	23
NNE	20	2	0	0	0	0	22
NE	30	6	0	0	0	0	36
ENE	32	13	0	0	0	0	45
E	40	10	0	0	0	0	50
ESE	55	16	0	0	0	0	71
SE	55	16	0	0	0	0	71
SSE	32	16	0	0	0	0	48
S	49	38	1	0	0	0	88
SSW	16	13	0	0	0	0	29
SW	6	5	1	0	0	0	12
WSW	6	6	1	0	0	0	13
W	9	1	0	0	0	0	10
WNW	6	2	0	0	0	0	8
NW	17	0	0	0	0	0	17
NNW	9	2	0	0	0	0	11
TOTAL	399	152	3	0	0	0	554

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: G DT/DZ
ELEVATION: SPEED: SPD10M DIRECTION: DIR10M LAPSE: DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	3	0	0	0	0	0	3
NNE	8	0	0	0	0	0	8
NE	15	1	0	0	0	0	16
ENE	52	9	0	0	0	0	61
E	95	3	0	0	0	0	98
ESE	80	1	0	0	0	0	81
SE	83	1	0	0	0	0	84
SSE	52	4	0	0	0	0	56
S	71	19	1	0	0	0	91
SSW	27	6	0	0	0	0	33
SW	14	1	0	0	0	0	15
WSW	8	2	0	0	0	0	10
W	8	1	0	0	0	0	9
WNW	8	0	0	0	0	0	8
NW	15	1	0	0	0	0	16
NNW	5	1	0	0	0	0	6
TOTAL	544	50	1	0	0	0	595

Periods of Calm (Hours): 0
Variable Direction: 0
Hours of Missing Data: 32

HOURS AT EACH WIND SPEED AND DIRECTION

PERIOD OF RECORD = 92010101 - 92123124
STABILITY CLASS: ALL DT/DZ
ELEVATION: SPEED: SPD10M DIRECTION: DIR10M LAPSE: DT60M

WIND SPEED (MPH)

Wind Direction	1-3	4-7	8-12	13-18	19-24	>24	Total
N	126	418	254	28	1	0	827
NNE	92	154	50	6	0	0	302
NE	112	148	39	1	0	0	300
ENE	151	209	52	8	0	0	420
E	222	212	84	15	0	0	533
ESE	241	262	67	5	0	0	575
SE	258	256	98	4	0	0	616
SSE	171	234	110	10	0	0	525
S	216	459	180	50	1	0	906
SSW	83	235	183	42	2	0	545
SW	54	227	196	36	0	0	513
WSW	58	190	190	21	1	0	460
W	84	260	154	26	0	0	524
WNW	86	316	144	23	1	0	570
NW	123	261	108	9	0	0	501
NNW	118	334	170	13	0	0	635
TOTAL	2195	4175	2079	297	6	0	8752

Periods of Calm (Hours): 0

Variable Direction: 0

Hours of Missing Data: 32

EARTHQUAKES WITH EPICENTERS LOCATED WITHIN 200 MILES OF PLANT SITE

(Intensity V or Greater)

Year	Date	Time	Intensity	Location (Remarks)	N. Lat.	W. Long	Distance From Site (miles)	Felt Area (square miles)
1804	August 24	14:10	VI	Fort Dearborn, Illinois (Chicago	42.0	87.8	70	30,000
1872	February 6	08:00	V	Weonona, Michigan (three shocks lasting 30 seconds)	43.5	83.8	165	Local
1875	June 18	07:43	VII	Ohio - most severe at Urbana and Sidney	40.2	84.0	185	40,000
1877	August 17	10:50	IV-V	Southeastern Michigan, near Detroit	42.3	83.3	160	200
1882	February 9	14:00	V	Ohio - felt at Swandors and Bodkins, near Anna	40.5	84	165	
1883	February 4	05:00	VI	Indiana and Michigan, felt at Kalamazoo, Michigan (possibly invalid see section 2.5.1)	42.3	85.6	50	8,000
1884	September 19	14:14	V	near Lima, Ohio	40.7	84.1	155	125,000
1909	May 26	08:42	VII	Northern Illinois	42.5	89.0	135	500,000
1912	January 2	10:21	VI	Northern Illinois	41.5	88.5	115	40,000
1929	March 8	04:06	V	near Bellefontaine, Ohio	40.4	84.2	165	5,000
1930	September 30	14:40	VII	Ohio, strongest at Anna	40.3	84.3	165	-
1931	September 20	17:05	VII	Ohio, felt at Anna, Sidney and Houston	40.2	84.3	175	40,000
1937	March 2	09:48	VII	Western Ohio, maximum intensity at Anna and Sidney	40.7	84.0	160	90,000
	March 3	03:50	V	Ohio, felt at Sidney, Anna, Jackson Center and Botkins	40.50	84	165	
	March 8	23:45	VII-VIII	Western Ohio, near Anna	40.6	84.0	165	150,000
1947	May 6	15:25	V	Milwaukee, Wisconsin	43	88	90	3,000
	August 9	20:47	VI	South Central Michigan	42.0	85.0	75	50,000
1956	January 27	06:03	V	West Central Ohio	40.50	84	165	
1961	February 22	03:45	V	North Western Ohio, felt at Amsden and Arcadia	41. 2	83.4	170	

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SUMMARY OF PLUME AREAS, WIDTHS AND VOLUMES

AUGUST-SEPTEMBER, 1978

Date	8/23	8/25	8/25	9/5	9/5	9/6	9/6	9/7	9/7	9/8	9/8
Area (acres)	24	193	311	237	80	287	117	336	568	549	740
Width (feet)	984	2394	2362	2230	1148	2165	1673	4100	4838	5642	4264
Volume (acre-ft.)	413	2327	2771	1720	1342	1732	1537	1996	4029	3678	4852

Average area	-	313 acres
Average width	-	2890 feet
Average volume	-	2400+ acre-ft

NOVEMBER-DECEMBER, 1978

Date	11/1	11/1	1112	1112	11/3	11/3	11/7	11/7
Area (acres)	154	389	142	200	655	631	294	515
Width (feet)	1771	2854'	2394	1705	3838	4648	2066	6724
Volume (acre-ft)	2414	3747	1105	1520	5197	5615	2883	4103

Average area	-	372 acres
Average width	-	3250 feet
Average volume	-	3323+ acre-ft

JULY, 1979

Date	7/24	7/24	7/25	7/25	7/26	7/26	7/27	7/27	7/28	7/28
Area (acres)	297	450	109	161	149	269	30	21	171	342
Width (feet)	2034	3182	2296	3116	1804	2821	918	886	2624	2755
Volume (acre-ft)	2363	3295	951	1551	1190	1625	540	173	1494	2412

Average area	-	200 acres
Average width	-	2244 feet
Average volume	-	1559+ acre-ft

COMMON AND SCIENTIFIC NAMES OF FISH SPECIES COLLECTED FROM COOK PLANT STUDY AREAS, SOUTHEASTERN LAKE MICHIGAN, 1973-1982

Common name	Scientific name
Alewife	Alosa pseudoharengus
Banded killifish	Fundulus diaphanus
Black bullhead	Ictalurus melas
Blackchin shiner	Notropis heterodon
Black crappie	Pomoxis nigromaculatus
Blacknose dace	Rhinichthys atratulus
Blacknose shiner	Notropis heterolepis
Bloater	Coregonus hoyi
Bluegill	Lepomis macrochirus
Bluntnose minnow	Pimephales notatus
Brook silverside	Labidesches sicculus
Brown trout	Salmo trutta
Burbot	Lota lota
Central mudminnow	Umbra limi
Channel catfish	Ictalurus punctatus
Chinook salmon	Oncorhynchus tshawytscha
Coho salmon	Oncorhynchus kisutch
Common carp	Cyprinus carpio
Common shiner	Notropis cornutus
Creek chub	Semotilus atromaculatus
Emerald shiner	Notropis atherinoides
Fathead minnow	Pimephales promelas
Freshwater drum	Aplodinotus grunniens
Gizzard shad	Dorosoma cepedianum
Golden redhorse	Moxostoma erythrurum
Golden shiner	Notemigonus crysoleucas
Grass pickerel	Esox americanus vermiculatus
Green sunfish	Lepomis cyanellus
Johnny darter	Etheostoma nigrum
Lake chub	Couesius plumbeus

COMMON AND SCIENTIFIC NAMES OF FISH SPECIES COLLECTED FROM COOK PLANT STUDY AREAS, SOUTHEASTERN LAKE MICHIGAN, 1973-1982

Common name	Scientific name
Lake herring	Coregonus artedii
Lake sturgeon	Acipenser fulvescens
Lake trout	Salvelinus namaycush
Lake whitefish	Coregonus clupeaformis
Largemouth bass	Micropterus salmoides
Logperch	Percina caprodes
Longnose dace	Rhinichthys cataractae
Longnose sucker	Catostomus catostomus
Mottled sculpin	Cottus bairdi
Ninespine stickleback	Pungitius pungitius
Northern pike	Esox lucius
Pumpkinseed	Lepomis gibbosus
Quillback	Carpiodes cyprinus
Rainbow smelt	Osmerus mordax
Rainbow trout	Salmo gairdner
Rock bass	Ambloplites rupestris
Round whitefish	Prosopium cylindraceum
Sand shiner	Notropis stramineus
Shorthead redhorse	Moxostoma macrolepidotum
Silver redhorse	Moxostoma anisurum
Slimy sculpin	Cottus cognatus
Smallmouth bass	Micropterus dolomieui
Spotfin shiner	Netropis spilopterus
Spottail shiner	Notropis hudsonius
Trout-perch	Percopsis omiscomaycus
Walleye	Stizostedion vitreum vitreum
White crappie	Pomoxis annularis
White sucker	Catostomus commersoni
Yellow perch	Perca flavescens

COMMON NAMES * AND TOTAL NUMBER OF EACH SPECIES IMPINGED DURING 1975-1982 AT THE D. C. COOK NUCLEAR PLANT SOUTHEASTERN LAKE MICHIGAN

(WEIGHT IS IN KG)

Species	1975	1976	1977	1978	1979	1980	1981	1982
Alewife	174,341	114,958	31,498	238,133	330,709	1,815,490	1,415,821	831,051
Black bullhead	35	45	16	12	4	9	35	68
Black crappie	11	4	7	2	5	6	5	9
Bloater	49	63	302	23,085	2,456	21,448	3,144	212
Bluegill	48	23	10	11	-	12	73	37
Brown bullhead	-	-	-	11	4	-	7	6
Brown Trout	-	37	24	61	95	120	166	176
Bur bot	37	75	51	108	575	1,248	876	1,018
Central mudminnow	9	9	-	-	5	24	43	66
Channel catfish	50	70	27	26	50	87	175	87
Chestnut lamprey	4	-	-	5	-	-	-	-
Chinook salmon	7	16	-	59	729	875	22	34
Coho salmon	8	22	22	78	165	63	44	530
Common carp	2	6	-	5	34	33	18	12
Deepwater sculpin	1	5	-	-	-	27	80	33

* ACCORDING TO ROBINS ET AL 1980

COMMON NAMES * AND TOTAL NUMBER OF EACH SPECIES IMPINGED DURING 1975-1982 AT THE D. C. COOK NUCLEAR PLANT SOUTHEASTERN LAKE MICHIGAN

(WEIGHT IS IN KG)

Species	1975	1976	1977	1978	1979	1980	1981	1982
Emerald shiner	1	-	-	5	-	-	-	-
Flathead catfish	-	-	-	-	-	31	-	-
Freshwater drum		-	-	18	2	4	3	8
Gizzard shad	278	1,780	35	692	252	669	1,682	1,925
Golden shiner	5	-	-	-	-	-	-	9
Goldfish	2	-	-	-	5	4	-	-
Grass pickerel	-	1	-	-	-	-	-	-
Green sunfish	13	6	4	6	-	6	14	-
Johnny darter	180	346	103	108	59	107	682	13
Lake chub	-	5	6	6	-	13	-	32
Lake chubsucker	-	-	4	-	4	-	-	-
Lake herring	-	-	-	-	-	-	-	5
Lake sturgeon	-	-	-	-	-	8	-	-
Like trout	101	115	115	243	282	320	517	342
Lake whitefish	1	-	-	-	10	15	7	8
Largemouth bass	13	4	8	-	11	5	-	-
Logperch	1	-	-	-	-	-	-	-

COMMON NAMES * AND TOTAL NUMBER OF EACH SPECIES IMPINGED DURING 1975-1982 AT THE D. C. COOK NUCLEAR PLANT SOUTHEASTERN LAKE MICHIGAN

(WEIGHT IS IN KG)

Species	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**
Longnose dace	6	8	19	43	-	5	8	8
Longnose gar	-	-	-	-	-	-	-	3
Longnose sucker	23	43	20	165	210	490	266	629
Mottled sculpin	-	-	14	392	532	1,078	1,364	373
Ninespine suckleback	194	107	95	288	65	429	111	71
Northern pike	3	17	-	5	-	-	17	7
Pirate perch	1	-	-	-	-	-	-	-
Pumpkinseed	23	32	2	15	-	-	5	9
Quillback	2	-	-	-	-	-	-	-
Rainbow smelt	3,746	2,772	1,488	51,013	35,398	149,085	112,837	13,863
Rainbow trout	4	17	-	6	14	20	37	24
Rock bass	3	1	4	8	5	3	14	3
Round whitefish	-	-	-	-	-	-	39	-
Sea lamprey	-	-	-	-	5	9	8	30
Shorthead redhorse	-	-	5	30	68	-	14	5
Silver redhorse	-	-	-	5	11	-	-	-
Slimy sculpin	8,136	7,402	2,232	1,034	2,622	8,371	6,974	5,820

COMMON NAMES * AND TOTAL NUMBER OF EACH SPECIES IMPINGED DURING 1975-1982 AT THE D. C. COOK NUCLEAR PLANT SOUTHEASTERN LAKE MICHIGAN

(WEIGHT IS IN KG)

Species	1975	1976	1977	1978	1979	1980	1981	1982
Smallmouth bass	5	21	10	3	5	15	8	
Spottail shiner	9,985	24,104	5,032	178,009	52,761	106,009	86,260	33,842
Spotted sucker	1	-	-	-	-	-	3	-
Stonecat	-	-	-	-	-	11	-	-
Tadpole madtom	-	5	-	-	-	-	-	6
Trout-perch	15,373	10,357	4,826	88,692	15,002	31,063	23,711	1,998
Walleye	-	-	-	-	-	-	-	6
Warmouth	-	-	-	-	-	2	-	-
White crappie	6	-	-	11	2	5	18	-
White sucker	16	27	14	186	271	173	141	584
Yellow bullhead	5	1	2	-	-	-	3	6
Yellow perch	12,006	21,309	7,195	32,811	38,349	170,262	391,983	38,811
Total number	**224,735**	**183,813**	**53,190**	**615,390**	**480,776**	**2,307,654**	**1,947,235**	**913,768**
Total weight	**6,131**	**4,927**	**1,833**	**10,475**	**9,480**	**71,209**	**17,395**	**25,173**

ESTIMATES (IN MILLIONS) OF ANNUAL ENTRAINMENT LOSSES OF FISH LARVAE AND FISH AT THE D.C. COOK NUCLEAR PLANT, SOUTHEASTERN LAKE MICHIGAN, 1975 - 1982.

CALCULATIONS USE ACTUAL REPORTED FLOW RATES OF THE CIRCULATING WATER SYSTEM

	YEAR OF ESTIMATE									
Taxon	1975	1976	1977	1978	1979	1980	1981	1982	Total	% Total
Alewife	63.708	53.7550	27.3888	31.098	125.6180	49.35	111.54	92.425	554.8828	74.34
Spottail shiner	3.41	0.9361	2.760	1.681	1.8228	21.06	7.257	28.2297	67.1566	9.00
Rainbow smelt	1.3608	0.4145	0.1795	0.3496	0.3726	11.954	2.6265	18.5233	35.7808	4.79
Yellow perch	0.17554	0.03807	1.3224	3.0655	0.3840	0.8971	2.506	4.9700	13.3586	1.79
Trout-perch	1.079	0.2509	0.1456	0.0194	0.6288	0.4858	0.5394	1.3749	4.5238	0.61
Johnny darter	0.0440	0.210	0.707	0.772	0.8105		0.153	0.7046	3.4011	0.46
Slimy sculpin	0.2431	0.06092	0.0256	0.130		0.553	1.002	0.4887	2.5033	0.34
Mottled sculpin	0.152	0.146	0.0483		0.131		0 143	0.4870	1.1073	0.15
Common carp		0.0912	0.0235	0. 175	0.3603	0.0513	0 187		0.8883	0.12
Ninespine stickleback				0.124		0.379	0.156	0.0112	0.6702	0.09
Quillback			0.0628				0.534		0.5968	0.08

ESTIMATES (IN MILLIONS) OF ANNUAL ENTRAINMENT LOSSES OF FISH LARVAE AND FISH AT THE D.C. COOK NUCLEAR PLANT, SOUTHEASTERN LAKE MICHIGAN, 1975 - 1982.

CALCULATIONS USE ACTUAL REPORTED FLOW RATES OF THE CIRCULATING WATER SYSTEM

	YEAR OF ESTIMATE									
Taxon	1975	1976	1977	1978	1979	1980	1981	1982	Total	% Total
Burbot		0.0202		0.102				0.3428	0.4650	0.06
Deepwater sculpin				0.178	0.0141				0.1921	0.03
Unidentified sculpins	0.1899	0.0892	0.0918	0.175	0.0905	0.607	0.5953	0.5744	2.4731	0.33
Unidentified minnows			0.1248		0.8138	0.2846	0.1714	1.0280	2.4226	0.32
Unidentified coregonines			0.0850						0.0850	0.01
Unidentified darters			0.0276						0.0276	<0.01
Poor condition	0.555	2.8642	0.4274	3.352	5.9935	6.4765	11.859	17.9458	55.4734	7.43
Unidentified larvae	0.1693	0.0349	0.0887	0.100					0.3929	0.05
Total larvae	77.08664	58.91119	33.5088	41.3215	137.0399	92.1583	139.2696	167.1054	746.4013	
Total eggs	743.1879	2,269.4543	1,320.301	5,840.8138	1,392.5408	3,334.692	995.94	7,005.26	22,902.1898	

ESTIMATES (IN MILLIONS) OF ANNUAL ENTRAINMENT LOSSES OF FISH LARVAE AND FISH AT THE D.C. COOK NUCLEAR PLANT, SOUTHEASTERN LAKE MICHIGAN, 1975 - 1982.

CALCULATIONS USE ACTUAL REPORTED FLOW RATES OF THE CIRCULATING WATER SYSTEM

	YEAR OF ESTIMATE									
Taxon	1975	1976	1977	1978	1979	1980	1981	1982	Total	% Total
Total Cook Plant Flow (millions of m^3)	1,298	1,292	1,138	2,370	2,476	2,830	2,753	2,749.		

CONDITIONS/EFFECTS CONSIDERED

CONDITIONS[1]		EFFECTS CONSIDERED
1	NORMAL	Deadweight, Thermal, Pressure (Pressure is considered for vessel and pipe stress only)
2	UPSET	Same as 1, OBE
3	EMERGENCY	Same as 1, DBE (Thermal is considered for supports loads only)
4	FAULTED	Same as 1, Postulated Pipe Rupture (Thermal is considered for supports loads only)
5	FAULTED (Including DBE)[2]	Same as 3, Postulated Pipe Rupture

NOTES

The Operating Load Combination categories are defined as follows:		
1	NORMAL Condition	Any condition in the course of system startup, operation in the design power range and system shutdown, in the absence of Upset, Emergency or Faulted Conditions.
2	UPSET Condition	Any deviations from Normal Conditions anticipated to occur often enough that design should include a capability to withstand the conditions without operational impairment. The Upset Condition includes those transients caused by a fault in a system component requiring its isolation from the system, transients due to a loss of load or power and any system upset not resulting in a forced outage. The Upset Conditions include - the effect of the specified earthquake for which the system must remain operational or must regain its operational status.
3	EMERGENCY Condition	Any deviations from normal conditions which require shutdown for correction of the conditions or repair of damage in the system. The conditions have a low probability of occurrence but are included to provide assurance that no gross loss or structural integrity will result as a concomitant effect of any damage developed in the system. The total number of postulated occurrences for such events shall not exceed twenty-five (25). Among the Emergency Conditions may be a specified earthquake for which safe shutdown is required.
4	FAULTED Condition	Those combinations of conditions associated with extremely low probability postulated events whose consequences are such that the integrity and operability of the nuclear energy system may be impaired to the extent where considerations of public health and safety are involved. Such considerations require compliance with safety criteria as may be specified by jurisdictional authorities.

[1] Definition of Terms based on the Summer 1968 Addenda to the ASME Boiler and Pressure Vessel Code, Section III.

[2] The Westinghouse Nuclear Steam Supply System Equipment (piping and equipment) was designed for the faulted (including Design Basis Earthquake) condition by using the methodology presented in WCAP 5890 Rev. 1, which includes combining LOCA (Reactor Coolant Pipe Break) and Design Basis Earthquake (DBE) via Square Root Sum of Squares (SRSS).

(PART A)

LOADING CONDITIONS AND STRESS LIMITS: PRESSURE VESSELS

LOADING CONDITIONS		STRESS INTENSITY LIMITS	NOTE
1.	Normal Conditions	(a) $P_m \leq S_m$	
		(b) P_m (or P_L) + $P_B \leq 1.5S_m$	1
		(c) P_m (or P_L) + $P_B + Q \leq 3.0S_m$	2
2.	Upset Condition	(a) $P_m \leq S_m$	
		(b) P_m (or P_L) + $P_B \leq 1.5S_m$	1
		(c) P_m (or P_L) + $P_B + Q \leq 3.0S_m$	2
3.	Emergency Condition	(a) $P_m \leq 1.2S_m$ or S_y whichever is larger	
		(b) P_m (or P_L) + $P_B \leq 1.5(1.2S_m)$ or $1.5S_y$ whichever is larger	3
4.	Faulted Condition	See Note 4	

KEY:

P_m = primary general membrane stress intensity

P_L = primary local membrane stress intensity

P_B = primary bending stress intensity

Q = secondary stress intensity

S_m = stress intensity value from ASME B&PV Code, Section III, Nuclear Vessels - 1968 Edition, Table N-421

S_y = minimum specified material yield (ASME B&PV Code, Section III, Nuclear Vessels - 1968 Edition, Table N-424

(PART B)

LOADING CONDITIONS AND STRESS LIMITS: PRESSURE PIPING

LOADING CONDITIONS		STRESS LIMITS
1.	Normal Conditions	(a) $P_m \leq S_h$
		(b) $P_L + P_B \leq S_h$
		(c) $S_E \leq S_A$
2.	Upset Conditions	(a) $P_m \leq 1.2S_h$
		(b) $P_L + P_B \leq 1.2S_h$
		(c) $S_E \leq S_A$
3.	Emergency Conditions	(a) $P_m \leq 1.2S_h$
		(b) $P_L + P_B \leq 1.5(1.2\ S_h)$
4.	Faulted Conditions	See Notes 4 & 5

WHERE:

$P_m =$ primary hoop membrane stress (pressure)

$P_L =$ primary longitudinal membrane stress (pressure)

$P_B =$ primary longitudinal bending stress (deadweight, seismic)

$S_h =$ allowable stress at temperature from USAS B31.1 Code for Pressure Piping, 1967 Edition

$S_C =$ allowable stress at 70°F from USAS B31.1 Code for Pressure Piping, 1967 Edition

$S_E =$ computed expansion stresses

$S_A =$ allowable stress range for expansion stresses (fatigue criteria) = $(1.25\ S_C + 0.25\ S_h)\ f$ (See Note 5)

F = stress range reduction factor for cycling per USAS B 31.1 Code for pressure piping, 1967 Edition

(PART C)

LOADING CONDITIONS AND STRESS LIMITS: EQUIPMENT SUPPORTS

LOADING CONDITIONS		STRESS INTENSITY LIMITS
1.	Normal Condition	Working Stresses or Applicable Factored Load Design Values
2.	Upset Condition	Working Stresses or Applicable Factored Load Design Values
3.	Emergency Condition	Within yield after load redistribution
4.	Faulted Condition	Permanent Deflection of Supports Limited to Maintain Supported Equipment Within Design Limits. See Note 4

Support loads are combined by algebraic summation, in plus and minus directions of the three orthogonal planes, so as to obtain the maximum positive or maximum negative value of design load.

The thermal load component is not considered when algebraic summation with this load would lessen the support design load.

The seismic load component is considered to have both a positive and a negative sign. The sign of the seismic component is chosen so as to maximize the absolute value of the support design load.

NOTES

Note 1: The limits on local membrane stress intensity ($P_L \leq 1.5S_m$) and primary membrane plus primary bending stress intensity (P_m (or P_L) + $P_B \leq 1.5S_m$) need not be satisfied at a specific location if it can be shown by means of limit analysis or by tests that the specified loading’s do not exceed 2/3 or the lower bound collapse load as per paragraph N417.6(b) of the ASME B&PV Code, Section III, Nuclear Vessels - 1968 Edition.

Note 2: In lieu of satisfying the specific requirements for the local membrane ($P_L \leq 1.5S_m$) or the primary plus secondary stress intensity ($P_L + P_B + Q \leq 3S_m$) at a specific location, the structural action may be calculated on a plastic basis and the design will be considered to be acceptable if shake-down occurs, as opposed to continuing deformation, and if the deformations which occur prior to shakedown do not exceed specified limits, as per paragraph N417.6(a) (2) of the ASME B&PV Code, Section III, Nuclear Vessels - 1968 Edition.

Note 3: The limits on local membrane stress intensity ($P_L \leq 1.5S_m$) and primary membrane plus primary bending stress intensity (P_m (or P_L) + $P_B \leq 1.5S_m$) need not be satisfied at a specific location if it can be shown by means of limit analysis or by tests that the specified loading do not exceed 120 percent of 2/3 of the lower bound collapse load as per paragraph N417.10(c) of the ASME B&PV Code, Section III, Nuclear Vessels - 1968 Edition.

Note 4: A plastic instability analysis may be performed for specific cases considering the actual strain-hardening characteristics of the material, but with yield strength adjusted to correspond to the tabulated value at the appropriate temperature in Table N-424 or N-425, as per paragraph N-417.11(c) of the ASME B&PV Code, Section III, Nuclear Vessel - 1968 Edition.

Note 5: Where the sum of P_L and P_B stresses due to pressure, deadweight and other sustained loads is less than S_h, the difference between S_h and this sum may be added to the term 0.25 S_h in the formula for S_A stated above for determining the allowable stress range S_A. (see Para. 102.3.2 of the USAS B31.1 Code for pressure piping, 1967 Edition.)

The following segments of piping systems and components have been analyzed to ASME III, Appendix F for faulted conditions:

1. RCP seal leak-off return line penetration piping between inside and outside containment isolation valves (CPN 37) and

2. Piping from the RCP seal bypass line check valves to the normally closed QRV-150 valve in the common discharge header (no CPN).

3. Piping from normally closed PRT drain line isolation valve and the RCDT drain line check valve inside containment to the normally closed isolation valve outside containment (CPN 40).

4. Accumulator fill line piping from outside containment isolation valve to the normally closed inlet valves at each accumulator and the normally closed valves in the flow path to the low head SI hot leg loops (CPN 32).

5. U-1 only: Piping between Primary Water supply line isolation valve outside containment to isolation valves inside containment. (CPN 33).

6. U-1 only: Piping between Demineralized Water supply line isolation valve outside containment to manual isolation valves for hose connections inside containment. (CPN 36).

7. U-1 only: Piping between sump pump discharge check valves inside containment and discharge isolation valve outside containment. (CPN 41).

8. U-1 only: NESW Supply to and Return from Lower Containment Ventilation Units (CPN-17, -18, -19, & -20 for NESW supply; CPN-21, -22, -23,-24 for NESW return).

9. U-1 only: NESW Supply to and Return from Upper Containment Ventilation Units (CPN-26, -27, -84, & -85 for NESW supply and return).

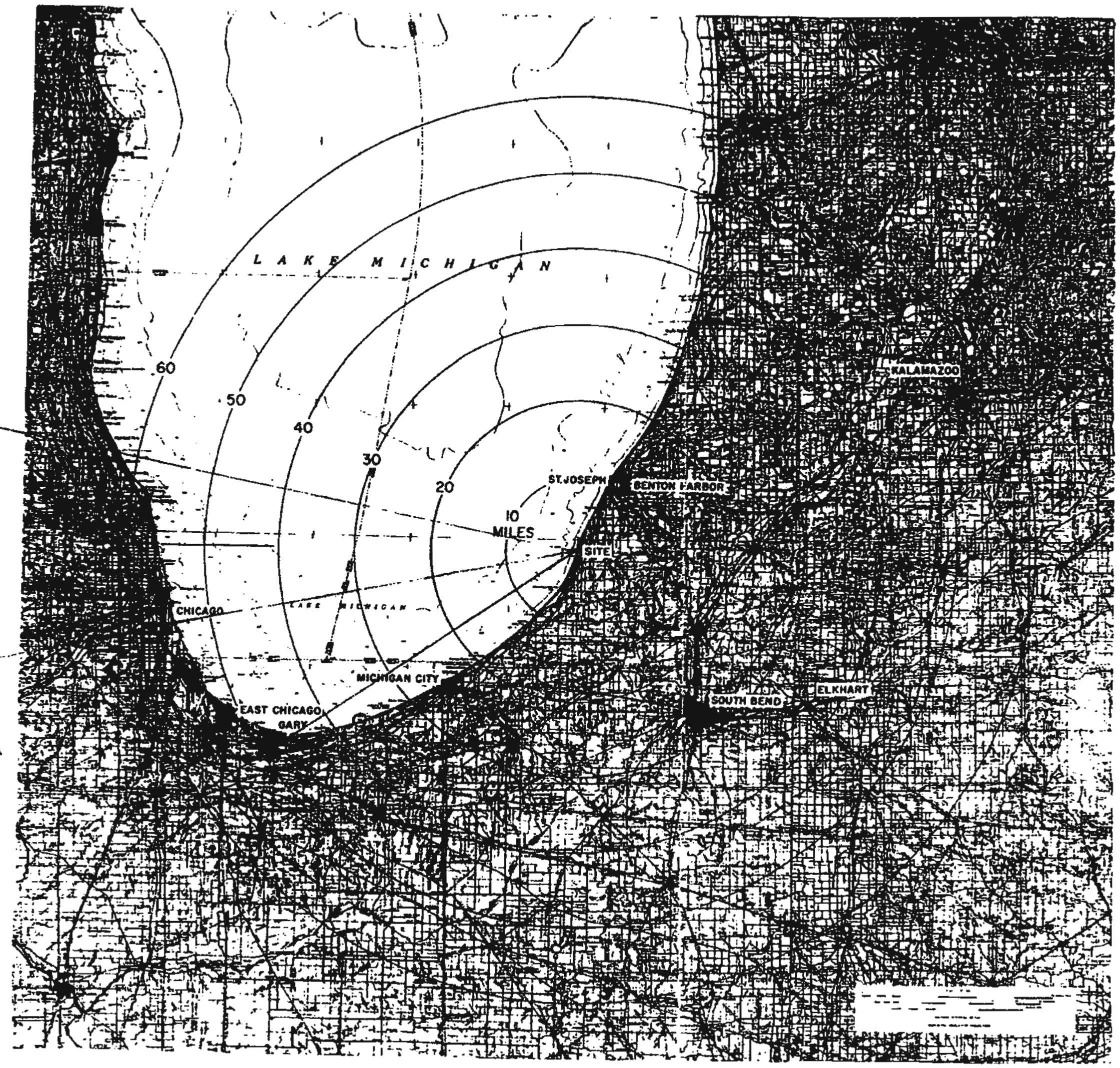
10. U-1 only: NESW Supply and Return to Instrumentation Room Ventilation Units (CPN-73 for both ventilation units NESW supply and return).

11. U-1 only: NESW Supply to and Return from the RCP Motor Air Coolers (CPN-26, -27, -84, & -85 for NESW supply and return).

12. U-1 only: Reactor Vessel Head Vent Piping from Reactor Head to Anchor 1-ARC-R626 (analyzed to Appendix F for post-accident head vent valve operation).

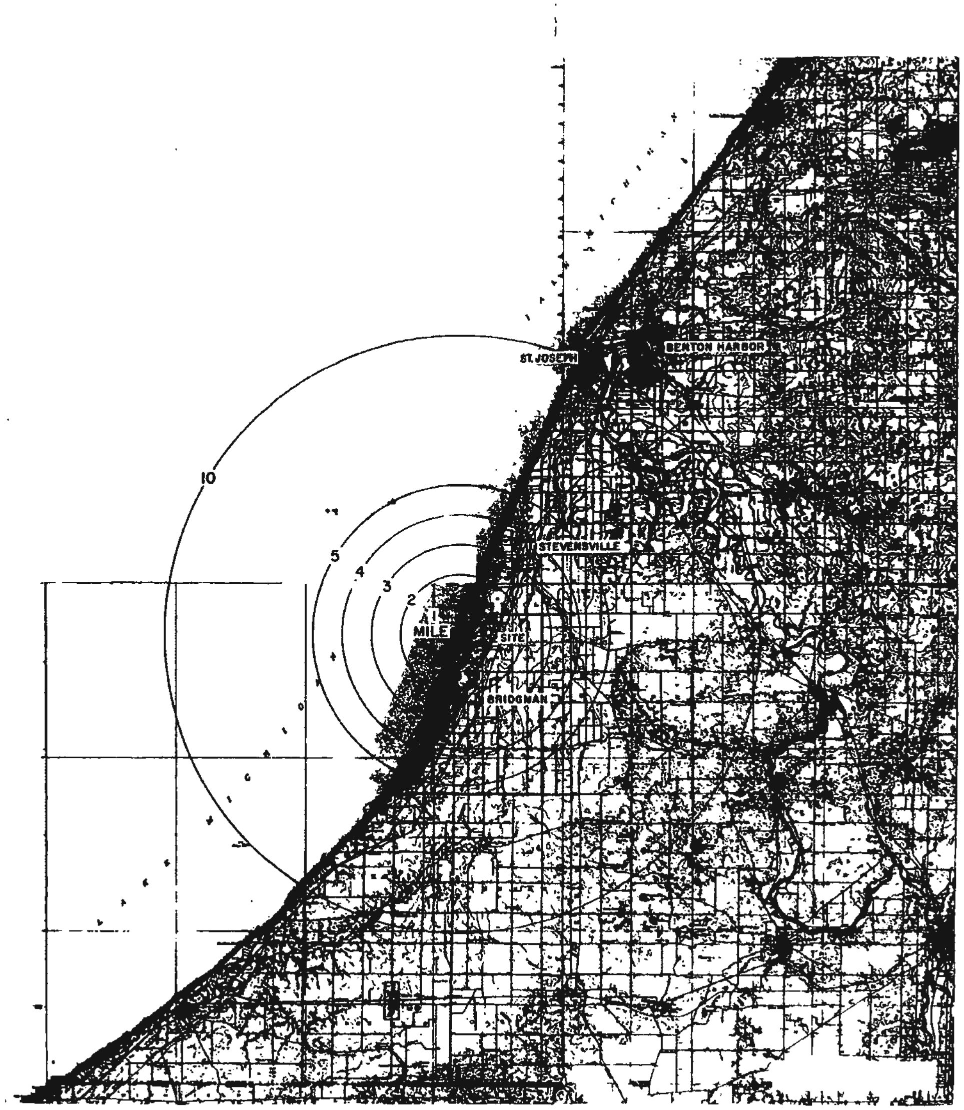
13. The Seismic Class 1 Enhanced Service Structure Components, including the lift rig assembly (without tripod), CRDM seismic platform, safety related pipe supports and safety class cable trays, bridges and associated supports are designed to Section III, subsection NF, of the 1995 ASME Boiler and Pressure Vessel Code, through 1996 Addenda.

14. U-2 only: Reactor Vessel Head Vent Piping from the Reactor Head to Anchor 2-ARC-R665 (analyzed to Appendix F for post-accident head vent valve operation).



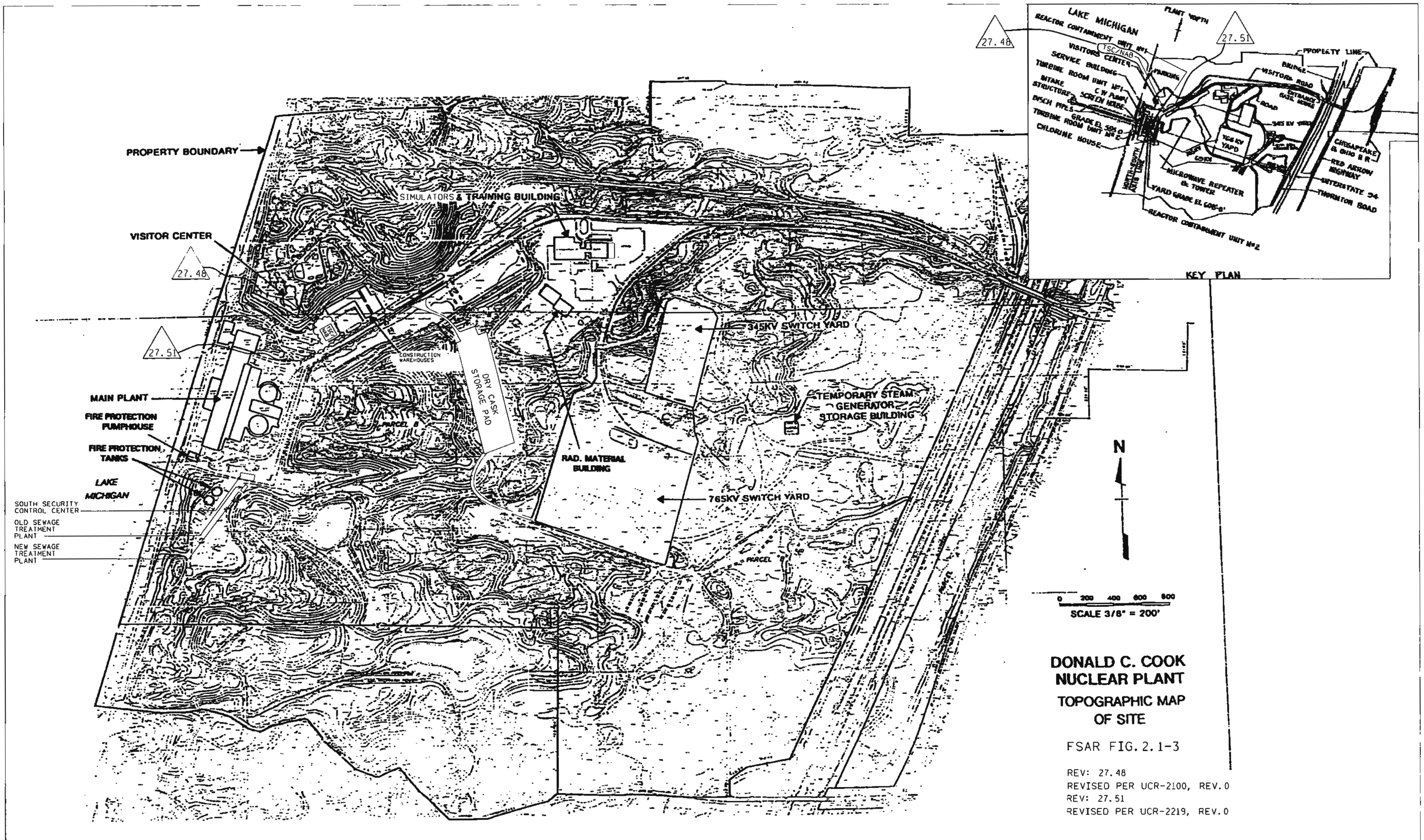
July, 1982

REGIONAL FEATURES
FIG. 2.1-1



July, 1982

LOCAL FEATURES
FIG. 2.1-2



DONALD C. COOK NUCLEAR PLANT

TOPOGRAPHIC MAP OF SITE

FSAR FIG. 2.1-3

REV: 27.48
REVISED PER UCR-2100, REV. 0
REV: 27.51
REVISED PER UCR-2219, REV. 0

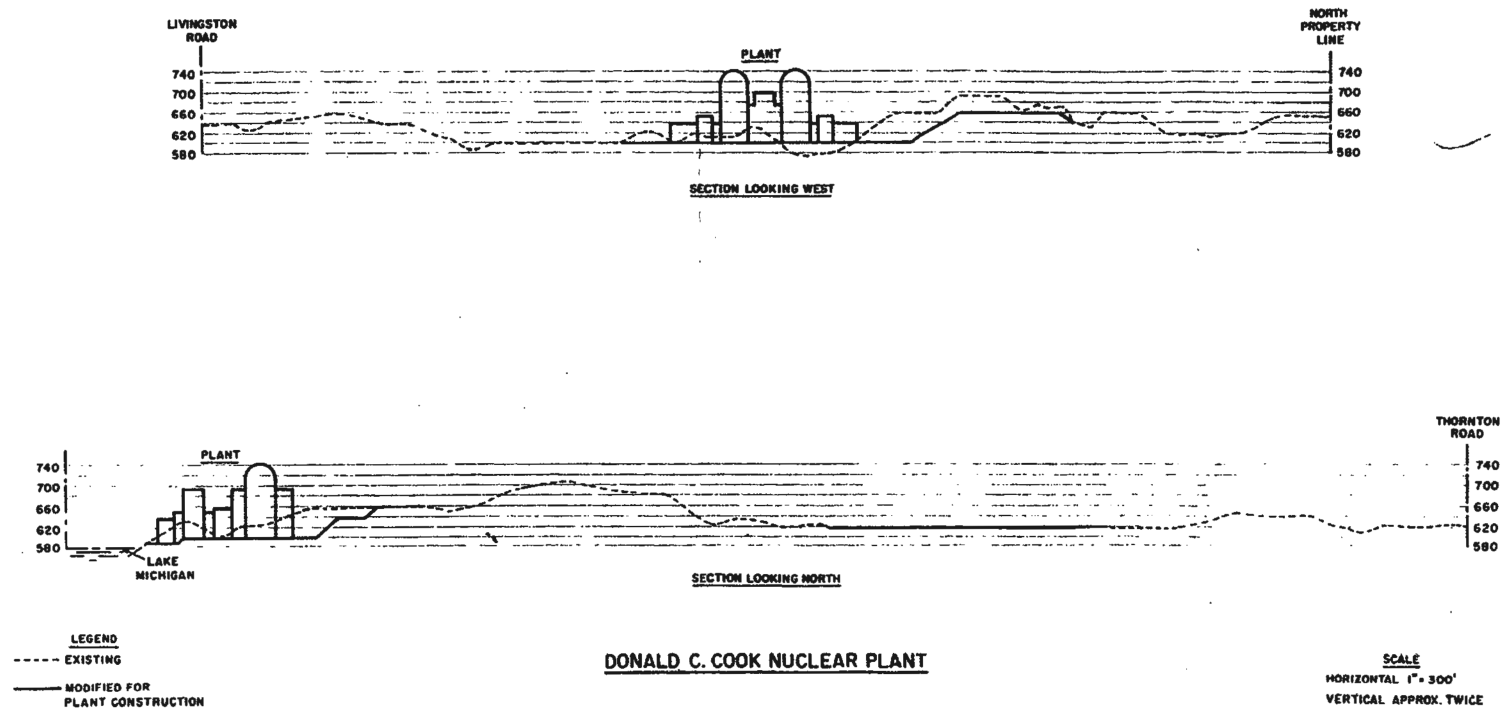
DATE: 12/6/17 USER: SRK
STATUS: JOB: UCR-2219, -2100

FILENAME: fsar-fig-2.1-3 26.dgn
(raster file): fsar-fig-2.1-3 26.cit

TOPOGRAPHIC VIEW OF PLANT SITE

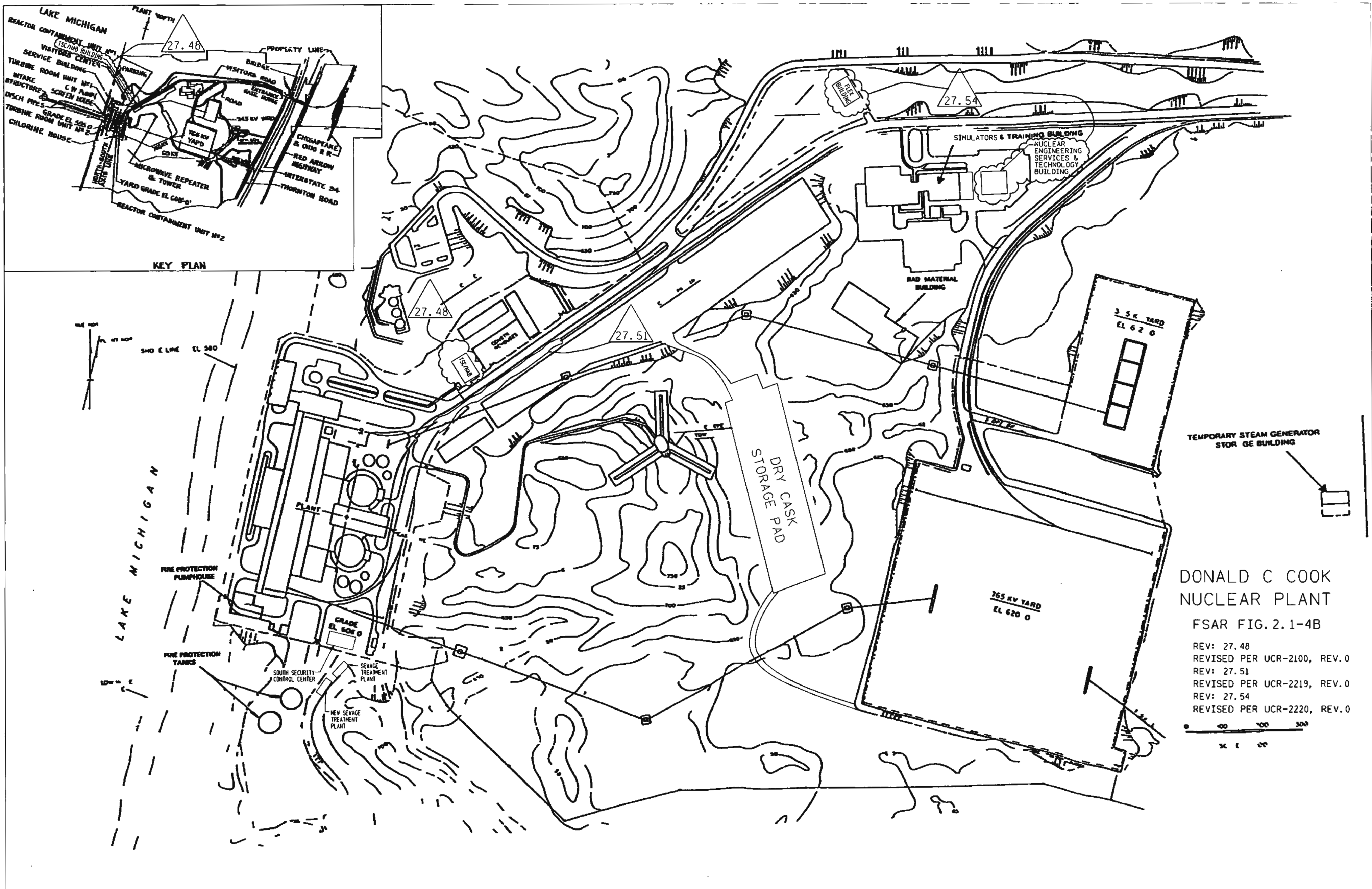
FIG. 2.1-4

July, 1982



DONALD C. COOK NUCLEAR PLANT

FIG. 2.1-4a



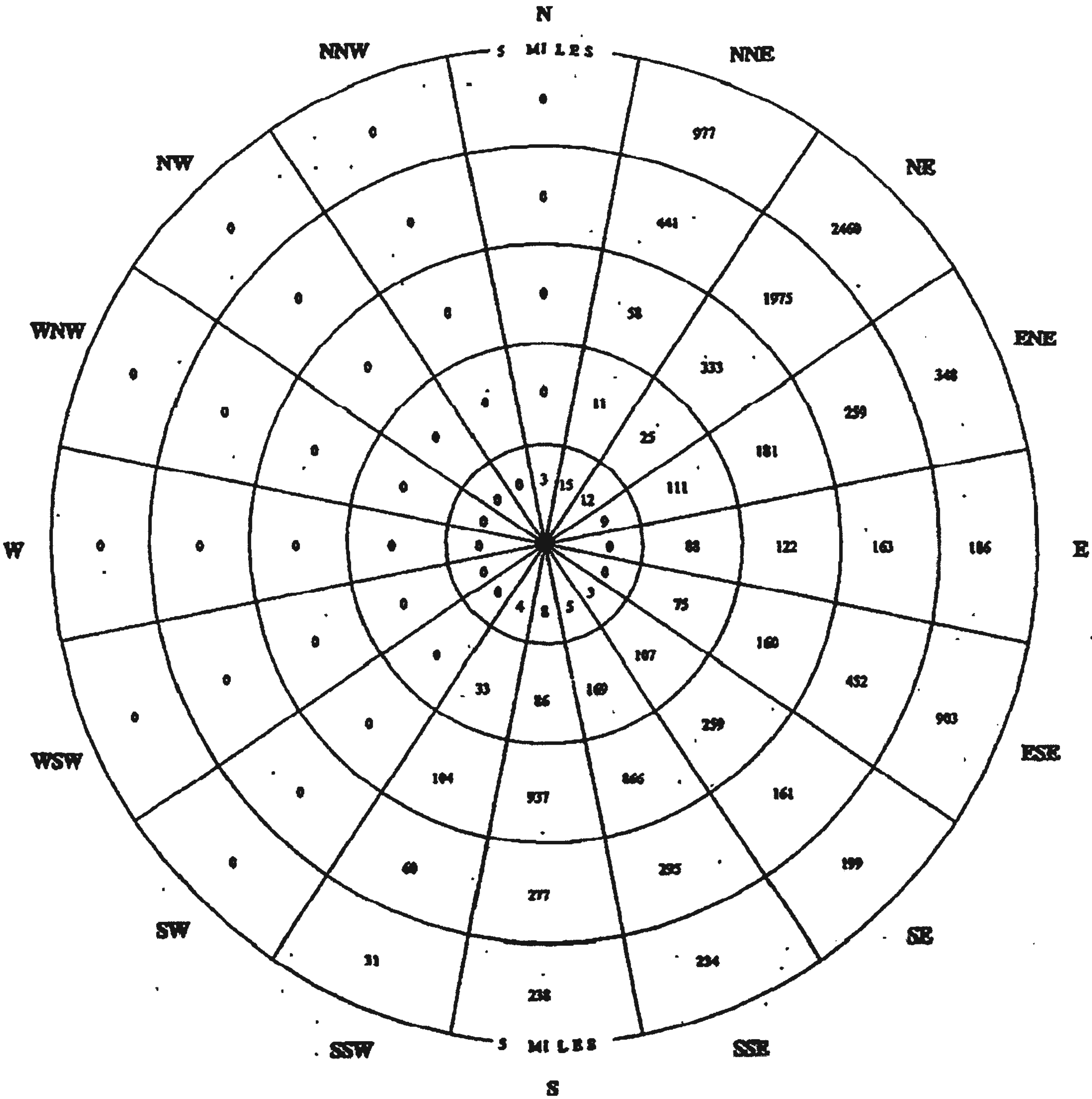
..\fsar-fig-2.1-4b_28.dgn 12/14/2017 12:55:34 PM

1990 POPULATION DISTRIBUTION FIGURE

Sector	Direction	0-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	50-60 Miles	Total
A	N	3	0	0	0	0	0	3
B	NNE	16,151	16,833	3,297	12,645	8,912	33,593	91,431
C	NE	17,439	20,189	16,571	10,659	11,876	30,608	107,342
D	ENE	3,397	4,295	5,618	17,126	27,209	183,270	240,915
E	E	1,861	12,339	14,532	7,322	20,825	16,610	73,489
F	ESE	2,908	18,843	18,920	69,710	31,639	16,366	158,386
G	SE	1,432	11,920	178,696	55,516	44,563	17,581	309,708
H	SSE	2,486	3,081	18,023	11,923	24,797	10,871	71,181
J	S	2,896	7,253	6,254	8,626	13,435	12,396	50,860
K	SSW	2,471	4,536	37,033	11,299	9,839	9,297	74,475
L	SW	0	3,993	42,892	25,429	186,622	157,635	416,571
M	WSW	0	0	0	0	17,298	1,182,109	1,199,407
N	W	0	0	0	0	0	1,279,601	1,279,601
P	WNW	0	0	0	0	0	0	0
Q	NW	0	0	0	0	0	0	0
R	NNW	0	0	0	0	0	0	0
	Total	51,044	103,282	341,836	230,255	397,015	2,949,937	4,073,369

POPULATION TOTALS (1990)			
Ring Miles	Ring Population	Total Miles	Cumulative Population
0–10	51,044	0–10	51,044
10–20	103,282	0–20	154,326
20–30	341,836	0–30	496,162
30–40	230,255	0–40	726,417
40–50	397,015	0–50	1,123,432
50–60	2,949,937	0–60	4,073,369
Total	4,073,369		

FIGURE 2.1-5



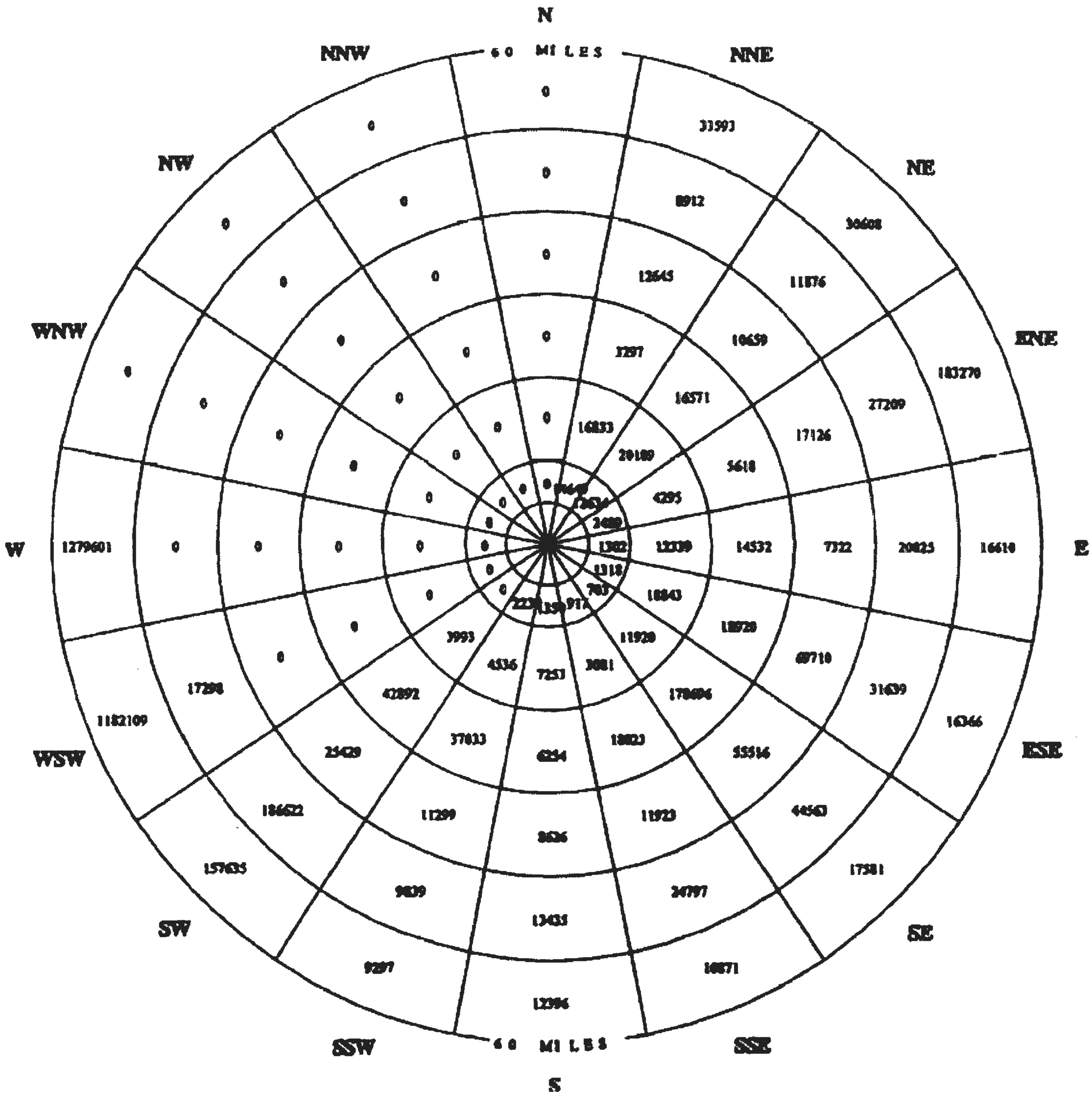
1990

POPULATION DISTRIBUTION

0 - .5 MILES

FIGURE 2.1-6

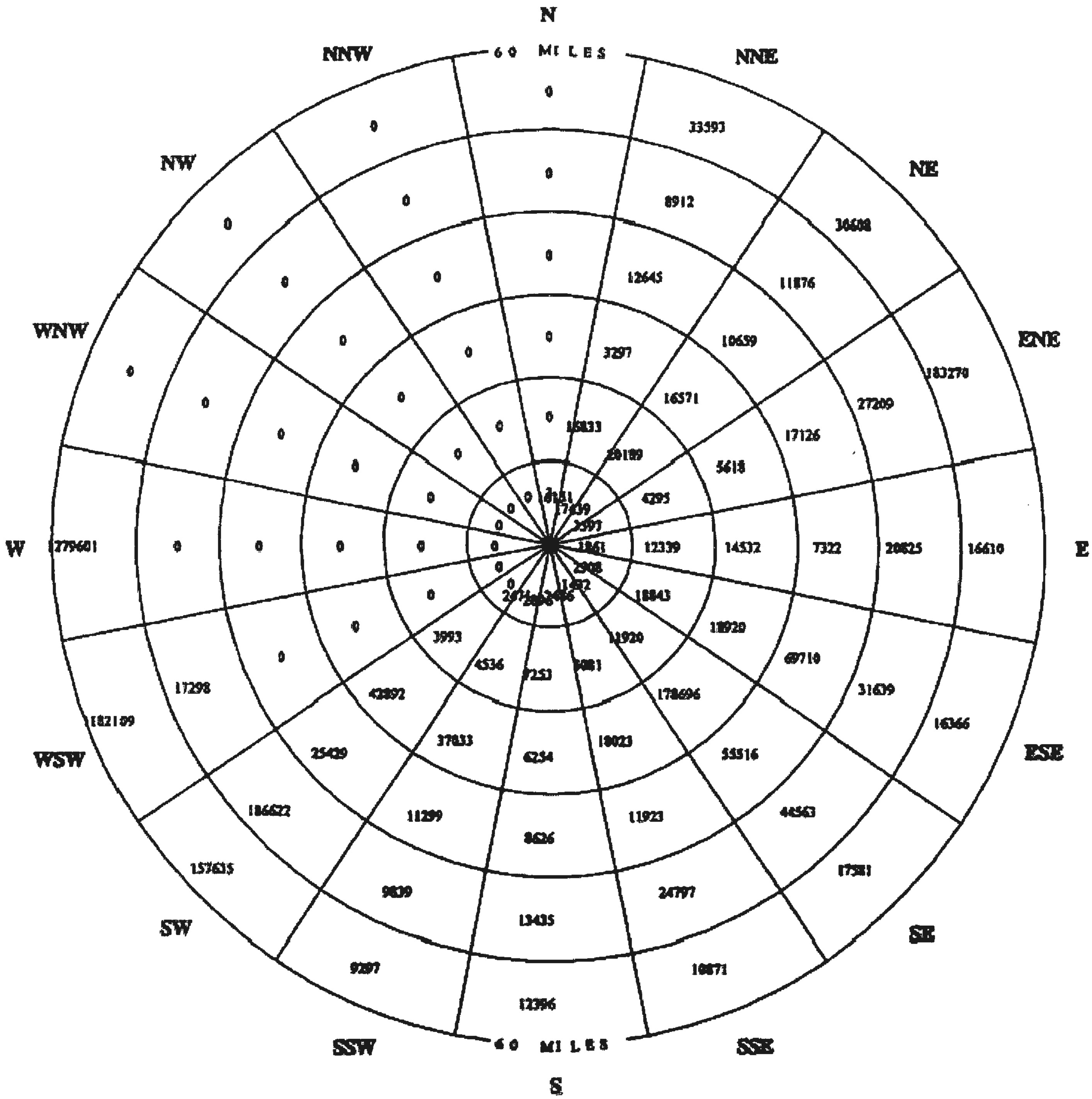
July 1995



1990
POPULATION DISTRIBUTION
5 - 60 MILES

FIGURE 2.1-6a

July 1995



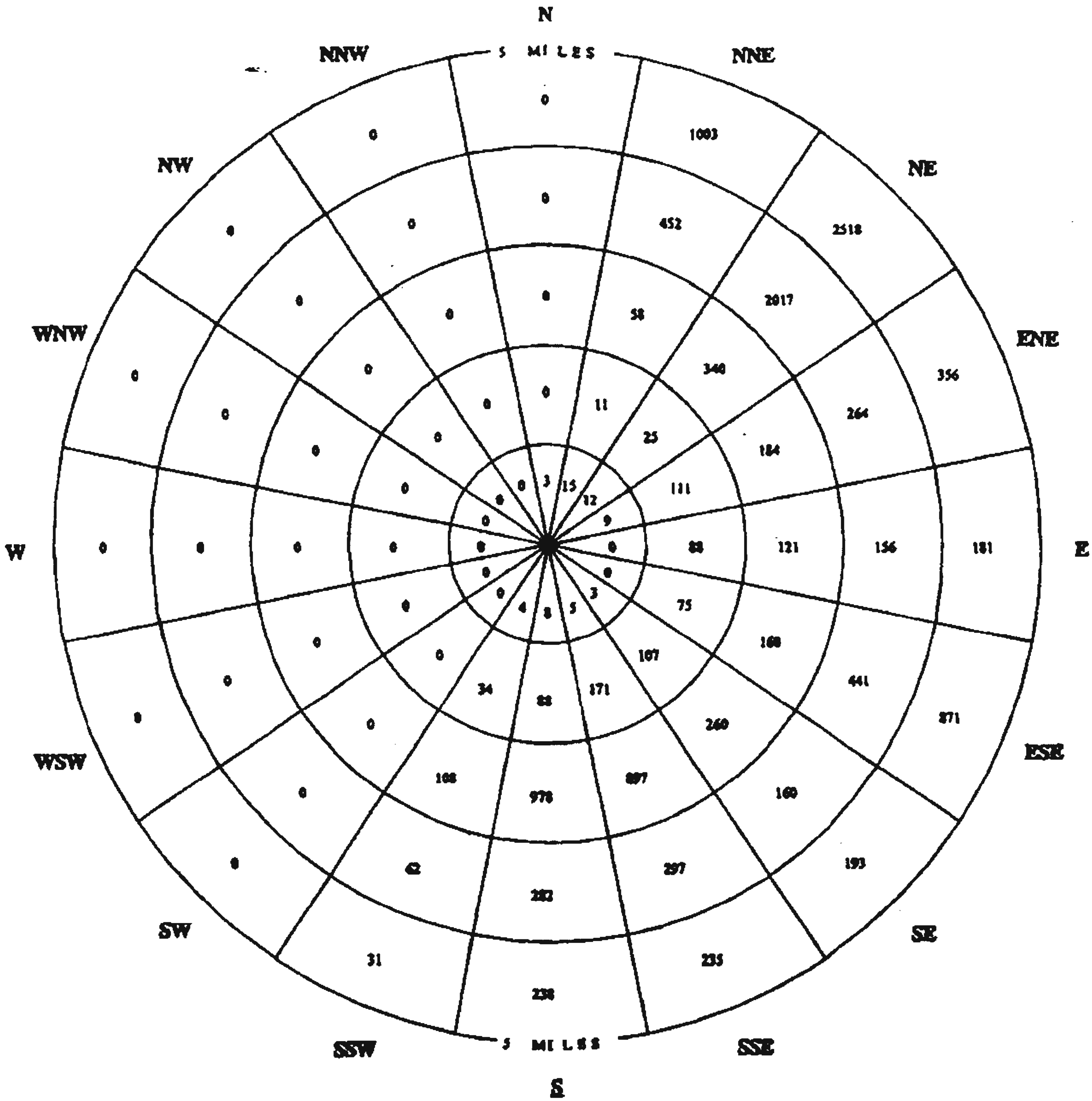
1990

POPULATION DISTRIBUTION

10 - 60 MILES

FIGURE 2.1-6b

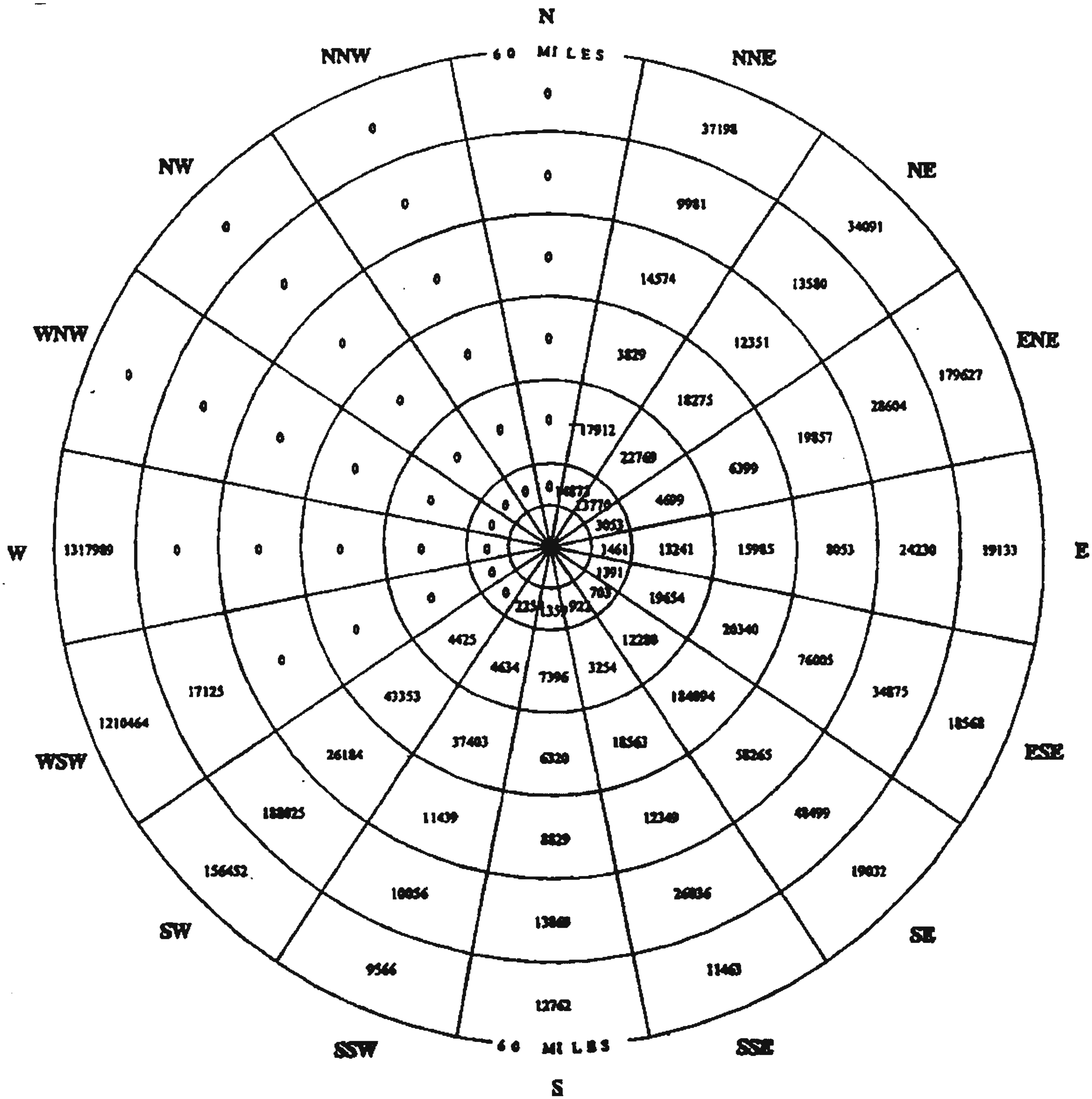
July 1995



2000

POPULATION DISTRIBUTION

0 - 5 MILES



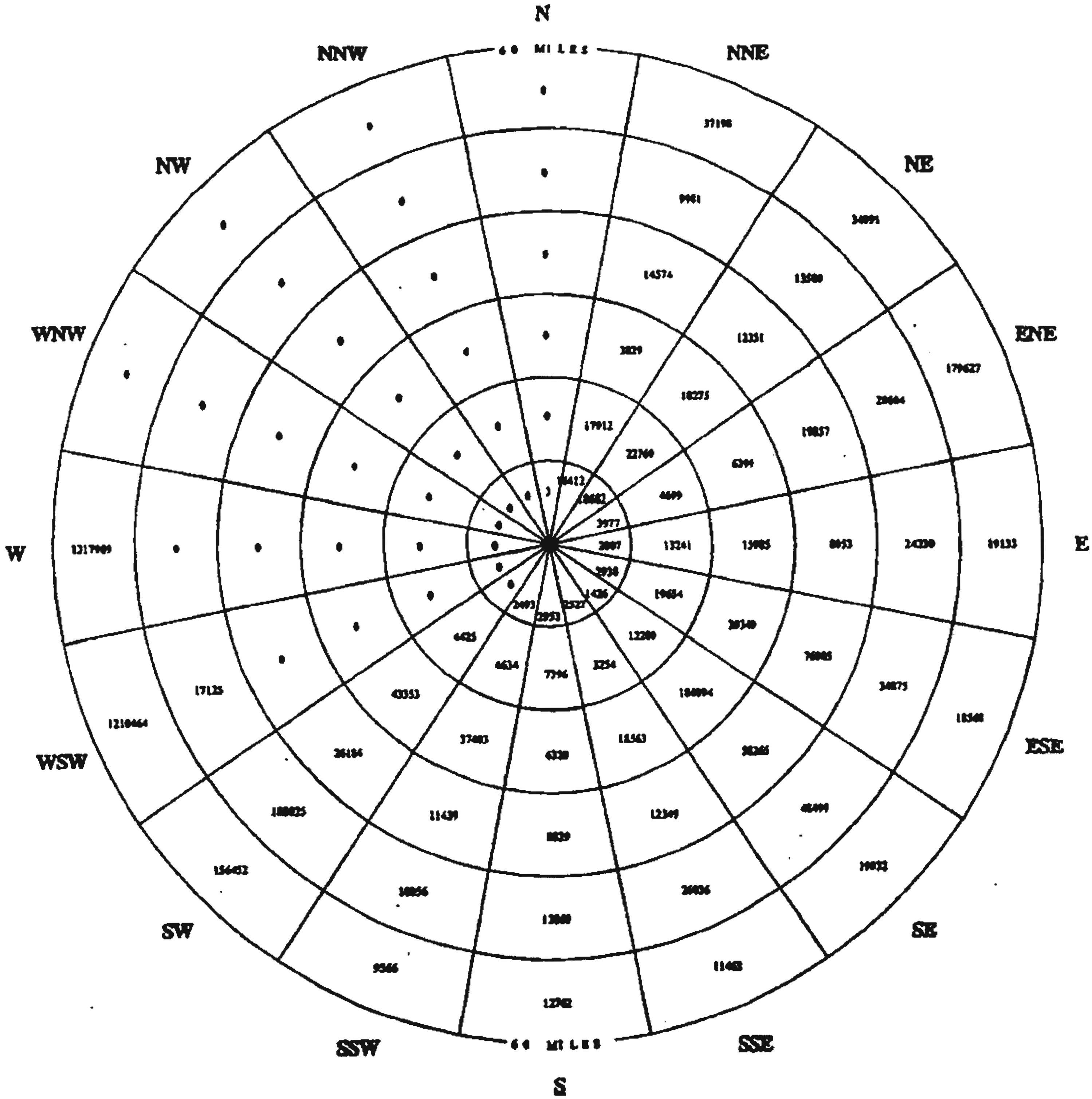
2000

POPULATION DISTRIBUTION

5 - 60 MILES

FIGURE 2.1-7a

July 1995



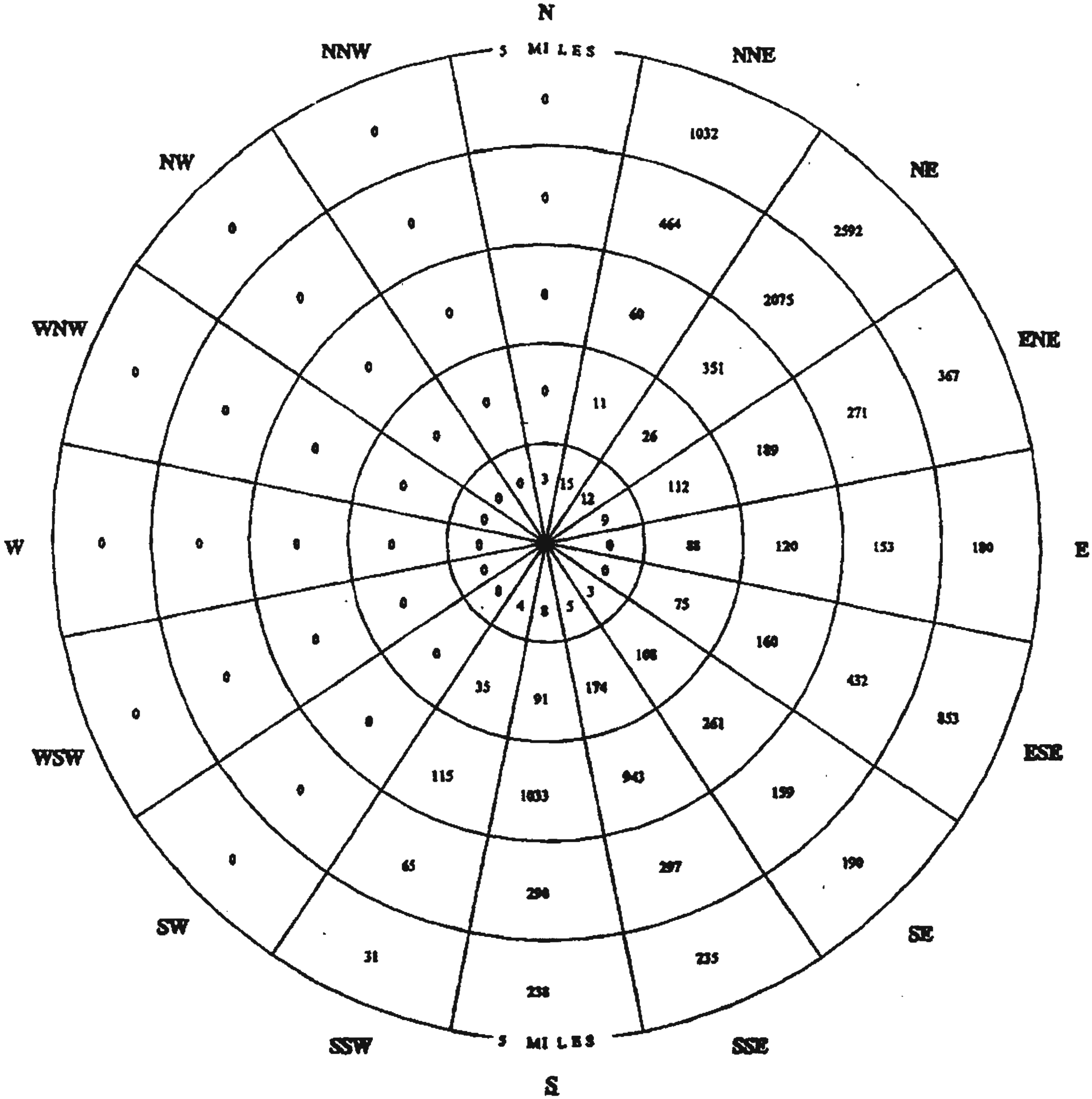
2000

POPULATION DISTRIBUTION

10 - 60 MILES

FIGURE 2.1-7b

July 1999

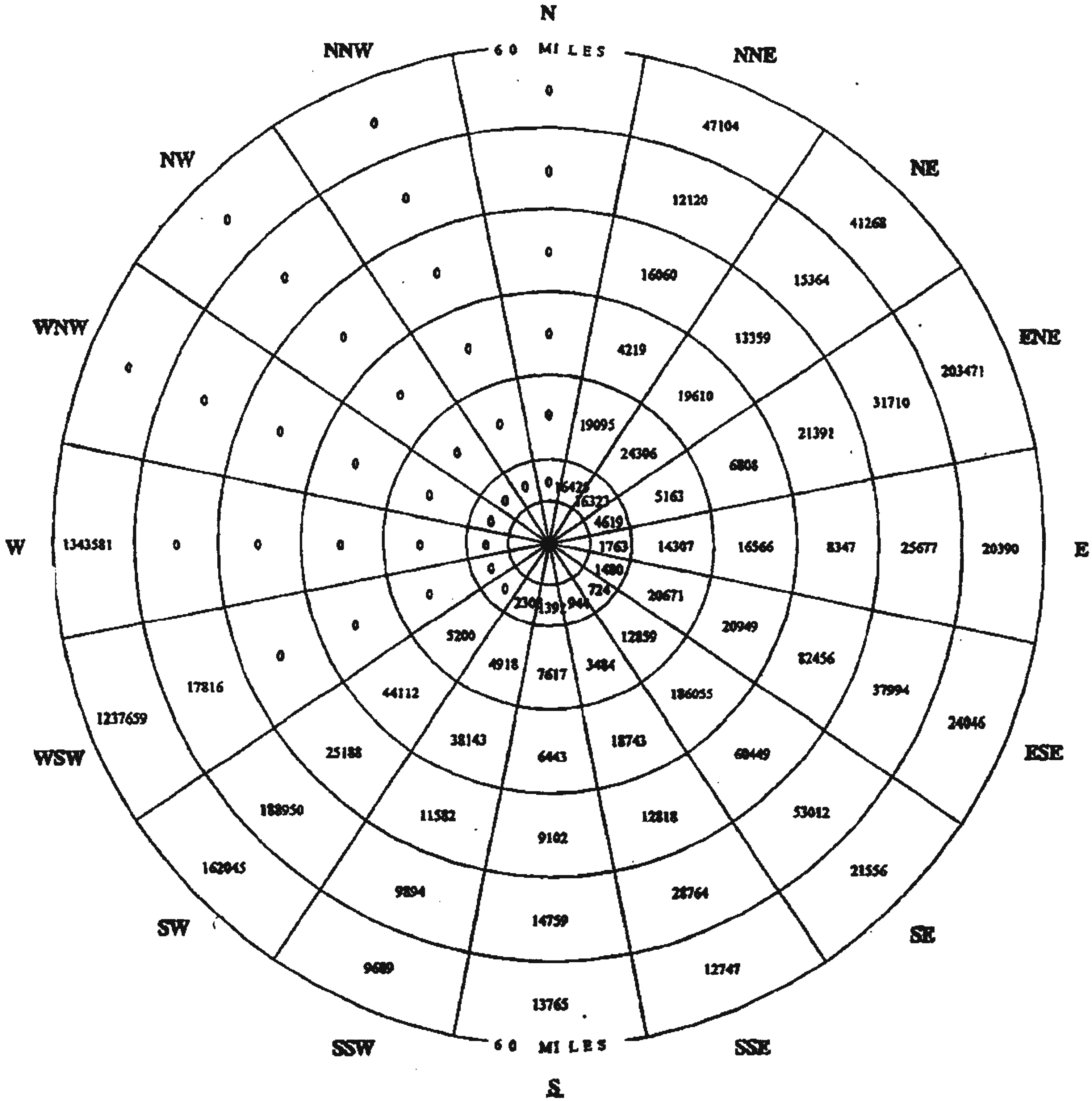


2037

POPULATION DISTRIBUTION

0 - 5 MILES

FIGURE 2.1-8



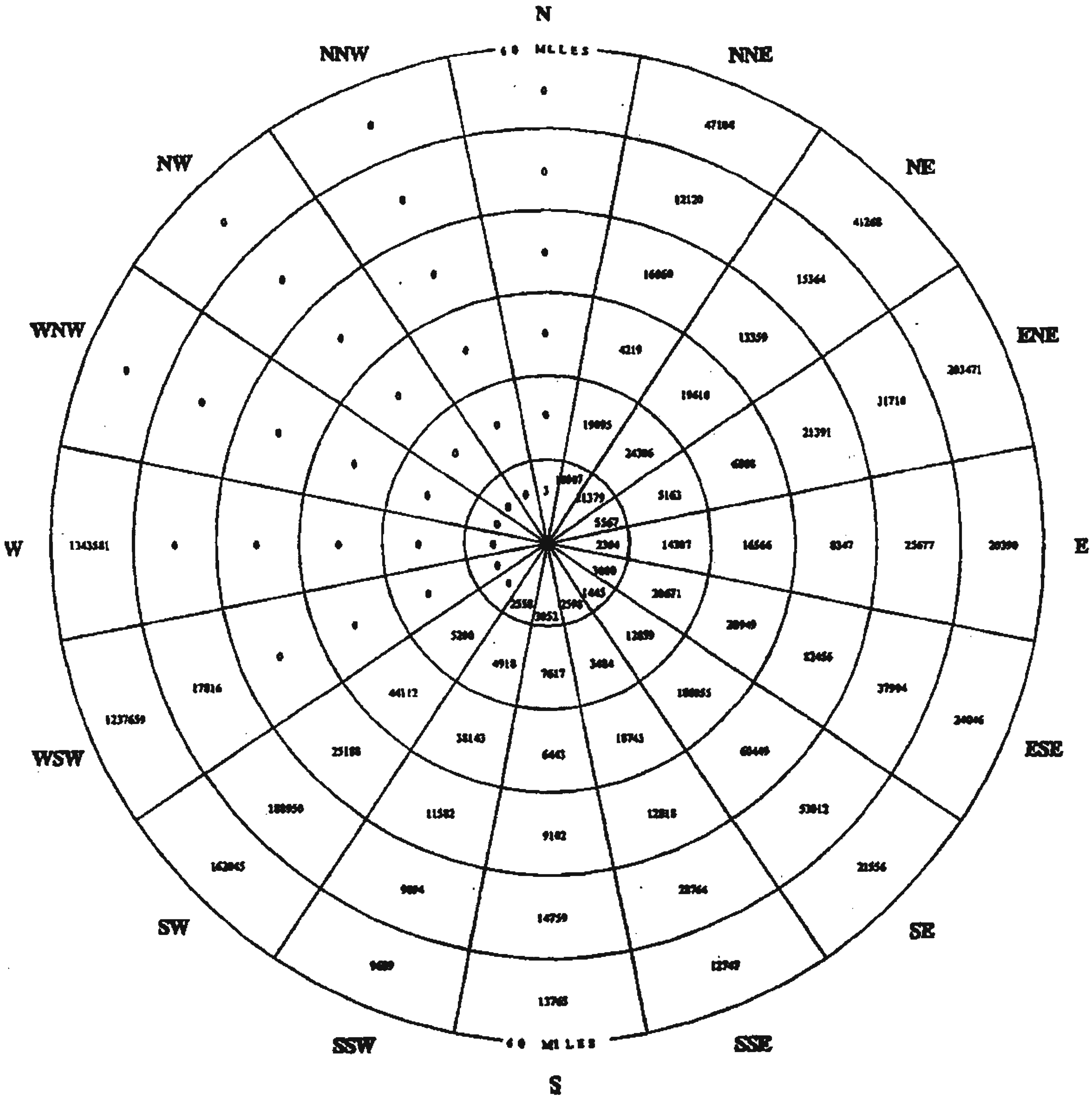
2037

POPULATION DISTRIBUTION

5 - 60 MILES

FIGURE 2.1-8a

July 1995



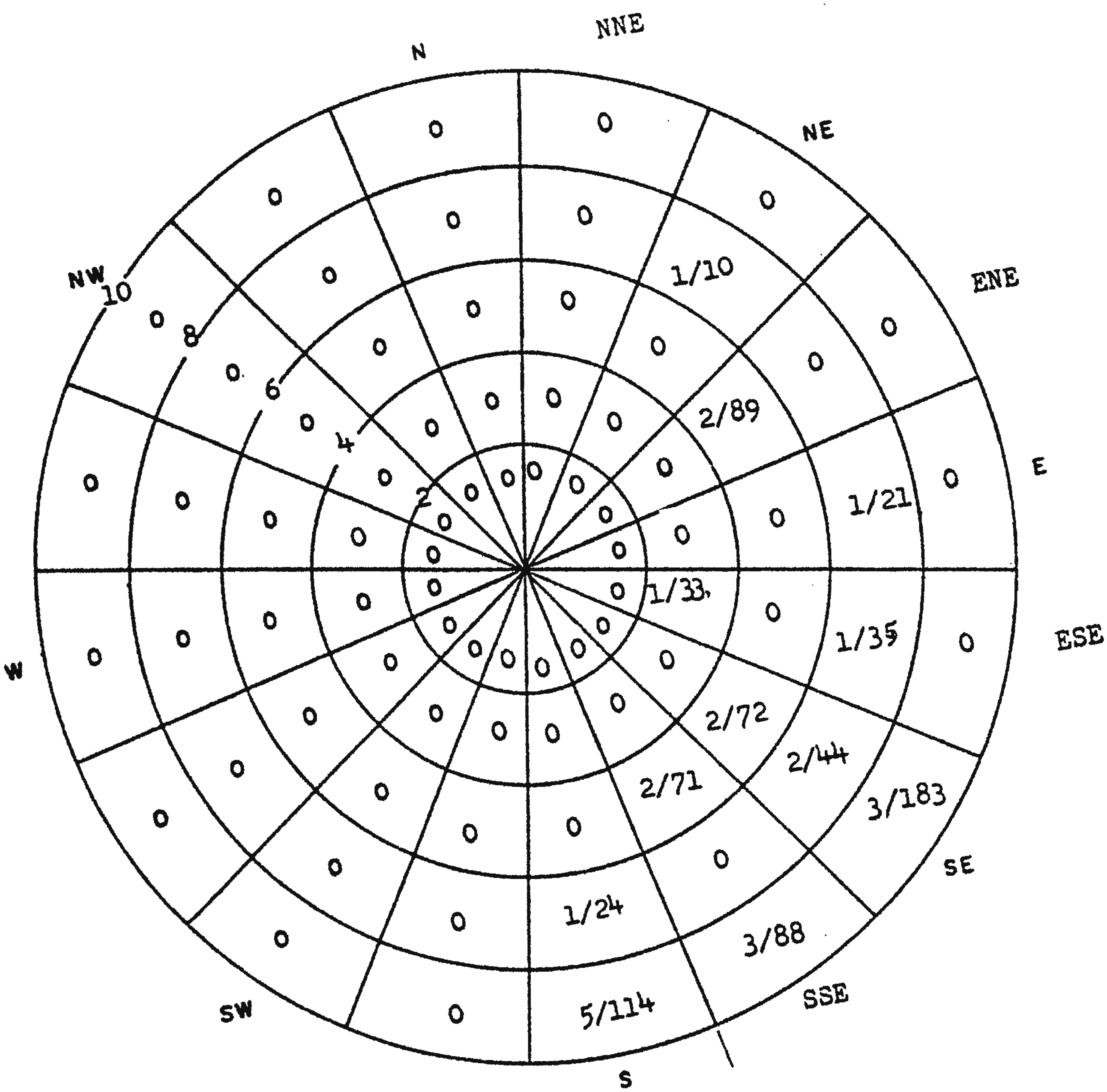
2037

POPULATION DISTRIBUTION

10 - 60 MILES

FIGURE 2.1-8b

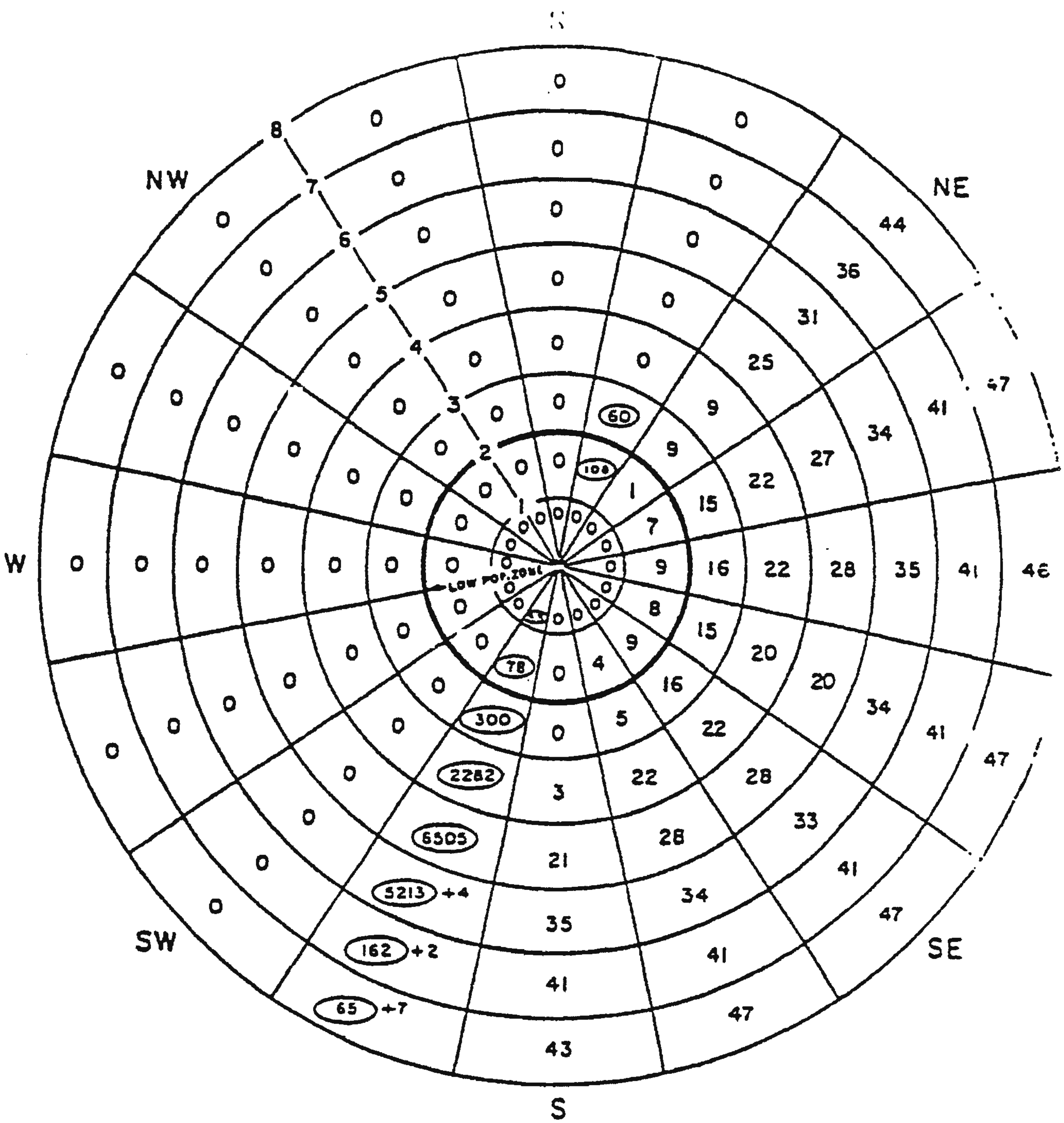
July 1995



1972
Dairy Cattle Distribution
0 - 10 Miles
Low Population Zone
0 - 2 Miles

Legend:
Farms/Cattle

Figure 2.1-9
July, 1993

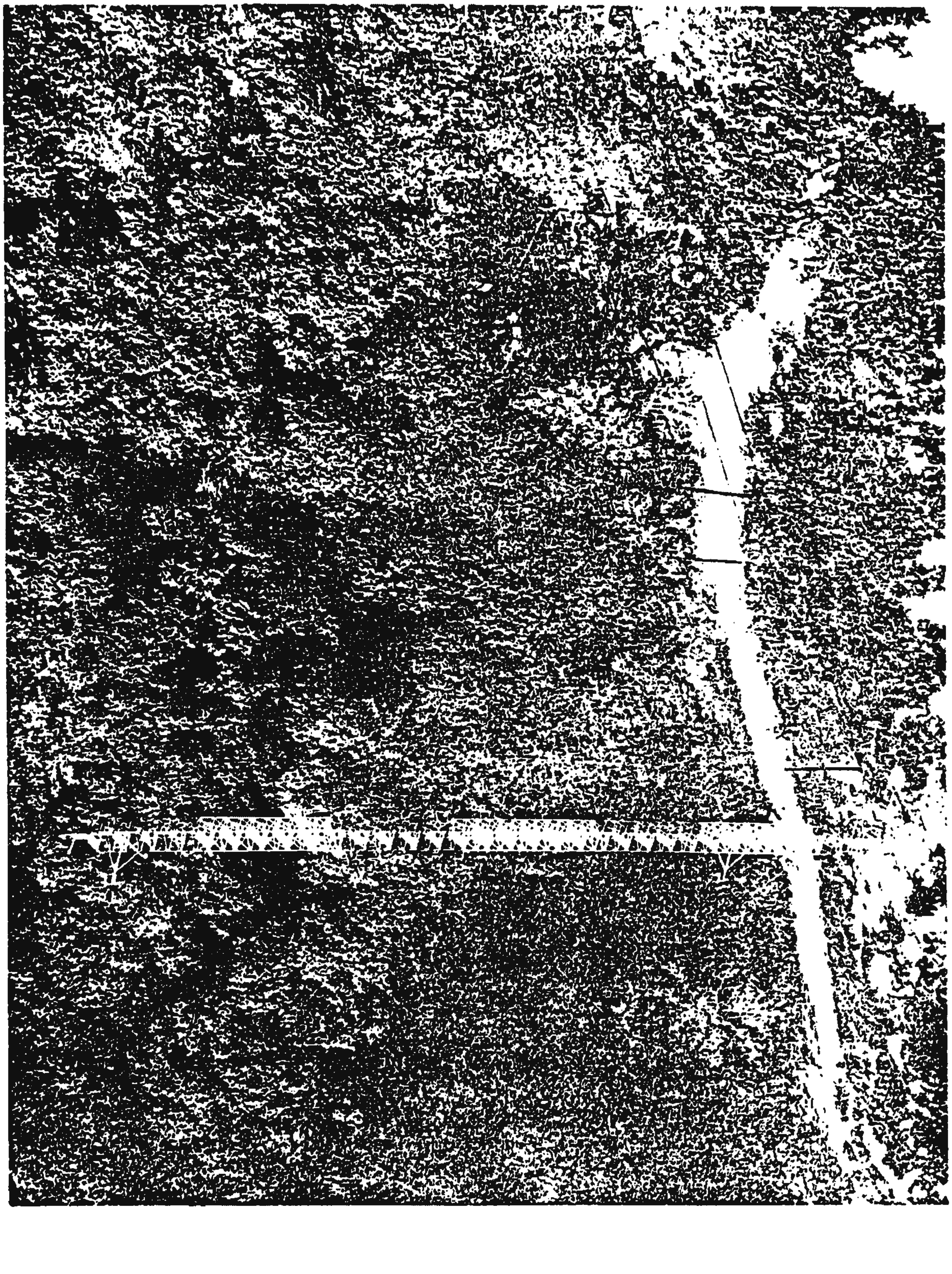


1971
TRANSIENT POPULATION DISTRIBUTION
WITHIN POPULATION CENTER DISTANCE
0-8 MILES
LOW POPULATION ZONE = 0-2 MILES

LEGEND:
(00) SUMMER PEAK VACATIONISTS
00 YEARLY AVERAGE MIGRANT CROP PICKERS

Figure 2.1-10

July, 1993



METEOROLOGICAL TOWER

FIG. 2.2-1

July, 1982

Figure 2.2-2

Tornados in the State of Michigan

1950 - 1989

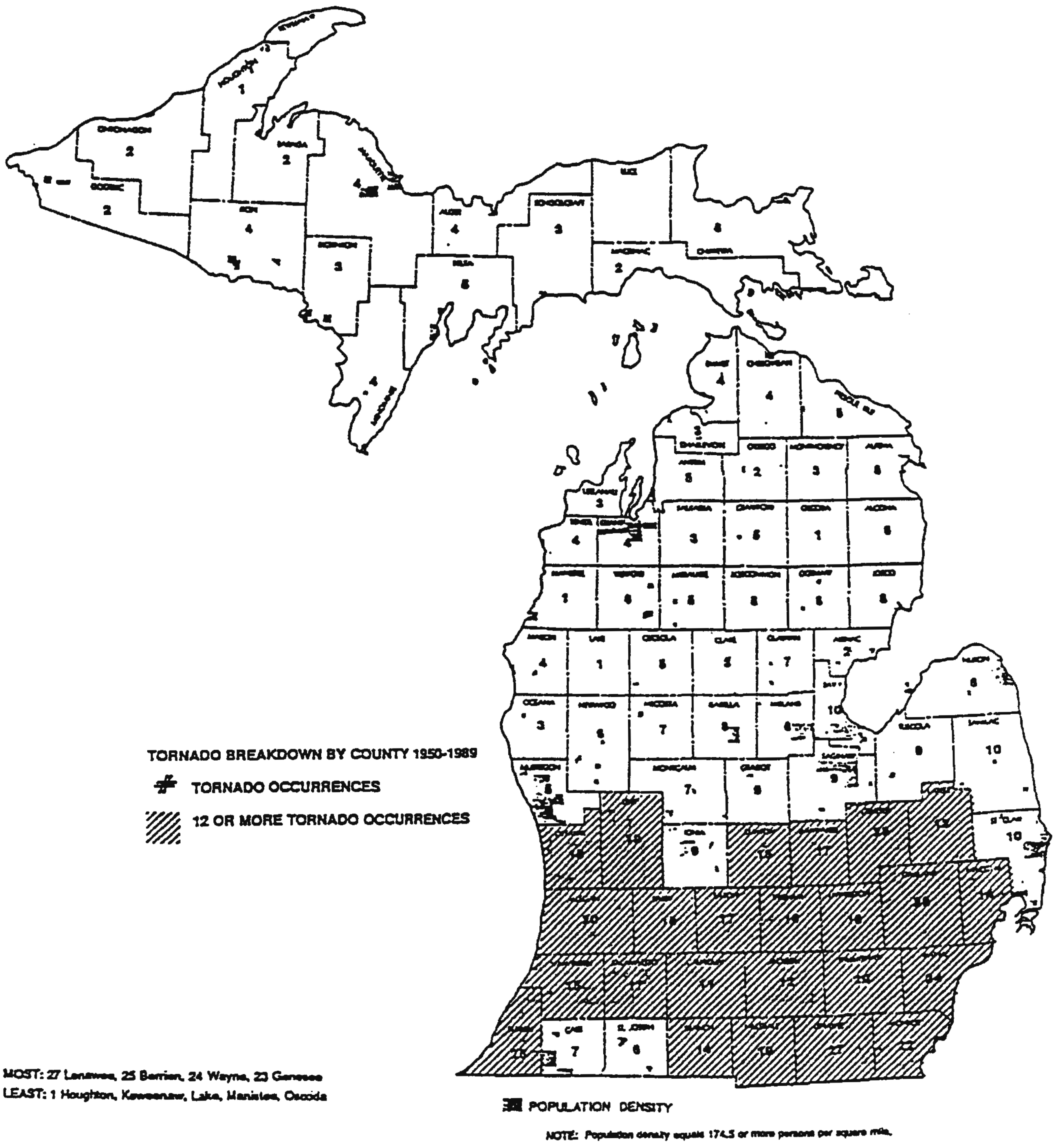


Figure 2.2-3

Main Tower Wind Rose

January - December 1992

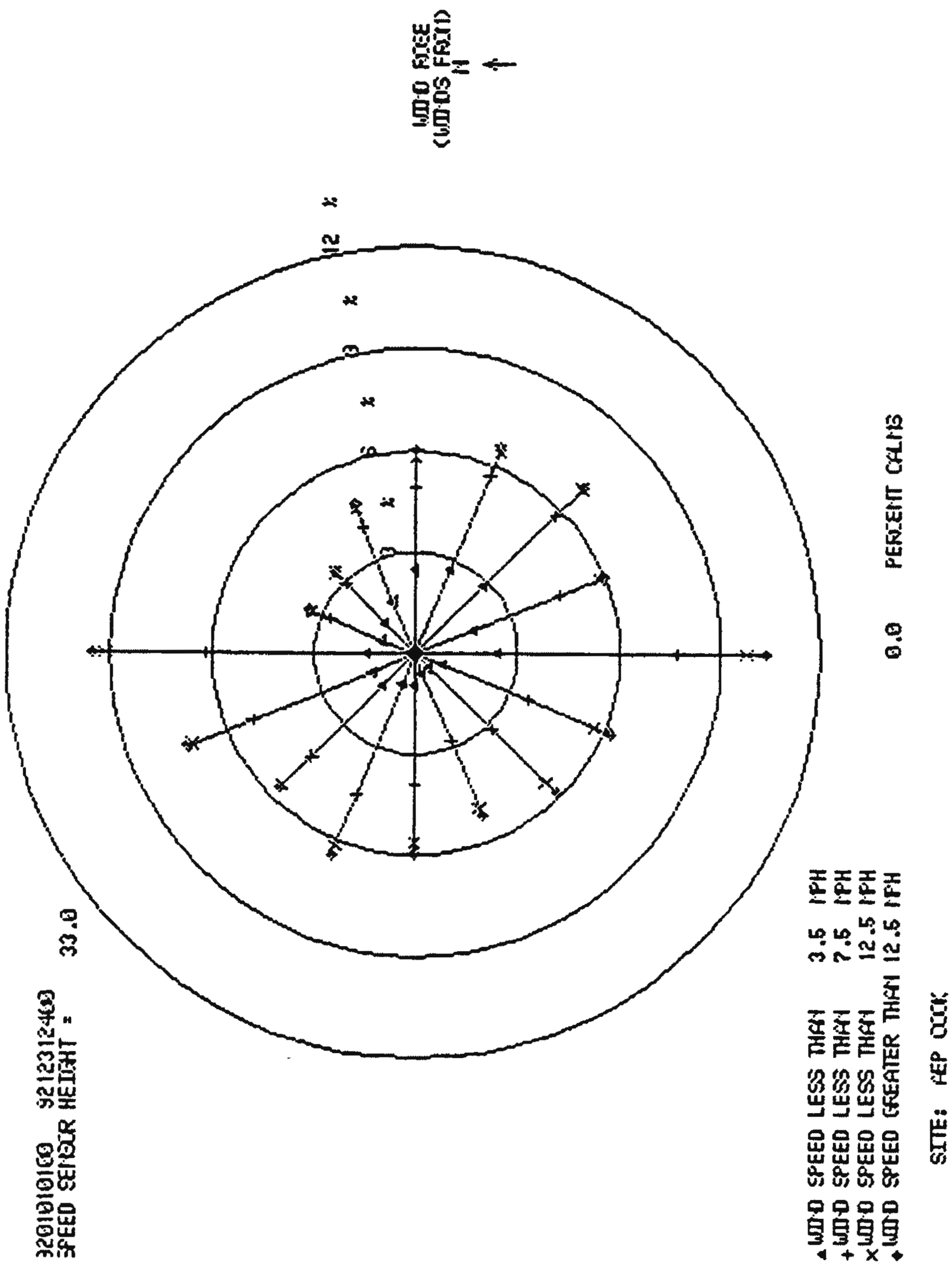
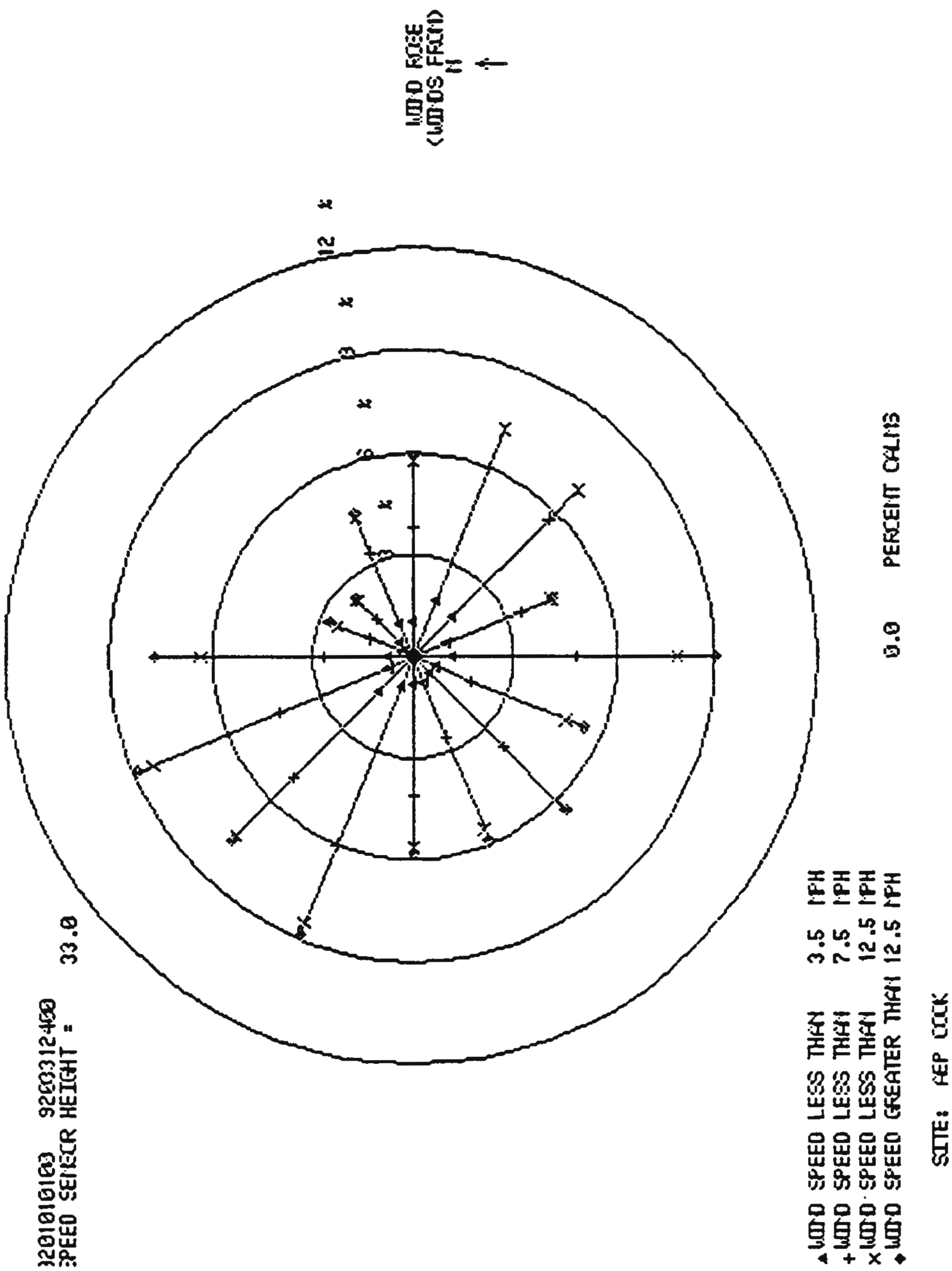


Figure 2.2-4

Main Tower Wind Rose

January - March 1992



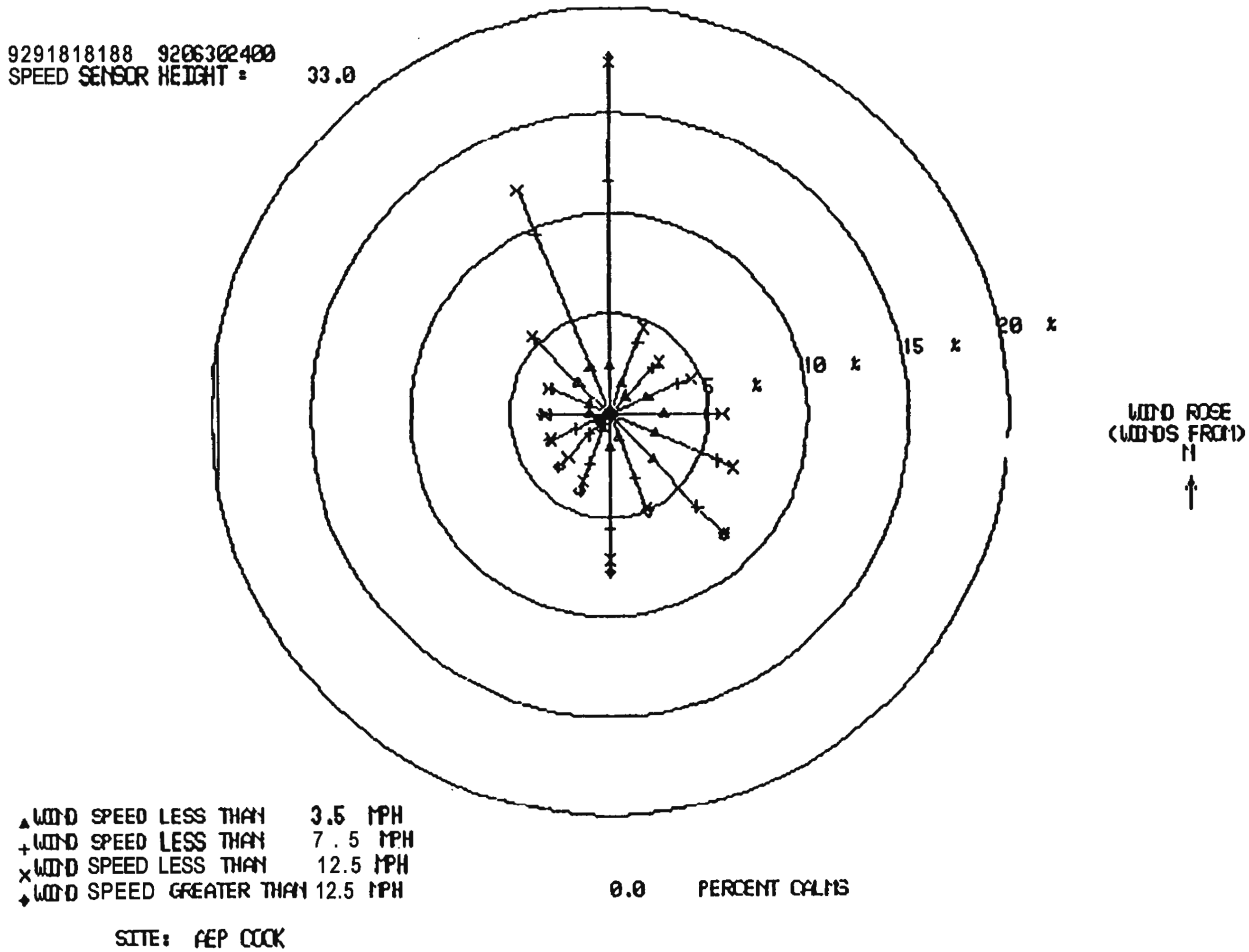
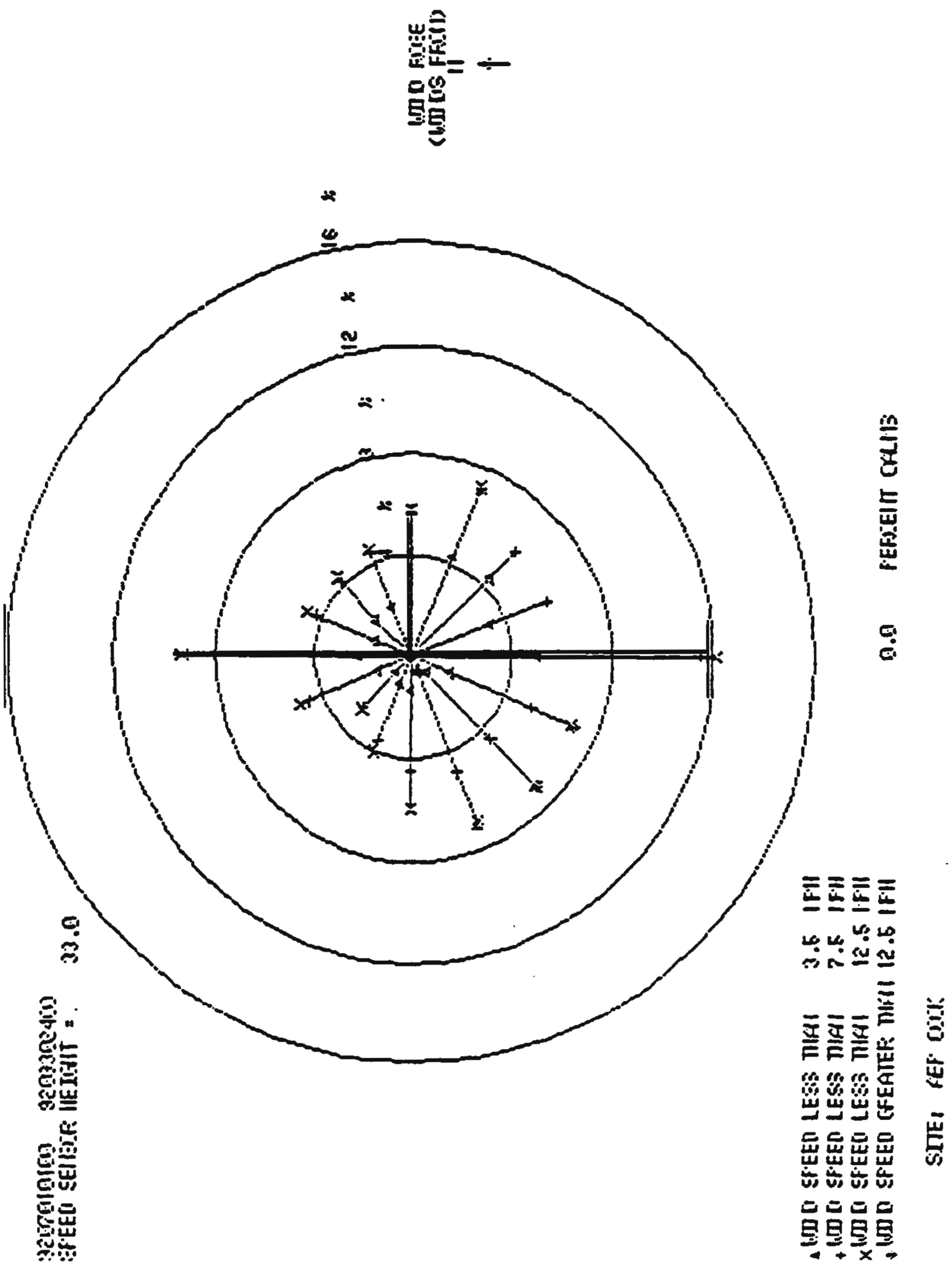


Figure 2.2-5
Main Tower Wind Rose
April - June 1992

Figure 2.2-6

Main Tower Wind Rose

July - September 1992



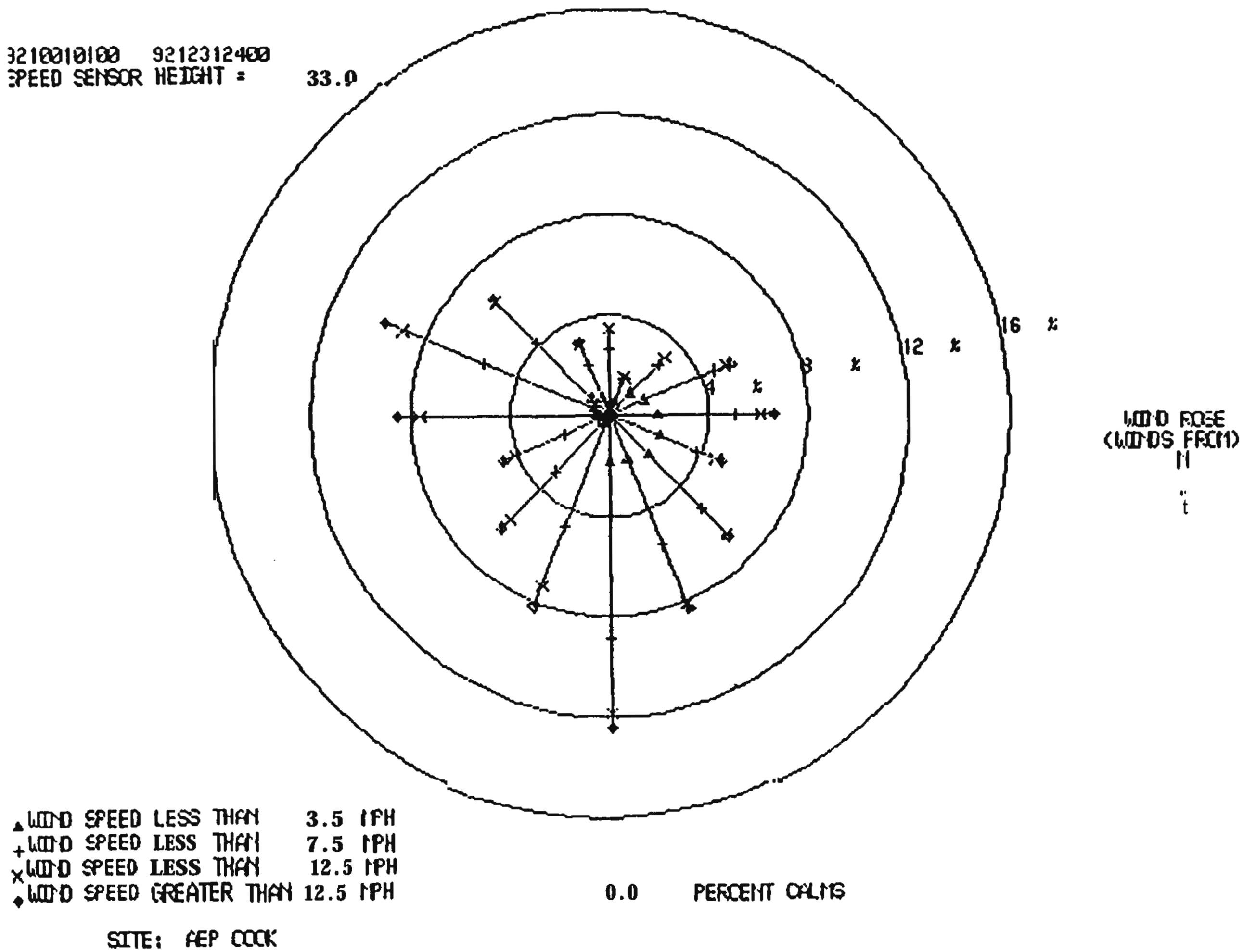


Figure 2.2-7
Main Tower Wind Rose
October - December 1992

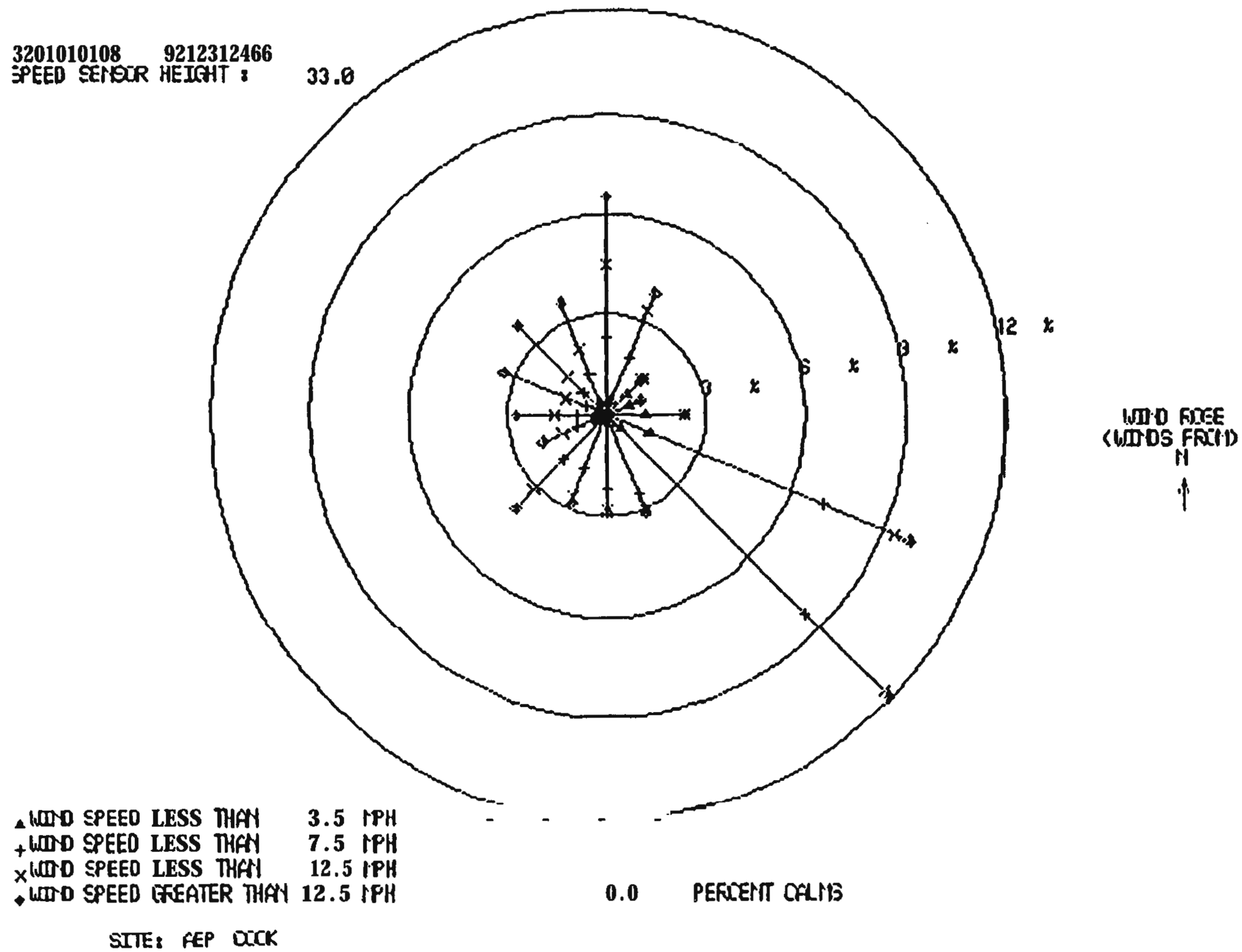


Figure 2.2-8
Shoreline Tower Wind Rose
January - December 1992

Figure 2.2-9

Shoreline Tower Wind Rose

January - March 1992

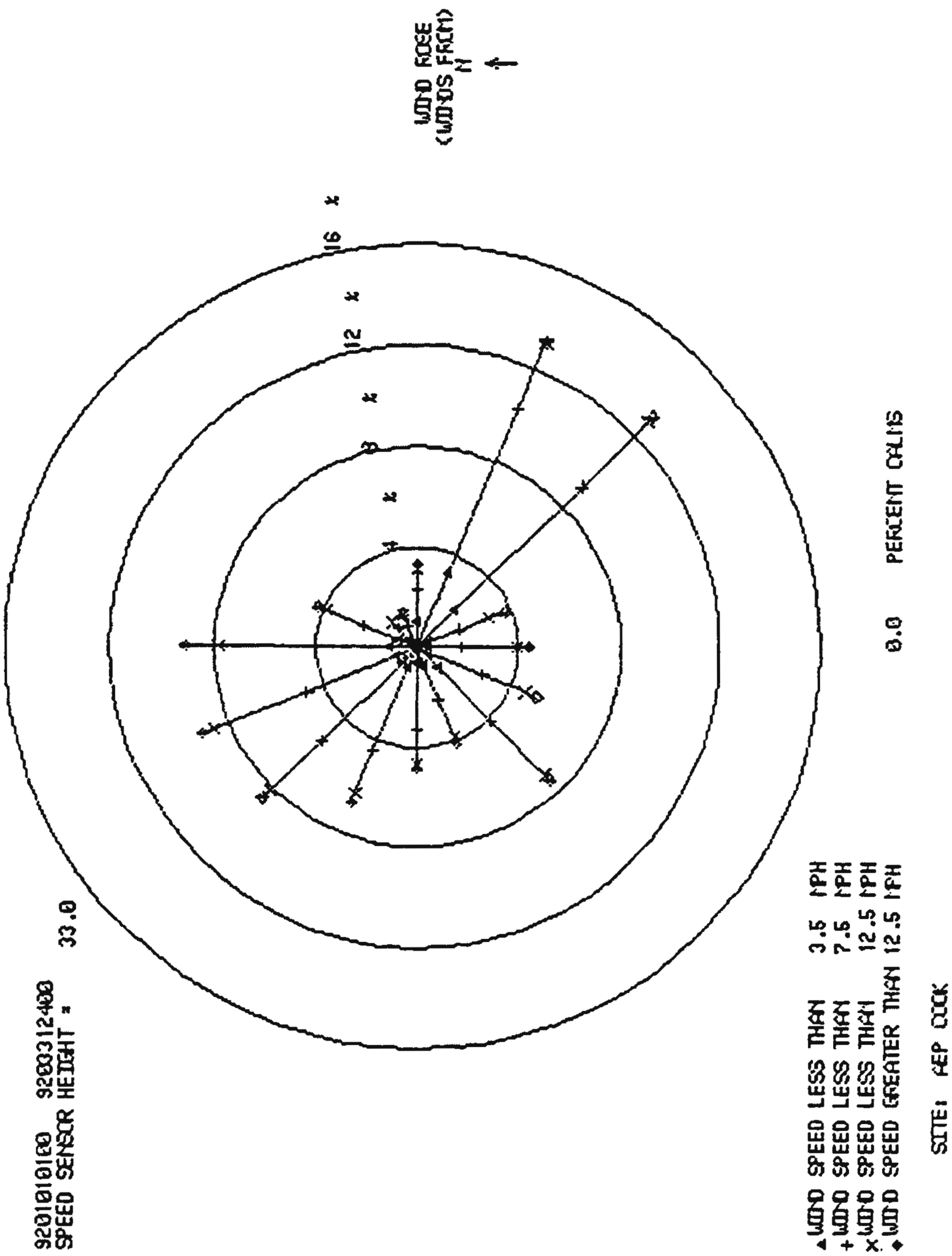
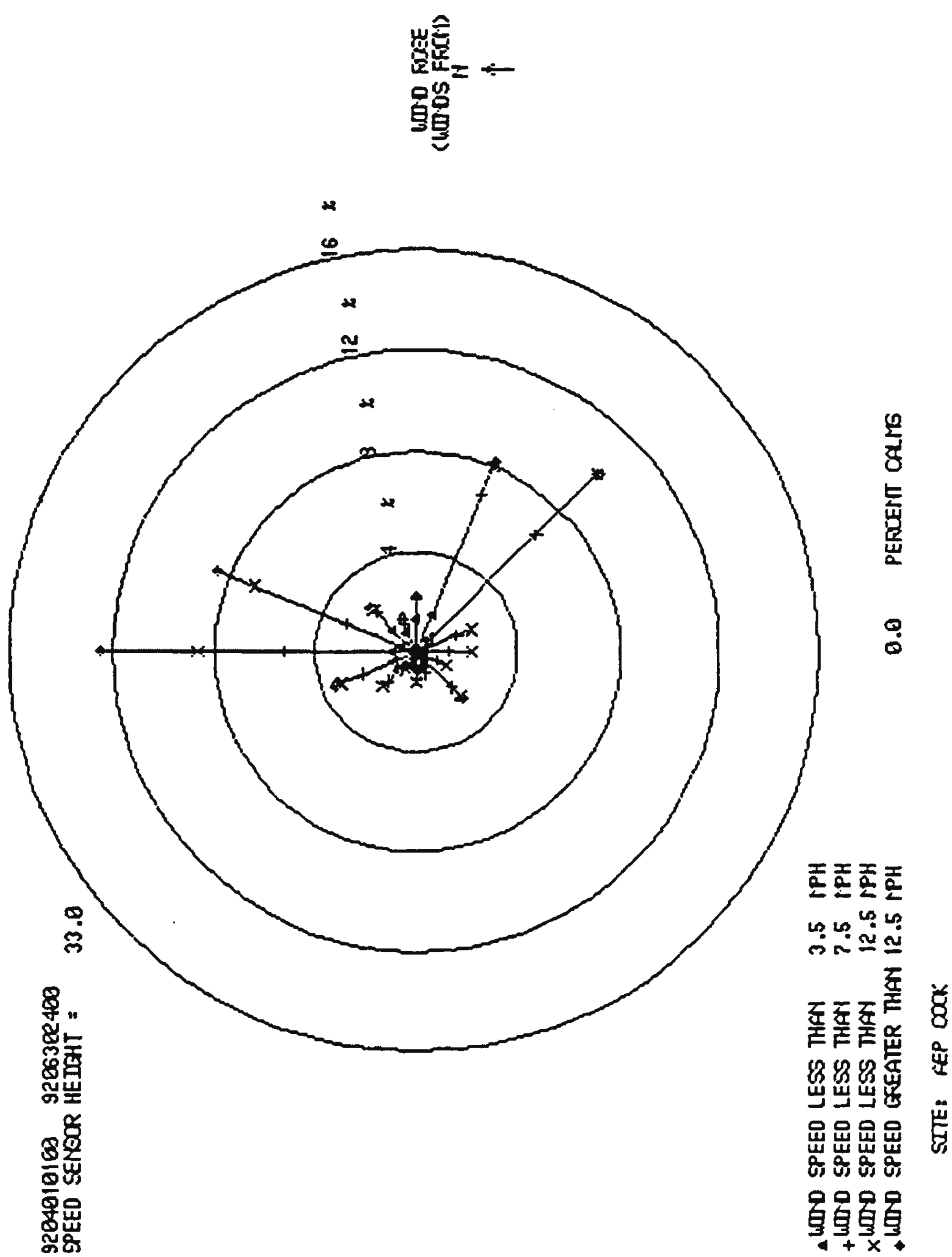


Figure 2.2-10

Shoreline Tower Wind Rose

April - June 1992



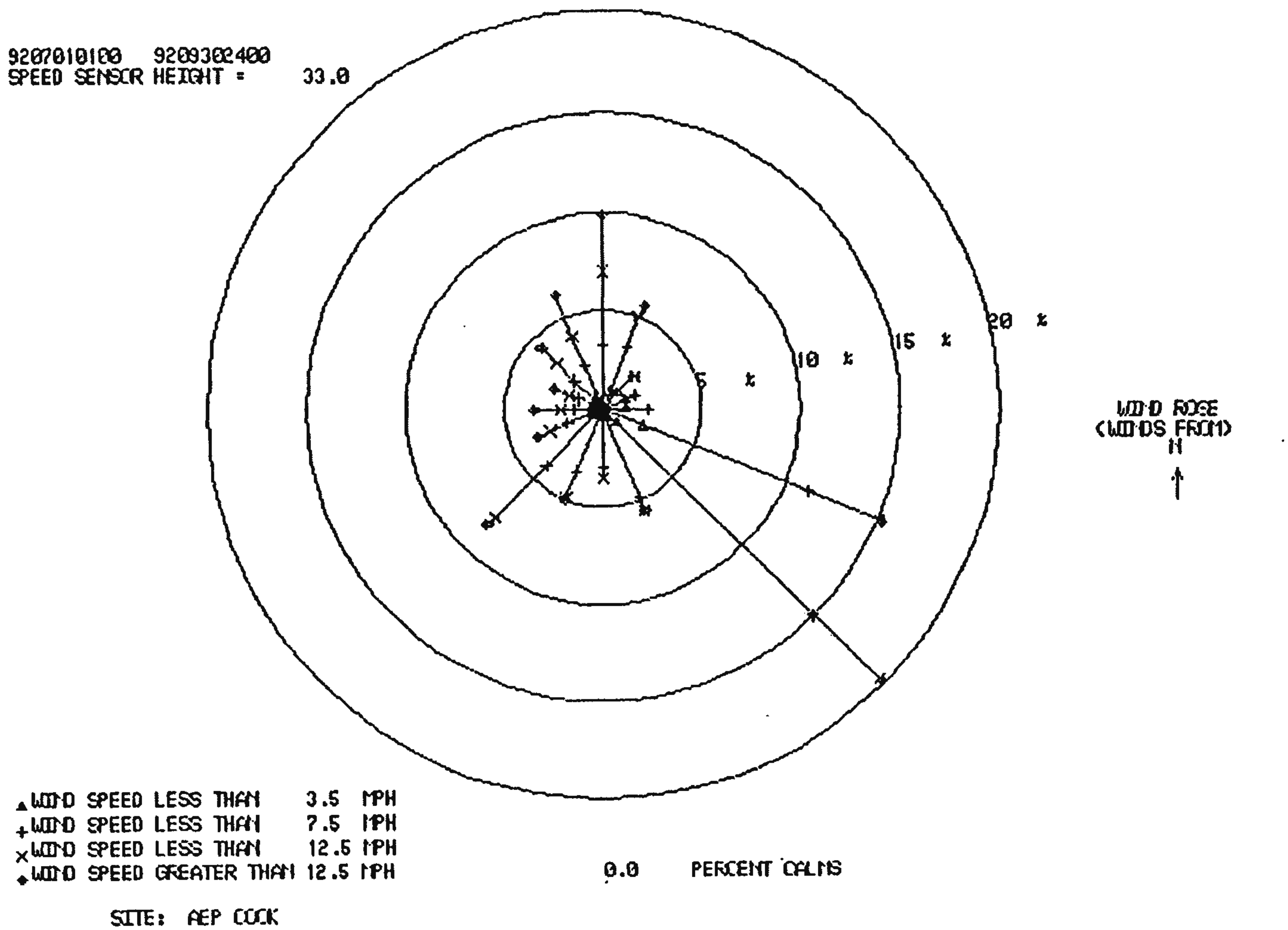
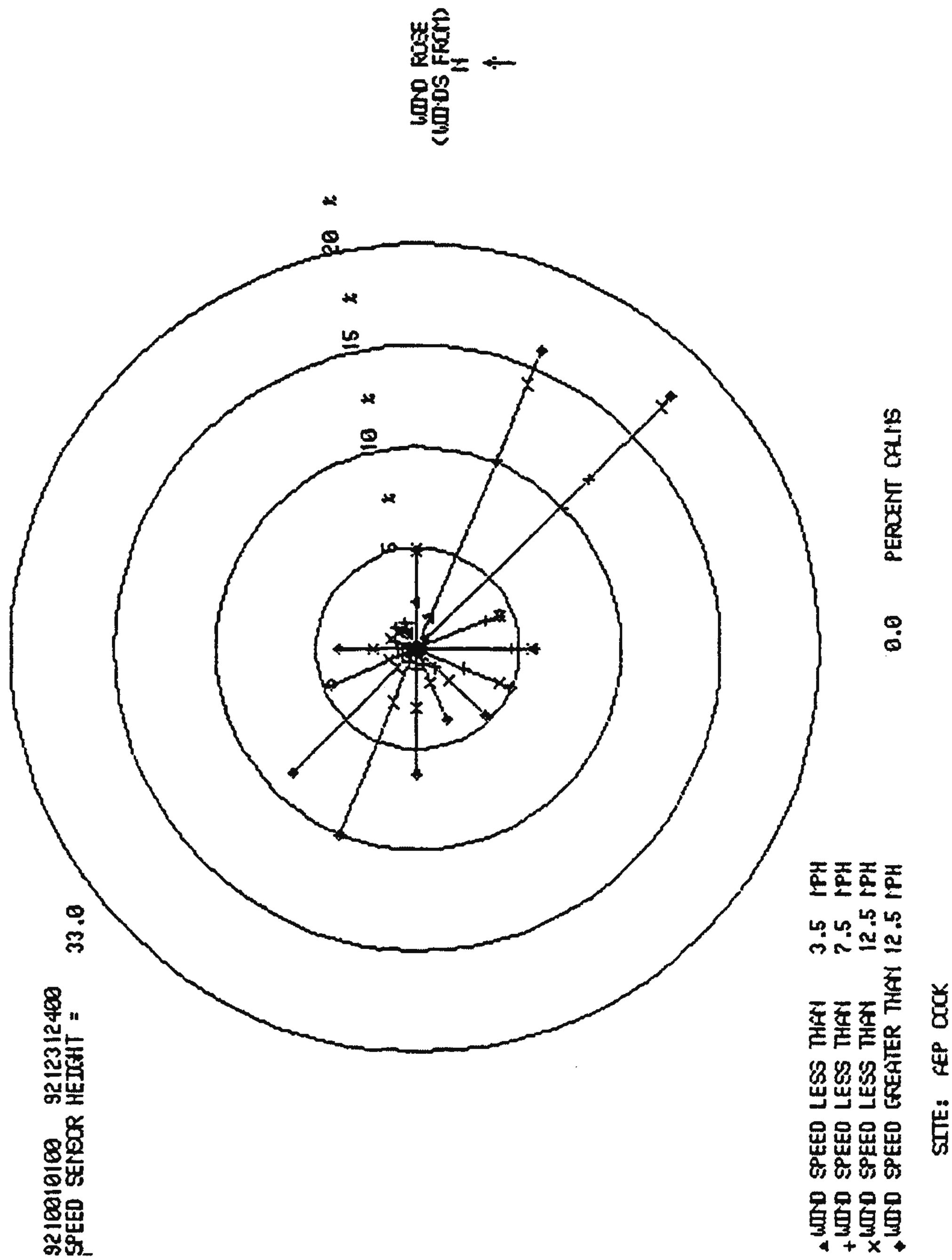


Figure 2.2-11
Shoreline Tower Wind Rose
July - September 1992

Figure 2.2-12

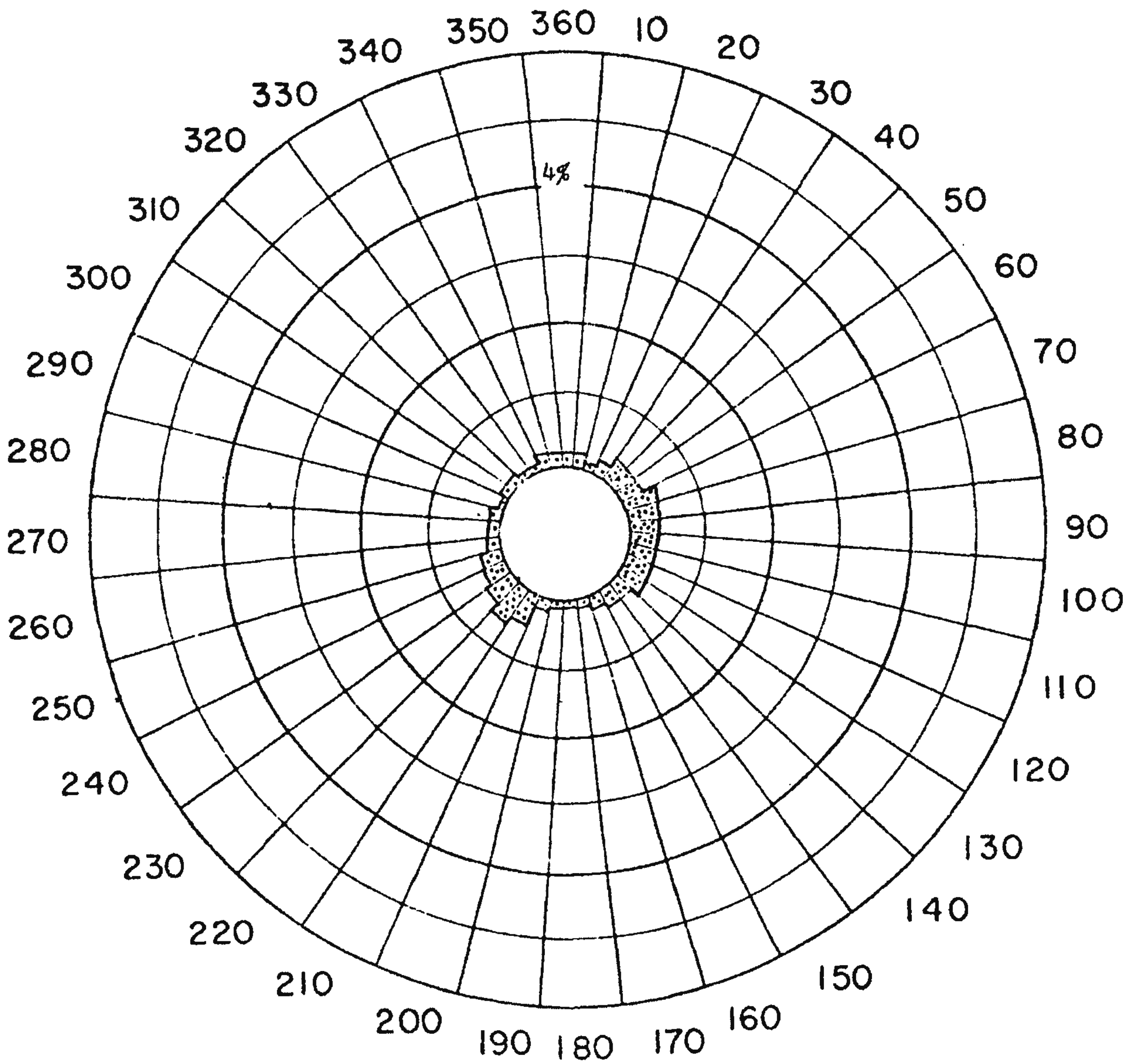
Shoreline Tower Wind Rose

October - December 1992



STATION	BENTON HARBOR
HEIGHT	200-FOOT LEVEL
PERIOD	ANNUAL

TURBULENCE CLASS IV

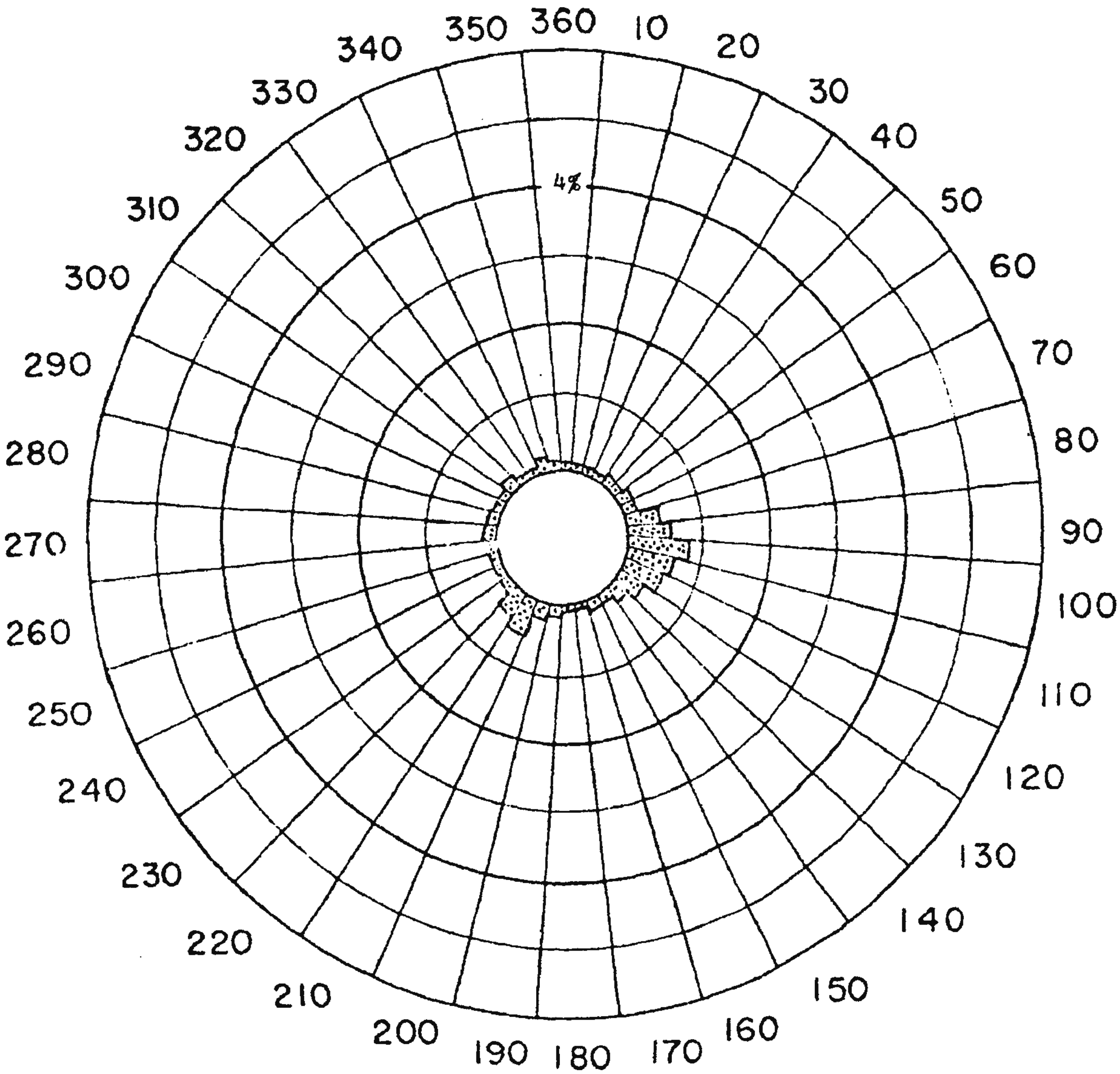


MEAN WIND SPEED 8 MPH

FIGURE 2.2-13

July, 1982

STATION BENTON HARBOR
HEIGHT 50-FOOT LEVEL
PERIOD ANNUAL
TURBULENCE CLASS IV



MEAN WIND SPEED 4 MPH

FIGURE 2.2-14

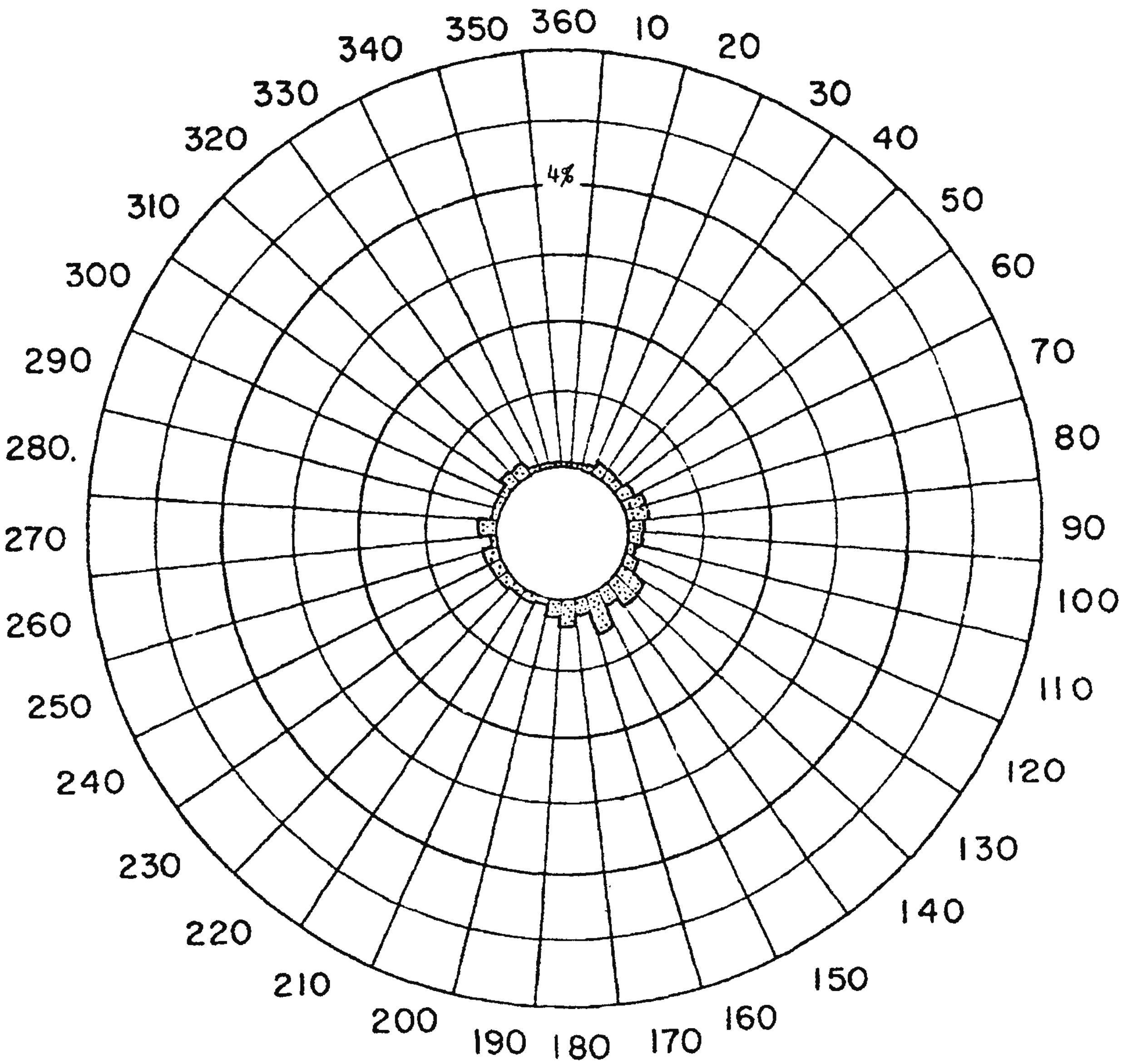
July, 1982

STATION: BENTON HARBOR

HEIGHT: SATELLITE

PERIOD: ANNUAL

TURBULENCE CLASS IV



MEAN WIND SPEED 3 MPH

FIGURE 2.2-15

July, 1982

STATION BENTON HARBOR
HEIGHT 200-FOOT LEVEL
PERIOD ANNUAL
ALL HOURS

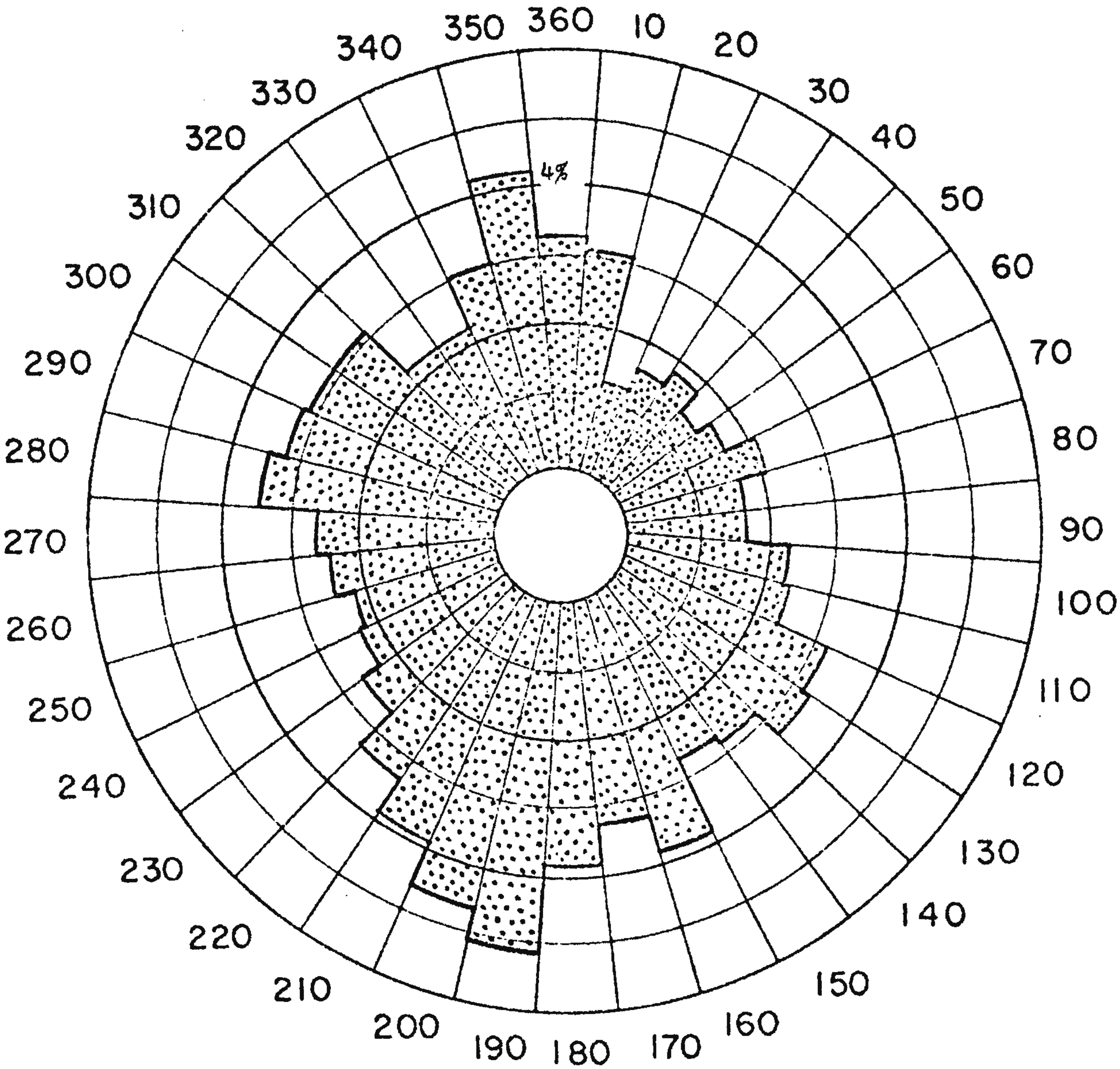


FIGURE 2.2-16

July, 1982

STATION	BENTON HARBOR
HEIGHT	50-FOOT LEVEL
PERIOD	ANNUAL
	ALL HOURS

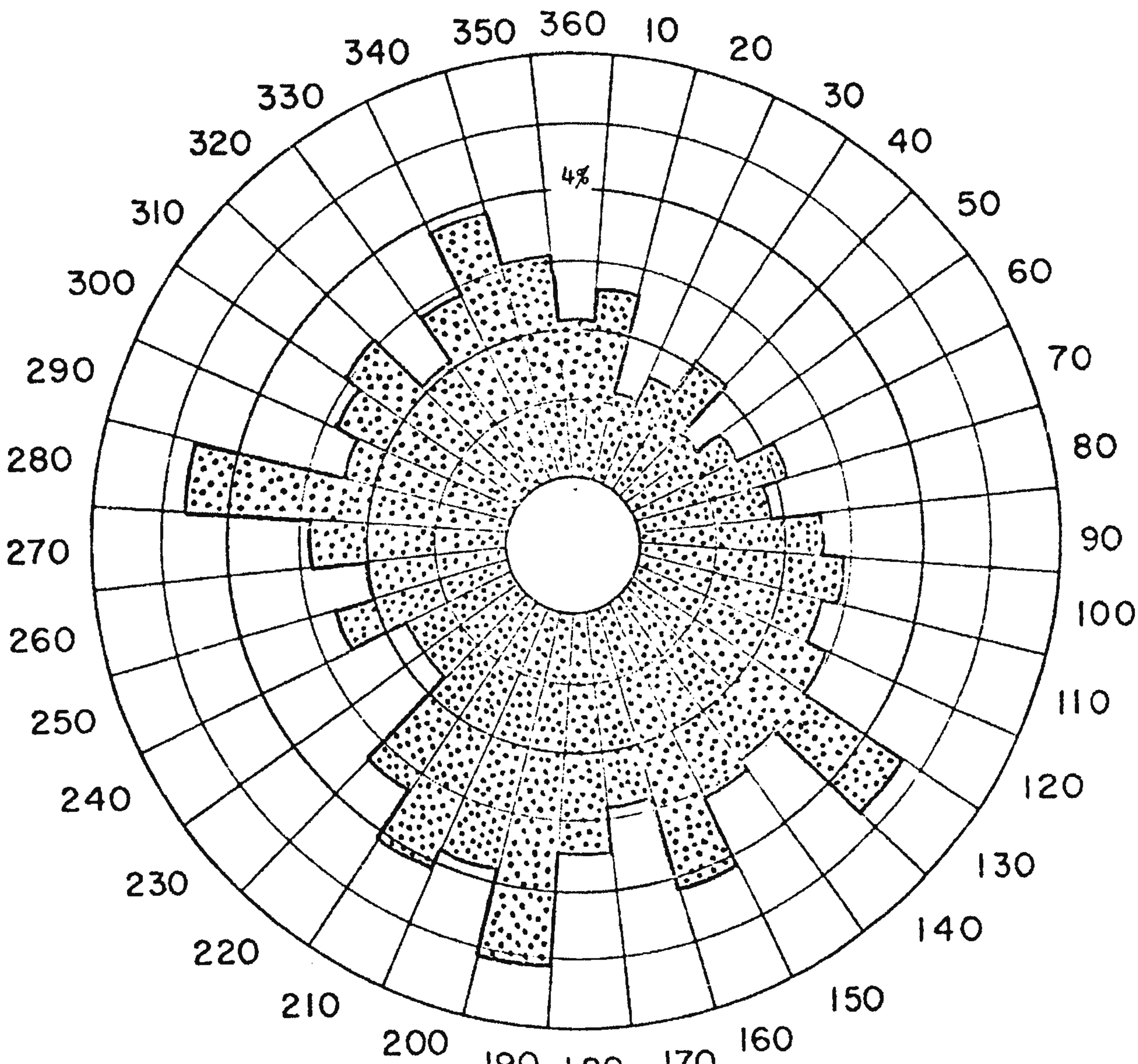


FIGURE 2.2-17

July, 1982

STATION BENTON HARBOR

HEIGHT SATELLITES

PERIOD ANNUAL

ALL HOURS

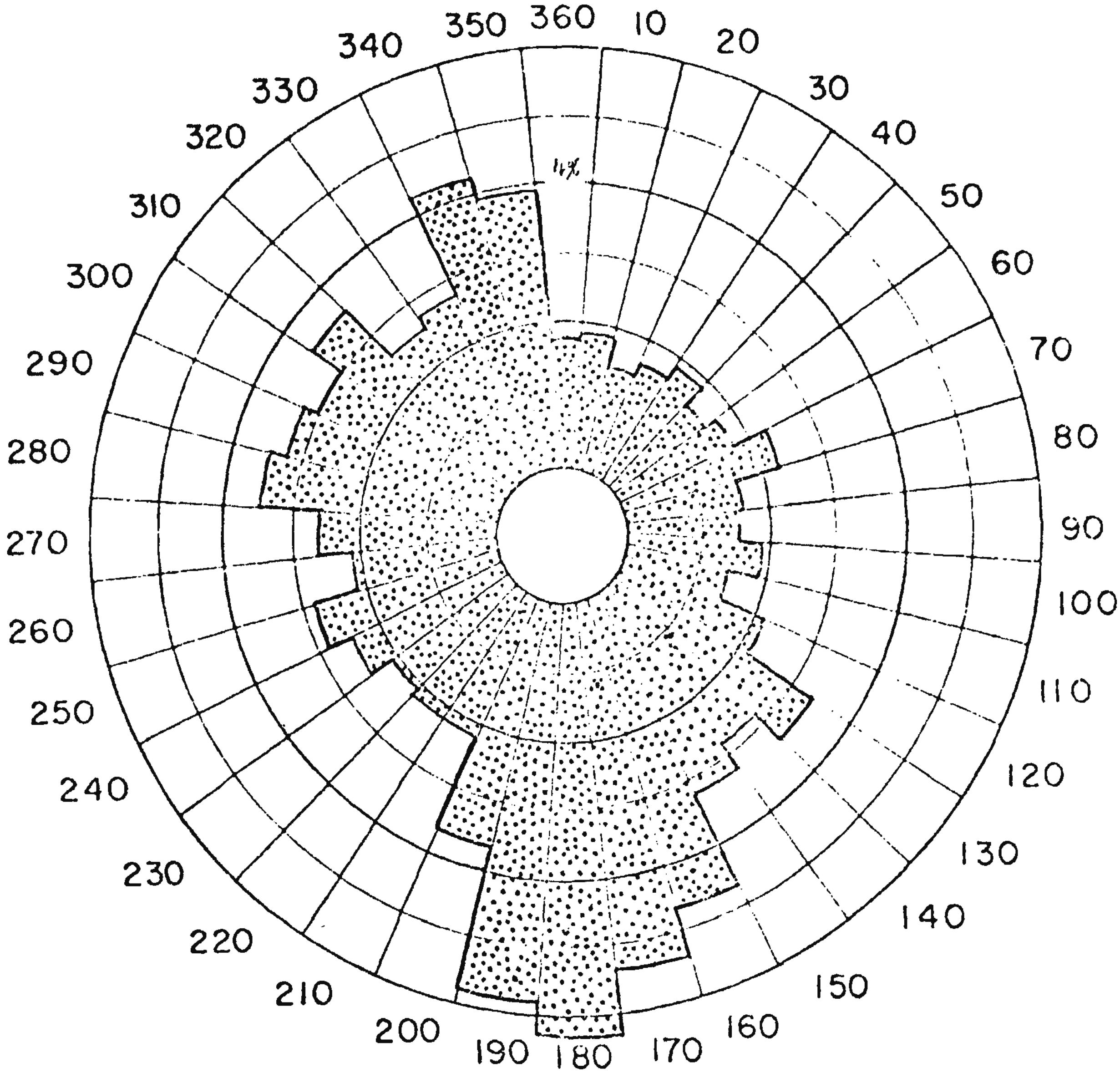


FIGURE 2.2-18

July, 1982

STATION BENTON HARBOR

HEIGHT 200-FOOT LEVEL

PERIOD WINTER

TURBULENCE CLASS - ALL

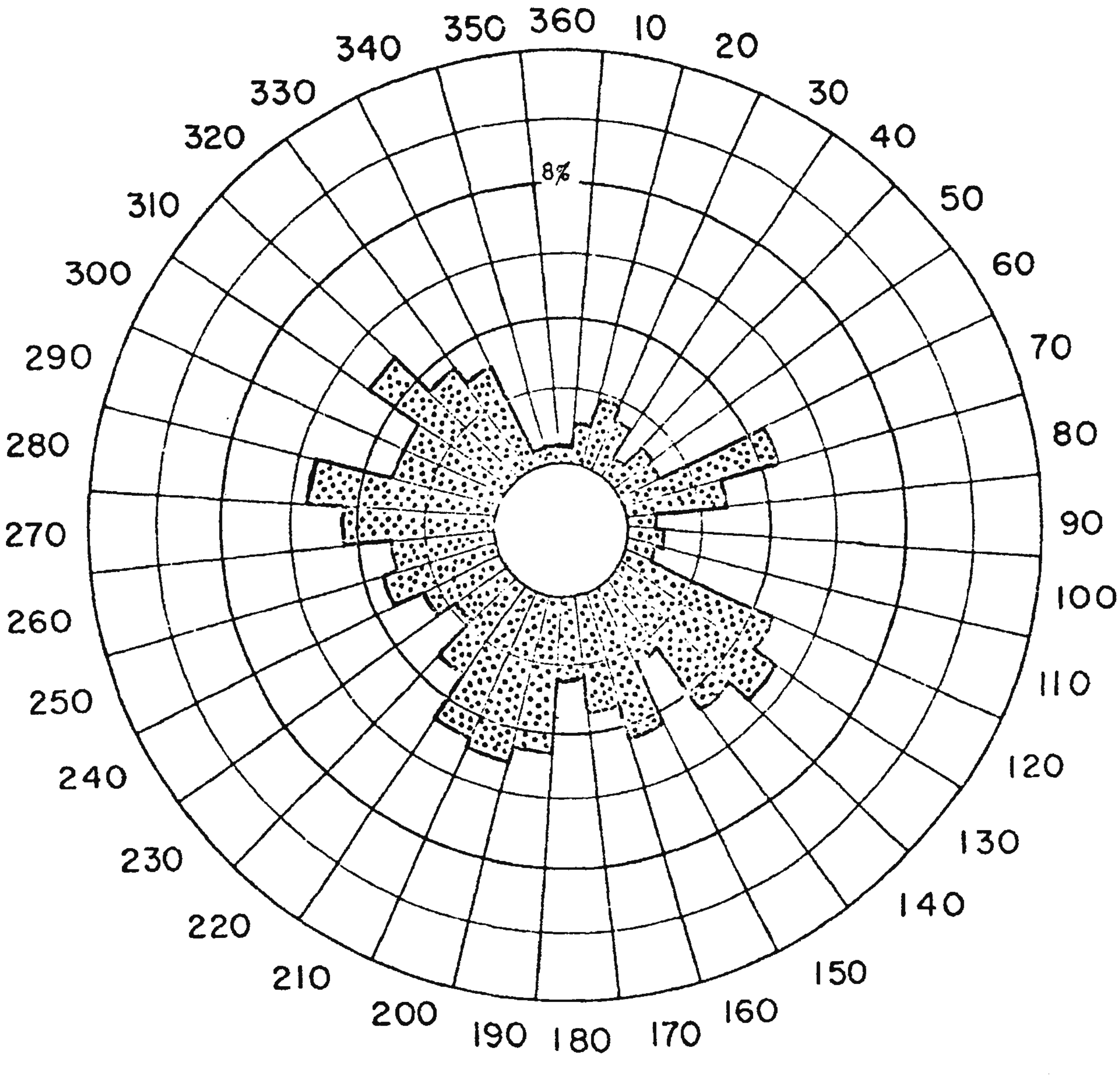


FIGURE 2.2-19

July, 1982

STATION BENTON HARBOR

HEIGHT 200-FOOT LEVEL

PERIOD SPRING

TURBULENCE CLASS - ALL

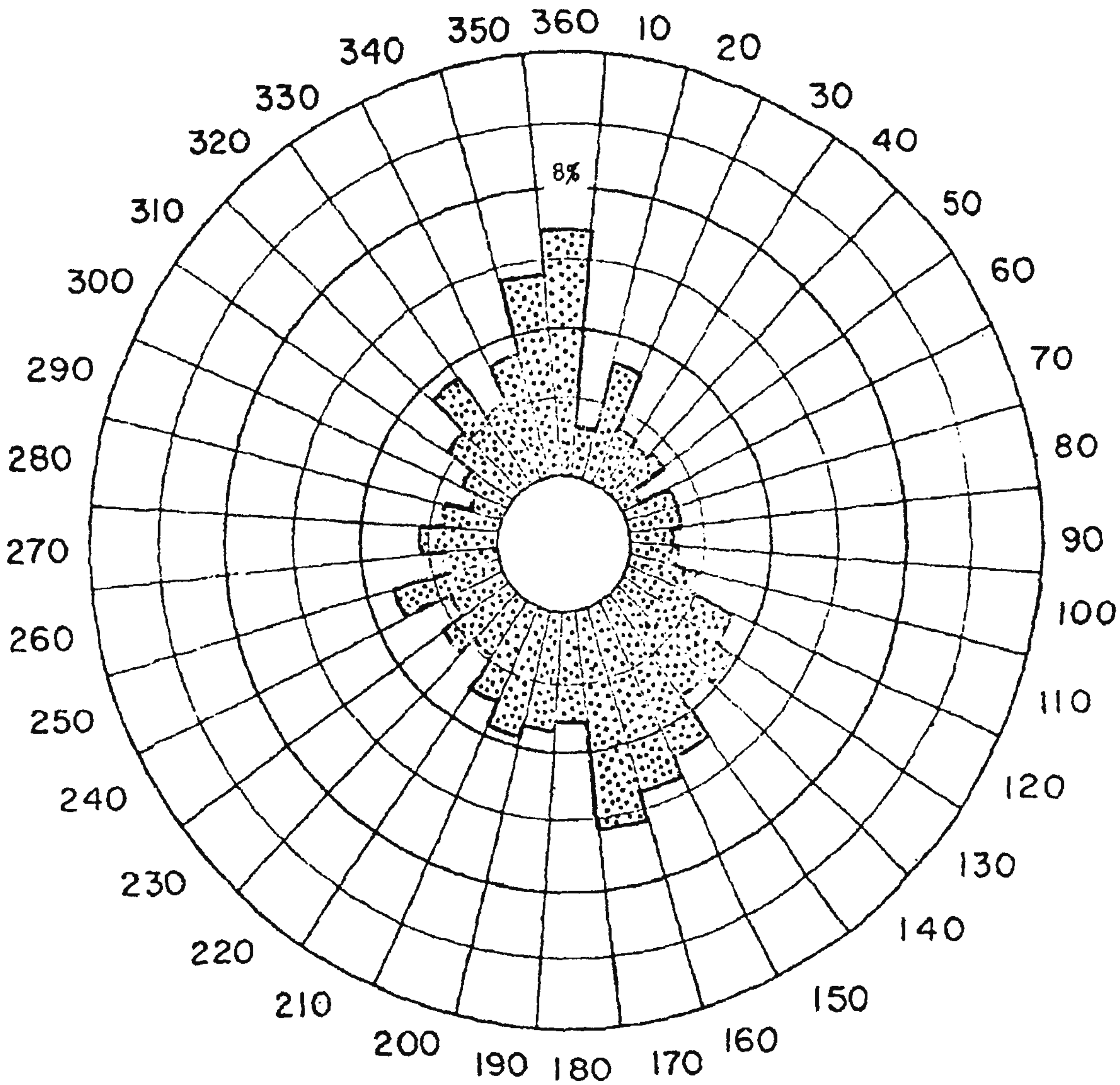


FIGURE 2.2-20

July, 1982

STATION	BENTON HARBOR
HEIGHT	200-FOOT LEVEL
PERIOD	SUMMER

TURBULENCE CLASS - ALL

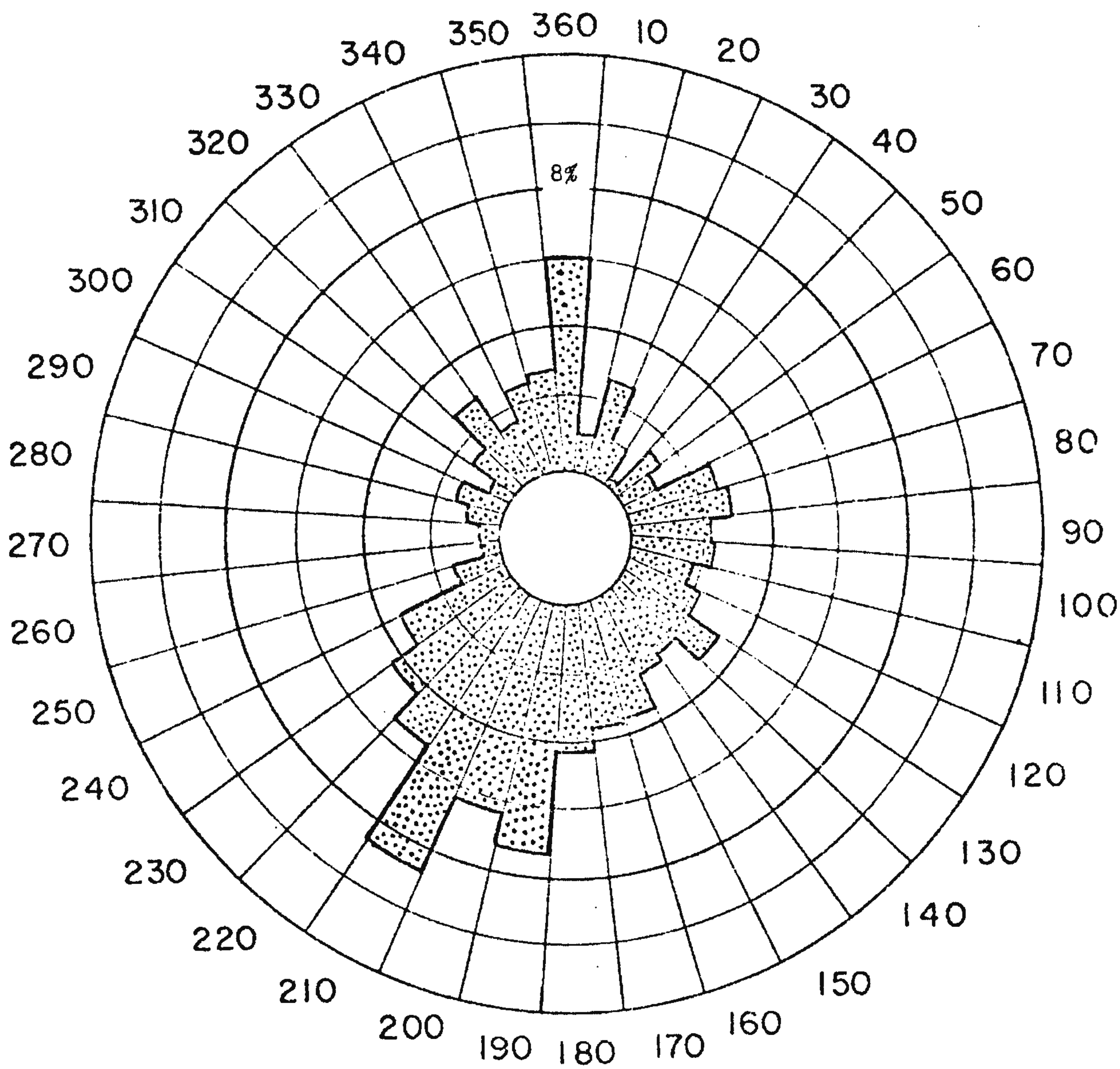


FIGURE 2.2-21

July, 1982

STATION BENTON HARBOR

HEIGHT 200-FOOT LEVEL

PERIOD FALL

TURBULENCE CLASS - ALL

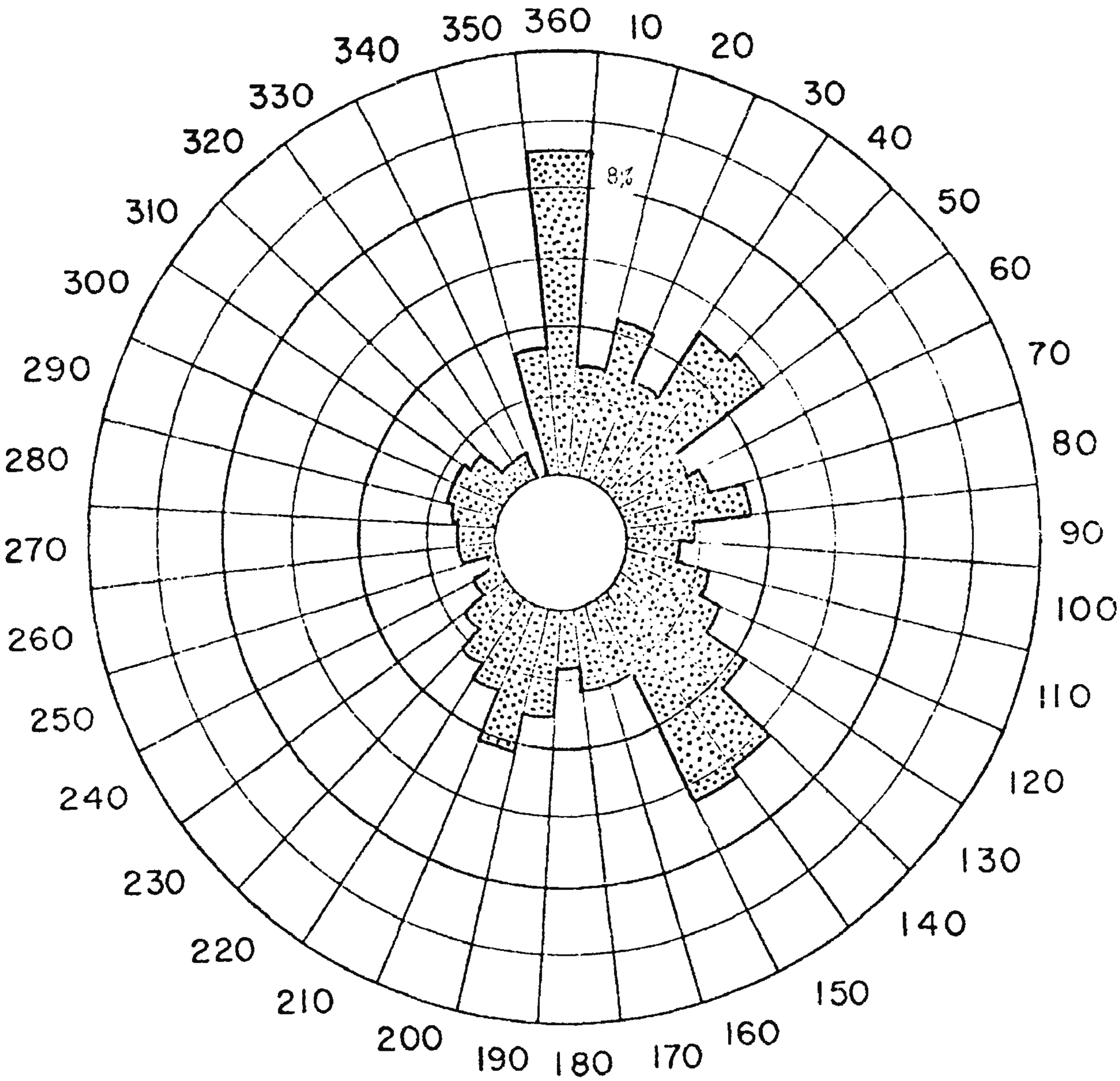


FIGURE 2.2-22

July, 1982

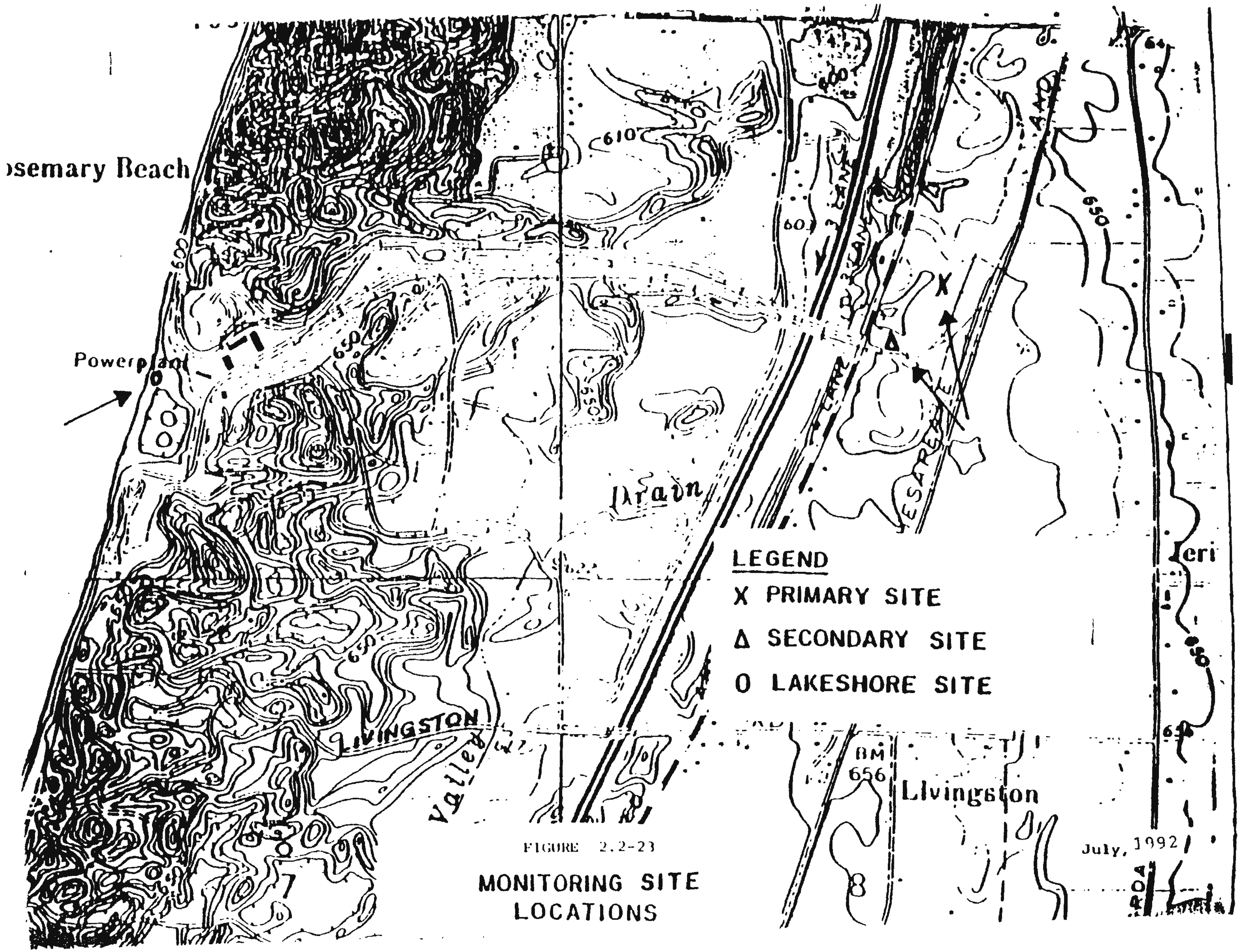
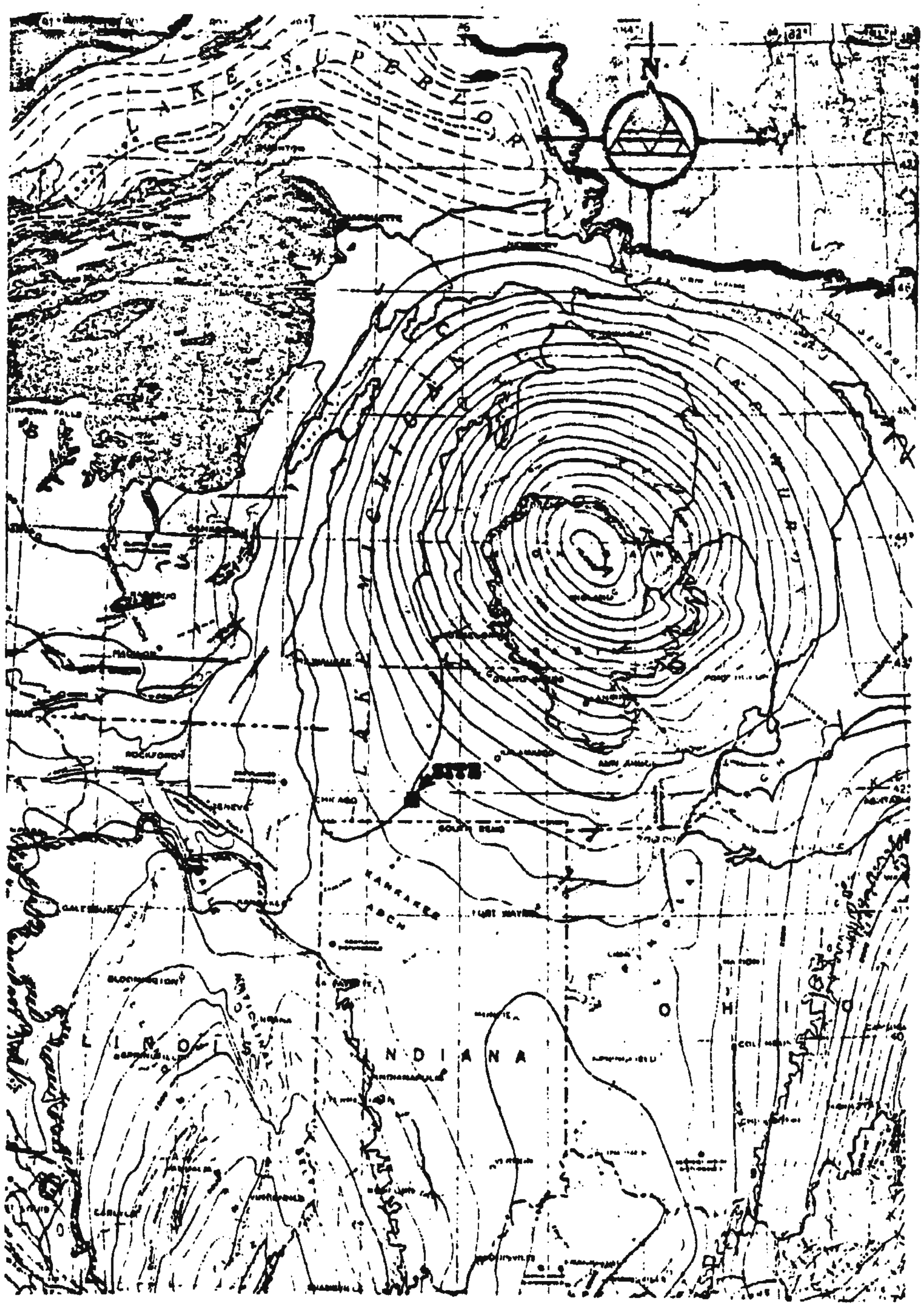


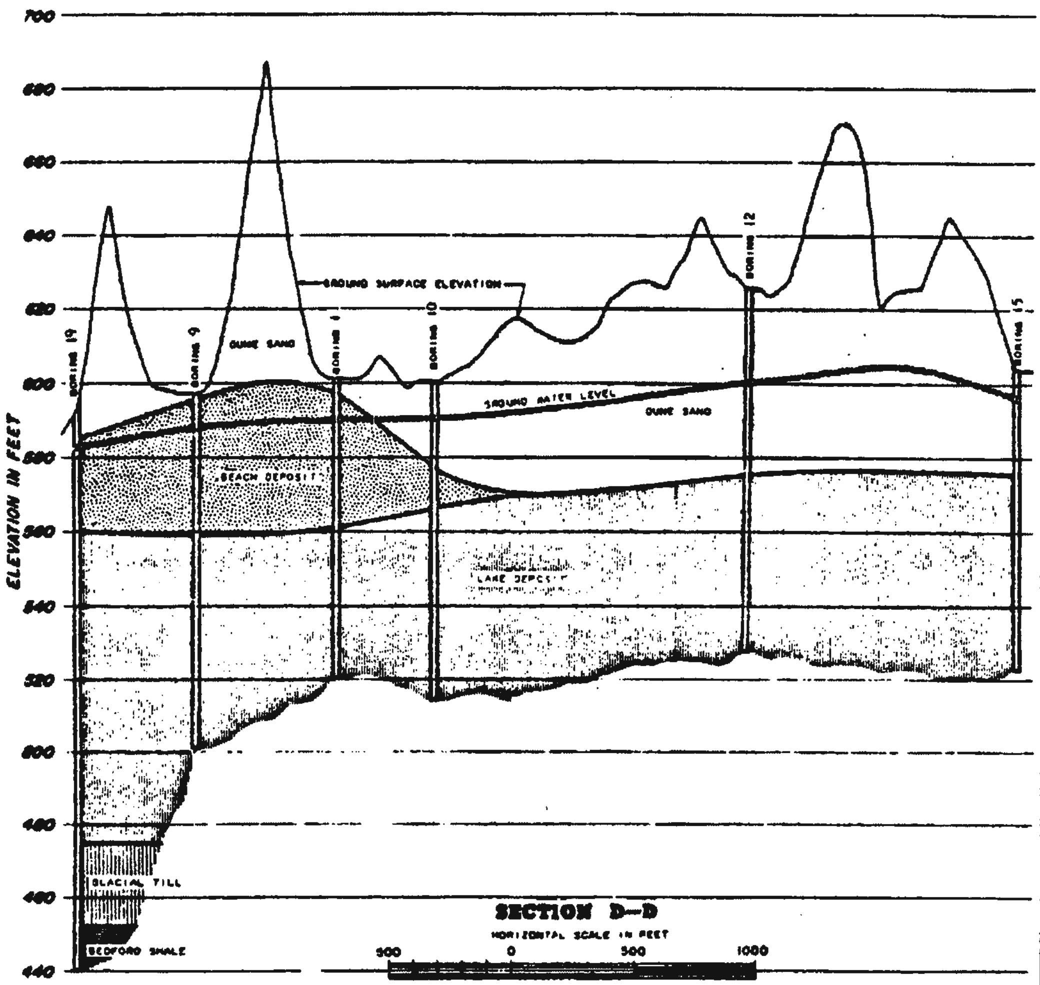
FIGURE 2.2-23

MONITORING SITE LOCATIONS



REGIONAL TECTONIC MAP

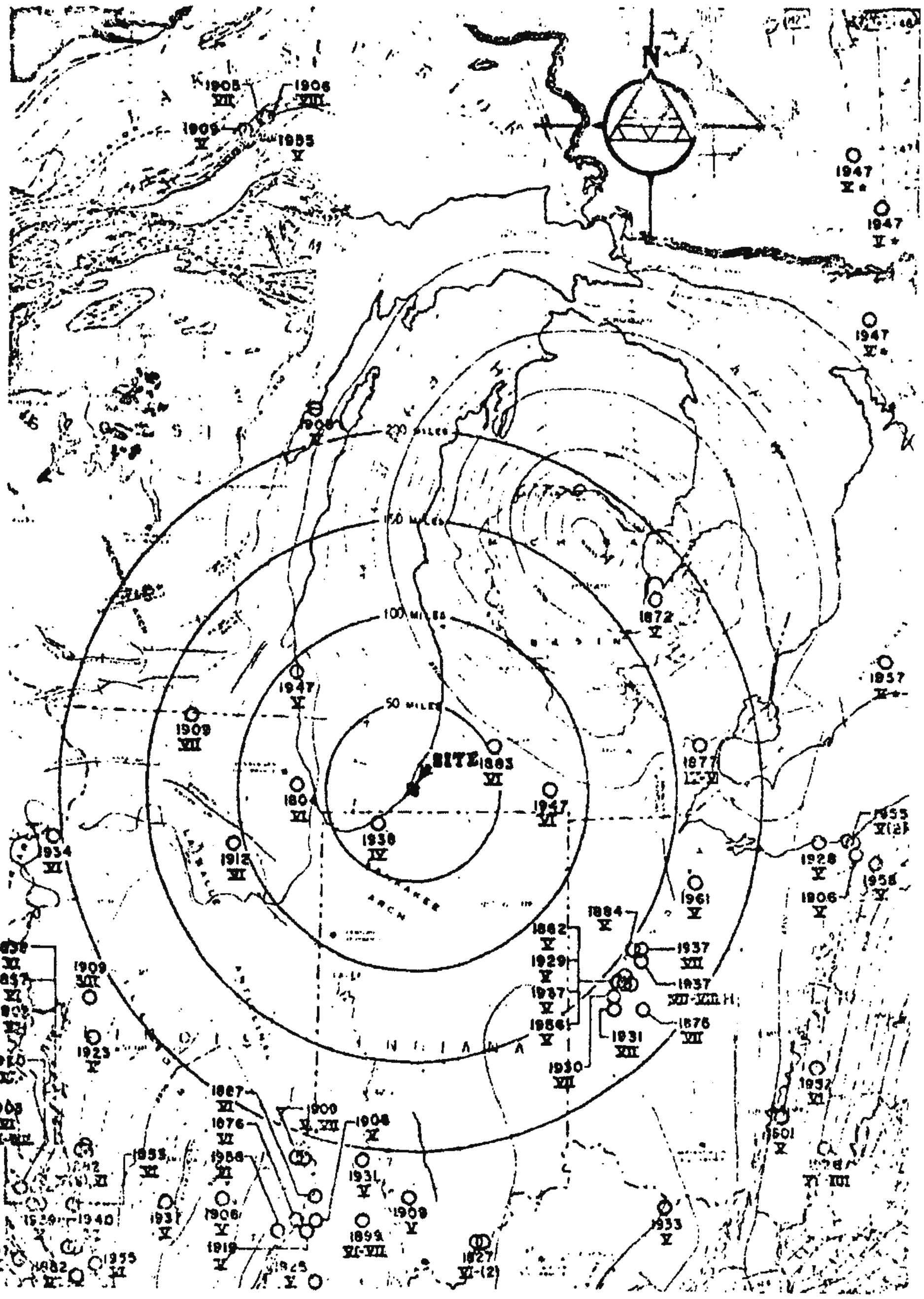
MILES 25 0 25 50 75 100



GEOLOGIC CROSS-SECTION

JULY 1982

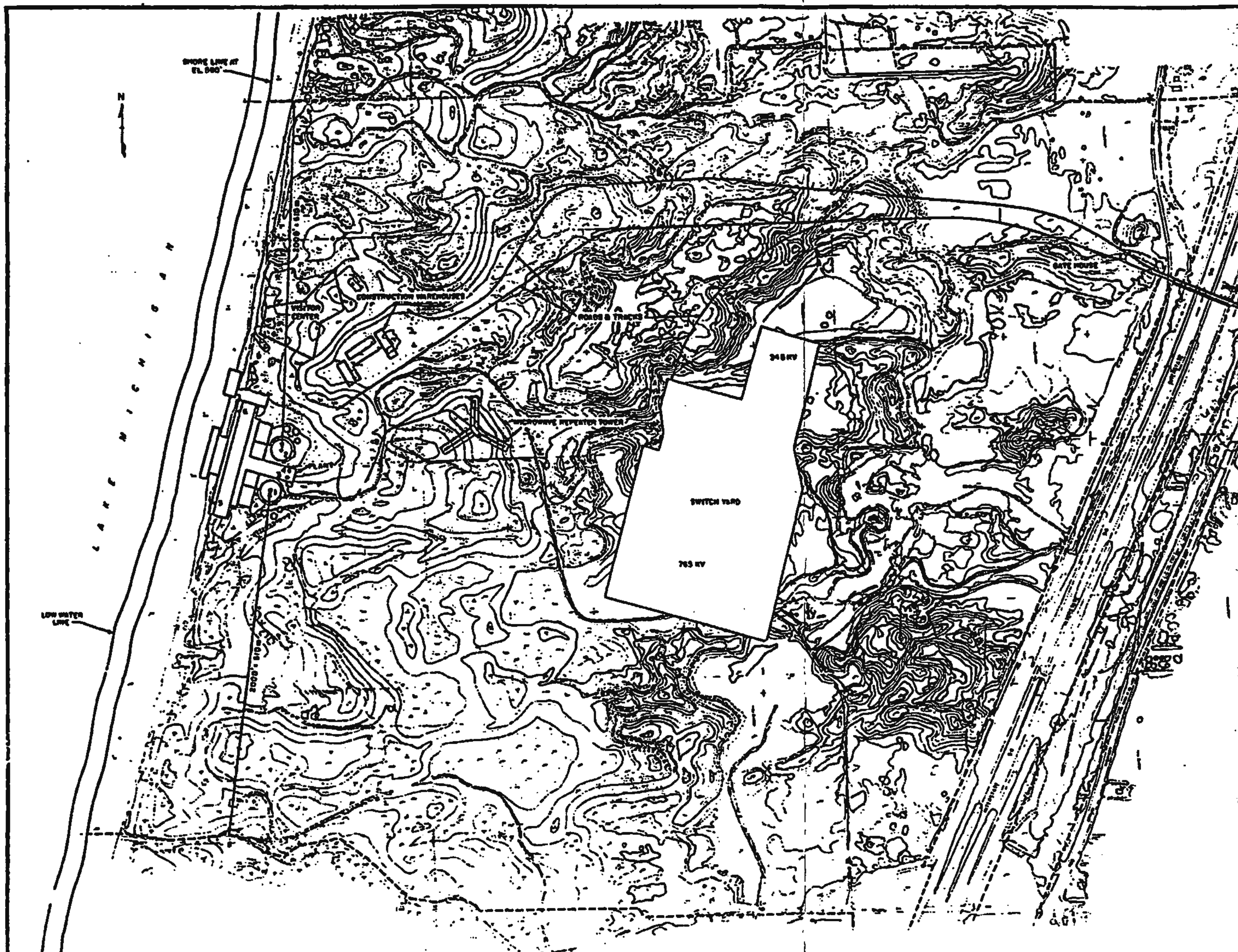
FIG. 2.3-2



EPICENTRAL LOCATION MAP

THE SYMBOL ★ INDICATES AN ESTIMATED EPICENTRAL INTENSITY.

FIG. 2.5-1



DONALD C. COOK NUCLEAR PLANT

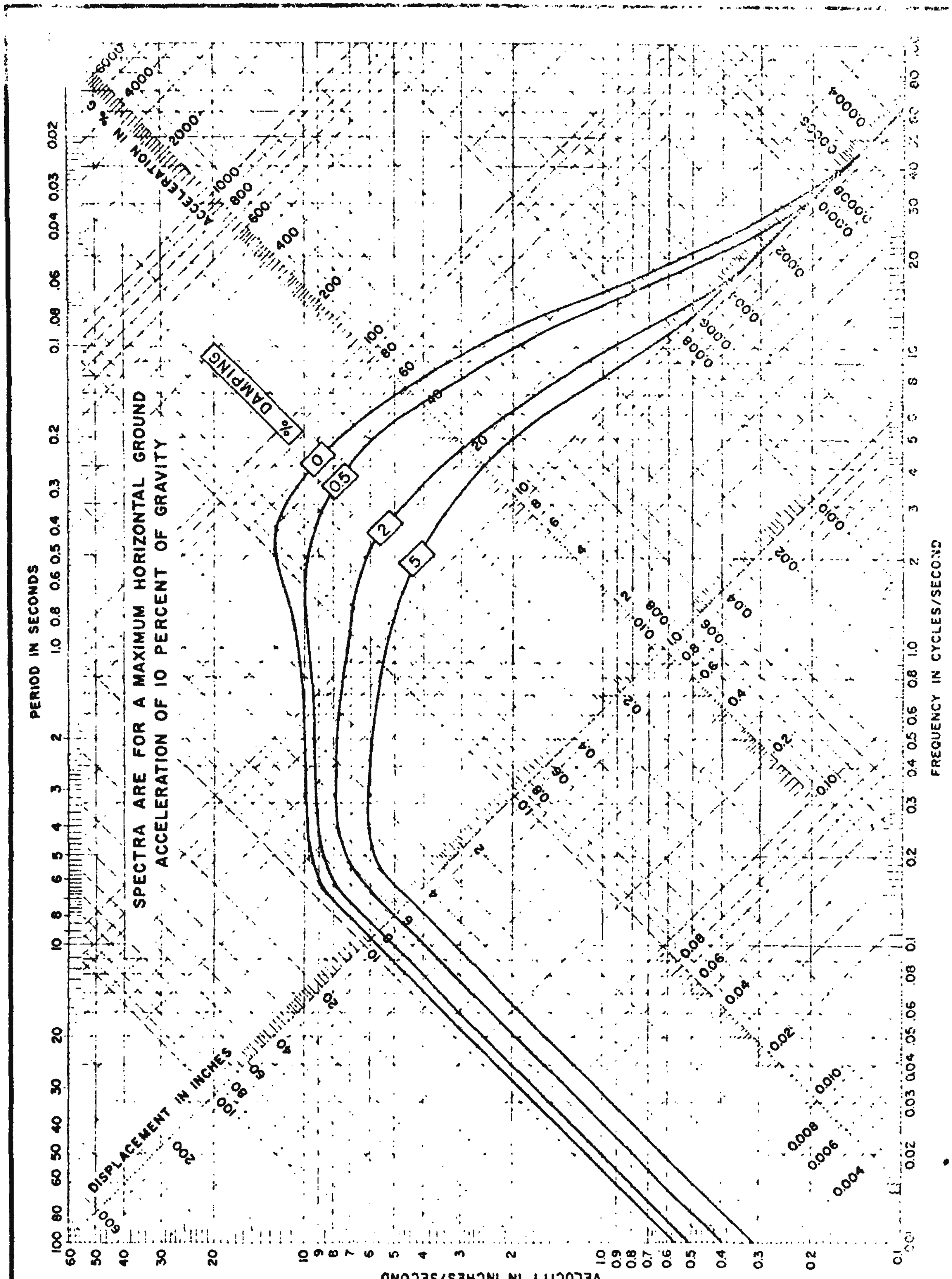
FIG. 2.5-1a

MAP OF PLANT SITE

NUMBER	ITEM	DISTANCE
1	UNIT #1 VENT	2000' = 610 m
2	UNIT #2 VENT	2,000' = 610 m
3	SG. BLOWDOWN #1 VENT	2,050'
4	SG. BLOWDOWN #2 VENT	1,960'
5	STEAM JET AIR EJECTOR #1	1,920'
6	STEAM JET AIR EJECTOR #2	1,780'

JULY 1996

/usr11/nmec/cook/ul2 app/ufsar2.400
/usr11/nmec/cook/ul2 app/ufsar2.cit



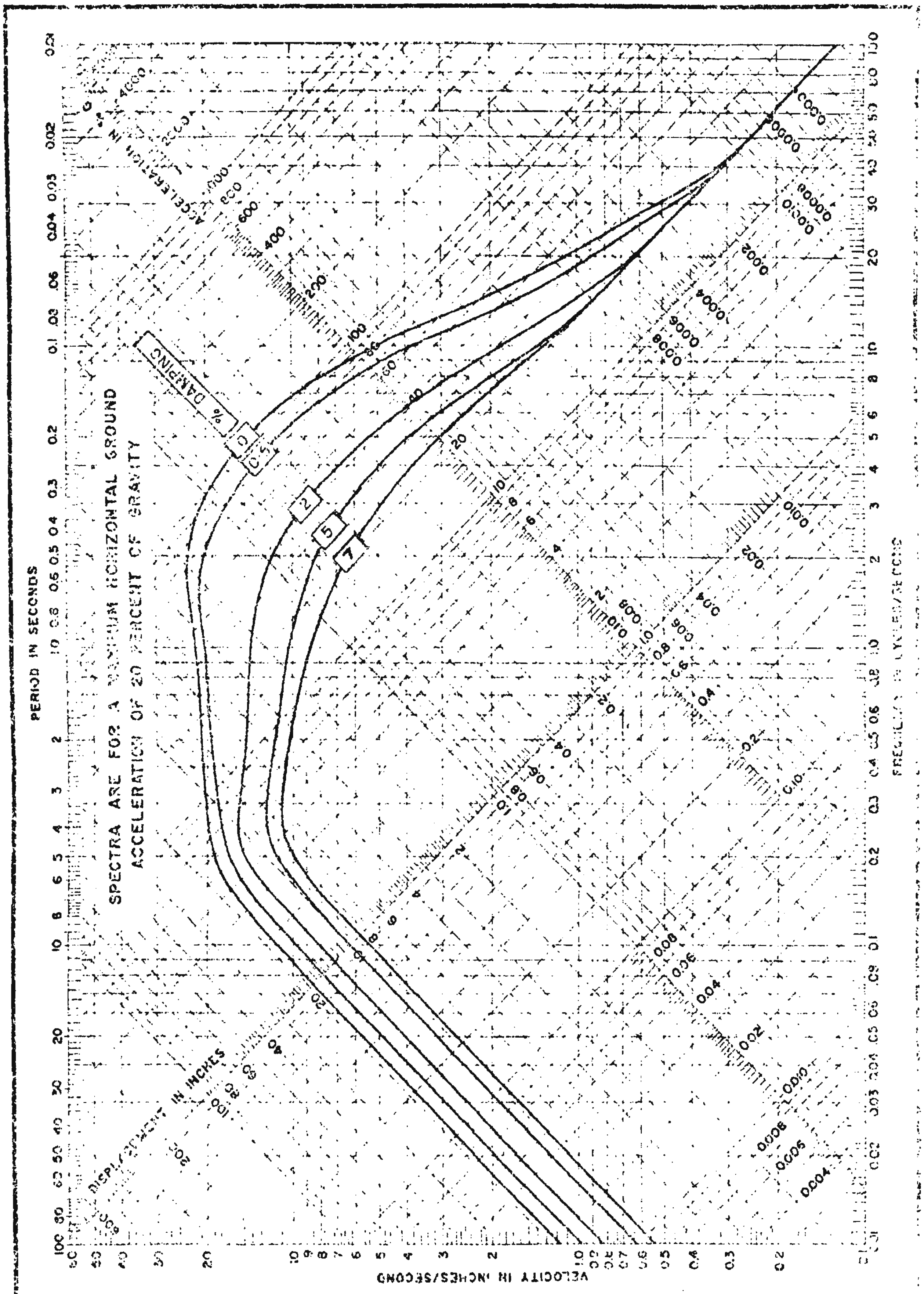
July, 1982

RECOMMENDED RESPONSE SPECTRA

OPERATING BASIS EARTHQUAKE

DAMES & MOORE

FIGURE 2.5-2



RECOMMENDED RESPONSE SPECTRA

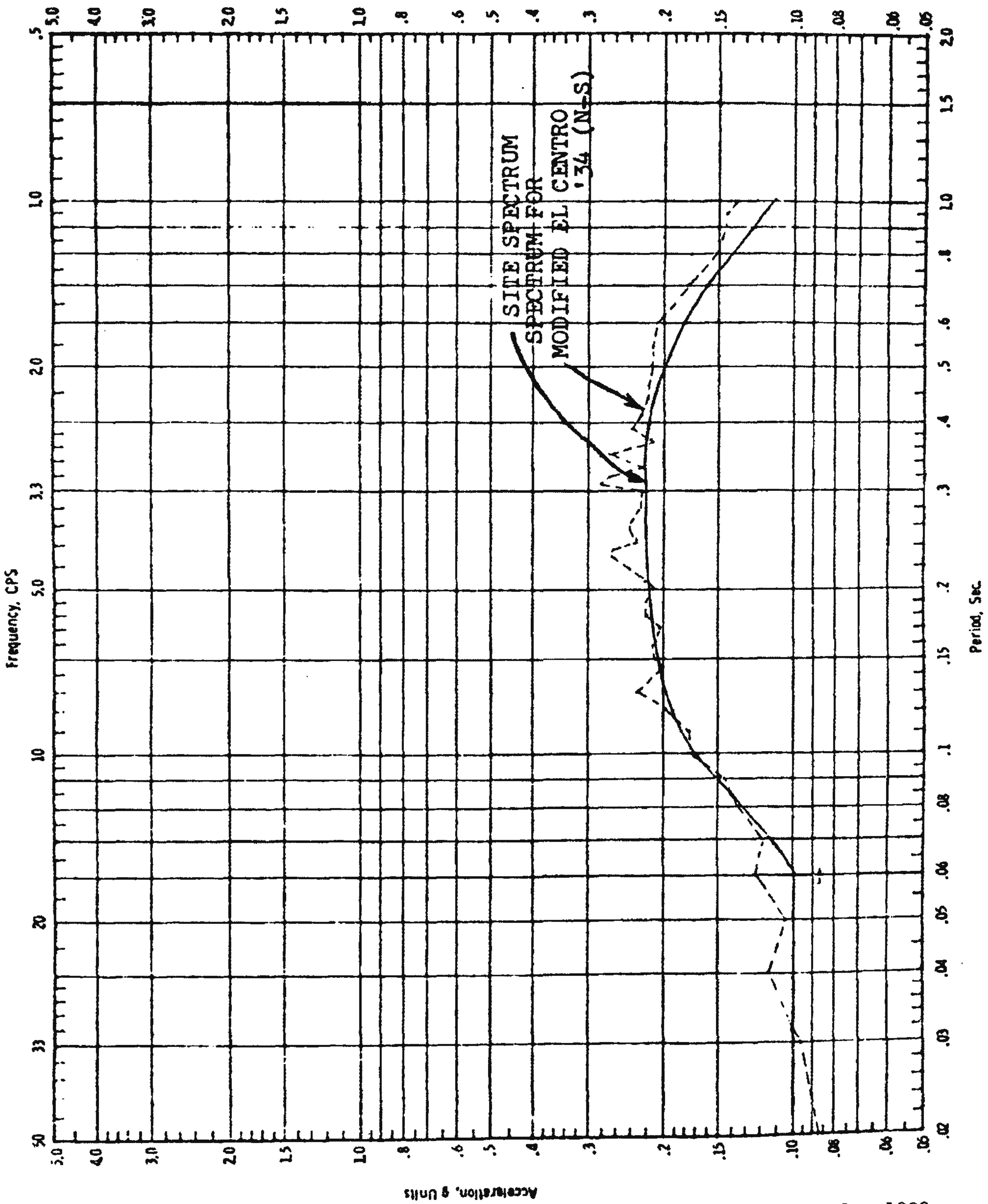
DESIGN BASIS EARTHQUAKE

July, 1982

FIGURE 2.5-3

SARGENT & LUNDY
ENGINEERS

CLIENT AEP SERVICE CORPORATION
PROJECT D.C. COOK JOB NO. 4210
DESIGN BY SGM DATE OCTOBER 12, 1972
CHECKED BY HHS DATE " SHEET ___ OF ___



July, 1982

Figure 2.5-3a SITE SPECTRA V.S. MODIFIED EL CENTRO '34
OPERATING BASIS EARTHQUAKE
(2% DAMPING)

SARGENT & LUNDY ENGINEERS	CLIENT AEP SERVICE CORPORATION
	PROJECT D. C. COOK JOB NO. 4210
	DESIGN BY SGH DATE October 12, 1972
	CHECKED BY HHS DATE 10-12-72 SHEET __ OF __

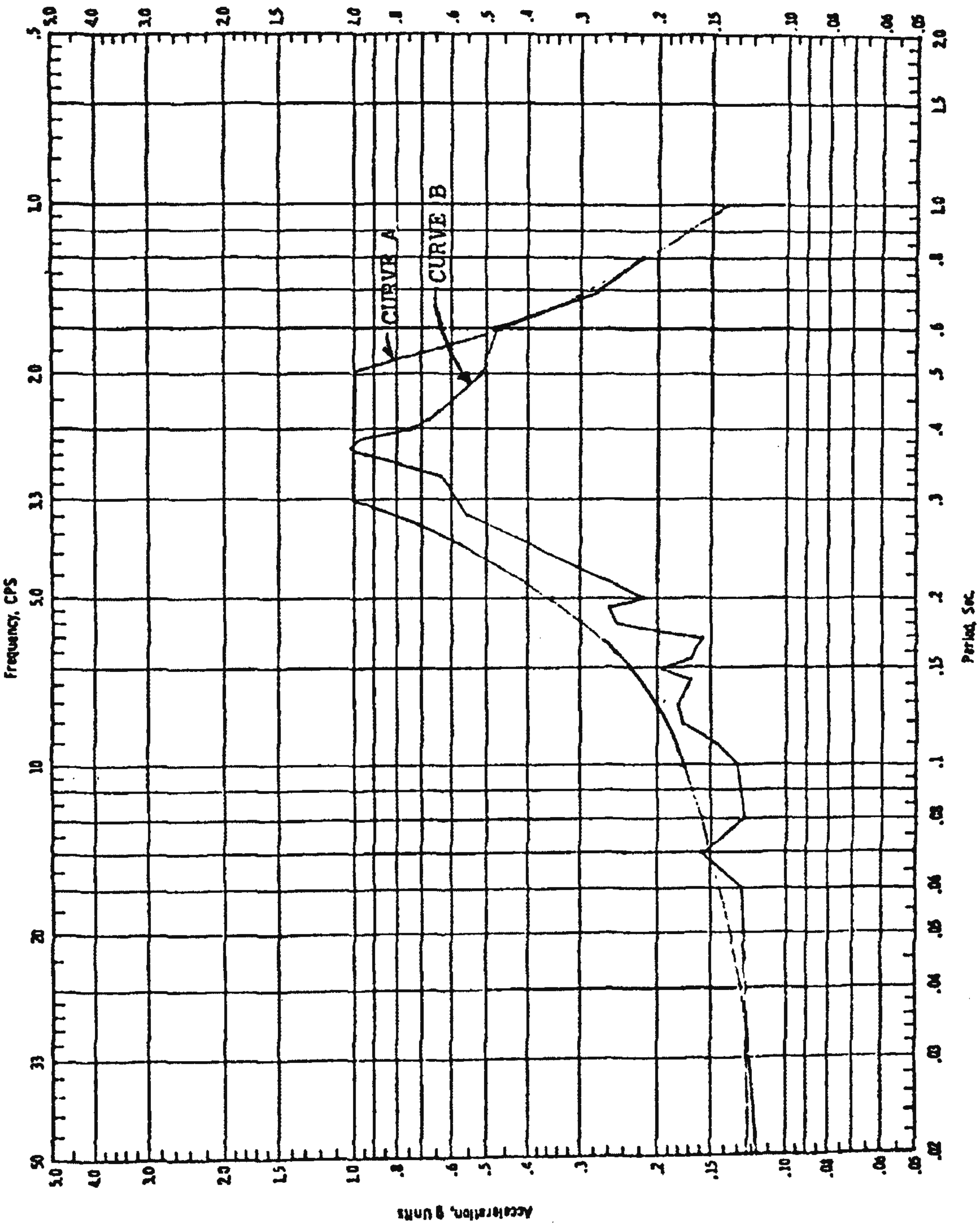


Figure 2.5-3b

RESPONSE SPECTRA (½% DAMPING)
COOK AUXILIARY BUILDING
FLOOR EL. 650'-0"
OPERATING BASIS EARTHQUAKE

July, 1982

ENGINEERS

CLIENT AEP SERVICE CORPORATION
PROJECT D.C. COOK JOB NO. 4210
DESIGN BY SGM DATE OCTOBER 12, 1972
CHECKED BY HHS DATE 10-16-72 SHEET ___ OF ___

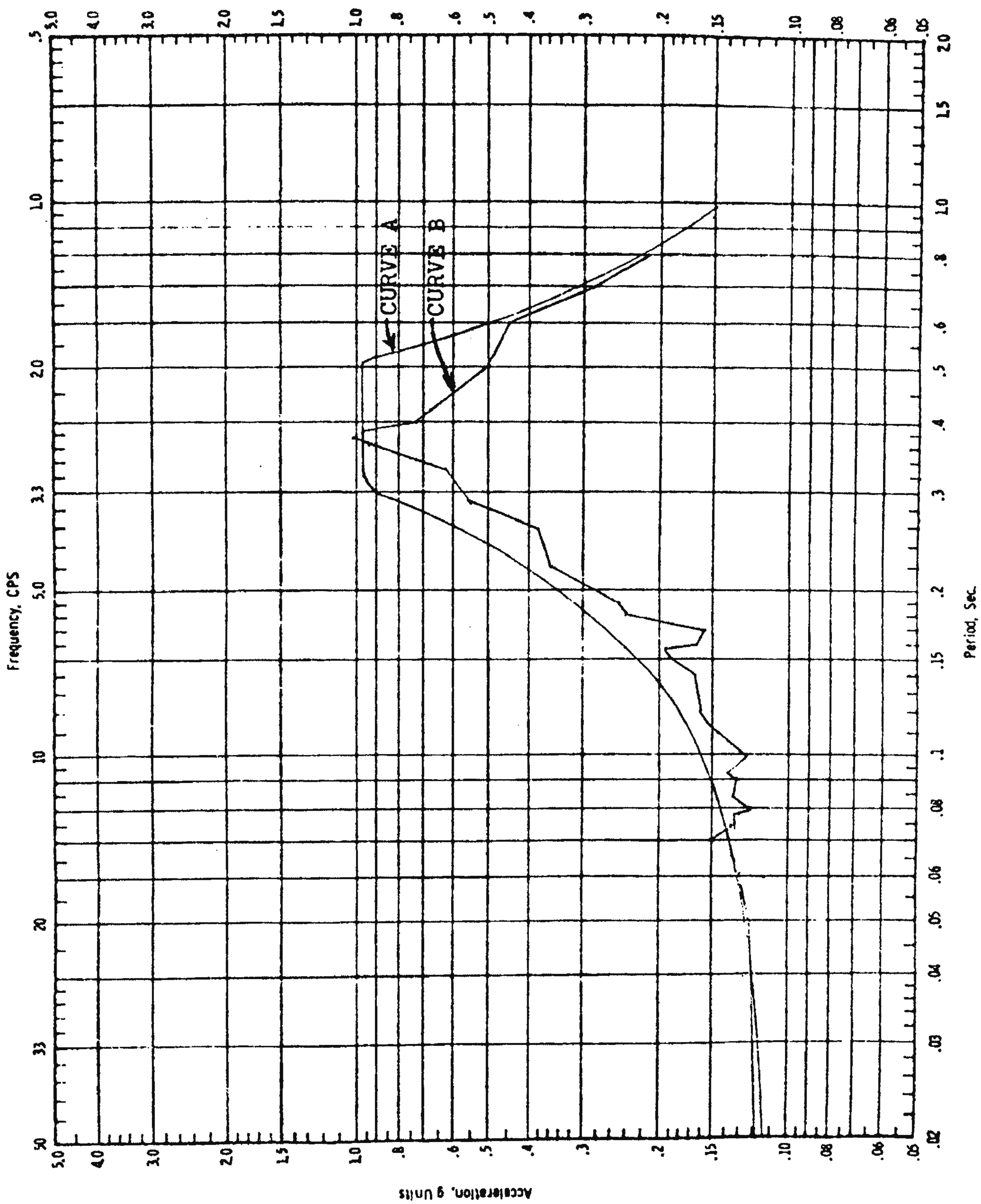


Figure 2.5-3c RESPONSE SPECTRA (½% DAMPING)
COOK AUXILIARY BUILDING
FLOOR EL. 633'-0"
OPERATING BASIS EARTHQUAKE

July, 1982

SARGENT & LUNDY
ENGINEERS

CLIENT AEP SERVICE CORPORATION
PROJECT D.C. COOK JOB NO. 4210
DESIGN BY SGM DATE OCTOBER 12, 1972
CHECKED BY HHS DATE 10-16-72 SHEET ___ OF ___

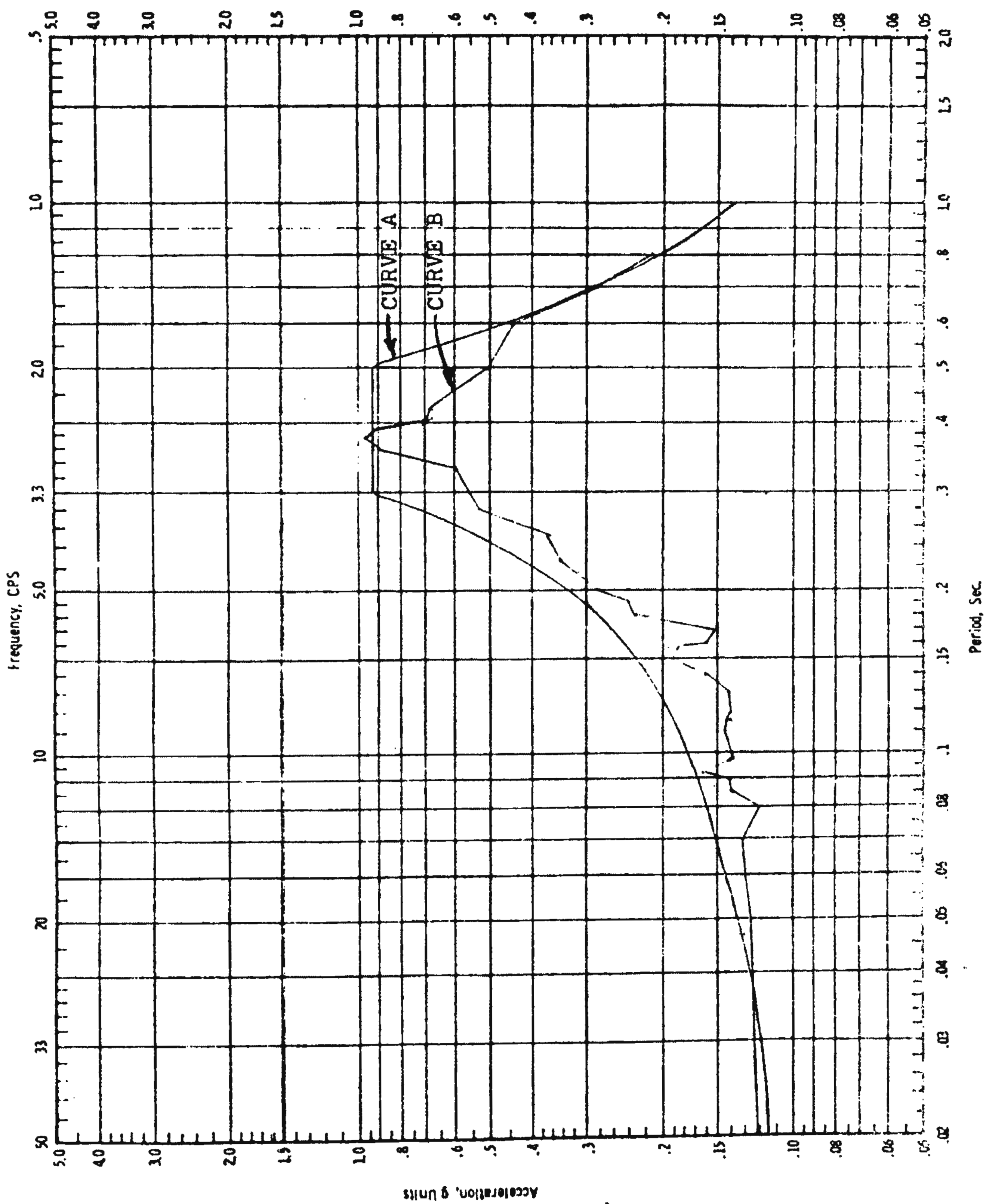


Figure 2.5-3d RESPONSE SPECTRA (½% DAMPING)
COOK DIESEL GENERATOR BUILDING
FLOOR EL. 609'-0"
OPERATING BASIS EARTHQUAKE

July, 1982

SARGENT & LUNDY ENGINEERS

CLIENT AEP SERVICE CORPORATION
PROJECT D.C. COOK JOB NO. 4210
DESIGN BY SGM DATE OCTOBER 12, 1972
CHECKED BY HHS DATE 10-16-72 SHEET ___ OF ___

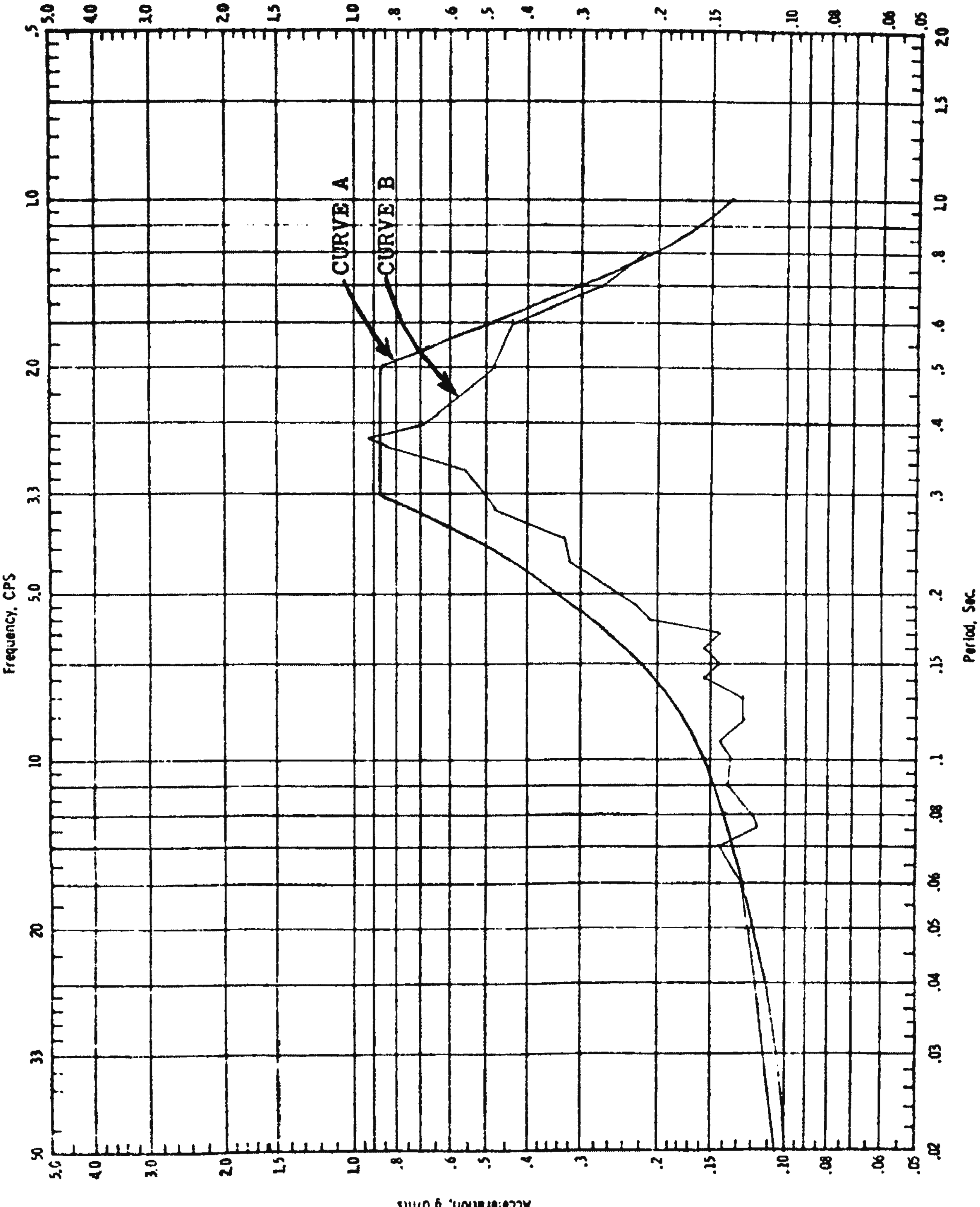
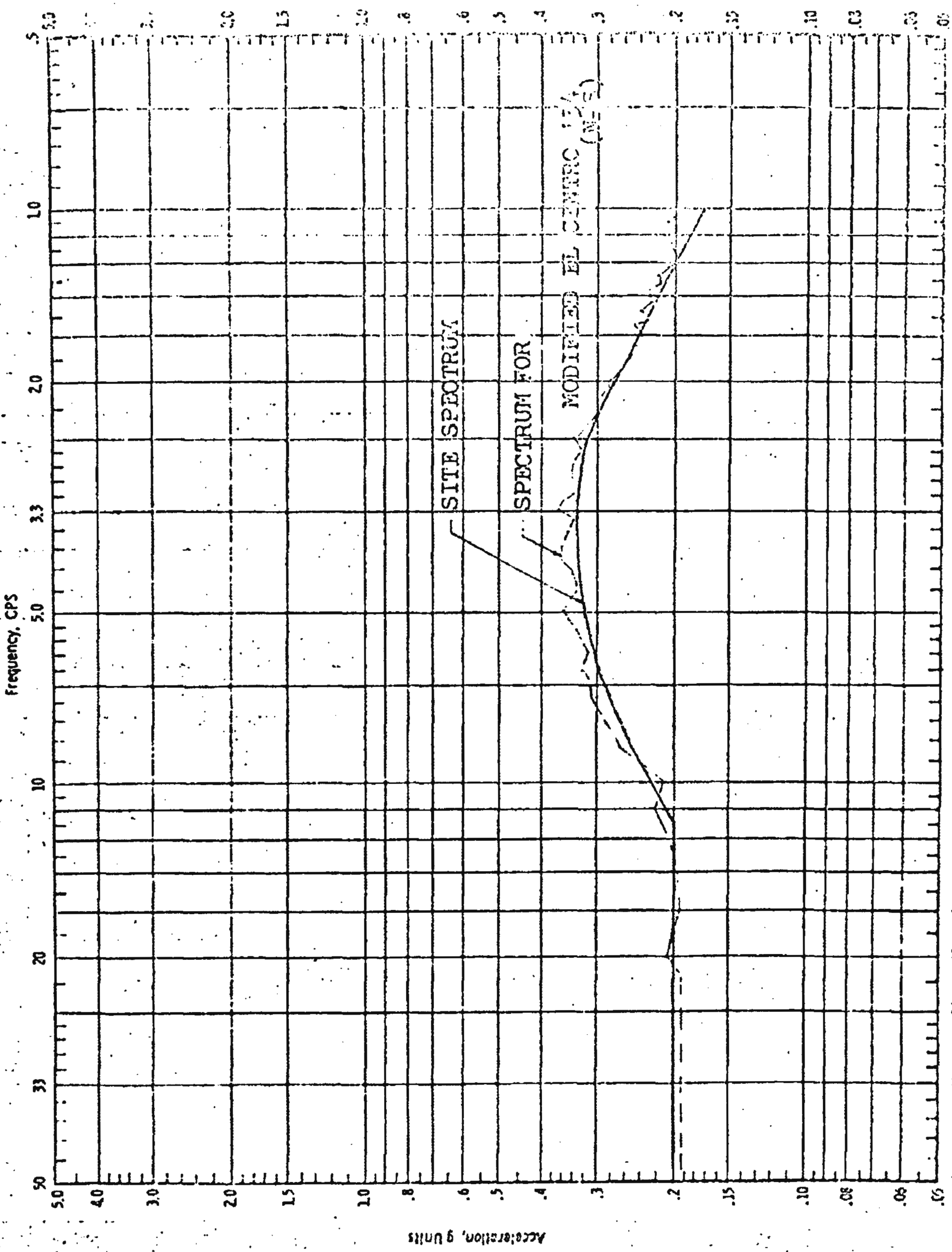


Figure 2.5-3e

RESPONSE SPECTRA (½% DAMPING)
COOK AUXILIARY BUILDING
FLOOR EL. 587'-0"
OPERATING BASIS EARTHQUAKE

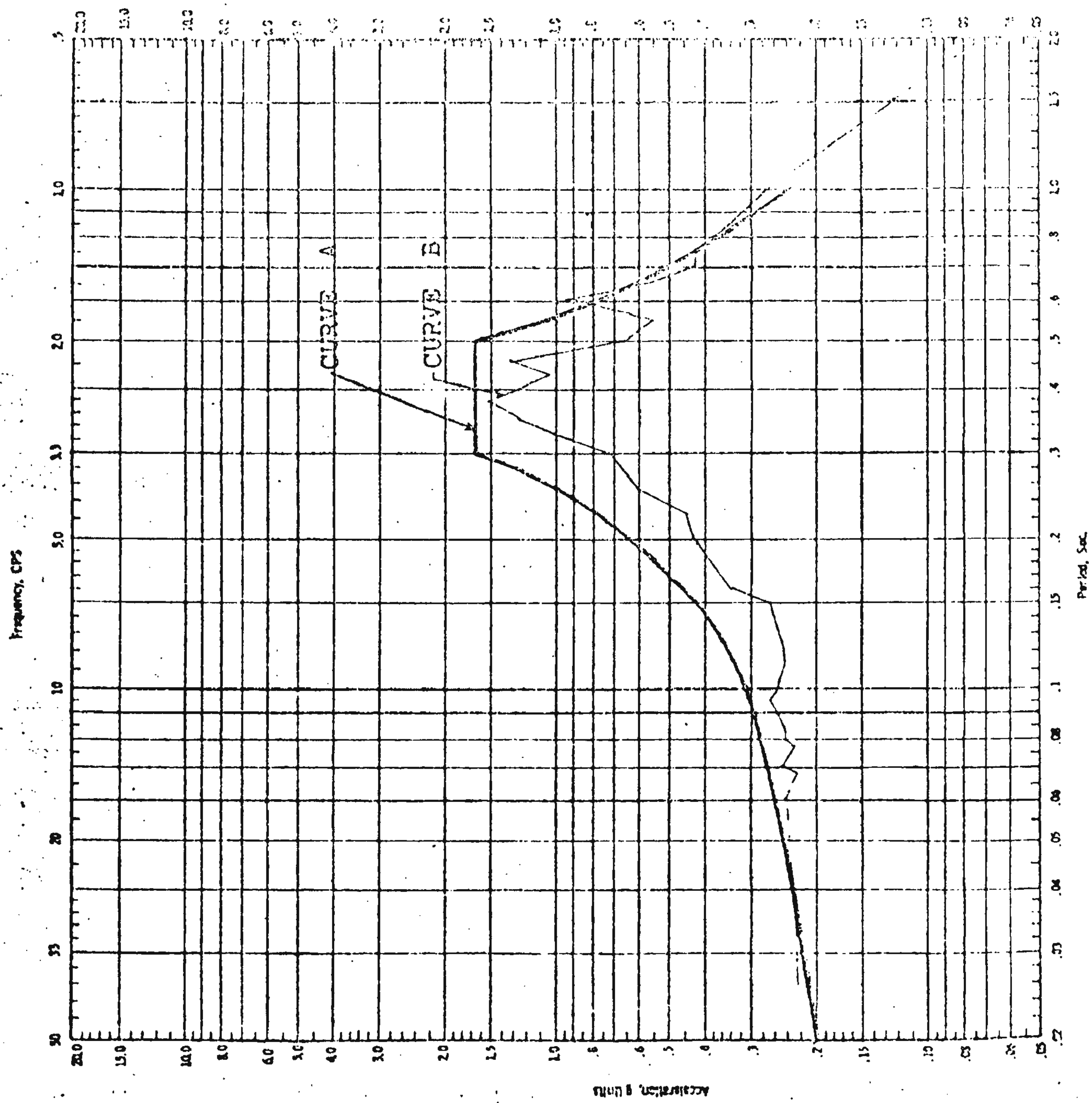
July, 1982



SITE SPECTRA VS. MODIFIED EL CENTRO '34
DESIGN BASIS EARTHQUAKE
(5% DAMPING)

Figure 2.5-3f

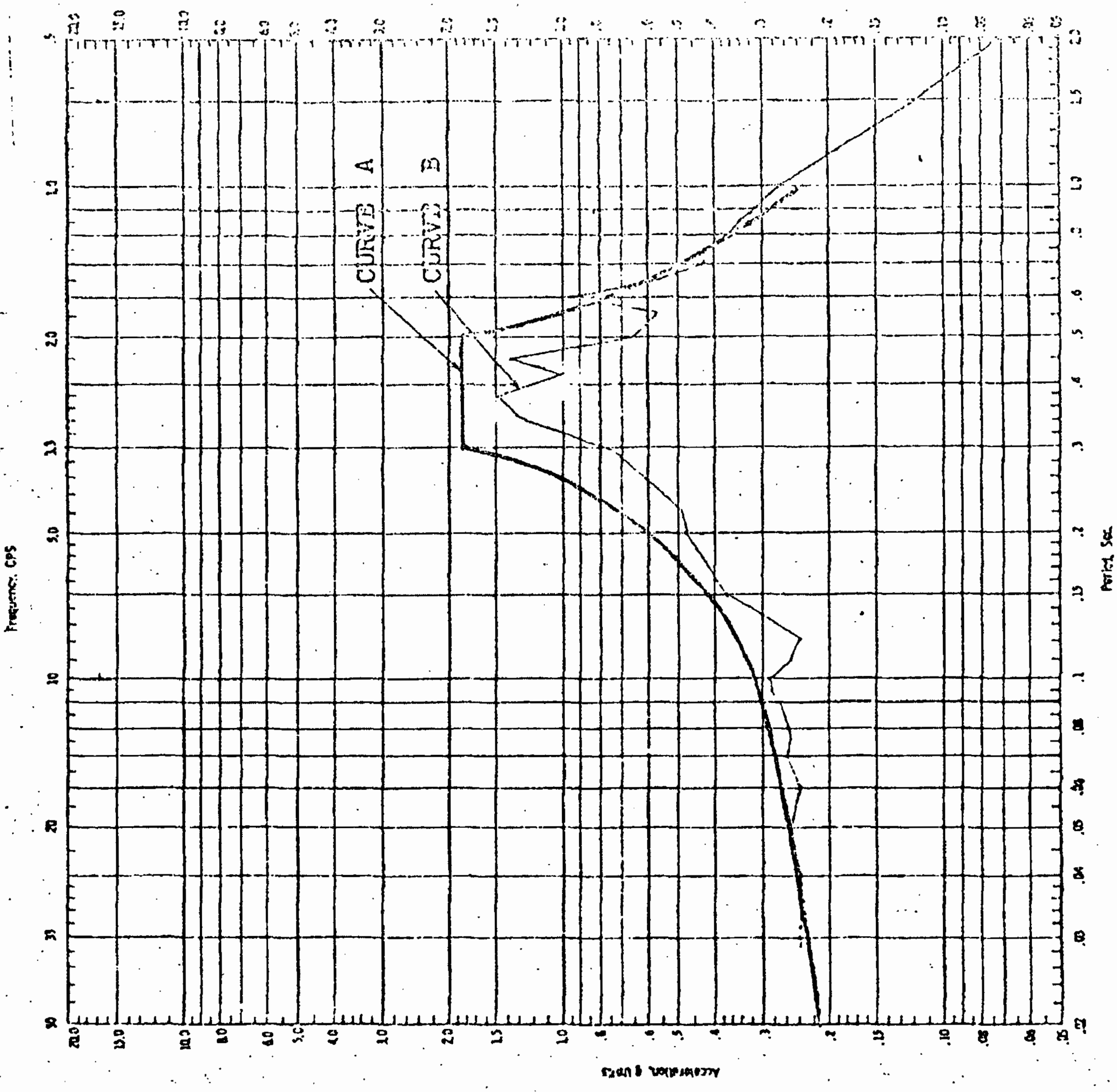
July, 1982



RESPONSE SPECTRA (½% DAMPING)
AUXILIARY BUILDING
FLOOR EL. 587'-0"
DESIGN BASIS EARTHQUAKE

Figure 2.5-3g

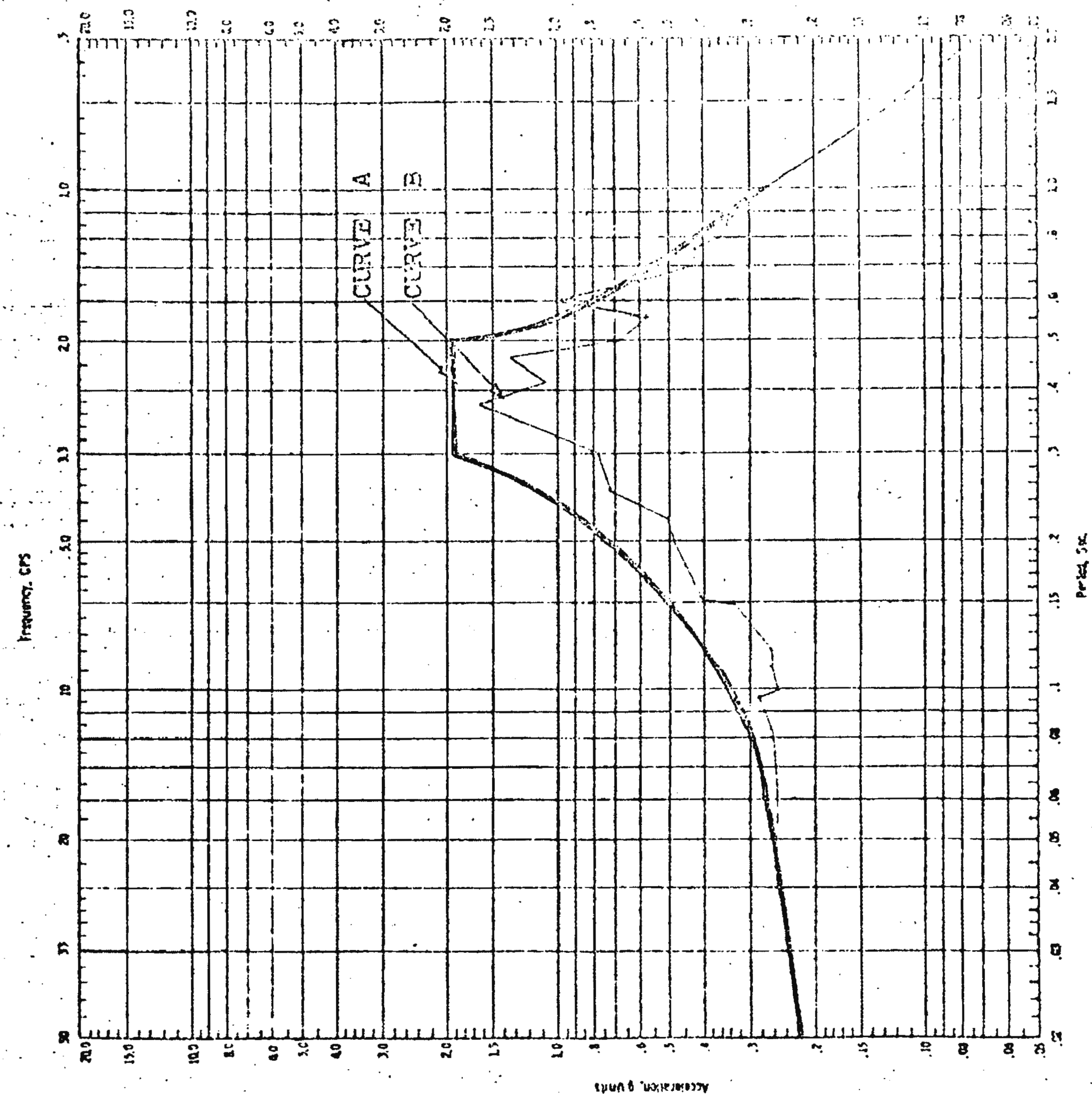
July, 1982



RESPONSE SPECTRA (½% DAMPING)
DIESEL GENERATOR BUILDING
FLOOR EL. 609'-0"
DESIGN BASIS EARTHQUAKE

Figure 2.5-3h

July, 1982

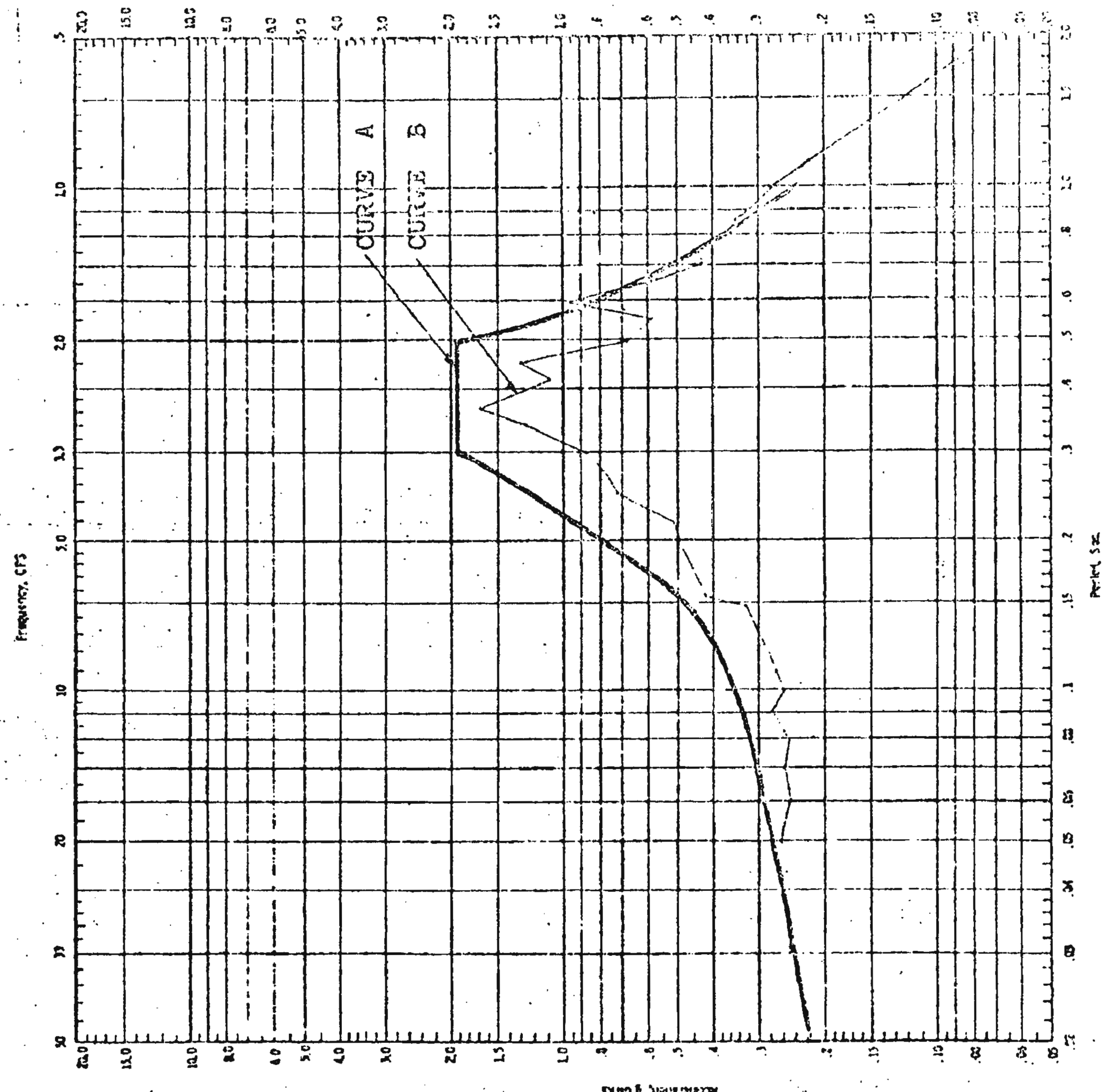


RESPONSE SPECTRA (½% DAMPING)
AUXILIARY BUILDING
FLOOR EL. 633'-0"
DESIGN BASIS EARTHQUAKE

Figure 2.5-3i

July, 1982

CLIENT ___
PROJECT ___
DESIGN BY ___ DATE ___
CHECKED BY ___ DATE ___



RESPONSE SPECTRA
(½% DAMPING)
AUXILIARY BUILDING
ELEVATION 650'-0"

Figure 2.5-3j

July, 1982

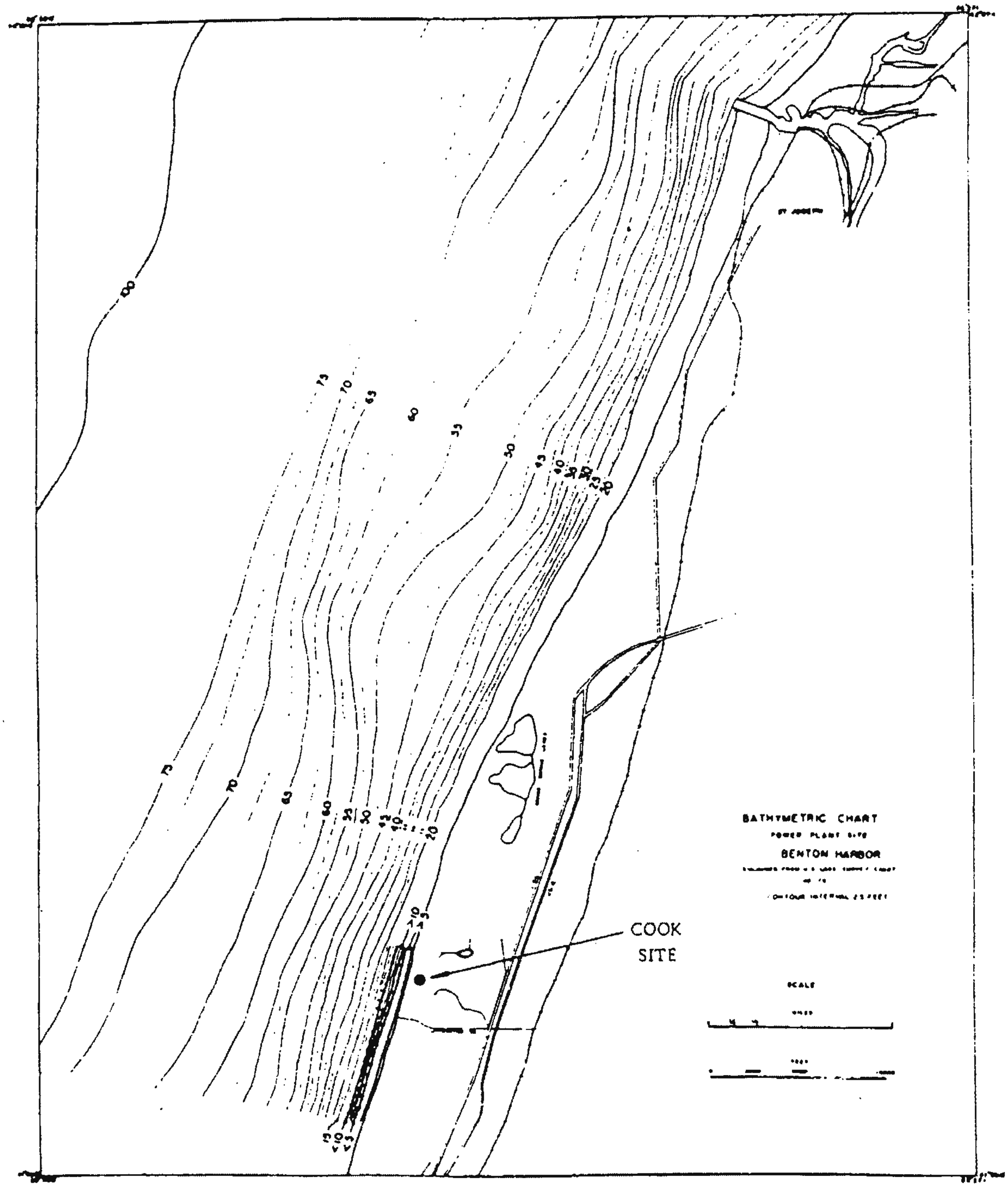
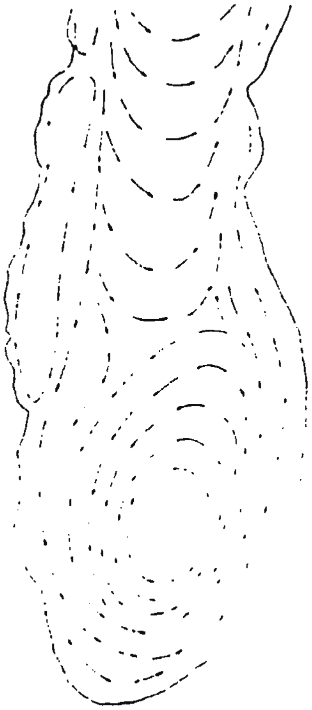
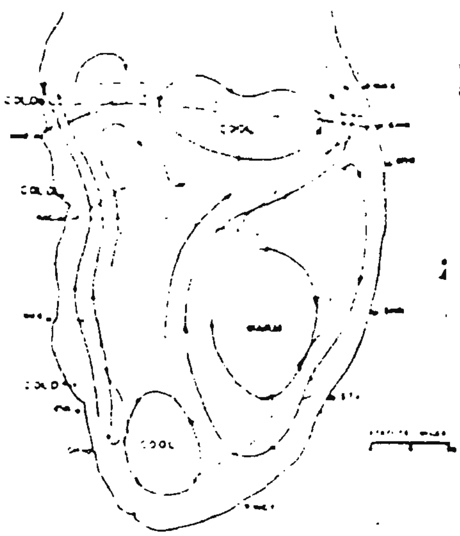


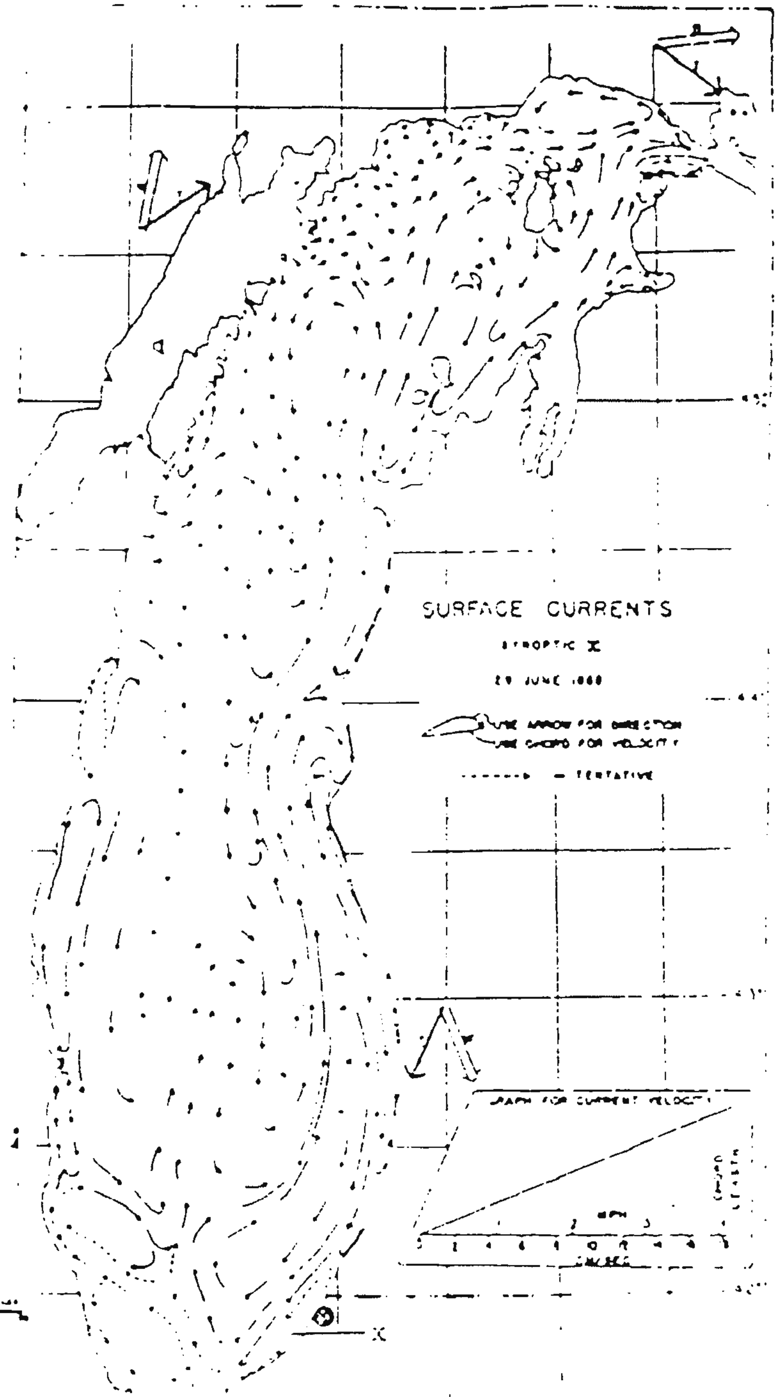
Figure 2.6-1. Bathymetric Chart of Lake Michigan Offshore from Donald C. Cook Nuclear Plant.



after Harrington (1895)
(from Hough 1958)



from Bellaire (1964)



from Ayers *et al* (1958)

Three concepts of the surface currents of Lake Michigan.

Figure 2.6-2

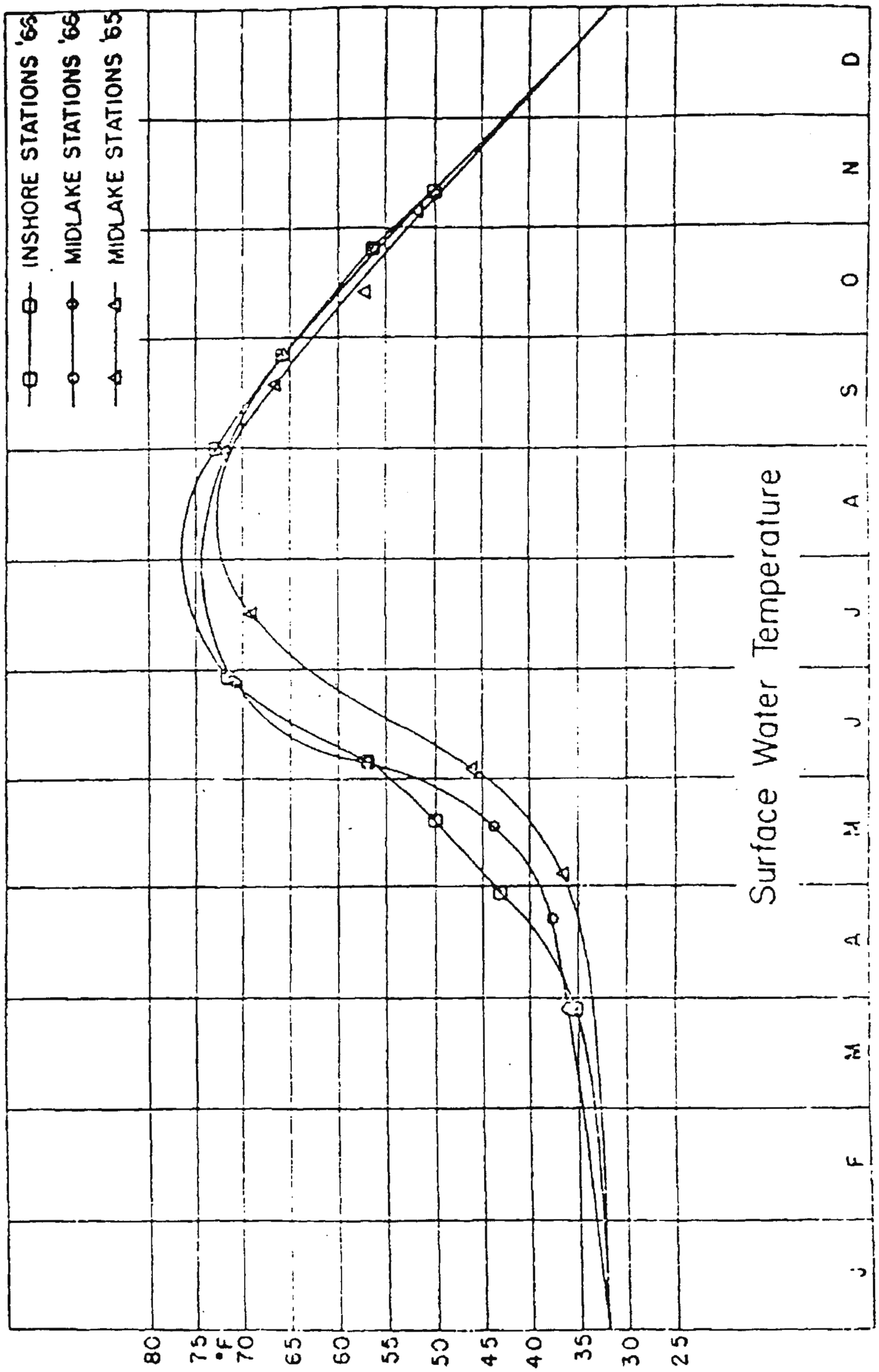


Figure 2.6-3: Surface Water Temperatures Measured Prior to Operation of the Donald C. Cook Nuclear Plant.

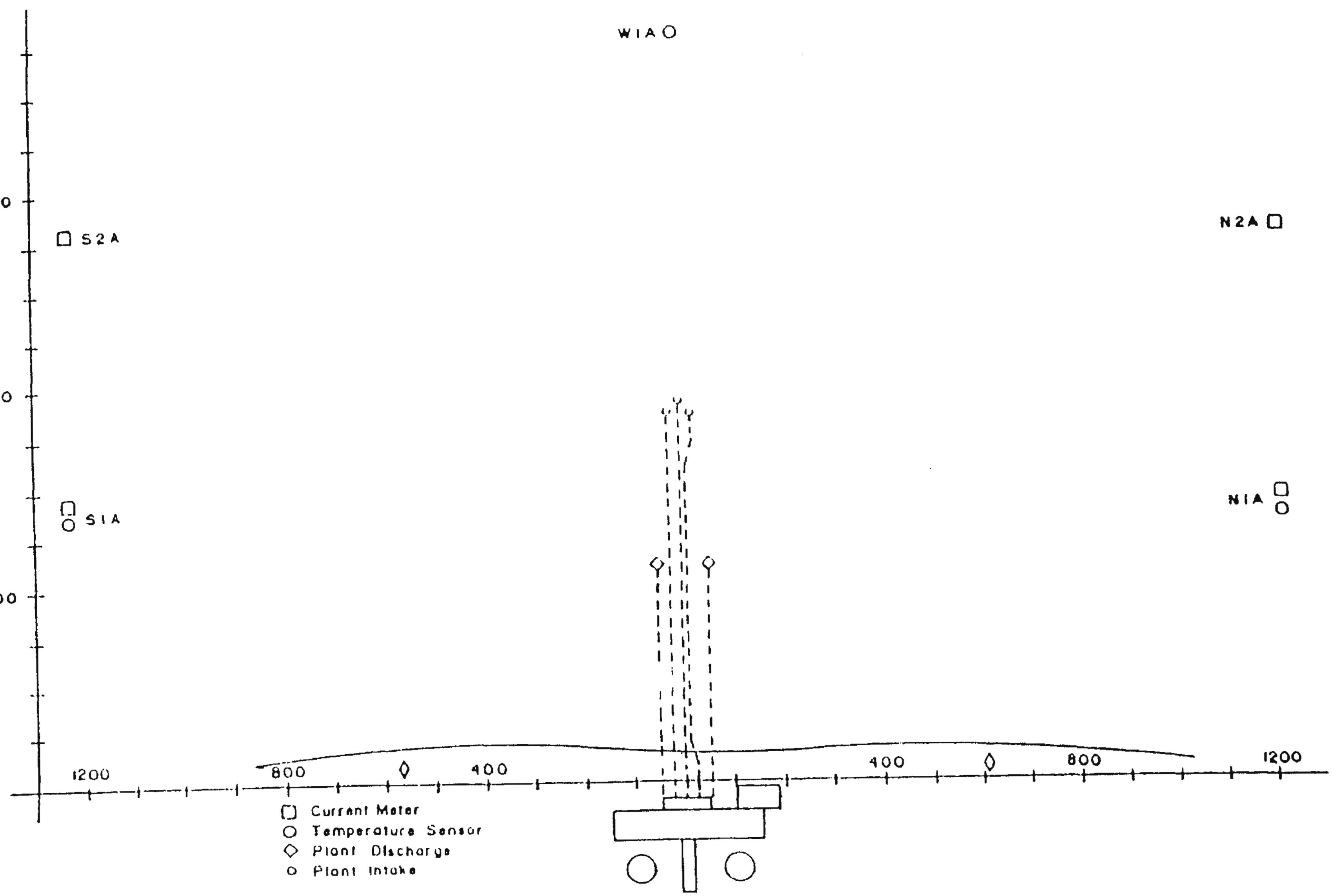


Figure 2.6-4. Locations of Current Meters and Temperature Recorders

9 3 1 0 1 0 3 0 7 3 5

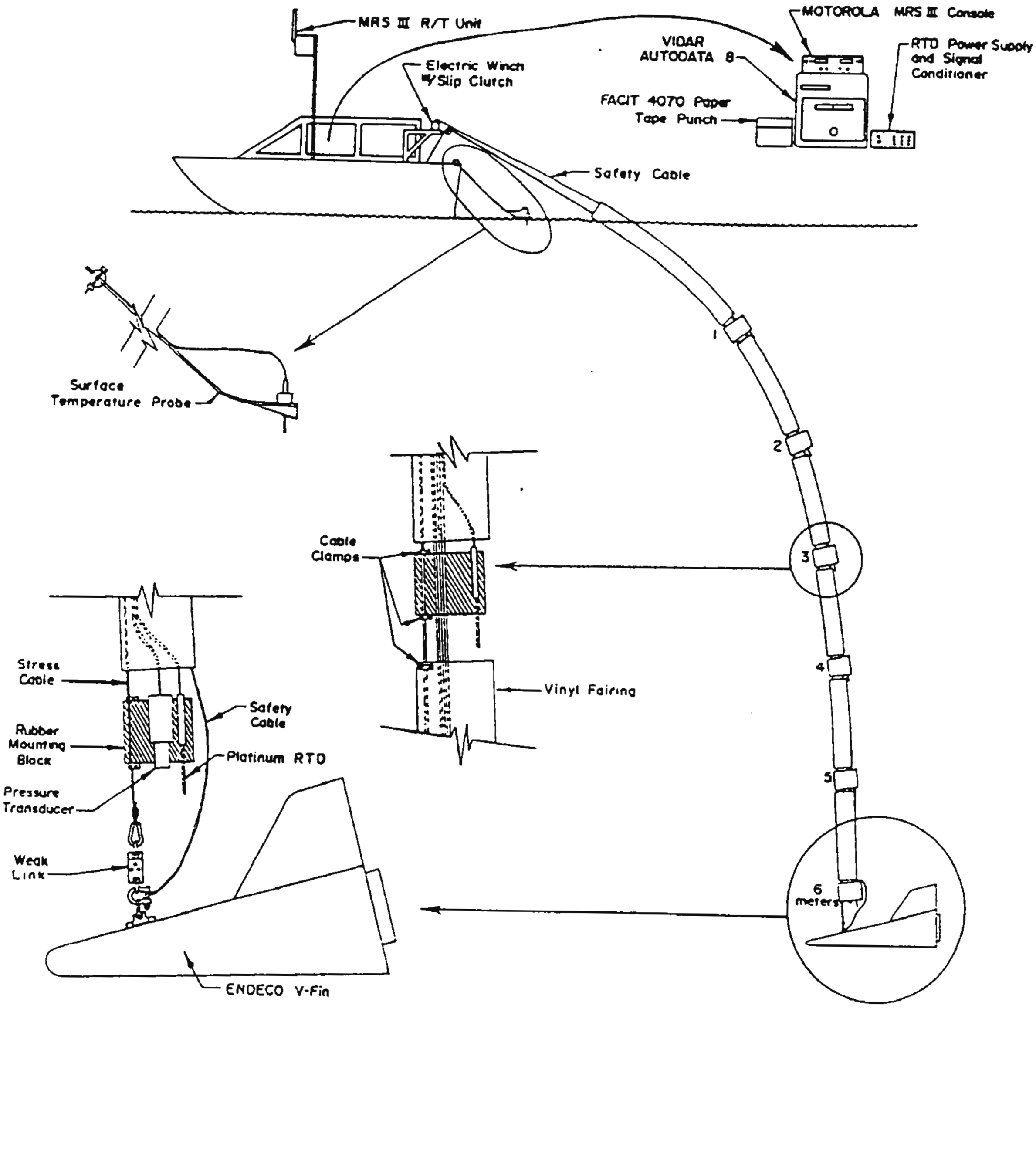
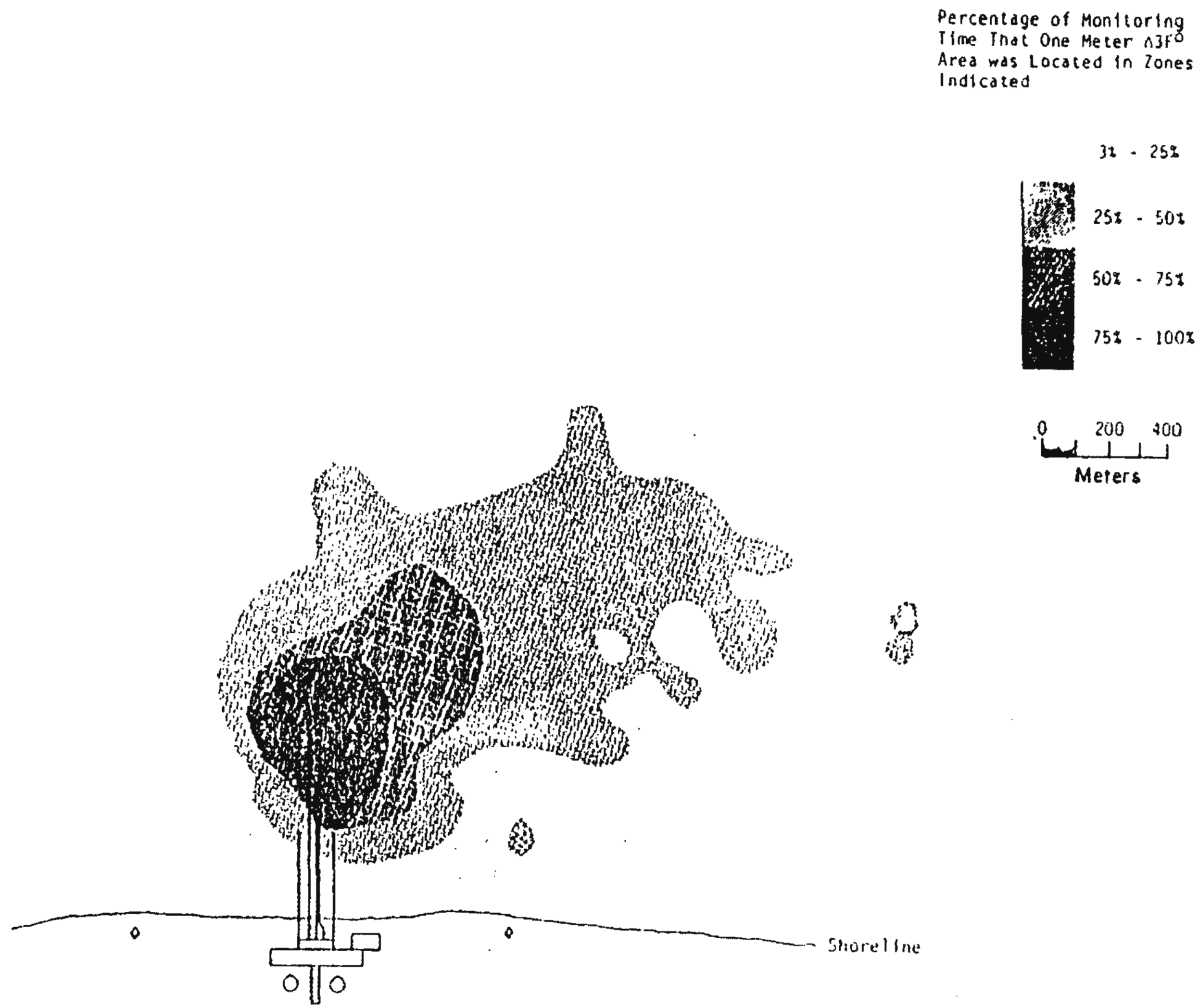


Figure 2.6-5. Schematic of Towed Array



Region of Lake Influence by D. C. Cook Units 1 & 2
Discharge (Power Levels Greater than 75%)

Figure 2.6-6

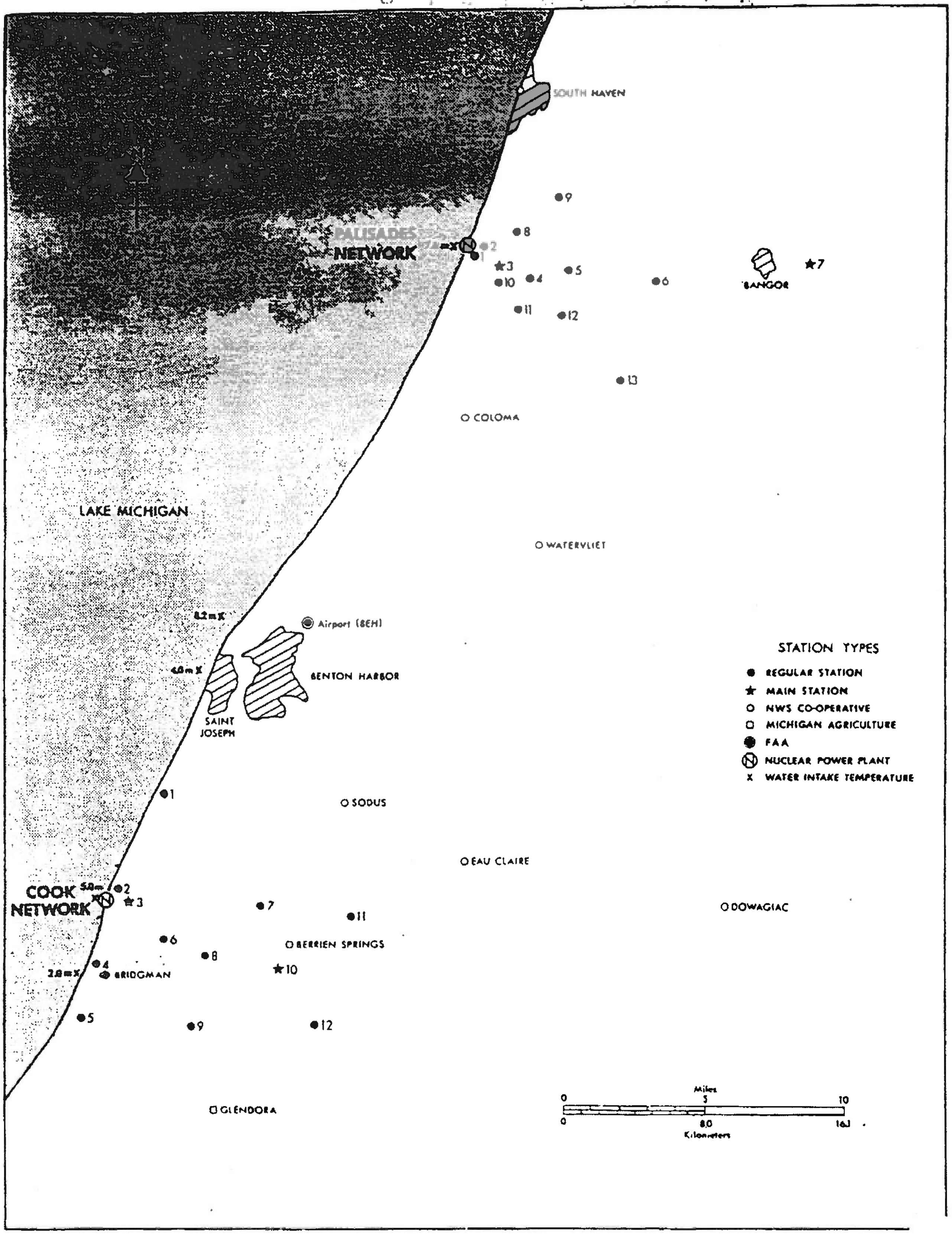


Figure 2.6-7 Donald C. Cook and Palisades Nuclear Plants meteorological networks. Network sites are given by numbers. Main sites are C03A, C10A, P03A, and P07A. Open circles are other locations with meteorological information.

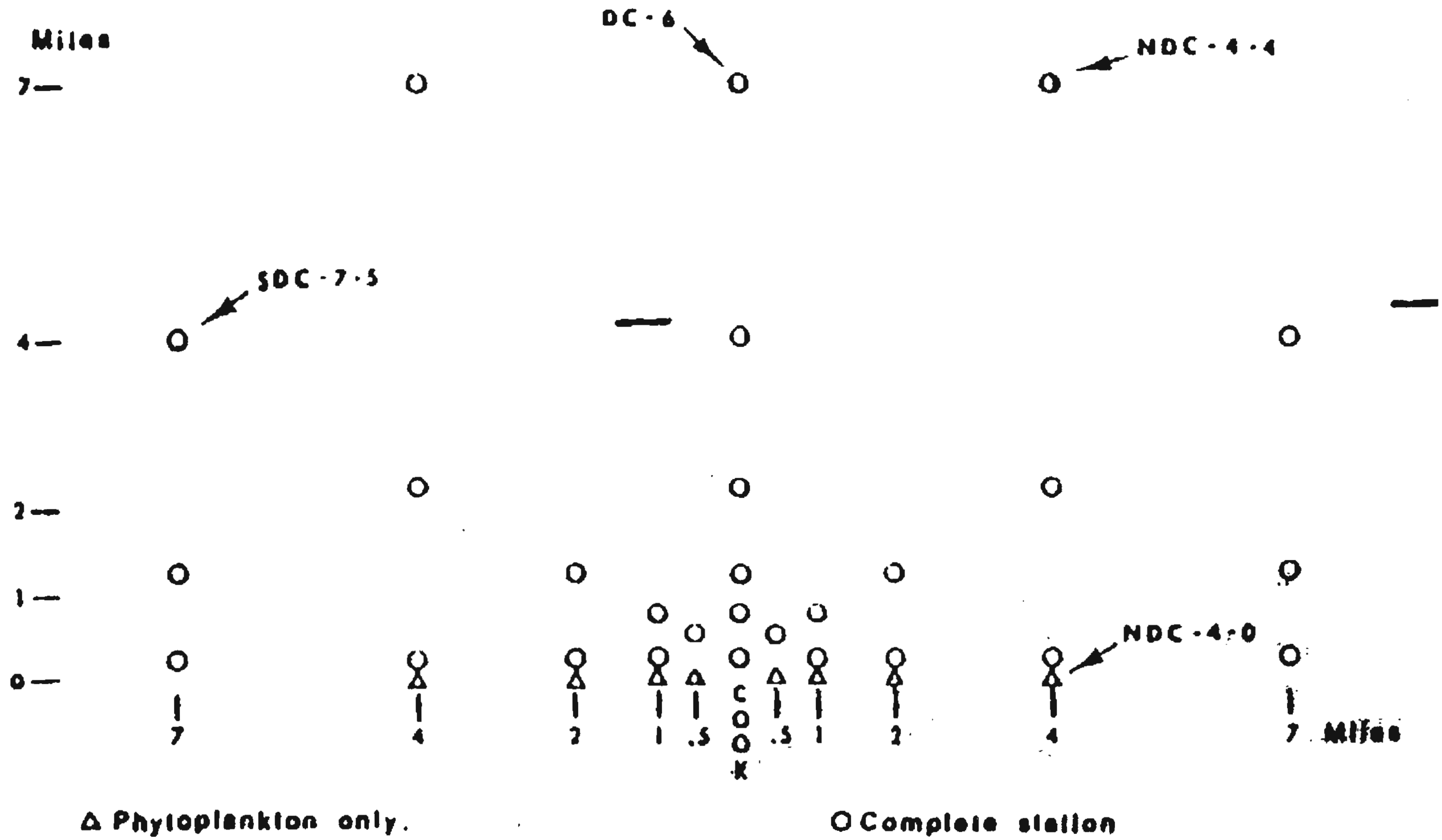


Figure 2.6-8

The 36-station Cook Plant sampling grid, used after April of 1972
The stations are designated as follows: SDC stations are located south of the plant, NDC stations are north of the plant, and DC stations are directly offshore of the plant The first number of the designation is the number of miles north or south of the plant. The second number is the serial number of the station from shore lakeward. The serial number of the phytoplankton-only stations is 0.

FIRURE 2.6-8

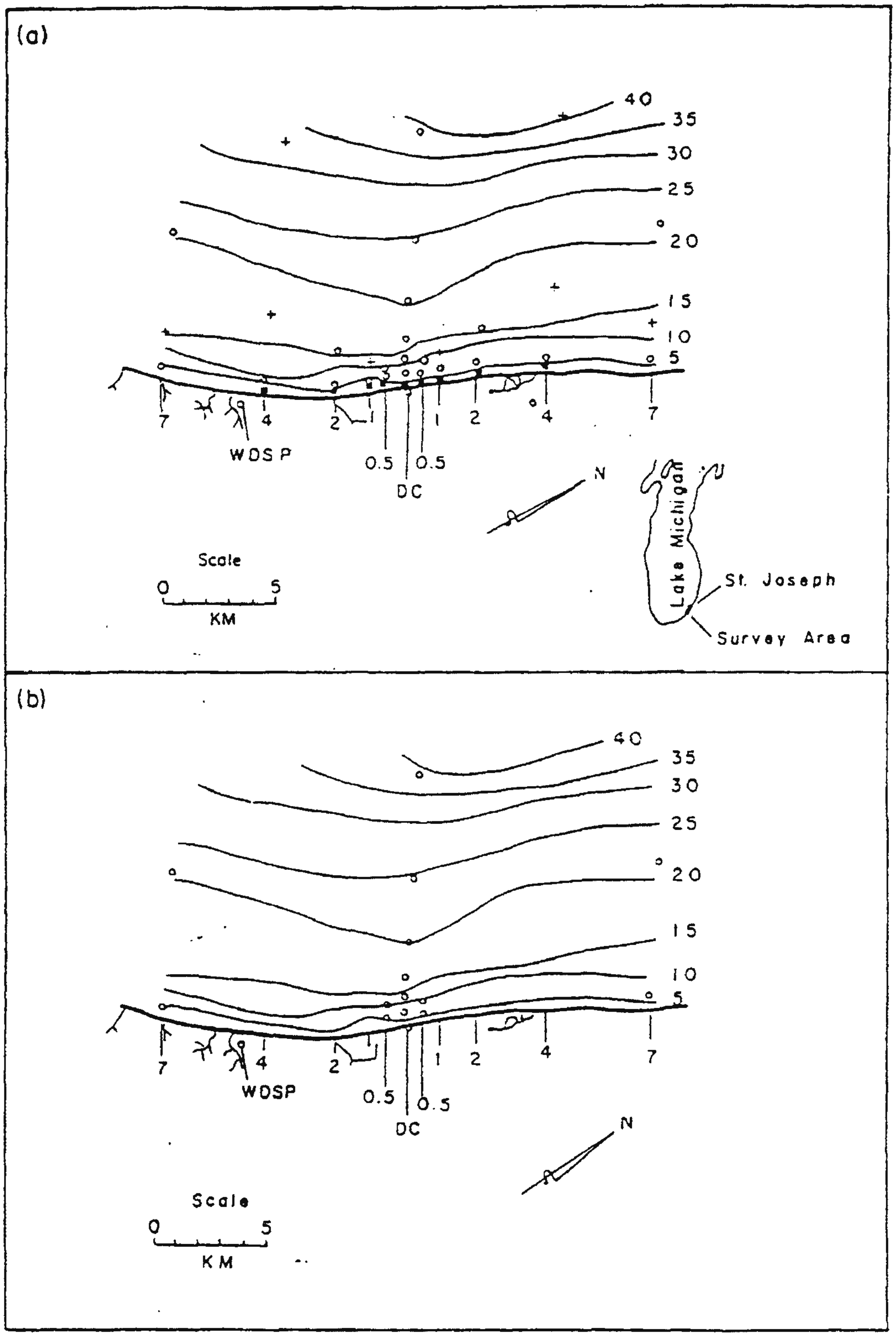


Figure 2.6-9. Station locations for the major surveys (a) and short surveys (b). Beach region stations (■) are included on the major survey grid. Depth contours are in meters. Other symbols: 0 indicates a station where all species were enumerated; + indicates a station where only genera were enumerated. WDSP indicates Warren Dunes State Park.

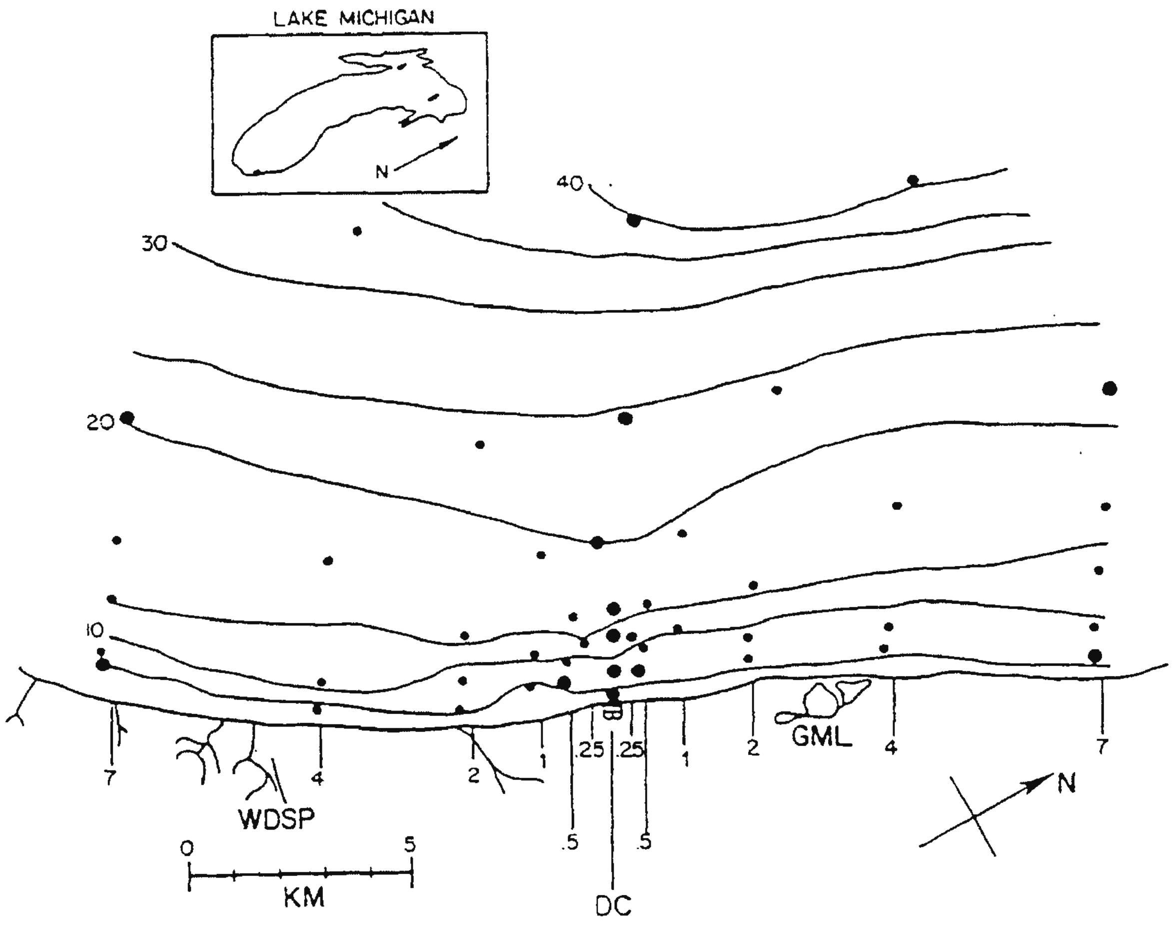


Figure 2.6-10

Grid of stations used in benthic sampling near the D. C. Cook Power Plant (DC), southeastern Lake Michigan, for minor survey months with 5-m contour depth intervals. Solid large circles represent minor survey sites. Locations of Grand Marais Lakes (GML) and Warren Dunes State Park (WDSP) are indicated.

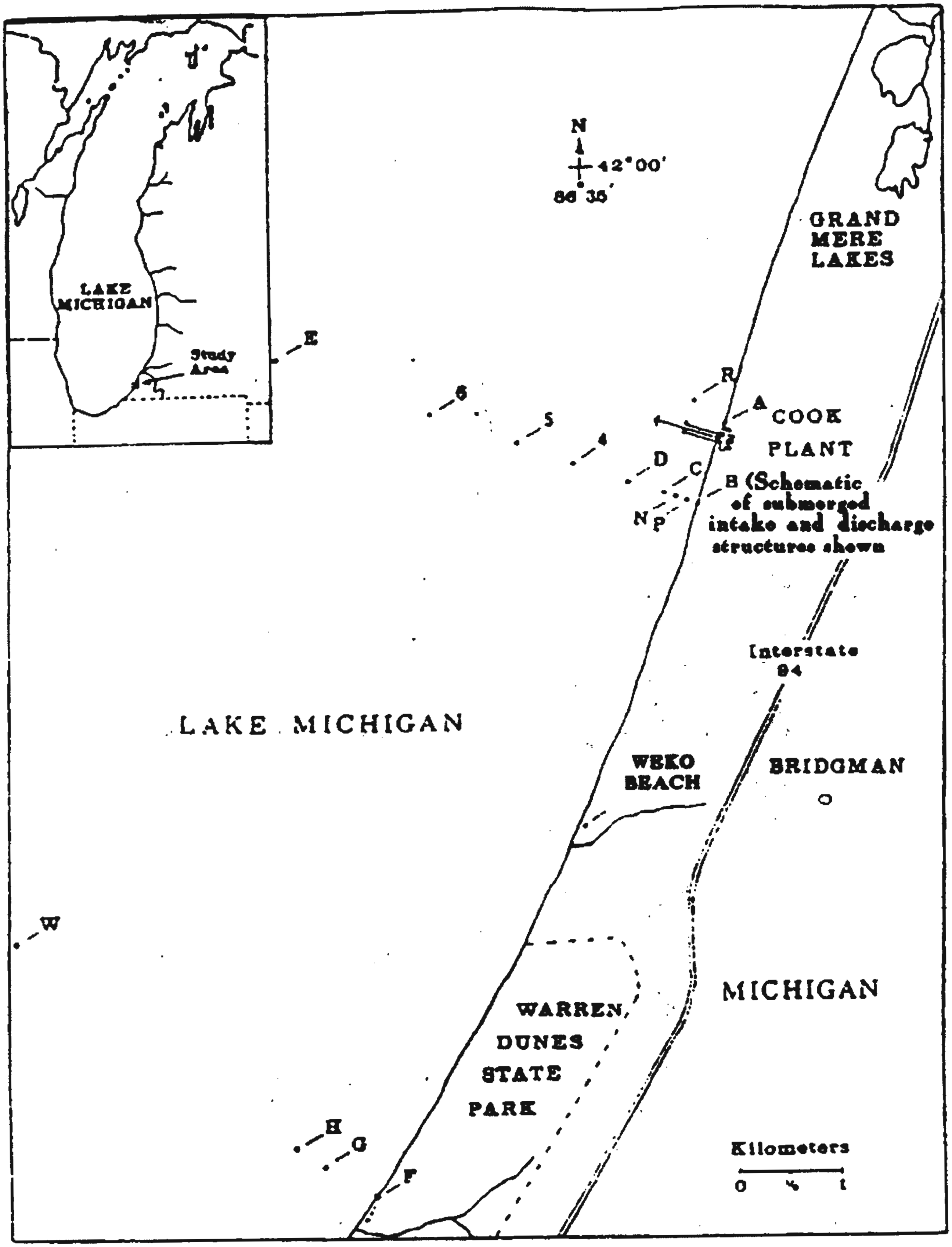


Figure 2.6-11. Map of southeastern Lake Michigan, showing locations of the Donald C. Cook Plant and our field fish larvae sampling stations.

JULY, 1997

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(raster file) \fig2 611.cir

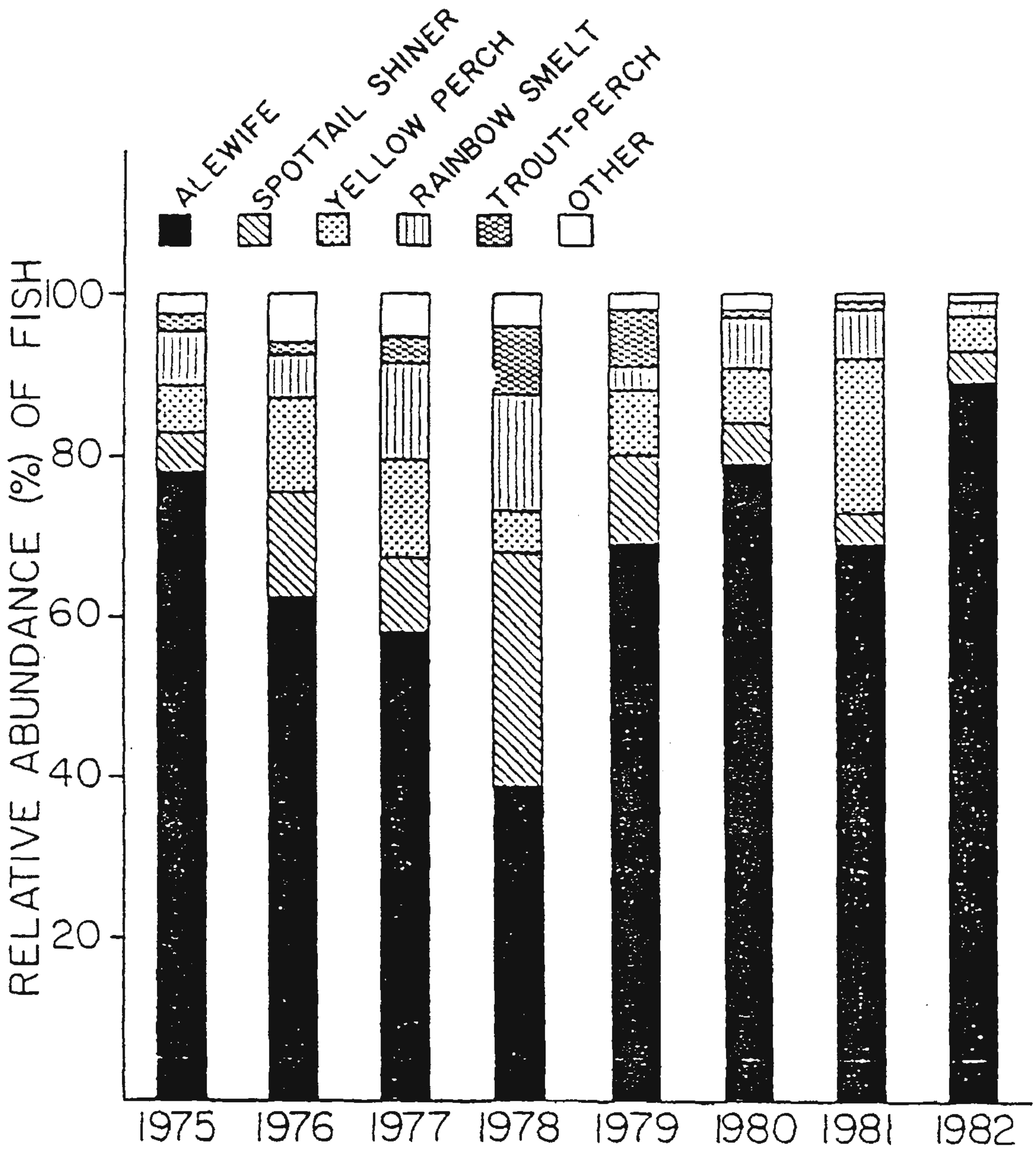

Figure 2.6-12. Species composition of the total number of fish impinged each year during 1975-1982 at the Donald C. Cook Plant, southeastern Lake Michigan.