CHAPTER 2: SITE CHARACTERISTICS

2.1 GEOGRAPHY AND DEMOGRAPHY

Section 2.1 was prepared circa 1974 at the time of preparation of the original FSAR. It has not been updated in the area of geography and demography since it represents the area at the time the Construction Permit was issued. Minor changes were made in Subsection 2.1.3.5 in response to questions from the NRC in 1979.

2.1.1 Site Location

The Fermi 2 power plant is located at the Fermi site on the western shore of Lake Erie at Lagoona Beach, Frenchtown Township, Monroe County, Michigan (see Figures 2.1-1 through 2.1-3). The plant is approximately 8 miles east-northeast of Monroe, Michigan; 30 miles southwest of downtown Detroit, Michigan; and 25 miles northeast of downtown Toledo, Ohio.

The coordinates of the Fermi 2 reactor containment structure are latitude 41°57'48"N, and longitude 83°15'31"W. The Universal Transverse Mercator coordinates are 4,647,950 m north and 312,930 m east, Zone 17T.

2.1.2 Site Description

The Fermi site comprises approximately 1260 acres of land solely owned by The Detroit Edison Company (Edison). The site is bounded on the north by Swan Creek, on the east by Lake Erie, on the south by Pointe Aux Peaux Road, and on the west by Toll Road. Entrance to the site is from the west by way of Enrico Fermi Drive, a private road owned by Edison, and from the south via Pointe Aux Peaux Road to another private road also owned by Edison.

The northern and southern areas of the site are dominated by large lagoons. The western areas are dominated by several woodlots and quarry lakes. Site elevation ranges from the level of Lake Erie, on the eastern edge of the site, to approximately 25 ft above the lake level, on the western edge of the site.

An aerial photograph of the site taken May 5, 1983, is presented in Figure 2.1-4. A plot plan of the Fermi site showing the plant, its natural draft cooling towers, and other major structures is presented in Figure 2.1-5.

In accordance with 10 CFR 100, the exclusion area for Fermi 2 has been defined as that area within 915 m of the reactor containment structure. As indicated in Figure 2.1-5, this area encompasses a portion of adjoining Lake Erie.

2.1.2.1 Exclusion Area Control

The land portion of the exclusion area for Fermi 2 is entirely within the Fermi site. Consequently, Edison has the authority to determine all activities within the land portion of the exclusion area, including authority for the exclusion of personnel and property. No public roads, waterways, or railroads traverse the land portion of the exclusion area.

The Lake Erie shoreline of the plant site is unsuitable for beach activities. The limited beach area available is inaccessible to the public from the land side and is posted as private property. Few plant-unrelated activities are expected to take place on Lake Erie adjacent to the plant site. These will be primarily fishing from boats and pleasure craft; however, due to poor fishing and the shallow characteristics of the lake in this area, boating activities are not carried out in proximity to the shoreline. Past experience at the site has indicated the public has made little or no attempt to use the shoreline area or to approach the site from the lake. The emergency plans are described in Section 13.3.

2.1.2.2 Boundaries for Establishing Effluent Release Limits

The boundary used to establish Technical Specifications limits for the release of gaseous effluents from Fermi 2, in accordance with 10 CFR 20.106(a) and other related as-low-as-reasonably-achievable provisions, is based on the boundary of the Fermi site. The site boundaries for gaseous effluents and for liquid effluents shall be as shown in Figure 2.1-5. As shown in Figure 2.1-5, the closest on-land boundary line is approximately 915 m from the center line of the reactor building. This closest on-land boundary line corresponds to the maximum site boundary value of the meteorological dispersion parameter (c/Q) calculated for the baseline year 1974-1975.

Virtually all of the 1120-acre site is enclosed by a perimeter fence, restricting casual access to the property. Additionally, a fenced-in area surrounds the immediate plant area within the Fermi site, shown in Figure 2.1-5. Access to the plant area will be continually and actively controlled by Edison. Only those persons specifically authorized will have access to this area.

In those areas of the southern portion of the Fermi site outside the plant fenced-in area, the public will be permitted to use only those facilities specifically designated by Edison. Normal surveillance of these areas will be maintained by Edison, which, as sole owner of the entire Fermi site, has the authority to exclude personnel and property from the designated areas.

2.1.3 Population and Population Distribution

Figure 2.1-3 shows the locations of the municipalities and other cultural features surrounding the plant within 10 miles. Towns and cities in the region surrounding the plant within 50 miles are shown in Figure 2.1-2. These centers of population are listed in Table 2.1-1, along with their 1970 resident populations and their distances and directions from the plant.

2.1.3.1 Population Within 10 Miles

Within 10 miles of the plant, the estimated 1970 population was 63,963 persons; within 5 miles, it was 11,135 persons. The following communities, as identified by the 1970 Census of Population, and indicated in Figure 2.1-3, are within 10 miles of the plant:

	1973 Population	Distance (miles) and Direction from Plant
Stony Point	1,370	1 SSW
Estral Beach	419	2 NE
Woodland Beach	2,249	3 WSW
Detroit Beech	2,053	4 WSW
Monroe (closest point)	23,894	5.5 SW
South Monroe	3,012	6 SW
South Rockwood	1,477	8 N
Rockwood	3,119	9 N
Carleton	1,503	9 NW
Patterson Gardens	2,169	9 W

The City of Monroe and the villages of Estral Beach, South Rockwood, and Carleton are the only incorporated communities.

Estimates of the 1970 resident population within 5 miles of the plant were determined from house counts and 1970 census data. The house counts were determined from June 1970 aerial photographs obtained from the Southeast Michigan Council of Governments (SEMCOG) (Reference 1). House counts were converted to population by applying the ratios of persons to housing units obtained from 1970 census data (Reference 2). For the townships concerned (all in Monroe County), these ratios are

Berlin	3.53
Frenchtown	3.62
Ash	3.71

The resultant population data were assumed to be applicable, without adjustments, to April 1970.

Beyond the 5-mile radius, population estimates were based on 1970 census data (Reference 3) and the corresponding state map, account being taken of the population estimated to be within 5 miles of the plant. Use was made of data for the smallest applicable census unit (e.g., village, town, city, or township). From this state map, census units within each segment of the population wheel were identified, and their fractions within each segment determined. It was assumed that the population within each census unit was uniformly distributed.

Population projections for areas within 10 miles for the years 1980, 1990, 2000, 2010, and 2020 were based on corresponding projections for the individual counties concerned. There were no population projections available for census units smaller than counties. It was assumed that each component (or fraction) of a county had the same decennial rate of growth as that for the county as a whole.

Monroe and Wayne are the only counties with areas within 10 miles of the plant. Projections by SEMCOG were available for both counties for 1970, 1980, and 1990 (Reference 1). The

1970-1980 and 1980-1990 decennial rates of growth derived from these projections were applied to the 1970 census data to obtain the projected 1980 and 1990 populations. The projected 2000, 2010, and 2020 populations of the counties were derived by assuming their decennial rate of growth from 1990 to 2020 to be constant and equal to the average of the 1970-1980 and 1980-1990 rates of growth.

Figure 2.1-6 shows the estimated 1970 population distribution within 10 miles of the plant. Figures 2.1-7 through 2.1-11 show corresponding projected populations for the years 1980, 1990, 2000, 2010, and 2020. These projected population data are the unrounded mathematical results of the methods described above.

2.1.3.2 Population Between 10 and 50 Miles

The 1970 population and projections between 10 and 50 miles were determined in accordance with the method used for the area between 5 and 10 miles from the plant. For the areas within Canada, use was made of the June 1, 1971, Canadian census data (Reference 4) and corresponding provincial map. Using data from the previous Canadian census of June 1, 1966 (Reference 5), and assuming linearity, the 1971 Canadian census data were adjusted to April 1, 1970, so they would coincide with the 1970 U.S. census data.

For population projection purposes, counties between 10 and 50 miles of the plant were divided into four groups:

a. SEMCOG counties

b. Other Michigan counties

c. Ohio counties

d. Canadian counties.

The SEMCOG counties are Monroe, Wayne, Oakland, Macomb, Livingston, and Washtenaw. Wayne County was separated into two parts consisting of Detroit, and Wayne County minus Detroit. Projected populations for these counties for the years 1980-2020 were obtained as explained in Subsection 2.1.3.1 for Monroe and Wayne County projections at 5 to 10 miles. The projected 1980 and 1990 populations for Detroit were similarly derived; however, its population was assumed to remain unchanged (rather than to continue decreasing) from 1990 to 2020.

Other Michigan counties consist of Jackson and Lenawee. The projected populations for each of these counties were derived by assuming their decennial rates of growth from 1970 to 2020 to be constant and equal to the average of their 1960-1970 rates of growth, obtained from census data, and their 1970-1980 rates of growth, derived from 1970 census data and their 1978 population estimated by the State of Michigan (Reference 6).

The Ohio counties consist of Seneca, Sandusky, Ottawa, Lucas, Huron, Henry, Fulton, Erie, and Wood. The projected populations for each of these counties were derived by assuming their decennial rates of growth from 1970 to 2020 to be constant and equal to the 1970 to 1980 rates of growth obtained from 1970 to 1975 to 1980 to 1985 projections by the State of Ohio (Reference 7).

Official projections for Essex and Kent, the two Canadian counties, were not available. Projected 1980-2020 populations of these counties were based on their adjusted April 1, 1970, populations and were derived by assuming their decennial rates of growth from 1970 and 2020 to be constant and equal to their 1961-1971 rates of growth determined from Canadian census data.

Figure 2.1-6 shows the estimated 1970 population distribution between 10 and 50 miles from the plant. Figures 2.1-7 through 2.1-11 show corresponding projected populations for the years 1980, 1990, 2000, 2010, and 2020. These projected population data are the unrounded mathematical results of the methods described above.

2.1.3.3 Low-Population Zone

In accordance with criteria specified in 10 CFR 100, the outer boundary of the low-population zone (LPZ) for Fermi 2 will be 3 miles (4827 m) from the containment structure. The estimated resident population distribution within this distance for the years 1970 through 2020 is shown in Table 2.1-2. Population distribution for distances up to 50 miles from the plant is shown in Figures 2.1-6 through 2.1-11; a detailed map of the LPZ is shown in Figure 2.1-12.

The area within the LPZ does not contain either agricultural or industrial activities that would create a daily transient population of any magnitude. Therefore, other than the recreational activities that draw daily users, the daily population is relatively stable. As stated in Subsection 2.1.4.2.3, the population in the communities within the LPZ that have beach and boating facilities is predominantly permanent, and the facilities are for resident use. The schools, hospitals, institutions, and recreational areas are shown in Tables 2.1-3 through 2.1-5.

Sterling State Park and Point Mouillee State Game Area are approximately 5 miles from the Fermi 2 site and annually attract about 385,000 and 180,000 visitors, respectively, as shown in Table 2.1-5. Approximately 70 percent of use occurs between April and November.

2.1.3.4 Transient Population

2.1.3.4.1 Seasonal Agricultural and Horticultural Labor

Needs for seasonal agricultural and horticultural labor (including migrant workers) in Monroe County are listed in Table 2.1-6. Peak requirements, which occur in the month of October, are for a total of about 2335 seasonal workers, 34 percent of whom are expected to be migrant workers. Needs for such seasonal labor are at a minimum during the winter months, down to a total of about 230 workers, 12 percent of whom would be migrant workers. Following are 1972 data on migrant workers within 10 miles of Fermi 2 (Reference 8):

Employers	Number of Migrant Workers	Distance (miles) and Direction From Plant
Smith and Son	75	8 NW
J. F. Ilgenfritz	30	10 WSW

Employers	Number of Migrant Workers	Distance (miles) and Direction From Plant
Tracy Gaynier	12	11 SW
Don Wolmer	20	12 WSW
Walter Iott	20	12 WSW

2.1.3.4.2 Historical Attractions

There are two facilities in the City of Monroe that draw large numbers of visitors each year: the Custer Museum, 8 miles west-southwest of the plant; and the Monroe County Historical Museum, 8 miles west-southwest of the plant. In 1972, the former had approximately 12,000 visitors and the latter about 45,000 (Reference 9).

2.1.3.4.3 Commuters

Monroe and Wayne are the only two counties with areas within 10 miles of the plant site. Monroe County has an inflow of 1500 commuters and an outflow of 19,292 commuters, a net loss of 17,792 individuals per day. Wayne County, with an inflow of 139,305 and an outflow of 165,754 commuters, has a net loss of 26,449 individuals per day (Reference 10).

2.1.3.4.4 Seasonal Homes

Within 10 miles of the plant, according to the 1970 census data, there were 51 seasonal homes in Monroe County and 26 in Wayne County (Reference 11).

Many of the houses that had been used in the past as summer cottages are currently used as permanent homes.

2.1.3.5 Population Center

The nearest population center, as defined in 10 CFR 100, is the City of Monroe, which had a 1970 population of 23,894. Its nearest corporate boundary is approximately 5.5 miles southwest of Fermi 2.

The residential population distribution of the city and the surrounding jurisdiction (Frenchtown Township) shows this distance to be a valid, conservative figure for use as the population center distance. The concentrated residential section of the city is farther distant from the plant site, with the closest portion of the city along the northeastern boundary being predominantly open for industrial development (Reference 12).

Frenchtown Township in 1977 was composed of scattered, small residential clusters and a few small communities along the shore of Lake Erie (Reference 13). The 1975 total population was estimated to be 15,900 over a land area of 27,000 acres an average density of about 0.6 person/acre (Reference 13). Future land use and residential population distribution for the city and township were also examined to determine the potential influence of proposed growth on the population center distance. The Monroe land use plan did not propose further expansion on the northeast edge of the city. Some annexation had taken place on the west, but further annexation was not considered likely in 1979 (Reference 14).

The land area within the city boundary was slated to remain predominantly open or industrial. One small tract (approximately 39 acres) was proposed for potential residential development (Reference 12). The future growth of Monroe based on data available in 1979 would not create any densely populated residential land closer than 5.5 miles from Fermi 2.

Land use plans for Frenchtown Township indicated that future residential growth will take place in the vicinity of Fermi 2. Land use plans call for development of the corridor between Monroe and Fermi 2 and along the Lake Erie shore (Reference 13). A mixture of land uses was proposed; however, it was mainly recreational and low density (average of one dwelling unit per acre) and medium density (1 to 4 dwelling units per acre) residential. A 450-acre tract on the northeastern corner of the growth area had been rezoned from agricultural to residential use. This land, like most of the area, had severe soil limitations based on high water table, fair-to-poor bearing capacity, and moderate volume change. For this reason, the staff of the Monroe County Planning Commission had reservations about the residential rezoning of the site and suggested rezoning only for low density (Reference 15) (one dwelling unit per acre).

Based on the distribution and density of the proposed future land use, Frenchtown Township was not expected to form a contiguous extension of the population center of Monroe or develop into a separate densely populated center. From these facts it was apparent that the 5.5-mile population center distance would remain valid in the future.

2.1.3.6 Public Facilities and Institutions

A survey was conducted to locate public facilities and institutions, such as schools, hospitals, prisons, and parks, within 10 miles of the plant.

2.1.3.6.1 Schools

Schools within 10 miles of the plant are listed in Table 2.1-3 and indicated in Figure 2.1-13 (References 16 through 20). Closest to the plant is the Brest School at Woodland Beach (2.5 miles west-southwest) with a 1972 enrollment of 163. The Monroe County Community College, a 2-year college, is located 11 miles west-southwest of the plant and had a 1972 enrollment of 1676 students.

2.1.3.6.2 Hospitals

Data on hospitals and nursing facilities are contained in Table 2.1-4 (References 21 through 26). The closest facility to the plant is the Frenchtown Convalescent Center, 6 miles west, with 226 beds.

2.1.3.6.3 Prisons

The only jail within 10 miles of the plant is the Monroe County Jail, located in the City of Monroe. It has an average of 50 inmates per day (Reference 27).

2.1.3.6.4 Recreational Areas

Recreational areas within 10 miles of the plant are listed in Table 2.1-5 and indicated in Figure 2.1-14 (References 9 and 28 through 30). The recreational facilities closest to the plant are Stony Point Beach, about 2 miles south, and Estral Beach, 2 miles northeast. Swimming is reported to take place there. The largest facility in the area is Sterling State Park, 5 miles southwest of the plant.

2.1.4 Uses of Adjacent Lands and Waters

2.1.4.1 Agricultural Activities

Approximately 95 percent of the land area within 10 miles of Fermi 2 is within Monroe County, with the remaining 5 percent in Wayne County. About 71 percent of the land in Monroe County was used for farming; however, only 55 percent of the land within 10 miles of the plant consisted of farms. Farmland use within 10 miles of the plant in 1973 was as follows (Reference 31):

Crop	Percentage of Farmland
Soybeans	50
Corn	22
Wheat	7
Miscellaneous (vegetables, hay, oats, and grazing and pastureland)	7
Idle Cropland	14
Total	100

Data on the principal crops grown within 10 miles of the plant site in 1973 (Reference 31) were as follows:

Crop	Acreage	Annual Production (bushels)	Value
Soybeans	21,000	840,000	$2,940,000
Corn	9,500	902,500	$1,173,250
Wheat	3,150	126,000	$252,000

All soybeans and wheat were sold as cash crops. Approximately 75 percent of the corn was sold as a cash crop; the remaining 25 percent was used for feed.

The large livestock, poultry, and crop farms located within the environs of the Fermi site in 1973 are listed below:

Owner	Farm Type and Information	Distance (miles) and Direction From Plant
Ronald Welb	Poultry – 2,500 laying hens	5 NW
Del Chapman	Livestock – 1,500 sheep	7 N
Smith and Sons	Vegetables and greenhouse products	8 NW
Butler Farms	Livestock – 500 beef cattle	10 W
St. Mary's Farm	Livestock – 200 beef cattle	10 W
Clayton Dick	Poultry – 15,000 to 20,000 laying hens	16 WSW
Lennard and Sons	Potato farm - 2,000 acres	16 WSW

The Lennard and Sons farm was the largest potato farm in the State of Michigan, with a gross annual income of approximately $1.8 million. The Smith and Sons farm was one of the largest vegetable and greenhouse-product producers in the State of Michigan, with a gross annual income exceeding $500,000.

Table 2.1-7 contains data on the 29 dairy farms within 18 miles of the plant in 1971, and Figure 2.1-15 indicates their locations. Ten of these dairy farms were within 10 miles. The closest, owned by John Reiger and containing about 30 milking cows, was approximately 4 miles west of the plant. The only other dairy farm within 5 miles was that of Henry Noel. This dairy farm was approximately 5 miles northwest of the plant and had approximately 25 milking cows in 1973 (References 32, 33, and 34). The productive cows nearest the plant were located 3 miles north-northwest. Milk from these four cows was used for home consumption.

Livestock and dairy operations within 10 miles of the plant had been going out of business. Tax increases over the past years (an increase of $40 per acre in 1972) and attractive offers for farmland ($1000 to $1500 per acre) resulted in many farmers selling their grazing and pastureland and accepting employment with local industries (Reference 31). Agricultural statistics for Monroe County indicated that in 1964 there were approximately 3549 dairy cattle. In 1972 there were only 2100 dairy cattle. The County Agricultural Cooperative Extension Service was then discouraging new livestock and dairy operations within the county; however, it was assisting established farms to remain in operation. Crop farmers in the county were able to continue their operations due to the high productivity of the land, which compensated for the large tax increases (Reference 31).

In 1967, approximately 10 percent (approximately 37,700 acres) of the county's land was developed. However, agricultural land was being rapidly developed for nonagricultural purposes as the county became more urbanized. The comprehensive development plan of 1967 (Reference 35) for Monroe County called for the retention of agricultural land to serve as buffers between recommended major development corridors. Accordingly, this plan specified that the majority of land located west of U.S. Route 23 and U.S. Route 24, and west of Interstate 75 in the northeast quadrant of the county, be reserved primarily for agricultural use (Figure 2.1-16).

Economic projections showed that as the county grew and became more urbanized, some farmlands would be lost to urban development and farm employment would decrease. Farm employees would continue to be attracted to high-paying nonagricultural occupations, and farms would adopt additional labor-saving methods and machinery. It was estimated that by 1980 farm employment in the county would decrease to about 2 percent of the labor force as compared to 5.8 percent in 1960 (Reference 35).

The small portion of Wayne County within 10 miles of the plant was predominantly a residential area and had only a limited amount of agricultural activity: small crops of field corn, soybeans, hay, and some fresh market vegetables. There were no dairy farms in this area in 1973 (Reference 36).

Agricultural statistics of all counties within 50 miles of the plant site are presented in Tables 2.1-8 through 2.1-11 for the 1969 to 1971 time period (References 37 and 38).

2.1.4.2 Water Uses

The most prominent body of water in the environs of the Fermi site is Lake Erie. Rivers and streams entering Lake Erie within 10 miles of the site are shown in Figure 2.1-17. The five drainage basins within a 10-mile radius of the site are as follows (Reference 39):

Drainage Basin	Drainage Area (square miles)
Area between the Huron and Rouge Basins	120
Huron River	923
Stony and Swan Creeks	290
River Raisin	1,043
Southeast Monroe County	189

A detailed description of the hydrology of the region is presented in Section 2.4.

2.1.4.2.1 Potable Water Supplies

As shown in Figure 2.1-18, privately owned wells and four municipal water systems served the area within 10 miles of the Fermi site in the 1970 time period. The four municipal systems are those of Detroit, Monroe, Flat Rock, and Toledo (Ohio).

The Detroit system served most of Wayne County. In the area within 10 miles of the plant, this water system served portions of Brownstown Township, Rockwood, South Rockwood, the City of Carleton, and Berlin Township. The Flat Rock system served portions of Brownstown Township and Rockwood. The Monroe system, which has its intake on Lake Erie, served most of Frenchtown Township, the City of Monroe, and Monroe Township. The service area of the Toledo system included portions of La Salle and Erie Townships. Although these municipal water systems provided services in these areas, homeowners who had wells prior to the construction of the municipal water services were not obligated to use them. Consequently, about 15 percent of the homeowners in the service areas of these municipal systems were still obtaining their potable water from individually owned wells.

Owners of newly constructed dwellings in these service areas, however, were obligated to obtain their potable water from the municipal system.

Within 10 miles of the plant, homeowners outside the service areas of the municipal systems obtained their potable water from individually owned wells. These wells ranged in depth from 50 to 120 ft; however, well depths generally do not exceed 70 ft (Subsection 2.4.13.2). Throughout Monroe County there were approximately 6000 active wells in 1972, mostly in the western half of the county. The number of wells drilled from 1964 to 1972 in each of the townships wholly or partially within a 10-mile radius of the Fermi site was reported (Reference 40) to be as follows:

Frenchtown	336
Ash	216
Raisinville	324
Berlin	207
Monroe	115
Exeter	132
La Salle	288

Figure 2.1-19 shows the approximate number of wells in use in 1972 and their distribution within 10 miles of the currently unused quarry at the Fermi site (Reference 41).

The quality of well-water in Monroe County is generally poor. Efforts were being made for expanded use of municipal water services from the Detroit, Monroe, and Toledo systems. Plans in 1973 showed that Toledo would eventually serve not only La Salle and Erie Townships, but Bedford and Whiteford Townships as well (Reference 40). The Monroe system was planning a new treatment facility in the same region as the 1973 facility to increase the intake capacity to 4.5 billion gal per year, an increase of approximately 125 percent over the 1973 capacity. Future plans called for the servicing of the entire Frenchtown region, Raisinville, Dundee, and parts of London Township. No data on initial construction were available in 1972 (Reference 42). The Monroe water system has its intake on Lake Erie, in the Pointe Aux Peaux region, approximately 1 mile south of the Fermi site. The intake is 5260 ft long and 2.5 ft in diameter (Reference 43).

The 1973 plans for the Detroit water system showed that Ash Township was considering the use of Detroit water, while Exeter and London Townships were negotiating for service (Reference 40).

At one time, bottled water was being used as potable water by the communities along the Lake Erie shoreline because of the poor quality of the well-water. This condition has since been alleviated as a result of the services provided by the municipal water systems (Reference 40).

The following 1973 data on other municipal water systems in Monroe County (Reference 43) are provided for reference:

System	Source	Distance (miles) and Direction From Plant	Yearly Production (millions of gallons)	Area Served
Village of Dundee	River Raisin	19 W	70.8	Village of Dundee
Village of Petersburg	2 wells	21 WSW	53.0	Village of Petersburg

The Flat Rock water intake is located on the Huron River at a point about 10 miles north of the plant. Its average withdrawal is about 750,000 gal per day (Reference 44).

Data on municipal water intakes (including those of Toledo and Monroe) from Lake Erie are presented in Table 2.1-12 (1969-1972 data). The locations of the intakes for these municipal water systems are shown in Figure 2.1-20 (References 31, 45, and 46).

2.1.4.2.2 Agricultural Water Supplies

Within 10 miles of the plant in 1973, the Smith and Sons farm was the only agricultural user of surface water. The intake of this farm was on Swan Creek, at a point about 8 miles northwest of the plant. Water from this intake was used for irrigation and cattle watering. Within 50 miles of the plant, there were no known withdrawals of water from Lake Erie for agricultural irrigation or livestock watering. Previously existing withdrawals for agricultural purposes had been discontinued in this area. This was primarily a result of the residential development along the lakeshore (Reference 31).

2.1.4.2.3 Recreational Water Uses

Along the shoreline of Lake Erie in Monroe County there are numerous communities with beach and boating facilities.

Recreational activities at these places include swimming, water-skiing, motorboating, and sportfishing. The following are the principal recreational areas in the environs of the Fermi site:

Community	Distance (miles) and Direction From Plant
Pointe Aux Peaux	1 S
Stony Point	1 SSW
Estral Beach	2 NE
Woodland Beach	3 WSW
Detroit Beach	4 WSW
Avalon Beach	9 SW
Toledo Beach	11 SW
Luna Pier	15 SW

The majority of the homes in these communities were at one time used as summer cottages; however, most of them were being used as permanent homes in 1973. The water quality along the beaches of these communities was below that required by applicable standards for sports involving body contact with the water. Sterling State Park, located along the Lake

Erie shoreline 5 miles southwest of the plant site, was closed for swimming because of poor water quality. However, in spite of water quality and water-quality standards, water-sport activities continued to take place on the shoreline area in 1973 (Reference 40).

2.1.4.2.4 Fishing

Sportfishing activities in the general environs of the Fermi site are conducted off the shores of Lake Erie and along the shores of the River Raisin, and Stony and Swan Creeks. Lake Erie fish include carp, sheepshead, bullheads, suckers, channel catfish, white bass, yellow perch, and walleye. Fish in the River Raisin and Stony and Swan Creeks include panfish, suckers, catfish, perch, and bass (Reference 47).

There were approximately six commercial fishermen in 1973 who used the shores of Lake Erie in the Monroe County area. In 1971, the fish catch was approximately 172,736 lb, representing an estimated value of $24,343 (Reference 47). Commercial fishing in this area slackened over the 2-year period of 1972 and 1973 because of low availability of fish. However, as a result of improving conditions, it was predicted that commercial fishing would increase.

A summary of commercial fish landings taken from Lake Erie statistical districts in 1971 is presented in Table 2.1-13 for the Province of Ontario, and Table 2.1-14 for the State of Ohio (References 48 and 49). The respective districts are illustrated in Figure 2.1-21.

2.1.4.2.5 Industrial Water Use

Within 10 miles of the plant site, 1974 industrial users of Lake Erie water included the Fermi 1 Power Plant, the Monroe Power Plant, Union Camp Corporation, and Consolidated Packaging Corporation. The Fermi 1 plant, an oil-fired peaking unit located on the Fermi site, drew both potable and cooling water from Lake Erie. Potable water usage during 1971 and 1972 was 25 million gal per year and 19 million gal per year, respectively. It should be noted that the potable water system for Fermi 1 was the source of demineralized water for the construction of Fermi 2. Cooling water use averaged approximately 72 million gal per day when Fermi 1 was in operation. The Fermi 1 breeder reactor and oil-fired power plant have been permanently decommissioned. Four combustion turbine peakers are still in use on the site. The Monroe Power Plant, which is approximately 6 miles south-southwest of the Fermi site, obtains the major portion of its cooling water from Lake Erie at an intake located about 1300 ft from Lake Erie on the River Raisin. Monroe Unit 1 began operating in 1971, Unit 2 in 1972, Unit 3 in 1973, and Unit 4 in 1974. Each of these four units requires an average of 350,000 gpm for cooling purposes. Discharge is through a canal to Lake Erie. Their potable water supply is obtained from the City of Monroe (Reference 50).

The Union Camp Corporation (Reference 51) and the Consolidated Packaging Corporation (Reference 52), both located in the City of Monroe, have their Lake Erie intakes in the Sterling State Park region, which is approximately 5 miles southwest of the Fermi site. The water is piped approximately 3 miles overland to the corporate sites. After usage, it is discharged into the River Raisin at a point approximately 2 miles inland from Lake Erie. Both of these industries share the same pumping and discharging facilities. Their average daily withdrawals are approximately 3 million and 2.6 million gal, respectively. Both facilities obtain their potable water supplies from the Monroe municipal water system.

In Monroe, the Ford Motor Company has a large manufacturing plant (2700 employees) that has a water intake on the River Raisin at a point approximately 1.2 miles upriver from Lake Erie. From this intake, the Ford plant draws an average of approximately 12 million gal per day. This water is used for industrial purposes only. The potable water required for the plant is obtained from the City of Monroe at the rate of 200,000 gal per day (Reference 53).

2.1 GEOGRAPHIC AND DEMOGRAPHY

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24. Louise Moore, NUS Corporation, and Clerk, Monroe Convalescent Center, Monroe, Michigan, Conversation, February 1, 1973.

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26. Louise Moore, NUS Corporation, and Miss Graizyk, Rockwood Children's Home, Rockwood, Michigan, Conversation, February 21, 1973.

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28. Gerald Edgley, NUS Corporation, and Mr. James Akers, Director of Environmental Health, Monroe County, Monroe, Michigan, Telephone Conversation, February 17, 1973.

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44. Lawrence R. Kolbicka, NUS Corporation, and Floyd Bransheau, Operator, Flat Rock Water Company, Flat Rock Township, Michigan, Telephone Conversation, February 27, 1973.

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REFERENCES

45. Gerald Edgely, NUS Corporation, and the following officials, Telephone Communications:

Water Systems	Name	Title
Ashtabula	Mr. Smith	Administrative Assistant
Conneaut	Mr. Coates	Chief Operator
Vermilion	Mr. Strittrather	Superintendant of Water
Lorain	Mr. Emerick	Superintendant of Water
Cleveland	Mr. Mash	Duty Project Engineer
Fairport	Mr. Killimen	Superintendant of Water
Erie	Mr. Prazer	Bureau Chief
Buffalo	Mr. Martin	Senior Administrative Assistant
Dunkirk	Mr. Smagner	Assistant Operator
Port Colborne	Mr. Farbiak	Area Foreman
Port Maitland	Mr. Sakamopo	Project Service Manager
Port Stanley	Mrs. Taylor	Secretary-Treasurer
Blenheim	Mr. Gawley	Secretary-Treasurer
Leamington	Mr. Sanger	Secretary-Treasurer
Kingsville	Mr. Sanger	Secretary-Treasurer
Detroit	Mr. Janeczko	Public Information
Monroe	Mr. J. D. D'Haene	Supervisor of Filtration
Toledo	Mr. Hixson	Chief Engineer for Water
Port Clinton	Mr. Held	Chief Operator
Sandusky	Mr. Showalter	Assistant Superintendant
Huron	Mr. Hetrick	Director of Utilities
Port Dover	Mr. Barry	Foreman
Wheatly	Mr. Thompson	Secretary-Treasurer

46. Lake Erie, Ohio, Pennsylvania, New York Intake Water Quality, Summary 1970, Environmental Protection Agency, Region V, August 1971.

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52. Gerald Edgely, NUS Corporation, and Mr. Duval, Senior Plant Engineer, Consolidated Packaging Corporation, Monroe, Michigan, Telephone Conversation, February 28, 1973.

53. Lawrence R. Kolbicka, NUS Corporation, and Mr. Ash, Supervisor of Water and Waste Treatment, Ford Motor Company, Monroe, Michigan, Telephone Conversation, February 27, 1973.

TABLE 2.1-1 TOWNS AND CITIES WITHIN 50 MILES OF THE FERMI SITE

Town/City[a]	1970 Population	Distance (miles) and Direction From Site
0-10 Miles		
Stony Point	1,370	1 SSW
Estral Beach	419	2 NE
Woodland Beach	2,249	3 WSW
Detroit Beach	2,053	4 WSW
Monroe (closest point)	23,894	5.5 SW
South Monroe	3,012	6 SW
South Rockwood	1,477	8 N
Patterson Gardens	2,169	9 W
Rockwood	3,119	9 N
Carleton	1,503	9 NW
10-20 Miles		
Flat Rock	5,643	11 N
Gibralter	3,325	11 NNE
Amherstburg, Ontario (Canada)	5,045	12 NE
Luna Pier	1,418	12 SW
Woodhaven	3,330	13 N
Trenton	24,127	13 NNE
Maybee	485	14 WNW
Grosse Ile	7,799	15 NNE
Riverview	11,342	17 NNE
Harrow, Ontario (Canada)	1,964	18 ENE
Southgate	33,909	18 N
Harbor View, Ohio	238	19 SSW
Reno Beach, Ohio	1,049	19 S
Wyandotte	41,061	19 NNE
20-30 Miles		
Dundee	2,472	20 W
Taylor	70,020	20 N
Belleville	2,406	21 NNW
Allen Park	40,747	22 N
Ecorse	17,515	22 NNE

TABLE 2.1-1 TOWNS AND CITIES WITHIN 50 MILES OF THE FERMI SITE

Town/City[a]	1970 Population	Distance (miles) and Direction From Site
Lambertville	5,721	22 SW
Lincoln Park	52,984	22 NNE
Melvindale	13,862	23 NNE
Petersburg	1,227	23 W
River Rouge	15,947	23 NNE
Milan	4,533	24 WNW
Dearborn	109,358	25 N
Inkster	38,420	25N
Norwood	30,420	25 SSW
Toledo, Ohio	383,818	25 SW
Wayne	21,054	25 NNW
Clay Center	370	26 S
Essex, Ontario (Canada)	3,941	26 NE
Deerfield	834	27 W
Detroit	1,511,482	27 NE
Garden City	41,864	27 N
Kingsville, Ontario (Canada)	3,952	27 ENE
Ottawa Hills, Ohio	4,270	27 SW
Dearborn Heights	80,069	28 N
Milbury, Ohio	771	28 SSW
Sylvania, Ohio	12,031	28 SW
Windsor, Ontario (Canada)	200,790	28 NNE
Westland	86,749	28 NNW
Ypsilanti	29,538	28 NW
Britton	697	29 W
Genoa, Ohio	2,139	29 S
Rocky Ridge, Ohio	385	29 S
Rossford, Ohio	5,302	29 SSW
Walbridge, Ohio	3,208	29 SSW
30-40 Miles		
Highland Park	35,444	31 NNE
Oak Harbor, Ohio	2,807	31 SSE
Put-In-Bay, Ohio	135	31 SE
Saline	4,811	31 WNW
Tecumseh, Ontario (Canada)	124	31 NE
Blissfield	2,758	32 WSW

TABLE 2.1-1 TOWNS AND CITIES WITHIN 50 MILES OF THE FERMI SITE

Town/City[a]	1970 Population	Distance (miles) and Direction From Site
Elmore, Ohio	1,316	32 S
Holland, Ohio	1,108	32 SW
Maumee, Ohio	15,937	32 SW
Perrysbury, Ohio	7,693	32 SW
Plymouth	11,758	32 NNW
St. Clair Beach, Ontario (Canada)	1,931	32 NE
Ann Arbor	99,797	33 WSW
Berkey, Ohio	294	33 S
Woodville, Ohio	1,834	33 S
Hamtramck	27,245	34 NNE
Hazel Park	23,784	34 NNE
Leamington, Ontario (Canada)	10,229	34 E
Port Clinton, Ohio	7,202	34 SSE
Grosse Pointe Park	15,585	35 NNE
Grosse Pointe	6,637	36 NNE
Luckey, Ohio	996	36 SSW
Oak Park	36,762	36 N
Tecumseh	7,120	36 W
Farmington	13,337	37 N
Belle River, Ontario (Canada)	2,739	37 NE
Metamora, Ohio	594	37 WSW
Northville	5,400	37 NNW
Clinton	1,677	37 WNW
Ferndale	30,850	38 NNE
Gibsonbury, Ohio	2,585	38 S
Grosse Pointe Farms	11,701	38 NNE
Huntington Woods	8,536	38 N
Lathrup Village	1,429	38 N
Novi	9,668	38 NNW
Pemberville, Ohio	1,301	38 SSW
Quaker Town	837	38 N
Pleasant Ridge	3,989	38 N
Berkley	22,618	39 N
Center Line	10,379	39 NNE
Grosse Pointe Shores	3,042	39 NNE
Grosse Pointe Woods	21,878	39 NE
Harper Woods	20,186	39 N
Marblehead, Ohio	726	39 SE

TABLE 2.1-1 TOWNS AND CITIES WITHIN 50 MILES OF THE FERMI SITE

Town/City[a]	1970 Population	Distance (miles) and Direction From Site
Wood Creek Farms	1,090	39 N
40-50 Miles		
Adrian	20,382	40 W
Franklin	10,075	40 N
Haskins, Ohio	549	40 SW
Quaker Town North	7,101	40 N
Royal Oak	85,499	40 N
Bay View	798	41 SE
Beverly Hills	13,598	41 N
Bingham Farms	566	41 N
East Detroit	45,920	41 NNE
Helena, Ohio	298	41 S
Madison Heights	38,599	41 NNE
Southfield	69,285	41 N
South Lyon	2,675	41 NNW
Warren	179,260	41 NNE
Waterville, Ohio	2,940	41 SW
Wheatley, Ontario (Canada)	1,631	41 ENE
Ballville, Ohio	1,652	42 S
Birmingham	26,170	42 N
Clawson	17,617	42 N
Dexter	1,729	42 NW
Fremont, Ohio	18,490	42 SSE
Manchester	1,650	42 WNW
St. Clair Shores	88,093	42 NNE
Stoney Prairie, Ohio	1,913	42 S
Witmore Lake	2,763	42 NW
Wixom	2,010	42 NNW
Bowling Green, Ohio	21,760	43 SSW
Bradner, Ohio	1,140	43 S
Roseville	60,529	43 NNE
Tontogany, Ohio	395	43 SW
Walled Lake	3,759	43 NNW
Bloomfield Hills	3,672	44 N
Castalia, Ohio	1,045	44 SSE
Fraser	11,868	44 NNE

TABLE 2.1-1 TOWNS AND CITIES WITHIN 50 MILES OF THE FERMI SITE

Town/City[a]	1970 Population	Distance (miles) and Direction From Site
Sandusky, Ohio	32,674	45 SE
Lyons, Ohio	630	45 WSW
Troy	39,419	45 N
Wayne, Ohio	921	45 SSW
Wolverine Lake	4,301	45 NNW
Delta, Ohio	2,544	46 WSW
Orchard Lake Village	1,487	46 N
Sterling Heights	61,365	46 NNE
Burgoon, Ohio	221	47 S
Clyde, Ohio	5,503	47 SSE
Portage, Ohio	494	47 SSW
Chelsea	3,858	48 NW
Bettsville, Ohio	833	48 S
Brighton	2,457	48 NNW
Grand Rapids, Ohio	976	48 SW
Keego Harbor	3,092	48 N
Milford	4,699	48 NNW
Onsted	555	48 W
Rising Sun, Ohio	730	48 S
Sandusky South, Ohio	8,501	48 SE
Sylvan Lake	2,219	48 N
Tilbury, Ontario (Canada)	2,572	48 ENE
Green Springs, Ohio	1,279	49 SSE
Pontiac	85,279	49 N
Utica	3,504	49 NNE
West Milgrove, Ohio	215	49 SSW
Weston, Ohio	1,269	49 SSW
Clair Haven West	1,367	50 NNE
Clayton	773	50 W
Mt. Clemens	20,476	50 NNE
Jerry City, Ohio	470	50 SSW
Pinckney	921	50 NW

a. Towns and cities identified by the 1970 Census of Population.

TABLE 2.1-2 POPULATION DISTRIBUTION WITHIN THE LOW-POPULATION ZONE

Direction	1970	1980	1990	2000	2010	2020
N	387	504	612	771	970	1,021
NNE	267	348	422	532	669	842
NE	428	557	678	863	1,073	1,350
ENE	0	0	0	0	0	0
E	0	0	0	0	0	0
ESE	0	0	0	0	0	0
SE	0	0	0	0	0	0
SSE	0	0	0	0	0	0
S	445	579	705	886	1,116	1,404
SSW	1,682	2,191	2,662	3,349	4,216	5,307
SW	225	293	356	448	564	710
WSW	940	1,224	1,487	1,872	2,356	2,966
W	144	167	128	287	361	455
WNW	91	118	144	182	228	287
NW	184	240	291	367	462	581
NNW	603	785	954	1,201	1,512	1,902
TOTAL	5,396	7,006	8,439	10,748	13,527	16,825

TABLE 2.1-3 SCHOOLS WITHIN 10 MILES OF THE FERMI SITE

	School[a]	1972 Enrollment	Distance (miles) and Direction From Plant Site
1.	Brest	163	2.5 WSW
2.	Jefferson High	848	2.8 W
3.	Jefferson Jr. High	928	2.8 W
	Jefferson Elementary	155	
4.	St. Charles Schools	257	3 NNW
5.	St. Anne School	205	4 WSW
6.	Henry Niedermeir Elementary	230	4 NW
7.	Hurd Road Elementary	752	5 WSW
8.	Pt. Moulier School	57	5 NNE
9.	Airport Elementary	340	6 NW
10.	Golden Elementary	166	7 W
11.	Zion Lutheran School	174	7 WSW
12.	Cantrick Jr. High	1,437	7 WSW
13.	Hollywood Elementary	455	7 WSW
14.	Fred W. Riter Elementary	396	7 N
15.	Christiancy Elementary	406	7 WSW
16.	St. Mary Parish School	357	7 WSW
17.	Orchard Elementary	137	8 WSW
18.	Lincoln Elementary	700	8 WSW
19.	Monroe Catholic Central	454	8 WSW
20.	Riverside Elementary	298	8 WSW
21.	Trinity Lutheran School	275	8 WSW
22.	Monroe High	2,842	8 WSW
23.	St. Mary Academy	526	8 WSW
24.	Hall of the Divine Child	218	8 WSW
25.	St. John School	230	8 WSW
26.	St. Michael's School	350	8 WSW
27.	Manor Elementary	339	8 WSW
28.	Chapman Elementary	378	8 N
29.	Rockwood Elementary	286	8 N
30.	Borrow Elementary	170	9 N
31.	Airport Community High	1,417	9 NW
32.	South Monroe Townsite Elementary	357	9 WSW
33.	Waterloo Elementary	257	9 WSW
34.	Holy Ghost Lutheran School	101	9 WNW
35.	Parsons Elementary	748	9 NW
36.	Church Street Elementary	345	9 NW
37.	St. Mary	345	9 NW
38.	Carleton High and Jr. High	1,782	9 NW
39.	Raisinville Elementary	654	10 W
40.	St. Patrick School	240	10WNW
41.	Carleton Elementary	227	10 NW
42.	Custer Elementary I	949	10 WSW

TABLE 2.1-3 SCHOOLS WITHIN 10 MILES OF THE FERMI SITE

	School[a]	1972 Enrollment	Distance (miles) and Direction From Plant Site
43.	Custer Elementary II	428	10 WSW
44.	Monroe County Community College	1,676	11 WSW
TOTAL (within 10 miles)		23,183	

[a] Numbers refer to Figure 2.1-13.

TABLE 2.1-4 HOSPITALS AND NURSING FACILITIES WITHIN 10 MILES OF THE FERMI SITE

Hospital/Nursing Home	Number of Beds	Distance (miles) and Direction From Plant Site
Frenchtown Convalescent Center	226	6 W
Memorial Hospital of Monroe	78	7 W
Mercy Hospital	126	7 WSW
Monroe Convalescent Center	85	7 WSW
Rockwood Children's Home	8	8 N
Monroe County Shelter	17	8 WSW
Beech Nursing Home	123	8 WSW
Lutheran Home for the Aged	102	9 WSW
Monroe Care Center (a nursing facility)	103	9 WSW
TOTAL	868	

TABLE 2.1-5 RECREATIONAL AREAS WITHIN 10 MILES OF THE FERMI SITE

Park/Recreational Facility /Museum[a]	Distance (miles) and Direction
1. Estral Beach	2 NNE
2. Stony Point Beach	2 S
3. Woodland Beach	3 WSW
4. Frenchtown Park[b]	4 W
5. Willow Beach	4 WSW
6. Detroit Beach	4 WSW
7. Sterling State Park[b]	5 SW
8. Point Mouillee State Game Area[b]	5 NE
9. Point Mouillee State Game Area[b]	6 NE
10. Custer Park	6 WSW
11. Lake Erie Marshes	7 WSW
12. Heck Park	7 WSW
13. Soldiers and Sailors Park	8 WSW
14. Custer Museum[b]	8 WSW
15. Monroe County Historical Museum[b]	8 WSW
16. Bolles Harbor Public Boat Ramp	9 SW
17. Plum Creek Park	9 WSW
18. Waterloo Park	9 WSW
19. Avalon Beach	10 SW
20. Monroe County Fairgrounds[b]	10 W
21. Huron River (canoeing)	12 WNW

[a] Numbers refer to Figure 2.1-14.

[b] Attendance data were available for the following six facilities:

	Number of Visitors Annually
Sterling State Park	385,394
Custer Museum	12,000
Monroe County Historical Museum	45,000
Monroe County Fairgrounds	110,000
Frenchtown Park	20,000-30,000 (1974 estimates)
Point Mouillee State Game Area	180,000 User Days*

*A User Day is defined as one person using the facility for at least several hours at a time.

TABLE 2.1-6 NEEDS FOR SEASONAL AGRICULTURAL AND HORTICULTURAL LABOR IN MONROE COUNTY[a]

	Peak	Winter Only	March	April	May	June	July	August	September	October	November
Nursery and Landscape											
Number of Workers	300	-	200	300	300	200	175	175	300	300	200
Percent Migrants	15	-	0	5	15	20	20	10	10	10	10
Commercial Fruits											
Number of Workers	140	10	20	40	40	120	40	40	140	140	60
Percent Migrants	40	0	0	10	10	40	10	10	40	40	20
Greenhouse Produce											
Number of Workers	120	120	60	60	50	30	10	10	10	20	20
Percent Migrants	20	20	25	25	25	10	10	10	10	10	10
Commercial Vegetables, Tomatoes											
Number of Workers	1200	30	40	250	300	300	500	1000	1200	1200	150
Percent Migrants	50	0	0	10	10	10	30	45	45	50	10
General Farm Produce											
Number of Workers	500	50	50	250	300	200	250	250	450	500	250
Percent Migrants	5	0	0	0	5	10	10	5	5	5	0
Potatoes											
Number of Workers	75	20	10	20	25	25	40	60	75	75	40
Percent Migrants	60	20	0	10	10	10	20	50	60	60	20

TABLE 2.1-6 NEEDS FOR SEASONAL AGRICULTURAL AND HORTICULTURAL LABOR IN MONROE COUNTY[a]

	Peak	Winter Only	March	April	May	June	July	August	September	October	November
						Totals					
Number of Workers	2335	230	380	920	1015	875	1015	1535	2165	2335	720
Percent Migrants	34	12	4	7	11	17	11	30	32	34	8
Average Number Migrants	795	28	15	61	110	144	223	515	695	795	57

a "Seasonal worker" does not include farm manager, year-round hired labor, paid or unpaid year-round workers of the immediate farm family, or pick-your-own consumers. "Seasonal worker" includes migrant laborers, students, neighbors, trade-off time efforts, and others who work for 1 week or more during the year, at one location.

TABLE 2.1-7 DAIRIES WITHIN 18 MILES OF THE FERMI SITE

Number and Owner[a]		Number of Cows	Distance (miles) and Direction From Plant Site
1.	Fred Kemp	35	10 NW
2.	Henry Noel	25	5 NW
3.	William King	12	7 NNW
4.	Robert Reaume	25	6 NW
5.	Irving Langton	25	10 NW
6.	F. Hawley and J. Van Buskirk	50	8 NW
7.	Laurence Mieden	25	10 NW
8.	John Reiger	30	4 W
9.	Fred Falkenberg	35	9 WNW
10.	Frank Kominek	25	11 WNW
11.	William McGowan	30	12 WNW
12.	Earl and Robert Nowitzke	40	10 NW
13.	William Barnaby, Jr.	15	16 W
14.	George and Ruth Doty	49	13 W
15.	Wilbert Knapp	20	15 W
16.	Rolland Lemerand	30	16 W
17.	Stella Opferman	30	14 W
18.	Alvin Parron	44	14 W
19.	Lloyd Schafer	29	15 W
20.	M. Knapp and W. Young	50	17 W
21.	Glenn Lassey	45	13 WSW
22.	Arnold Hotchkiss	40	15 W
23.	Donald Doty	35	12 W
24.	Jerome Verhille	6	13 WNW
25.	Robert Doty	20	13 WNW
26.	St. Mary's Farm	93	11 W
27.	Glen Johnson	49	11 WSW
28.	Reuhs Bros.	149	18 W
29.	Julius Jaworski	71	18 W

[a] Numbers refer to Figure 2.1-15.

TABLE 2.1-8 FARM SIZE, FARMLAND USE, AND FARM SALES OF COUNTIES WITHIN 50 MILES OF THE FERMI SITE (1969)

COUNTY	Land Area of County (Acres)	Land in Farms (Acres)	Percent of Land in Farms	Number of Farms	Average Farm Size (Acres)	FARMLAND USE (ACRES): CROPLAND: Total	FARMLAND USE (ACRES): CROPLAND: Harvested	FARMLAND USE (ACRES): CROPLAND: Pasture or Grazing	FARMLAND USE (ACRES): CROPLAND: All Other Cropland[a]	FARMLAND USE (ACRES): Woodland	FARMLAND USE (ACRES): All Other Land[b]	FARMLAND USE (ACRES): Irrigated Land	FARM SALES (THOUSANDS OF DOLLARS): Value of All Agricultural Products Sold[c]: Total	FARM SALES (THOUSANDS OF DOLLARS): Value of All Agricultural Products Sold[c]: Average Per Farm	FARM SALES (THOUSANDS OF DOLLARS): Crops Including Nursery Products and Hay	FARM SALES (THOUSANDS OF DOLLARS): Forest Products	FARM SALES (THOUSANDS OF DOLLARS): Livestock, Poultry, and their Products
MICHIGAN																	
Monroe	356,544	253,927	71.2	2,000	126.9	221,396	162,585	4,001	54,810	15,292	17,239	726	20,052	10.0	2	40	6,317
Wayne	387,200	49,527	12.8	597	82.9	38,887	25,562	2,378	10,947	4,567	6,073	326	5,865	9.8	4,866	6	993
Macomb	307,328	96,934	31.5	997	97.2	77,368	47,335	6,901	23,132	9,029	10,537	1,248	13,382	13.4	9,122	22	4,237
Oakland	554,560	101,820	18.4	863	117.9	68,085	33,362	14,182	20,541	13,706	20,029	499	8,852	10.2	4,387	43	4,421
Livingston	366,080	174,047	47.5	1,099	158.3	119,832	71,810	16,496	31,526	21,125	33,090	702	11,228	10.2	2,855	56	8,317
Washtenaw	464,720	260,283	57.2	1,699	153.1	196,810	126,019	24,074	46,717	26,136	37,337	490	18,439	10.8	5,293	50	13,097
Jackson	446,848	258,094	57.8	1,577	163.6	175,259	100,751	25,618	48,890	27,559	55,276	573	16,923	10.7	3,516	62	13,346
Lenawee	481,856	403,602	83.8	2,558	157.7	335,283	241,044	12,293	81,946	30,913	37,406	640	31,912	12.5	13,427	33	18,453
OHIO																	
Fulton	260,288	239,839	92.1	1,738	137.9	207,129	166,959	4,477	35,693	15,942	16,768	119	35,663	20.5	10,302	35	25,327
Lucas	219,776	98,521	44.8	785	125.5	88,640	74,932	1,726	11,982	4,264	5,617	279	12,386	15.8	9,646	6	2,739
Henry	265,920	266,064	100.1	1,695	156.9	238,297	200,319	5,062	32,916	11,632	16,135	13	25,876	15.3	15,088	12	10,776
Wood	396,288	371,279	93.7	2,181	170.2	333,725	280,223	7,411	46,091	16,998	20,556	326	28,256	12.9	18,202	1	10,053
Putman	311,040	306,085	98.4	1,975	154.9	272,049	231,113	9,436	31,500	16,129	17,979	123	30,056	15.2	15,738	21	14,297
Seneca	352,640	329,755	93.5	1,887	174.7	271,501	207,941	13,167	50,393	31,816	26,438	112	20,873	11.1	11,562	33	9,277
Ottawa	167,296	130,272	77.9	976	133.0	115,093	87,620	1,910	25,563	5,493	9,686	302	9,254	9.4	6,212	7	3,035
Sandusky	261,888	240,924	92.0	1,488	161.9	208,239	160,598	6,939	40,702	13,852	18,903	566	21,225	14.2	13,188	17	8,020
Erie	168,832	106,733	63.2	702	152.0	87,830	64,461	3,434	19,935	7,869	11,034	207	9,026	12.8	4,863	15	4,143
ONTARIO CANADA																	
Kent	616,320	559,811	d	3,748	d	484,482	d	21,229	11,076	16,296	32,911	d	d	d	d	d	d
Essex	460,160	353,203	d	3,768	d	318,138	d	5,573	9,978	9,279	8,248	d	d	d	d	d	d

[a] Includes cropland used for soil-improvement crops, crops failure, cultivated summer fallow and idle cropland.

[b] Includes pastureland other than cropland and woodland pasture, rangeland, and land in house lots, barn lots, ponds, roads, etc.

[c] Represents market value, before taxes and expenses, of all agricultural products sold by all farms in the census areas.

[d] Data not available.

TABLE 2.1-9 CROPS HARVESTED IN U.S. COUNTIES WITHIN 50 MILES OF THE FERMI SITE (1969)

	Field Corn			Sorghum														
	Grain		Silage	Grain		Silage	Wheat		Other Small Grains	Soy Beans		Hay	Potatoes	Veg. and Melons	Berries	Land in Orchards	Other Crops	Green House Products Under Glass
County	Acres	Bushels	Acres	Acres	Bushels	Acres	Acres	Bushels	Acres	Acres	Bushels	Tons	Acres	Acres	Acres	Acres	Acres	Square feet
MICHIGAN																		
Lenawee	77,037	7,069,410	12,682	104	4,492	96	31,343	1,379,556	15,532	78,292	2,213,558	61,216	276	1,340	5	719	3,932	128,400
Jackson	31,384	2,389,527	9,211	-	-	114	9,963	577,637	10,287	1,431	25,999	87,817	184	961	64	1,126	2,443	36,000
Washtenaw	37,167	3,058,604	7,423	159	4,208	265	15,489	596,895	14,486	11,439	287,359	89,833	340	1,929	66	773	1,991	357,921
Livingston	19,418	1,479,003	8,061	-	-	134	6,418	233,206	5,688	723	16,108	77,040	23	475	19	763	2,324	21,136
Oakland	7,862	603,518	1,792	3	180	23	3,540	130,298	2,907	355	7,351	33,208	96	615	52	1,232	607	984,360
Macomb	10,188	796,486	3,789	25	800	24	4,837	176,756	4,514	3,021	76,976	29,855	482	5,480	28	1,458	1,962	1,770,327
Wayne	4,275	295,448	448	-	-	-	2,177	74,820	1,258	11,537	237,768	5,597	8	2,174	39	469	716	1,196,462
Monroe	39,262	3,518,839	3,524	66	4,030	48	22,684	902,666	9,283	70,220	1,826,878	16,125	2,670	4,899	70	503	4,694	630,306
OHIO																		
Erie	17,754	1,396,548	2,097	112	3,770	20	10,810	393,438	4,636	17,174	422,382	14,742	114	3,946	28	1,305	2,378	645,000
Sandusky	43,863	3,451,504	3,449	1,341	80,513	45	20,595	769,702	8,237	54,651	1,481,979	33,877	357	7,254	46	1,409	8,159	86,840
Ottawa	10,124	670,171	1,285	270	18,250	18	13,109	429,732	5,939	37,348	791,278	28,920	2	2,827	9	1,741	4,112	33,480
Seneca	57,490	4,801,680	2,959	22	1,650	48	31,221	1,443,581	13,710	81,916	2,269,753	40,243	181	1,694	16	24	4,183	111,600
Putman	64,934	5,575,890	2,789	223	14,763	28	27,129	1,091,547	11,314	96,768	2,650,298	33,322	261	5,236	9	14	10,995	-
Wood	85,879	6,313,301	3,445	30	2,975	80	40,787	1,688,582	20,604	103,803	2,749,362	48,286	13	3,336	36	69	6,513	431,796
Henry	64,190	5,627,260	2,947	12	550	6	26,306	1,141,355	10,060	78,233	2,336,747	27,171	57	3,888	5	22	7,067	3,000
Lucas	22,048	1,878,614	877	-	-	-	7,628	323,785	2,760	31,038	787,416	9,631	771	3,653	23	612	2,844	3,203,755
Fulton	69,122	6,330,547	10,556	50	1,000	46	17,326	742,313	6,529	50,984	1,454,446	24,669	839	2,834	21	124	695	40,148

TABLE 2.1-10 CROPS HARVESTED IN CANADIAN COUNTIES WITHIN 50 MILES OF THE FERMI SITE (1971)

	Ontario Province County[a]	
	Kent	Essex
Corn		
Grain	233,745	81,002
Silage	18,013	6,479
Wheat	43,299	48,724
Oats		
Grain	18,453	12,719
Silage	267	350
Barley	4,962	2,068
Mixed grain	2,226	516
Rye	340	158
Field beans	11,719	492
Tame hay	10,537	13,521
Soy beans	115,119	118,703
Potatoes	505	3,186
Tobacco	2,005	963
Other field crops	1,322	661

[a] All figures are in acres.

TABLE 2.1-11 LIVESTOCK AND POULTRY OF COUNTIES WITHIN 50 MILES OF THE FERMI SITE (1969)

County	Cattle	Milk Cows	Hogs	Sheep	Horses	Chickens	
						Total	Hens
Monroe	13,984	2,190	15,408	4,441	942	106,870	104,781
Wayne	2,328	537	1,584	500	669	32,362	31,758
Macomb	12,574	4,966	2,649	1,683	737	62,489	61,306
Oakland	12,008	2,820	3,009	2,584	2,442	58,162	57,779
Livingston	27,660	9,508	5,812	7,497	1,426	10,550	8,721
Washtenaw	33,588	10,550	23,890	53,361	1,961	126,700	111,633
Jackson	40,794	9,566	15,283	17,327	1,616	64,048	59,572
Lenawee	46,691	10,822	39,036	12,765	1,523	284,342	258,350
Fulton[a]	39,548	6,340	71,393	2,922	670	566,494	436,571
Lucas[a]	3,968	499	10,470	421	250	113,068	112,861
Henry[a]	13,744	3,686	23,026	4,103	412	513,142	416,951
Wood[a]	23,376	1,622	23,093	7,160	812	109,996	108,852
Putnam[a]	20,686	6,348	57,715	6,713	285	571,304	478,747
Seneca[a]	19,352	7,587	38,744	22,911	680	106,832	99,468
Ottawa[a]	5,645	1,876	5,643	1,040	200	140,324	123,916
Sandusky[a]	18,801	3,973	21,959	6,465	566	137,632	110,883
Erie[a]	8,212	3,604	7,108	2,489	437	71,477	31,808
Kent[b]	47,883	1,500	113,070	3,934	1,132	452,558	286,199
Essex[b]	16,162	6,505	27,520	865	1,133	381,461	199,870

[a] Counties located in Ohio.

[b] Counties located in Canada.

TABLE 2.1-12 MUNICIPAL WATER INTAKES FROM LAKE ERIE

Intake Point	Year	Withdrawal (10^6 gal/year)	Number of People Served	Percent to Industry	Percent to Residents	Distance (miles) From Plant Site[a]
Monroe	1972	2,000	40,000	35	65	6
Toledo	1972	29,200	500,000	40	60	28
Kingsville	1972	156	1,400	10	90	28
Leamington	1972	450	10,000	50	50	32
Port Clinton	1971	577	12,000	10	90	37
Wheatley	1972	114	1,059	54	46	42
Sandusky	1972	3,960	47,000	60	40	48
Huron	1972	450-500	7,500	33	67	53
Vermilion	1972	33	9,000	-	-	62
Lorain	1972	5,027	85,000	39	61	70
Blenheim	1972	90	4,000	5	95	70
Cleveland	1972	130,875	2,000,000	52	48	93
Fairport	1971	274	36,000	66	34	108
Port Stanley	1971	88	(summer residents only)	0	100	112
Ashtabula	1972	1,900	34,000-36,000	45	55	130
Conneaut	1969	477	15,000	52	48	140
Erie	1972	16,700	180,000	35	65	167
Port Dover	1972	165	4,000-7,000	10	90	170
Port Maitland	1972	4,100	1,000	90	10	197
Dunkirk	1972	1,487	30,000	51	49	207
Port Colborne	1972	1,191	20,000	5	95	212
Buffalo	1972	47,950	500,000	30	70	233

[a] See Figure 2.1-20 for locations.

TABLE 2.1-13 SUMMARY OF COMMERCIAL FISH LANDINGS (POUNDS) BY STATISTICAL DISTRICT FOR 1971 FOR THE PROVINCE OF ONTARIO[a]

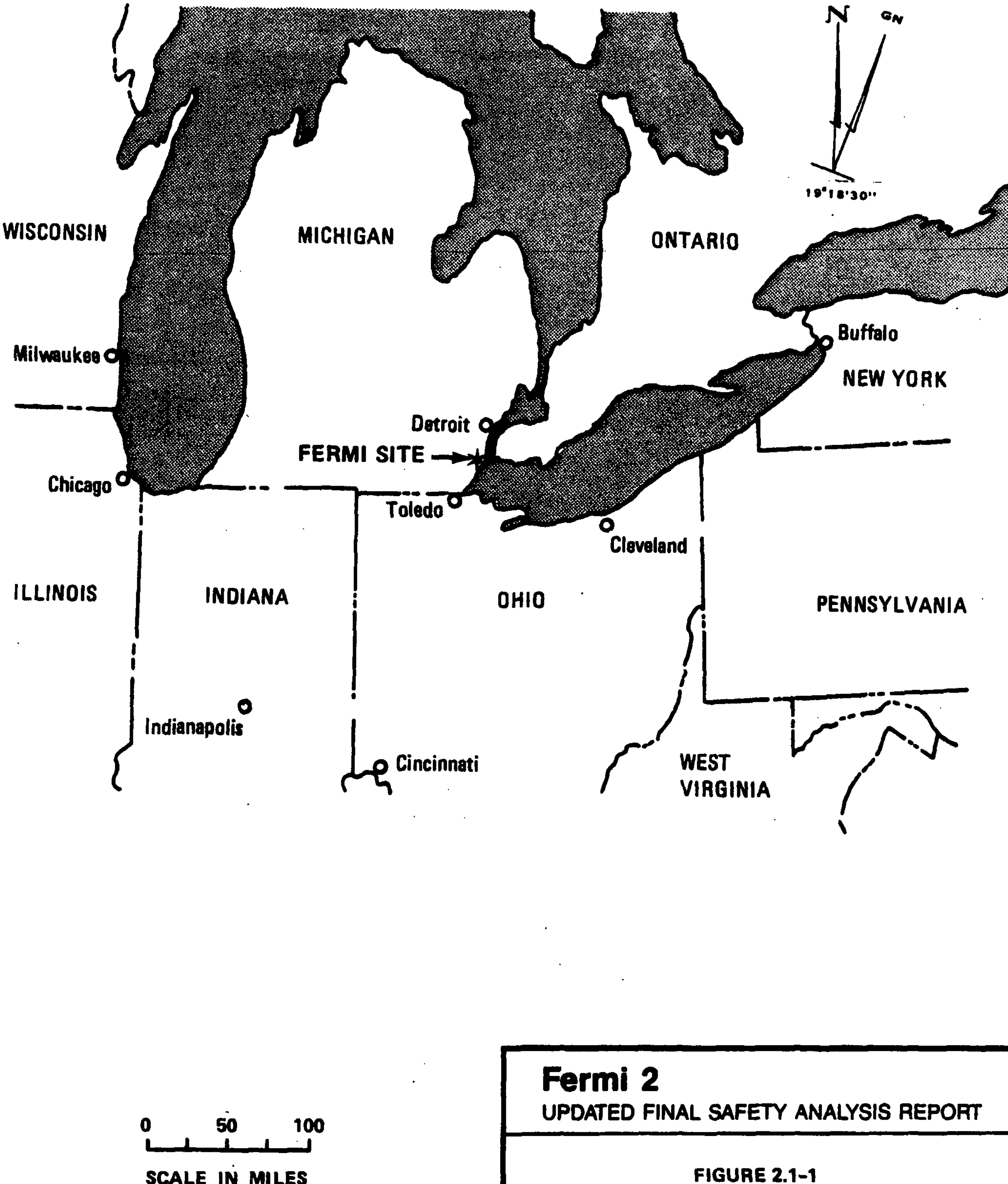
Species	S.D. 1	S.D. 2	S.D. 3	S.D. 4	S.D. 5	Totals Pounds	Totals Dollars
Bowfin	-	-	-	19,640	-	19,640	589
Bullhead	-	-	-	34,259	383	34,642	5,307
Carp	27,052	522	-	23,233	1,793	52,600	3,548
Catfish	38,514	40,949	11,159	9,207	1,207	101,036	24,474
Northern Pike	-	-	15	1,642	410	2,067	323
Yellow Perch	3,770,391	6,383,547	2,880,354	360,175	523,144	13,917,611	3,563,039
Suckers	4,536	262	65	5,488	2,192	12,543	1,248
Rock Bass	-	284	-	18,439	8,271	26,994	5,987
Freshwater Drum	355	65,946	9,460	8,424	8,788	92,973	2,953
Smelt	12,324	958,481	1,117,242	11,041,802	526	13,130,375	571,461
Sunfish	-	-	-	84,271	-	84,271	23,664
White Bass	3,210	9,274	44,006	23,869	11,668	92,027	22,182
Lake Whitefish	630	21	-	179	2	832	312
Yellow Pickerel	5,300	1,703	6	117	23,049	30,175	15,272
Others	371,153	985,503	16,451	25,900	78,766	1,477,773	14,333
Total Catch (lb)	4,233,465	8,446,492	4,078,758	11,656,645	660,199	29,075,559	
Total Value ($)	896,694	1,719,527	852,174	613,199	173,098		4,254,692

[a] See Figure 2.1-21 for district areas.

TABLE 2.1-14 SUMMARY OF COMMERCIAL FISH LANDINGS (POUNDS) BY STATISTICAL DISTRICT FOR 1971 FOR THE STATE OF OHIO[a]

Species	S.D. 6	S.D. 7	S.D. 8	S.D. 9	Totals
Buffalo	6,628	35	100	2,347	9,110
Bullhead	14,753	55	4	21,657	36,469
Carp	2,237,111	10,058	44	912,211	3,159,424
Catfish	423,822	9,882	78	193,518	627,300
Freshwater Drum	245,313	138,085	856	441,982	826,236
Goldfish	2,754	1	-	76,821	79,576
Quillback	27,644	412	-	-	28,056
Smelt	230	183	-	-	413
Suckers	67,675	19,636	138	31,020	118,469
White Bass	676,287	62,989	4,687	184,949	928,912
Yellow Perch	691,726	937,868	531,917	27,395	2,188,906
Total Catch	4,393,943	2,358,408	537,824	1,891,900	8,002,871

[a] See Figure 2.1-21 for district areas.



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UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.1-1

SITE LOCATION

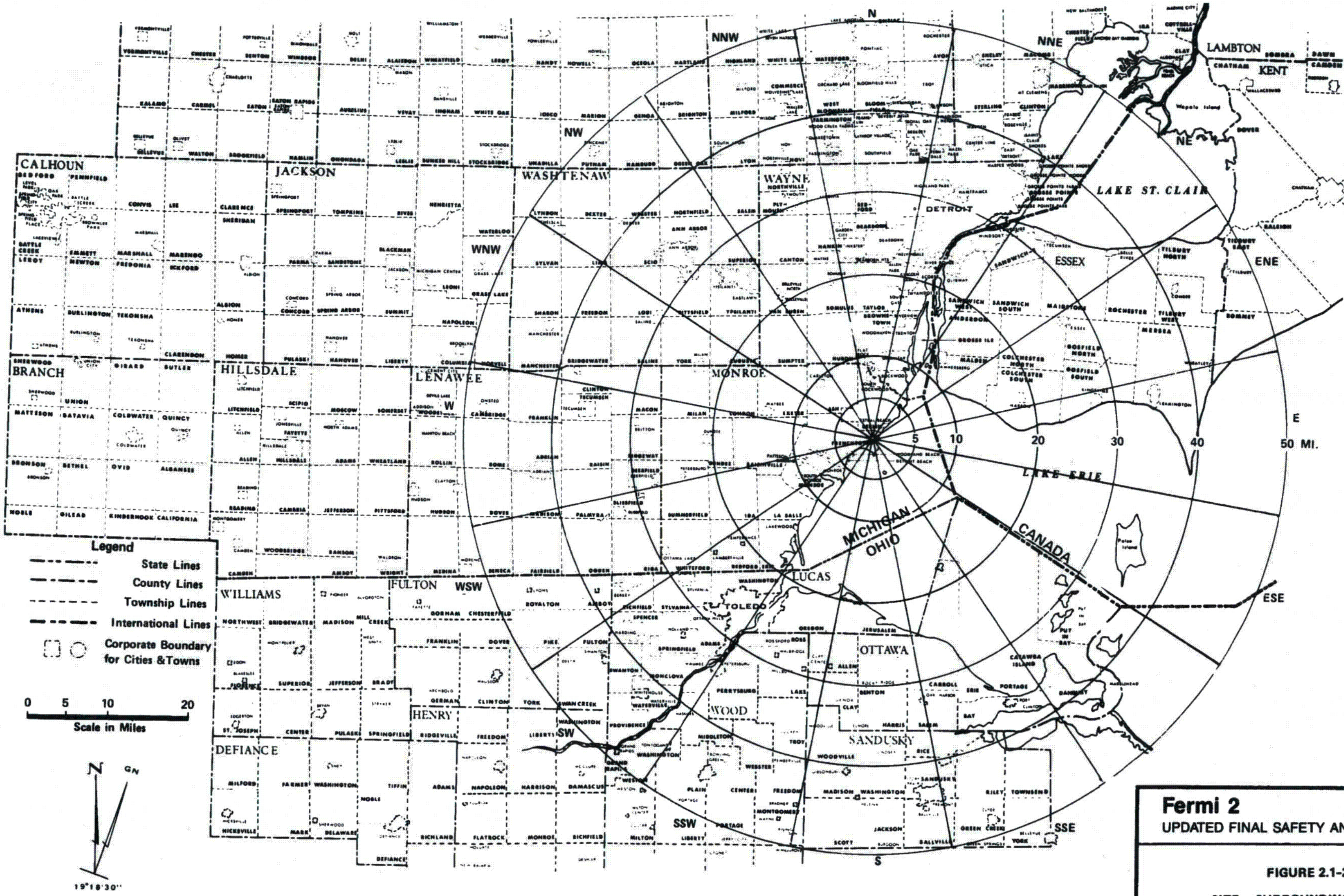

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FIGURE 2.1-2

SITE – SURROUNDING REGION

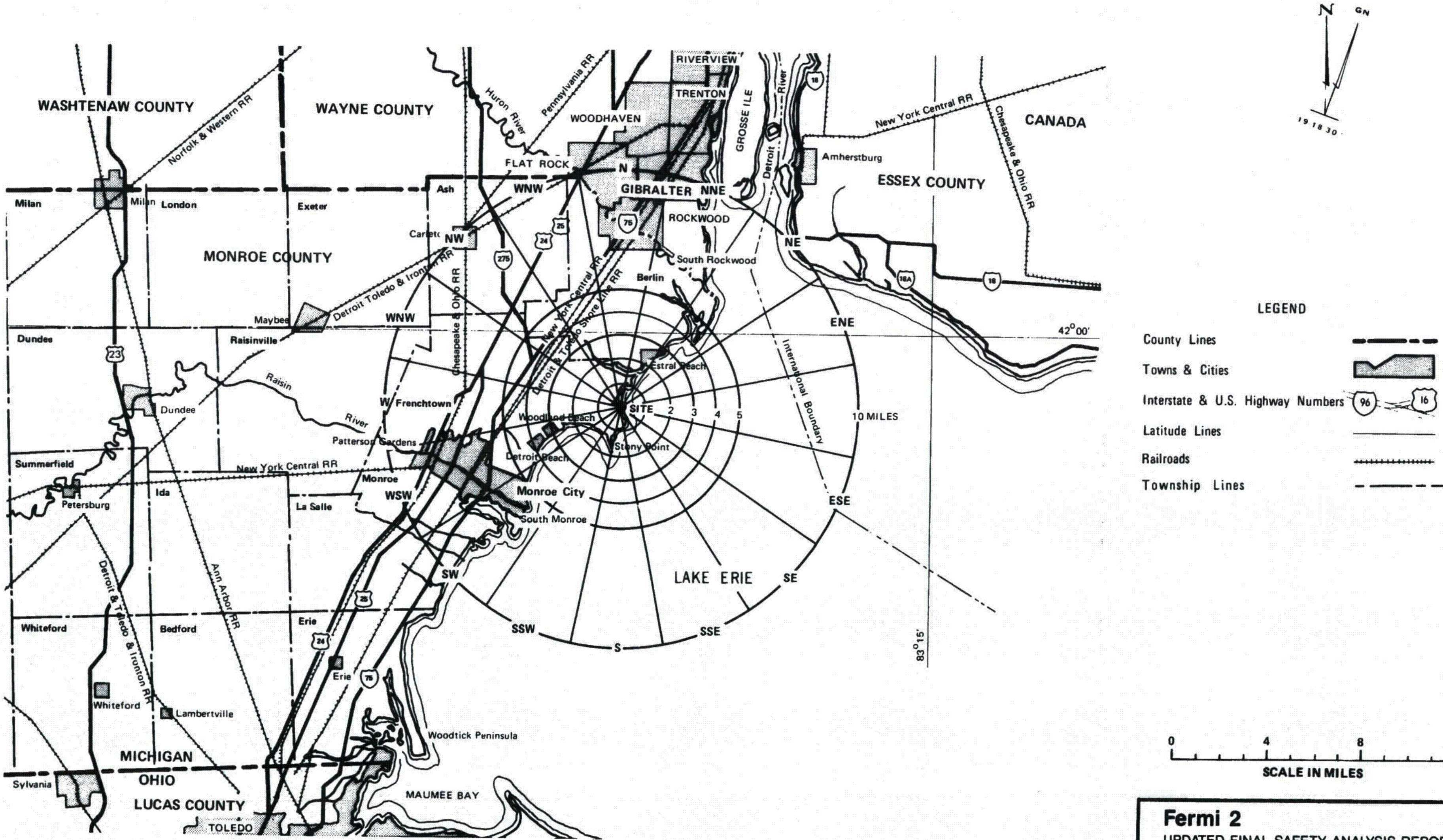

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FIGURE 2.1-3

SITE – IMMEDIATE ENVIRONS

REFERENCE:
ADAPTED FROM DETROIT EDISON COMPANY
SERVICE AREA GENERAL MAP, 1971

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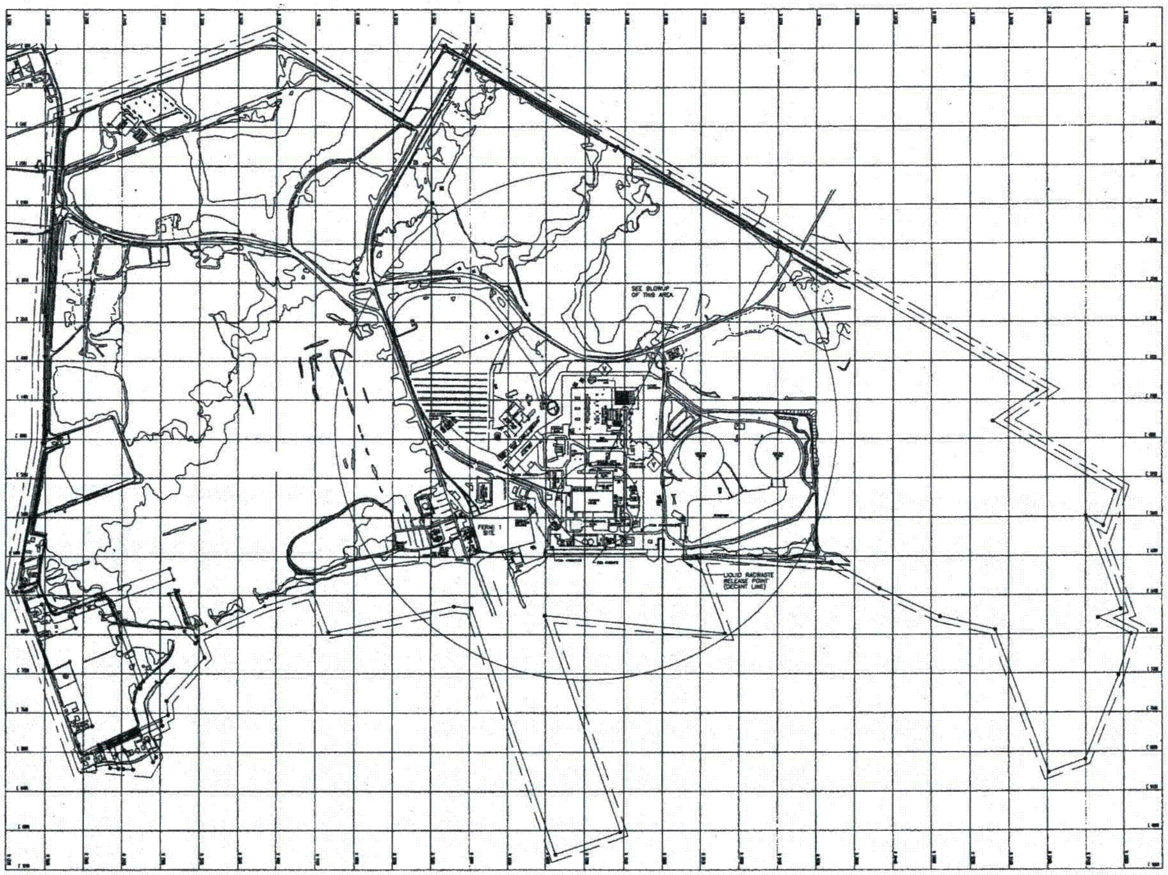
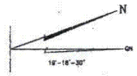
FIGURE 2.1-4

SITE AERIAL VIEW





KEY

NORMAL RADIOLOGICAL RELEASE POINTS

LEGEND:

□ GASEOUS

△ LIQUID

— — — LIQUID UNRESTRICED AREA BOUNDARY

—— – —— GASEOUS UNRESTRICTED AREA BOUNDARY

GASEOUS RELEASE ELEVATIONS

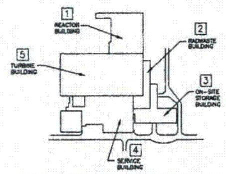
1. REACTOR BUILDING	-751 ft.
2. RADWASTE BUILDING	-729 ft.
3. ON-SITE STORAGE BUILDING	-676 ft.
4. SERVICE BUILDING	-632 fT.
5. TURBINE BUILDING	-720 ft.

NOTES:

THIS DRAWING WAS PREPARED FROM CARTOGRAPHY'S GENERAL YARD MAP FILES AND AERIAL PHOTOGRAPHY DATED MAY 1985. ANY CHANGES OR REVISIONS SHALL BE REFERRED TO THE ARCH/CIVIL DIVISION OF GENERATION ENGINEERING DEPARTMENT.

ALL PREVIOUS REVISIONS TO THIS DOCUMENT HAVE BEEN APPROVED BY DETROIT EDISON AND ARE ON MICROFILM IN DOCUMENT CONTROL.

THIS DRAWING WAS UPDATED TO DELETE DETAILS ON FERMI 1 DUE TO DECOMMISSIONING ACTIVITIES.



BLOWUP OF CIRCLED PORTION

NOT TO SCALE

Fermi 2

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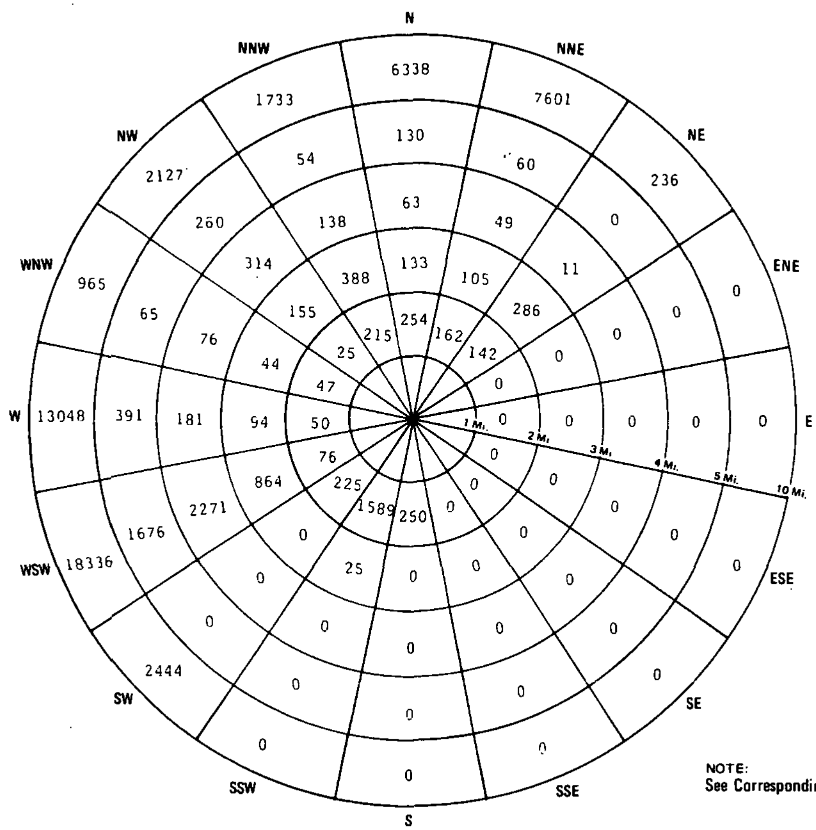
FIGURE 2.1-5

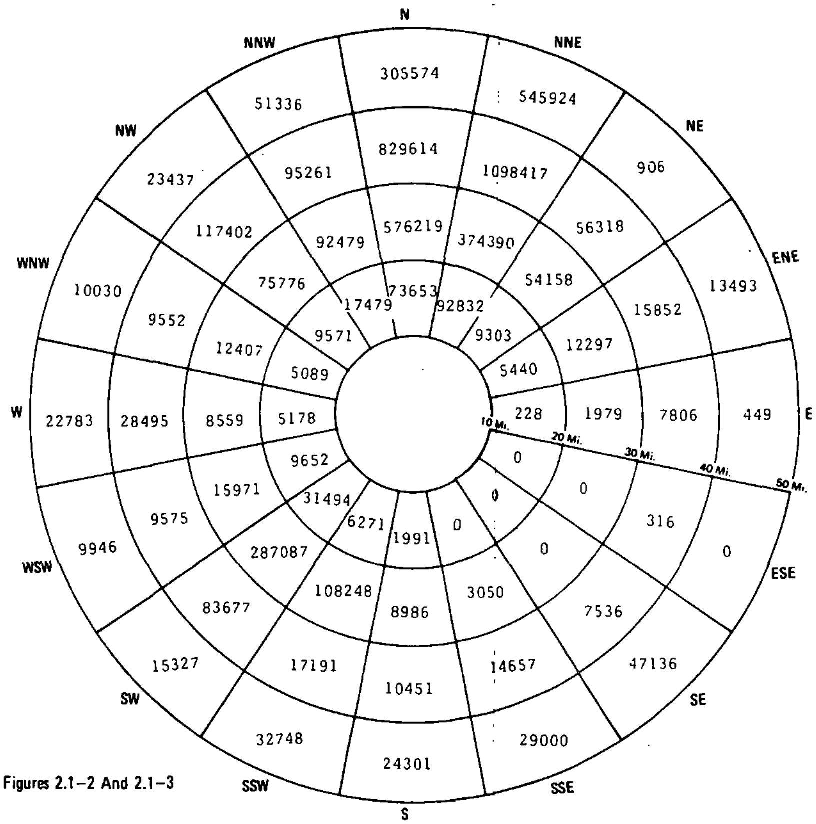
SITE PLOT PLAN

DETROIT EDISON COMPANY DRAWING NO. 6A721-2102, REV. V (MARKUP)

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	267	3035	2094	3103	2636	52828	63963

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50 Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	268181	1631606	2402120	1132390	5434297	5498260





NOTE:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
195	68	0	0	0	0	4	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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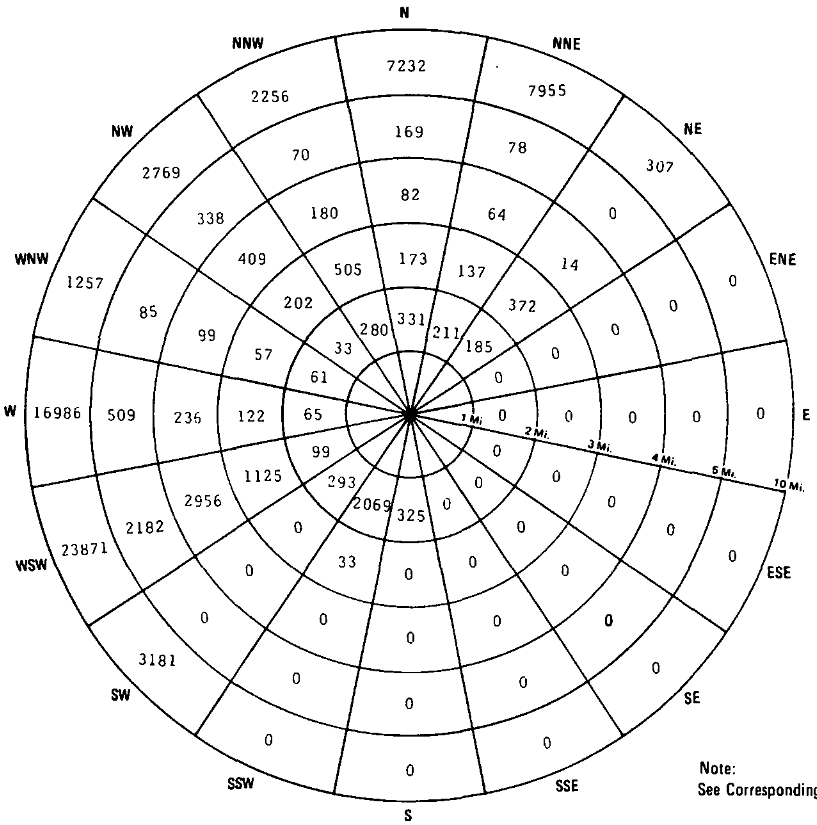
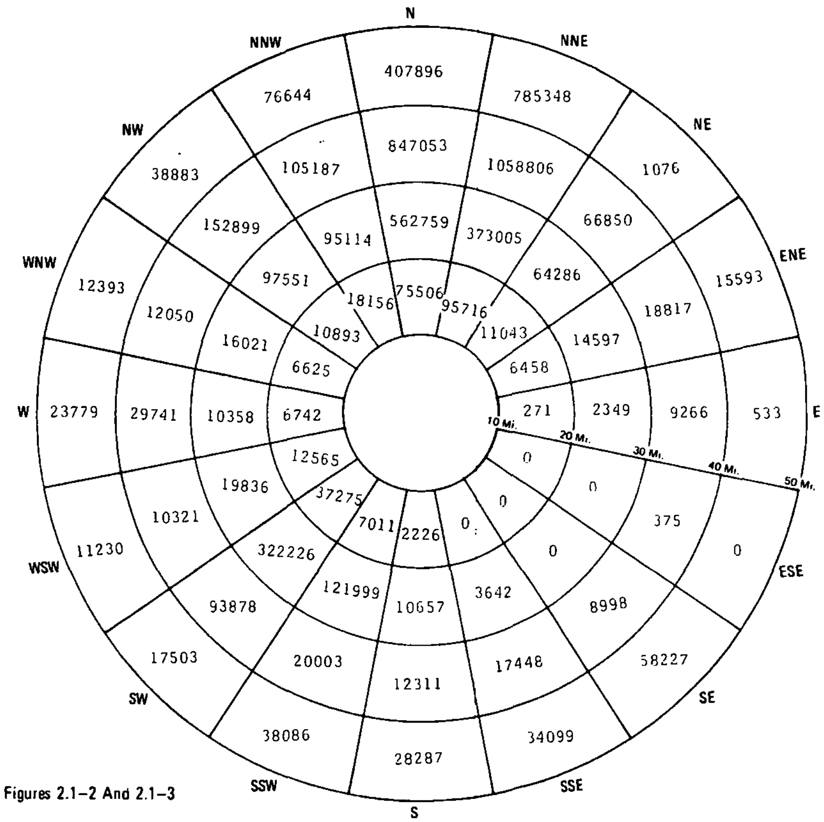
FIGURE 2.1-6

POPULATION DISTRIBUTION – 1970
0-10 MILES AND 10-50 MILES

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	348	3952	2726	4040	3431	65814	80311

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50 Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	290487	1714400	2464003	1549577	6018467	6098778





Note:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
254	89	0	0	0	0	5	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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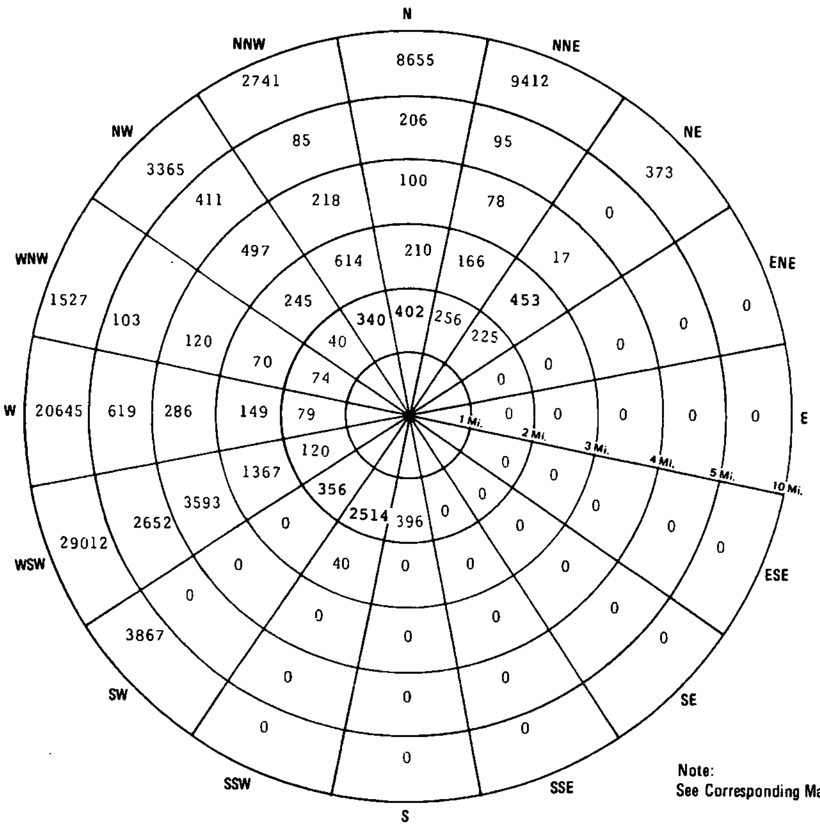
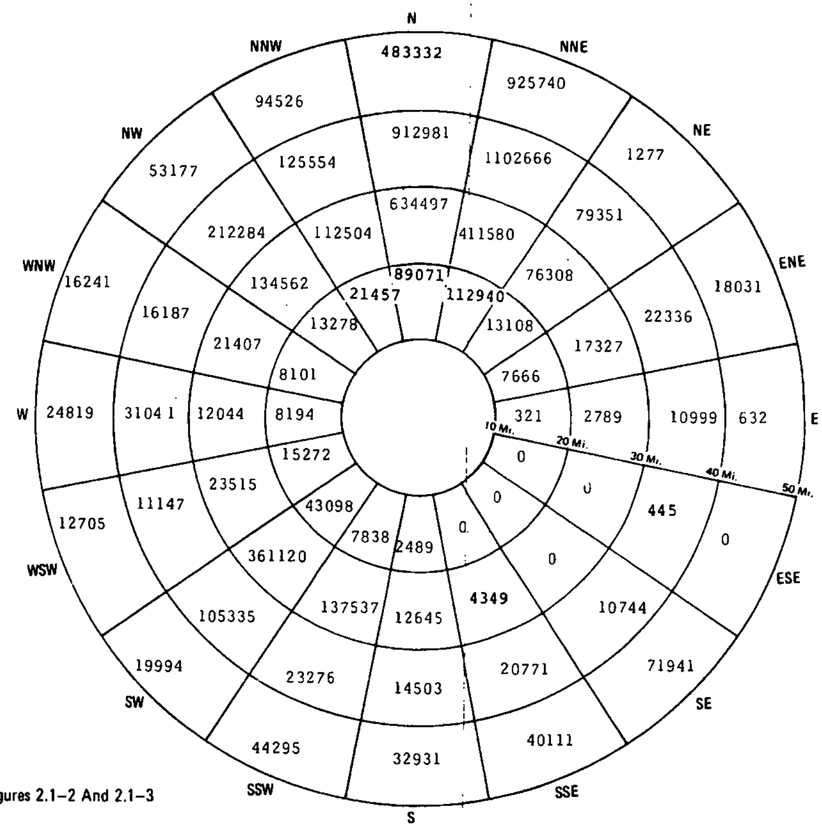
FIGURE 2.1-7

POPULATION DISTRIBUTION – 1980
0-10 MILES AND 10-50 MILES

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	423	4802	3314	4909	4171	79597	97216

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50 Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	342833	1962184	2699620	1839752	6844389	6941605





Note:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
309	108	0	0	0	0	6	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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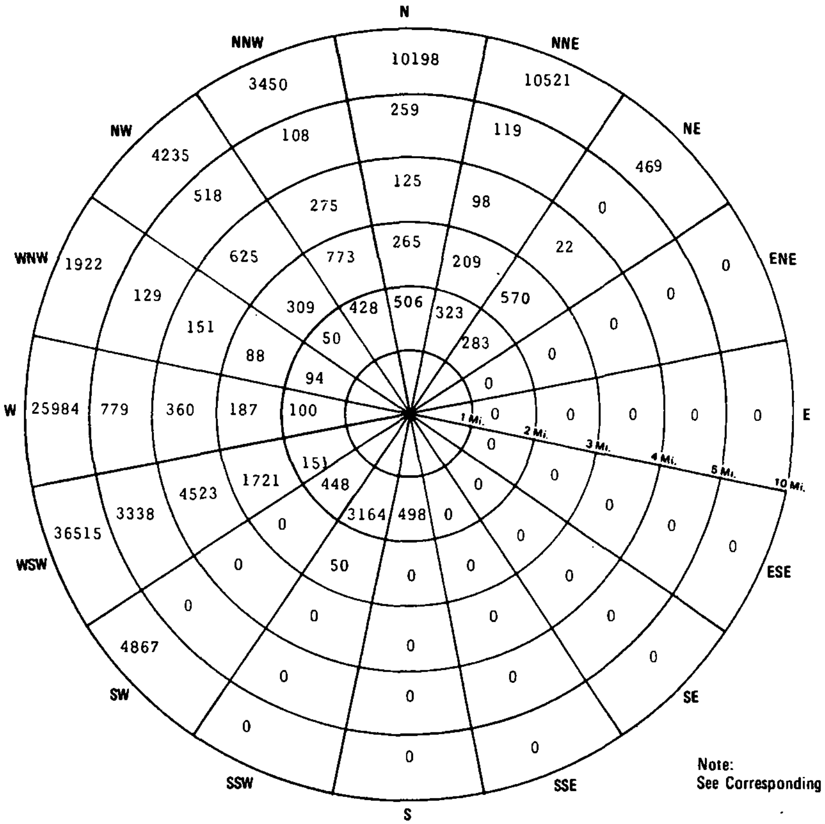
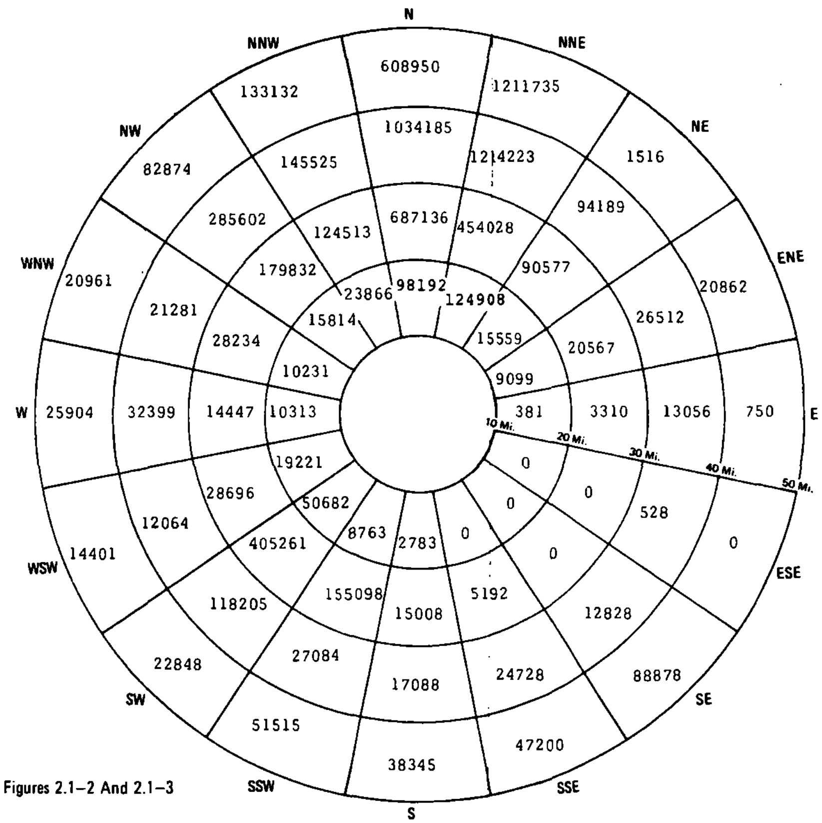
FIGURE 2.1-8

POPULATION DISTRIBUTION – 1990
0-10 MILES AND 10-50 MILES

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	531	6045	4172	6179	5250	98161	120338

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50 Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	389812	2211899	3079497	2369871	8051079	8171417





Note:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
388	135	0	0	0	0	8	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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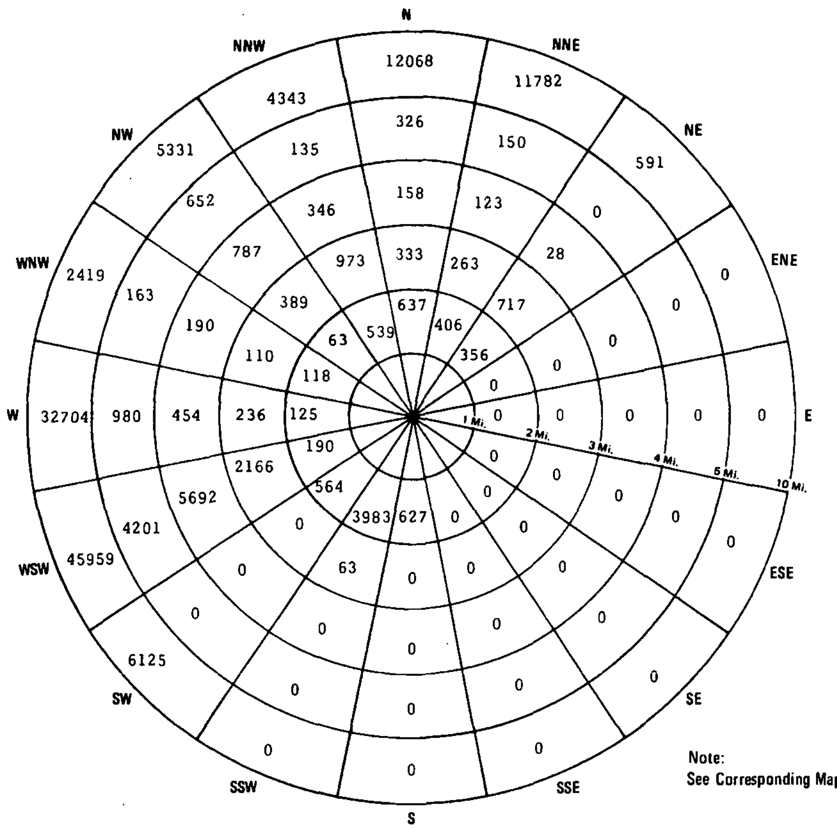
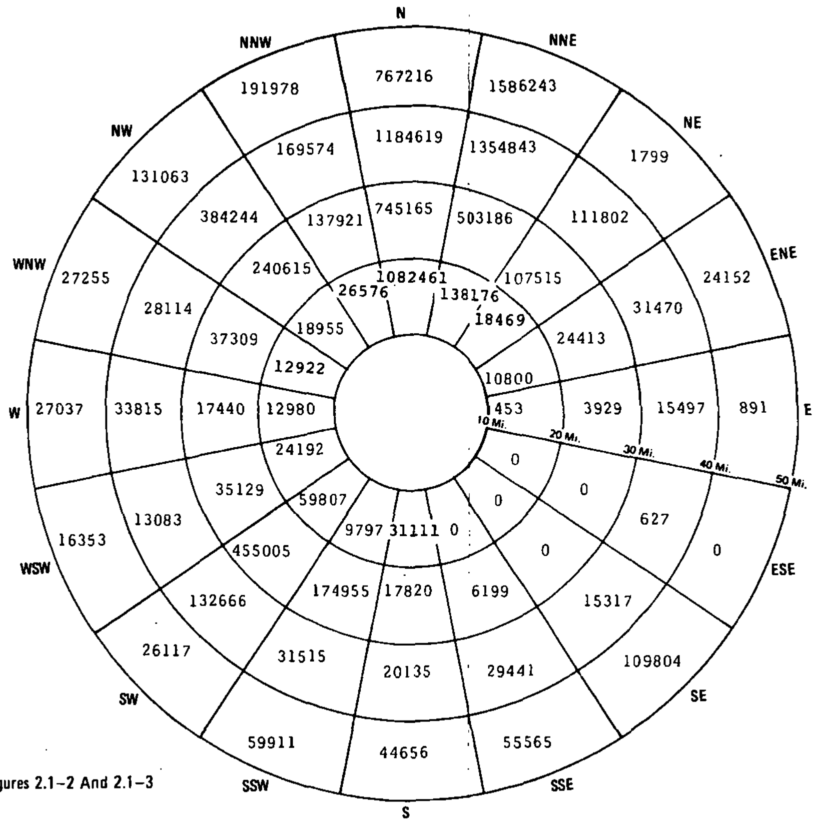
FIGURE 2.1-9

POPULATION DISTRIBUTION – 2000
0-10 MILES AND 10-50 MILES

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	669	7608	5250	7778	6607	121322	149234

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	444484	250601	3556762	3070040	9577887	9727121





Note:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
489	170	0	0	0	0	10	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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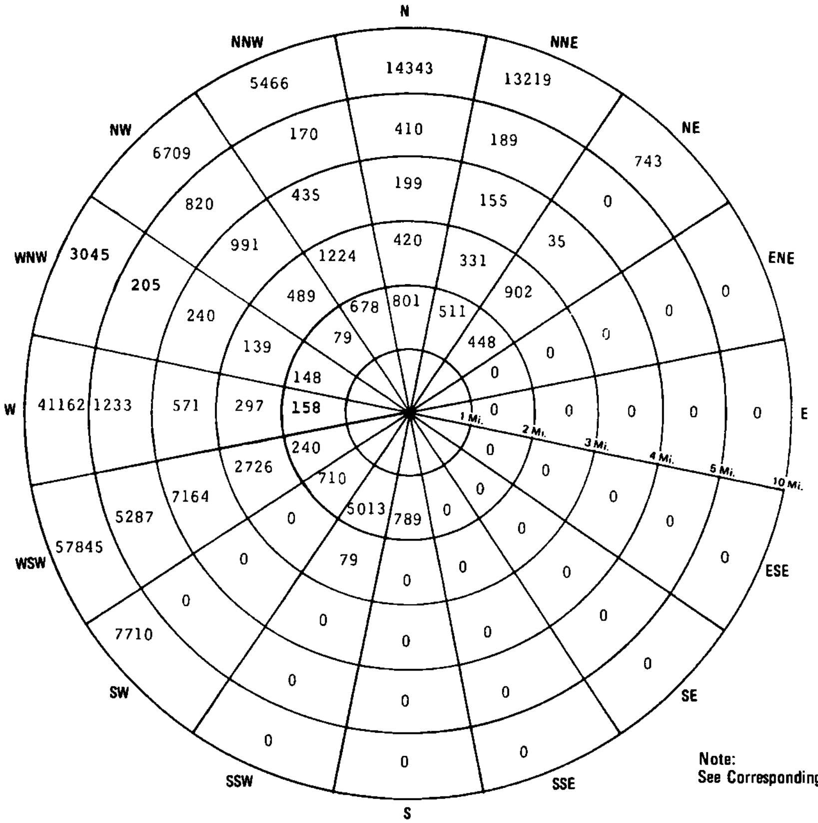
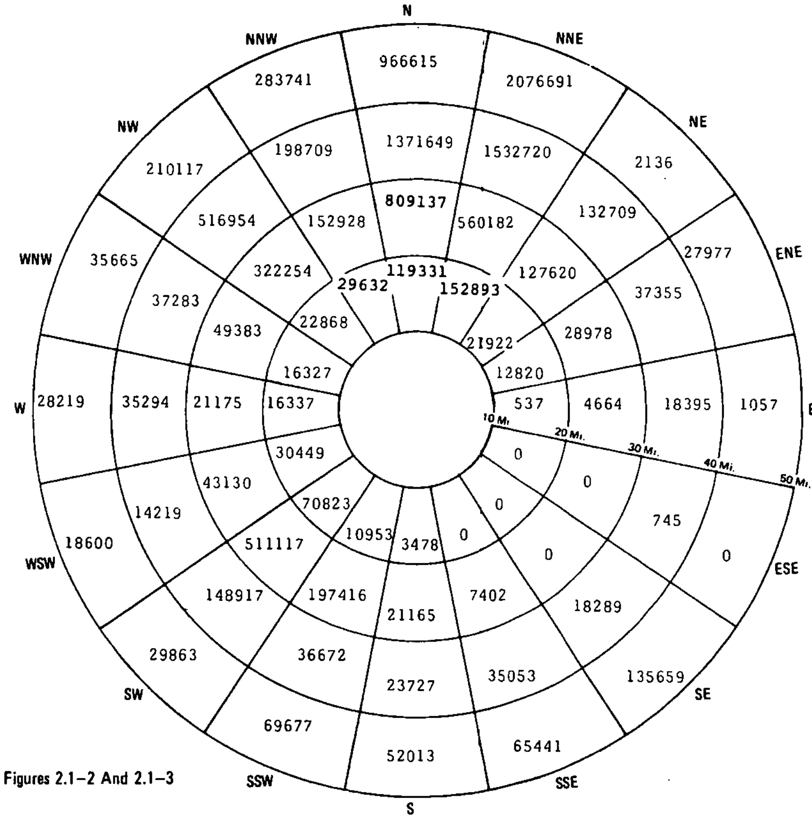
FIGURE 2.1-10

POPULATION DISTRIBUTION – 2010
0-10 MILES AND 10-50 MILES

Annulus	0–1 Mi.	1–2 Mi.	2–3 Mi.	3–4 Mi.	4–5 Mi.	5–10 Mi.	Total 0–10 Mi.
Population	843	9575	6607	9790	8314	150242	185371

Annulus	10–20 Mi.	20–30 Mi.	30–40 Mi.	40–50 Mi.	Total 10–50 Mi.	Total 0–50 Mi.
Population	508370	2856551	4158690	4003471	11527082	11712453





Note:
See Corresponding Maps, Figures 2.1–2 And 2.1–3

Values For 0–1 Mile Annulus

N	NNE	NE	ENE	E	ESE	SE	SSE
0	0	0	0	0	0	0	0
615	215	0	0	0	0	13	0
S	SSW	SW	WSW	W	WNW	NW	NNW

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FIGURE 2.1-11

POPULATION DISTRIBUTION – 2020
0-10 MILES AND 10-50 MILES

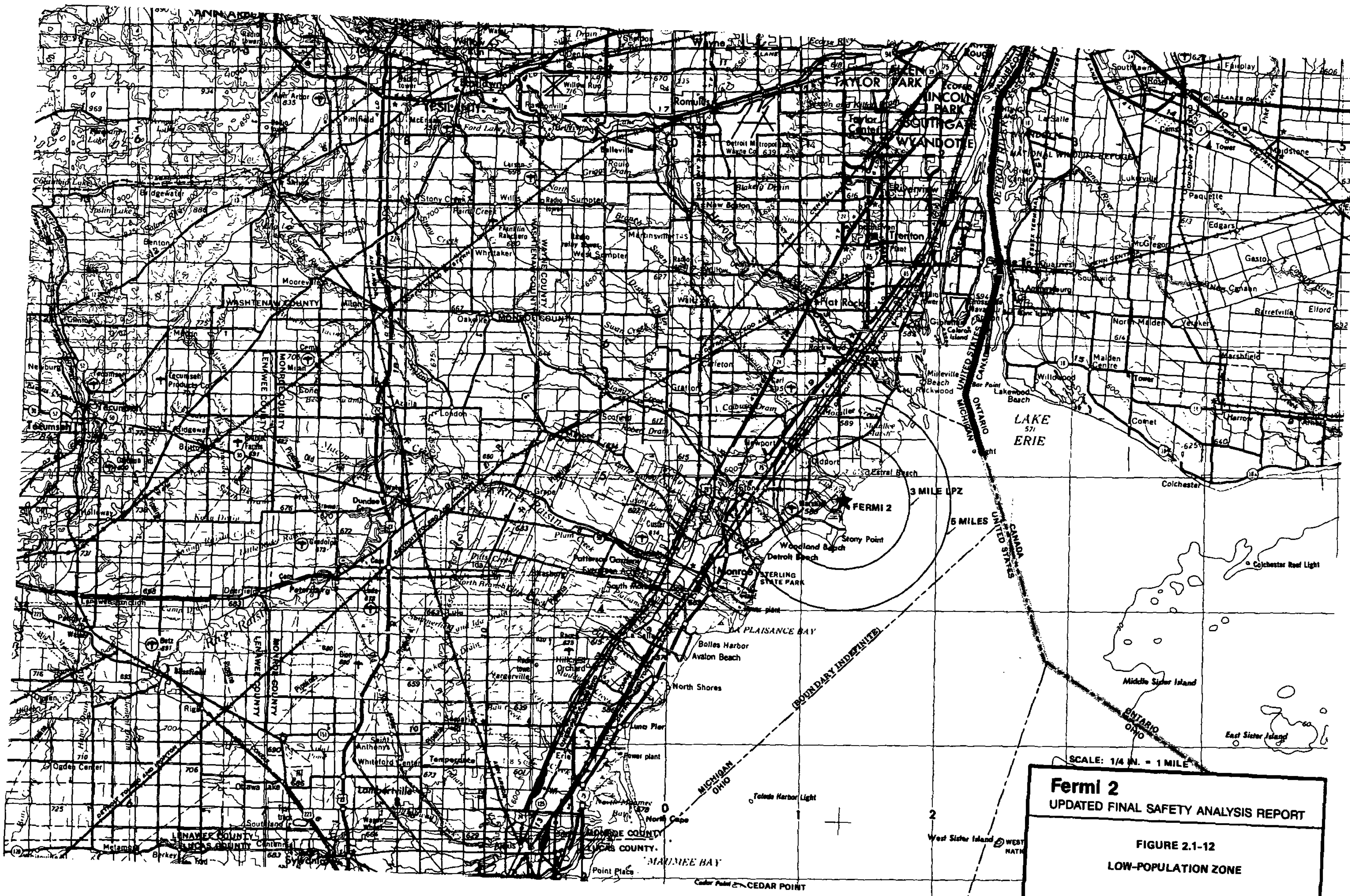

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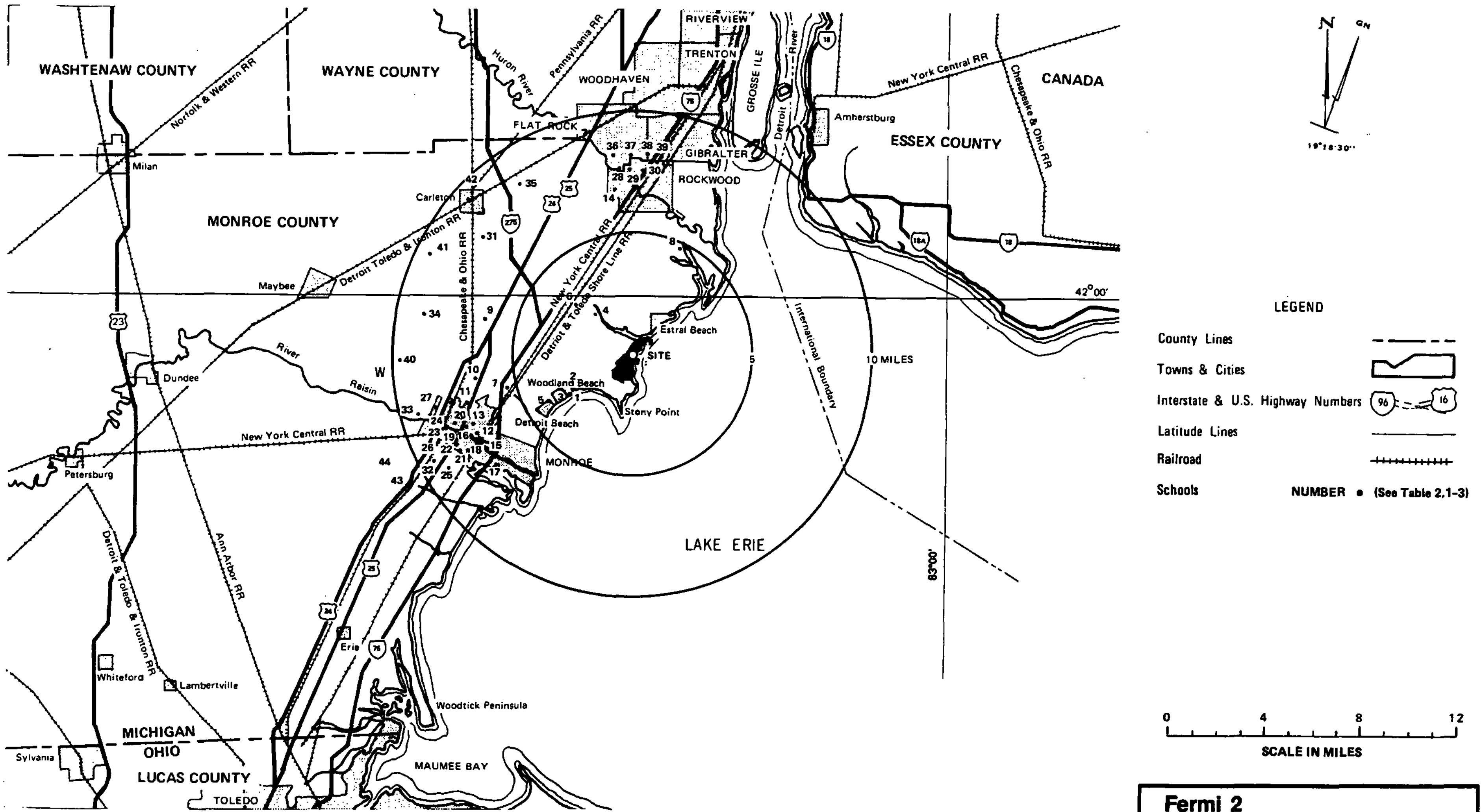
FIGURE 2.1-12
LOW-POPULATION ZONE



REFERENCE:
ADAPTED FROM DETROIT EDISON COMPANY
SERVICE AREA GENERAL MAP, 1971

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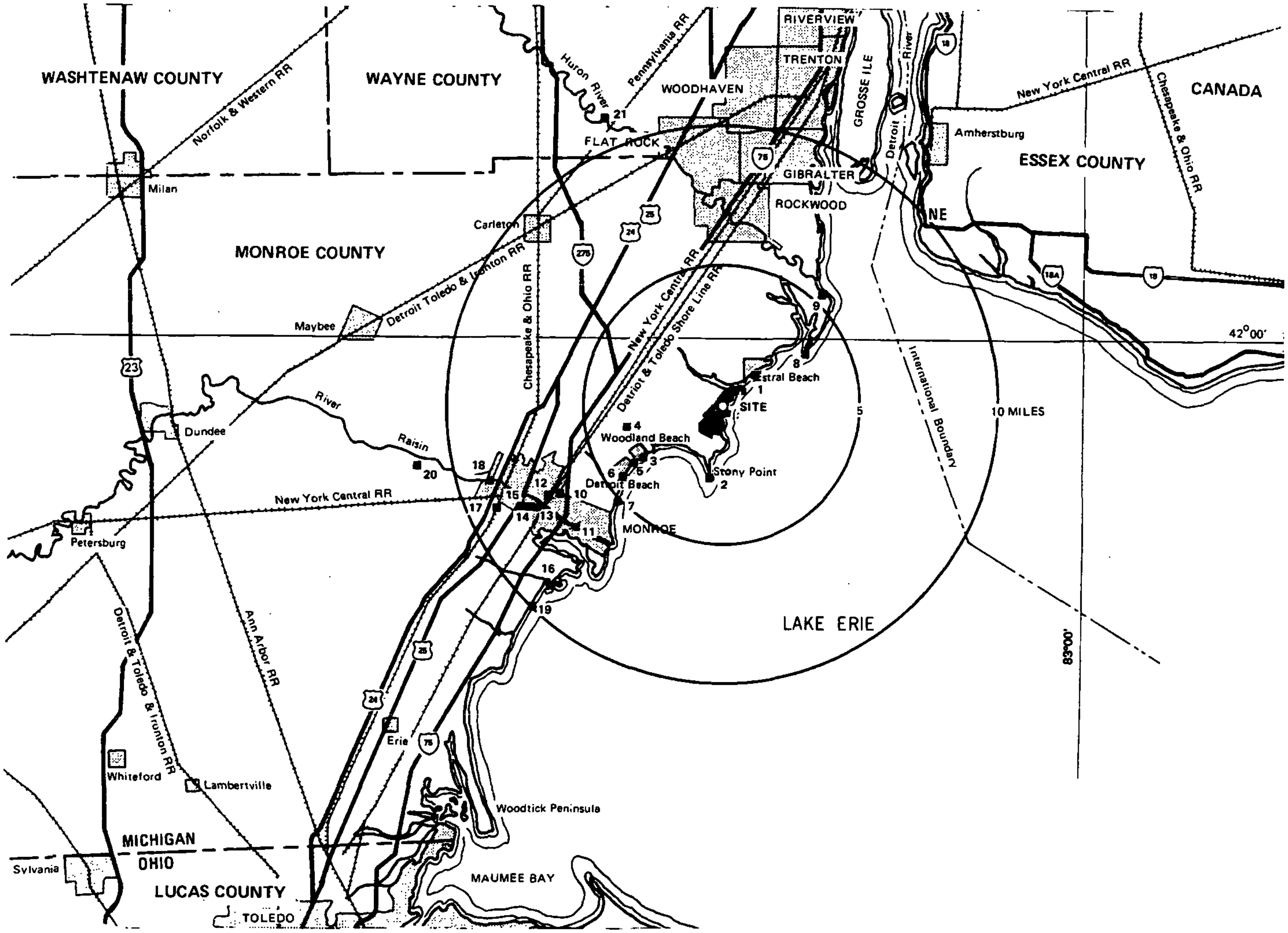
FIGURE 2.1-13
SCHOOLS IN THE VICINITY

REV 6 3/93



LEGEND

County Lines	
Towns & Cities	
Interstate & U.S. Highway Numbers	96, 16
Latitude Lines	
Railroad	
Recreational Areas	NUMBER ■ (See Table 2.1-3)

0 4 8 12

SCALE IN MILES

REFERENCE:
ADAPTED FROM DETROIT EDISON COMPANY
SERVICE AREA GENERAL MAP, 1971

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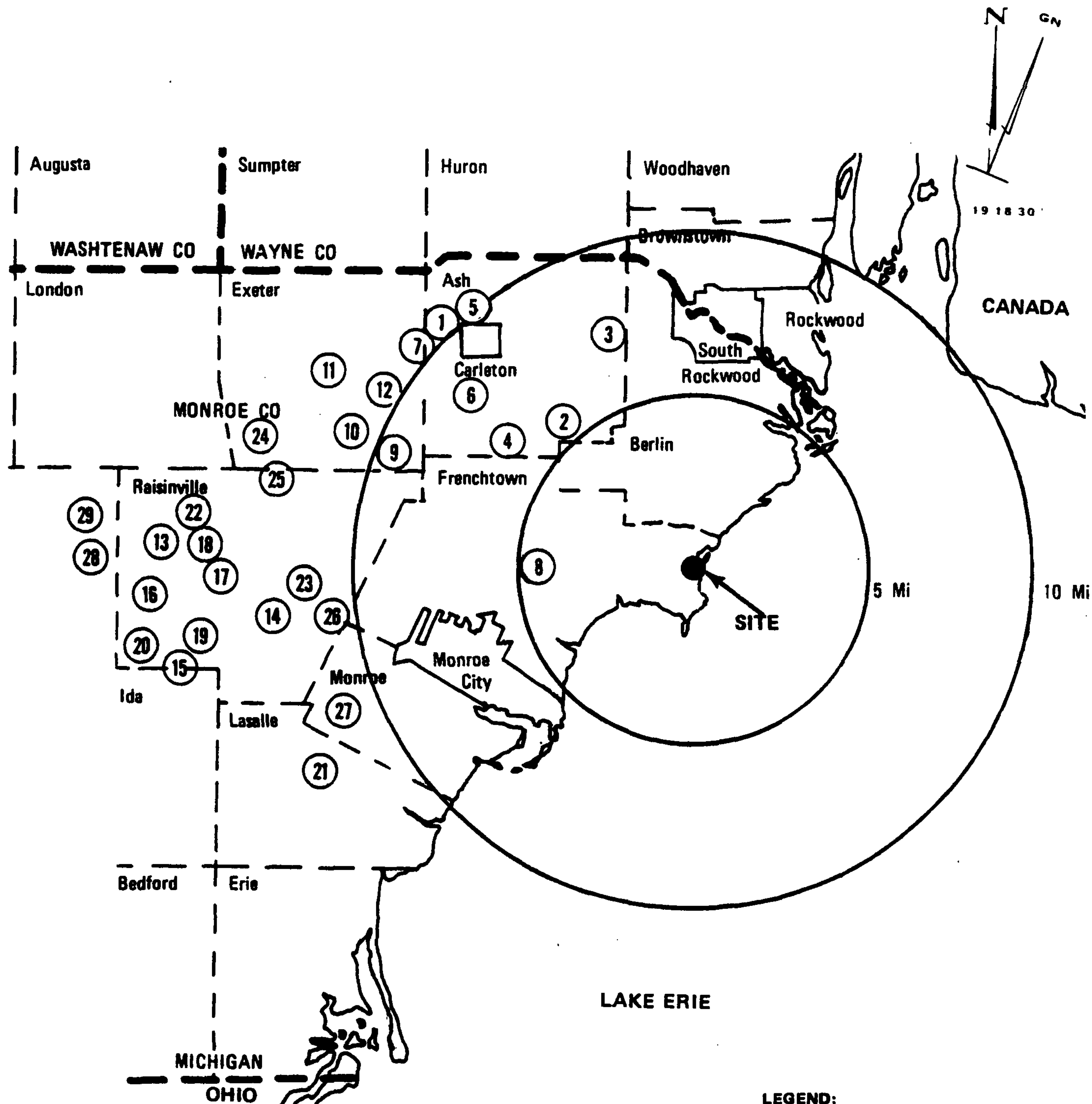
FIGURE 2.1-14

RECREATION AREAS IN THE VICINITY

REV 6 3/93



LEGEND:
(N) DAIRY
(SEE TABLE 2.1-7)

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FIGURE 2.1-15

DAIRY FARMS IN THE VICINITY

REFERENCE:
ADAPTED FROM SOUTHEAST MICHIGAN COUNCIL OF GOVERNMENTS – COUNTY-TOWNSHIP-CITY-VILLAGE MAP, 1971

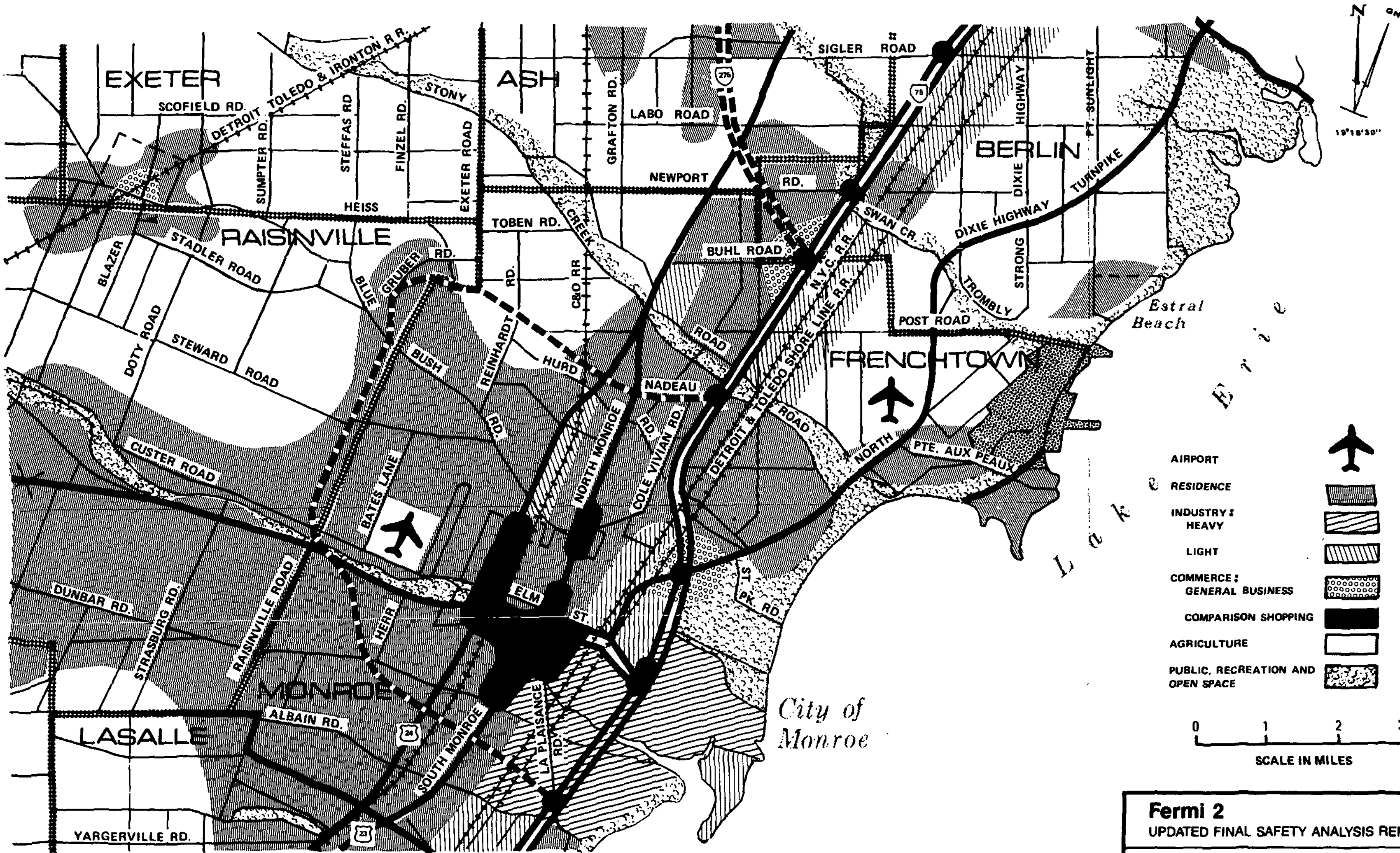

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FIGURE 2.1-16

MONROE COUNTY LAND USE PLAN

REFERENCE:
ADAPTED FROM MONROE COUNTY COMPLAN, 2000, 1967

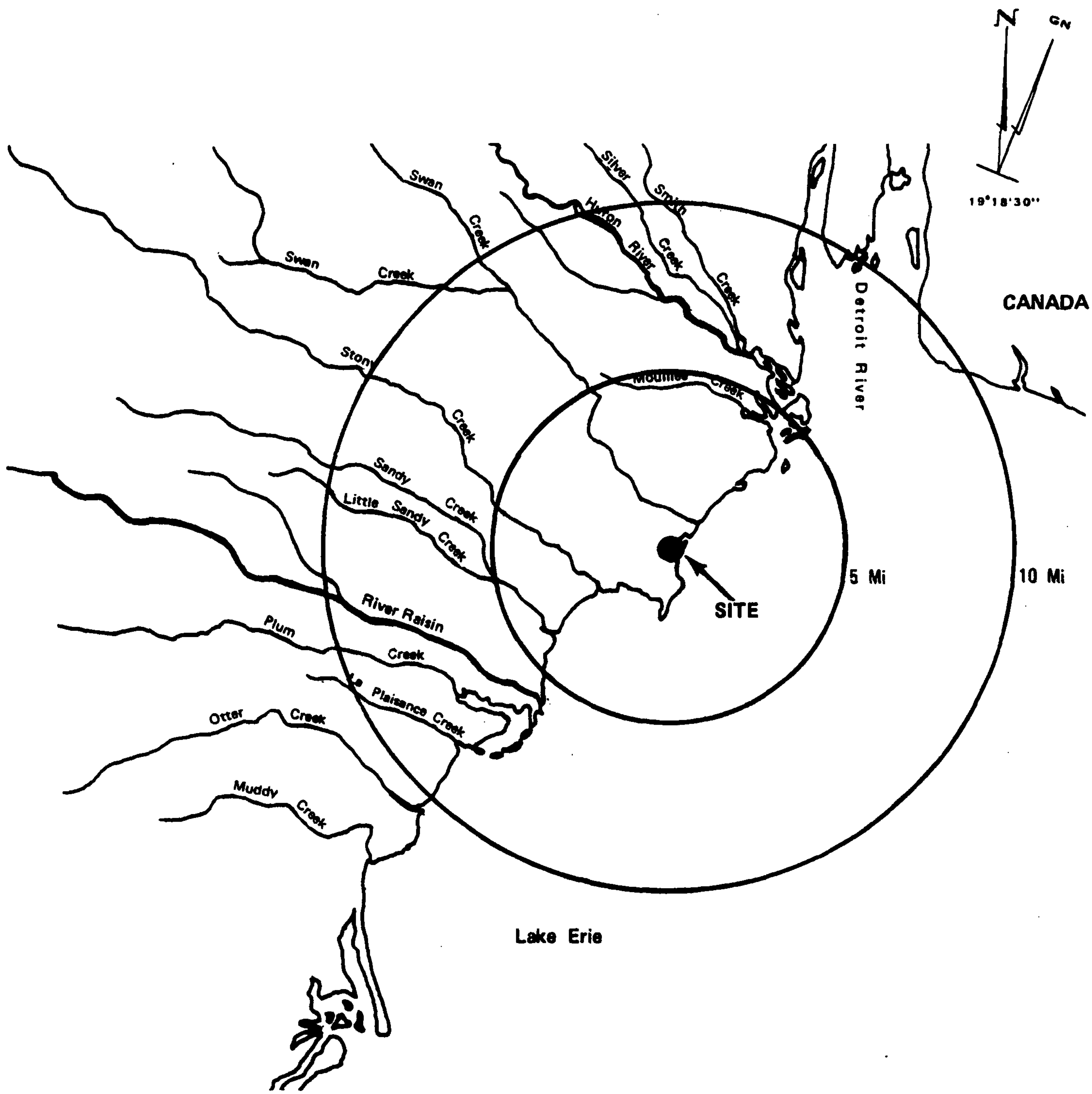

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FIGURE 2.1-17

LAKES, RIVERS, AND STREAMS IN THE VICINITY

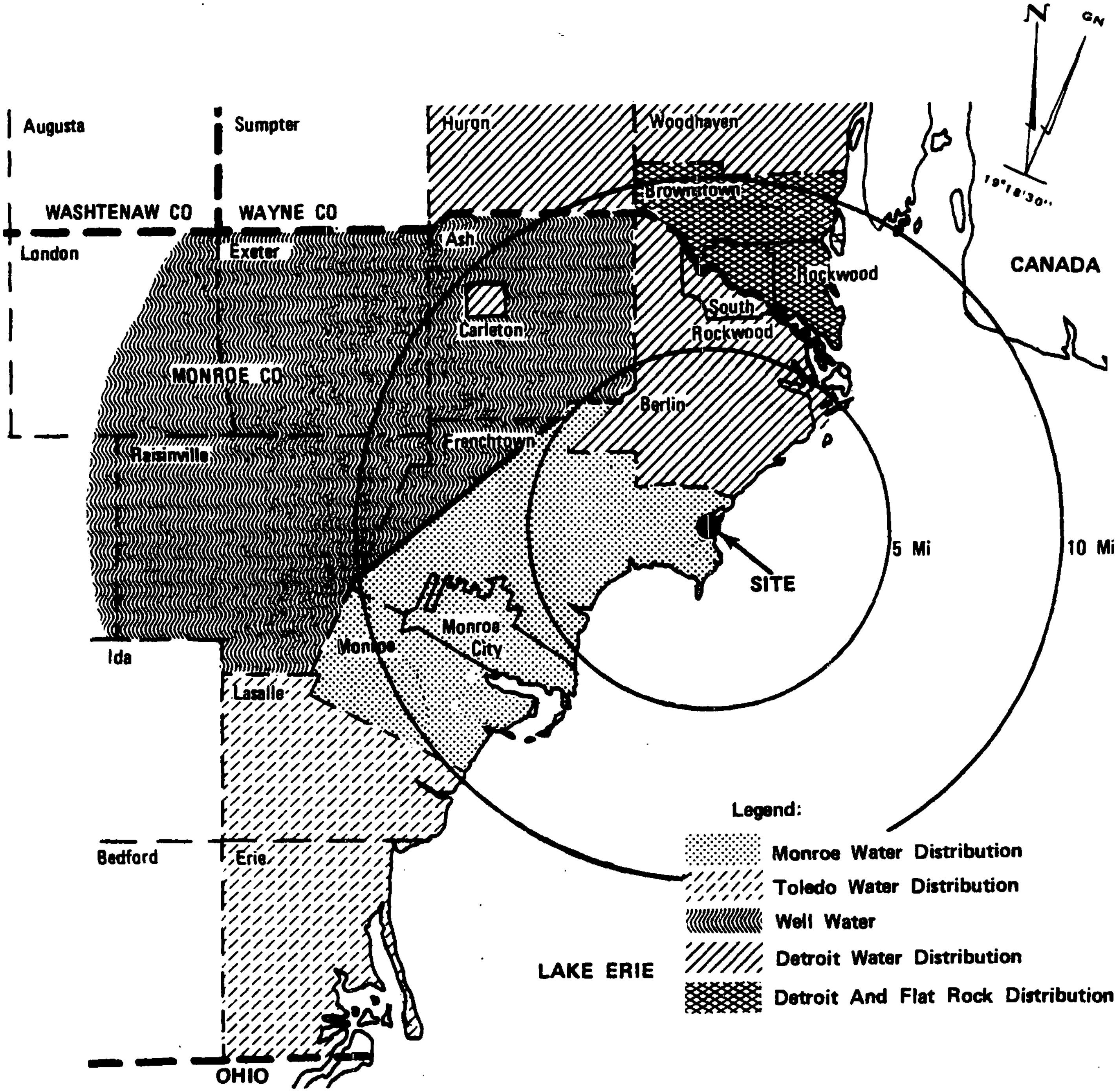

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FIGURE 2.1-18

POTABLE WATER SUPPLIES IN THE VICINITY

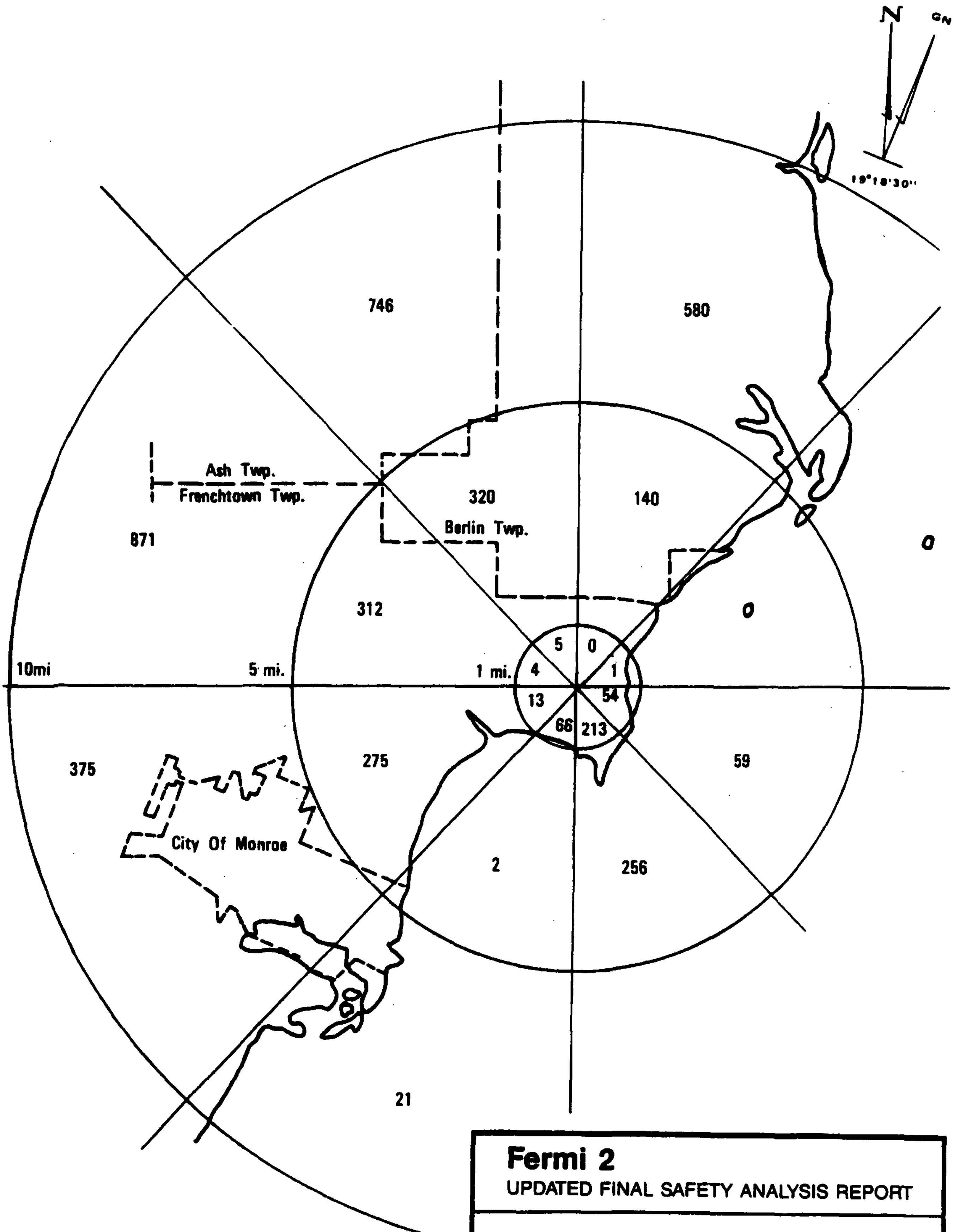

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FIGURE 2.1-19

DISTRIBUTION OF WATER WELLS WITHIN A 10 MILE RADIUS OF THE SITE

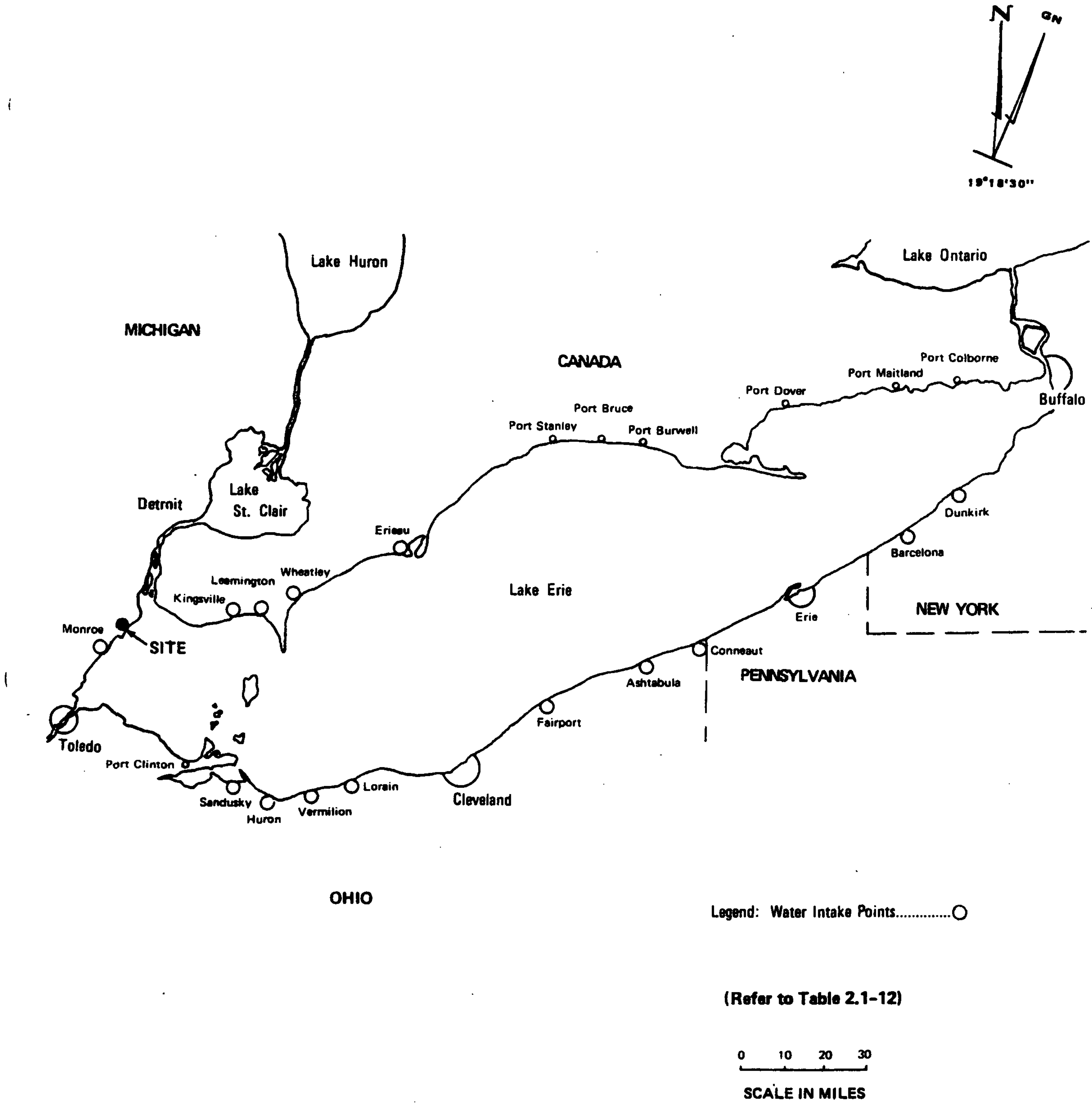

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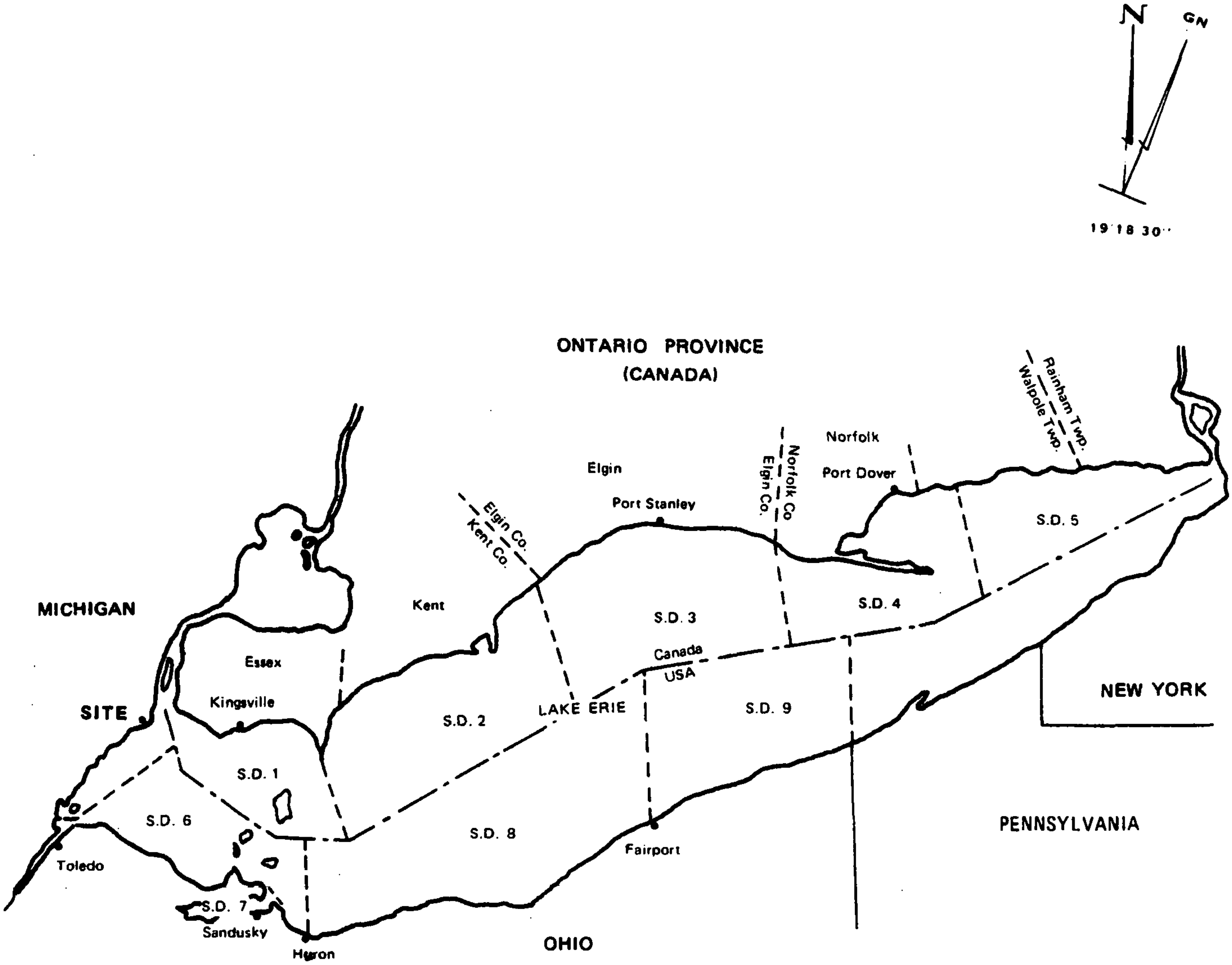
FIGURE 2.1-20

POTABLE WATER INTAKES ON LAKE ERIE



(Refer to Tables 2.1-13 and 2.1-14)

0 10 20 30
SCALE IN MILES

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FIGURE 2.1-21

COMMERCIAL FISHING STATISTICAL DISTRICTS IN LAKE ERIE

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

Section 2.2 was prepared circa 1974 at the time of preparation of the original FSAR. It has not generally been updated in the area of nearby industrial, transportation, and military facilities since it represents the area at the time the Construction Permit was issued. However, changes have been made based on additions/modifications of facilities in the area.

2.2.1 Locations and Routes

2.2.1.1 Industrial Facilities

Industrial (and commercial) facilities within 5 miles of Fermi 2 are listed in Table 2.2-1, along with their products and number of employees (Reference 1).

The Fermi 1 breeder reactor, also on the Fermi site, is not operating and has been permanently shut down. The Fermi 1 plant is located on the site with Fermi 2. The Fermi 1 oil-fired plant has also been decommissioned, and it has been demolished. The 800,000-gal oil storage tank, which supplied the oil-fired boiler, presently supplies the four combustion turbine peakers. There is an additional nuclear power plant site within 30 miles of the Fermi site (Reference 2). This is Toledo Edison Company's Davis-Besse Nuclear Power Station, approximately 26 miles to the south-southeast.

There are three extractive industries within 10 miles of the site. The France Stone Company of Monroe, Michigan, is located 9.4 miles southwest of the Fermi site; [redacted] (Reference 3). The Halloway Construction Company operates a quarry about 8 miles north of the site. [redacted] (Reference 4). Rockwood Stone, Inc., operates a quarry 3 miles north-northeast of the site. As reported to the NRC in July 1986, [redacted].

Redacted in accordance with 10 CFR 2.390

The Monroe Branch of the Austin Powder Company maintains a maximum storage of [redacted] at a site 6.7 miles west-southwest of the Fermi site. [redacted] (Reference 5).

The Frenchtown Township water treatment facility is located approximately 2.5 miles south of the site. There are no explosives stored at this facility. The facility has a 1,000 gallon underground fuel oil storage tank for an onsite emergency generator. (Reference 5a).

2.2.1.2 Transportation Facilities

There are two major roads within 10 miles of the plant, Interstate 75 and U.S. Routes 24/25, shown in Figure 2.1-3. Their closest approach to the plant is 4.1 miles and 5.8 miles north-west of the plant site, respectively, with average 24-hr traffic flows of 27,300 and 9200 vehicles, respectively (Reference 6).

Within 10 miles of the plant, there are four Class I railroads. The Detroit and Toledo Shore Line Railroad, 4 miles northwest of the site, passes closest to and serves the Fermi site through the use of a single spur track. This company operates a freight service only between Detroit, Michigan, and Toledo, Ohio. At their closest approach to the plant, the other three lines (the Penn Central Railroad, the Chesapeake and Ohio Railroad, and the Detroit Toledo and Ironton Railroad) come to within 4 miles northwest, 7 miles west-northwest, and 9 miles northwest, respectively. The railroad yard in Monroe is the nearest yard to the plant. It is operated by the Penn Central Railroad and has a capacity of 230 cars (Reference 7).

Airports within 25 miles of the plant are listed in Table 2.2-2 and indicated in Figure 2.2-1. There are no major airports within 15 miles of the site. Three smaller airports are located about 9 miles from the site (Custer), 5 miles (Carl), and 2 miles (Marshall). The closest airport, Marshall Field, is 2 miles west of the plant. This is a small airfield with two sod runways, the longer being 1962 ft. This runway is oriented about northeast-southwest, approximately 30 degrees offset from the reactor site. Only light aircraft use this field. The weight of the heaviest aircraft using this field is about 3400 lb.

The closest major airports are Detroit Metropolitan and Willow Run, which are 19 miles north-northwest and 24 miles northwest of the plant, respectively (Reference 8). Figure 2.2-2 illustrates the approach patterns for Custer, Grosse Ile, and Detroit Metropolitan Airports. None of these approach patterns lie within 5 miles of the Fermi site.

There are three low level federal airways within 5 miles of the plant: V297, V96, and V10-188. The center line of airway V297 passes directly over the Fermi 2 plant and follows a southeast-northwest path. The center lines of airways V96 and V10-188 are 6.5 miles to the southeast and 4.0 miles north of the plant, respectively (Reference 8). (Airways are 4 miles wide.)

The shipping port nearest the plant is the Port of Monroe. Shipping traffic to this port is through an unobstructed channel, approximately 4.5 miles long, east-southeast of the site and extending from the head of navigation of River Raisin to the deep water in Lake Erie. As shown in Figure 2.2-3, the nearest approach of this channel to the Fermi site is approximately 6 miles south of the plant. Shipping traffic to the Port of Monroe is minimal in comparison to the traffic through the Detroit River. In 1964 there were only six commercial vessel trips inbound to the Port of Monroe, as compared to 10,999 upbound and 9693 downbound through the Detroit River (Reference 7). As shown in Figure 2.2-3, the Detroit River navigation channel connects to the West Outer Channel and the East Outer Channel in Lake Erie at a point approximately 7 miles northeast of the plant. The majority of the Detroit River traffic utilizes the East Outer Channel. Traffic on the West Outer Channel has a 5-mile nearest approach to the plant.

[redacted] of the Fermi site are shown in Figure 2.2-4 and are described in Subsection 2.2.2.2.

Redacted in accordance with 10 CFR 2.390

2.2.1.3 Military Facilities

There are currently no military facilities within 10 miles of the plant. [redacted]

[redacted] (Reference 9).

Redacted in accordance with 10 CFR 2.390

2.2.2 Descriptions

2.2.2.1 Industrial Facilities

The Fermi 1 power plant and the storage tank supporting the combustion turbine peakers of that plant are described in Subsection 2.2.1.1. The industrial facilities within 5 miles of the plant, including a description of their products and/or services and number of employees, are listed in Table 2.2-1.

The Frenchtown Township water treatment facility is a water processing plant for Frenchtown Township. The water treatment plant has the capacity to process 4,000,000 gallons of water per day. The chemicals used for water processing are not a hazard to Fermi 2 (Reference 5a).

2.2.2.2 Transportation Facilities

[redacted]

Redacted in accordance with 10 CFR 2.390

2.2.3 Evaluations

2.2.3.1 Cooling Water Intake Structure

The cooling water intake structure for Fermi 2 is a shoreline structure located adjacent to the existing Fermi 1 intake channel. This channel is protected by two rock jetties that extend into the lake. This intake provides cooling water and makeup water to the 5.5-acre pond, which is part of the closed-loop source of cooling water to operate the plant; the lake level at the mouth of the intake varies from 3 ft to 10 ft, depending on the status of the sandbar that continually forms at the end of the jetties and the prevailing level of Lake Erie. (Refer to Figure 2.4-9.)

Navigation by large ships and barges in the Western Basin does not normally approach within approximately 5 miles of the Fermi site. As a result of the very shallow water in the vicinity of the site, no large vessel could be expected to reach the site and damage the intake structure, even if this were attempted.

In addition, assuming that the intake structure is damaged sufficiently to prevent normal cooling water intake for an extended period of time, the 5.5-acre closed-cycle circulating water reservoir is of sufficient size to allow limited periods of normal plant operation with sufficient reserve to accomplish normal shutdown. If it were ascertained that the intake structure were to be inoperable for an extended period of time, reduction in load and shutdown would be initiated in a timely manner. In addition to the circulating water reservoir, the ultimate heat sink [residual heat removal (RHR) complex] provides cooling for 7 days in conformance with Regulatory Guide 1.27.

2.2.3.2 Industrial Facilities

The industrial facilities within 5 miles of the site (Table 2.2-1) do not present any potential danger to the safe operation of Fermi 2.

[redacted]

Redacted in accordance with 10 CFR 2.390

The Frenchtown Township water treatment plant is located approximately 2.5 miles south of the site. No chemicals with a potential to cause an explosion are used at this facility. Sodium hypochlorite is used for water treatment. This is not considered a hazard to Fermi 2 and it does not impact the chlorine release accident analysis as described in Section 6.4.

2.2.3.3 Offsite Transportation Facilities

As described in Subsections 2.2.1.2 and 2.2.2, no roads, railroads, or pipelines cross or pass close to the plant except for the site access road and railroad spur. No conceivable event associated with offsite highways, railroads, and pipelines in the area could be expected to influence normal operation of the plant.

The two principal shipping channels (described in Subsection 2.2.1.2) are 5 and 6 miles away from the Fermi 2 site. There is no potential for fire or explosion from any ship in one of these lanes to interfere with normal plant operation.

Redacted in accordance with 10 CFR 2.390

[redacted]

Table 2.2-2 and Figures 2.2-1 and 2.2-2 indicate the nearest airports to the Fermi site and the approach patterns for Custer, Grosse Ile, and Detroit Metropolitan airports.

The annual aircraft flights along the three low level federal airways V297, V96, and VI0-I88, described in Subsection 2.2.1.2, are provided in Table 2.2-3, along with the aircraft types using these airways and an estimate of the probability of a crash at the Fermi site involving one of these aircraft. Also provided in Table 2.2-3 are estimates of the probabilities of crashes of private and corporate aircraft into the Fermi 2 spent fuel pool.

The Detroit Flight Service Center, which handles air traffic along 15 airways, including V297, V96, and V10-188, makes an average of about 34,000 radio contacts per year (References 11, 12, and 13). Between one-third and one-half of all flights along these airways make at least one radio contact with the Detroit Flight Service Center; thus a conservative estimate of the total flights per year along these 15 airways is about 100,000 or about 7000 per airway. About 40 percent of these flights are by commercial aircraft.

Aircraft crash data for the years 1970 through 1972 indicate that the probability of a crash during level or near-level flight is about 0.2 per million miles of operation for private and corporate aircraft (References 12, 14, and 15) and about 0.003 per million miles of operation for commercial air carriers (Reference 16).

Aircraft crash probabilities provided in Table 2.2-3 are based on crash bands of 13 miles for V96, 8 miles for V10-188, and 2 miles for V297. The target area for the plant was conservatively assumed to be 0.015 square miles (References 17, 18, 19, 20, and 21). The conservatively estimated probability of a commercial aircraft crash into the Fermi 2 plant is 8.9×10^{-8} per year and for a private aircraft 8.9×10^{-6} per year.

The target area for the spent fuel pool was taken to be 0.0001 square miles. A conservatively estimated probability of a private aircraft crash into the spent fuel pool is 5.9×10^{-8} per year. The exterior walls of the Category I reactor/auxiliary building were analyzed for the crash of the largest private aircraft capable of using Marshall Field and were found able to withstand such a postulated event.

2.2.3.4 Onsite Storage of Fuels and Explosives

The site access rail spurs are not used for the transportation of explosives or fuel oil. Fuel oil is transported by truck to the fuel-oil storage tanks onsite. A winter blend of #2 and #1 fuel oil is required for operation of the 62.2 MWe combustion turbine peakers south of Fermi 1.

The 800,000-gal fuel-oil storage tank for the Fermi 1 combustion turbine units is located approximately 1/3 mile south from the plant and safety-related plant structures. The results of any event related to the transportation and storage of fuel oil at this tank would have no effect on the normal operation of Fermi 2 or endanger safety-related plant structures or equipment. The tank is surrounded by a conservatively sized clay-lined dike with a polyethylene geomembrane inner dike liner and is equipped with piping to a foam distribution manifold on the tank. In the event of a fire involving the tank, a foam-generating fire truck can be connected to a nearby hydrant (furnished for the purpose). The foam

discharge lines from the truck can be connected to the tank manifold piping using the provided fire department connection, and foam distributed within the tank. Should the tank rupture, the tank contents will be contained within the dike, and any fire extinguished using conventional fire fighting methodologies as well as the manifold. The fuel storage facility has been designed in accordance with applicable fire codes.

A 20,000 gallon liquid hydrogen storage tank is located at the HWC gas supply facility. The gas supply facility is approximately 1100 feet northwest of the RHR Complex. The tank location has been chosen to ensure that the results of any event related to transportation or storage of hydrogen at this tank would have no effect on the safe operation of Fermi 2 or endanger safety-related plant structures or equipment. The gas supply facility has been designed in accordance with applicable fire codes and the nuclear industry guidelines for permanent HWC installations.

Other onsite fuel storage facilities are identified and evaluated in Subsection 9.5.1 and Appendix 9A.

The only storage of explosives in the vicinity of the unit will be in quantities sufficiently small and at such a distance that no postulated accident can endanger the safe operation of the unit.

2.2.3.5 Onsite Storage of Toxic Chemicals

Sodium hypochlorite and a small quantity of acids are stored onsite.

Sulfuric acid for circulating water is transported in accordance with all applicable regulations. Safety measures are taken near handling and storage facilities. Any spills during transfer operations will soak into the ground and be neutralized or will drain to a chemical sump for neutralization.

Sodium hypochlorite used to treat the circulating water is stored at the circulating water pumphouse in a tank located within a nominal 150 percent tank capacity retention dike and pad.

Sodium hypochlorite used to treat the GSW System is stored at the GSW pumphouse in a tank located within a nominal 150 percent tank capacity retention dike and pad.

2.2.3.6 Cooling Tower Collapse

The cooling towers are hyperbolic in design and any postulated failure of this tower would cause it to collapse inwardly. This failure would in no way endanger the safe shutdown of the unit.

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

REFERENCES

1. Monroe County Manufacturers Directory, Monroe County Library System and the Greater Monroe Chamber of Commerce, Monroe, Michigan.

2. Electricity from Nuclear Power, Central Station Nuclear Power Plants in the U.S., Atomic Industrial Forum, Inc.

3. G. Edgley, NUS Corporation, and Mr. Elson, Plant Supervisor, France Stone Company, Monroe, Michigan, Telephone Conversation, February 28, 1973.

4. G. Edgley, NUS Corporation, and W. Jarvi, Research and Development, Dow Chemical Company, Telephone Conversation, May 1, 1974.

5. G. Edgley, NUS Corporation, and G. Dridalt, Austin Powder Company, Monroe, Michigan, Telephone Conversation, February 28, 1973.

5a. Letter from M. P. Faeth, P.E., McNamee, Porter & Seeley, Inc., to E. F. Madsen, Detroit Edison, Subject: Frenchtown Charter Township WTP, dated April 25, 1994.

6. 1971 Average 24 Hour Traffic Flow Map, Report No. 223, Michigan Department of State Highways.

7. Inventory of Airports, Harbors, Railroads, Pipelines, and Truck Terminals; Detroit Regional Transportation and Land Use Study, January 1968.

8. Sectional Aeronautical Chart (Scale 1:500,000) - Detroit - 4th Edition; U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Washington, D.C., May 25, 1972.

9. Preliminary Safety Analysis Report for the Davis-Besse Nuclear Power Station, Appendix 2A, pp. 2A-1 through 2A-14 and Amendment No. 6, pp. 2A-13 through 2A-15, Docket No. 50-346, The Toledo Edison Company and Cleveland Electric Illuminating Company.

10. Letter from J. J. Stefano, NRC, to B. R. Sylvia, Detroit Edison, Subject: Fermi 2 Site Potential Hazards Due to Operation of the Nearby Rockwood Stone, Inc., Quarry, dated October 15, 1987.

11. Telephone conversations with G. Brainerd, Supervisor, Detroit Center, Flight Service Station, FAA, 11499 Conner Avenue, Detroit, Michigan 48213. February 22 to February 28, 1975.

12. FAA Statistical Handbook of Aviation, Department of Transportation, 1972 Edition (Stock Number 5007-0188).

13. Detroit Sectional Aeronautical Chart, Lambert Conformal Projection Standard Parallels 41°20' and 45°40', 9th Edition, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C.

14. K. A. Solomon, et al., Airplane Crash Risk to Ground Population, UCLA-ENG 7424, March 1974.

2.2 NEARBY INDUSTRIAL, TRANSPORTATION, AND MILITARY FACILITIES

REFERENCES

15. Annual Review of Aircraft Accident Data, U.S. General Aviation, Adopted May 29, 1974, NTSB-74-2.

16. U.S. Nuclear Regulatory Commission, Standard Review Plan, Section 3.5.1.6, Aircraft Hazards, June 1975.

17. Darrell G. Eisenhut, " A Review of Testimony by the Division of Reactor Licensing, Long Island Lighting Company, Unit 1," May 3, 1971.

18. Shoreham Nuclear Power Station, Amendment 3, USAEC Docket No. 150-322, February 5, 1969.

19. "Zion Station Amendment," USAEC 18-Docket 50-295, December 1971.

20. Karl Hornyik, "Airplane Strike Probability Near a Flight Target," ANS Annual Meeting, Chicago, Illinois, June 10-15, 1973.

21. "Probability of an Airplane Strike," Appendix D and Appendix E, USAEC 5-Docket-50-289, February 23, 1968.

TABLE 2.2-1 INDUSTRIAL FACILITIES WITHIN 5 MILES OF THE FERMI SITE

Company[a]	Products and/or Services	Number of Employees
B&M Industry, Inc.	Metal stamping	50
Lisowski Brothers, Inc.	Plating equipment and supplies	9
Marshall (Olen) Hardware and Airport	Hardware, paint, pumps; plumbing and electrical supplies; airport-flight instruction, tie down, gas and oil	2
Neidermeier Oil Company	Distribution of Union 76 fuel oil	4
Newport State Bank	General banking services	16
Ohio China Company	Retail and wholesale china	28
Rockwood Stone, Inc.	Limestone quarry	30
Frenchtown Township Water Treatment Plant	Potable water	4

[a] All of these facilities, except Rockwood Stone, Inc., are in Frenchtown Township, Monroe County, Michigan. Rockwood Stone is in Berlin Township, Monroe County, Michigan.

TABLE 2.2-2 AIRPORTS WITHIN 25 MILES OF THE FERMI SITE

Airport	Distance (miles) and Direction From Site	Number and Type of Aircraft Based at the Airport	Largest Type of Aircraft Likely to Land at Airport	Runway Direction/and Length (ft)	Runway Composition	Hours Attended	Average Weekly Flight Operations
Marshall	2 W	6 single-engine	Piper Aztec	50°-230°/1962	Sod	0800-dusk	10
Carl	6 NNW	21 single-engine	Cessna 310	180°-360°/2400 90°-270°/2300	Turf	0800-dusk	10
Wickenheiser	7 NW	3 single-engine	Cessna 172	90°-270°/1900 80°-360°/2600	Turf	-	2
Custer	9 W	53 single-engine 3 multi-engine	DC-3	20°-200°/3500	Blacktop	0800-2000	150
Grosse Ile	11 NNE	142 single-engine 6 multi-engine 2 helicopters	Convair 440	30°-210°/4980 170°-350°/5480	Blacktop Blacktop	0700-2400	1000
Detroit Metro	19 NNW	90 single-engine 60 multi-engine	Boeing 747	30°L-210°R/ 10500 30°L-210°L/ 8500 90°-270°/ 8700 150°-330°/ 4331	Concrete Concrete Concrete Concrete	24hrs	5544
Bielec	21 WNW	Information not available		180°-3600°/ 1900 50°-1750°/ 1750	Turf Turf	-	-
Frankman Ranchero	21 NW	3 single-engine	Piper-Apache	60°-240°/ 1930 90°-270°/ 1340	Turf Turf	-	12
Larsen	21 NW	48 single-engine	Twin Beach 45	180°-360°/ 1752	Turf	Not Given	300
Lada	22 W	1 single-engine	Piper Navajo	180°-3600°/2600	Sod	Daylight	1
Willow Run	24 NW	69 single-engine 105 multi-engine	DC-8	90°L-270°R/ 7294 90°R-270°L/ 7294 50°L-230°R/ 6656 50°L-230°L/ 7526 140°-320°/ 6911	Concrete-asphalt Concrete Concrete-asphalt Concrete-asphalt	24hrs	3800
Chippewa	25 S	Information not available	-	90°-270°/ 2600	Turf	None	-
Gradolph	25 W	10 single-engine 1 multi-engine	-	90°-270°/ 2600	Turf	Jan-Dec/ Mon-Sat 0800-1800	18

TABLE 2.2-3 AIRCRAFT CRASH PROBABILITY FOR THE FERMI SITE

Airway	Aircraft Type[a]	Estimated Flights Per Year	Target	Estimated Crash Probability Per Year
V297	U.S. Air Carrier	2800	Plant	6.3×10^{-8}
	General Aviation	4200	Plant	6.3×10^{-6}
	General Aviation	4200	Spent Fuel Pool	4.2×10^{-8}
V96	U.S. Air Carrier	2800	Plant	9.7×10^{-9}
	General Aviation	4200	Plant	9.7×10^{-7}
	General Aviation	4200	Spent Fuel Pool	6.5×10^{-9}
V10-188	U.S. Air Carrier	2800	Plant	1.6×10^{-8}
	General Aviation	4200	Plant	1.6×10^{-6}
	General Aviation	4200	Spent Fuel Pool	1.1×10^{-8}

[a] U.S. Air Carrier flights include such planes as the C-747, B-707, B-720, B-727, DC-8, DC-9, DC-10, L-1011, and others. General Aviation includes flights by U.S. Civil Aircraft owned and operated by persons, corporations, etc., other than those engaged in air carrier operations authorized by a Certificate of Public Convenience and Necessity.

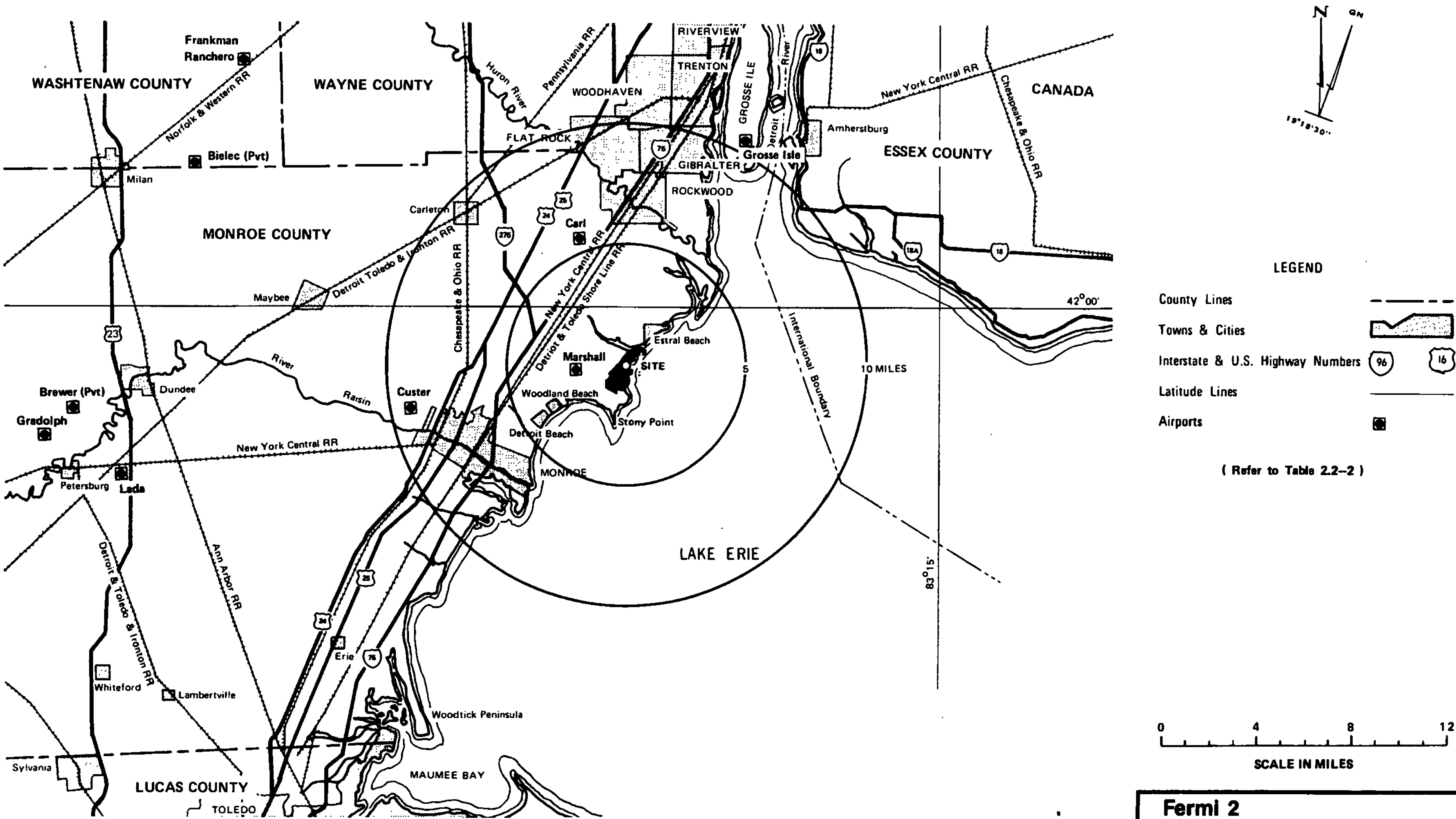

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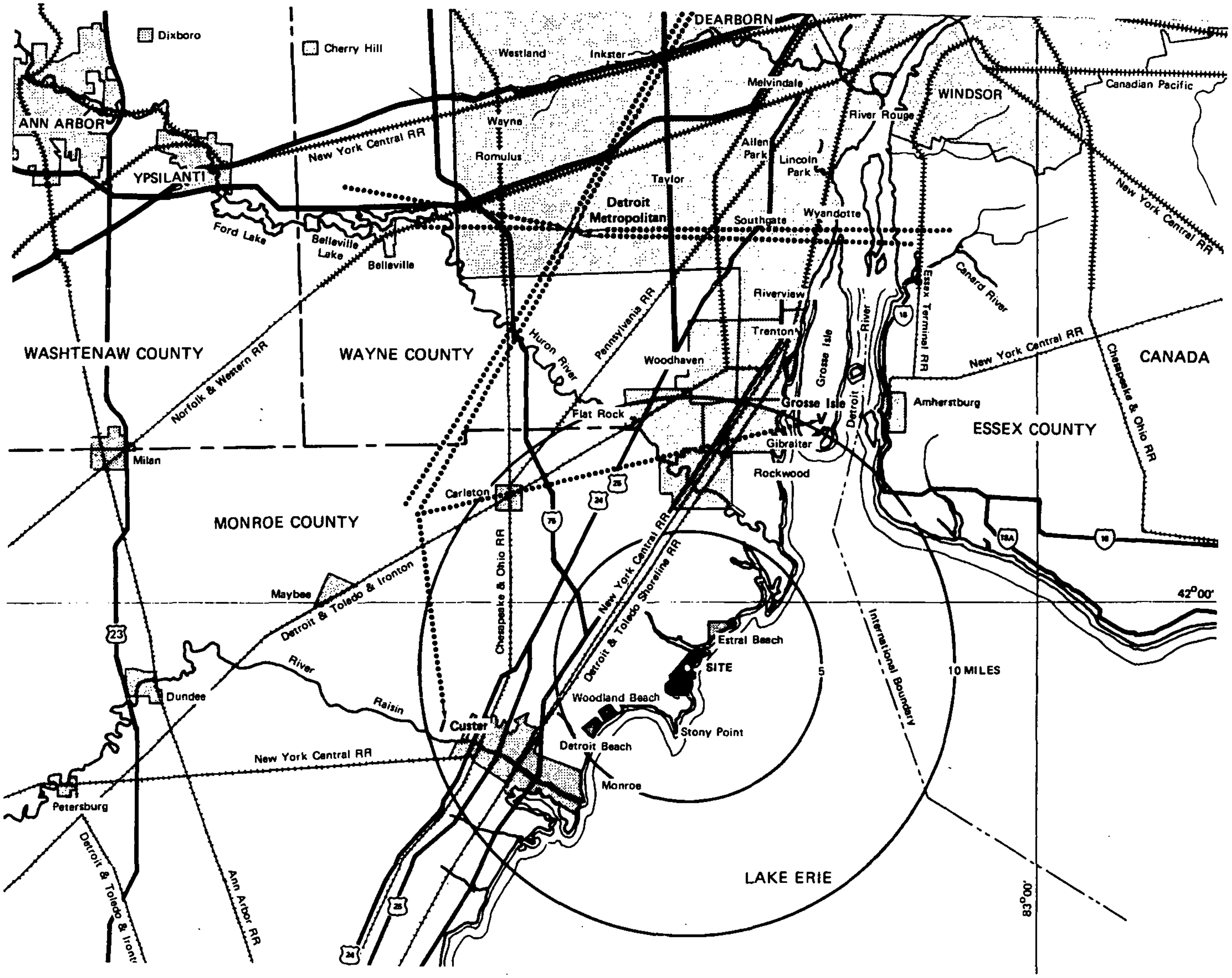
FIGURE 2.2-1
AIRPORTS IN THE VICINITY



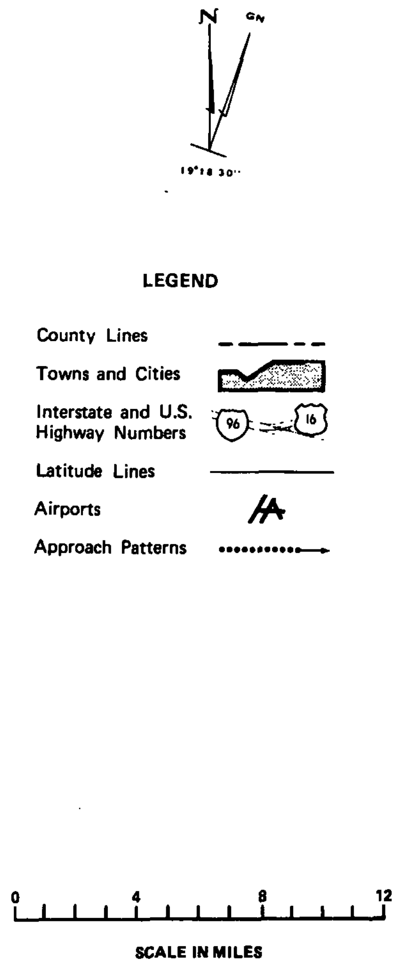


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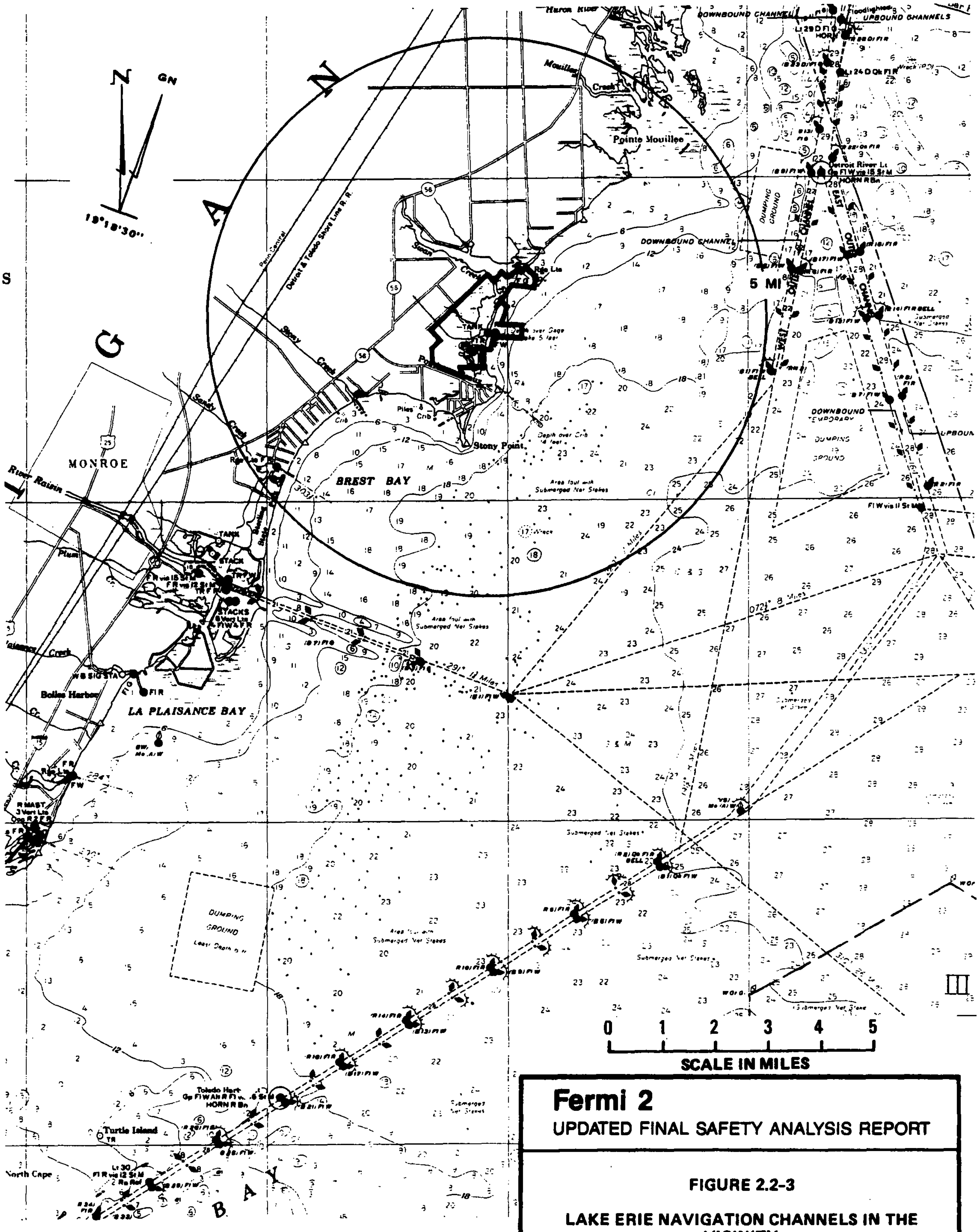
FIGURE 2.2-2

SELECTED AIRPORTS AND APPROACH PATTERNS IN THE VICINITY



REFERENCE:
U.S. LAKE SURVEY
CHART NO. 39, 1968

Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.2-3

LAKE ERIE NAVIGATION CHANNELS IN THE VICINITY

[redacted]

1 0 1 2 3 4 5 6 7

SCALE IN MILES

Redacted in accordance with 10 CFR 2.390

Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.2-4

OIL AND NATURAL GAS PIPELINES IN THE VICINITY

2.3 METEOROLOGY

2.3.1. Regional Climatology

2.3.1.1. Data Sources

The regional climatology pertinent to the Fermi site was determined from data acquired by the National Weather Service and summarized by the Environmental Data Service. The 1971 through 1974 local climatological data were obtained for the Detroit Metropolitan Airport (Reference 1), Detroit City Airport (Reference 2), and for Toledo, Ohio (Reference 3). The climatological summary was obtained for the cities of Monroe (Reference 4) and Willis (Reference 5), Michigan. These data provided sufficient information to determine the climatological characteristics of the area surrounding the Fermi site.

Extreme wind data were obtained from studies by Thom (Reference 6). Severe storm and tornado data were obtained from monthly storm data (Reference 7), climatological data national summary (Reference 8), the tornadoes of western Canada (Reference 9), and tornado probabilities (Reference 10).

The data for meteorological extremes were obtained for Detroit Metropolitan Airport, Detroit City Airport, and for Toledo Express Airport from the local climatological data for each station. Extremes for Monroe and Willis, Michigan, were obtained from the climatological summary for each station.

Monthly storm data were used to determine the number of occurrences of hailstorms and ice storms.

Climatological data for restrictive dilution conditions were obtained from a variety of sources concerned with stagnating conditions in the United States (References 11 and 12).

2.3.1.2. General Climate

The Fermi site is located in the southeast lower climatic district of Michigan on the western shore of Lake Erie. The lake smooths out most climatic extremes, with the most pronounced lake effect occurring in the coldest part of the winter when there is an excess of cloudiness and very little sunshine. Prevailing winds are from the western sectors in winter. Periods of easterly winds (off Lake Erie) and local lake breezes modify temperatures during the summer months. The climate in the area alternates between semi-marine and continental (Reference 4).

The predominant wind in the area is from the southwest, averaging approximately 10 mph (Reference 1). The average afternoon (1:00 p.m.) relative humidity for the Fermi site area is 58 percent, and varies from 52 percent in May to 71 percent in December (Reference 1). The highest temperature recorded in the area was 105°F (Reference 2) and the lowest was -19°F (References 1 through 5).

Precipitation is well distributed throughout the year. The Fermi site area receives an average of 31.15 in. of precipitation per year, with 56 percent occurring between the months of May and October. Minimum amounts of precipitation generally occur during the winter months (December, January, and February) and average approximately 2.0 in. per month. Maximum

amounts of precipitation generally occur during the summer months (June, July, and August) and average approximately 3.0 in. per month (References 1 through 3). The mean annual snowfall in the area is 33.7 in. (References 1 through 5).

2.3.1.3. Severe Weather

2.3.1.3.1. Extreme Winds

According to a compilation by Thom (Reference 6) for characterizing extreme winds, the extreme mile wind speed at 30 ft above the ground, which is predicted to occur once in 100 years, is approximately 90 mph. The approximate values for other recurrence intervals are listed in Table 2.3-1, with the extrapolated value of 117 mph for the 1000-year recurrence interval (Reference 6). The extreme mile wind speed is defined as being the 1-mile passage of wind with the highest speed for the day. Based on the gustiness factor of 1.3, the highest instantaneous gust expected in 100 years is 117 mph. The highest mile wind recorded at Detroit City Airport, based on the 1934 through 1965 period of record, was 77 mph from the northwest (Reference 2). Based on the 1956 through 1972 period of record, the highest mile wind recorded at Toledo, Ohio, was a 72-mph wind from the southwest (Reference 3).

The Category I structures of Fermi 2 are designed to withstand a 90 mph fastest mile sustained wind velocity, 30 ft above ground level. This wind velocity has a 100-year recurrence interval.

The relationships to determine the vertical velocity distribution of the wind are obtained from Page 1139 of ASCE Paper No. 3269 for coastal areas and are as follows:

for $V_{30} \leq 60$ mph

$$V_z = V_{30}\left(\frac{z}{30}\right)^{0.3}$$

for $V_{30} > 60$ mph

$$V_Z = V_{30}\left(\frac{z}{30}\right)^{x}$$

where

V_{30}	=	basic wind velocity (mph) at a height 30 ft above ground level (grade)
x	=	factor which varies from 0.3 when V_{30} = 60 mph to 0.143 when V_{30}= 130 mph (Reference 3)
V_z	=	wind velocity (mph) at a height (z) above grade
Z	=	distance above grade in ft

Thus, at heights between 100 and 150 ft above grade, the height of the upper portion of the reactor building, the wind velocity is calculated to be 123.5 mph. Gust factors have also been determined by the methods given on pages 1124 through 1198 in ASCE Paper No. 3269. For all Category I structures, the gust factor varies linearly from 1.1 at grade level to 1.0 at 400 ft. However, a gust factor of 1.1 was used for the full height of both the reactor/auxiliary building and the residual heat removal complex except for the blow-away siding design during the design tornado, where a factor of 1.0 was used.

2.3.1.3.2. Tornadoes

2.3.1.3.2.1. Frequency

During the period January 1951 through December 1974, a total of 51 tornadoes were reported within a 50-mile radius of the Fermi site (References 8 and 9). These 51 tornadoes occurred within the United States. This is an average of two tornadoes per year within this radius. There were no tornadoes reported within 50 miles of the site in Canada for the period 1951 through 1960 (Reference 9). Canadian tornado data were not available for the period 1961 to 1974. There was one tornado reported at Tecumseh, Ontario, on August 1, 1973. This tornado was not included in this analysis.

According to the statistical methods proposed by Thom (Reference 10), the probability of a tornado striking a point within a given area may be estimated as follows:

$$P = \frac{\bar{z}\bar{t}}{A}$$

where

P	=	mean probability per year
$\bar{z}$	=	geometric mean tornado path area
$\bar{t}$	=	mean number of tornadoes per year
A	=	area of concern

For the region surrounding the Fermi site, the geometric mean path length computed was approximately 2.15 miles, and the geometric mean path width computed was approximately 75 yd (References 7 and 10), yielding a mean path area ($\bar{z}$) of 0.092 square mile, based on the January 1951 through December 1974 period of record. The use of a 50-mile radius to compute A (excluding the water area of Lake St. Clair and Lake Erie and the land area in Canada) and a value of 2.125 for $\bar{t}$ yields a tornado probability of 4.075×10^{-5} per year, or a recurrence interval of 24,500 years.

It should be noted that the June 8, 1953, tornado in northern Ohio had a reported path length of 100 miles and a path width of 440 to 1760 yd. These data were not used in the computation of $\bar{z}$, as recommended by Thom (Reference 10), who states that tornadoes with reported paths longer than 100 miles and paths wider than 1000 yd are considered doubtful observations. However, including this tornado, this yields a probability of 4.7×10^{-5}, or a recurrence interval of 21,200 years.

During the period of record studied, three tornadoes occurred within 5.5 miles of the Fermi site, but it is difficult to determine which occurred closest to the site. These were (1) on June 28, 1973, a tornado was observed 3 miles south of Estral Beach; no data on path length or width were given; (2) on June 12, 1973, a tornado occurred 3 miles west of South Rockwood with a path length of 0.1 mile and width of 40 yd; and (3) another nearby tornado occurred on June 11, 1968, at Monroe, Michigan. The path length reported was "short" and no path width was given. No persons were reported killed or injured, and the damage was estimated at from $500 to $5000 (References 7 and 8).

Not included in the above tornado discussion were water spouts and funnel clouds sighted in the area that did not touch the ground. Only one water spout was sighted within 50 miles of the site during the period 1965 through 1974. This occurred on August 1, 1965, 13 miles southeast of Mt. Clemens; there was no damage reported.

2.3.1.3.2.2. Parameters

Category I structures housing the systems required for a safe shutdown of the plant in the event of a tornado are designed to withstand the effects of a tornado by providing either sufficiently strong structures or appropriate venting. The design parameters of the Fermi 2 design-basis tornado are

a. A rotational wind velocity of 300 mph
b. A translational wind velocity of 60 mph
c. An external pressure drop of 3 psi at the rate of 1 psi/sec.

2.3.1.3.3. Precipitation Extremes

Tables 2.3-2 through 2.3-6 list extremes of precipitation and other meteorological parameters for several stations that surround the Fermi site. The maximum amount of precipitation recorded for a 24-hr period was 4.39 in. at Toledo, Ohio, in July 1969. The maximum monthly snowfall measured in the region was 28.5 in. at Monroe, Michigan, in March 1954 (Reference 1 through Reference 5). A December 1 and 2, 1974, snowstorm deposited 19.3 in. of snow at the Detroit Metropolitan Airport.

The 100-year recurrence snowpack and 100-year recurrence daily snowfall were computed using data from the Detroit Metropolitan Airport for the years 1971-1974 inclusive (see Figures 2.3-1 and 2.3-2). Each of these had the data ranked according to the amount and number of occurrences in the 4-year period. From these ranked amounts, a cumulative distribution table was generated. This cumulative percentage was graphed as a function of amount and the curve visually extrapolated to the value occurring in 100 years.

Snowpack

Number of Occurrences	Maximum Snowpack (in.)	Cumulative Number of Occurrences	Cumulative Percentage
10	Trace	36	100.00
8	1	21	72.22
3	2	18	50.00
5	3	15	41.67
3	4	10	27.78
1	5	7	19.41
2	7	6	16.67
1	8	4	11.11
1	9	3	8.33
2	11	2	5.56

The average number of observations per year is nine for this calculation, so that 100 years would provide 900 samples. The 100-year recurrence percentage would therefore be 0.11 percent. Referring to the graph of the cumulative frequency of snowpack versus amount, the extrapolated 100-year recurrence value is 27.8 in.

Daily Snowfall

Number of Occurrences	Maximum Daily Snowfall (in.)	Cumulative Number of Occurrences	Cumulative Percentage
4	Trace	28	100.00
2	0.1	24	85.71
1	0.5	22	78.57
1	0.6	21	75.00
2	1.0	20	71.43
1	1.3	18	64.29
1	1.5	17	60.71
1	1.6	15	57.14
1	1.7	15	53.14
1	2.5	14	50.00
2	2.7	13	46.43
1	2.8	11	39.29
1	2.9	10	35.71
1	3.1	9	32.14
1	3.2	8	28.57
1	3.7	7	25.00
1	3.8	6	21.43
1	4.7	5	17.86
1	5.2	4	14.29
1	8.4	3	10.71
1	8.7	2	7.14
1	19.3	1	3.75

The average number of observations per year is seven for this calculation, so that 100 years would provide 700 samples. The 100-year recurrence percentage would therefore be 0.15 percent. Referring to the graph of the cumulative frequency of maximum daily snowfall versus amount, the extrapolated 100-year recurrence value is 28.2 in.

2.3.1.3.4. Hailstorms

A review of hailstorm data for the period of 1962 through 1974 is reported in storm data for Monroe County and the immediately surrounding counties of Lenawee, Washtenaw, Wayne, Lucas (Ohio), and Ottawa (Ohio). This review indicates that there were 93 days with

hailstorms in this area. Generally, these hailstorms occurred with scattered thunderstorms which covered a wide area (i.e., northern Ohio or southern Michigan). One of the most severe storms in the area occurred on July 19, 1967, in Wayne and Monroe Counties. Hailstones varying in size from "small peas to larger than golf balls" were reported to have accumulated to depths of 6 to 7 in. in spots. Damage to both crops and property ranged from $5000 to $50,000 (Reference 7).

2.3.1.3.5. Ice Storms

A study of ice storm data for the 1962 through 1974 period for Monroe County and the immediately surrounding counties indicates that there were 26 storms in this region. The storms were rarely limited to a small area, but were widespread over the state. The greatest accumulation of ice in the region came from the January 26 and 27, 1967, storm, which deposited up to 3 in. of ice in northern Ohio (Reference 7).

2.3.1.3.6. Thunderstorms

Thunderstorms occur on an average of 35 days per year, approximately 80 percent occurring in the months of June, July, and August (References 1 through 3). Generally, these thunderstorms encompass a large area (on the order of several hundred square kilometers each) and are associated with strong winds, intense precipitation for short time intervals, and lightning. Lightning incidence is estimated at about 10 flashes per year per square kilometer.

Each thunderstorm produces an average of about 120 independent flashes to ground (an average of one every 20 sec. for an interval of about 40 minutes). Each thunderstorm (isolated) encompasses an area of about 400 km^2 (20 km on a side). With 35 days per year associated with thunderstorms, these estimates give

$$\frac{35 \text{ Storms}}{400 \text{ km}^2} \text{ x } 120 \frac{\text{flashes}}{\text{storm}} = 10 \frac{\text{flashes}}{\text{Km}^2} \text{ per year.}$$

2.3.1.3.7. Restrictive Dilution Conditions

The frequency of occurrence of low-level inversions or isothermal layers based at or below a 500-ft elevation in the site region is approximately 28 percent of the total hours on an annual basis, according to Hosler (Reference 11), who takes into account lake and ocean effects on inversion frequencies. Seasonally, the greatest frequencies of inversions based on percent of total hours are 30 percent during the summer and fall. The inversion frequencies are 25 percent in the spring and 20 percent in the winter. The majority of these inversions are nocturnal in nature.

The mean mixing depth is another restriction to atmospheric dilution. The mixing depth is the thickness of the atmospheric layer, measured from the surface upward, in which convective overturning is taking place, caused by the daytime heating at the surface. The mixing depth is usually at its shallowest during the early morning hours, just after sunrise, when the nocturnal inversion is being modified by solar heating at the surface. The mixing depth is at its greatest during the later part of the afternoon, 3:00 p.m. to 4:00 p.m., when the maximum surface temperature of the day is reached. The monthly mean daily mixing depths, based on Flint, Michigan, upper air data for the period January 1960 through December

1964, are presented in Table 2.3-7 (Reference 12). Shallow mixing depths have a greater frequency of occurrence during the fall and winter months.

Periods of high air pollution potential are usually related to a stagnating anticyclone, with the average wind speed less than or equal to 9.0 mph (4.0 m/sec), no precipitation, and a mixing depth of less than 1600 ft (Reference 14).

The greatest air pollution potential in the site region occurs during the months of August, September, and October, when the tendency is greatest for a quasi-stationary anticyclone to develop in the region (Reference 15).

According to Korshover (Reference 15), there were approximately 19 anticyclone stagnation cases, each 4 days or more, reported in the site region during the period 1936-1967.

2.3.1.3.8. Maximum Roof Loadings

The following data itemize the maximum snow and ice load in inches of water that the roofs of safety-related structures are capable of withstanding during plant operation. The operating- basis conditions are based on the service conditions allowable stresses or strengths. The design-basis conditions are based on the strength of the structure at yield stresses with a load factor of 1.0.

Safety-Related Structure	Operating-Basis Snow and Ice Load (psf)	Water Equivalent (in.)	Design-Basis Snow and Ice Load (psf)	Water Equivalent (in.)
Reactor / auxiliary building	30	5.8	87	16.7
RHR Complex	70	13.5	276	53.0*

*This depth exceeds parapet height

2.3.2. Local Meteorology

2.3.2.1. Data Sources

The original Fermi 2 FSAR was filed with 12 months (June 1, 1974, to May 31, 1975) of onsite data obtained from a 60-m tower equipped with sensors that meet the requirements of Regulatory Guide 1.23 (Reference 16). Data from previous site meteorological systems and offsite National Weather Service sources were included as appropriate.

Offsite wind, stability, precipitation, temperature, relative humidity, and fog data were based on meteorological observations from Detroit Metropolitan Airport and Toledo Express Airport, both first-order National Weather Service stations (References 1 and 3). Additional temperature and precipitation data were obtained from National Weather Service cooperative stations at Monroe and Willis, Michigan (References 4 and 5). The 1956 to 1959 period site wind, stability, and precipitation data were obtained and summarized by the University of Michigan from the Fermi 1 100-ft meteorological tower (Subsection 2.3.3.1.1) (References 17 and 18). Additional onsite data from a low-level 33-ft tower at Langton Road are presented in this section, based on data obtained and reduced by the University of Michigan for the period January 1, 1972, to December 31, 1972. These data include ambient

temperature and relative humidity; however, the low-level wind data are only briefly discussed because of unfavorable (42 percent) data recovery.

Wind stability and fog data summaries for Detroit Metropolitan Airport and Toledo Express Airport were also obtained.

2.3.2.2. Normal and Extreme Values of Local Meteorological Parameters

The distribution of wind direction and speed is an important factor when considering transport conditions relevant to site diffusion climatology. The monthly, seasonal, and annual distributions of wind direction and speed from the 60-m tower at the Fermi site (June 1, 1974, to May 31, 1975) are presented in Figures 2.3-3 through 2.3-19. For comparative purposes, data from Detroit City Airport (81-ft level, 1951 to 1960) and Toledo Express Airport (20-ft level, 1950 to 1955) are presented in Figures 2.3-20 through 2.3-31; each month presented represents averaged data for the years reported. These data are summarized and presented in annual wind roses in Figure 2.3-32. Average wind directions for all locations show a predominance of winds from the southwest through west-southwest. Limited site data from the Langton Road Tower (33-ft level) for the January 1, 1972, to December 31, 1972, period indicate a predominance of winds from the south through west-southwest.

Atmospheric dilution is directly proportional to the wind speed, with other factors remaining constant. Table 2.3-8 presents the average wind speeds and frequencies of calms for the Fermi site, the Detroit Metropolitan Airport, and the Toledo Express Airport. A calm is defined as a wind speed of $\leq$1.0 mph for the Fermi site 60-m and 150-m tower data and $\leq$1.2 mph for data recorded at National Weather Service stations and the Fermi site 100-ft tower. The threshold of the anemometer was used as the determining value of calm conditions. The highest average speed of the four stations, summarized in Table 2.3-8, is at the Fermi site at the 60-m level. This can be attributed to the higher exposure height of the wind sensors at the Fermi site and the shoreline location of the site, since wind speeds during onshore wind flows may be greater, and a lake breeze situation can develop during periods when light winds or calms are recorded at inland meteorological stations. Variations in speed can also be attributed to differences in instrumentation, data reduction techniques, and periods of record.

2.3.2.2.1. Wind Direction Persistence

Wind direction persistence is important when considering potential effects from a contaminant release. Wind direction persistence is defined as a continuous flow from a given direction or range of directions. Figure 2.3-33 shows the probability of occurrence of a 22-1/2° sector wind flow persistence as a function of duration, based on data from the 60-m tower (June 1, 1974, to May 31, 1975) and offsite data from the Detroit Metropolitan Airport (1959 to 1962 data period) and the Toledo Express Airport (1959 to 1963 data period). The wind persistence summary from onsite data (60-m tower) is shown in Table 2.3-9 in increments of 1 hr.

Based on the onsite observation time (12 months), the 10-m level data indicate a 5 percent probability of continuous wind direction persistence of about 7 hr and a 1 percent probability of 11-hr duration. At the 60-m level, these same percentages are 7 hr and 13 hr, respectively.

The 5 and 1 percent probabilities of continuous wind direction persistences at the 60-m level were greater than those observed at the 10-m level, as should be expected. The Detroit Metropolitan Airport data at 58 ft indicate a 5 percent probability of continuous wind direction persistence periods greater than 9 hr and a 1 percent probability of continuous wind direction persistence periods greater than 15.5 hr. The Toledo Express Airport data at 20 ft indicate a 5 percent probability of continuous wind direction persistence for periods greater than about 16 hr.

The maximum wind persistence at the Fermi site within a 22-1/2° sector, recorded on the 60-m tower during the June 1, 1974, to May 31, 1975, period, was one period lasting for 32 hr at the 10-m level from the south, associated with an average speed of 21 mph. The maximum wind persistence at the Detroit Metropolitan Airport within a 22-1/2° sector, recorded during the 1959 to 1963 period, was a 37-hr wind from the east-southeast, associated with an average speed of 17 mph. The maximum wind persistence at the Toledo Express Airport within a 22-1/2° sector, recorded during the 1959 to 1963 period, was a 37-hr wind from the east-northeast associated with an average wind speed of 17.0 mph. Episodes of maximum wind persistence within a 22-1/2° sector for the Fermi site 10-m level (60-m tower) data, Detroit Metropolitan Airport, and the Toledo Express Airport are presented in Figure 2.3-34.

2.3.2.2.2. Atmospheric Stability

Stability is a measure of the degree of atmospheric turbulence. A low degree of wind turbulence can be expected for stable conditions, resulting in relatively suppressed diffusion conditions. Conversely, during periods of instability, a high degree of wind turbulence can be associated with relatively enhanced diffusion conditions.

The seasonal and annual frequencies of stability indices for the Detroit Metropolitan Airport, Toledo Express Airport, and the Fermi site 60-m tower are presented in Tables 2.3-10 and 2.3-11. The stability data for the two airports were classified according to the Pasquill-Turner approach (Reference 19). This method is an indirect approach and involves the utilization of factors such as cloud cover, solar insulation, time of day, and wind speed to classify data that are generally available at National Weather Service observation stations. The onsite stability data were determined for the 60-m tower for the June 1, 1974, to May 31, 1975, period. The stabilities were classified from $\Delta T_{(60\ m-10\ m)}$ data, using the procedure outlined in Regulatory Guide 1.23 (Reference 16). Examination of Tables 2.3-10 and 2.3-11 indicates the predominance of neutral conditions. The frequency of stable (E, F, and G) conditions for both Detroit Metropolitan Airport and Toledo Express Airport is similar to the frequency of inversions based on Fermi site $\Delta T_{(100\ ft-25\ ft)}$ data from the 100-ft tower on a seasonal and annual basis (Table 2.3-12). The onsite data from the 60-m tower show a larger spread in the stability data.

Onsite stability data for the 1956 to 1959 period were compiled on a seasonal and annual basis and summarized in reports by the University of Michigan (References 17 and 18). The data were based on a $\Delta T_{(100\ ft-25\ ft)}$ and were obtained from the 100-ft tower described in Subsection 2.3.3.1. The data were classified into the following three groups:

a. Strong vertical temperature gradients ($\Delta T_{(100\ ft-25\ ft)} < 0.98°C/100\ m$ or -5.4°F/1000 ft)

b. Weak vertical temperature gradients ($\Delta T_{(100\ ft-25\ ft)}$ >0.98°C/100 m or 5.4°F/1000 ft, and ≤0)

c. Inversions (temperature increases with height).

In addition, $\Delta T_{(300\ ft-20\ ft)}$ data are available from the WJBK-TV tower located in the northwest suburbs of Detroit, approximately 35 miles north of the Fermi site. Data from this tower were analyzed for the 1956 to 1959 period for inversion conditions only.

Fermi site $\Delta T_{(60\ m-10\ m)}$ data from the 60-m tower are presented on an hourly basis over the June 1, 1974, to May 31, 1975, period in Tables 2.3-13 and 2.3-14. Additional Fermi site $\Delta T_{(100\ ft-25\ ft)}$ data from the 100-ft tower are presented on a seasonal and annual basis in Table 2.3-12. WJBK-TV $\Delta T_{(300\ ft-20\ ft)}$ data for inversion conditions only are presented in Table 2.3-15 for comparative purposes. These two locations compare favorably as to frequency of occurrence of inversion conditions. Both have a maximum during the summer and a minimum during the spring. The diurnal distribution of frequency of inversions at the WJBK-TV tower compares well with that at the Fermi site using data from the 60-m tower. The maximum frequency of inversions occurs in the midmorning hours (5:00 a.m. to 8:00 a.m.), while the maximum frequency of unstable conditions occurs in the early afternoon hours (1:00 p.m. to 3:00 p.m.).

Table 2.3-16 shows the inversion persistence derived from the 60-m tower measurements over the June 1, 1974, to May 31, 1975, period.

The stability classes were determined from $\Delta T_{(60\ m-10\ m)}$ 60-m tower data using the classification scheme outlined in Regulatory Guide 1.23. For Table 2.3-16, an inversion was defined as the existence of a temperature difference between the 60-m level and the 10-m level of greater than -0.0°C (i.e., temperature change with height (°C/100 m) >-0.0).

Figure 2.3-35 presents the probability of inversion persistence for durations greater than 6 hr, based on the frequency of occurrence with respect to surface-based inversions only. These data are based on Fermi ΔT site data from the 100-ft tower for the 1956 to 1959 period and ΔT site data from the 60-m tower for the June 1, 1974, to May 31, 1975, period. Figure 2.3-35 shows a 5 percent probability of an inversion lasting longer than 25 hr and a 1 percent probability of an inversion lasting longer than 43 hr, using the 100-ft tower data. For the 60-m tower data, these same percentages produce inversions of 18 hr and 30 hr, respectively.

Joint frequency tables of wind directions and speed by stability class are presented in Appendix 2A of the original FSAR for onsite Fermi data from the 60-m tower from June 1, 1974, to May 31, 1975. Current data for the 10-m level and 60-m level are provided by the operational meteorological system (Subsection 2.3.3.2). Annual summaries of meteorological data are prepared as required by the Technical Specifications.

2.3.2.2.3. Distribution and Frequency of Precipitation

Distribution of precipitation as a function of wind direction is presented in Table 2.3-17 for the Fermi site, using data from 1956-1959 from the 100-ft tower and from June 1, 1974, to May 31, 1975, from the 60-m tower. The 100-ft tower data show that the highest frequency of precipitation occurs when associated with winds from the southwest through west-northwest. The average wind speeds (100-ft level) during precipitation are 11.0 mph for all

directions. The frequency of precipitation during calm conditions is 0.2 percent of the total hours of precipitation (Reference 18). The 60-m tower data show a larger spread, which may be due to the smaller sample size (12 months). A wind rose showing the distribution of wind speed versus wind direction with respect to precipitation only is presented in Figure 2.3-36.

2.3.2.2.4. Natural Fog Occurrences

Fog is essentially a cloud that has developed on the ground. Therefore, the processes leading to fog formation are similar to those for cloud formation. In general, the conditions that promote water-vapor condensation in ground-level air may lead to fog conditions. Aside from the interrelated thermodynamics of the ambient air and the ground surface, a number of other factors may influence the formation of fog. These factors include the size, character, and number of condensation nuclei; the extent of cloud cover; the wind speed and direction; the time of day; and the atmospheric turbulence.

The surface air may generally be treated as a mixture of dry air and water vapor. The most frequent and effective cause of fog is the cooling of humid surface air to a point where vapor condensation occurs. The condensation generally takes place on larger and more active condensation nuclei, and may occur somewhat before the dewpoint temperature (saturation) is reached. However, as long as the moisture content is sufficiently below the saturation value, condensation does not occur and fog conditions do not exist.

According to Byers, there are three types of fog which predominate in the Great Lakes area (Reference 20). Spring and early summer conditions (warm atmosphere and cold lake) contribute to the formation of land and lake breeze fogs. In the fall, advection-radiation fogs form over the land. During the fall and winter, steam fogs form over the lakes.

In the formation of a land and lake breeze fog, warm moist air from the land is transported out over the cold lake and, if the winds are light, a dense surface fog may develop over the lake. The fog may then be carried out over the land by a lake breeze during the day and may recede at night during a land breeze flow. These fogs rarely penetrate very far inland (i.e., 2 or 3 miles).

An advection-radiation fog is formed by nighttime radiational cooling of air of high humidity that has been advected inland from the lake during the day. This advection of lake air with a high relative humidity makes possible the formation of fog with normal nocturnal cooling.

Steam fog will form when cold air with a low vapor pressure passes over warm water. Steam fog is generally shallow in depth (i.e., 50 ft to 100 ft thick). According to Rondy, the western end of Lake Erie will have 70 percent to 90 percent ice coverage out to 35 miles by January 15 during a normal winter. The extreme western shoreline, where the Fermi site is located, will have 100 percent coverage out to 5 miles from the shore by January 15 (Reference 21). Therefore, steam fog in the Fermi site area will occur mostly during the fall.

Fog occurs predominantly during the early morning hours when the moisture-bearing air is cooled to the lowest temperature and the vapor saturation of the air is most closely approached. This effect is illustrated in Figure 2.3-37 where the probability of fog occurrence at the Detroit Metropolitan Airport, for the December 1, 1958, to September 1, 1962, period, is plotted versus the hour of the day for the annual average. Over the year, the peak frequency of fog occurrence is about 32.1 percent of the total hours of fog and occurs

between 5:00 a.m. and 7:00 a.m. There is a notably higher frequency of fog between the hours of 11:00 p.m. and 10:00 a.m. Fog (other than frontal fog) is normally expected to dissipate during the late morning hours, particularly on clear, sunny days. However, cloud cover can extend the period of fog well into the daytime hours.

The monthly percentage occurrences of fog based on Detroit Metropolitan Airport data are presented in Figure 2.3-38. As can be seen in Figure 2.3-38, the monthly distribution of fog at the Detroit Metropolitan Airport does not show the distribution of fog for a Great Lakes area station predicted by Byers. Great Lakes area fogs have peak occurrences in the spring, early summer, and fall. The Detroit Metropolitan Airport shows peaks in the fall and winter. The major cause of the difference between occurrences observed at the Detroit Metropolitan Airport and those predicted by Byers is the location of the airport with respect to Lake Erie. Detroit Metropolitan Airport is located approximately 20 miles from Lake Erie. Because of this, lake- land breeze-type fogs, which rarely penetrate more than 2 to 3 miles inland, will not be evident at the airport. Because the Toledo Express Airport is 20 miles from Lake Erie, these types of fogs will not be evident there either. However, in a location such as the Fermi site, the lake will have a greater effect on natural fog occurrences, and the types and frequencies of fog should be the same as outlined by Byers.

The presence of fog onsite (at the shoreline) is associated with, for the most part, calm wind conditions. The ability of the natural draft cooling tower plume to rise to considerable heights is a significant factor in reducing the potential of adverse ground-level environmental effects. For example, under calm wind conditions, a typical plume penetration height for the Fermi 2 cooling towers is about 1000 ft above the top of the towers. In addition, the major roadways in the vicinity of the site are Interstate 75 and U.S. 24/25, whose closest approaches are 5.1 and 5.8 miles to the northwest, respectively. Dixie Highway, Pointe Aux Peaux Road, and Toll Road are closer, but are not considered major highways (Reference 22).

2.3.2.2.5. Meteorological Parameters

The extremes and means of meteorological parameters have been tabulated in Tables 2.3-2 through 2.3-6 for the Detroit City Airport, Detroit Metropolitan Airport, Toledo Express Airport, and Monroe and Willis, Michigan.

Table 2.3-18 presents the average temperature and relative humidity by month during the January 1, 1972, through December 31, 1972, period at the Fermi site (Langton Road Tower), the Detroit City Airport, and the Toledo Express Airport, for comparative purposes. However, the average relative humidity values by month for Fermi site data seem somewhat high and may, to some extent, be attributed to instrumentation and calibration inaccuracies. (Prevailing winds for the period were from the south through west-southwest.)

Figures 2.3-39 and 2.3-40 show the means of the daily averages and extremes of ambient air temperature and relative humidity, respectively. Relative humidity data were derived from ambient air temperature and dewpoint temperature data collected at the 10-m level of the 60-m tower from June 1, 1974, through May 31, 1975.

A comparison of monthly average temperatures and monthly high and low temperatures between the Fermi site data and National Weather Service data nearby, for the June 1, 1974, through May 31, 1975, period, is shown in Table 2.3-19.

2.3.2.3. Potential Influence of the Plant and the Facilities on Local Meteorology

The physical structures of the plant, especially the large natural draft cooling towers, are expected to locally increase atmospheric turbulence. There is also a potential for somewhat decreased low-level wind speeds in the immediate vicinity of the physical structures of the plant due to a wind-shielding effect. A study has shown that a cooling tower has an extended downwind wake upward to at least one and one-half times the tower height and downwind approximately two to three times the tower diameter. This will occur for wind speeds greater than 5 to 8 mph. Analysis has shown that any increase in precipitation due to the natural draft system will be minimal. Maximum precipitation from drift is predicted to occur at a distance of 3 km (1.8 miles) both northeast and west-southwest of the cooling towers at a total rate of approximately 0.008 in. annually. The increase in surface relative humidity is insignificant. The greatest relative humidity increase (nearly 21 percent at 1500 m downwind) will occur on winter mornings at an approximate height of 470 m (1542 ft). This 21 percent increase is ample to cause a visible plume from the natural draft cooling tower to extend downwind approximately 1000 m during the winter. There will be no significant fogging problems offsite on an annual basis. The offsite ground-level visibility reduction (to <1000 m) is predicted to occur only about 1 hr per year (Reference 22).

The cited cooling tower studies were conducted specifically for the Fermi 2 cooling towers by the NUS Corporation. The parameters used and the results of these studies are presented in the Fermi 2 Environmental Report in Section 5.1. The models used are described in Section 6.1 and were filed with the NRC on August 30, 1974, as the reports listed below as supporting documents to Docket Nos. 50-500 and 50-501.

a. Langrangian Vapor Plume Model - Version 3 (LVPM-3), NUS-TM-S-184
b. FOG Model Description, NUS-TM-S-185
c. ICE Model Description, NUS-TM-S-186.

2.3.2.4. Topographic Description

2.3.2.4.1. General Description

The terrain in the region of the Fermi site is characterized by flat plains, with the relief varying from 0 to 100 ft. More than 80 percent of the area is gently sloping. However, the actual site area is relatively flat and characterized by marshlands. Figures 2.3-41 and 2.3-42 are topographic maps of the area within 5- and 50-mile radii, respectively. Figure 2.3-43 is a topographic cross section of the Fermi site area out to 5 miles from the plant site and Figure 2.3-44 is a topographic cross section of the Fermi site out to 50 miles.

2.3.2.4.2. Topographic Influences on Meteorological Diffusion Estimates

The major local topographic effect on site meteorology is the presence of Lake Erie and the resultant occurrences of lake and land breeze circulations. Lake and land breeze circulations are driven by horizontal pressure gradients across the shoreline. These pressure gradients are the result of the temperature variation between water and land. This temperature differential between water and land can be most readily explained by the turbulent mixing and transport of surface heat by wave action and currents in a lake. This turbulent mixing process within

the lake effects a continuous downward transport of surface heat through the water, thus lowering the surface water temperature (and also lowering the temperature of the overlying air), in contrast with the strong surface heating of the air over the shoreline region. This contrast is also intensified because the lake water has a higher thermal capacity than that of the soil. The temperature differential across the shoreline is enhanced under clear skies and light geostrophic winds.

Because the land is heated faster than the lake, the air above the land becomes warmer than the air above the lake. The warmer air over the land begins to rise as it expands and becomes less dense. At an average height aloft of 700 m, a pressure gradient from the land to the lake is formed (Reference 23). Because of this pressure gradient, air begins to flow from the land toward the lake. This offshore flow aloft is known as the return flow. Typical return flows extend above 1500 m and have velocities that can exceed 5 m/sec.

Because air is advected from the land to over the lake aloft, a surface low is formed over the land and a surface high is formed over the water. With a surface pressure gradient thus formed, an onshore wind flow at the surface (the lake breeze) is started. To complete the circulation cell of the lake breeze, there is strong upward motion (with average updrafts of over 1 mph) over the land and subsiding air over the lake. Figure 2.3-45 is a schematic representation of the streamlines during a well-developed lake breeze cell (Reference 23). Although formation of the lake breeze circulation is usually perpendicular to the shoreline, Coriolis forces become significant as the system matures. During the later afternoon, the lake breeze can be expected to have a major component parallel to the shore (i.e., to the right of the original trajectory).

In the middle latitudes, lake breezes can occur during 30 to 60 percent of the days in the spring and summer months of the year. Lake breezes can also occur during the fall and winter seasons, although less frequently than during the spring and summer. Land breezes are the converse of lake breezes and may develop when lake temperatures are warmer than land temperatures, such as during the fall and early winter, or during the night in the summer. However, land breezes are generally weaker and less frequent than lake breezes. Once the lake becomes covered by ice, the temperature differential between lake and land becomes minimal, and the lake effect becomes nonexistent.

The front edge of the lake breeze flow has the basic characteristics of a cold front with cool, moist lake air behind the front advancing inland. This lake breeze front may advance 30 km or more inland (Reference 24).

During onshore wind flow, such as a lake breeze, cool air flowing off the lake is modified by thermal surface heating and by surface roughness effects as the air flows over the land. The air from the lake is modified significantly as it flows over the land, especially during the spring and early summer. The air is heated from below, resulting in an unstable vertical temperature gradient and hence enhanced diffusion conditions. Surface roughness effects over the land increase atmospheric turbulence (also resulting in enhanced diffusion conditions), although low-level wind speeds will decrease. The thermal and roughness effects occur at the shoreline and form a "boundary layer" which increases vertically with distance inland. Within this boundary layer is unstable air, with stable air and an intense elevated inversion (suppressed diffusion) above the boundary layer. During the late fall and winter seasons, especially when there is not as large a temperature differential between the

lake and the land as during the spring and early summer, the boundary layer is more shallow and the surface-based inversion (suppressed diffusion), normally formed right at the lakeshore, penetrates further inland.

Offshore wind flows generally result in somewhat suppressed diffusion conditions. The warm air advected from over the land is cooled from below, resulting in a stable vertical temperature gradient (inversion) and less diffusion for the over-water flow than for an overland flow. There is also a decrease in wind turbulence, although wind speeds will increase as the air flows from the relatively rough land surface over the smooth water surface. In addition to lake land breezes near a shoreline, there are also downwash and upwash effects. The primary cause of a downwash or upwash condition is the difference in surface roughness between the land and the lake (Reference 24). The upwash situation occurs with the winds blowing off the lake. The air flows from the relatively frictionless lake surface over the rough land, and a reduction in low-level wind speed occurs. This reduction in wind speed enhances plume rise to the extent that the plume can more easily escape the dynamic downwash effects of the plant structure. Downwash effects occur primarily with an offshore wind. The low-level winds coming off the relatively rough land over the smooth lake increase in speed. This increase in wind speed enhances plume downwash toward the lake surface.

A qualitative study of the surface characteristics of lake breezes at and in the near vicinity of the Fermi 2 site has been reported in Reference 25. The preliminary results of this study confirm the aforementioned factors. During the summer months, about one-third of the days were determined to give rise to a lake breeze situation. The inland penetration of these airflows averaged about 4 miles with a mean temperature decrease at the site of about 2°F and a relative humidity increase at the site of about 10 percent. The mean wind speed change due to a lake breeze situation was small (1 to 2 mph) when the lake breeze was in a direction so as to enhance the wind speed. Under conditions when the lake breeze occurred in opposition to a gradient wind, some wind direction changes were found. However, the infrequency of these situations makes it doubtful that the lake breeze could significantly change the atmospheric dispersion of effluents on an annual basis.

Edison performed a short-term meteorological study, specifically for emergency planning application, during the lake breeze seasons of 1983 and 1984 to determine the effect of Lake Erie on plume transport characteristics at the Fermi 2 site.

2.3.3. Onsite Meteorological Programs

2.3.3.1. Preoperational Onsite Meteorological Program

2.3.3.1.1. Meteorological Facility Operations

Onsite data presented in this report were collected from three different locations within the site boundary: from a 60-m tower approximately 2400 ft southwest of the Fermi 2 reactor building (since June 1, 1974) (Data from the 60-m tower were used for the diffusion estimate modeling); from the Fermi 1 100-ft tower located approximately 500 ft south-southeast of the Fermi 1 turbine building (December 1, 1956, to November 30, 1959); and from a 10-m (33-ft) tower located near Langton Road (January 1, 1972, to December 31, 1972).

Data were also collected from a 150-m tower that was located approximately 2400 ft south of Fermi 2 on the Lake Erie shoreline. One year of data (June 1, 1974, to May 31, 1975) from the 150-m tower and the 60-m tower were compared (Reference 26). The results of that study show that the 60-m tower data are representative of the Fermi 2 onsite meteorological conditions. When the Fermi 2 preoperational meteorological program was completed May 31, 1976, the 150-m tower was decommissioned. At that time, the 60-m tower operations were also discontinued until approximately 18 months prior to Fermi 2 fuel load (Reference 27). Following this, meteorological data have been collected only from the 60-m tower; thus the 60-m tower data are presented in this section. The 60-m tower data were collected, developed, and analyzed according to Regulatory Guides 1.23 and 1.111, Revision 1 (Reference 26).

The bases for decommissioning the 150-m tower, which was approved by the NRC (Reference 27), were as follows:

a. The analysis of the meteorological data collected shows the 60-m tower data are, for most parameters including χ/Q values, a more conservative characterization of the Fermi 2 conditions
b. The inland location of the 60-m tower is more representative of the air layer into which the plant effluent will be released since the gaseous release point is approximately 250 m from the shoreline on the west side (inland) of the building complex
c. Gas turbine peaking units located north of the 150-m tower affect the temperature measurements at the 10-m and 60-m levels, and consequently ΔT values, when the winds are from the north-northwest sector. During these periods, the data have to be rejected, which can seriously jeopardize the 90 percent data-recovery requirement of Regulatory Guide 1.23
d. The Fermi 1 plant structures are located such that building wake may bias the wind data for the 150-m tower for northerly directions
e. The 60-m tower is less susceptible to the icing conditions and localized lake shoreline effects experienced at the 150-m tower
f. The 2 years of data collected on the 150-m tower compare favorably, indicating only minor variations between seasons that are considered to be within the expected statistical variations between years. Thus 1 year of data at either tower, since it can be assumed the 60-m tower correlations would be valid for any year period, can be considered representative of site meteorology.

Data and discussions for the 100-ft and Langton Road towers are presented to provide supplementary site information. Data reduction on the 100-ft tower covered only the period from 1956 to 1959 to obtain data for the Fermi 1 plant; therefore, neither the instruments, data collection methods, nor data-reduction methods meet Regulatory Guide 1.23 requirements. The 33-ft Langton Road tower was originally installed as a satellite to the 150-m tower and was not instrumented to meet Regulatory Guide 1.23 requirements. A brief description of the 100-ft and 33-ft towers is presented in the following paragraphs.

On the 100-ft tower, wind speed and direction were measured at the 24-ft (7 m) level, 56-ft (17 m) level, and the 100-ft (30 m) level. Temperature sensing elements were located at 5 ft (1.5 m), 25 ft (7.6 m), 57 ft (17 m), and 100 ft (30 m). A standard National Weather Service

rain gage was located near the base of the tower. Specifically, the instrumentation of the 100-ft tower included

a. Wind instrumentation - three Bendix aerovanes
b. Temperature instrumentation - four ventilated and shielded iron-constantan thermojunctions
c. Precipitation instrumentation - one standard National Weather Service rain gage located at the base of the tower.

Data analyses are available from the above station for the December 1, 1956, to November 30, 1959, period and include only the 100-ft wind and temperature measurements ΔT(100 ft-25 ft).

The Langton Road tower (33 ft) was onsite in an open field, approximately 3500 ft west of the plant. This 10-m tower was maintained and operated by the University of Michigan. Wind data at Langton Road were collected at the 10-m level; temperature and relative humidity were recorded on a hygrothermograph housed in a conventional instrument shelter at a height of approximately 5 ft (1.5 m). Specifically, the instrumentation at the Langton Road tower included

a. Wind instrumentation - Gill propeller vane direction and speed sensors at the 10-m level
b. Temperature and humidity instrumentation - Belfort hygrothermograph housed in a conventional instrument shelter.

The specifications for the above equipment are summarized in Table 2.3-20. Data have been collected and reduced from this station for the January 1, 1972, to December 31, 1972, period.

2.3.3.1.2. Preoperational 60-Meter Tower Meteorological Data System

All the preoperational meteorological data systems that have been used during the Fermi 2 program are described in this section. The data are available from the 150-m tower (Reference 26), but are not reported herein.

2.3.3.1.2.1. Instrumentation

A revised Fermi 2 site meteorological program was initiated in November 1973 that more adequately measured meteorological conditions at the Fermi site and met the requirements of Regulatory Guide 1.23. The revised program included the reinstrumentation of the 150-m tower on January 23, 1974, and the installation of a 60-m tower with identical instrumentation. The two-tower program monitored most meteorological conditions, with the 150-m tower measuring undisturbed onshore flow off Lake Erie, and the 60-m tower measuring the perturbed onshore flow characteristic of conditions that could affect gaseous effluent releases during overland flow conditions. Figure 2.3-46 is a map of the Fermi site area with the meteorological tower locations.

Instrumentation on the 60-m tower measured wind speed, wind direction, and temperature at the 10-m level and the 60-m level. In addition, dewpoint was measured at the 10-m level, and precipitation was measured at ground level.

The interface electronics and backup analog recorders were located at the base of the 60-m tower in an environmentally controlled instrument shelter. The primary recording was accomplished using a digital system with teletype printout in engineering units and a computer-compatible paper tape. A minicomputer, located in the instrument shelter at the base of the 150-m tower, provided continuous automatic sensor polling every 15 sec and printed out averages of the data collected from the last 15 minutes once every hour. During periods when data might be desired more often than once an hour, the operator could call for a printout at any desired time interval. The 60-m tower instrumentation was interconnected to the 150-m tower system by a 2500-ft data-transmission line. Thus, the tower was controlled by the minicomputer. The 2500-ft data-transmission line was protected at each end by optical isolators designed to withstand 10 kV. This minimized the interface effects of all but the closest lightning flashes.

The revised meteorological program instrumentation specifications are shown in Table 2.3-21. The revised site meteorological program was fully operational in May 1974. Onsite data from the preoperational test program were acquired and analyzed from the 60-m tower from June 1, 1974, to May 31, 1975, from the digital printouts and the computer-compatible paper tape. AST operational onsite program data were also selected and analyzed from the 60-m tower for the period January 1, 1995 through December 31, 1999.

2.3.3.1.2.2.Calibration

Analog. Every 6 months, all sensors, electronics, and recording equipment were calibrated. Additional onsite calibrations were performed during the service visits. Any necessary adjustments were made onsite and equipment that malfunctioned was either corrected onsite or replaced with similar spare equipment. After any adjustments or repairs, the calibration was repeated. Electronics calibrations were performed by simulating the output of each of the sensors with precision test equipment and monitoring the recorded values for each parameter. Wind speed sensors were replaced by a square wave frequency generator (with its output monitored by a frequency counter) that was adjusted to provide frequencies corresponding to known wind speeds. Wind direction sensors were replaced by a stable voltage source (with its output monitored by a digital voltmeter), which was adjusted to provide an output corresponding to known wind vane orientations. Temperature sensors were replaced with a stable decade resistance box, which was adjusted to provide accurate resistances corresponding to known temperatures. In all cases, the test instrument settings used were those for which the sensor manufacturer published calibration equivalents. Sensor calibrations are performed by the manufacturer. All results of both electronics and sensor calibrations are kept and filed onsite.

Digital. The complete instrumentation system was calibrated every 6 months. Electronics calibrations were virtually the same as were performed on the analog system. Dewpoint electronics calibrations were performed in the same manner as those for air temperature electronics. With the exception of precipitation, sensor calibrations were performed by the manufacturer. The precipitation sensor and electronics were calibrated by placing known weights in the emptied weighing bucket corresponding to a known amount of rainfall. All results of both electronics and sensor calibration were kept and filed onsite.

2.3.3.1.2.3.Service and Maintenance

Analog. Visits were made twice a week to the 150-m tower to change chart paper, fill inkwells and pens, and change ribbons. A visual inspection of the sensors was made to see if they had been damaged. Using the same precision test equipment used for calibration, all instrumentation was checked to ensure reliable operation.

Digital. Daily operational checks and service were performed by a resident technician. These checks included inspection of the data to determine that all sensors were functioning correctly and of the strip charts to ensure accurate recording. In addition, the technician marked the correct time to the nearest minute on the strip chart and verified the correct time of the digital system. Visual inspections of sensors were also performed to ensure that they had not been physically damaged.

2.3.3.1.3. Data Analysis Procedures

The data analysis procedures discussed in this subsection were those used for the data reported herein, which includes data from the 60-m tower, 100-ft tower, and Langton Road tower. The total preoperational meteorological program also included the 150-m tower from which data were collected and analyzed over the period from July 3, 1973, to May 31, 1975. However, approximately 170 m north of the 150-m tower, four peaking units were located that were operated during periods of high electrical demand. When the peaking units were in operation and the wind was from the north, it was occasionally noticed that significant increases in temperature at the 60-m and 150-m levels occurred. Because of this, it was deemed necessary to delete periods during which peaking unit operation influenced the determination of the lapse rate. This influence was apparent several times during the course of the annual data collection. Because of the problems associated with the 150-m tower's location, the 60-m tower was installed. An analysis of 1 year of simultaneous meteorological data from the 150-m tower and 60-m tower (Reference 26) showed that the 60-m tower data were representative of the onsite meteorology. Thus, after the Fermi 2 preoperational onsite meteorological data collection was completed, the 150-m tower was decommissioned. Future data will be collected using the 60-m tower only (Reference 26).

2.3.3.1.3.1.60-Meter Tower Data Reduction

The meteorological monitoring systems for the Fermi site are described in Subsection 2.3.3.1.2. The data acquisition system utilized two levels of instrumentation (10-m and 60-m) on the 60-m tower located approximately 2400 ft southwest of the Fermi 2 plant. The atmospheric stability conditions were determined from the temperature differences (ΔT) between the 10-m and 60-m temperature measurements, in accordance with the Pasquill Stability Criteria, Conditions A through G. Data from the 60-m tower were read by computer from paper tape to an IBM computer-compatible disk pack and magnetic tape for further use in modeling the site meteorological conditions and χ/Q calculations for various time periods. Strip charts were used only for backup. The strip- chart data, when needed, were read manually and the data put on IBM cards. Data from the charts were recovered by averaging the 15-minute period immediately preceding the hour. As long as 90 percent of the time span (13.5 minutes) was available for averaging, the data were deemed valid.

As a continuing operational verification of data validity, comparisons for all sensors at all levels on the tower between analog and digital averages were made on a random basis during the preoperational phase. The results of these comparisons for all parameters at the 10-m level and the air temperature at the 60-m level of the 60-m tower are shown in Table 2.3-22. For all checks the correlations are excellent. Differences can be attributed to strip-chart-reading error combined with the greater resolution of the digital system.

Precipitation at ground level was recorded onsite starting December 7, 1973. With the digital system operational, the strip charts were used only for backup, thus eliminating the strip-chart-reading task. Digital data were verified periodically against strip charts.

2.3.3.1.3.2. Langton Road Tower and 100-Ft Tower Data Reduction

Data from the 10-m Langton Road tower were recorded on strip charts and manually reduced. One 10-minute sample for each 1-hr available-data period was obtained for values of the wind direction range (i.e., the extremes of the direction trace peaks). Average values of wind direction and wind speed were obtained by visually estimating a median for the 1-hr sample of the analog traces. One reading was taken for each 1 hr of data available to obtain instantaneous values of temperature and relative humidity. The manually reduced data were transcribed on cards and were used as computer input for data analysis and summary.

Data from the 100-ft tower were also recorded on strip charts and manually reduced. Hourly averages of wind direction, wind speed, and temperature were obtained by estimating a median for the analog trace.

2.3.3.1.4. Meteorological Data Recovery

2.3.3.1.4.1. 60-Meter Tower Data Recovery

The meteorological data recovery rates for the 60-m tower data for the June 1, 1974 through May 31, 1975 period are listed in Table 2.3-23. The joint data recovery (ΔT, wind speed, wind direction) for the June 1, 1974, to May 31, 1975, period of 91.16 percent meets the 90 percent required by Regulatory Guide 1.23

The joint data recovery of wind speed and direction and ΔT for the January 1, 1995 through December 31, 1999 10-meter tower data that was utilized in the PAVAN model for accidental releases at offsite locations is 96.2 percent, also meeting the NRC 90 percent criterion.

For the calculations presented herein, only 10-m wind speed and direction, and temperature differences between 60-m and 10-m were used to calculate the short-term postulated accidental release diffusion estimates based on the 1995-1999 data. The 10-m and 60-m wind speeds were used to calculate the long-term mixed-mode annual average X/Q and D/Q values based on the June 1974 through May 1975 period.

2.3.3.1.4.2. Langton Tower and 100-Ft Tower Data Recovery

The meteorological data-recovery rates for the 33-ft Langton Tower data are listed in Table 2.3-24. Wind data for the January 1, 1972, to December 31, 1972, period have not been included in this report due to a low data-recovery rate. The recovery was 94 percent for the

temperature and relative humidity data for the report period. The data-recovery rate for the 100-ft tower was 77 percent for temperature data, and 96 percent for the 100-ft- level wind data for the December 1, 1956, to November 30, 1959, period. Data-recovery information for other levels of the 100-ft tower are not readily available.

2.3.3.2. Operational Meteorological Monitoring System

The previously described preoperational meteorological program was upgraded for plant operation. The upgraded program is composed of two independent meteorological trains of instrumentation – a primary train and a secondary train – mounted on the 60-m tower. Both trains feed the data acquisition equipment of the Integrated Plant Computer System (IPCS) located in the Fermi 2 control center. The IPCS has the capability to share the meteorological data with other plant computers, display the data on IPCS terminals at various plant locations, and perform plume dispersion analysis in support of Emergency Plan activities. Users at remote locations can access the meteorological data on IPCS through dedicated remote access devices. The NRC can also receive selected meteorological data through the Emergency Response Data System (ERDS). The operational meteorological monitoring system is described in further detail in the following subsections and is illustrated in Figure 2.3-47.

2.3.3.2.1. Instrumentation

Table 2.3-25 lists the meteorological parameters monitored, the sampling height(s), and the sensing technique for the primary and secondary systems.

To minimize data loss due to ice storms, external heaters are installed on all primary wind sensors. The heaters are thermostatically controlled and are of the slip-on/slip-off design for easy attachment. The wind sensor specifications are not affected by these heaters.

A windscreen is mounted around the precipitation gage to minimize the amount of windblown snow and debris deposited in the gage.

Electrical power is supplied to the primary and secondary systems by independent power supplies. One source of power is Fermi 2; the other is an offsite source. If one supply fails, the other automatically supplies the necessary power for both systems. Two precautions are taken to minimize lightning damage to the system. Two of the three legs are grounded and the signal cables are routed through a lightning protection panel. Each signal line is protected by transient protection diodes specifically designed to stay below the individual line voltage breakdown point.

2.3.3.2.2. Signal Conditioning

Inside the environmentally controlled instrument shelter, sensor signals are conditioned. Each sensor signal requires a single printed-circuit board to perform the necessary conversion, amplification, and scaling to provide a pair of analog outputs for each parameter. Zero and full-scale test switches are front-panel mounted on each printed-circuit board to facilitate parameter testing.

After conditioning through their respective printed-circuit boards, the 10-m horizontal wind direction and vertical wind speed signals pass into the Climatronics Standard Deviation Computer boards to compute the 15-minute average sigma theta and sigma phi.

The primary and secondary signal conditioner and standard deviation computer boards are completely independent of each other.

2.3.3.2.3. Data Transmission

The outputs of the instrument signal conditioning equipment is transmitted to the control center via two independent transmission lines. The one line incorporates a phone line between the shelter and the nuclear operations center, where information is microwaved to the Office Service Building. From the Office Service Building, the signals are transmitted to the control center. The second line uses a separate phone line from the shelter to the nuclear operations center, where the data are transmitted to the office service building via a phone line. From the office service building, the signals are transmitted to the control center. The two signals are electrically separated from one another from the 60-m tower to the control center. The instrumentation at the 60-m tower is electrically isolated from the equipment in the control center computer room.

2.3.3.2.4. Data Acquisition

The dual IPCS data acquisition multiplexors accept two trains of data from the Meteorological system primary and secondary data acquisition equipment. This data is provided to the IPCS computers to perform meteorological calculations, update the data archive, display the information on the man-machine interface, and output the data to communication devices. The IPCS provides redundant computers that provide a main (Master) and backup (Slave) capability. The redundant computers in conjunction with the two trains of data acquisition provide two independent paths of data. The IPCS system monitors available error signals to determine equipment status. If an instrument input malfunctions, if data are suspect, or an instrument input is manually removed from service, the IPCS will substitute the reading from the next level of redundancy as listed in Table 2.3-26 and indicate the substitution on the IPCS computers.

Meteorological data are available in five different formats: instantaneous values, 1-minute blocked averages, 15-minute rolling averages, 15-minute blocked averages, and 1-hour blocked averages.

In the event that a data path to IPCS is unavailable, a recorder is available on each train of instrumentation at the meteorological instrument building to archive the raw data.

2.3.4. Short-Term (Accident) Diffusion Estimates

2.3.4.1. Calculation of Offsite Atmospheric Diffusion Coefficients

2.3.4.1.1. Objective

To evaluate the dispersion potential of the atmosphere in the Fermi site area, calculations were made of concentrations of effluents normalized by the source strength of the power

plant release. These atmospheric dilution factors were calculated using the meteorological data collected onsite from January 1, 1995 - December 31, 1999.

Short-term offsite transport was modeled using the PAVAN software (Reference 28), which is based on the NRC design-basis-accident methodology in Regulatory Guide 1.145 (Reference 31). PAVAN is a commercial software package applicable to nuclear safety-related analyses as well as non-safety related studies and evaluations. Its use is applicable for determining normalized offsite concentrations as required for the Exclusion Area Boundary (EAB) and the Low Population Zone (LPZ). These locations are defined in UFSAR Sections 2.1.2 and 2.1.3.3 as radial distances of 915 m and 4827 m, respectively, from the containment building.

Six different χ/Q values, corresponding to six different time periods following an accident, were calculated. The time periods postulated to follow an accident are those specified by the NRC in Regulatory Guide 1.145. These are 0-2 hr, 0-8 hr, 8-24 hr, 1-4 days, 4-30 days and the annual period.

2.3.4.1.2. Dispersion Equations

This section describes the governing atmospheric dispersion modeling equations and assumptions in accordance with Regulatory Guide 1.145.

Ground-level χ/Q values were calculated for the 2 hours following the accident for the EAB and LPZ, and for the annual period for the LPZ. Calculations were based on the following equations:

$$\chi/Q = \frac{1}{\bar{U}_{10}(\pi\sigma_y\sigma_z + A/2)} \quad (2.3\text{-}1)$$

$$\chi/Q = \frac{1}{\bar{U}_{10}(3\pi\sigma_y\sigma_z)} \quad (2.3\text{-}2)$$

$$\chi/Q = \frac{1}{\bar{U}_{10}\pi\Sigma_y\sigma_z} \quad (2.3\text{-}3)$$

Where:

χ/Q is relative concentration, in sec/m^3

π is 3.14159

$\bar{U}_{10}$ is wind speed at 10 meters above plant grade, in m/sec

σ_y is lateral plume spread, in m, a function of atmospheric stability and distance

σ_z is vertical plume spread, in m, a function of atmospheric stability and distance

Σ_y is lateral plume spread with meander and building wake effects (in meters), a function of atmospheric stability, wind speed, and distance [for distances of 800 m or less, $\Sigma_y = M\sigma_y$, where M is determined from Regulatory Guide 1.145 Figure 3; for distances greater than 800 m, $\Sigma_y = (M-1)\sigma_{y800m} + \sigma_y$

A is the smallest vertical-plane cross-sectional area of the reactor building, in m^2 (other structures or a directional consideration may be justified when appropriate). Offsite χ/Qs are calculated assuming a minimum cross-sectional

area, A, of the combined reactor/auxiliary building of 2300 m^2, as shown in Figure 2.3-48

Plume meander is only considered during neutral (D) or stable (E, F, or G) atmospheric stability conditions where the highest χ/Q values resulting from equations 2.3-1, 2.3-2 and 2.3-3 is selected. For all other conditions (stability classes A, B, or C), meander is not considered and the highest χ/Q value of equations 2.3-1 and 2.3-2 is selected.

The χ/Q values calculated at the EAB based on meteorological data representing a 1-hour average is assumed to apply for the entire 2-hour period.

2.3.4.1.3. Determination of Max Sector and Overall 5 Percent Site χ/Q Values

2.3.4.1.3.1. Maximum Sector χ/Q

To determine the maximum sector χ/Q value at the EAB, a cumulative frequency probability distribution (probabilities of a given χ/Q value being exceeded in that sector during the total time) is constructed for each of the 16 sectors using the χ/Q values calculated for each hour of data. This probability is then plotted versus the χ/Q values and a smooth curve is drawn to form an upper bound of the computed points. For each of the 16 curves, the χ/Q value that is exceeded 0.5 percent of the total hours is selected and designated as the sector χ/Q value. The highest of the 16 sector χ/Q values is the maximum sector χ/Q.

Determination of the LPZ maximum sector χ/Q is based on a logarithmic interpolation between the 2-hour sector χ/Q and the annual average χ/Q for the same sector. For each time period, the highest of these 16 sector χ/Q values is identified as the maximum sector χ/Q value. The maximum sector χ/Q values will, in most cases, occur in the same sector. If they do not occur in the same sector, all 16 sets of values will be used in dose assessment requiring time-integrated concentration considerations. The set that results in the highest time-integrated dose within a sector is considered the maximum sector χ/Q.

2.3.4.1.3.2. 5 Percent Overall Site χ/Q

The 5 percent overall site χ/Q value for the EAB and LPZ is determined by constructing an overall cumulative probability distribution for all directions. χ/Q versus the probability of being exceeded is then plotted and an upper bound curve is drawn. From this curve, the 2-hour χ/Q value that is exceeded 5 percent of the time is found. The 5 percent overall site χ/Q at the LPZ for intermediate time periods is determined by logarithmic interpolation of the maximum of the 16 annual average χ/Q values and the 5 percent 2-hour χ/Q values.

2.3.4.1.4. Wind Speed Categorization

The meteorological database was prepared for use in PAVAN by transforming the five years (i.e., 1995-1999) of hourly meteorological tower data observations into a joint wind speed-wind direction-stability class occurrence frequency distribution. Seven (7) wind speed categories were defined according to Regulatory Guide 1.23 (Reference 16) with the first category identified as "calm". The higher of the starting speeds of the wind vane and anemometer (i.e., 0.75 mph) was used as the threshold for calm winds, per Regulatory Guide 1.145, Section 1.1. A midpoint was also assumed between each of the Regulatory Guide 1.23

wind speed categories, Nos. 2-6, as to be inclusive of all wind speeds. The wind speed categories have therefore been defined as follows:

Category No.	Regulatory Guide 1.23 Speed Interval (mph)	PAVAN-Assumed Speed Interval (mph)
1 (Calm)	0 to < 1	0 to < 0.75
2	1 to 3	≥ 0.75 to < 3.5
3	4 to 7	≥ 3.5 to < 7.5
4	8 to 12	≥ 7.5 to < 12.5
5	13 to 18	≥ 12.5 to < 18.5
6	19 to 24	≥ 18.5 to < 24
7	>24	≥24

In the equations shown in Section 2.3.4.1.2, it should be noted that wind speed appears as a factor in the denominator. This causes difficulties in making calculations for periods of calm. The procedures used by PAVAN to assign a direction to each calm period according to the directional distribution for the lowest wind-speed class. This is done separately for the calms in each stability class.

2.3.4.1.5. Short-Term X/Q Modeling Results

Atmospheric diffusion estimates developed for use in evaluating accidents are summarized in Table 2.3-27 for the above-mentioned periods following the accident. This table includes estimates for the maximum sector and overall 5 percent site χ/Q.

2.3.4.2. Calculation of Onsite (Control Room) χ/Q Values

2.3.4.2.1. Objective

To evaluate the dispersion potential of the atmosphere in the Fermi site area, calculations were made of concentrations of effluents normalized by the source strength of the power plant release. These atmospheric dilution factors were calculated using the meteorological data collected onsite from January 1, 1995-December 31, 1999.

Short-term onsite transport was modeled using the ARCON96 software, which is a commercially available general code for assessing atmospheric relative concentrations in the presence building wakes that is based on the NRC design-basis-accident methodology in Regulatory Guide 1.194 (Reference 32). The code user documentation and calculation methodology is documented in Revision 1 of NUREG/CR-6331, "Atmospheric Relative Concentrations in Building Wakes" (Reference 33).

ARCON calculates relative concentrations for a specified source-to-receptor configuration with the user supplied hourly meteorological data. It then combines the hourly averages to estimate concentrations for periods ranging in duration from 2 hours to 30 days. Wind direction is considered as the averages are formed. As a result, the averages account for persistence in both diffusion conditions and wind direction. Cumulative frequency distributions are prepared from the average relative concentrations. Relative concentrations that are exceeded no more than five percent of the time (95^{th} percentile relative concentrations) are determined from the cumulative frequency distributions for each averaging period. Finally, the relative concentrations for five standard averaging periods (0-

2 hr, 2-8 hr, 1-4 days and 4-30 days) are calculated from the 95^{th} percentile relative concentrations.

2.3.4.2.2. Dispersion Equations

This section describes the governing atmospheric dispersion modeling equations and assumptions (with noted exceptions) in accordance with Regulatory Guide 1.194.

The basic diffusion model implemented in the ARCON96 is a straight-line Gaussian model that assumes the release rate is constant for the entire period of release. This assumption is made to permit evaluation of potential effects of accidental releases without having to specify a complete release sequence.

$$\frac{\chi}{Q} = \frac{1}{\pi \sigma_y \sigma_z U} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (2.3\text{-}4)$$

where:

$\frac{\chi}{Q}$ is relative concentration, in sec/m^3

π is 3.14159

U is wind speed at 10 meters above plant grade, in m/sec.

σ_y is lateral diffusion coefficient (m)

σ_z is vertical diffusion coefficient (m), and

y is distance from the center of the plume (m)

This equation represents a ground level release that is assumed to be continuous, constant, and of sufficient duration to establish a relative mean concentration. It also assumes that the material being released is reflected by the ground. Diffusion coefficients are typically determined from atmospheric stability and distance from the release point using empirical relationships. ARCON96 uses the same diffusion coefficient (σ_z and σ_y) parameterizations utilized in the NRC PAVAN code for calculating the short-term post-accident offsite atmospheric dispersion.

Calculation of the onsite χ/Q values associated with stack releases (i.e., SGTS, RBHVAC, and the TBHVAC), the "vent release" option was specified in conjunction with a zero-vent velocity. According to Regulatory Guide 1.194, the NRC specifies a ground release as the acceptable release mode for performing atmospheric dispersion calculations, consistent with this philosophy, the NRC does not accept the ARCON96 vent release calculation methodology. However, ARCON96 is coded to use the ground release equations when the vent exiting velocity is less than the wind-speed. Thus, in specifying a zero vent exiting velocity for cases where the vent release option was selected, the ground release equations were implemented and the intent of Regulatory Guide 1.194 was met. The purpose for specifying the zero-velocity vent release option was to allow for consideration of the 60-meter meteorological data in the calculation of the atmospheric relative concentration. Alternatively, the ground release option could have been specified with same inputs for the release and receptor elevations with the same result. In addition, in specifying the vent release, no credit was assumed for pre-dilution of the relative source term concentration

inside the secondary containment or turbine building free air volumes or in the volumetric flows of the HVAC system associated with a particular vent location.

ARCON 96 includes the effects of low wind speed and building wake by replacing σ_z and σ_y above by composite wake diffusion coefficients of the following form:

$$\Sigma_y = \left(\sigma_y^2 + \Delta\sigma_{y1}^2 + \Delta\sigma_{y2}^2\right)^{1/2} \text{ and } \Sigma_z = \left(\sigma_z^2 + \Delta\sigma_{z1}^2 + \Delta\sigma_{z2}^2\right)^{1/2} \quad (2.3\text{-}5)$$

where σ_Z and σ_y are the normal diffusion coefficients and $\Delta\sigma_{z1}$ and $\Delta\sigma_{y1}$ are the low wind speed corrections and $\Delta\sigma_{z2}$ and $\Delta\sigma_{y2}$ correct for building wake. The building wake correction is calculated based on a 2300 m^2 building area cross-section.

ARCON96 was run assuming the default surface roughness factor of 0.1 meters. This value is representative of a terrain having low-lying vegetation; i.e., farmland, wetland, etc.

2.3.4.2.3. Wind Speed Categorization

The meteorological database was prepared for use in ARCON96 by transforming the five years (i.e., 1995-1999) of hourly meteorological tower data observations into the format required by ARCON96. The required input consists of the Julian day, hour, 10-meter wind direction, 10-meter wind speed, stability class, 60-meter wind direction, and 60-meter wind speed for each of these years. ARCON96 requires the specification of the calm threshold. χ/Q values calculated using wind velocities below the calm threshold are automatically included in the statistical evaluation of a specific χ/Q regardless of the associated wind direction. Regulatory Guide 1.194 suggests a minimum calm threshold of 0.5 m/s; however, the ARCON96 performed in support of Alternate Source Term implementation were reviewed and approved with a calm threshold of 0.33 m/s. Based on NRC endorsement of the regulatory guide and endorsement of the original AST submittal, both values are acceptable.

2.3.4.2.4. Physical Orientation of Source-Receptor Combinations and Dual Inlet Credit

Consistent with Regulatory Guide 1.194, Position 3.4, the source-to-receptor distances used to calculate the atmospheric dispersion coefficients were calculated as the slant distance or direct line-of-site distances. Conservatively, the values of relative air concentrations used to evaluate vital area doses do not credit the additional distance incurred in circumventing intervening plant structures. However, such credit is permitted in accordance with the NRC methodology and was considered in evaluating the relative importance of postulated potential MSIV and secondary containment bypass leak release locations against the Turbine Building exhaust stack as a single representative release point.

2.3.4.2.4.1. DBA LOCA

Post LOCA atmospheric dispersion of ECCS and primary containment leakage was evaluated based on an assumed release via the SGTS stack to the control room north and south emergency air intakes. The TBHVAC stack was the assumed release point for Main Steam Line Leakage, also having the main control room north and south emergency air intakes as receptors. The table below identifies the horizontal and vertical separation distances between the postulated source and receptor locations. The RBHVAC stack and

secondary containment wall were not assumed release locations evaluated in support of the LOCA analysis performed using the Alternate Source term. Nevertheless, their physical locations with respect to the control center emergency air intakes are included for historical purposes.

Source Release Location	Intake Separation Distance, meters [Horizontal/Vertical]	
	South Emergency/Normal*	North Emergency
SGTS Stack	39.4/24.9	17.2/35.8
TBHVAC Stack	69.1/10.7	111.1/21.6
RBHVAC Stack	11.6/24.9	48.8/35.8
Secondary Containment Wall	13.9/0	13.9/0

*Note that the vertical distance used to calculate the atmospheric dispersion coefficients for transport to the south emergency air intake for the LOCA analysis credits only the upper, missile-proof portion of the inlet plenum. The south emergency air intake also includes a safety-related sided enclosure that extends the intake down an additional 10.9 meters.

The Fermi 2 Control Center HVAC system is designed with dual emergency makeup air inlets located on the North and South sides of the Auxiliary Building. With the exception of the TBHVAC exhaust stack, the emergency air inlets have a separation distance that is sufficient to place them outside of a 90° wind direction window centered on the line-of-sight from any of the stack locations above to the opposite emergency air intakes. Thus, consistent with Regulatory Guide 1.194, Position 3.3.2, they are configured such that neither release point is capable of simultaneously impacting both air inlets. Furthermore, the Control Room Emergency Filtration System associated with CCHVAC is capable of automatically selecting the inlet with the lowest dose. However, the operators are procedurally instructed to take manual control of the inlet selection. On this basis, consistent with Regulatory Guides 6.4 and 1.194, Position 3.3.2.3, the χ/Q associated with the most favorable intake is assumed and divided by a factor of four. Fermi differs from the Regulatory Guide 1.194, Position 3.3.2.3 in that the factor of four is applied from the start of the accident rather than from the time the manual action is assumed to occur.

The TBHVAC stack is the assumed release point for the source term associated with Main Steam Isolation Valve leakage. This stack location does not have sufficient separation relative to the two inlets to allow dual inlet credit. The value of χ/Q calculated by ARCON96 is used directly (i.e., with no correction or reduction) to represent MSIV leakage transport to the control center with only credit for the ability of the operator to select the most favorable inlet. In this manner, the transport to the control center occurs instantaneously as the leakage occurs as if TBHVAC were in operation with no credit for any dilution in the TBHVAC airflow or the very large volume above the turbine deck. Each of the thirteen smoke vents on the Turbine Building roof and the external doors associated with the turbine and auxiliary buildings were also considered in selecting an appropriate release location. While the χ/Qs calculated for these locations were potentially larger than that associated with the TBHVAC stack value, the conservatism in the application of the stack value with no credit taken for mixing or deposition was considered adequately compensating.

2.3.4.2.4.2. Fuel Handling Accident

Fermi considers two types of fuel handling accidents, one that occurs 24 hours post-scram that involves a drop of recently irradiated fuel and credits only secondary containment and the operation of the SGTS for mitigation. The second type of fuel handling accident involving fuel that is no longer "recently irradiated," which occurs following a post-scram delay period sufficient such that credit for secondary containment and SGTS operation is not required.

Although not specifically required in Regulatory Guides 1.183 and 1.194, the FHA analyses submitted in support of Amendments 144 and 160, conservatively applied the 0-2 hr control room χ/Q values calculated by ARCON96 to the entire 30-day duration of accident.

Neither type of fuel handling accident assumes credit for the operation of the Control Room Emergency Filtration System. Consequently, the factor associated with the dual inlet configuration is not credited for reducing the value of χ/Q calculated by the ARCON96 software. Adequate separation is credited, however, to ensure that only the single most limiting air intake is specified.

The release and receptor locations used to evaluate the radiological consequences of the fuel handling accident differ from those associated with the DBA LOCA and depend on which of the two types of fuel handling accidents is to be evaluated.

2.3.4.2.4.2.1. 24-Hour Fuel Handling Accident Involving Recently Irradiated Fuel

This accident postulates an initial brief period of unfiltered release via the RBHVAC stack prior to secondary containment isolation and operation of the SGTS. ARCON96 was used to calculate the atmospheric dispersion coefficient representing transport from these stacks to each emergency air intake. The source-to-receptor distances are as specified in the table in Section 2.3.4.2.4.1 except the additional vertical distance of 10.9 meters associated with the full length of the south emergency air intake is credited.

2.3.4.2.4.2.2. Fuel Handling Accident Involving Fuel No Longer Considered Recently Irradiated

This accident assumes no credit for secondary containment isolation or operation of the SGTS. Consequently, the most likely release path would be via the RBHVAC stack as a consequence of continued RBHVAC operation. Several source-to-receptor locations were considered in establishing the limiting plant configuration, these included the SGTS and RBHVAC stacks as well as the reactor building railroad bay and first floor personnel air-lock (via the Outage Building front) doors.

While RBHVAC was identified and the most credible release point, the outage building front doors were conservatively selected as a bounding release location. Due to the location of the outage doors on the south side of the reactor building, the corresponding limiting receptor location is the south emergency air intake. The horizontal and vertical distances between these source and receptor locations are 29.3 m and 18.6 m for an overall slant distance of 34.7 m. The overall slant distance was input to ARCON96 in evaluating the associated atmospheric dispersion as a ground release.

This source-to-receptor pathway presumes the source term is removed from the building and is transported to the control room via the normal/emergency makeup air intakes. Thus, the control room envelope is effectively assumed to be intact and any maintenance that involves breaches of the control room envelope must include the controls necessary to preserve this assumption.

2.3.4.2.5. Short-Term Onsite χ/Q Modeling Results

Atmospheric diffusion estimates developed for use in evaluating accidents are summarized in Table 2.3-28.

2.3.5. Long-Term Diffusion and Deposition Calculations

To evaluate the long-term dispersion potential of the atmosphere in the Fermi site area, calculations were made of effluent concentrations normalized by source strength of the power plant release and relative deposition rate. These atmospheric dilution and deposition factors were calculated using meteorological data collected onsite at the 60-m tower over the period June 1, 1974, to May 31, 1975. The long-term calculations are based on the straight line trajectory airflow model where a mixed-mode release, depending on wind speed, is assumed as described in Regulatory Guide 1.111, Revision 1 (Reference 30).

The models used to evaluate the long-term (annual) estimates of χ/Q and D/Q are described in Annex B of Appendix 11A. The analyses reported herein were performed for three separate sources at the Fermi 2 site: the containment building vent, the turbine building vent, and the radwaste building vent. Since the calculations were performed assuming a mixed-mode release based on wind speed, the release characteristics of each source are given in Table 2.3-28.

It should be noted that the results of the calculations performed for χ/Q (undecayed and undepleted, and decayed and depleted for radioiodines) and D/Q for radioiodines and particulates are presented in Appendix 2A.

2.3.5.1. Undecayed and Undepleted χ/Q Estimates

Values of χ/Q assuming no decay or depletion were calculated for the three air effluent releases using the mixed-mode techniques referenced in Annex B to Appendix 11A and Regulatory Guide 1.111, Revision 1, July 1977. The calculations were performed for all 22-1/2° sectors at distances of

a. 0.4 to 1.6 km in 0.4-km increments
b. 1.6 to 16 km in 0.8-km increments
c. 16 to 80 km in 8-km increments.

These values of undecayed and undepleted χ/Q in units of seconds per cubic meter are presented in "wheel diagrams" for each source in Figures 2.3-52 through 2.3-54. Note that each figure provides values for the three distances for each release point. The numerical χ/Q values are presented by distance and sector in Appendix 2A.

2.3.5.2. Decayed and Depleted χ/Q Estimates

Values of χ/Q, assuming a radioactive effluent with a half-life of 8 days and using the plume depletion effect curves in Regulatory Guide 1.111, Revision 1, July 1977, in conjunction with the mixed-mode techniques, were calculated for the distances noted in Subsection 2.3.5.1.

These values of decayed and depleted χ/Q in units of seconds per cubic meter are presented for each of the three sources in Figures 2.3-55 through 2.3-57. The numerical values are presented by distance and sector in Appendix 2A.

2.3.5.3. Relative Deposition Estimates

Values of relative deposition (D/Q) per unit area were calculated for the three sources also using the mixed-mode techniques. The relative deposition-rate curves in Figures 6 through 9 of Regulatory Guide 1.111, Revision 1, July 1977, were used for the same distances as described above.

These values of relative deposition per unit area (square meters) are presented for each of the three sources in Figures 2.3-58 through 2.3-60. The numerical values are presented by distance and sector in Appendix 2A.

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2.3 METEOROLOGY

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TABLE 2.3-1 EXTREME WIND SPEED OCCURRENCE PROBABILITIES (AT 30 FT ABOVE GROUND)

Probability	Recurrence Interval (years)	Extreme Wind Speed (mph)
0.500	2	50
0.100	10	62
0.040	25	70
0.020	50	82
0.010	100	90
0.001	1000	117

TABLE 2.3-2 DETROIT, MICHIGAN METROPOLITAN AIRPORT NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Temperature – Extremes – Year	Temperature – Extremes – Record lowest	Temperature – Extremes – Year	Normal heating degree days (base 65°)	Precipitation – Normal total	Precipitation – Maximum monthly	Precipitation – Year	Precipitation – Minimum monthly	Precipitation – Year	Precipitation – Maximum in 24 hr	Precipitation – Year	Snow, Ice Pellets – Mean total	Snow, Ice Pellets – Maximum monthly	Snow, Ice Pellets – Year	Snow, Ice Pellets – Maximum in 24 hr	Snow, Ice Pellets – Year	Relative Humidity – hr 01 (Local time)	Relative Humidity – hr 07 (Local time)	Relative Humidity – hr 13 (Local time)	Relative Humidity – hr 19 (Local time)	Wind[g] – Mean speed	Wind[g] – Prevailing direction	Wind[g] – Fastest Mile[h] – Speed	Wind[g] – Fastest Mile[h] – Direction[i]	Wind[g] – Fastest Mile[h] – Year	Percent possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to Sunset – Clear	Mean number of days – Sunrise to Sunset – Partly cloudy	Mean number of days – Sunrise to Sunset – Cloudy	Mean number of days – Precipitation 0.01 in. or more	Mean number of days – Snow, ice pellets 1.0 in. or more	Mean number of days – Thunderstorms	Mean number of days – Heavy Fog	Mean number of days – Temperatures – Maximum – 90° and above[f]	Mean number of days – Temperatures – Maximum – 32° and below	Mean number of days – Temperatures – Minimum – 32° and below	Mean number of days – Temperatures – Minimum – 0° and below	Average daily solar radiation (langleys)
(a)	(b)	(b)	(b)	14		14		(b)	(b)	14		14		14		14	14		14		14	14	14	14	14	5	6	6		7	14	14	14	14	14	14	14	14	14	14	14	14	
J	33.3	19.0	26.2	62	1965	-14	1972	1203	1.93	3.63	1965	0.27	1961	1.72	1967	8.1	13.4	1959	6.6	1968	77	78	69	73	11.3	WSW	50	W	1971	38	7.5	4	7	20	13	3	(c)	3	0	17	30	4	
F	34.4	18.9	26.7	58	1966	-9	1971	1072	1.95	2.68	1971	0.15	1969	1.23	1965	8.3	17.4	1962	10.3	1965	75	77	64	69	11.3	WSW	52	SW	1967	45	7.2	5	6	17	11	3	(c)	2	0	12	27	2	
M	42.8	25.9	34.4	77	1963	1	1963	949	2.41	3.59	1965	0.92	1960	1.18	1972	6.3	16.1	1965	6.5	1968	76	78	61	65	11.2	WSW	36	SW	1969	52	7.2	5	8	18	13	2	1	2	0	5	25	0	
A	56.7	36.2	46.5	85	1970[d]	17	1964	555	3.05	5.40	1961	0.92	1971	1.97	1965	1.6	7.4	1961	4.2	1961	75	79	55	59	11.2	WSW	45	SW	1968	54	6.8	6	7	17	13	1	4	1	0	(c)	10	0	
M	68.8	46.4	57.6	92	1962	25	1966	259	3.54	5.88	1968	1.15	1965	2.87	1968	(e)	(e)	1970[d]	(e)	1970[d]	75	78	53	56	10.1	WSW	40	SW	1970	61	6.3	7	10	14	10	0	4	(c)	(c)	0	1	0	
J	79.0	56.8	67.9	99	1971	36	1972[d]	61	3.31	6.60	1960	2.12	1959	2.62	1960	0.0	0.0		0.0		80	80	54	59	8.8	SW	39	W	1970	62	5.9	8	10	12	11	0	6	1	3	0	0	0	
J	83.9	60.9	72.4	98	1966	41	1965	0	2.69	6.02	1969	1.11	1964	3.19	1966	0.0	0.0		0.0		81	82	53	58	8.3	SW	50	SW	1968	65	5.7	8	13	10	10	0	6	1	4	0	0	0	
A	82.1	59.4	70.8	97	1964	40	1964	11	2.84	7.70	1964	1.06	1969	3.21	1964	0.0	0.0		0.0		84	87	56	64	8.2	SW	36	NW	1971	71	5.4	10	11	10	9	0	6	2	3	0	0	0	
S	74.5	52.0	63.3	94	1971[d]	33	1970[d]	111	2.32	5.83	1961	0.43	1960	2.07	1961	0.0	0.0		0.0		84	87	57	68	8.6	SW	34	W	1970	58	6.4	8	9	13	10	0	4	2	1	0	0	0	
O	63.1	41.3	52.2	91	1963	18	1965	405	2.57	4.87	1967	0.35	1964	2.11	1959	(e)	(e)	1972[d]	(e)	1972[d]	81	84	56	68	9.2	WSW	33	SW	1968[d]	52	6.1	8	10	13	9	0	1	3	(c)	0	5	0	
N	47.3	31.2	39.3	77	1968	9	1969[d]	771	2.27	3.31	1968	0.80	1964	1.52	1968	3.2	11.8	1966	5.2	1966[d]	80	83	66	74	10.6	SW	37	SW	1968	28	7.8	3	7	20	11	1	(c)	2	0	1	17	0	
D	35.8	21.9	28.9	66	1966	-9	1960	1119	1.92	6.00	1965	0.46	1960	3.71	1965	8.0	17.3	1962	5.7	1966	79	81	71	76	10.8	SW	50	W	1972	25	7.9	3	7	21	13	3	(c)	3	0	13	26	1	
YR	58.5	39.2	48.9	99	June 1971	-14	Jan. 1972	6516	30.80	7.70	Aug. 1964	0.15	Feb. 1969	3.71	Dec. 1965	35.5	17.4	Feb. 1962	10.3	Feb. 1965	79	81	60	66	10.0	SW	52	SW	Feb. 1967	53	6.7	75	105	185	131	13	33	23	11	48	140	7	

[a] Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.

[b] Climatological standard normals (1931-1960)

[c] Less than one half.

[d] Also on earlier dates, months, or years.

[e] Trace, an amount too small to measure.

[f] at Alaskan stations.

[g] Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest Mile" the corresponding speeds are fastest observed 1-minute values.

[h] For period May 1966 through current year.

[i] To eight compass points only.

Below zero temperatures are preceded by a minus sign.

The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in °F; precipitation, including snowfall in in.; wind movement in mph; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65°F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice Pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes 1 $g/cal/cm^2$.

TABLE 2.3-3 DETROIT, MICHIGAN CITY AIRPORT NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Year	Temperature – Extremes – Record lowest	Year	Normal heating degree days (base 65°F)	Precipitation – Normal total	Precipitation – Maximum monthly	Year	Precipitation – Minimum monthly	Year	Precipitation – Maximum in 24 hr	Year	Snow, Ice Pellets – Mean total	Snow, Ice Pellets – Maximum monthly	Year	Snow, Ice Pellets – Maximum in 24 hr	Year
(a)	(b)	(b)	(b)	39		39		(b	(b)	35		35		35		37	37		32	
J	33.0	20.7	26.9	67	1950	-13	1963	1181	2.05	4.38	1950	0.23	1961	1.63	1960	8.1	21.1	1939	8.4	1957
F	33.9	20.4	27.2	68	1944	-16	1934	1058	2.08	4.95	1938	0.10	1969	2.43	1950	7.6	15.8	1965	10.0	1965
M	42.3	27.3	34.8	82	1945	-1	1943	936	2.42	4.40	1938	0.47	1958	1.85	1949	5.4	15.5	1954	9.8	1934
A	56.4	38.8	47.6	87	1942[d]	14	1954	522	3.00	6.89	1947	0.74	1946	2.94	1947	1.2	6.8	1943	4.2	1942
M	68.6	49.4	59.0	93	1962[d]	30	1966[d]	220	3.53	8.05	1943	0.58	1934	2.53	1948	(e)	0.1	1954	0.1	1954
J	79.1	60.3	69.7	104	1934	38	1969[d]	42	2.83	6.58	1960	1.01	1959	3.53	1968	0.0	0.0		0.0	
J	83.9	64.8	74.4	105	1934	42	1972	0	2.82	7.05	1969	0.81	1936	2.80	1957	0.0	0.0		0.0	
A	81.9	63.6	72.8	101	1936	43	1934	0	2.86	7.51	1940	1.07	1936	3.65	1956	0.0	0.0		0.0	
S	74.2	56.0	65.1	100	1953[d]	32	1942	87	2.44	5.90	1936	0.53	1969	2.56	1959	0.0	0.0		0.0	
O	62.8	44.7	53.8	92	1963	24	1972[d]	360	2.63	7.80	1954	0.50	1964	3.72	1954	(e)	1.0	1943	1.0	1943
N	47.1	33.7	40.4	81	1950	5	1958	738	2.21	4.14	1948	0.57	1939	2.18	1951	2.5	9.2	1950	5.6	1951
D	35.7	24.1	29.9	66	1971	-5	1960	1088	2.08	4.60	1957	0.43	1943	2.45	1965	6.8	24.0	1951	6.8	1951
YR	58.2	42.0	50.1	105	July 1934	-16	Feb. 1934	6232	30.95	8.05	May 1943	0.10	Feb. 1969	3.72	Oct. 1954	31.6	24.0	Dec. 1951	10.0	Feb. 1965

Month	Relative Humidity – hr 01 (Local time)	Relative Humidity – hr 07 (Local time)	Relative Humidity – hr 13 (Local time)	Relative Humidity – hr 19 (Local time)	Wind[g] – Mean speed	Wind[g] – Prevailing direction	Wind[g] – Fastest Mile – Speed	Wind[g] – Fastest Mile – Direction	Wind[g] – Fastest Mile – Year	Percent possible sunshine[h]	Mean sky cover sunrise to sunset[h]	Mean number of days – Sunrise to Sunset[h] – Clear	Sunrise to Sunset[h] – Partly cloudy	Sunrise to Sunset[h] – Cloudy	Precipitation .01 in. or more	Snow, ice pellets 1.0 in or more	Thunderstorms	Heavy Fog	Temperatures – Maximum – 90° and above[i]	Temperatures – Maximum – 32° and below	Temperatures – Minimum – 32° and below	Temperatures – Minimum – 0° and below	Average daily solar radiation (langleys)
(a)	35	39	35	39	39	14	6	6		32	32	32	32	32	35	35	39	39	39	39	39	39	
J	75	79	69	74	11.5	W	40	26	1971	32	7.8	4	6	21	13	3	(c)	2	0	16	28	1	
F	76	79	65	71	11.5	NW	40	23	1971[d]	43	7.3	4	7	17	12	3	1	1	0	13	26	1	
M	74	78	60	66	11.5	NW	40	23	1972	49	7.0	5	8	18	13	2	1	1	0	5	22	(c)	
A	71	74	53	58	11.1	NW	37	29	1967	52	6.8	6	8	16	12	(c)	3	1	0	(c)	8	0	
M	71	71	51	56	9.8	S	33	35	1972[d]	59	6.4	7	10	14	12	0	4	(c)	1	0	(c)	0	
J	75	74	53	57	9.0	S	40	28	1971[d]	65	6.0	7	12	11	11	0	6	(c)	4	0	0	0	
J	75	75	51	55	8.2	S	40	28	1966	70	5.3	9	13	9	9	0	6	(c)	6	0	0	0	
A	78	80	53	60	8.1	N	46	30	1968	65	5.4	10	12	9	9	0	5	1	4	0	0	0	
S	79	83	54	64	8.9	S	36	14	1971[d]	61	5.4	10	10	10	9	0	3	1	1	0	(c)	0	
O	77	71	55	66	9.5	S	25	29	1969	56	5.6	10	9	12	9	0	1	1	(c)	0	2	0	
N	76	79	64	70	11.3	SW	30	24	1970	35	7.5	4	7	19	11	1	(c)	1	0	2	13	0	
D	77	79	70	74	11.3	SW	43	21	1971	32	7.7	4	6	21	13	2	(c)	2	0	12	25	(c)	
YR	75	78	58	64	10.1	S	46	30	Aug. 1968	54	6.5	80	108	177	131	11	32	11	15	48	125	2	

[a] Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
[b] Climatological standard normals (1931-1960).
[c] Less than one half.
[d] Also on earlier dates, months, or years.
[e] Trace, an amount too small to measure.
[f] at Alaskan stations.
[g] Figures instead of letters in a direction column indicate direction in tens of degrees from true North: i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations If figures appear in the direction column under "Fastest Mile" the corresponding speeds are fastest observed 1-minute values
[h] Data accumulated through 1965.
[i] To eight compass points only.

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature -24 in December 1872; maximum monthly precipitation 8.76 in July 1878; minimum monthly precipitation 0.04 in February 1887; maximum precipitation in 24 hours 4.75 in July 1925; maximum monthly snowfall 38.4 in February 1908; maximum snowfall in 24 hours 24.5 in April 1886; fastest mile of wind 95 from Northwest in June 1890.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
Unless otherwise indicated, dimensional units used in this bulletin are: temperature in °F; precipitation, including snowfall, in in.; wind movement in mph; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65°F. Cooling degree day totals are the sums of positive departures of average daily temperatures from from 65°F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice Pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less
Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.
Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes 1 g/cal/cm^2.

TABLE 2.3-4 TOLEDO, OHIO NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Temperature: Normal: Daily minimum	Temperature: Normal: Monthly	Temperature: Extremes: Record highest	Temperature: Extremes: Year	Temperature: Extremes: Record lowest	Temperature: Extremes: Year	Normal heating degree days (base 65°)	Precipitation: Normal total	Precipitation: Maximum monthly	Precipitation: Year	Precipitation: Minimum monthly	Precipitation: Year	Precipitation: Maximum in 24 hr	Precipitation: Year	Snow, Ice Pellets: Mean total	Snow, Ice Pellets: Maximum monthly	Snow, Ice Pellets: Year	Snow, Ice Pellets: Maximum in 24 hr	Snow, Ice Pellets: Year
(a)	(b)	(b)	(b)	17		17		(b)	(b)	17		17		17		17	17		17	
J	34.1	18.4	26.3	62	1967[d]	-17	1972[d]	1200	2.33	4.61	1965	0.27	1961	1.78	1959	8.8	14.2	1970	6.6	1957
F	35.7	18.8	27.3	68	1957	-14	1967	1056	1.88	3.13	1960	0.27	1969	1.35	1959	7.8	14.4	1967	7.4	1967
M	44.7	25.6	35.2	80	1963	-1	1960	924	2.26	4.88	1964	0.58	1958	1.56	1964	6.9	11.6	1964	7.5	1962
A	58.4	35.4	46.9	87	1960	11	1964	543	2.77	4.94	1961	0.88	1962	2.39	1956	1.9	12.0	1957	9.8	1957
M	70.4	46.1	58.3	95	1962	26	1968	242	3.04	5.13	1968	0.96	1964	1.96	1970	(e)	(e)	1966[d]	(e)	1966[d]
J	80.3	56.3	68.3	99	1971	32	1972	60	3.79	4.86	1960	1.89	1964	2.50	1956	0.0	0.0		0.0	
J	85.1	60.2	72.7	96	1966[d]	43	1972[d]	0	2.59	6.75	1969	1.58	1964	4.39	1969	0.0	0.0		0.0	
A	83.0	58.8	70.9	98	1964	37	1965	16	3.33	8.47	1965	0.81	1967	2.42	1972	0.0	0.0		0.0	
S	75.5	51.3	63.4	95	1960	29	1961	117	2.13	8.10	1972	0.58	1963	3.97	1972	(e)	(e)	1967	(e)	1967
O	63.8	40.3	52.1	91	1963	16	1965	406	2.39	3.72	1959	0.28	1964	1.71	1957	(e)	0.2	1972[d]	0.2	1972[d]
N	47.3	29.8	38.6	78	1968	2	1958	792	2.04	4.63	1966	0.77	1964	2.06	1969	3.6	17.9	1966	8.3	1966
D	35.8	20.8	28.3	67	1971	-11	1960	1138	1.95	6.81	1967	0.54	1958	3.53	1967	7.7	19.0	1969	8.0	1969
YR	59.5	38.5	49.0	99	Jun. 1971	-17	Jan. 1972[d]	6494	30.50	8.47	Aug 1965	0.27	Feb. 1969[d]	4.39	Jul. 1969	36.7	19.0	Dec. 1969	9.8	Apr. 1957

Month	Relative Humidity: hr 01 (Local time)	Relative Humidity: hr 07	Relative Humidity: hr 13	Relative Humidity: hr 19	Wind[g]: Mean speed	Wind[g]: Prevailing direction	Wind[g]: Fastest Mile: Speed	Wind[g]: Fastest Mile: Direction[h]	Wind[g]: Fastest Mile: Year	Percent possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to Sunset: Clear	Mean number of days: Sunrise to Sunset: Partly cloudy	Mean number of days: Sunrise to Sunset: Cloudy	Mean number of days: Precipitation .01 in. or more	Mean number of days: Snow, ice pellets 1.0 in or more	Mean number of days: Thunderstorms	Mean number of days: Heavy Fog	Mean number of days: Temperatures: Maximum: 90° and above[f]	Mean number of days: Temperatures: Maximum: 32° and below	Mean number of days: Temperatures: Minimum: 32° and below	Mean number of days: Temperatures: Minimum: 0° and below	Average daily solar radiation (langleys)
(a)	17	17	17	17	17	8	17	17		17	17	17	17	17	17	17	17	17	17	17	17	17	
J	72	78	69	73	10.9	WSW	47	W	1972[d]	45	7.4	5	7	19	13	3	(c)	2	0	17	29	4	
F	72	78	65	70	10.9	WSW	56	SW	1967	47	7.3	4	7	17	11	2	(c)	2	0	12	27	2	
M	73	81	61	66	11.0	WSW	56	W	1957[d]	50	7.4	5	7	19	14	2	2	2	0	5	25	(c)	
A	76	80	55	59	10.9	E	72	SW	1956	54	6.9	6	7	17	13	1	5	1	0	(c)	11	0	
M	76	79	51	56	10.0	WSW	45	W	1957	63	6.3	6	11	14	12	0	3	1	1	0	2	0	
J	82	82	54	58	8.4	SW	50	W	1969	65	6.0	7	11	12	10	0	7	1	4	0	(c)	0	
J	84	86	55	61	7.5	WSW	54	NW	1970	68	5.8	7	14	10	10	0	8	1	4	0	0	0	
A	86	89	57	65	7.3	SW	47	W	1965	68	5.5	9	12	10	8	0	6	2	4	0	0	0	
S	86	90	57	70	7.8	SSW	47	NW	1969	62	5.9	8	10	12	10	0	4	2	1	0	(c)	0	
O	81	85	55	68	8.7	WSW	40	SW	1956	59	5.8	9	10	12	8	0	1	2	(c)	0	6	0	
N	81	83	67	74	10.3	WSW	65	SW	1957	39	7.7	4	7	19	11	1	(c)	2	0	3	18	0	
D	82	83	73	78	10.5	SW	45	SW	1971[d]	36	7.8	3	7	21	14	3	(c)	2	0	12	27	2	
YR	79	83	60	67	9.5	WSW	72	SW	Apr. 1956	56	6.7	73	110	182	134	12	40	19	4	49	146	8	

[a] Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.

[b] Climatological standard normals (1931-1960).

[c] Less than one half.

[d] Also on earlier dates, months, or years.

[e] Trace, an amount too small to measure.

[f] at Alaskan stations.

[g] Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest Mile" the corresponding speeds are fastest observed 1-minute values.

[h] To eight compass points only.

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 105° in July 1936; maximum monthly precipitation 8.49 in October 1881; minimum monthly precipitation 0.04 in November 1904; maximum precipitation in 24 hr 5.98 in September 1818; maximum monthly snowfall 26.2 in January 1918; maximum snowfall in 24 hr 19.0 in February 1900; fastest mile 87 in March 1948.

Below zero temperatures are preceded by a minus sign.

The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in °F; precipitation, including snowfall, in in.; wind movement in mph; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65°F. Cooling degree day totals are the sums of positive departures of daily temperatures from 65°F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice Pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes 1 g/cal/cm^2.

TABLE 2.3-5 CLIMATOLOGICAL SUMMARY MONROE, MICHIGAN (MEANS AND EXTREMES FOR PERIOD 1940-1969)

Latitude 41° 54'
Longitude 83° 22'
Elev. (Ground) 582 feet

Station Monroe, Michigan, Monroe County

Month	Temperature (°F)								Precipitation Totals (inches)								Mean number of days					Month
	Means			Extremes				Mean degree days**	Mean	Greatest daily	Year	Snow, Ice Pellets					Precip. .10 inch or more	Temperatures				
																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year					Mean	Maximum monthly	Year	Greatest daily	Year		90° and above	32° and below	32° and below	0° and below	
(a)	30	30	30	30		30		30	30	30		30	30		30		30	30	30	30	33	
JANUARY	32.9	18.5	25.7	70	1950	-16	1953	1218	1.95	1.74	1959	6.6	17.8	1943	7.0	1957	5	0	15	29	2	JANUARY
FEBRUARY	35.3	19.8	27.6	70	1944	- 8	1951	1057	1.73	1.74	1950	7.5	20.3	1962	12.8	1965	5	0	11	26	1	FEBRUARY
MARCH	44.1	27.1	35.6	81	1945	- 2	1943	911	2.39	1.99	1954	6.0	23.5	1954	9.0	1954	6	0	4	23	*	MARCH
APRIL	58.0	38.2	48.1	91	1942	16	1954	507	3.13	2.25	1965	.9	12.0	1957	8.5	1957	7	*	*	8	0	APRIL
MAY	69.0	48.7	53.9	95	1952+	29	1966	233	3.41	2.52	1968	T	.3	1954	.3	1954	7	1	0	1	0	MAY
JUNE	79.9	69.2	69.6	100	1944	39	1949	42	3.47	2.74	1944	0	0		0		7	4	0	0	0	JUNE
JULY	83.9	62.9	73.4	102	1941+	43	1945	3	2.80	2.57	1948	0	0		0		5	6	0	0	0	JULY
AUGUST	82.3	61.1	71.7	101	1964	42	1965	12	3.16	2.12	1964	0	0		0		6	4	0	0	0	AUGUST
SEPTEMBER	75.6	54.2	64.9	100	1954	30	1942	72	2.40	2.20	1959	0	0		0		5	2	0	*	0	SEPTEMBER
OCTOBER	64.9	43.6	54.4	91	1951	23	1952	344	2.58	2.67	1949	T	T	1969	T	1969	5	*	0	3	0	OCTOBER
NOVEMBER	48.9	33.3	41.1	81	1950	1	1958	717	2.11	1.66	1968	2.5	10.4	1966	4.0	1966	5	0	1	14	0	NOVEMBER
DECEMBER	36.5	22.7	29.5	64	1966+	- 8	1960	1097	2.08	2.75	1957	7.2	27.0	1951	8.0	1951	5	0	11	26	1	DECEMBER
Year	59.3	40.8	50.1	102	July 1941+	-16	Jan. 1963	6213	31.29	2.75	Dec. 1967	30.7	28.5	Mar. 1954	12.8	Feb. 1965	68	17	42	130	4	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F (H. C. S. Thom, Monthly Weather Review, January 1954)

\+ Also on earlier dates, months, or years.

* Less than one half.

TABLE 2.3-6 CLIMATOLOGICAL SUMMARY WILLIS, MICHIGAN (MEANS AND EXTREMES FOR PERIOD 1940-1969)

Latitude 41° 05'

Longitude 83° 35' Station WILLIS, MICHIGAN, WASHTENAW COUNTY

Elev. (Ground) 660 feet

Month	Temperature (°F)							Mean degree days**	Precipitation Totals (inches)								Mean number of days					Month
	Means			Extremes								Snow, Ice Pellets						Temperatures				
																		Max.		Min.		
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year		Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year	Precip. .10 inch or more	90° and above	32 and below	32° and below	0° and below	
(a)	33	30	30	30		30		30	30	30		30	30		30		30	30	30	30	33	
JANUARY	31.4	15.6	23.5	69	1950	-18	1957	1287	1.95	1.52	1960	7.9	19.5	1943	5.0	1968+	5	0	17	30	4	JANUARY
FEBRUARY	34.0	17.2	25.6	67	1944	-14	1963	1113	1.71	1.35	1949	7.5	19.5	1962	7.5	1950	5	0	12	27	2	FEBRUARY
MARCH	43.5	25.1	34.3	80	1915	-13	1943	952	2.46	1.84	1954	6.4	21.5	1954	9.0	1956	6	0	5	25	1	MARCH
APRIL	54.0	35.5	46.8	85	1942	12	1964	546	3.22	2.48	1956	1.3	8.3	1957	4.0	1947	8	0	*	13	0	APRIL
MAY	69.0	45.6	57.3	92	1962	22	1966	267	3.41	2.03	1968	T	.3	1940	.3	1940	7	*	0	2	0	MAY
JUNE	79.2	55.6	67.4	99	1952	35	1965+	65	3.53	3.05	1967	0	0		0		7	3	0	0	0	JUNE
JULY	83.2	63.7	71.0	100	1941	38	1965	12	2.97	2.74	1951	0	0		0		6	4	0	0	0	JULY
AUGUST	81.6	66.8	69.2	93	1948	35	1965	31	3.45	3.95	1949	0	0		0		6	4	0	0	0	AUGUST
SEPTEMBER	74.5	49.4	62.0	101	1953	25	1942	144	2.27	2.22	1945	T	T	1967	T	1957	5	1	0	1	0	SEPTEMBER
OCTOBER	64.1	33.6	51.9	91	1963+	15	1965+	400	2.62	2.42	1945	T	.7	1943	.7	1943	5	*	0	8	0	OCTOBER
NOVEMBER	47.7	30.1	39.0	81	1950	- 4	1969	780	2.39	1.76	1958	3.7	14.0	1966	8.0	1951	6	0	2	19	*	NOVEMBER
DECEMBER	35.1	19.7	27.4	65	1966	-19	1960+	1165	2.21	2.85	1957	7.1	21.0	1951	7.0	1951	5	0	13	27	2	DECEMBER
Year	58.5	37.4	48.0	101	Sep. 1953	-19	Dec. 1950+	6773	32.19	3.55	Aug. 1943	33.9	21.5	March 1954	9.0	March 1956	71	12	49	152	9	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

\+ Also on earlier dates, months, or years.

* Less than one half.

(H. C. S. Thom, Monthly Weather Review, January 1954)

TABLE 2.3-7 MONTHLY MEANS OF DAILY AFTERNOON ATMOSPHERIC MIXING DEPTHS (FLINT, MICHIGAN, 1960-1964)

Month	Depth (m)	Depth (ft)
January	700	2300
February	780	2560
March	1110	3650
April	1680	5500
May	1640	5380
June	1680	5510
July	1820	5970
August	1580	5180
September	1350	4430
October	1340	4400
November	910	2990
December	800	2620

TABLE 2.3-8 AVERAGE WIND SPEEDS AND FREQUENCY OF CALMS FOR THE FERMI SITE, 100-FT TOWER; DETROIT CITY AIRPORT; TOLEDO EXPRESS AIRPORT; AND FERMI SITE 60-M TOWER

Sensor Height	Data Period	Average Speed (mph)	Frequency of Calms (percent)
Fermi site - 10 m 60-m	1 June 1974 - 31 May 1975	8.85	0.4[a]
Fermi site - 60 m tower	1 June 1974 - 31 May 1975	14.64	0.6[a]
Fermi site - 100 ft	1 December 1956 - 30 November 1959	12.4	0.30[b]
Detroit City Airport - 58 ft	1956 - 1959	10.3	1.10[b]
Toledo Express Airport - 20 ft	1950 - 1955	11.01	1.38[b]

[a] Calms defined as wind speeds ≤ 1.0 mph.

[b] Calms defined as wind speeds ≤ 1.2mph.

TABLE 2.3-9 WIND DIRECTION PERSISTENCE, 60-METER TOWER

(Instrument Height – 10 M)

1 June 1974 to 31 May 1975

Number of Occurrences by Direction

Hours of Persistence	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total Cumulative Percentage
1	105	94	79	85	85	92	120	122	129	137	138	150	142	125	123	127	100.000
2	47	40	29	38	30	26	61	57	55	62	57	70	53	56	61	36	48.168
3	19	10	22	13	16	29	25	26	24	30	32	38	21	26	31	20	26.406
4	9	9	12	12	9	11	12	12	13	22	20	22	16	15	14	7	15.720
5	3	1	7	7	3	3	3	3	10	16	16	13	11	5	7	4	9.706
6	1	2	2	4	5	6	8	4	4	7	7	8	6	7	4	1	6.573
7	1	1	3	4	4	2	5	3	5	6	2	6	3	4	2	3	4.448
8	0	0	1	1	0	4	3	1	3	4	2	1	1	0	4	1	2.937
9	1	0	2	3	1	0	0	2	0	4	0	2	2	4	1	1	2.210
10	0	0	2	2	0	1	3	1	0	2	5	2	0	3	1	0	1.566
11	0	0	0	0	0	1	0	0	0	2	3	1	0	1	0	0	0.951
12	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0.727
13	0	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0.643
14	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0.531
15	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0.448
16	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.392
17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0.364
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.308
19	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0.280
20	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0.196
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.112
22	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.084
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.056
31	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.056
32	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.028

(Instrument Height – 60 M)

TABLE 2.3-9 WIND DIRECTION PERSISTENCE, 60-METER TOWER

1 June 1974 to 31 May 1975

Number of Occurrences by Direction

Hours of Persistence	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total Cumulative Percentage
1	68	72	66	81	84	100	111	126	112	129	156	150	124	101	89	66	100.000
2	26	25	39	43	37	35	39	71	62	79	65	52	52	55	42	28	52.011
3	8	15	23	16	16	21	26	31	25	35	36	28	33	26	18	22	29.997
4	11	4	14	8	17	12	9	14	14	33	26	21	11	19	20	10	18.873
5	3	5	7	9	3	3	5	4	6	16	12	12	5	10	4	1	11.741
6	1	7	6	3	3	5	2	3	9	12	15	10	9	7	4	2	8.659
7	1	2	5	5	5	2	4	4	5	7	9	6	6	3	3	4	5.782
8	2	1	2	2	1	0	1	3	1	3	7	3	4	2	1	1	3.698
9	0	0	3	0	0	1	0	2	2	3	2	3	0	0	2	1	2.700
10	0	1	3	0	1	0	1	1	3	2	5	3	0	2	2	0	2.143
11	0	0	0	0	0	0	0	0	0	2	0	3	1	2	0	0	1.438
12	0	0	2	0	0	2	1	0	0	4	2	2	2	1	0	1	1.203
13	0	0	1	0	2	0	0	0	1	0	2	0	0	0	0	0	0.704
14	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0.528
15	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0.440
16	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0.323
17	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0.235
18	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.176
19	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.147
20	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.117
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.088
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.088
23	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.088
24	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.059

TABLE 2.3-10 SEASONAL AND ANNUAL FREQUENCES OF STABILITY CATEGORIES AND ASSOCIATED WIND SPEEDS FOR DETROIT METROPOLITAN AIRPORT AND TOLEDO EXPRESS AIRPORT

Detroit Metropolitan Airport (1958 – 1962)

		A	B	C	D	E	F	G
Spring[a]	%	0.23	3.39	11.70	61.81	12.42	8.50	1.95
	mph	5.40	7.00	10.40	13.60	9.10	5.90	3.30
Summer[a]	%	1.39	8.89	18.56	39.95	11.89	14.48	4.84
	mph	5.10	7.00	10.00	11.20	8.40	5.80	3.30
Fall[a]	%	0.11	3.24	9.67	55.90	13.03	13.48	4.56
	mph	0.00	5.90	8.40	11.80	8.60	5.80	3.50
Winter[a]	%	0.02	0.92	4.11	74.41	10.89	7.42	2.23
	mph	0.00	4.00	7.80	12.90	9.20	5.60	2.90
Annual	%	0.44	4.13	11.05	57.95	12.06	10.98	3.39
	mph	5.20	6.80	9.60	12.50	8.90	5.80	3.30

TOLEDO EXPRESS AIRPORT (1959 – 1963)

		A	B	C	D	E	F	G
Spring[a]	%	0.41	4.26	11.52	58.04	9.34	10.85	5.59
	mph	5.00	6.60	9.70	12.60	8.30	5.50	3.00
Summer[a]	%	2.34	12.80	20.34	30.34	6.85	15.20	12.13
	mph	5.00	6.60	8.50	9.70	7.10	5.20	3.06
Fall[a]	%	0.06	4.05	11.56	50.29	10.23	14.52	9.20
	mph	0.00	5.60	7.80	10.90	8.10	5.40	3.04
Winter[a]	%	0.00	0.37	5.46	72.06	9.81	8.47	3.84
	mph	-	4.30	7.60	11.80	8.90	5.50	3.07
Annual[a]	%	0.71	5.40	12.26	52.58	9.05	12.27	7.76
	mph	5.00	6.30	8.50	11.40	8.20	5.40	3.01

[a] Seasons

Spring = March, April, May;

Summer = June, July, August;

Fall = September, October, November;

Winter = December, January, February.

TABLE 2.3-11 MONTHLY AND ANNUAL FREQUENCIES OF STABILITY CATEGORIES AND ASSOCIATED WIND SPEEDS FOR 10-METER LEVEL FERMI SITE DATA

Stabilities are determined from ΔT (10 - 60 M)

1 June 1974 to 31 May 1975

		A	B	C	D	E	F	G	Total
June 74	%	8.93	2.38	2.68	21.13	51.04	11.16	2.68	100
	mph	18.97	8.28	9.53	9.09	9.41	6.54	4.39	8.82
July 74	%	12.05	0.57	1.29	19.23	46.92	11.48	8.46	100
	mph	8.17	6.46	9.32	8.51	8.86	5.43	4.10	7.91
Aug 74	%	25.96	2.61	2.47	23.08	35.71	6.87	3.30	100
	mph	7.74	8.10	8.01	8.22	7.75	5.01	4.74	7.58
Sept 74	%	2.46	0.49	0.66	20.85	55.50	9.03	11.00	100
	mph	11.39	7.76	7.53	10.33	8.78	6.05	5.83	8.58
Oct 74	%	40.18	4.68	2.34	10.45	15.68	15.14	11.53	100
	mph	9.83	8.79	9.25	9.01	7.69	6.37	5.63	8.34
Nov 74	%	0.42	0.00	0.14	7.38	75.77	11.00	5.29	100
	mph	7.08	0.00	12.20	10.41	9.70	6.87	4.21	9.14
Dec 74	%	1.43	0.57	0.86	7.73	76.82	10.01	2.58	100
	mph	9.95	13.08	7.25	7.59	8.57	6.32	3.96	8.18
Jan 75	%	2.86	0.82	1.77	61.04	25.20	7.08	1.23	100
	mph	8.27	8.14	14.09	10.48	9.85	9.71	7.32	10.21
Feb 75	%	0.34	1.52	3.21	63.79	24.53	5.08	1.52	100
	mph	4.24	9.16	9.28	10.38	7.77	5.89	7.04	9.39
Mar 75	%	4.73	4.43	4.73	54.36	22.90	5.76	3.10	100
	mph	11.10	12.85	11.34	12.00	8.71	8.32	8.26	10.88
Apr 75	%	3.81	3.02	4.29	46.19	21.75	14.76	6.19	100
	mph	11.68	11.90	11.71	10.23	9.27	9.12	5.83	9.76
May 75	%	10.24	4.45	4.75	29.38	25.52	17.21	8.46	100
	mph	8.16	9.68	9.11	8.37	6.84	6.30	5.96	7.49
Annual	%	9.17	2.08	2.40	30.29	40.46	10.31	5.30	100
	mph	8.95	9.94	10.08	10.04	8.79	6.82	5.41	8.86

TABLE 2.3-12 THREE YEAR SUMMARY OF TEMPERATURE LAPSE RATE DATA FOR THE FERMI SITE (1956-1959)

Fermi Site Data ($\Delta T_{100\ ft - 25\ ft}$)

Season	Strong Vertical Temperature Gradients $\Delta T < -0.98°C/100m$ or $-5.4°F/1000\ ft$ (%)	Weak Vertical Temperature Gradients $\Delta T > -0.98°C/100m$ or $-5.4°F/1000\ ft$ (%) ≤ 0	Inversion (Temperature Increases with Height) (%)
Spring (March, April, May)	61.3	15.5	23.1
Summer (June, July, August)	38.0	27.3	34.8
Fall (September, October, November)	42.9	26.2	30.9
Winter (December, January, February)	40.6	35.5	23.8
ANNUAL	45.4	26.7	27.9

TABLE 2.3-13 METEOROLOGICAL DATA ANALYSIS HOURLY TEMPERATURE[a] AVERAGE OVER A 24-HR INTERVAL

Hours of Missing Data	10 - Meter	282
	60 - Meter	211
Total No. of Observations	10 - Meter	8478
	60 - Meter	8549

Hour	10-M	60-M
1	8.88	9.10
2	8.50	8.77
3	8.25	8.54
4	7.96	8.28
5	7.64	8.05
6	7.44	7.95
7	7.35	7.79
8	7.32	7.63
9	7.95	7.86
10	8.69	8.36
11	9.55	8.97
12	10.19	9.60
13	10.75	10.20
14	11.00	10.38
15	11.40	10.80
16	11.51	11.00
17	11.56	11.15
18	11.55	11.22
19	11.22	10.98
20	10.84	10.74
21	10.26	10.32
22	9.85	10.02
23	9.53	9.66
24	9.22	9.37
Minimum	-19.30	-19.30
Maximum	34.89	34.80
Annual Average	9.52	9.45

[a] All units in °C

TABLE 2.3-14 PASQUILL CATEGORIES HOURLY STABILITY INDEX DISTRIBUTION

1 June 1974 to 31 May 1975

	In Percent of Total Obs							In Percent of Hourly Obs						
Hour	A	B	C	D	E	F	G	A	B	C	D	E	F	G
1	0.27	0.04	0.01	0.93	1.94	0.65	0.35	6.53	0.85	0.28	22.16	46.31	15.62	8.24
2	0.19	0.04	0.04	1.04	1.92	0.56	0.40	4.56	0.85	0.85	24.79	45.87	13.39	9.69
3	0.14	0.06	0.02	0.95	2.01	0.60	0.39	3.42	1.42	0.57	22.79	48.15	14.25	9.40
4	0.14	0.02	0.05	0.99	1.80	0.67	0.49	3.44	0.57	1.15	23.78	43.27	16.05	11.75
5	0.18	0.02	0.06	0.90	1.76	0.75	0.48	4.30	0.57	1.43	21.78	42.41	18.05	11.46
6	0.13	0.02	0.02	1.02	1.79	0.62	0.52	3.17	0.58	0.58	24.78	43.23	14.99	12.68
7	0.17	0.06	0.02	1.04	1.79	0.52	0.56	4.01	1.43	0.57	24.93	42.98	12.61	13.47
8	0.21	0.02	0.08	1.08	1.89	0.50	0.30	5.23	0.58	2.03	26.45	46.22	12.21	7.27
9	0.44	0.10	0.07	1.30	1.83	0.23	0.17	10.66	2.31	1.73	31.41	44.38	5.48	4.03
10	0.67	0.06	0.10	1.51	1.60	0.12	0.11	16.05	1.43	2.29	36.39	38.40	2.87	2.58
11	0.64	0.15	0.20	1.58	1.39	0.11	0.07	15.47	3.72	4.87	38.11	33.52	2.58	1.72
12	0.81	0.13	0.14	1.61	1.23	0.12	0.05	19.83	3.21	3.50	39.36	30.03	2.92	1.17
13	0.82	0.25	0.27	1.36	1.21	0.12	0.04	20.12	6.12	6.71	33.53	29.74	2.92	0.87
14	0.81	0.26	0.24	1.44	1.26	0.08	0.06	19.48	6.30	5.73	34.67	30.37	2.01	1.43
15	0.79	0.14	0.33	1.46	1.18	0.18	0.05	19.02	3.46	8.07	35.45	28.53	4.32	1.15
16	0.73	0.18	0.18	1.57	1.21	0.19	0.08	17.53	4.31	4.31	37.93	29.31	4.60	2.01
17	0.61	0.10	0.17	1.64	1.38	0.20	0.11	14.45	2.27	3.97	39.09	32.86	4.82	2.55
18	0.48	0.08	0.15	1.58	1.50	0.26	0.13	11.36	1.99	3.69	37.78	35.80	6.25	3.12
19	0.38	0.06	0.05	1.38	1.89	0.33	0.12	9.04	1.41	1.13	32.77	44.92	7.91	2.82
20	0.27	0.10	0.04	1.21	1.89	0.56	0.14	6.50	2.26	0.85	28.81	44.92	13.28	3.39
21	0.27	0.05	0.05	1.13	1.83	0.75	0.15	6.46	1.12	1.12	26.69	43.26	17.70	3.65
22	0.29	0.06	0.02	1.08	1.77	0.77	0.24	6.74	1.40	0.56	25.56	41.85	18.26	5.62
23	0.23	0.06	0.06	1.17	1.75	0.67	0.29	5.37	1.41	1.41	27.68	41.53	15.82	6.78
24	0.25	0.02	0.05	1.06	1.92	0.61	0.32	5.92	0.56	1.13	25.07	45.35	14.37	7.61

TABLE 2.3-15 THREE YEAR SUMMARY OF TEMPERATURE LAPSE RATE ($\Delta T_{300\ FT-20\ FT}$) DATA FOR THE WJBK-TV TOWER (1956-1959)

Season	Inversions (Temperature increasing with height) (percent)
Spring (March, April, May)	23.0
Summer (June, July, August)	35.5
Fall (September, October, November)	33.1
Winter (December, January, February)	23.0
ANNUAL	28.6

TABLE 2.3-16 PROBABILITY OF OCCURRENCE OF INVERSIONS[a] FOR A GIVEN LENGTH OF TIME AT FERMI SITE

Number of Hours of Persistence t	Probability (percent) That Inversion Persisted for Periods Greater Than t
1	100.00
2	65.21
3	51.52
4	45.06
5	40.30
6	36.50
7	32.51
8	29.47
9	25.67
10	23.76
11	21.48
12	19.01
13	15.97
14	13.49
15	11.03
16	8.555
17	6.844
18	4.753
19	3.992
20	3.612
21	3.042
23	2.281
25	2.091
26	1.711
27	1.331
28	1.141
33	0.951
41	0.760
43	0.570
44	0.380
46	0.190

[a] From data from 60-m tower, 1 June 1974 through 31 May 1975.

TABLE 2.3-17 THE DISTRIBUTION AND FREQUENCY OF PRECIPITATION BY WIND DIRECTION AND SPEED FOR THE FERMI SITE

	(1956 -1959) 100 – Ft Tower		(June 74 – May 75) 60-M Tower	
Wind Direction	Average Wind Speed (100 ft Level) During Precipitation (mph)	Frequency With Respect to Precipitation Only (percent)	Average Wind Speed (10-m Level) During Precipitation (mph)	Frequency With Respect to Precipitation Only (percent)
NNE	12.5	4.1	7.5	7.6
NE	16.0	6.1	9.7	5.9
ENE	16.8	5.3	10.4	6.7
E	17.9	5.3	11.8	10.9
ESE	15.3	3.4	10.3	11.8
SE	14.4	3.2	10.2	5.0
SSE	13.3	3.9	9.5	8.4
S	12.5	5.3	11.7	5.9
SSW	12.6	7.3	13.6	5.0
SW	14.1	9.6	9.9	5.0
WSW	14.7	13.8	11.2	5.0
W	16.6	11.1	9.1	2.5
WNW	14.0	8.3	12.2	9.2
NW	12.5	6.4	7.4	5.9
NNW	12.9	5.1	4.2	1.7
N	11.2	3.4	8.3	3.4
CALM	----	0.2	----	----

TABLE 2.3-18 AVERAGE TEMPERATURE AND RELATIVE HUMIDITY SUMMARY FOR THE FERMI SITE, DETROIT CITY AIRPORT, AND TOLEDO EXPRESS AIRPORT

(1 January 1972 to 31 December 1972)

	Fermi Site (Langton Rd)		Detroit		Toledo	
Month	Temperature (°F)	Relative Humidity (percent)	Temperature (°F)	Relative Humidity (percent)	Temperature (°F)	Relative Humidity (percent)
January	26	85	26	66	23	69
February	25	86	25	64	24	69
March	29	83	33	62	34	57
April	42	80	45	48	46	51
May	58	82	61	58	60	61
June	63	78	65	62	64	70
July	69	80	73	62	71	73
August	67	90	70	74	68	79
September	62	88	64	75	62	78
October	48	78	49	70	47	71
November	37	84	39	74	37	74
December	29	84	31	76	30	76
Annual	47	83	48	66	47	69

TABLE 2.3-19 COMPARISON OF MONTHLY TEMPERATURE HIGH, LOW, AND AVERAGE BETWEEN FERMI 2 SITE DATA AND NATIONAL WEATHER BUREAU DATA COLLECTED AT THE NEAREST LOCATIONS FOR THE PERIOD JUNE 1974 THROUGH MAY 1975

		June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Fermi 2	High	84.8	94.2	89.5	81.0	74.4	72.7	42.9	52.9	44.7	60.8	62.9	84.7
	Avg.	68.4	76.3	74.2	61.5	50.5	41.9	30.4	29.5	27.3	32.5	39.6	62.5
	Low	47.0	52.0	55.0	34.5	24.3	15.9	11.3	8.6	-2.7	16.8	20.4	44.3
Monroe Sewage Plant 6.6 miles NW	High	88.0	100.0	93.0	89.0	81.0	76.0	44.0	57.0	53.0	68.0	70.0	93.0
	Avg.	68.4	76.3	74.2	63.8	51.6	42.8	30.1	28.9	28.2	33.5	42.5	63.8
	Low	47.0	52.0	55.0	34.0	24.0	15.0	11.0	7.0	-5.0	12.0	17.0	38.0
Willis 21.6 miles NW	High	85.0	95.0	88.0	85.0	77.0	75.0	40.0	57.0	49.0	64.0	69.0	88.0
	Avg.	65.0	70.7	69.1	57.7	48.2	39.2	26.9	27.5	26.7	32.3	40.7	62.2
	Low	45.0	43.0	45.0	26.0	13.0	11.0	-2.0	4.0	-11.0	8.0	18.0	36.0
Detroit Metro Airport 20 miles North	High	86.0	97.0	90.0	87.0	77.0	74.0	41.0	53.0	46.0	63.0	69.0	88.0
	Avg.	65.9	72.5	72.3	59.7	48.8	40.6	28.6	28.3	27.5	32.5	40.9	62.8
	Low	47.0	50.0	50.0	29.0	17.0	14.0	6.0	6.0	-6.0	10.0	19.0	40.0
Detroit City Airport 33.7 miles NNE	High	89.0	97.0	89.0	87.0	79.0	75.0	44.0	57.0	50.0	66.0	70.0	91.0
	Avg.	57.6	75.1	73.8	62.9	52.2	43.0	32.3	31.1	29.7	33.9	43.3	66.1
	Low	48.0	52.0	58.0	34.0	28.0	19.0	21.0	10.0	4.0	15.0	21.0	42.0

TABLE 2.3-20 METEOROLOGICAL SYSTEM EQUIPMENT SPECIFICATIONS (33-FT TOWER)

Instrument	Manufacturer	Model	Level	Specifications
Wind speed and direction	Gill	Model 35001 propeller vane	33 ft (10 m)	Wind Direction Range: 360°, mechanical 342°, electrical Wind Speed Range: variable 0-15 mph, 0-30 mph, 0-50 mph Threshold: Vane - 0.3-0.5 mph Propeller - 0.4-0.7 mph
Temperature and relative humidity	Belfort	Model 5-592 hygrothermograph	Shelter (Base approximately 4-1/2 ft above ground level)	Accuracy: Temperature: +1°F between -20°F to +100°F Humidity: ±3% RH between 20% and 95%, ±5% at extremes

TABLE 2.3-21 60-M TOWER ANALOG/DIGITAL METEOROLOGICAL SYSTEM INSTRUMENTATION (PREOPERATIONAL PROGRAM)

WIND SPEED SENSORS: All Levels

Sensor:	Climet Instruments model #WS-011-1. Wind speed transmitter and cup assembly.	
	Distance constant:	5 ft maximum
	Threshold wind:	0.6 mph
	Accuracy:	± 0.1% or 0.15 mph, whichever is greater
Electronics:	Analog signal conditioner constructed by EG&G, Albuquerque..	
	Accuracy:	± 0.1% full scale
Recorder:	Digital representation of Datel Systems, Inc. model #ADC-E 3-digit (BCD) analog to digital converter.	
	OVERALL SYSTEM ACCURACY:	± 1% or 0.15 mph
Recorder: (Backup)	Esterline Angus Model #EAL1102S dual analog recorder	
	Accuracy:	± 0.25% full scale
	OVERALL SYSTEM ACCURACY:	± 1.04% or 0.38 mph, whichever is greater

WIND DIRECTION SENSORS: All Levels

Sensor:	Climet Instruments model #WD-012-03 wind direction transmitter and wind vane assembly.	
	Distance constant:	1 m maximum
	Damping ratio:	0.4 standard
	Threshold:	0.75 mph
	Accuracy:	± 3°
Electronics:	Analog signal conditioner constructed by EG&G, Albuquerque	
	Accuracy:	± 0.10% full scale
Recorder:	Digital representation of Datel Systems, Inc. model #ADC-E 3-digit (BCD) analog to digital converter.	
	Accuracy:	± ½ LSB

TABLE 2.3-21 60-M TOWER ANALOG/DIGITAL METEOROLOGICAL SYSTEM INSTRUMENTATION (PREOPERATIONAL PROGRAM)

Recorder: (Backup) Esterline Angus Model #EAL1102S dual analog recorder.

Accuracy: ± 0.25% full scale

OVERALL SYSTEM ACCURACY: ± 3.2°

TEMPERATURE SENSORS: All Levels

Sensors: Rosemount Engineering model #171BM platinum resistance thermometer.

Linearity: 0.01% full scale

Stability: 0.01°C per year

Aspiration rate: 24 ft/sec flow over sensor

Electronics: Analog signal conditioner constructed by EG&G, Albuquerque.

Accuracy: ± 0.10% full scale

Recorder: Digital representation of Datel Systems, Inc. model #ADC-E 3-digit (BCD) analog to digital converter.

Accuracy: ± ½ LSB

Recorder: (Backup) Esterline Angus Model #EAL1102S dual analog recorder.

Accuracy: ± 0.25% full scale

OVERALL SYSTEM ABSOLUTE ACCURACY: ± 0.2°C

OVERALL SYSTEM DIFFERENCE ACCURACY: ± 0.1°C

DEWPOINT SENSOR:

Sensor: Environmental Equipment Division of EG&G, model #110S-M dewpoint measuring set.

Range: -80°F to +120°F

Accuracy: ± 0.5°F maximum

Electronics: Analog signal conditioner constructed by EG&G, Albuquerque.

Accuracy: ± 0.1% full scale

TABLE 2.3-21 60-M TOWER ANALOG/DIGITAL METEOROLOGICAL SYSTEM INSTRUMENTATION (PREOPERATIONAL PROGRAM)

Recorder: Digital representation of Datel Systems, Inc. model #ADC-E 3-digit (BCD) analog to digital converter.

Recorder: (Backup) Esterline Angus Model #EAL1102S dual analog recorder

Accuracy:	± 0.25% full scale
OVERALL SYSTEM ACCURACY:	± 0.35°C

PRECIPITATION SENSOR:

Sensor: Fisher & Porter Company model #35-1559 EA10, precipitation gage recorder.

Range:	0 to 19.5 in. precipitation
Accuracy:	± 0.015 in. of range span
Sensitivity:	0.025 in. response
OVERALL SYSTEM ACCURACY:	± 0.1 in.

TABLE 2.3-22 COMPARISON BETWEEN MANUALLY READ ANALOG AVERAGES AND DIGITAL AVERAGES FOR ALL PARAMETERS AT THE 10-METER LEVEL AND THE TEMPERATURE AT THE 60-METER LEVEL ON THE 60-METER TOWER

		Temperature at 10-m level		Dewpoint		Temperature at 60-m level		Wind Speed at 10-m Level		Wind Direction at 10-m Level	
Date	Time	Digital	Analog	Digital	Analog	Digital	Analog	Digital	Analog	Digital	Analog
1974											
June 15	04:00	18.46	18.42	15.71	15.74	18.41	18.45	12.6	12.7	198.4	198.4
June 15	14:00	18.83	18.84	16.33	16.31	18.93	18.96	12.5	12.5	191.8	192.4
June 25	03:00	11.45	11.46	6.23	6.25	11.98	11.93	6.7	6.8	341.3	341.5
June 29	09:00	19.92	19.96	14.44	14.40	20.20	20.28	5.7	5.7	231.6	230.9
July 10	16:00	23.40	23.41	21.12	21.19	23.20	23.22	12.2	12.2	042.3	042.6
July 14	03:00	25.35	25.31	16.37	16.37	25.62	25.69	7.4	7.4	244.4	244.0
July 24	06:00	14.06	14.05	13.86	13.83	17.20	17.25	2:1	2.1	319.5	319.3
July 29	09:00	24.06	24.00	19.46	19.46	23.52	23.51	6.9	6.8	274.6	274.7
August 8	13:00	23.35	23.39	18.23	18.22	22.63	22.68	8.8	8.8	137.3	136.4
August 11	02:00	23.08	23.07	19.38	19.31	23.01	23.04	11.7	11.7	159.8	160.9
August 22	02:00	20.53	20.53	16.06	16.01	20.45	20.46	7.7	7.8	057.4	056.2
August 25	02:00	16.85	16.86	14.14	14.12	18.45	18.42	5.8	5.7	027.6	027.2
September 11[a]	13:00	25.51	25.88	18.98	19.22	26.12	26.07	9.9	10.1	207.3	204.6
September 11	15:00	26.28	26.21	19.35	19.24	25.99	25.75	11.9	11.7	211.9	208.7
October 26	14:00	15.95	16.43	-03.15	-02.97	15.75	15.62	13.2	12.8	279.7	280.6
October 28	12:00	03.64	03.53	06.90	06.88	16.12	16.10	7.3	7.1	127.7	127.4
November 6	04:00	04.09	03.86	02.51	02.40	04.13	04.22	5.5	5.2	287.2	282.8
November 10	14:00	09.51	09.28	06.54	06.59	09.24	09.21	9.4	9.3	127.3	122.8
November 22	20:00	04.14	04.13	01.28	01.33	04.5	04.5	5.9	5.6	244.7	239.9
November 24	10:00	12.23	12.14	11.20	11.18	11.89	11.89	11.2	10.9	255.2	249.9
December 4	17:00	03.79	-03.58	-08.95	-08.58	-03.45	-03.72	3.5	3.1	281.3	279.2
December 9	11:00	-05.20	-05.20	-09.68	-09.22	-05.18	-05.37	12.3	11.9	285.1	282.6
December 19	11:00	0.61	00.64	-00.91	00.90	00.31	0.18	12.0	12.1	253.2	248.8
December 23	12:00	04.80	04.57	00.53	00.86	05.30	05.10	9.1	8.8	249.3	245.7

TABLE 2.3-22 COMPARISON BETWEEN MANUALLY READ ANALOG AVERAGES AND DIGITAL AVERAGES FOR ALL PARAMETERS AT THE 10-METER LEVEL AND THE TEMPERATURE AT THE 60-METER LEVEL ON THE 60-METER TOWER

		Temperature at 10-m level		Dewpoint		Temperature at 60-m level		Wind Speed at 10-m Level		Wind Direction at 10-m Level	
Date	Time	Digital	Analog	Digital	Analog	Digital	Analog	Digital	Analog	Digital	Analog
1975											
January 3	10:00	1.48	1.58	0.25	0.32	1.04	1.01	13.3	13.0	226.7	222.7
January 6	14:00	0.48	0.53	0.23	0.25	0.18	0.21	10.7	10.9	180.0	177.8
January 12	16:00	-6.15	-6.17	-16.66	-16.76	-6.83	-6.86	9.0	8.8	246.0	243.7
January 17	03:00	-7.60	-7.36	-14.26	-14.56	-7.96	-7.76	1.4	1.4	299.1	297.1
February 5	16:00	0.23	-0.15	-0.09	0.05	-0.22	-1.03	6.6	6.1	042.9	038.7
February 10	03:00	-17.25	-16.87	-22.99	-22.61	-17.22	-16.89	4.9	4.5	248.6	249.2
February 14	23:00	-4.21	-4.52	-08.9	-9.13	-4.62	-4.74	6.5	6.0	115.5	110.3
February 15	01:00	-4.11	-4.40	-8.38	-8.36	-4.48	-4.61	7.7	7.2	118.6	117.0
March 13	23:00	-2.49	-2.62	-9.76	-9.63	-2.97	-3.14	14.3	13.8	050.9	047.3
March 14	01:00	-2.55	2.73	-12.77	-12.26	-3.07	-3.41	16.8	16.3	065.7	063.1
March 17	10:00	0.02	0.08	-1.79	-1.92	-0.73	0.94	5.8	6.0	046.4	042.0
March 24	03:00	3.39	4.22	1.38	1.71	2.73	3.10	18.8	18.5	079.6	081.0
April 4	22:00	-1.91	-2.11	-11.72	-11.32	N/A	N/A	N/A	N/A	N/A	N/A
April 5	04:00	-6.14	-6.13	-11.84	-11.43	N/A	N/A	N/A	N/A	N/A	N/A
April 10	18:00	N/A	N/A	N/A	N/A	3.48	3.61[b]	12.5	12.4	060.2	056.7
April 11	13:00	N/A	N/A	N/A	N/A	2.86	3.02[b]	7.2	7.8	159.1	156.2
April 25	19:00	8.07	8.01	2.19	2.40	7.75	7.90	8.3	7.5	358.3	355.0
April 26	01:00	5.13	4.72	0.60	0.71	5.92	6.44	3.2	3.4	062.5	061.2
May 17	09:00	11.13[c]	11.01	9.99	9.73[c]	12.33	12.32	8.1	8.0	080.9	074.3
May 19	23:00	22.48	22.83	14.31	14.56	19.39	19.00[d]	10.4	10.4	201.6	197.6
May 27	21:00	20.97	21.04	8.36	8.24	21.96	21.87	4.0	3.6	314.9	312.3
May 28	07:00	16.02	16.51	7.05	6.67	15.44	15.86	9.5	9.4	069.7	064.7

[a] Digital system of the 60-meter tower was down from 9/17/74 to 10/26/74. Comparison checks for this time period are not available.
[b] Reading 1 hr later than indicated time.
[c] Reading 2 hr prior to indicated time.
[d] Reading 16 hr prior to indicated time.

TABLE 2.3-23 PERCENTAGE OF DATA RECOVERY FOR THE 60-M METEOROLOGICAL TOWER AT THE SITE

1 June 1974 through May 1975

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Annual
Regulatory Guide 1.23[a]	93.47	93.95	98.79	87.36	74.73	100.00	94.22	98.92	97.77	82.39	87.50	90.73	91.16
10-m wind speed	96.53	94.62	99.87	97.36	95.30	99.86	94.89	98.92	87.80	96.10	99.72	99.33	96.87
10-m wind direction	97.08	94.22	98.25	86.39	78.23	99.86	96.64	99.60	96.73	94.76	99.44	99.19	95.15
10-m air temperature	93.33	96.77	99.60	99.03	99.60	99.72	95.97	99.19	97.47	92.47	87.78	98.66	96.78
10-m dewpoint temp.	93.33	96.64	99.33	97.92	95.83	99.72	95.03	96.37	97.47	92.34	98.47	89.52	96.11
60-m wind speed	99.58	96.24	99.73	97.64	98.66	99.72	96.64	99.60	91.82	96.10	97.92	97.58	97.77
60-m wind direction	98.33	96.37	99.33	90.14	95.03	99.58	96.64	99.60	97.32	95.70	97.92	99.19	97.24
60-m air temperature	99.58	96.10	99.60	98.89	99.46	99.72	95.70	99.60	97.47	92.74	99.58	91.26	97.59

[a] Joint recovery between 10-m wind speed, 10-m wind direction, 10-m temperature, 60-m temperature.

TABLE 2.3-24 METEOROLOGICAL DATA RECOVERY (PERCENT) FOR 33-FT TOWER

(January 1, 1972 – December 31, 1972)

	Temperature Data	Relative Humidity Data
Spring (March, April, May)	94	93
Summer (June, July, August)	96	96
Fall (September, October, November)	96	96
Winter (December, January, February)	90	90
ANNUAL	94	94

TABLE 2.3-25 METEOROLOGICAL MONITORING NETWORK (OPERATIONAL PROGRAM)

Parameter	Sampling Height (m)	Sensing Technique
Primary Monitoring System		
Wind speed	10 and 60	Cups/light chopper
Wind direction	10 and 60	Vane/potentiometer
Vertical wind speed	10	Propeller
Differential temperature	10 to 60	Matched thermistors
Ambient temperature	10	Thermistor
Dewpoint	10	Lithium Chloride Type
Precipitation	1.5	Tipping bucket
Secondary Monitoring System		
Wind speed	10 and 60	Cups/light chopper
Wind direction	10 and 60	Vane/potentiometer
Vertical wind speed	10	Propeller/light chopper
Differential temperature	10 to 60	Matched thermistors
Ambient temperature	10	Thermistor

TABLE 2.3-26 METHOD FOR SUBSTITUTING REDUNDANT PARAMETERS FOR THE CRITICAL METEOROLOGICAL MEASUREMENTS

Level of Redundancy	10-Meter Level Wind Speed	10-Meter Level Wind Direction	Stability Indicator
0	Primary WS10	Primary WD10	Primary delta T
1	Secondary WS10	Secondary WD10	Secondary delta T
2			Primary sigma theta
3			Secondary sigma theta

TABLE 2.3-27 SUMMARY OF MAXIMUM SECTOR AND 5 PERCENT OVERALL SITE LIMIT χ/Q VALUES AT THE EAB AND LPZ FOR REGULATORY POST-ACCIDENT TIME PERIODS

EAB* (915 m)		LPZ* (4827 m)						
0-2 Hours		0-2 Hours		0-8 Hours	8-24 Hours	1-4 Days	4-30 Days	Annual Average
Max Sector	Site Limit	Max Sector	Site Limit	Max Sector	Max Sector	Max Sector	Max Sector	Max Sector
2.09 E-04	1.54 E-04	4.86 E-05	2.98 E-05	2.17 E-05	1.45 E-05	6.02 E-06	1.71 E-06	3.66 E-07
(ESE)		(ESE)		(ESE)	(ESE)	(ESE)	(ESE)	(ESE)

* For the EAB and LPZ, the 0-2 hour maximum sector χ/Q value is based on the highest sector-specific 0.5% χ/Q sector value; and the 0-2 hour site limit is based on the 5 percent overall site χ/Q value. In accordance with Regulatory Guide 1.145, the higher of these is selected as the controlling 0-2 hour χ/Q. Also, for the LPZ, per Regulatory Guide 1.145, logarithmic interpolation between the controlling 0-2 hour value and the maximum annual average χ/Q in any sector is performed to derive the approximate LPZ χ/Q value for each of the post-accident time periods.

TABLE 2.3-28 SUMMARY OF χ/Q (s/m^3) VALUES AT THE CONTROL CENTER COMPLEX FOR REGULATORY POST-ACCIDENT TIME PERIODS

Accident (source-to-receptor)	Time Interval				
LOCA					
	0-2 Hours	2-8 Hours	8-24 Hours	1-4 Days	4-30 Days
SGTS and ECCS leakage (SGTS stack-to-South control center intake)	6.18E-4	4.53E-4	1.88E-4	1.26E-4	8.70E-5
MSIV Leakage (TBHVAC Stack-to-North control center intake)	4.75E-4	3.78E-4	1.45E-4	9.80E-5	7.19E-5
Fuel Handling Accident					
	0-2 Hours	2-8 Hours	8-24 Hours	1-4 Days	4-30 Days
24-hr Drop of Recently Irradiated Fuel (SGTS-to-North Emergency Intake)	4.03E-3* 3.65E-3	The two-hour value is conservatively applied for the duration of accident.			
Fuel No Longer Recently Irradiated without SGTS (Outage Building-to-South Emergency Intake)	4.25E-3	The two-hour value is conservatively applied for the duration of accident.			

* This value applies during the initial unfiltered release via RBHVAC.

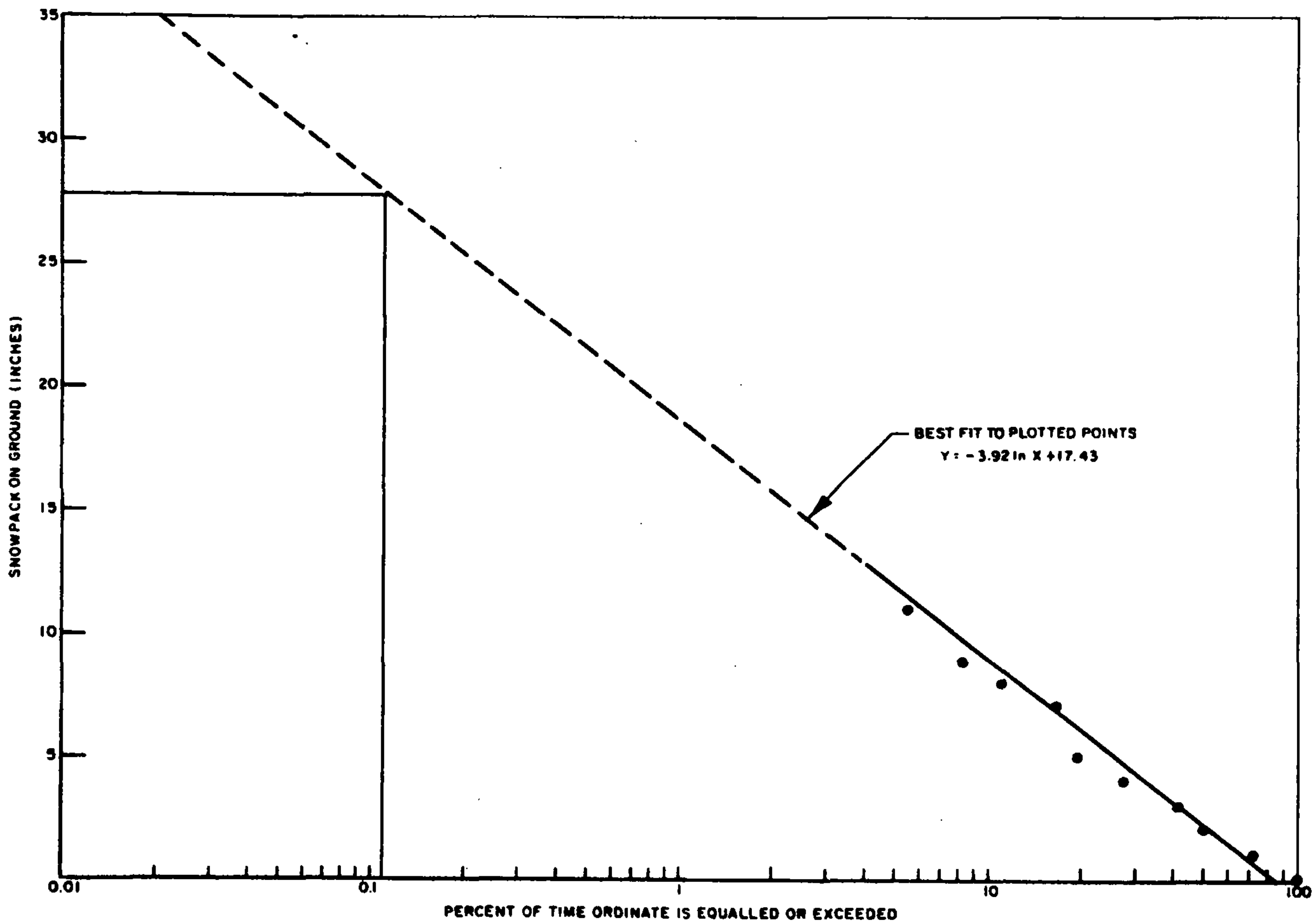

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FIGURE 2.3-1

CUMULATIVE FREQUENCY OF SNOWPACK

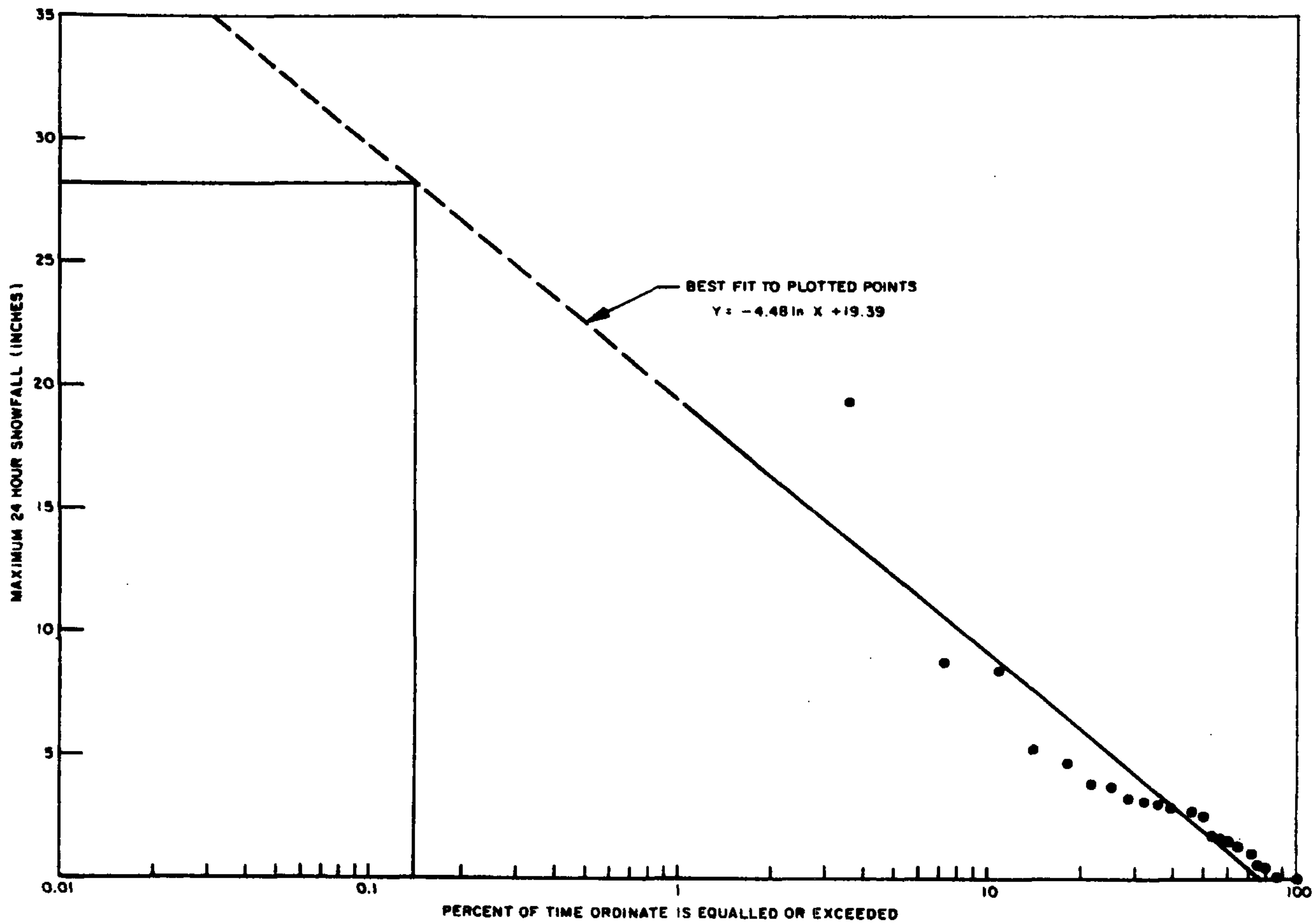

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FIGURE 2.3-2

CUMULATIVE FREQUENCY OF SNOWFALL

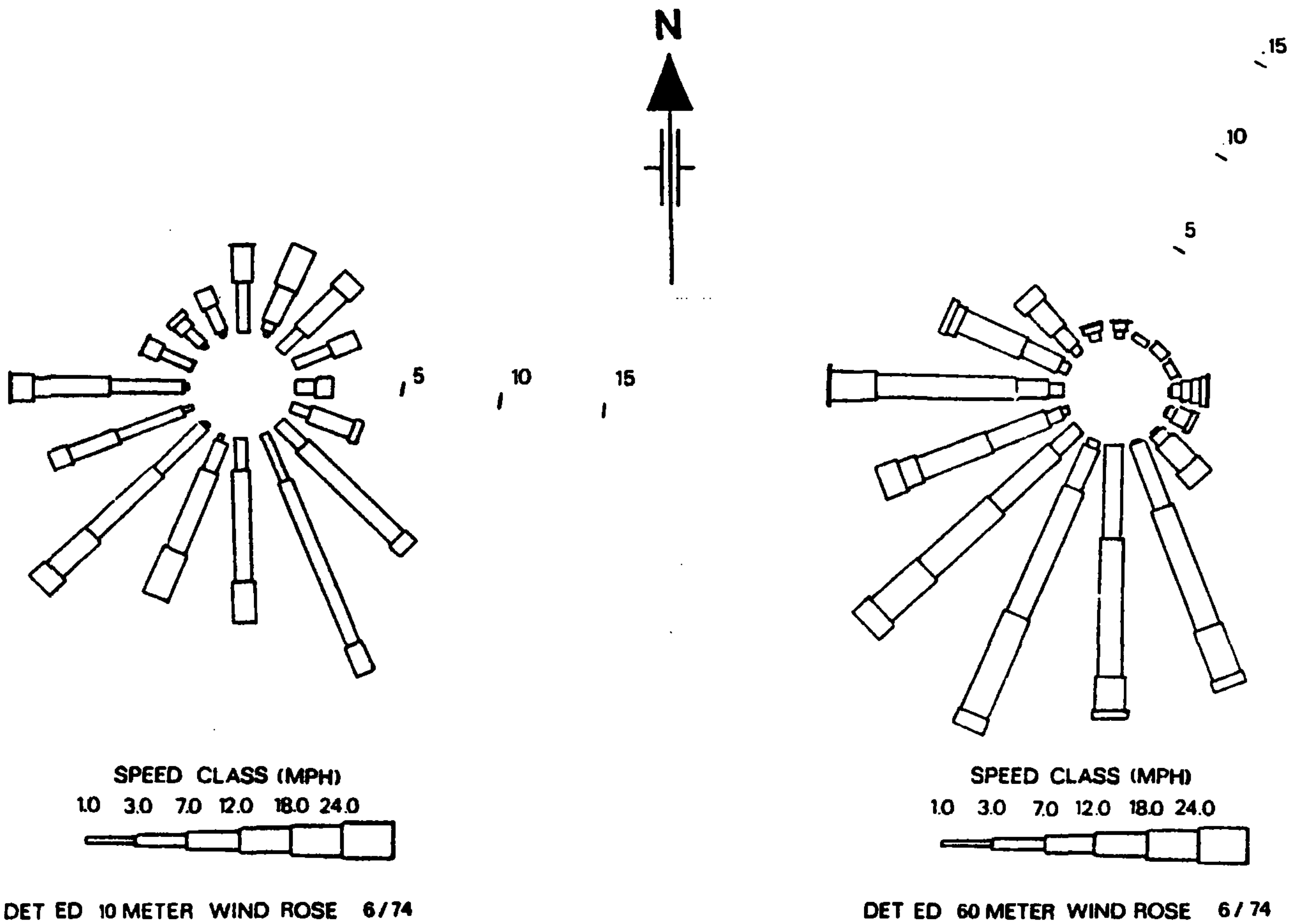

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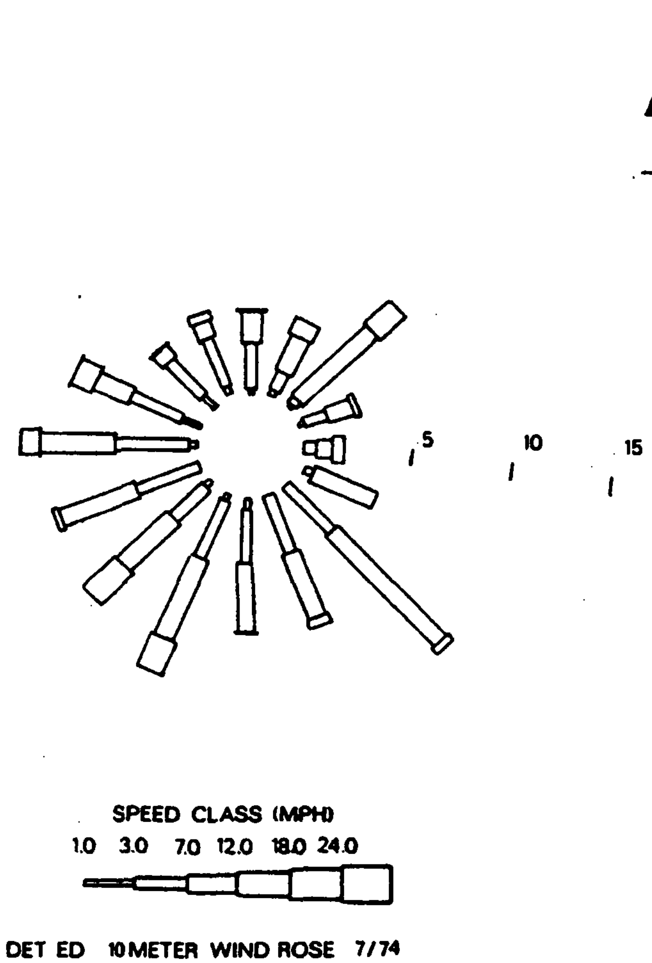
FIGURE 2.3-3

WIND ROSE DATA FOR JUNE 1974



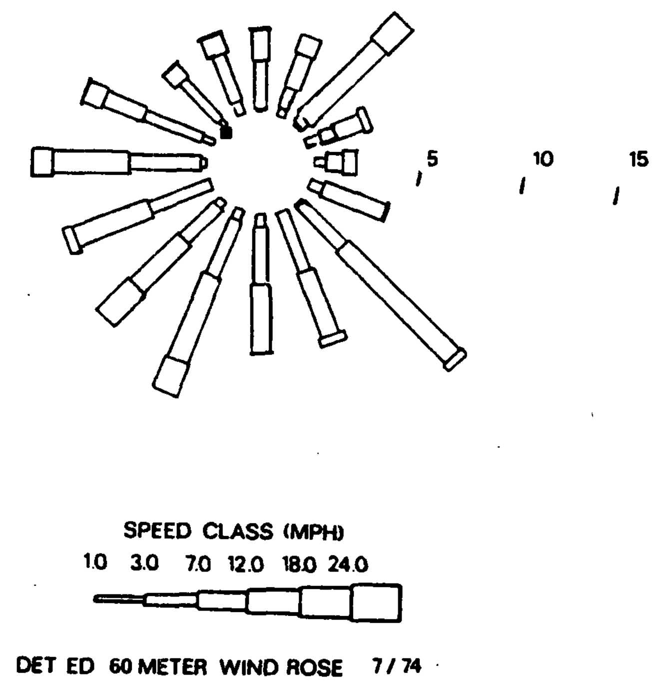


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FIGURE 2.3-4

WIND ROSE DATA FOR JULY 1974

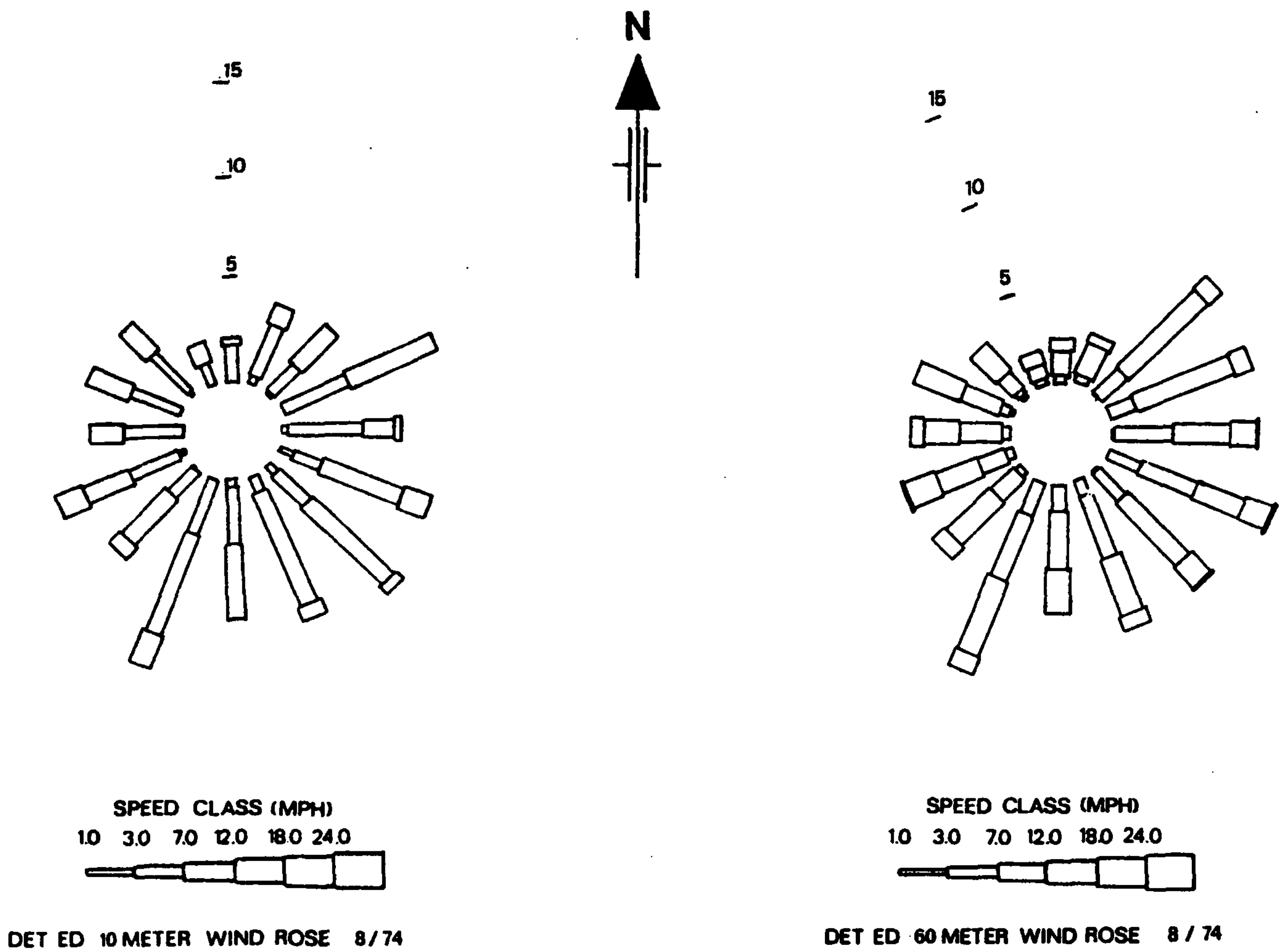

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FIGURE 2.3-5

WIND ROSE DATA FOR AUGUST 1974

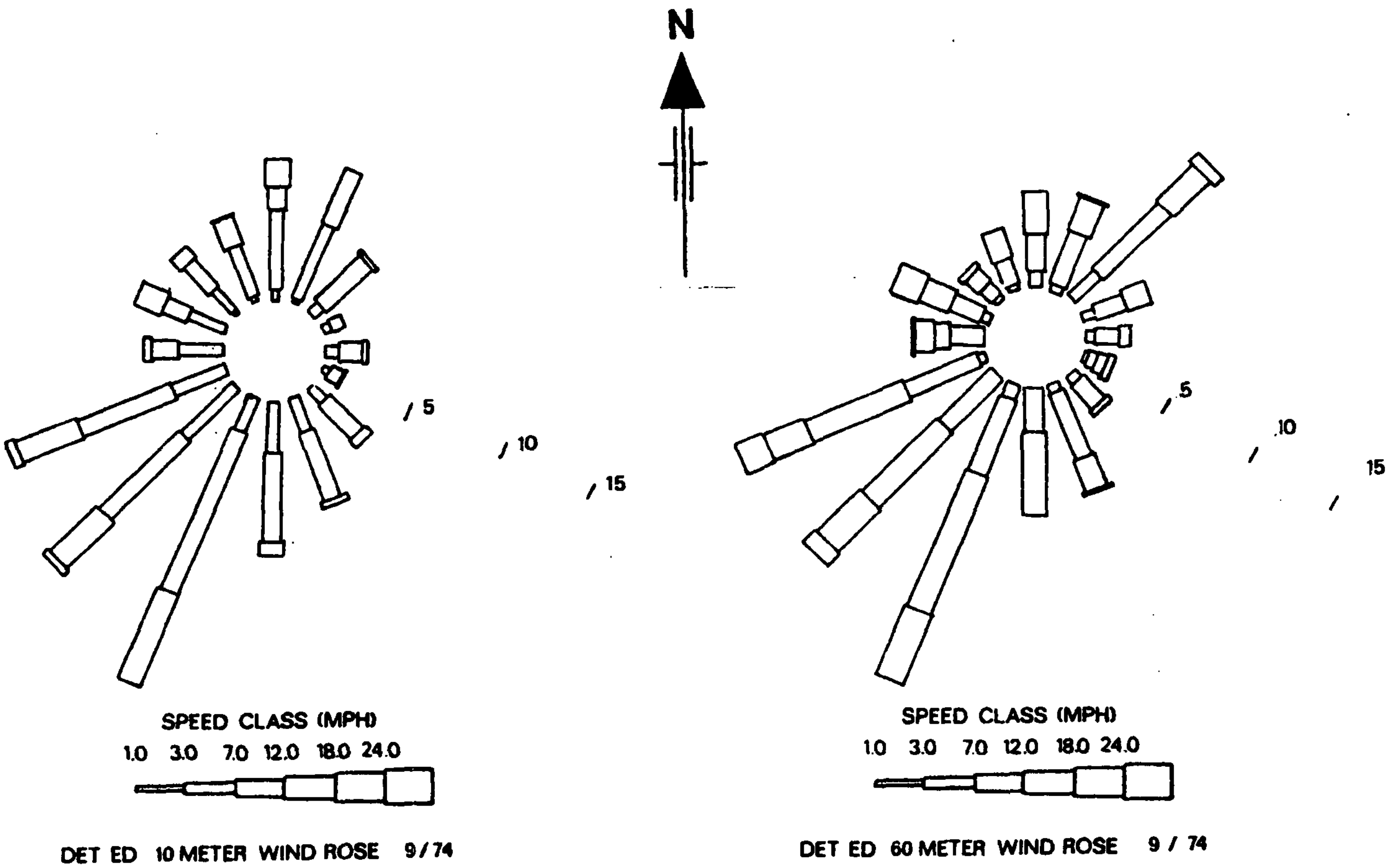

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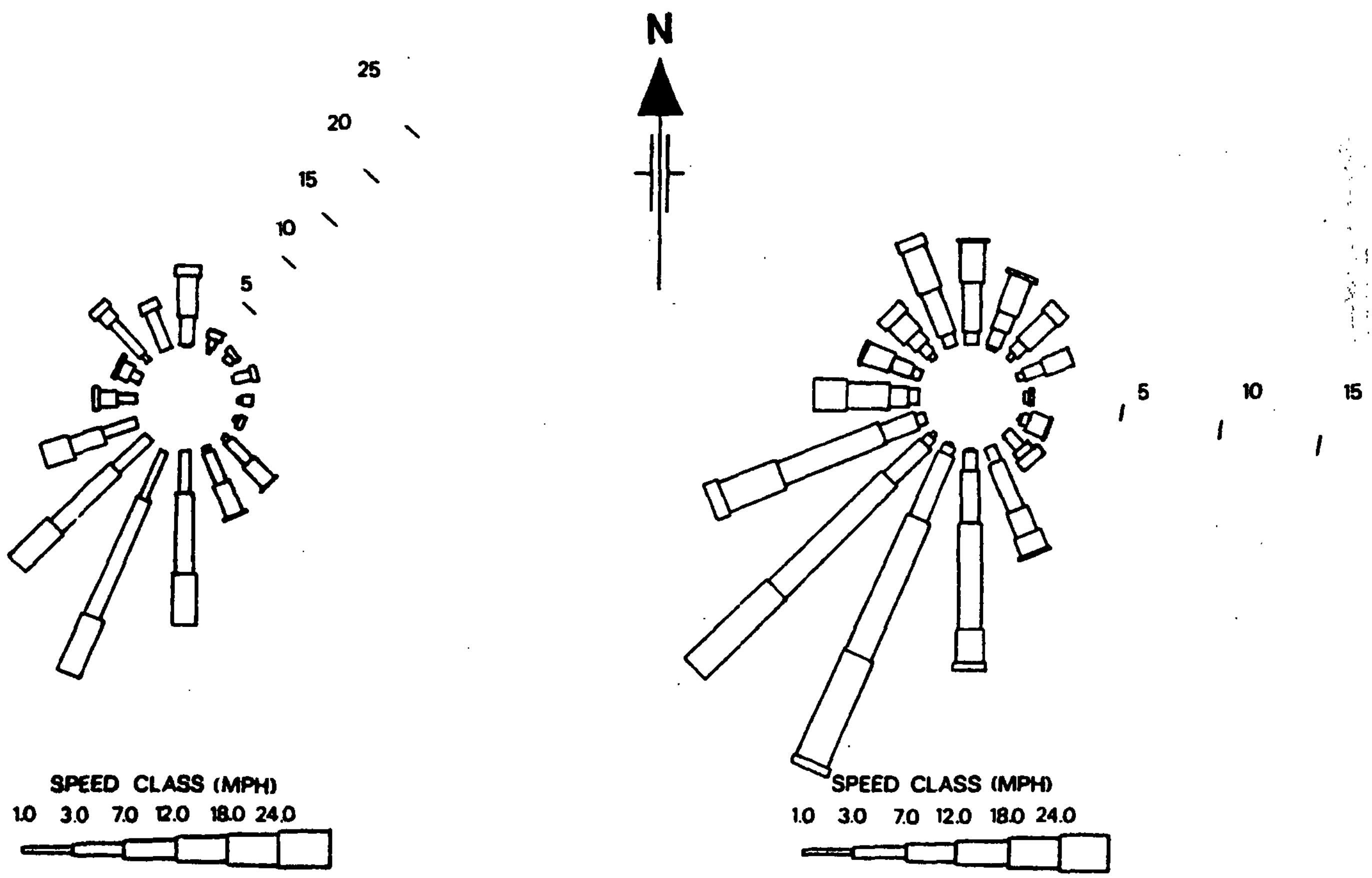
FIGURE 2.3-6

WIND ROSE DATA FOR SEPTEMBER 1974



DET ED 10 METER WIND ROSE 10/74

DET ED 60 METER WIND ROSE 10/74

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FIGURE 2.3-7

WIND ROSE DATA FOR OCTOBER 1974

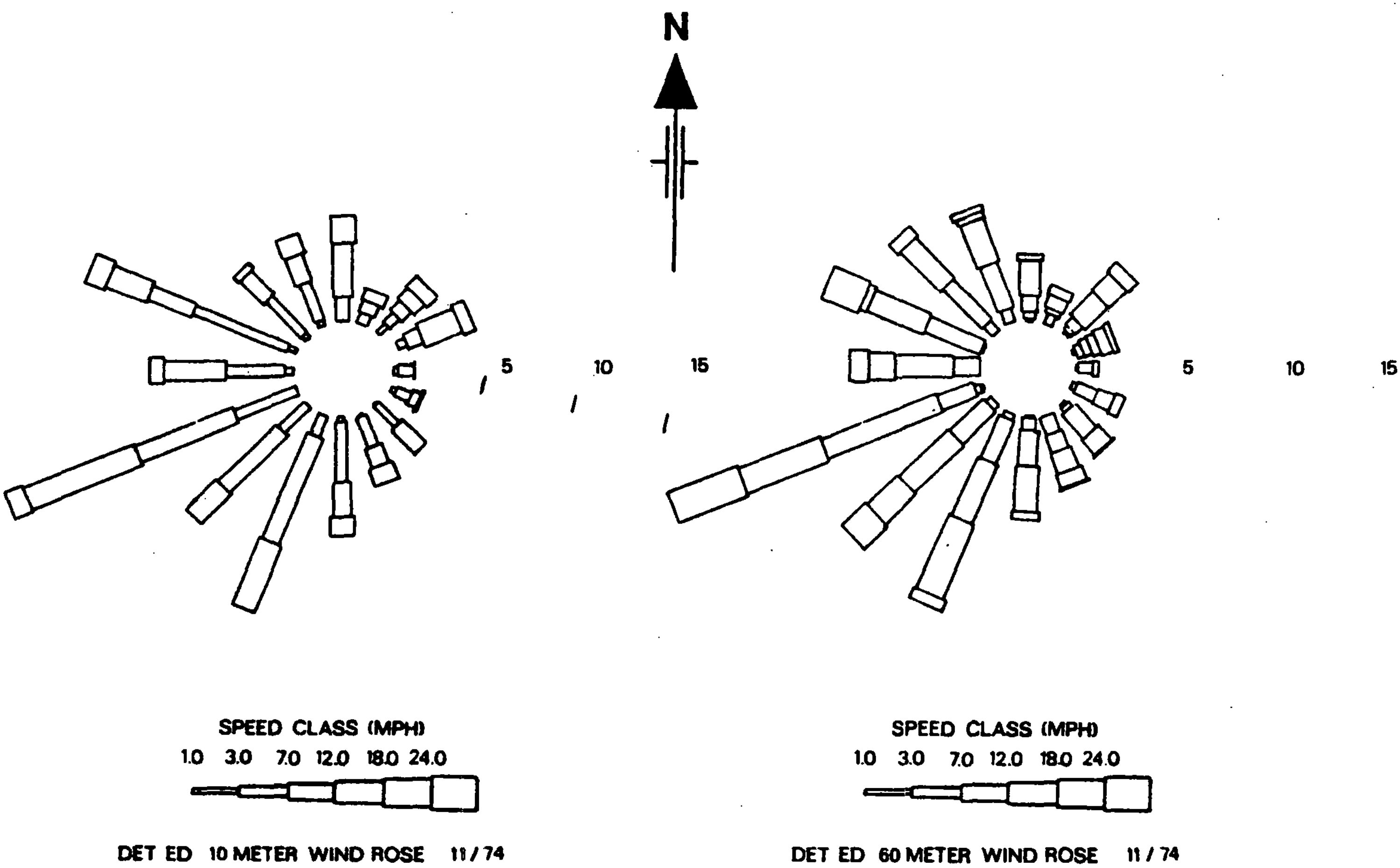

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FIGURE 2.3-8

WIND ROSE DATA FOR NOVEMBER 1974

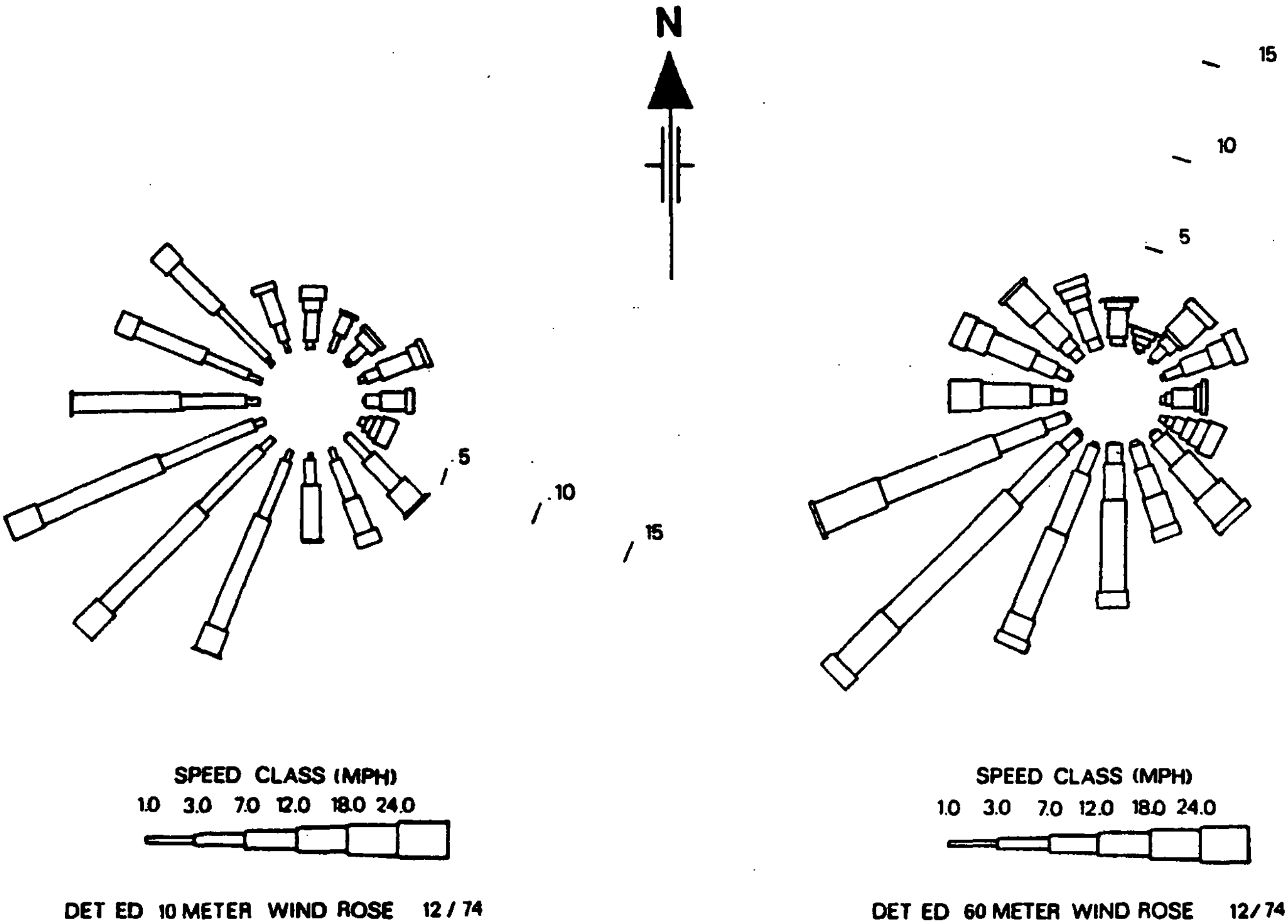

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FIGURE 2.3-9

WIND ROSE DATA FOR DECEMBER 1974

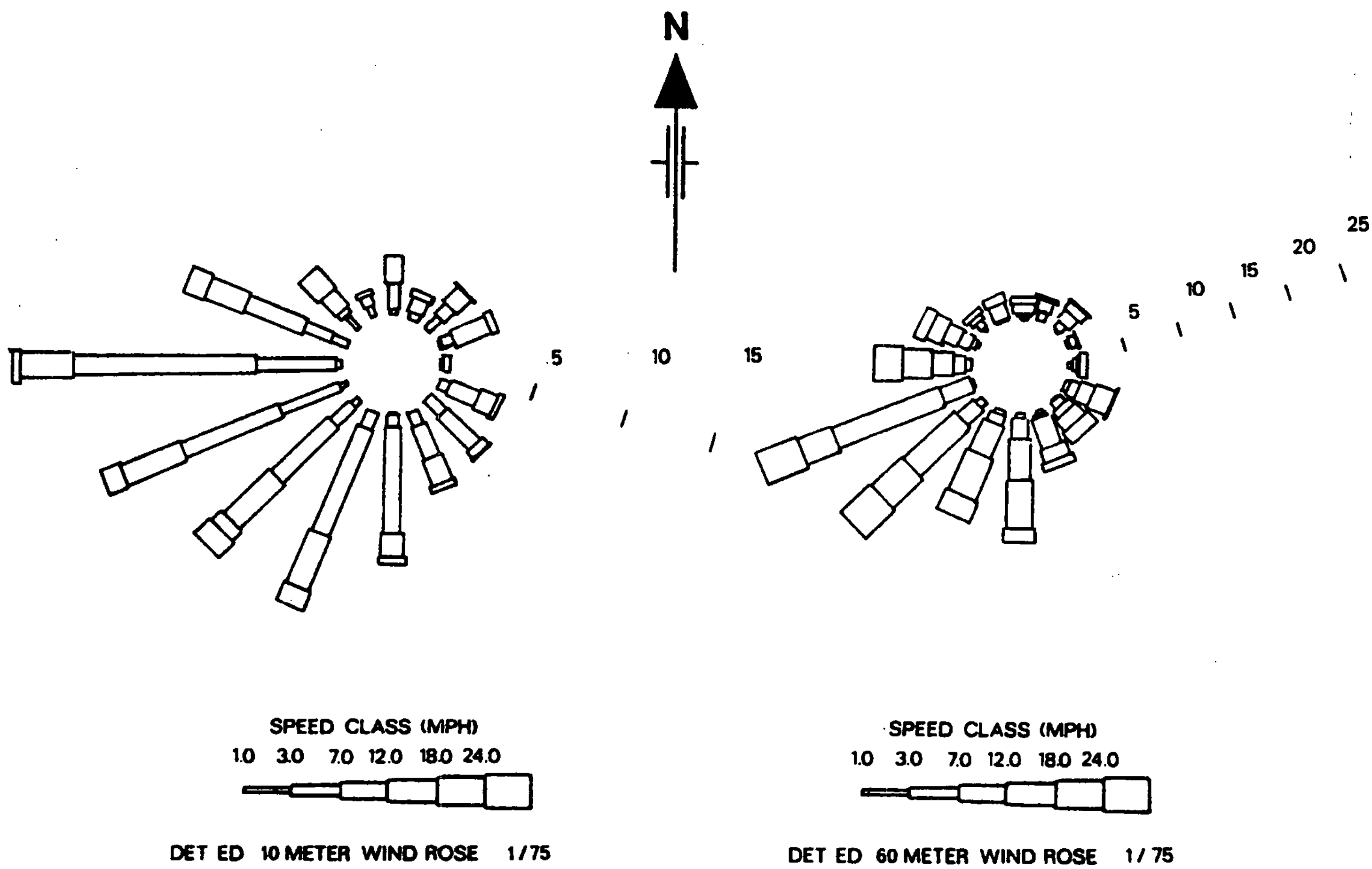

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FIGURE 2.3-10

WIND ROSE DATA FOR JANUARY 1975

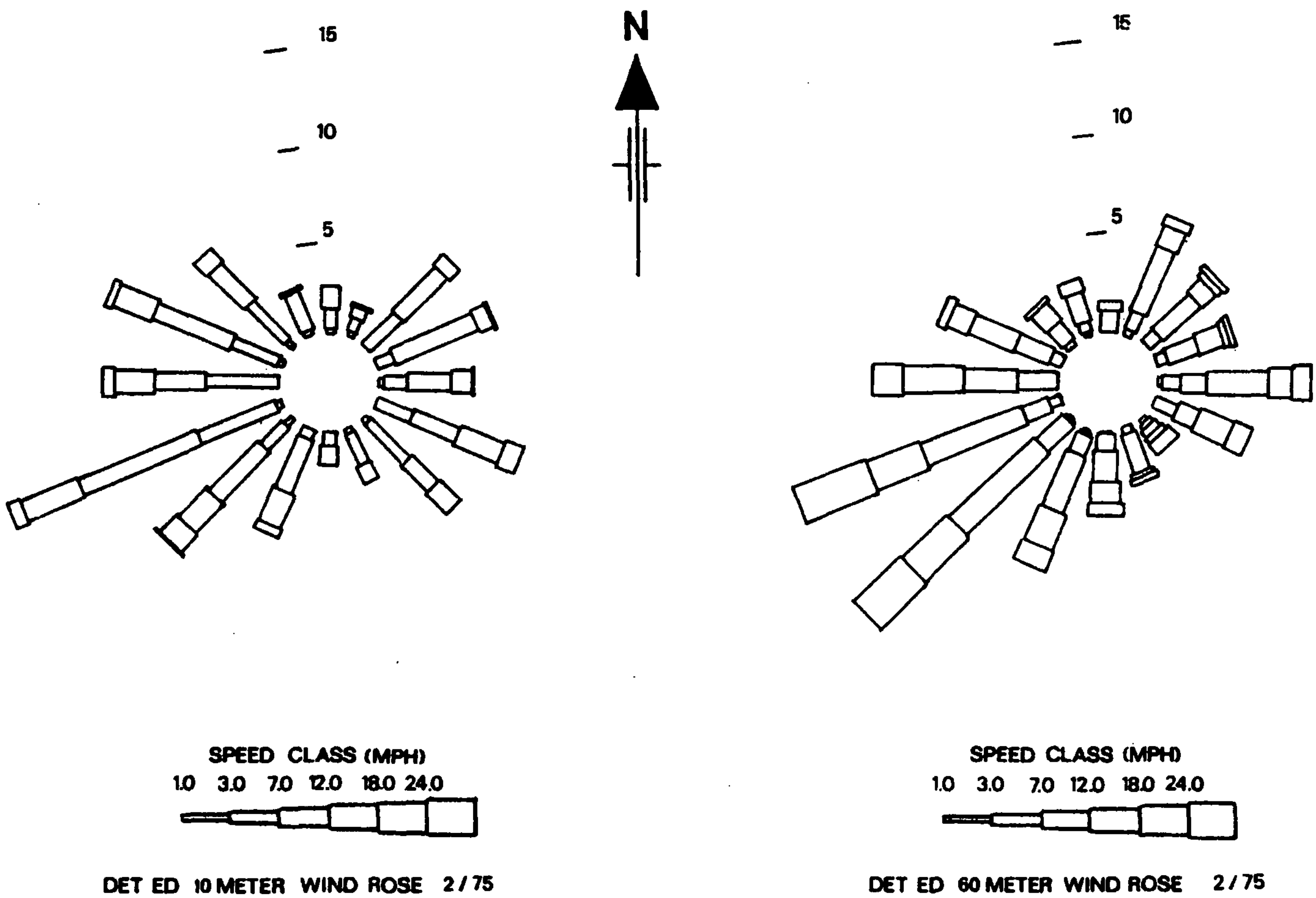

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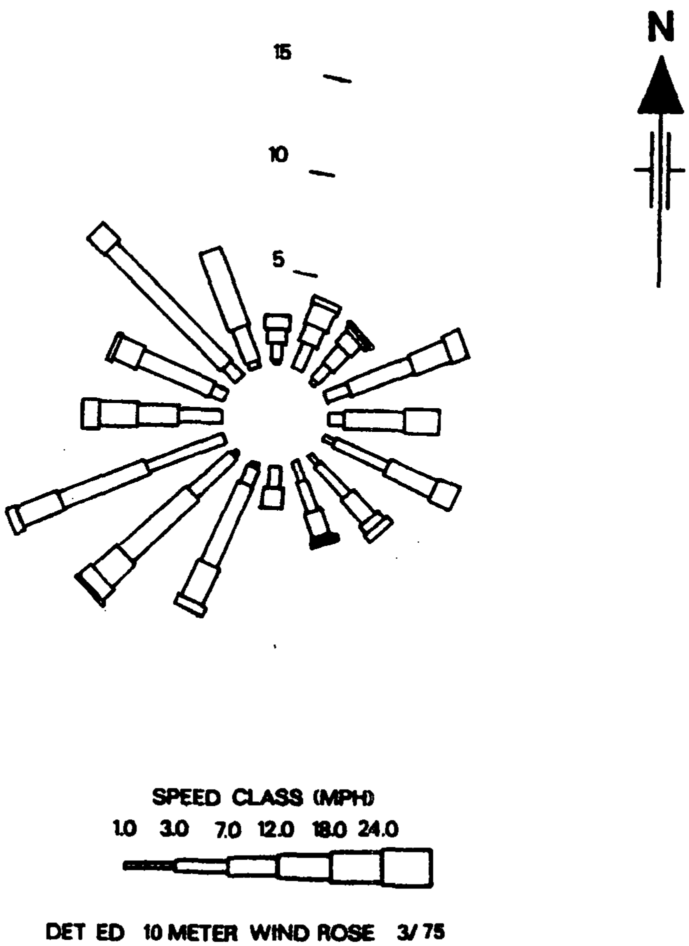
FIGURE 2.3-11

WIND ROSE DATA FOR FEBRUARY 1975



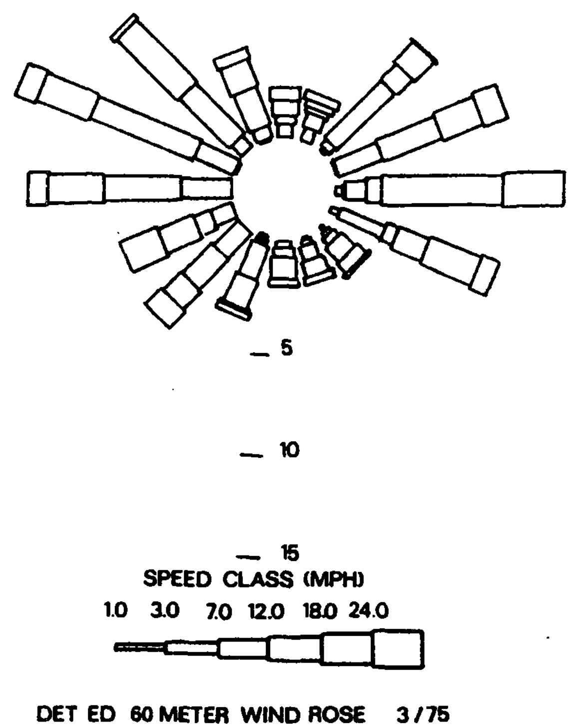


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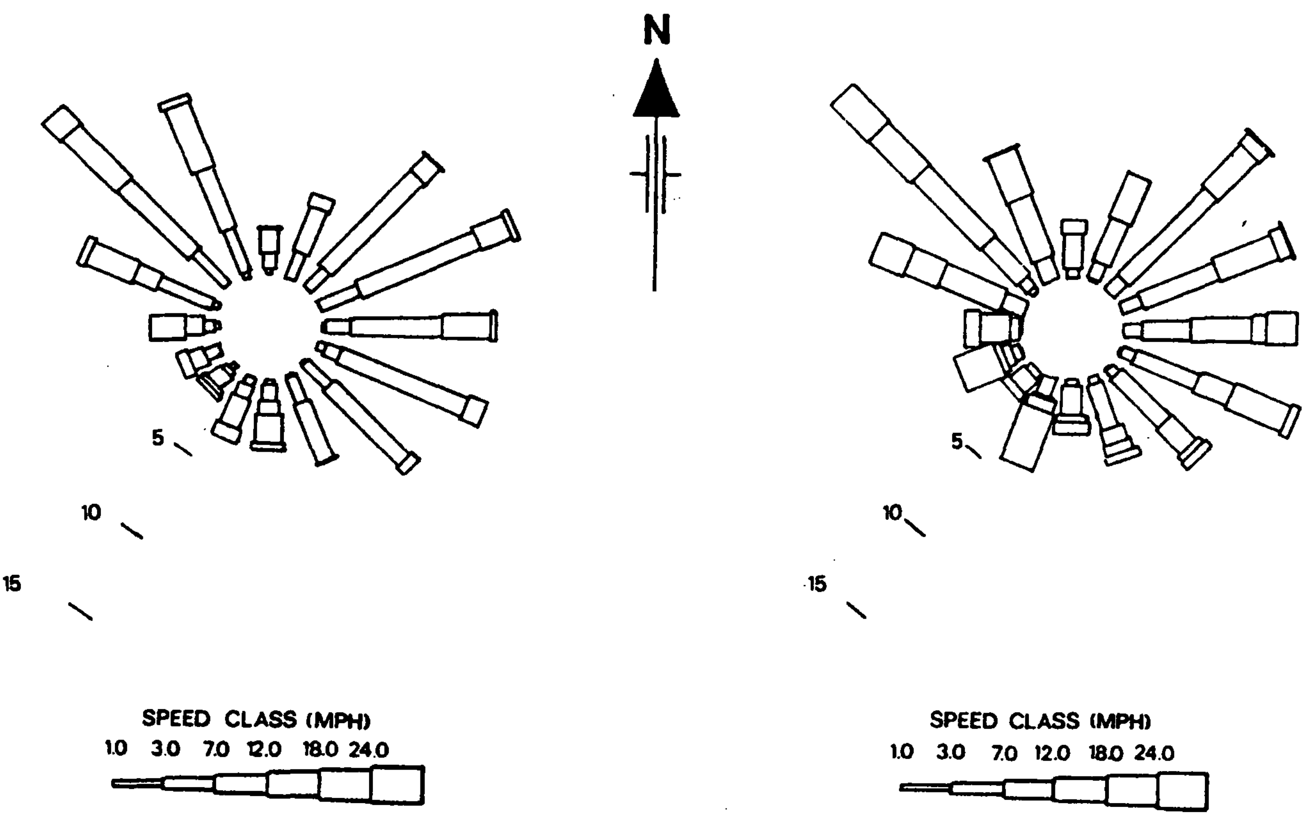
FIGURE 2.3-12

WIND ROSE DATA FOR MARCH 1975



DET ED 10 METER WIND ROSE 4/75

DET ED 60 METER WIND ROSE 4/75

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FIGURE 2.3-13

WIND ROSE DATA FOR APRIL 1975

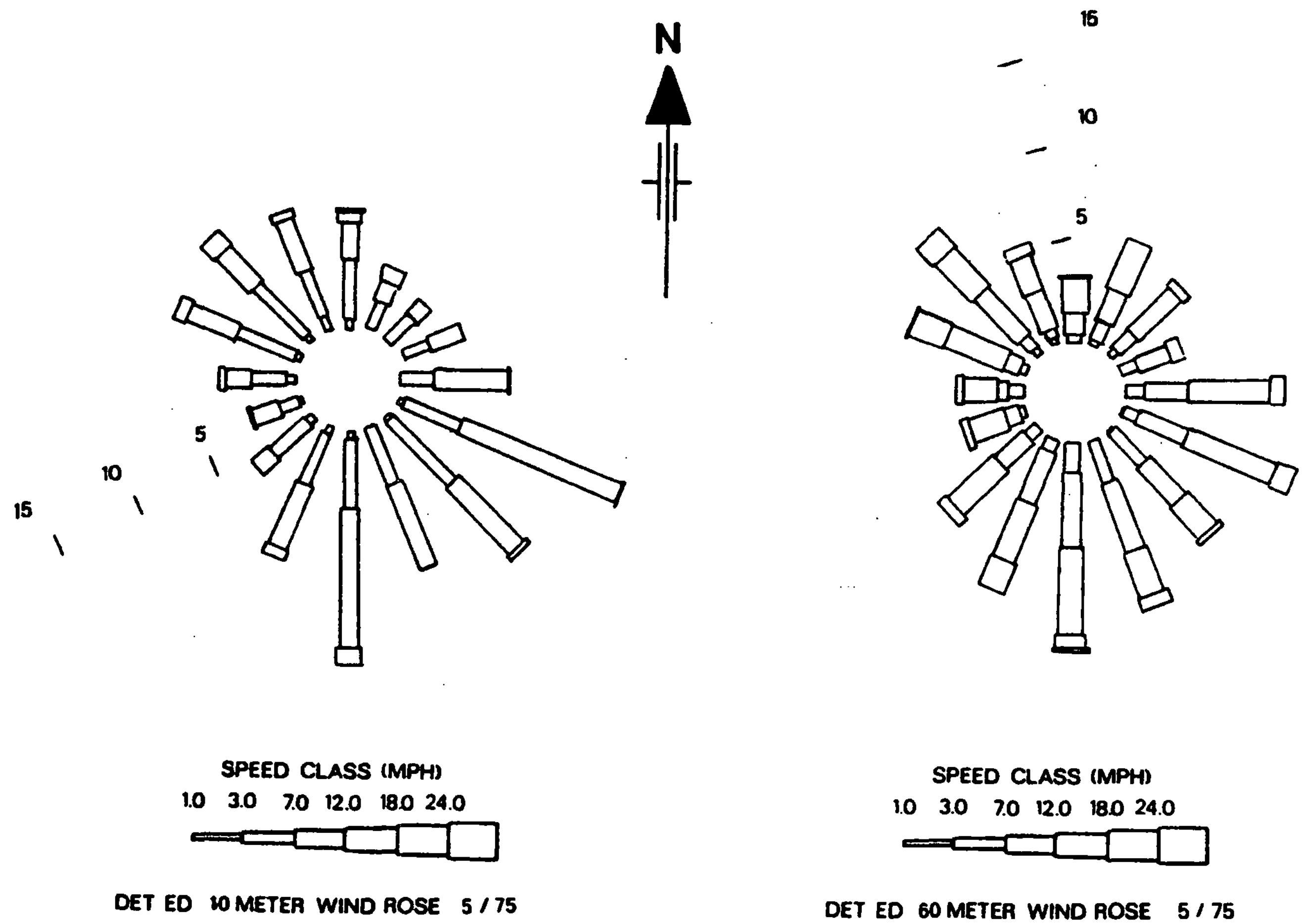

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FIGURE 2.3-14

WIND ROSE DATA FOR MAY 1975

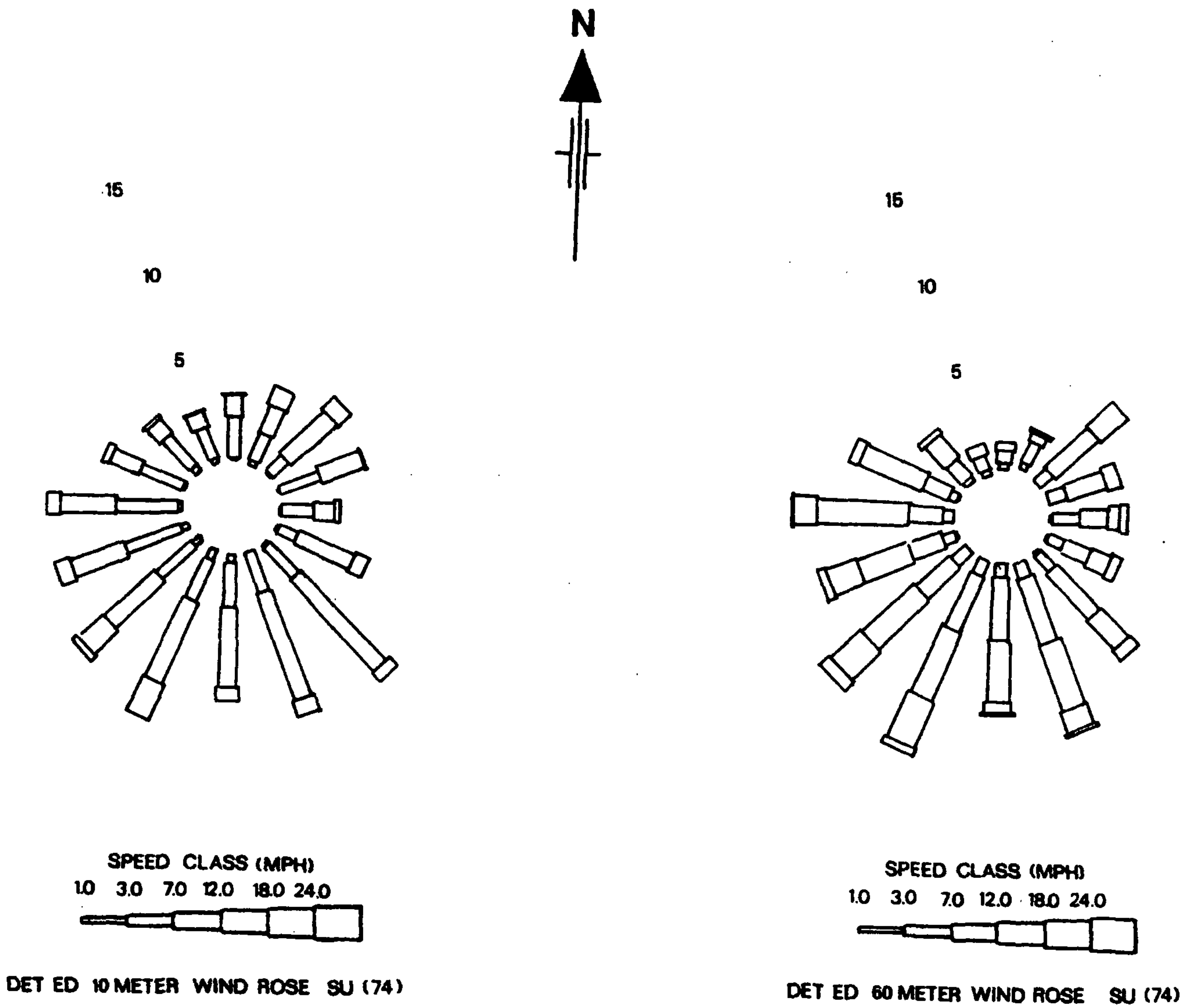

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FIGURE 2.3-15

FERMI SITE WIND ROSE DATA FOR SUMMER 1974

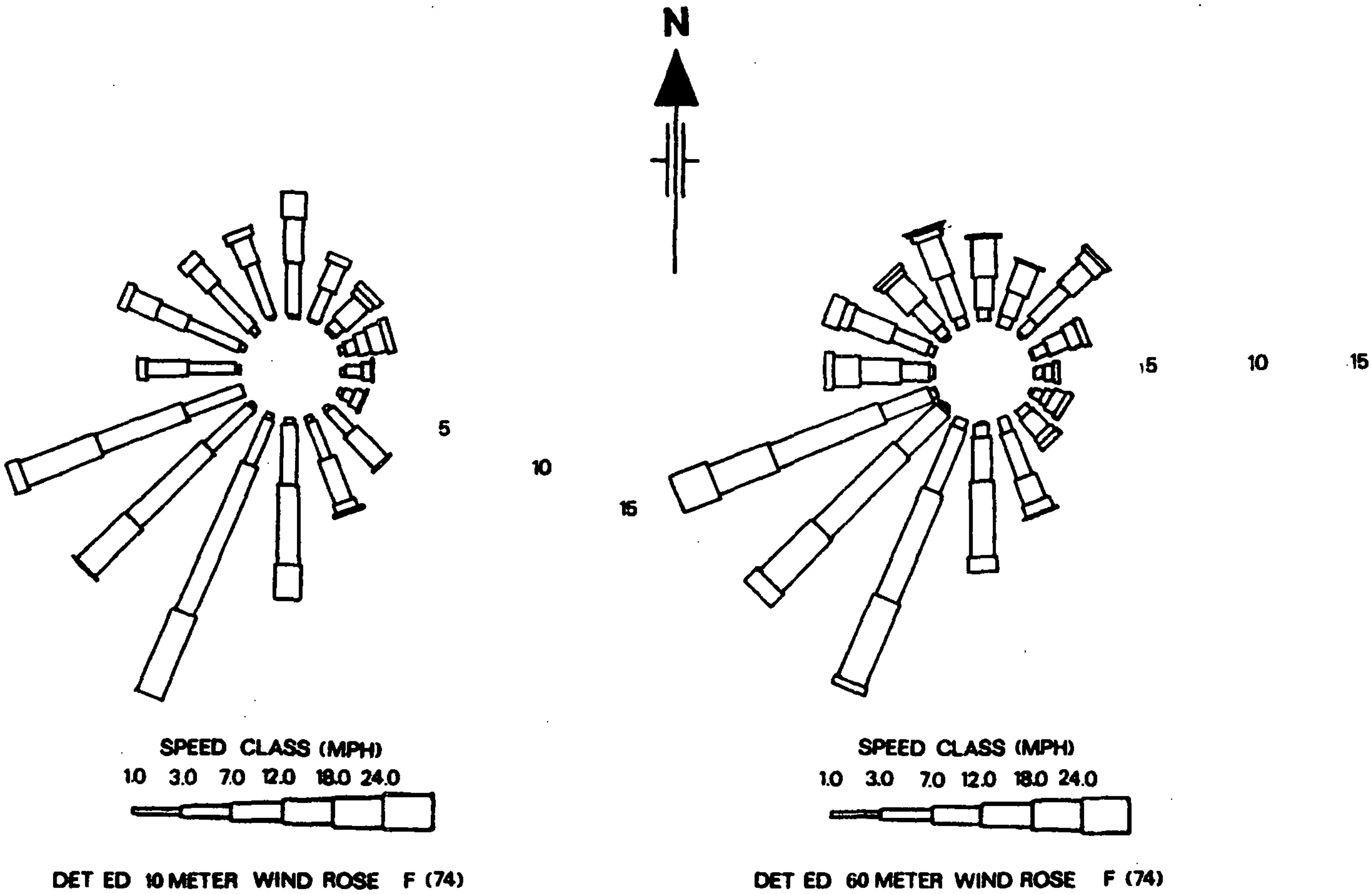

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FIGURE 2.3-16

FERMI SITE WIND ROSE DATA FOR FALL 1974/75

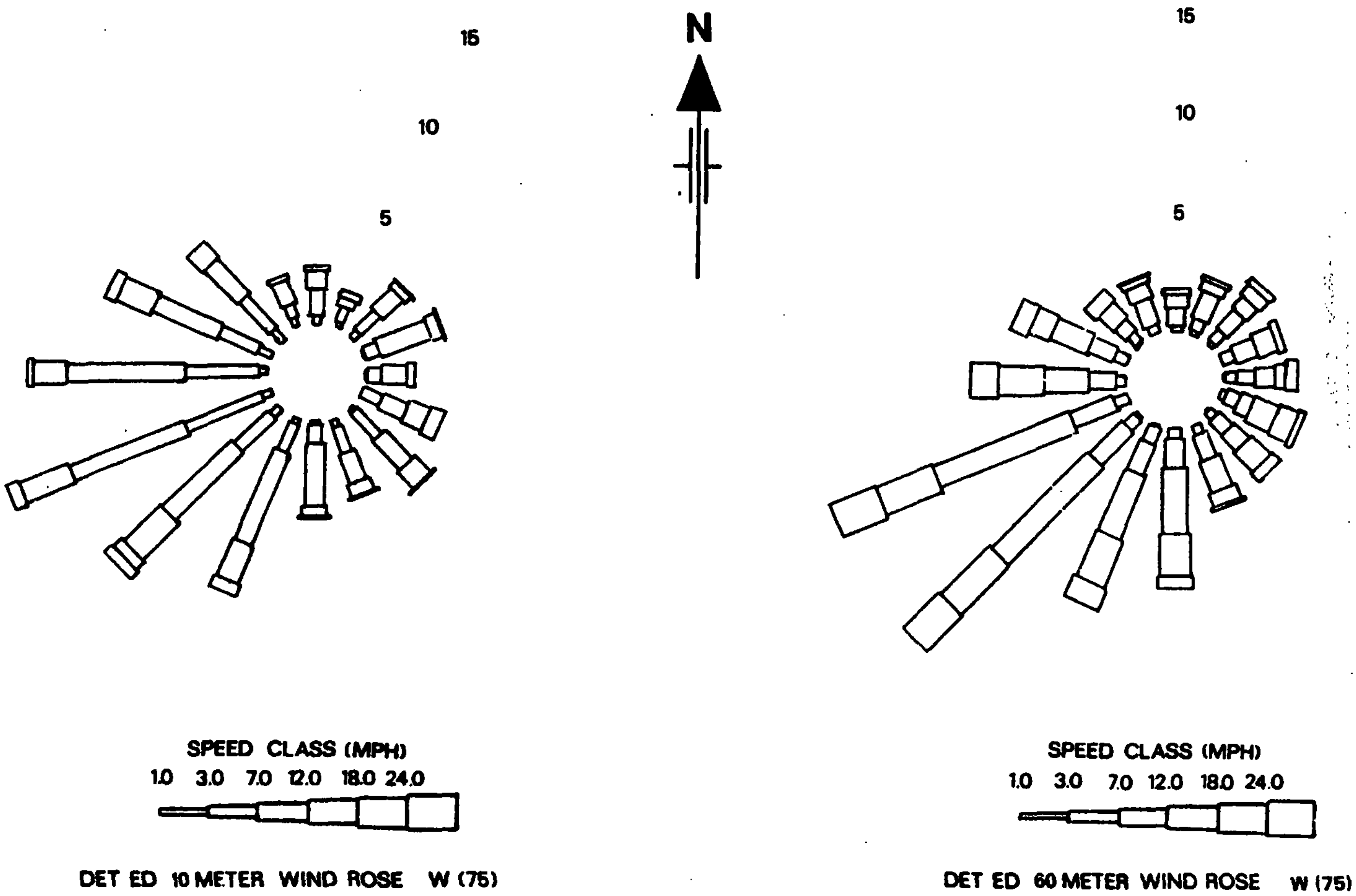

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FIGURE 2.3-17

FERMI SITE WIND ROSE DATA FOR WINTER 1975

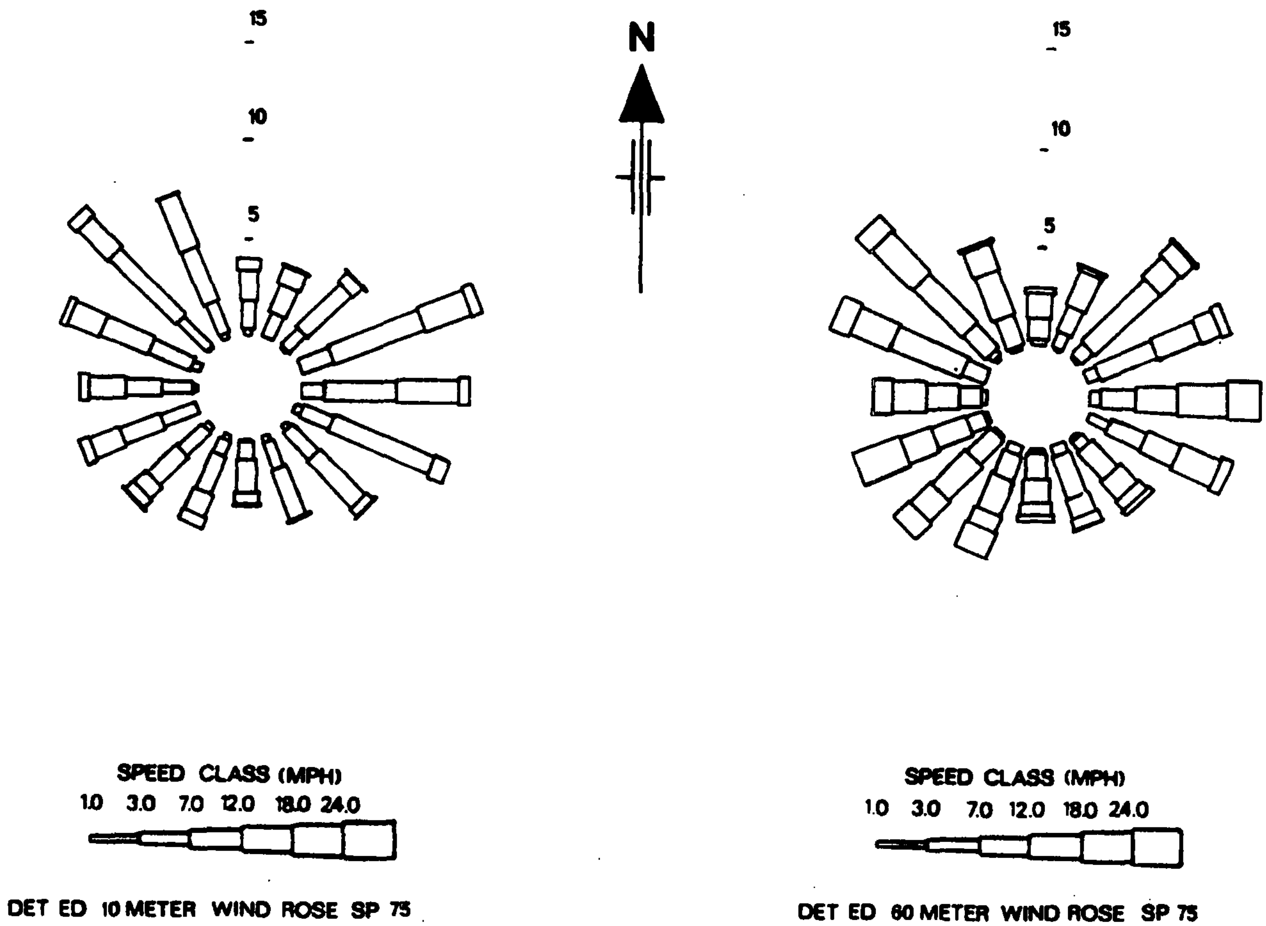

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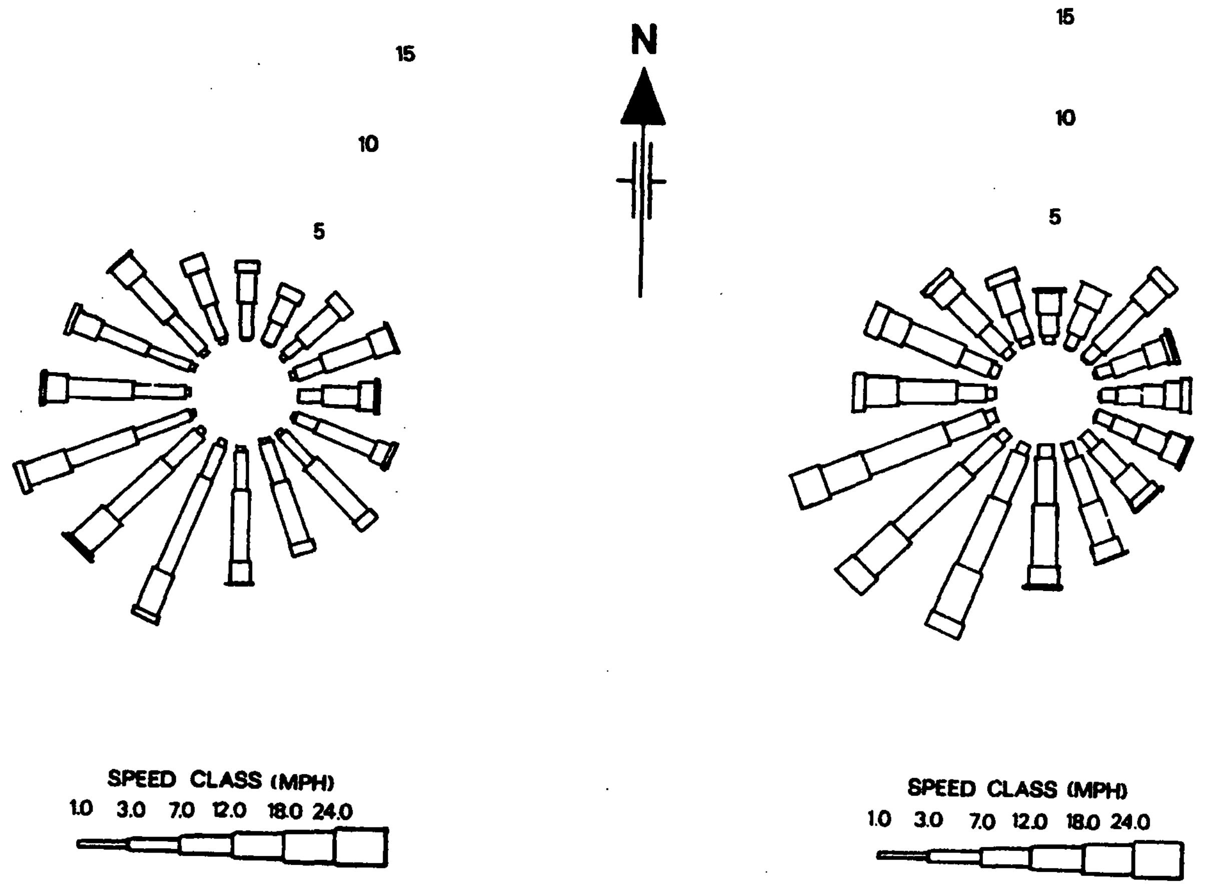
FIGURE 2.3-18

FERMI SITE WIND ROSE DATA FOR SPRING 1975



DET ED 10 METER WIND ROSE 74 / 75

DET ED 60 METER WIND ROSE 74 / 75

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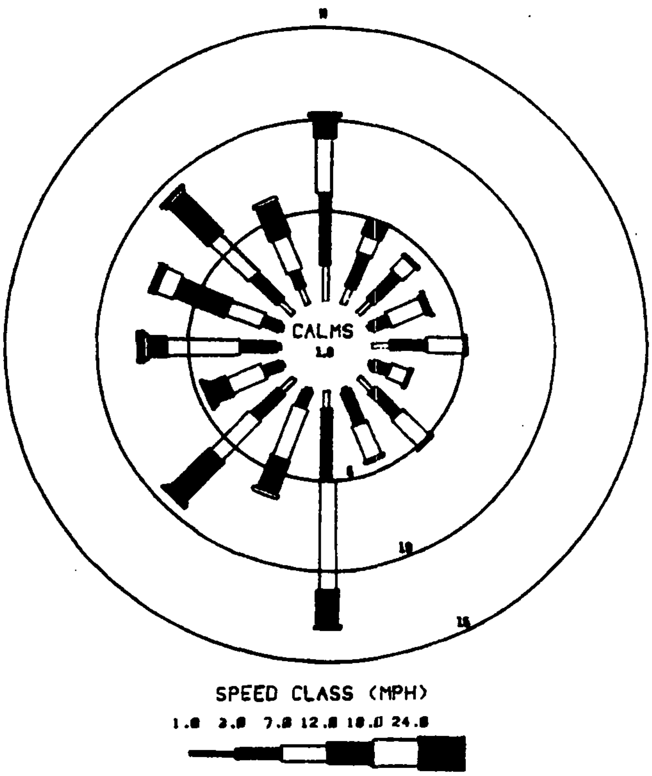
FIGURE 2.3-19

FERMI SITE WIND ROSE DATA FOR ANNUAL PERIOD 1 JUNE 1974 – 31 MAY 1975



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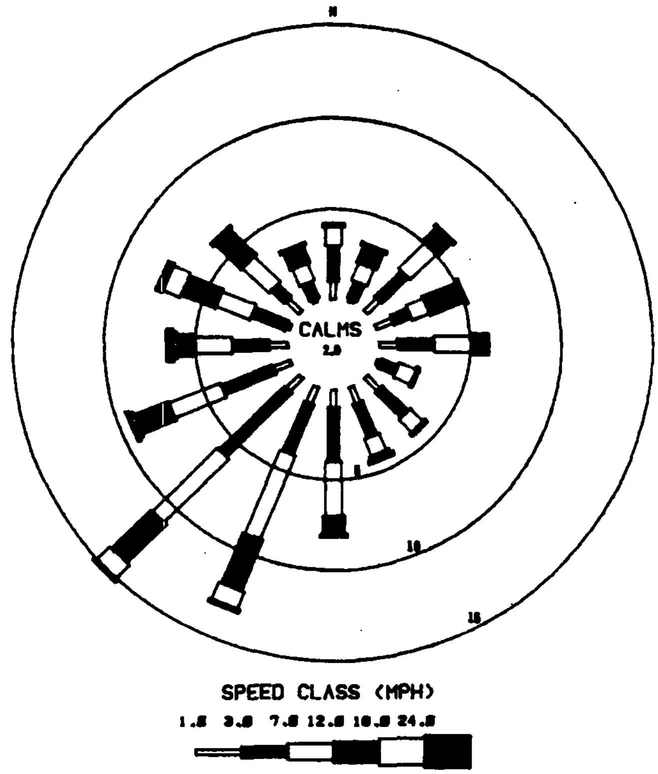

TOLEDO EXPRESS AIRPORT

1950 – 1955

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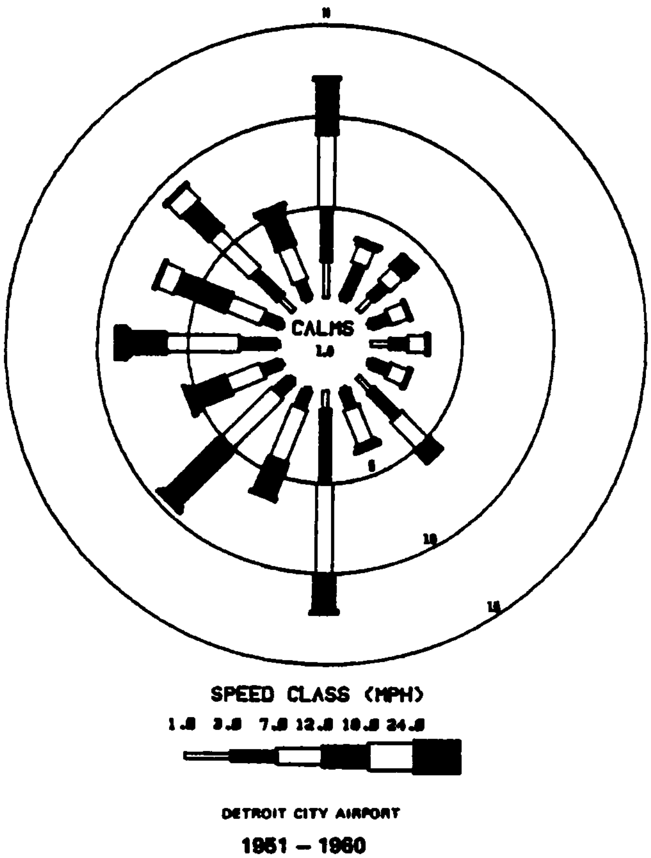
FIGURE 2.3-20

WIND ROSE DATA FOR SEPTEMBER



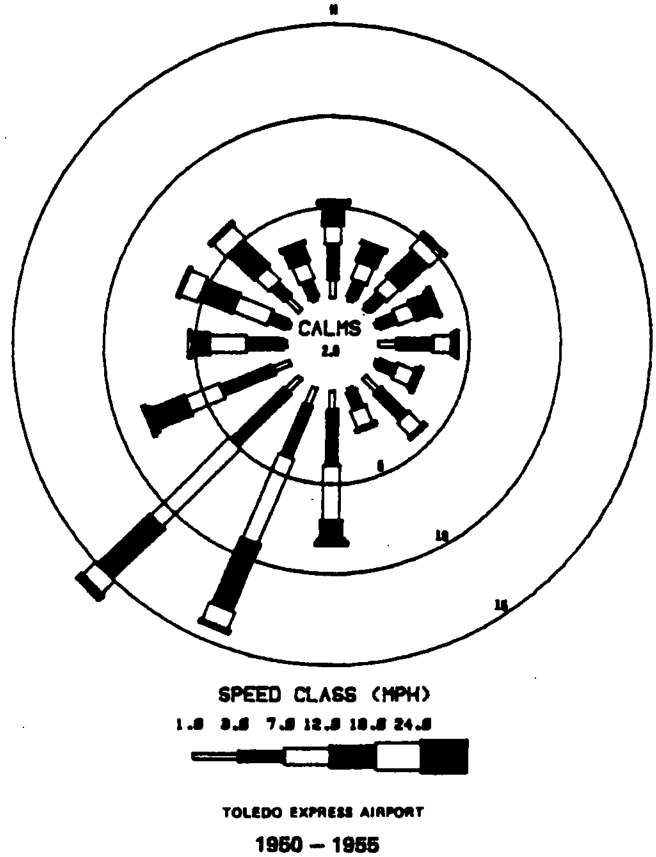


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FIGURE 2.3-21

WIND ROSE DATA FOR OCTOBER

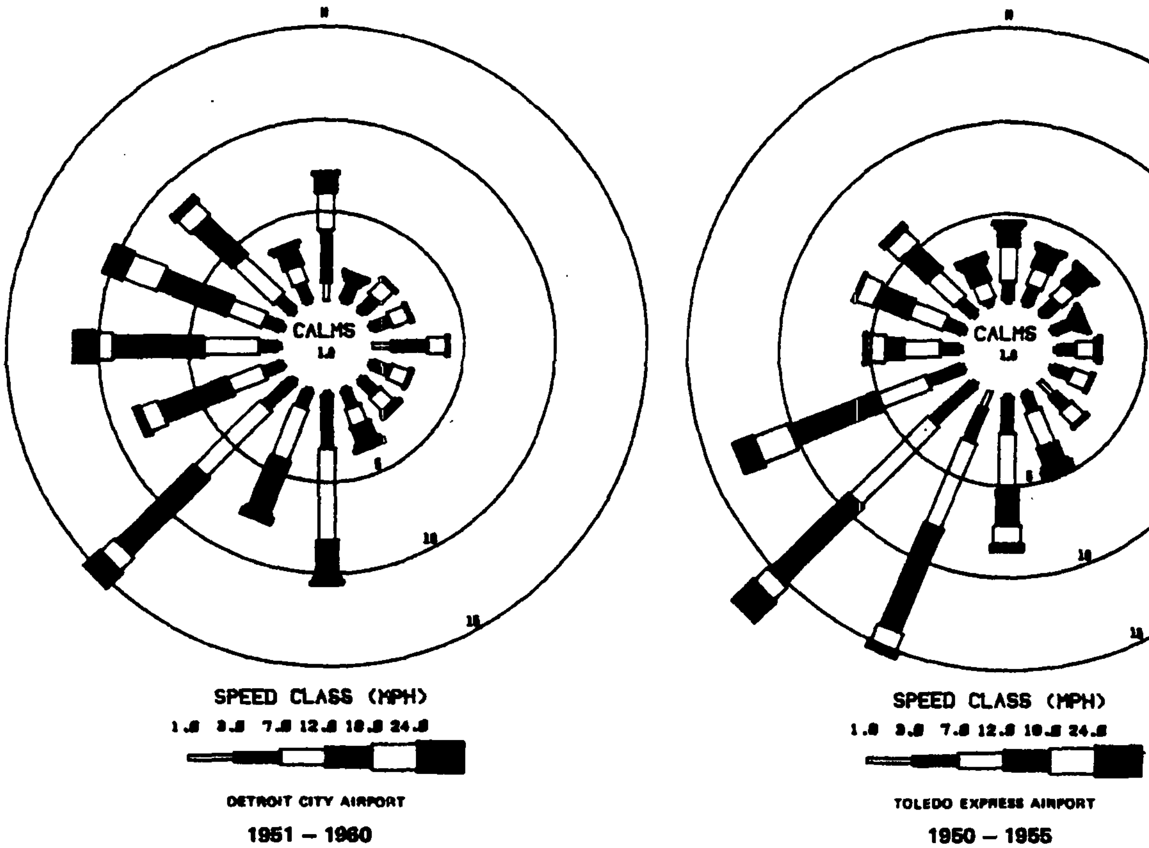

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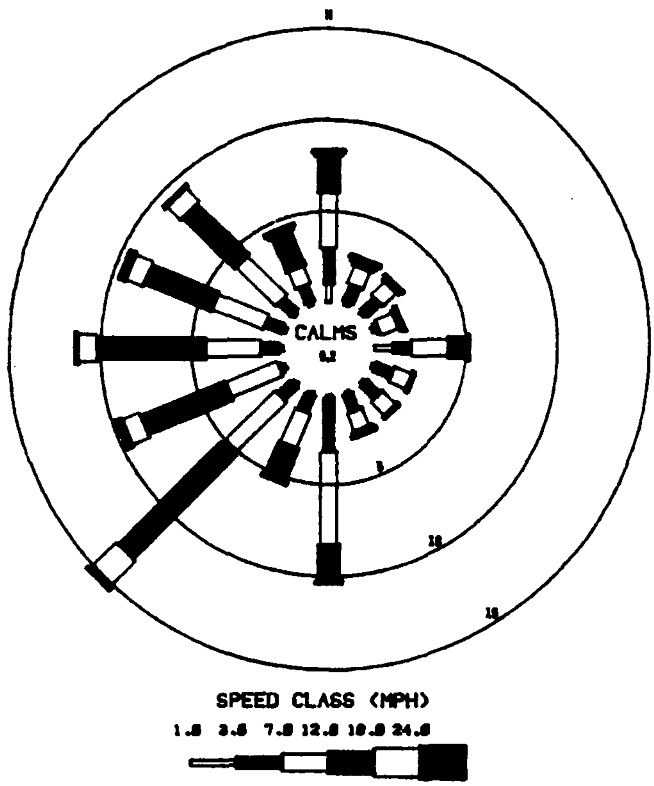
FIGURE 2.3-22

WIND ROSE DATA FOR NOVEMBER



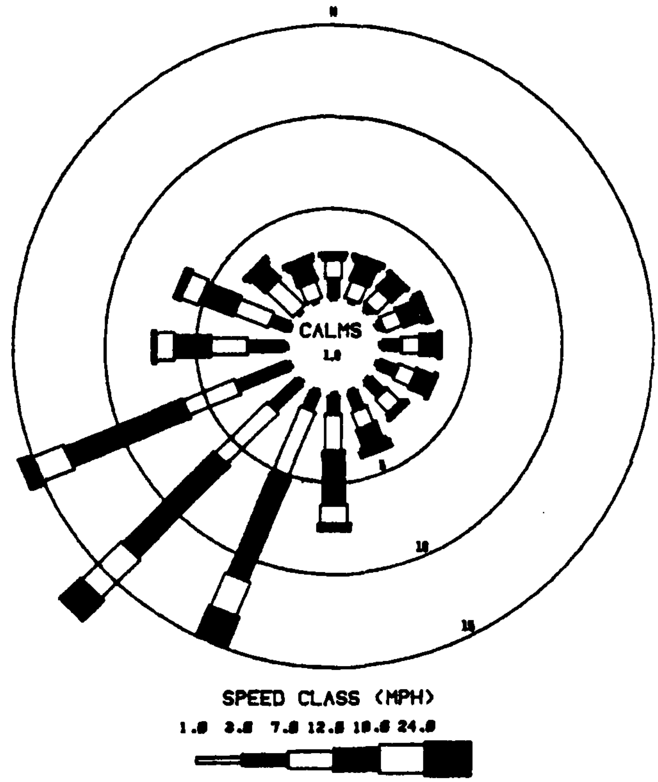


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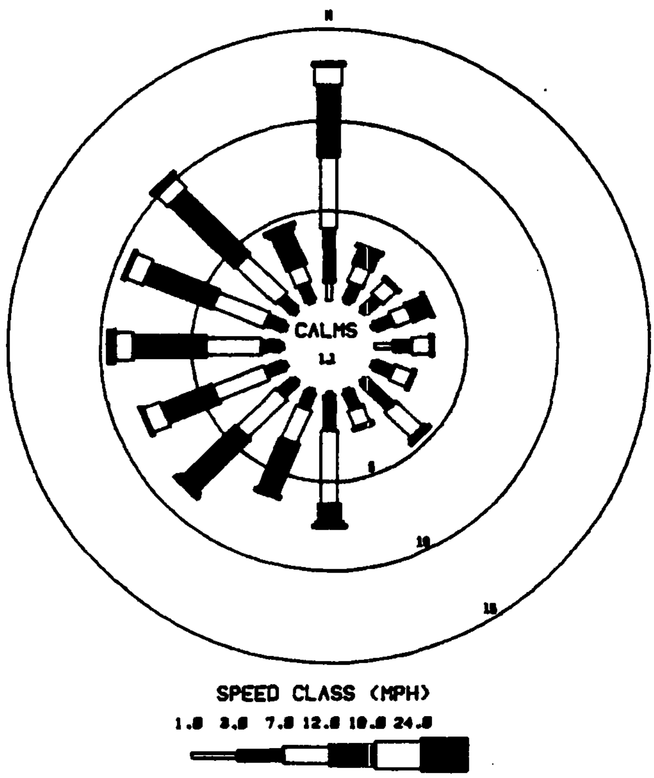
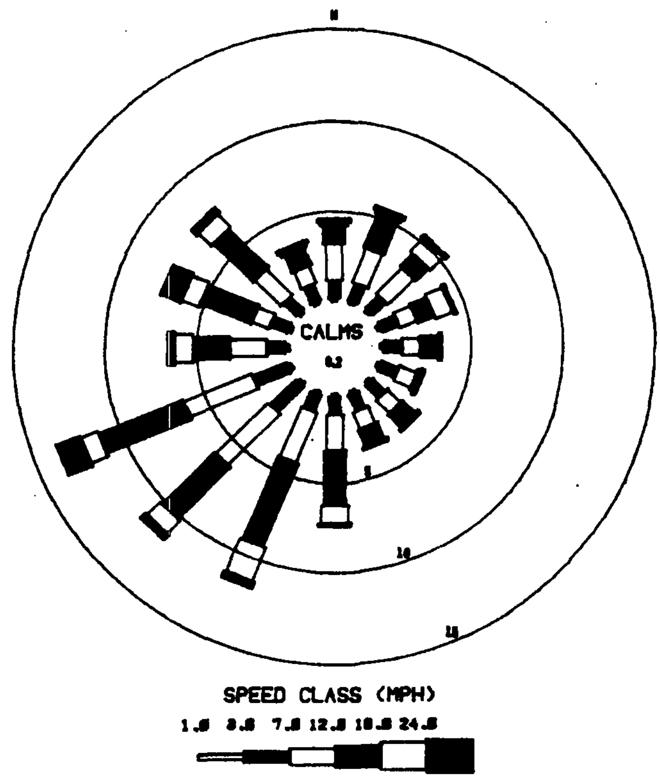
FIGURE 2.3-23

WIND ROSE DATA FOR DECEMBER



DETROIT CITY AIRPORT
1951 – 1960



TOLEDO EXPRESS AIRPORT
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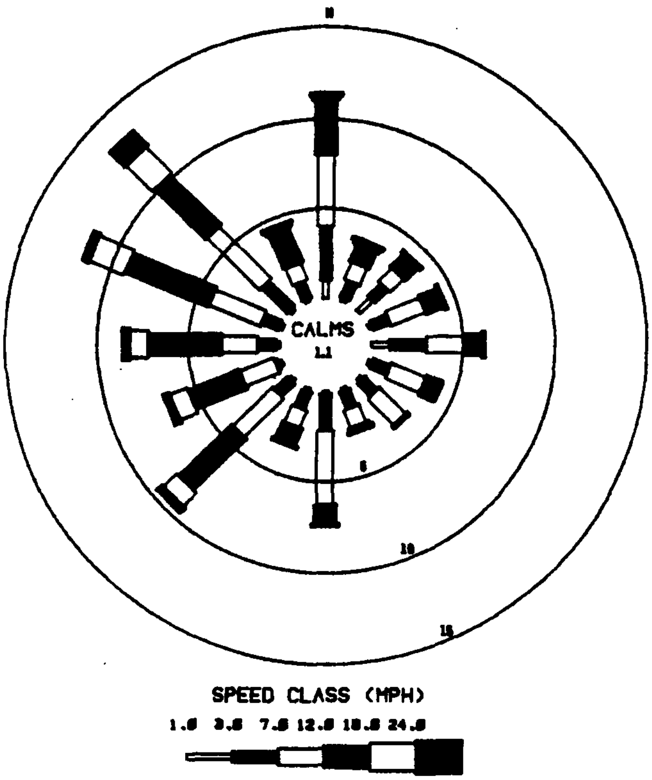
FIGURE 2.3-24

WIND ROSE DATA FOR JANUARY



DETROIT CITY AIRPORT

1951 – 1960

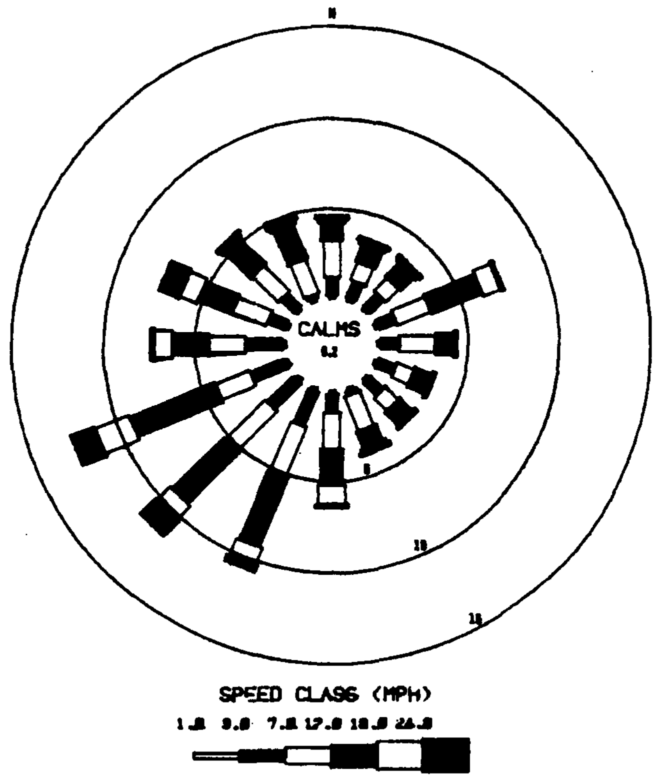


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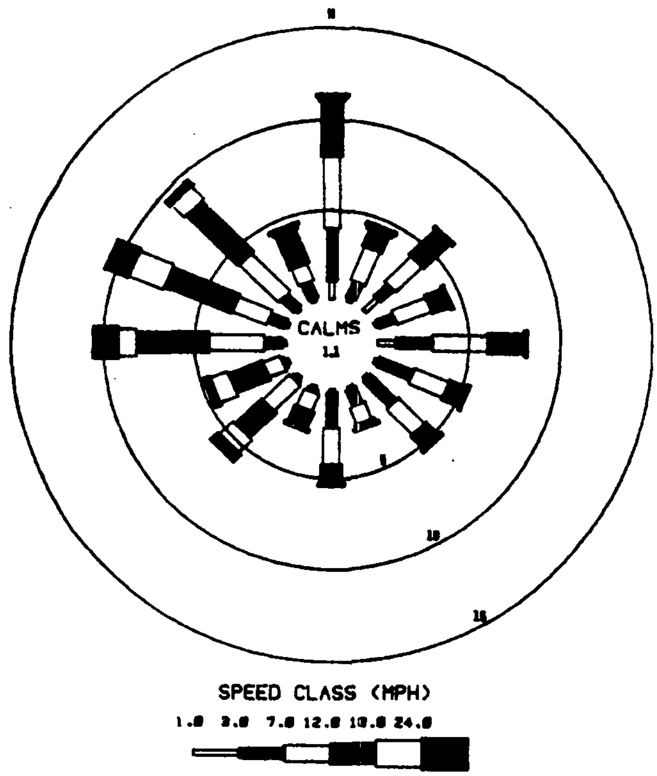
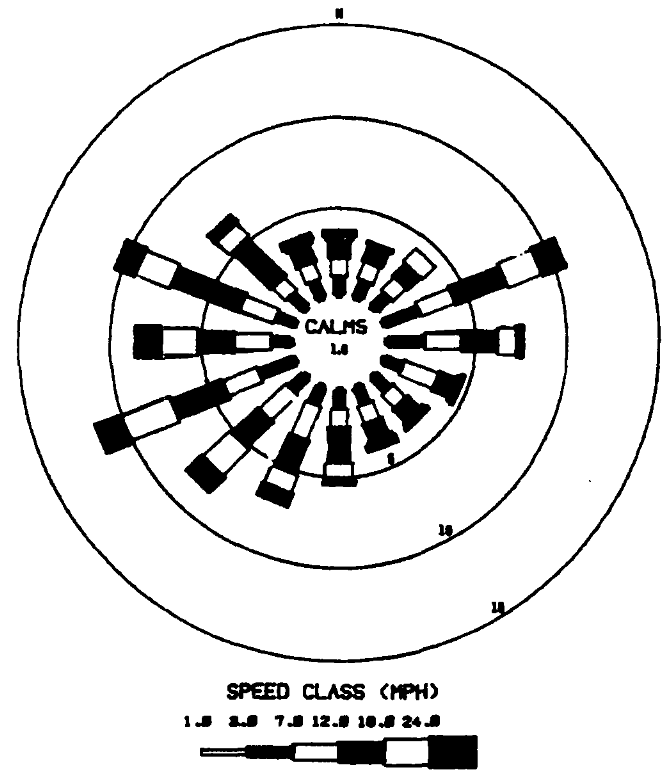
FIGURE 2.3-25

WIND ROSE DATA FOR FEBRUARY



DETROIT CITY AIRPORT

1951 – 1960



TOLEDO EXPRESS AIRPORT

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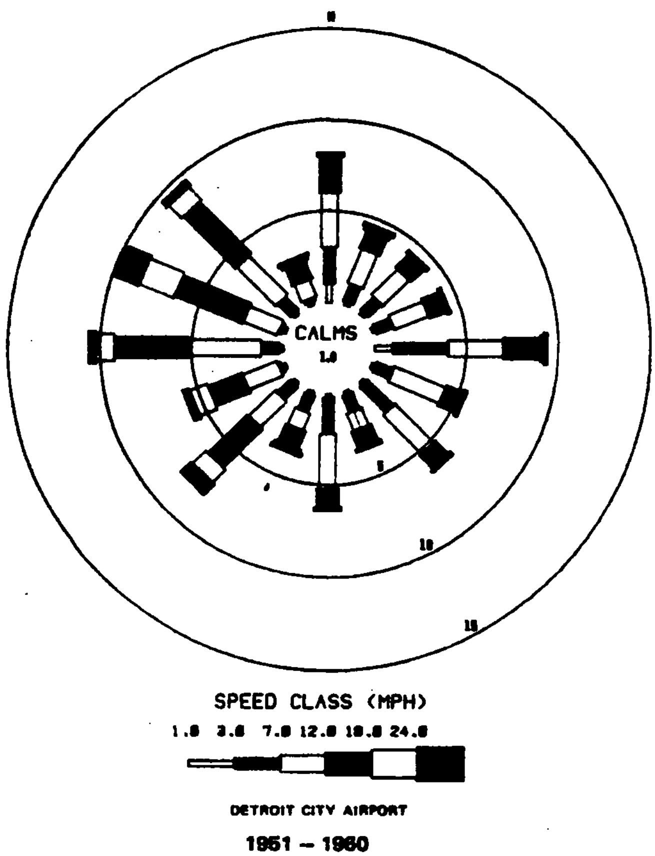
FIGURE 2.3-26

WIND ROSE DATA FOR MARCH



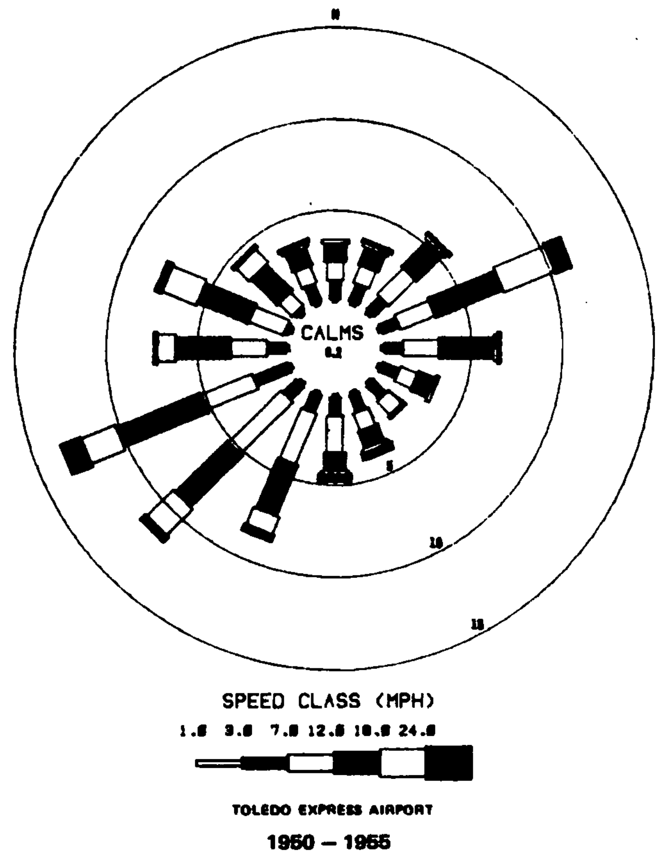


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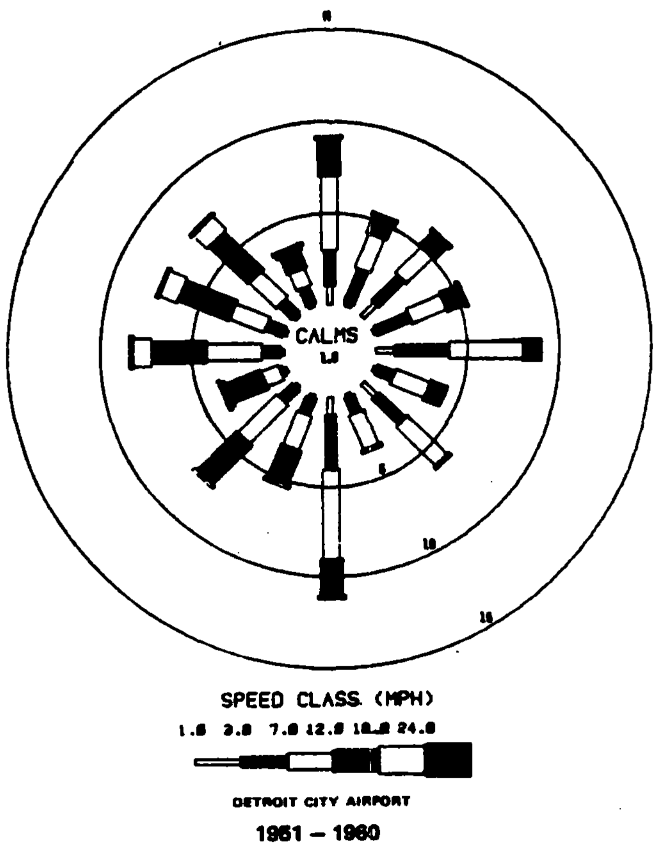
FIGURE 2.3-27

WIND ROSE DATA FOR APRIL



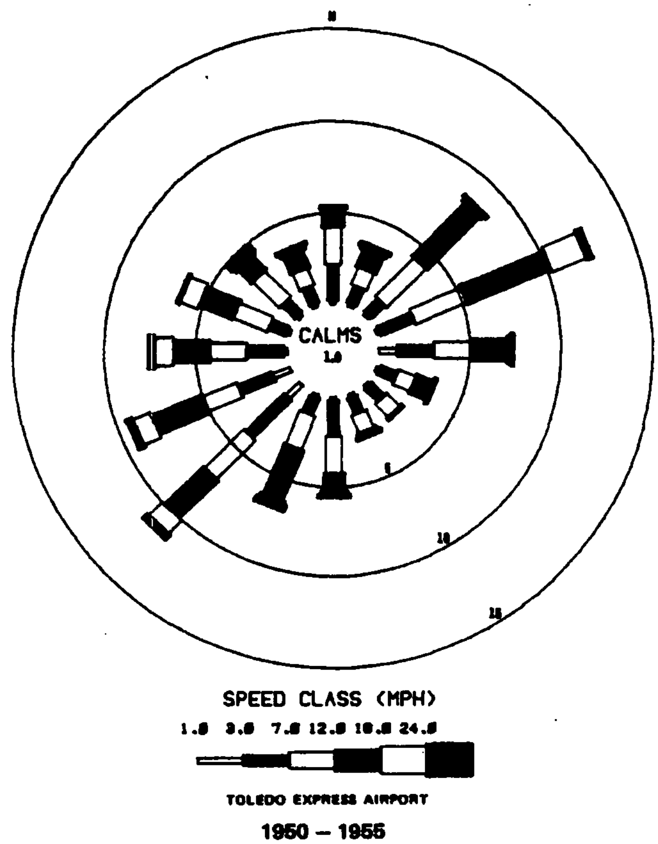


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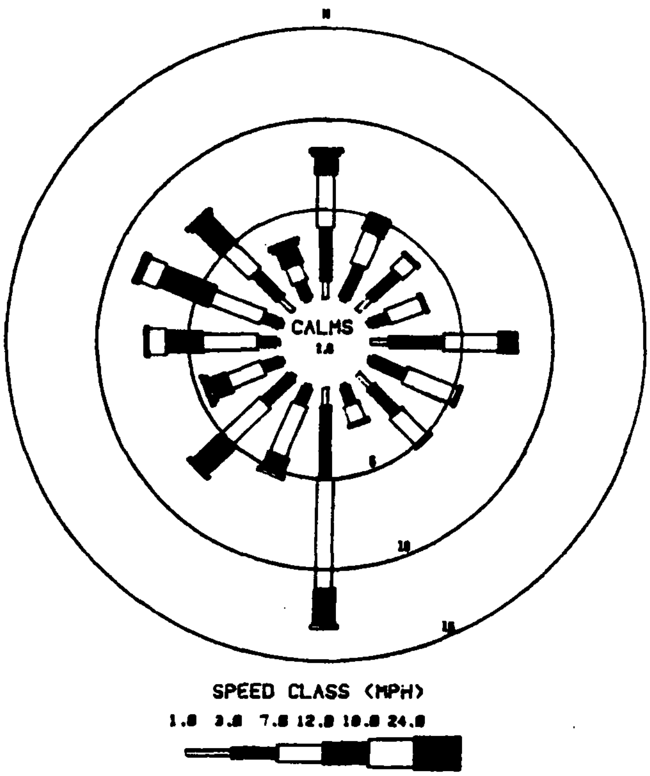
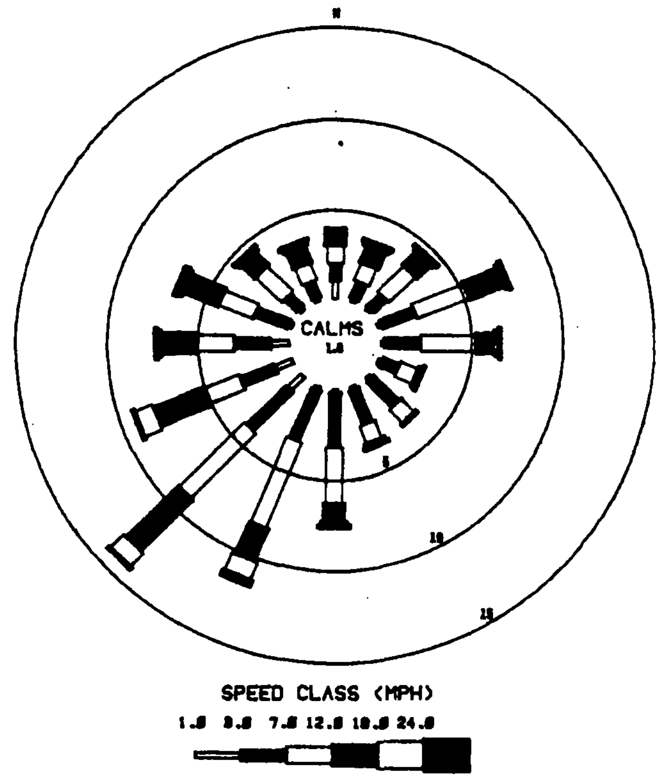
FIGURE 2.3-28

WIND ROSE DATA FOR MAY



DETROIT CITY AIRPORT
1951 – 1960



TOLEDO EXPRESS AIRPORT
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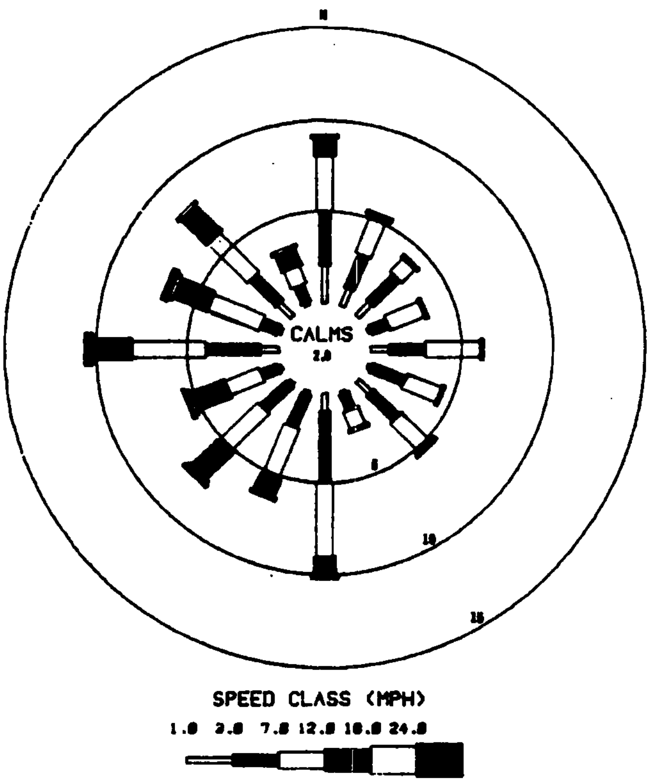
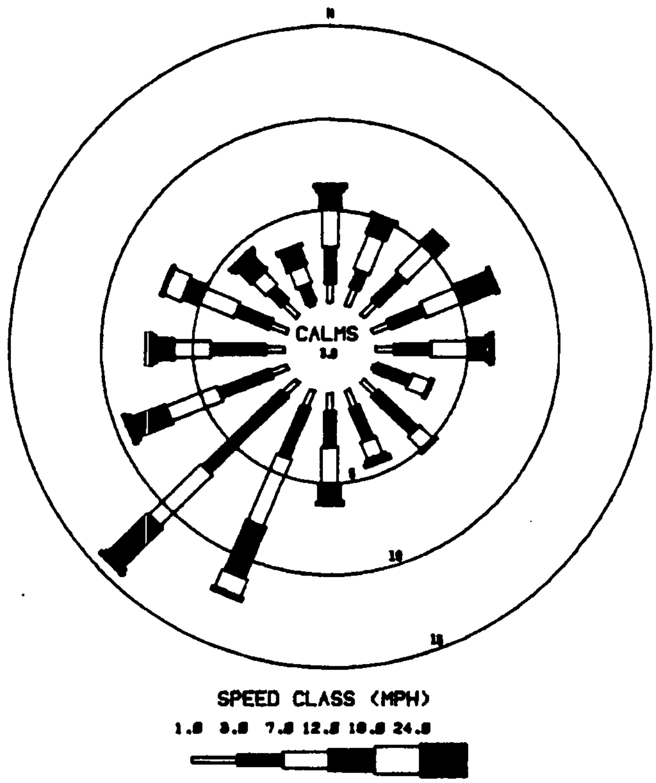
FIGURE 2.3-29

WIND ROSE DATA FOR JUNE



DETROIT CITY AIRPORT

1951 – 1960



TOLEDO EXPRESS AIRPORT

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FIGURE 2.3-30

WIND ROSE DATA FOR JULY

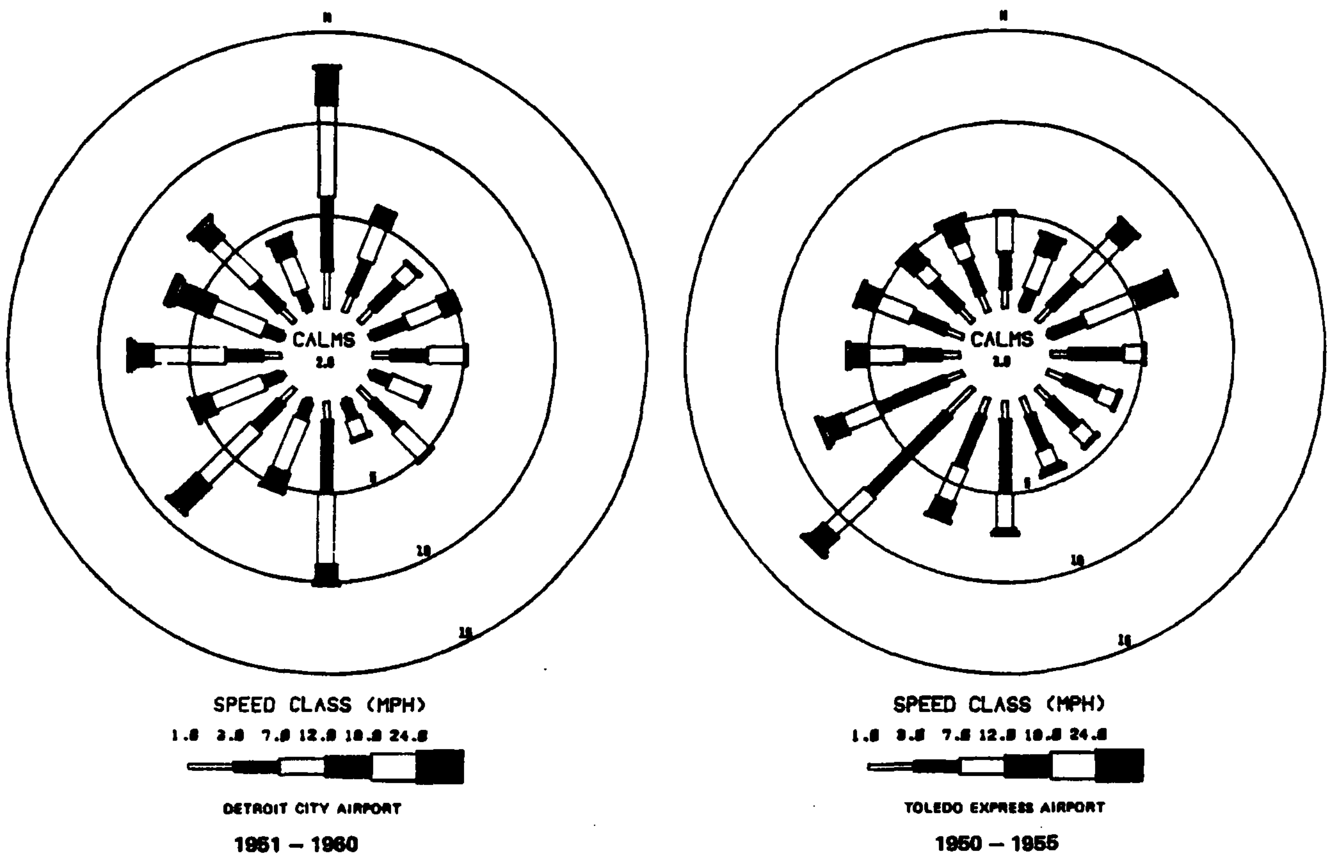

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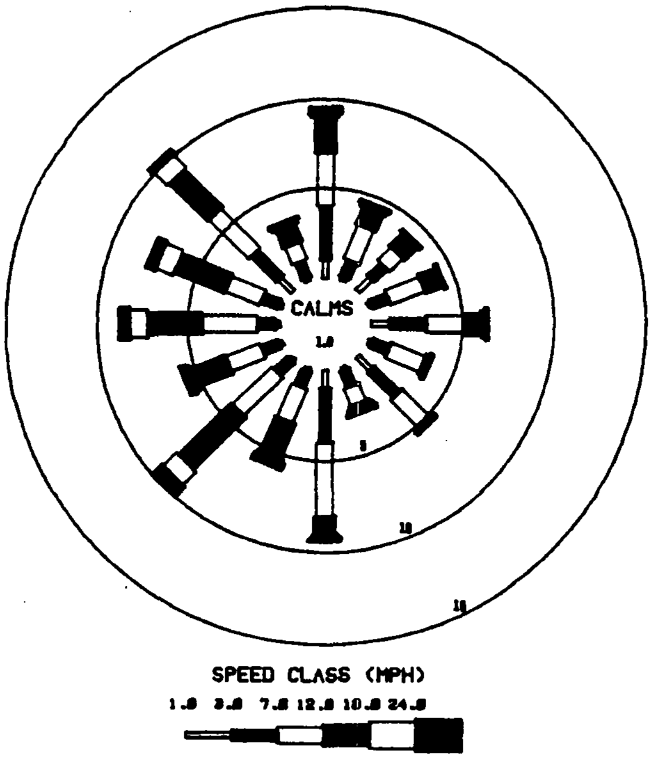
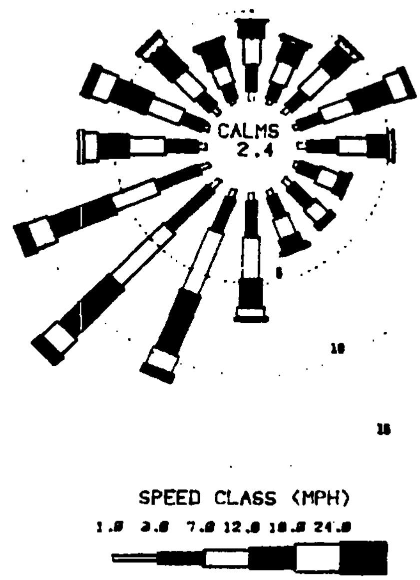
FIGURE 2.3-31

WIND ROSE DATA FOR AUGUST



DETROIT CITY AIRPORT

1951 – 1960



TOLEDO EXPRESS AIRPORT

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FIGURE 2.3-32

ANNUAL WIND ROSE DATA

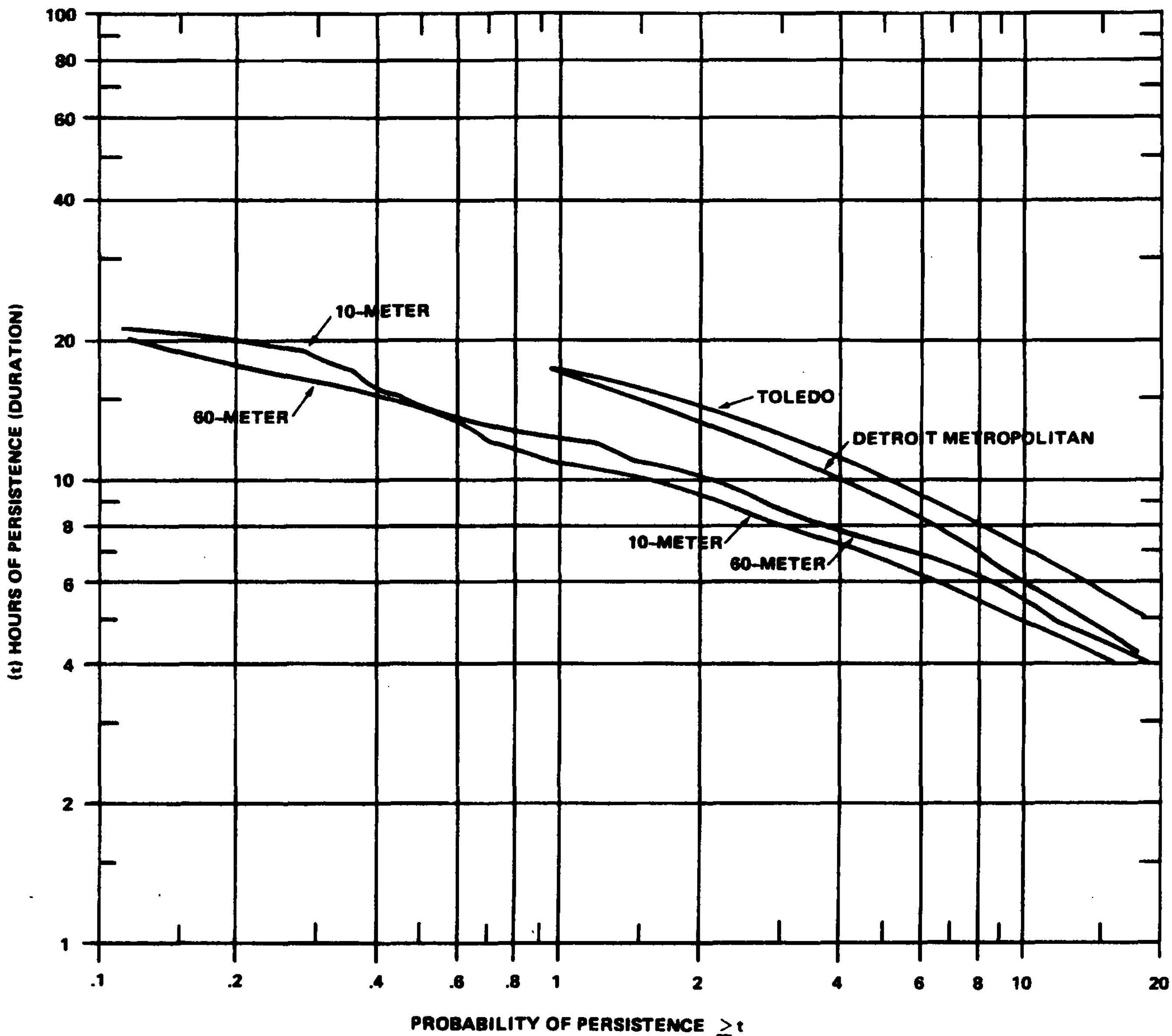

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FIGURE 2.3-33

ONE SECTOR (22½°) WIND DIRECTION PERSISTENCE PROBABILITY

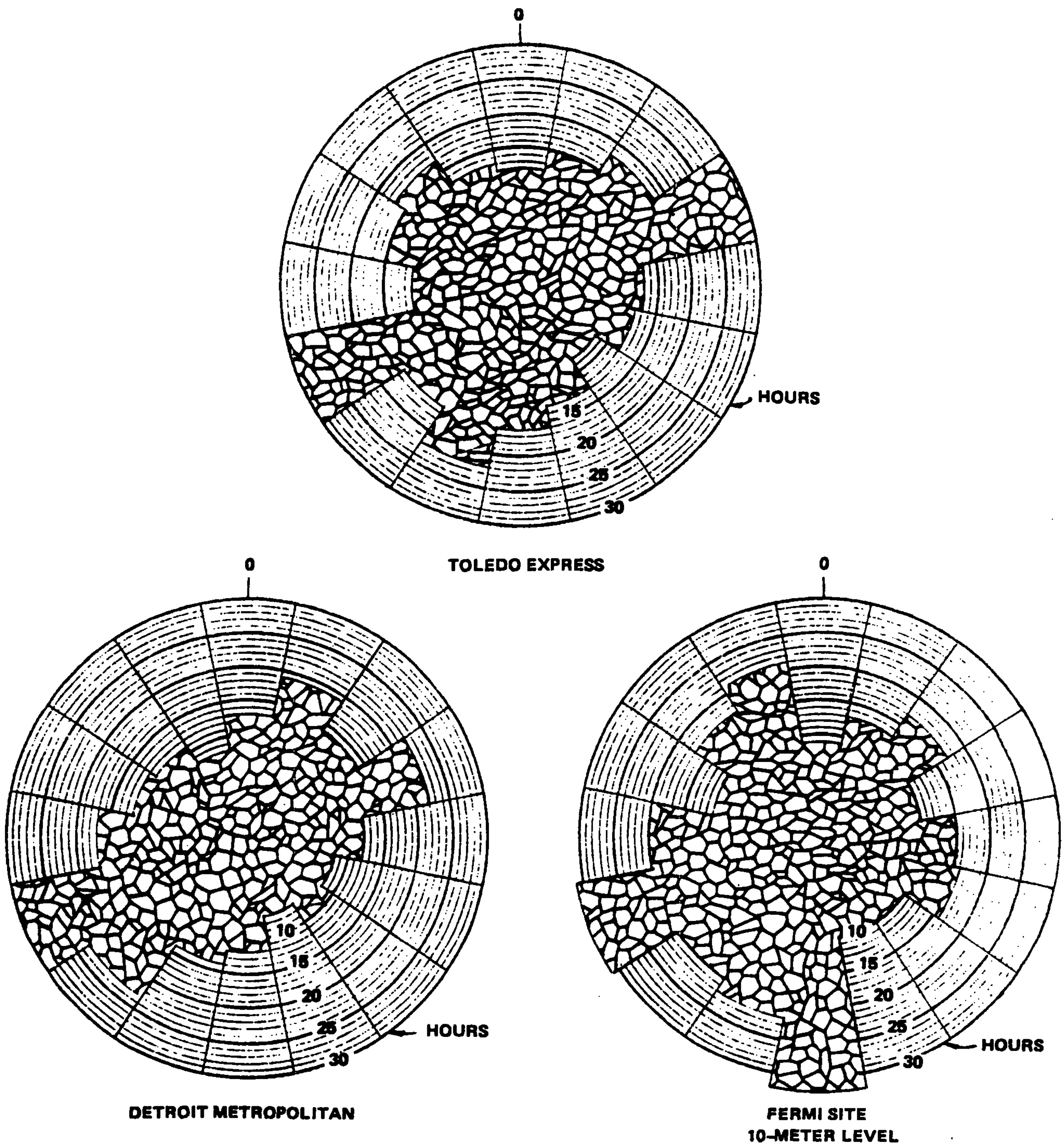

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FIGURE 2.3-34

MAXIMUM WIND PERSISTENCE ROSE

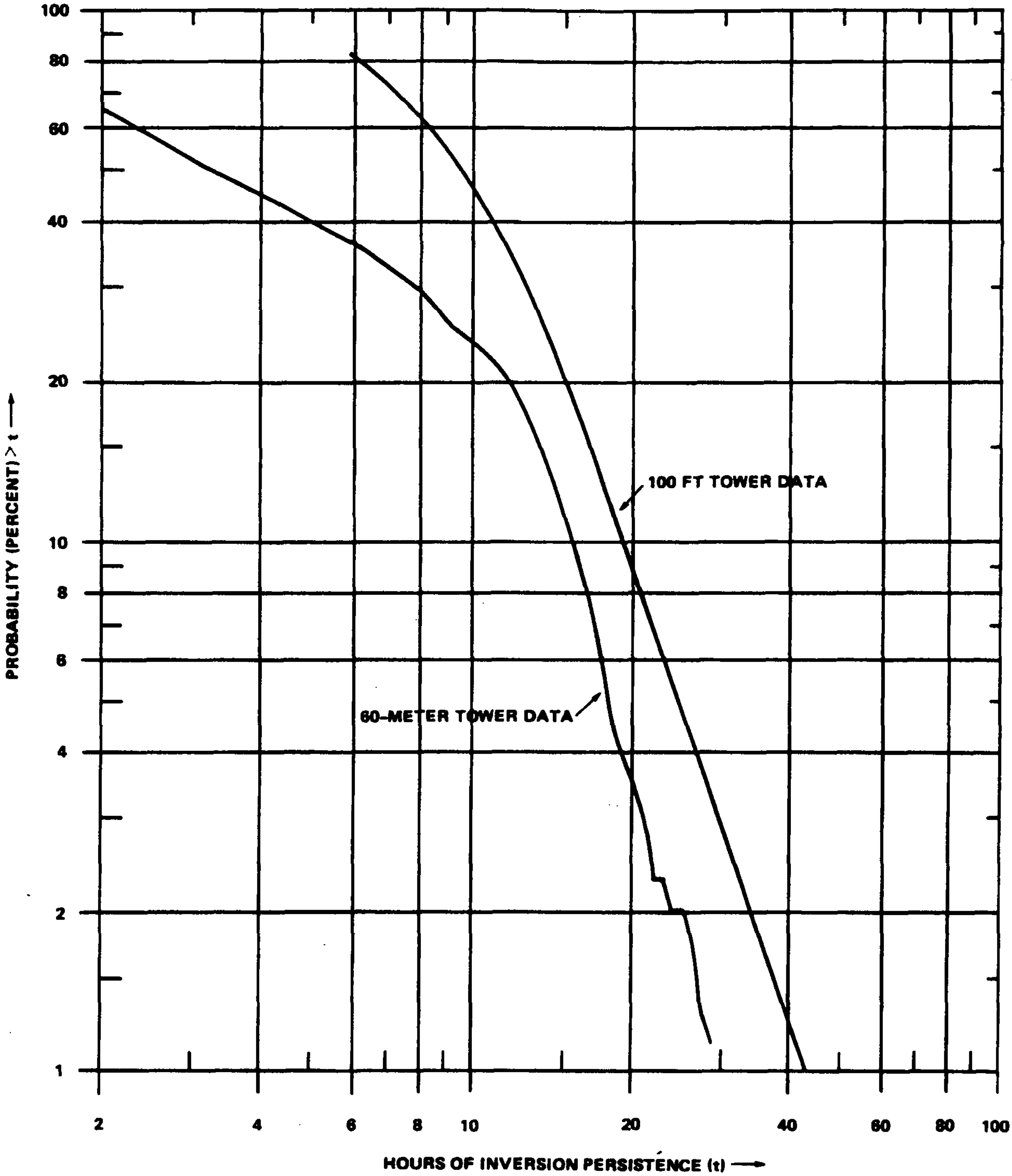

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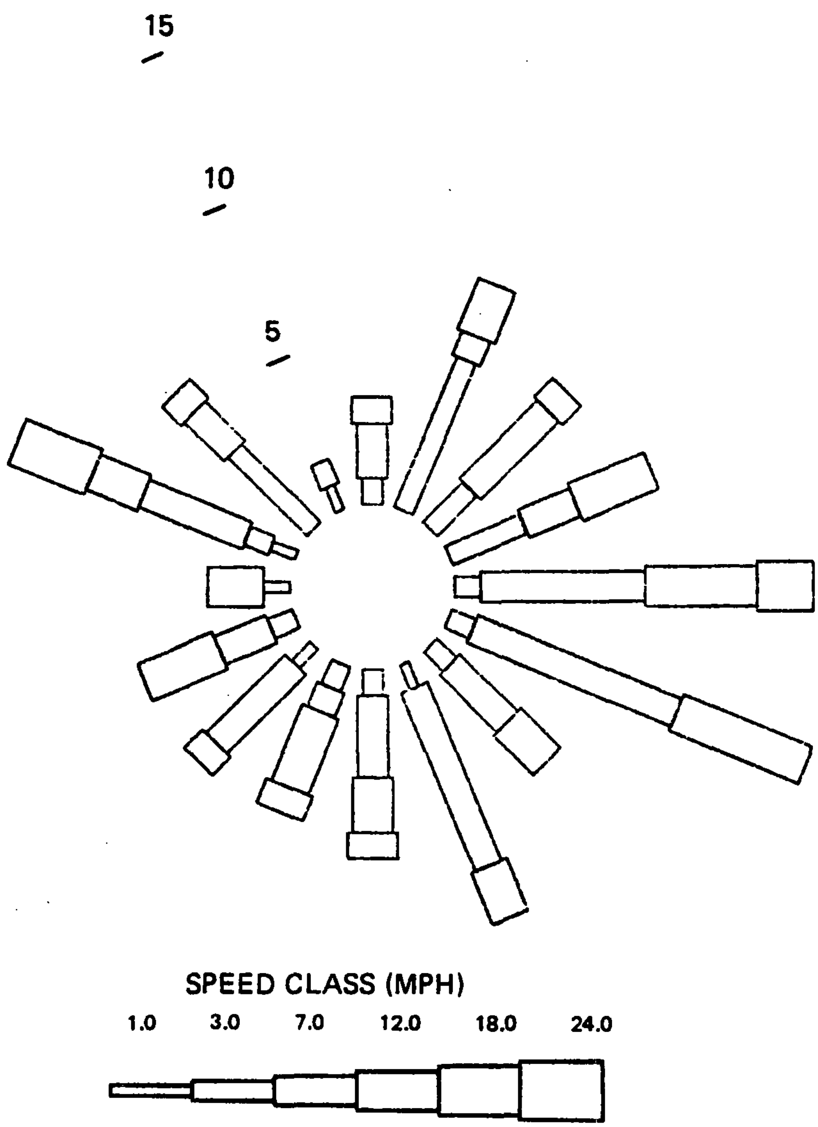
FIGURE 2.3-35

INVERSION PERSISTENCE PROBABILITY



DETROIT EDISON 60-METER TOWER 10-METER WIND ROSE
PRECIPITATION 1974-1975

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FIGURE 2.3-36

DISTRIBUTION OF WIND SPEED VERSUS WIND DIRECTION (PRECIPITATION ONLY)

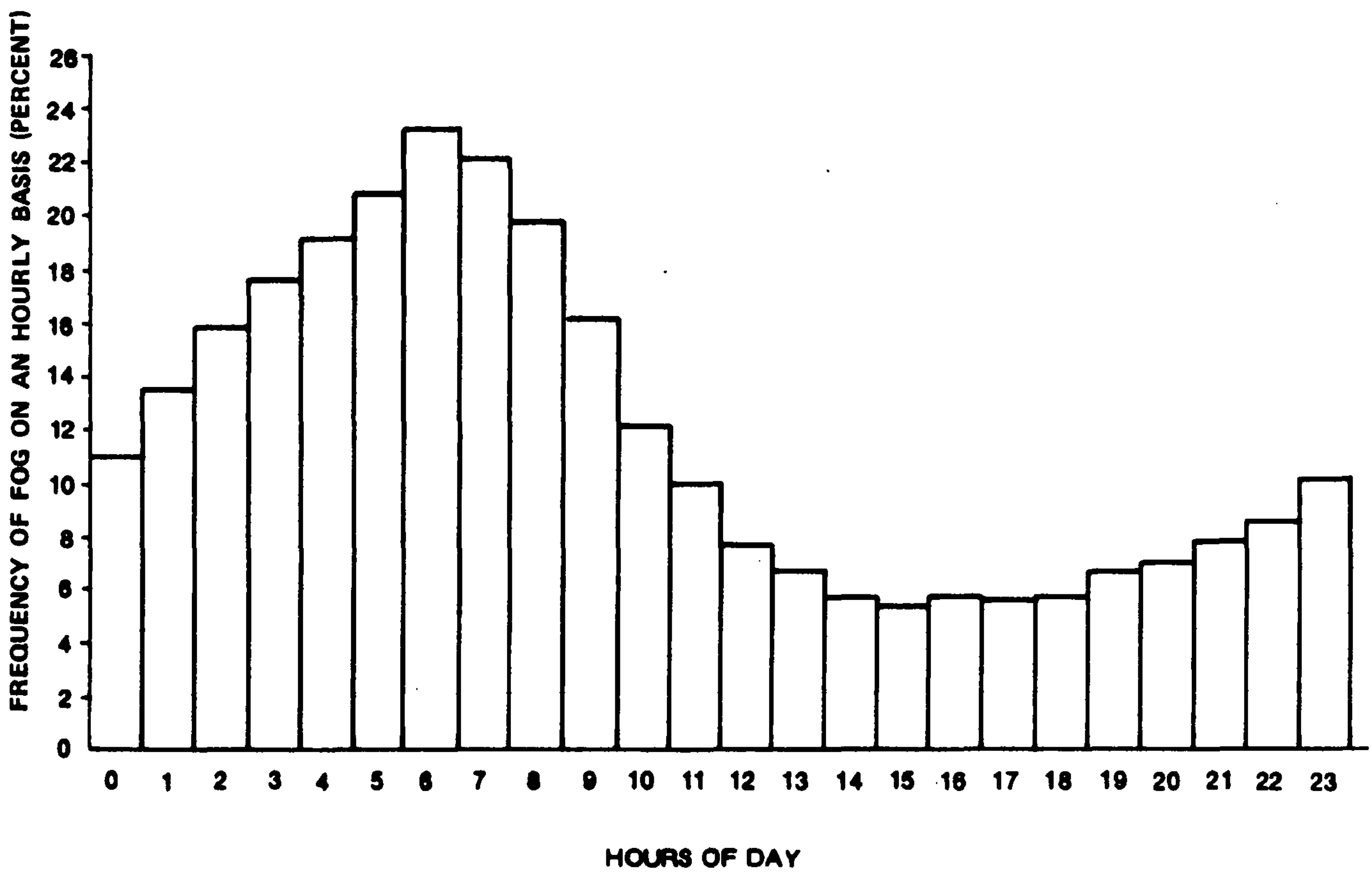

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FIGURE 2.3-37

FOG – OCCURANCE BY HOUR OF DAY
(DETROIT METROPOLITAN AIRPORT
1958-1962)

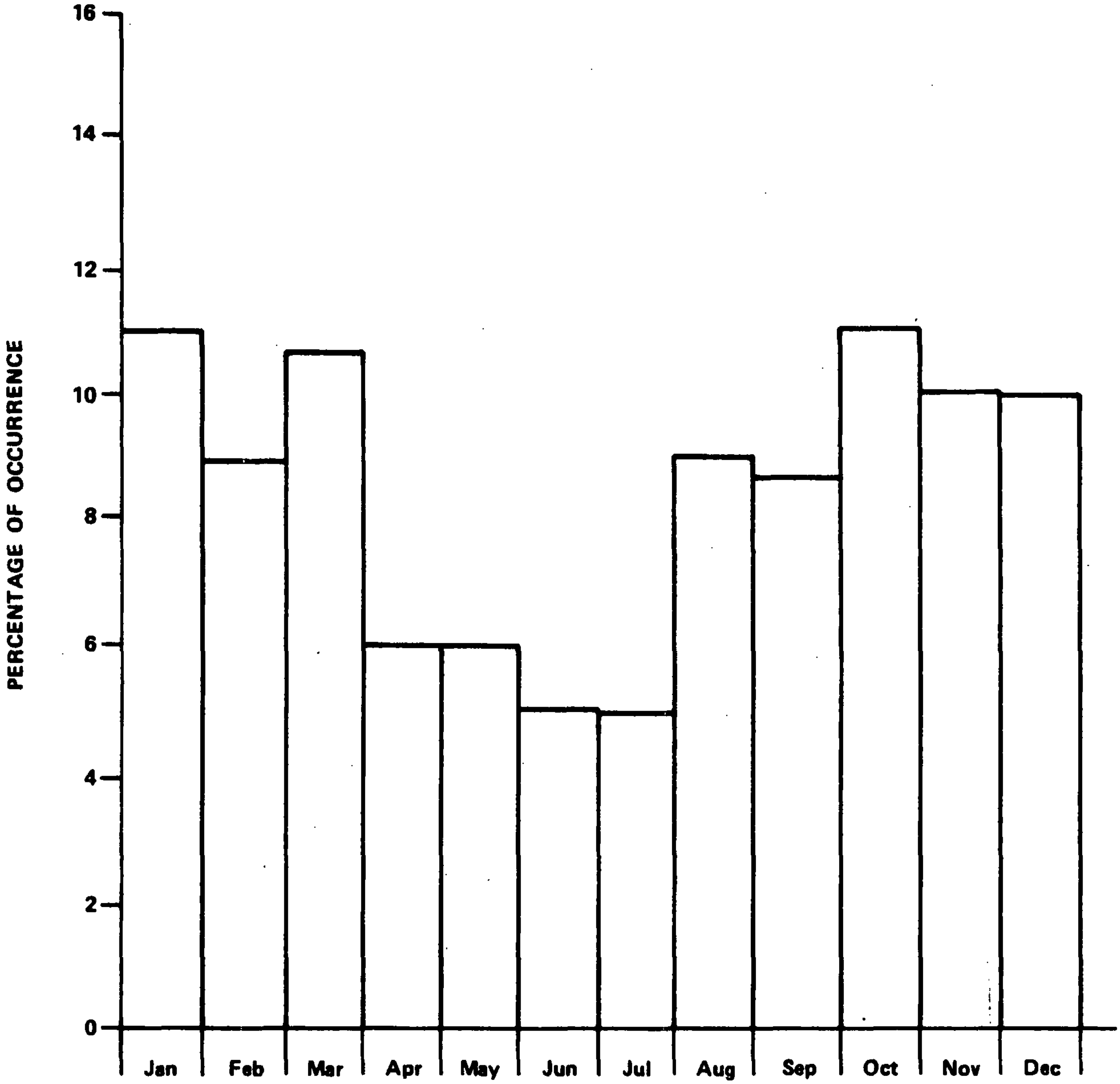

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FIGURE 2.3-38

FOG – MONTHLY PERCENTAGE OCCURANCE
(DETROIT METROPOLITAN AIRPORT
1958-1962)

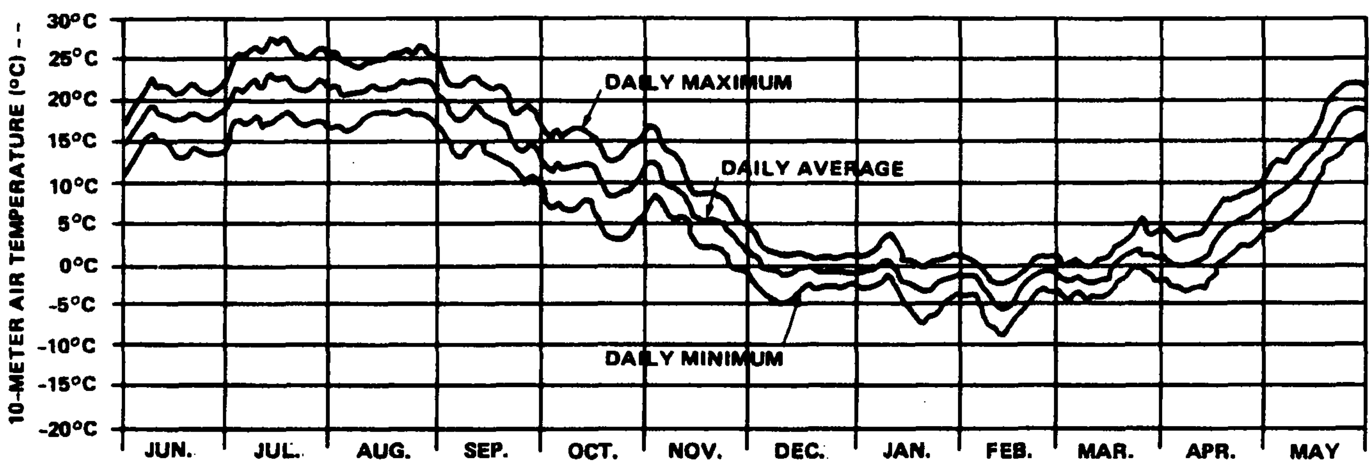

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FIGURE 2.3-39

MINIMUM, AVERAGE, AND MAXIMUM DAILY AIR TEMPERATURE AT THE FERMI SITE FROM 10-METER LEVEL DATA FROM JUNE 1974 THROUGH MAY 1975

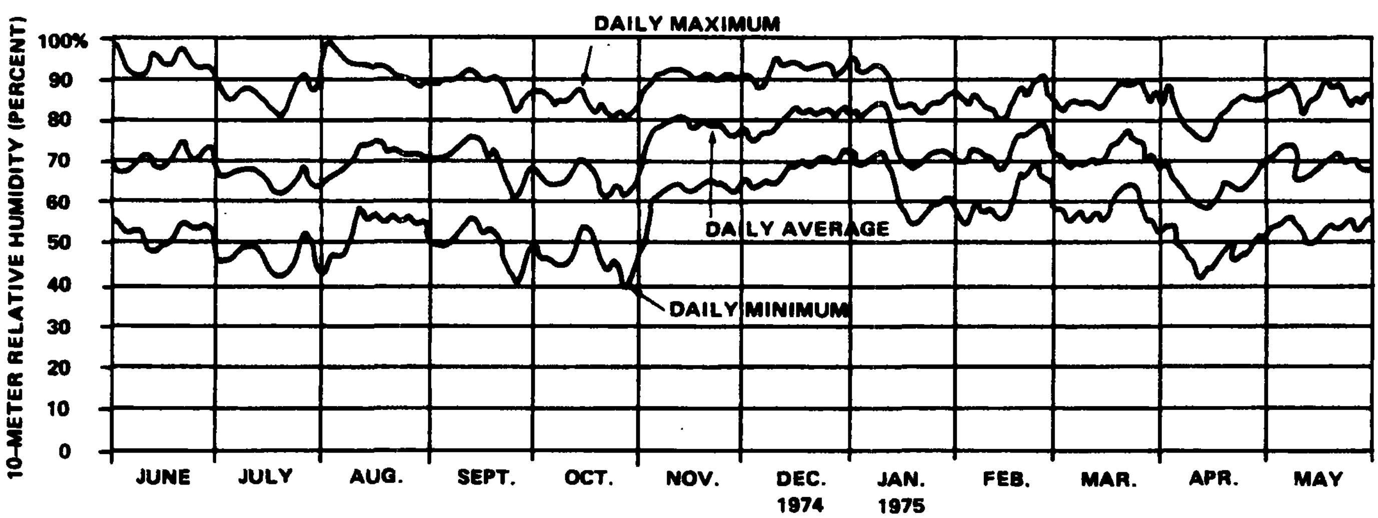

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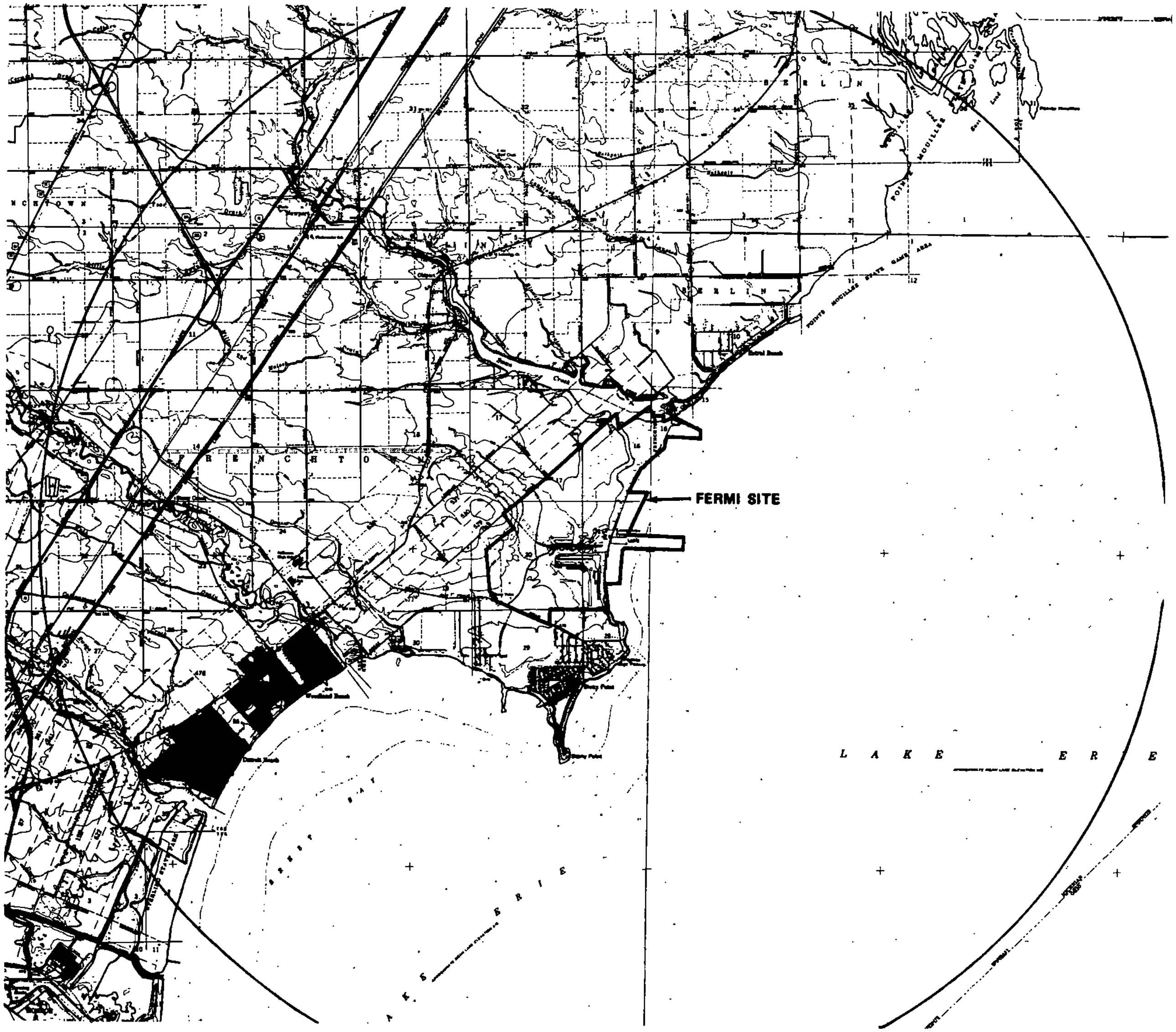
FIGURE 2.3-40

MINIMUM, AVERAGE, AND MAXIMUM DAILY RELATIVE HUMIDITY FROM JUNE 1974 THROUGH MAY 1975



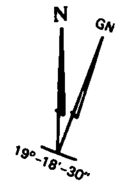


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FIGURE 2.3-41

TOPOGRAPHIC MAP OF THE AREA WITHIN A 5-MILE VICINITY

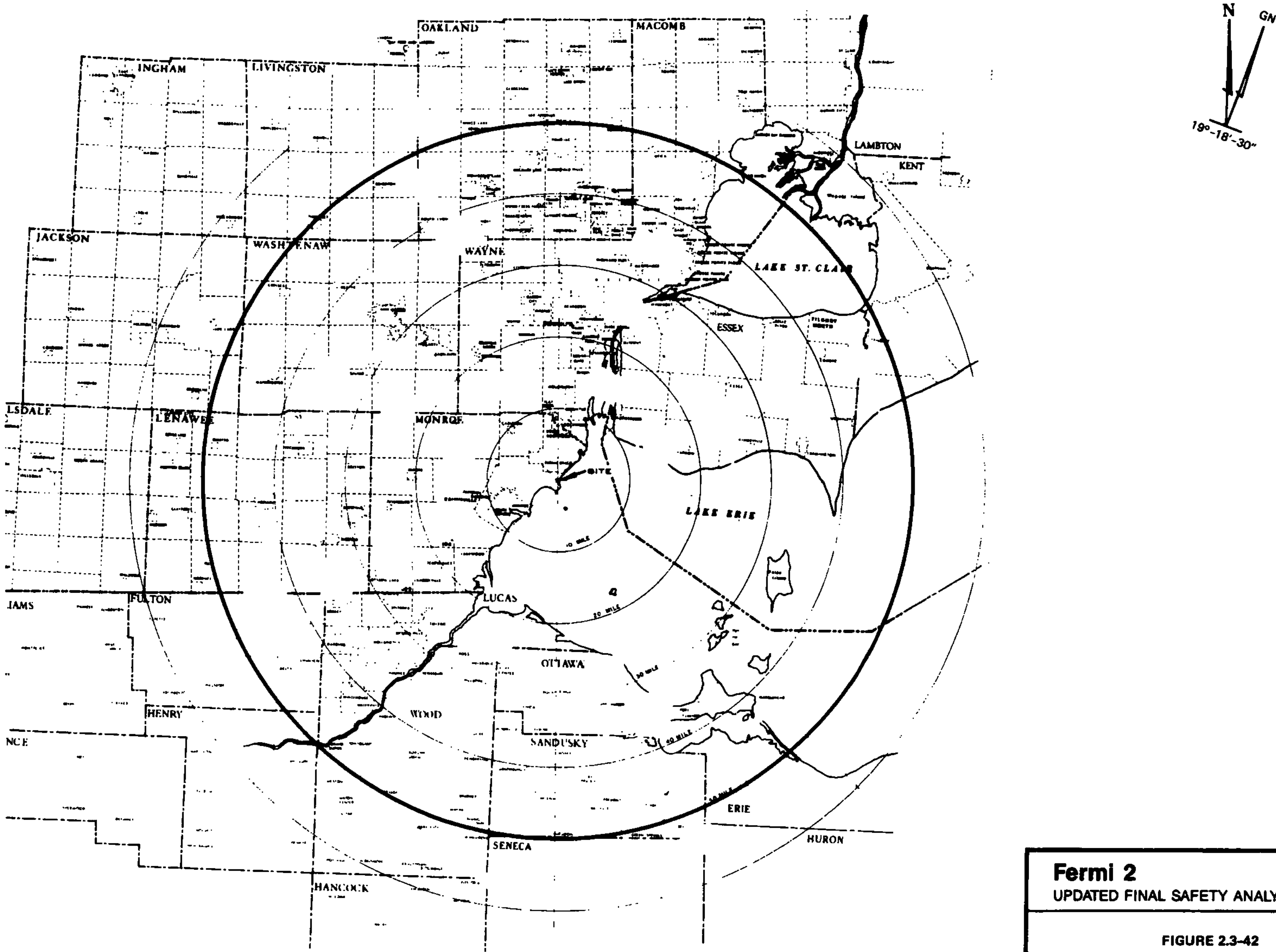

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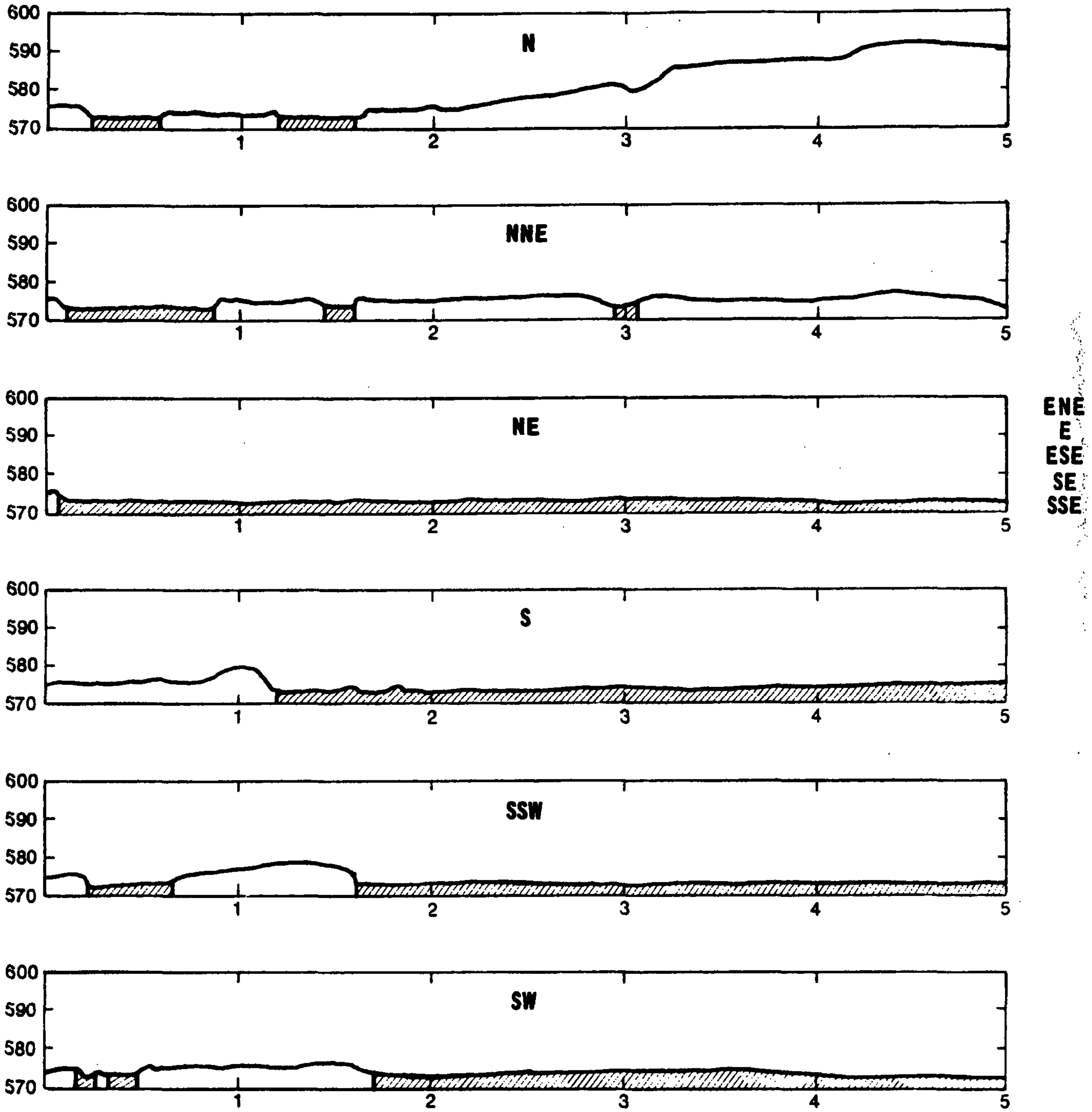
FIGURE 2.3-42

MAP OF THE AREA WITHIN A 50-MILE VICINITY



NOTE:

NE, ENE, ESE, SE, AND SSE DIRECTION ARE ALL IDENTICAL. ELEVATIONS IN FEET ABOVE SEA LEVEL (NEW YORK MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

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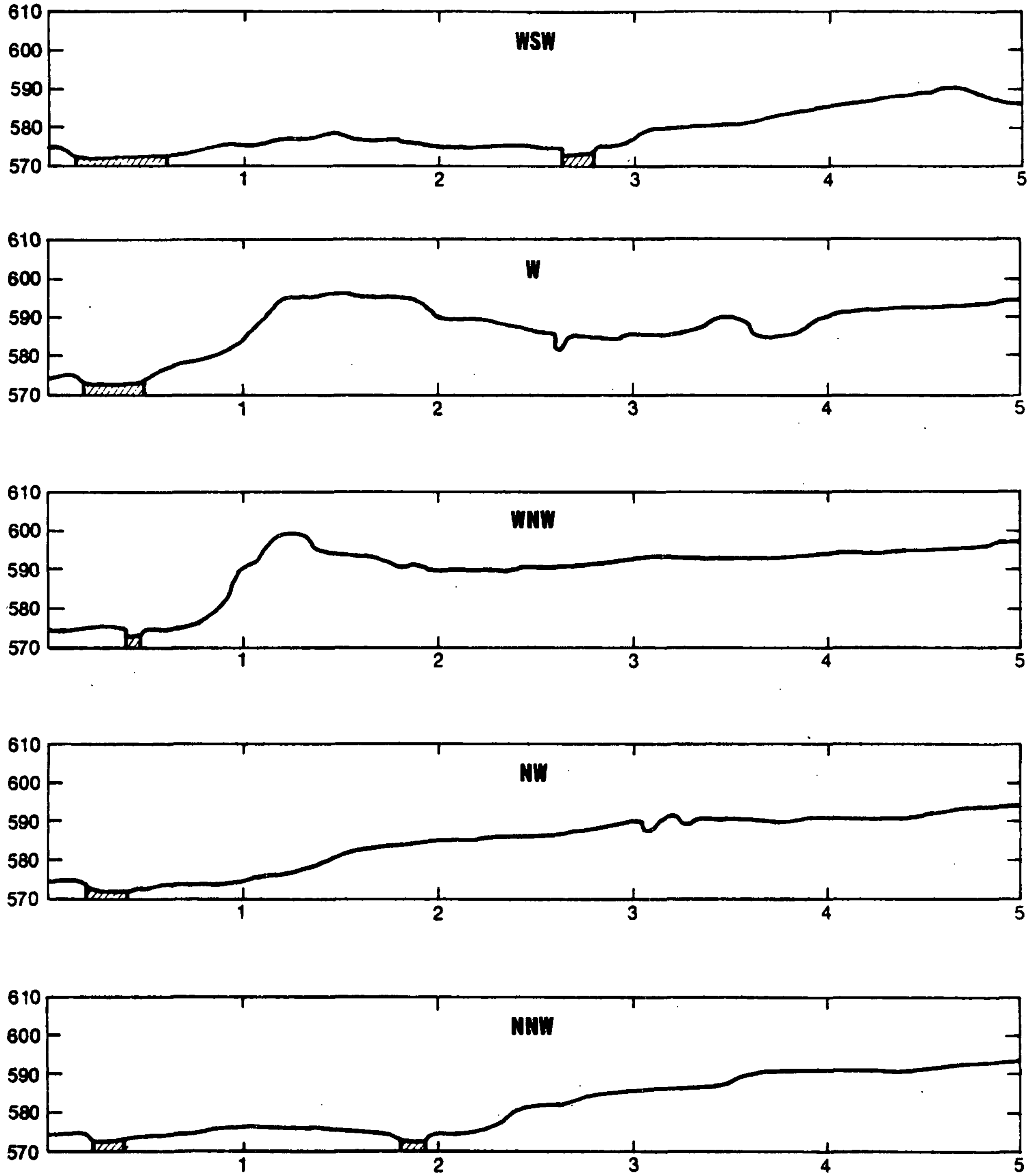
FIGURE 2.3-43, SHEET 1

TOPOGRAPHIC CROSS SECTION OUT TO 5 MILES



NOTE:

NE, ENE, ESE, SE, AND SSE DIRECTION ARE ALL IDENTICAL. ELEVATIONS IN FEET ABOVE SEA LEVEL (NEW YORK MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

WATER

LAND

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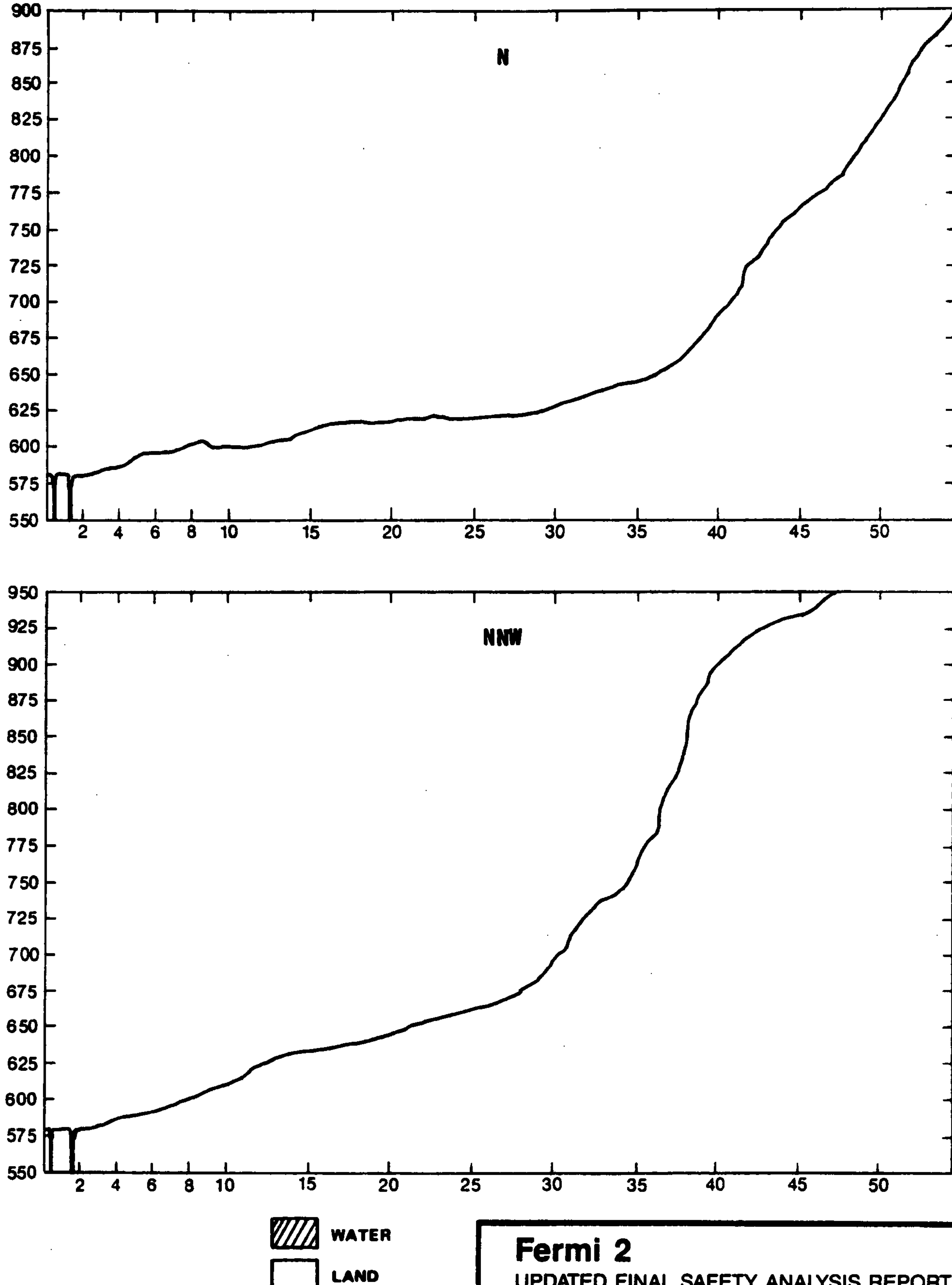
FIGURE 2.3-43, SHEET 2

TOPOGRAPHIC CROSS SECTION OUT TO 5 MILES



NOTE:

ELEVATION IS IN FEET ABOVE SEA LEVEL. (N.Y. MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

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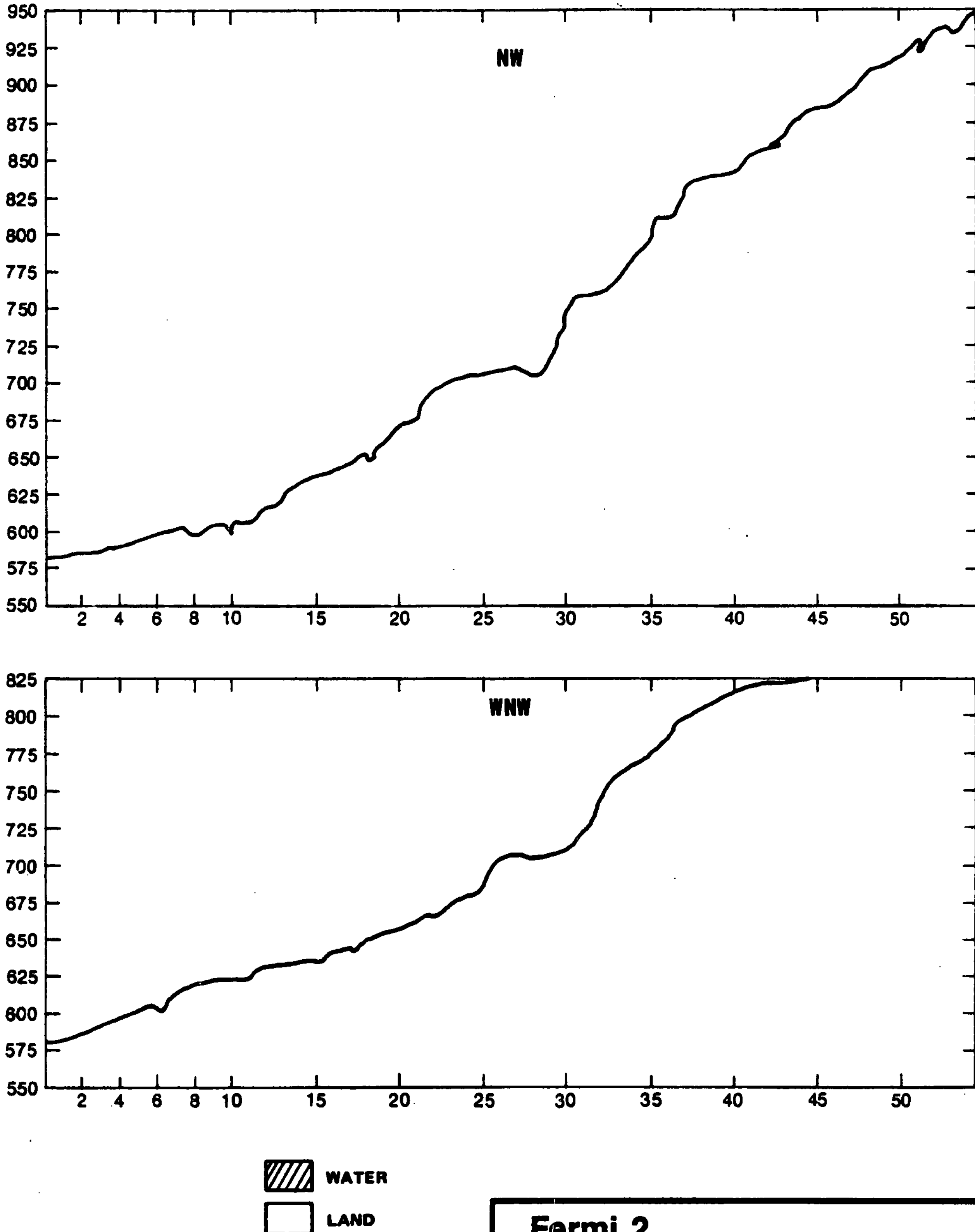
FIGURE 2.3-44, SHEET 1

TOPOGRAPHIC CROSS SECTION OUT TO 50 MILES



NOTE:

ELEVATION IS IN FEET ABOVE SEA LEVEL. (N.Y. MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

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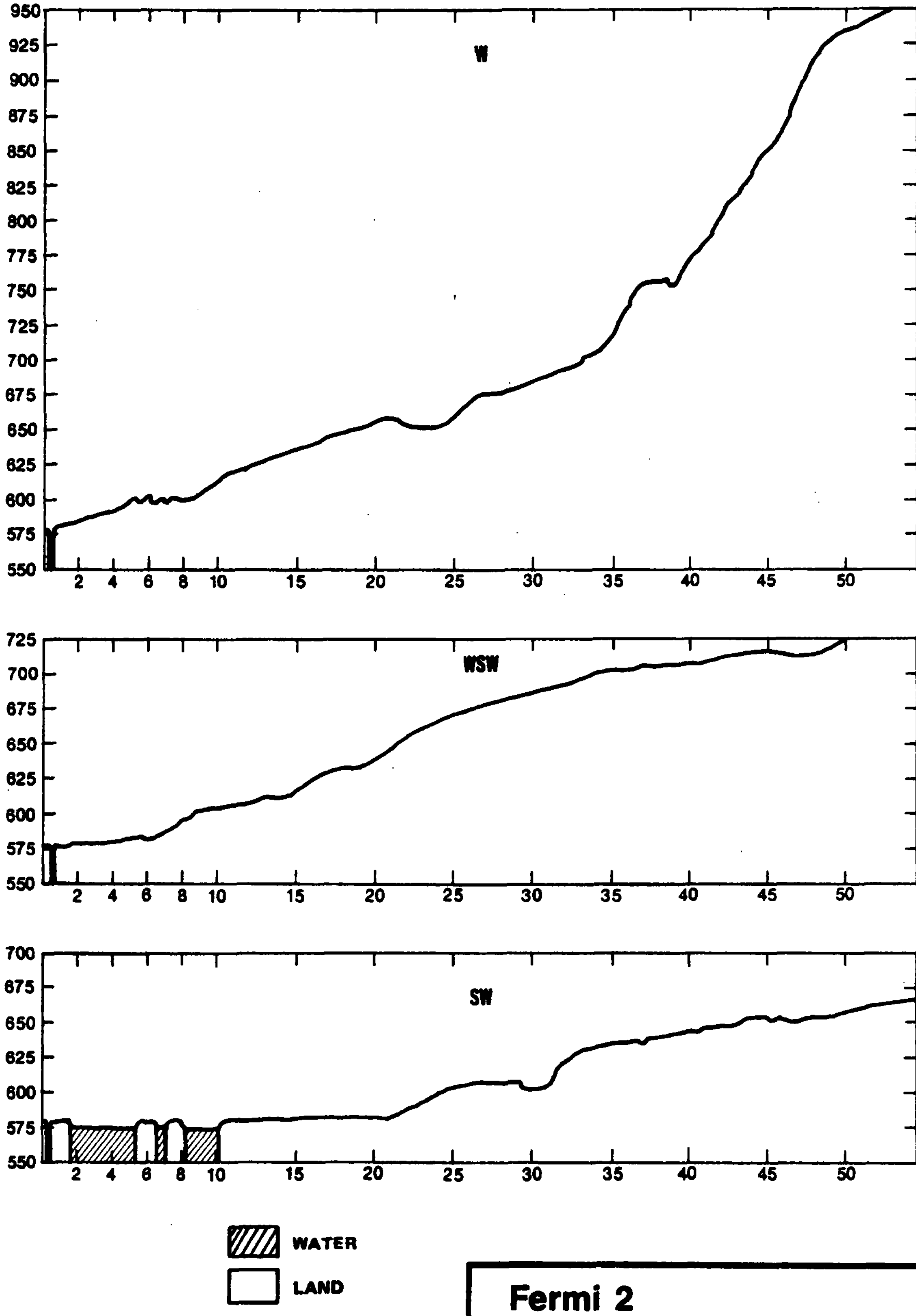
FIGURE 2.3-44, SHEET 2

TOPOGRAPHIC CROSS SECTION OUT TO 50 MILES



NOTE:

ELEVATION IS IN FEET ABOVE SEA LEVEL. (N.Y, MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

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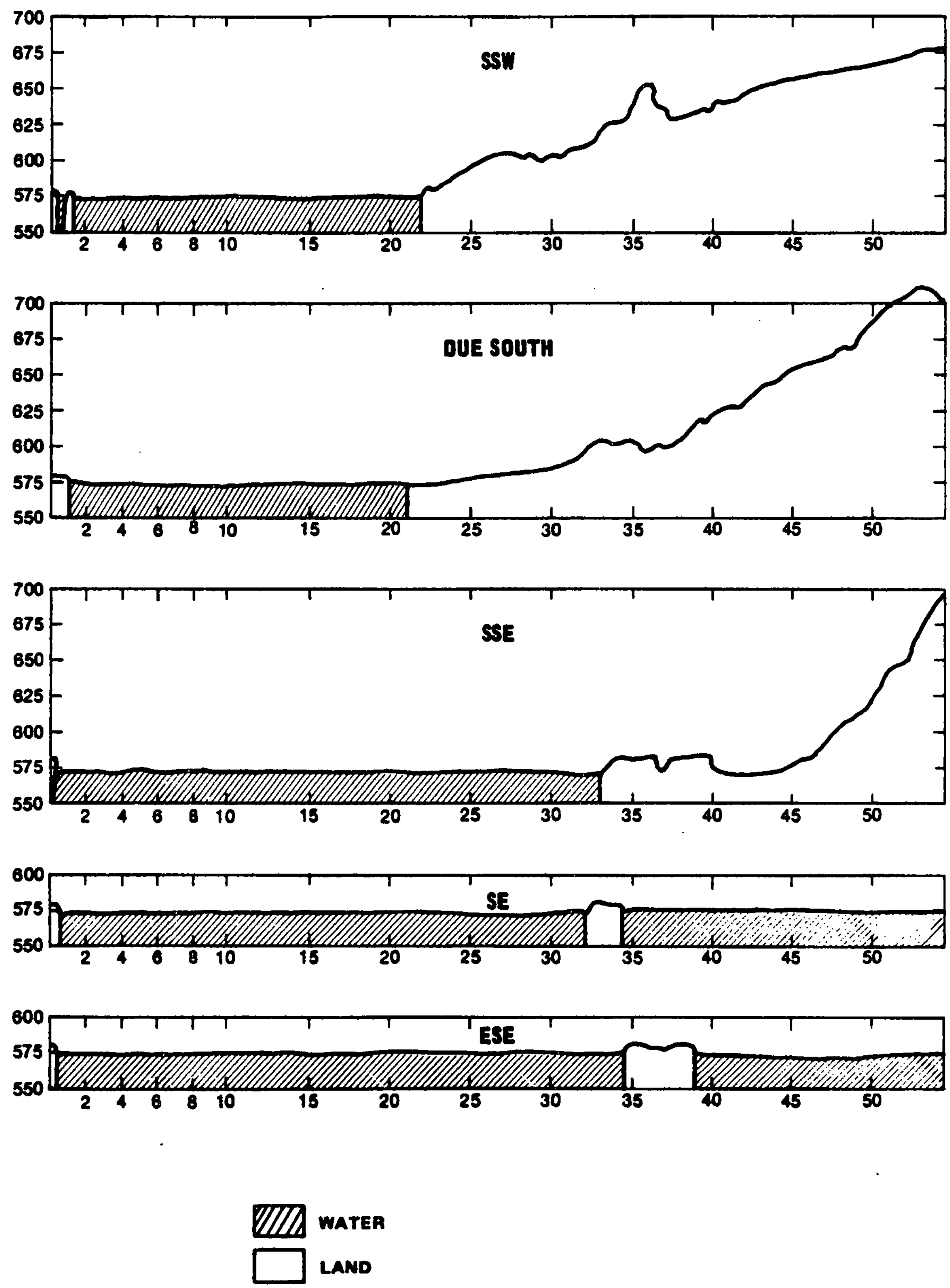
FIGURE 2.3-44, SHEET 3

TOPOGRAPHIC CROSS SECTION OUT TO 50 MILES



NOTE:

ELEVATION IS IN FEET ABOVE SEA LEVEL. (N.Y, MEAN TIDE, 1935). SECTION TAKEN IN DIRECTION INDICATED.

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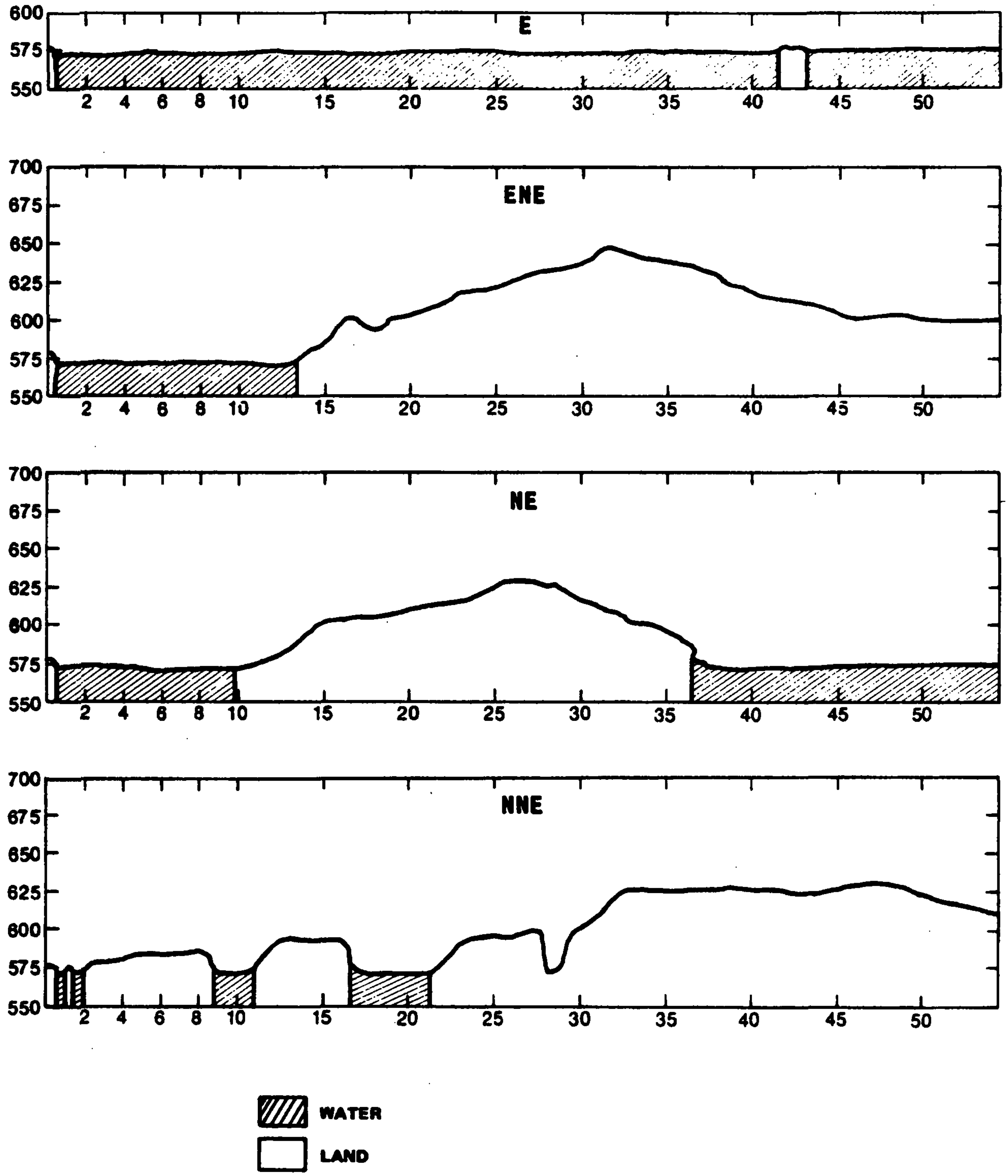
FIGURE 2.3-44, SHEET 4

TOPOGRAPHIC CROSS SECTION OUT TO 50 MILES



NOTE:

ELEVATION IS IN FEET ABOVE SEA LEVEL. (N.Y. MEAN TIDE, 1936). SECTION TAKEN IN DIRECTION INDICATED.

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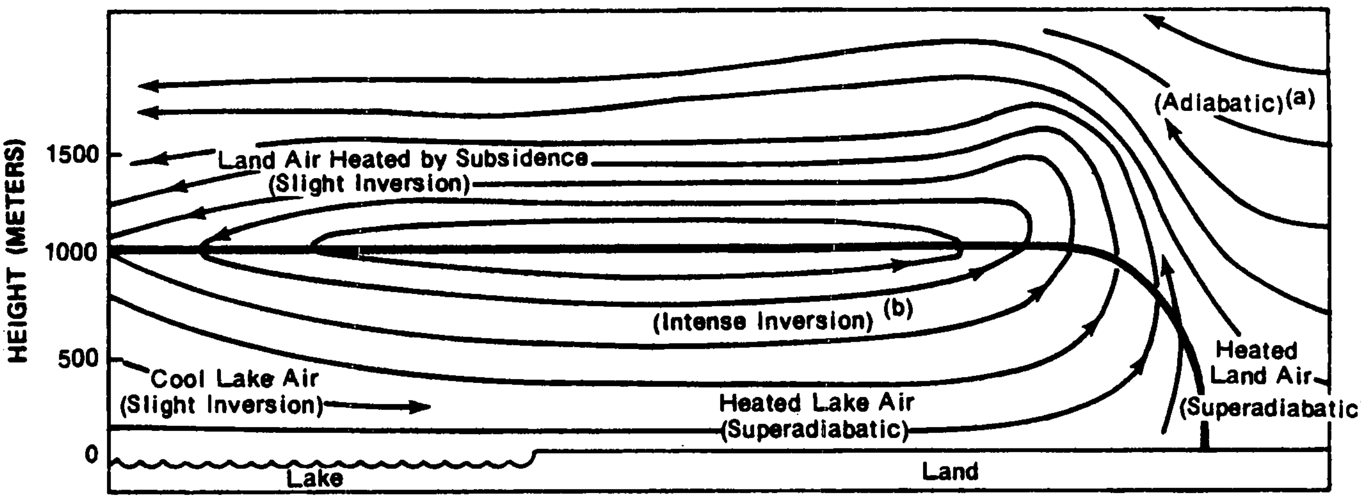
FIGURE 2.3-44, SHEET 5

TOPOGRAPHIC CROSS SECTION OUT TO 50 MILES



(a) Adiabatic Temperature Gradient = -.98 C 100m or -5.4 F 1000 ft

(b) Inversion = Temperature Increasing With Height

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FIGURE 2.3-45

STREAMLINES DURING A LAKE BREEZE SITUATION

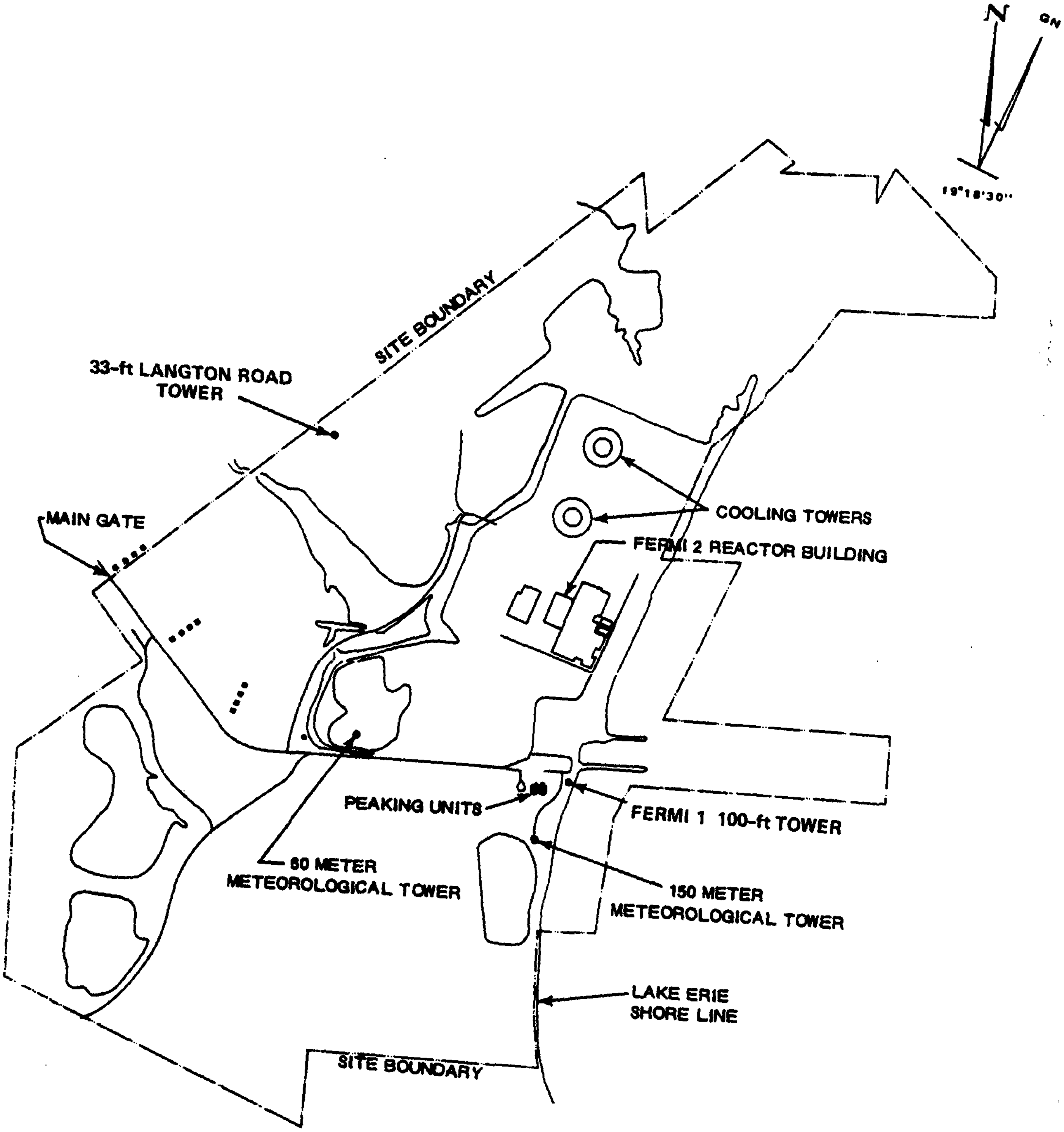

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FIGURE 2.3-46

MAP OF SITE INCLUDING TOWER LOCATIONS

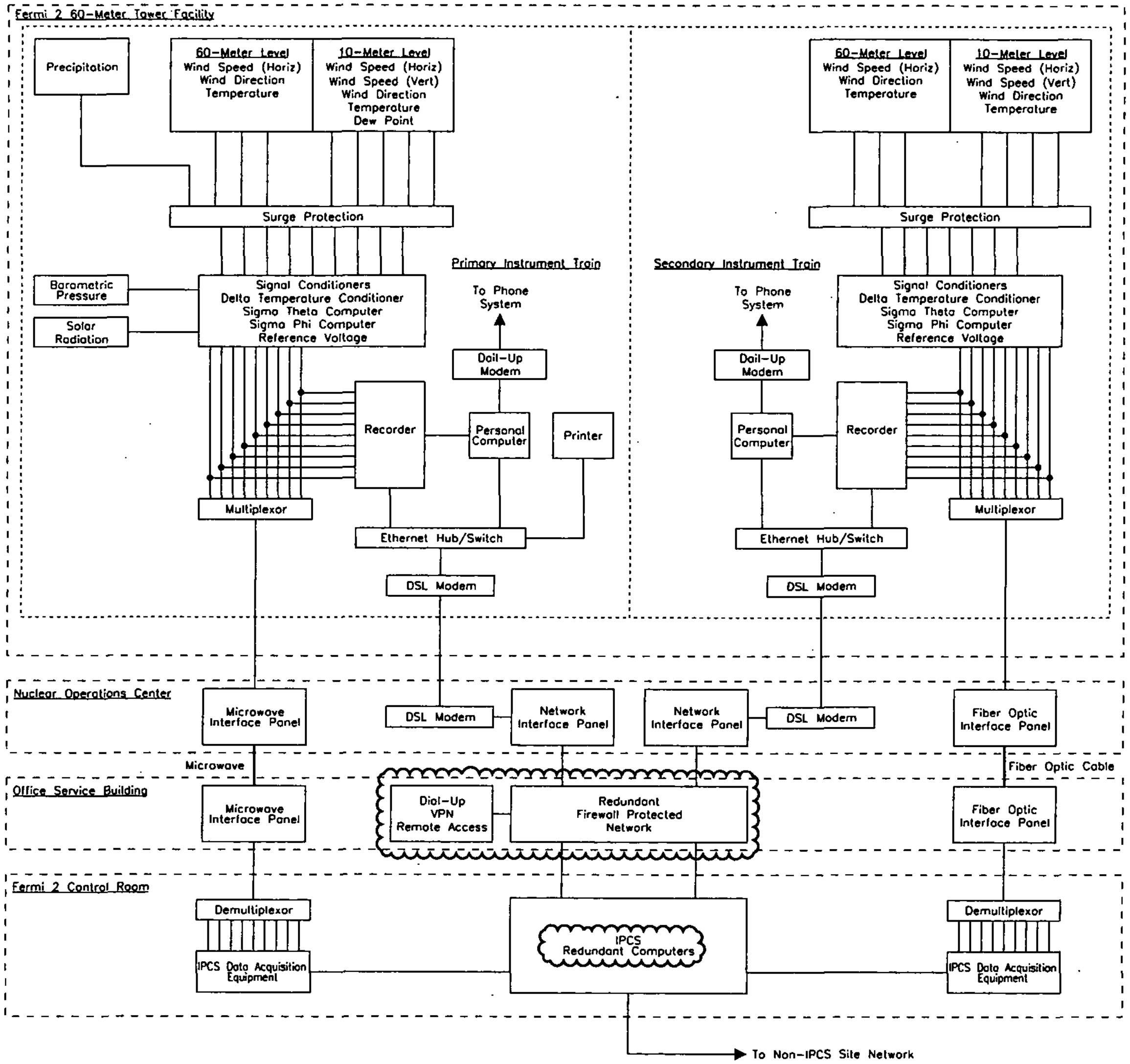

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FIGURE 2.3-47

BLOCK DIAGRAM OF DETROIT EDISON METEOROLOGICAL DATA ACQUISITION SYSTEM

[redacted]

Redacted in accordance with 10 CFR 2.390

DETROIT EDISON COMPANY DRAWING NO. 6A721-2042, REV. E

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FIGURE 2.3-48

CROSS SECTIONAL AREAS OF REACTOR BUILDING AND AUXILIARY BUILDING

FIGURES 2.3-49 THROUGH 2.3-51 HAVE BEEN DELETED

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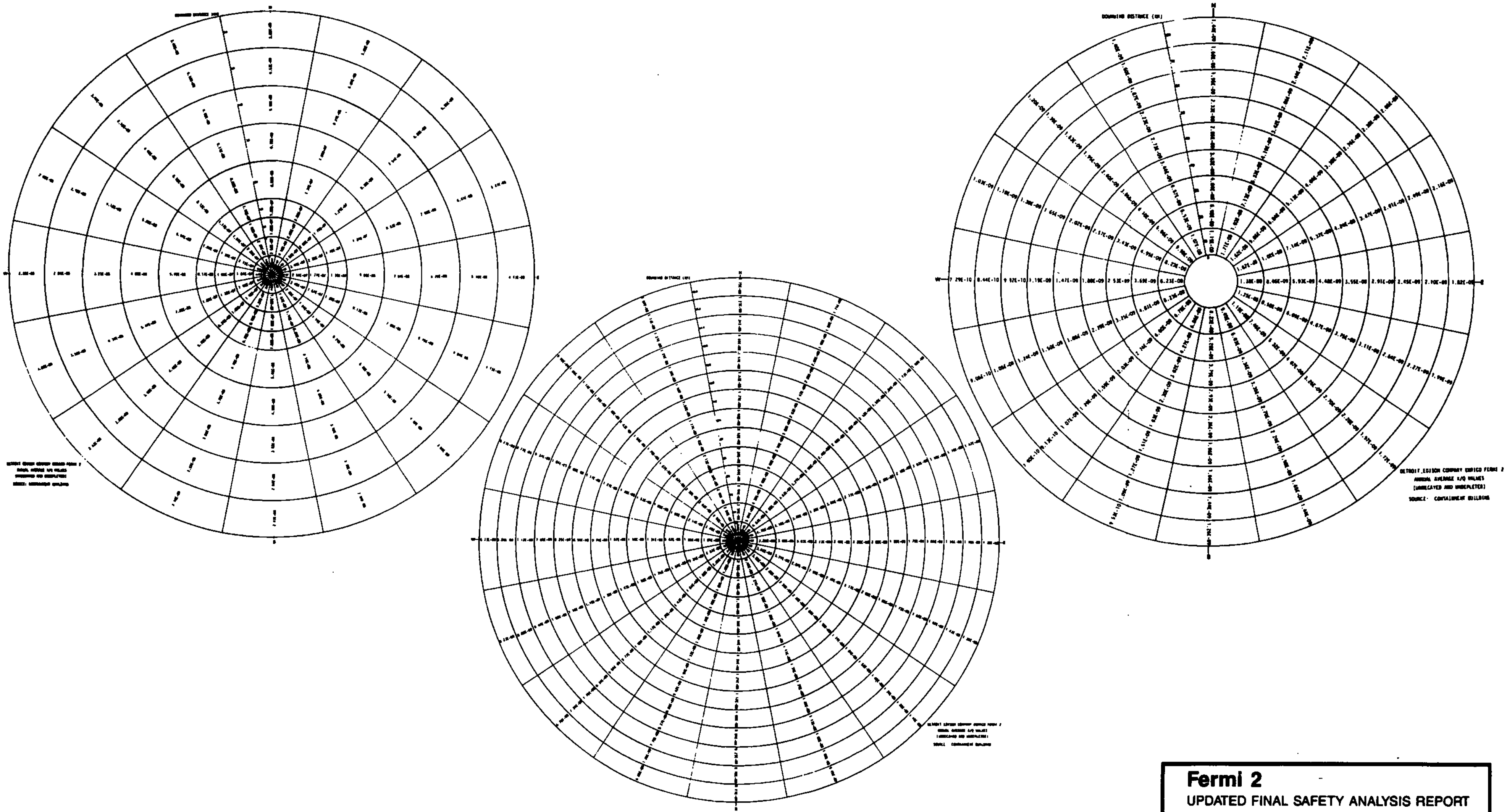

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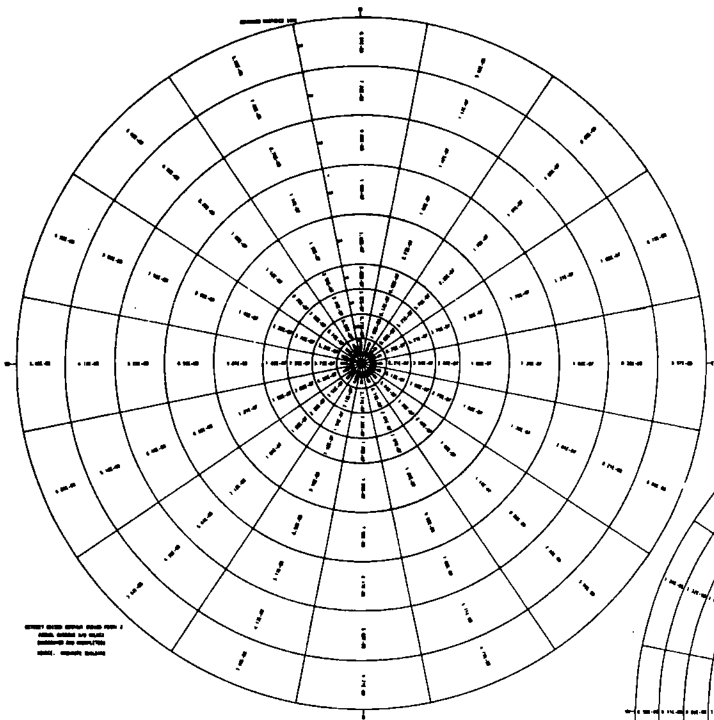
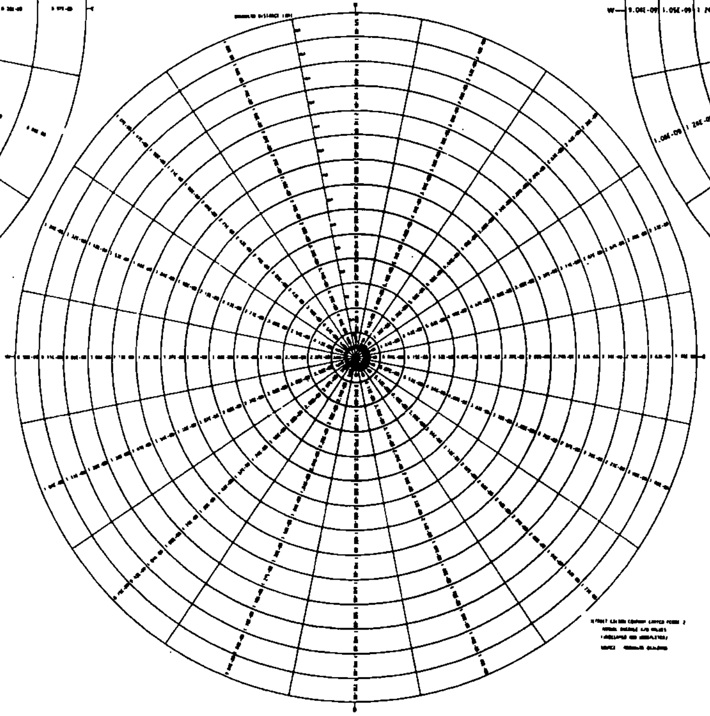
FIGURE 2.3-52

ANNUAL AVERAGE X/Q VALUES
CONTAINMENT BUILDING SOURCE
(UNDECAYED AND UNDEPLETED)





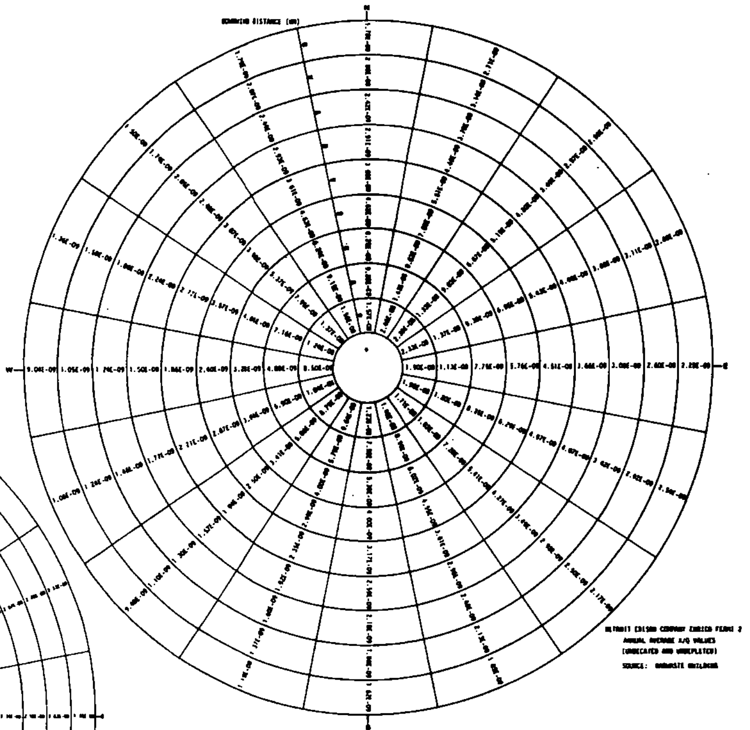


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FIGURE 2.3-53

ANNUAL AVERAGE X/Q VALUES
RADWASTE BUILDING SOURCE
(UNDECAYED AND UNDEPLETED)

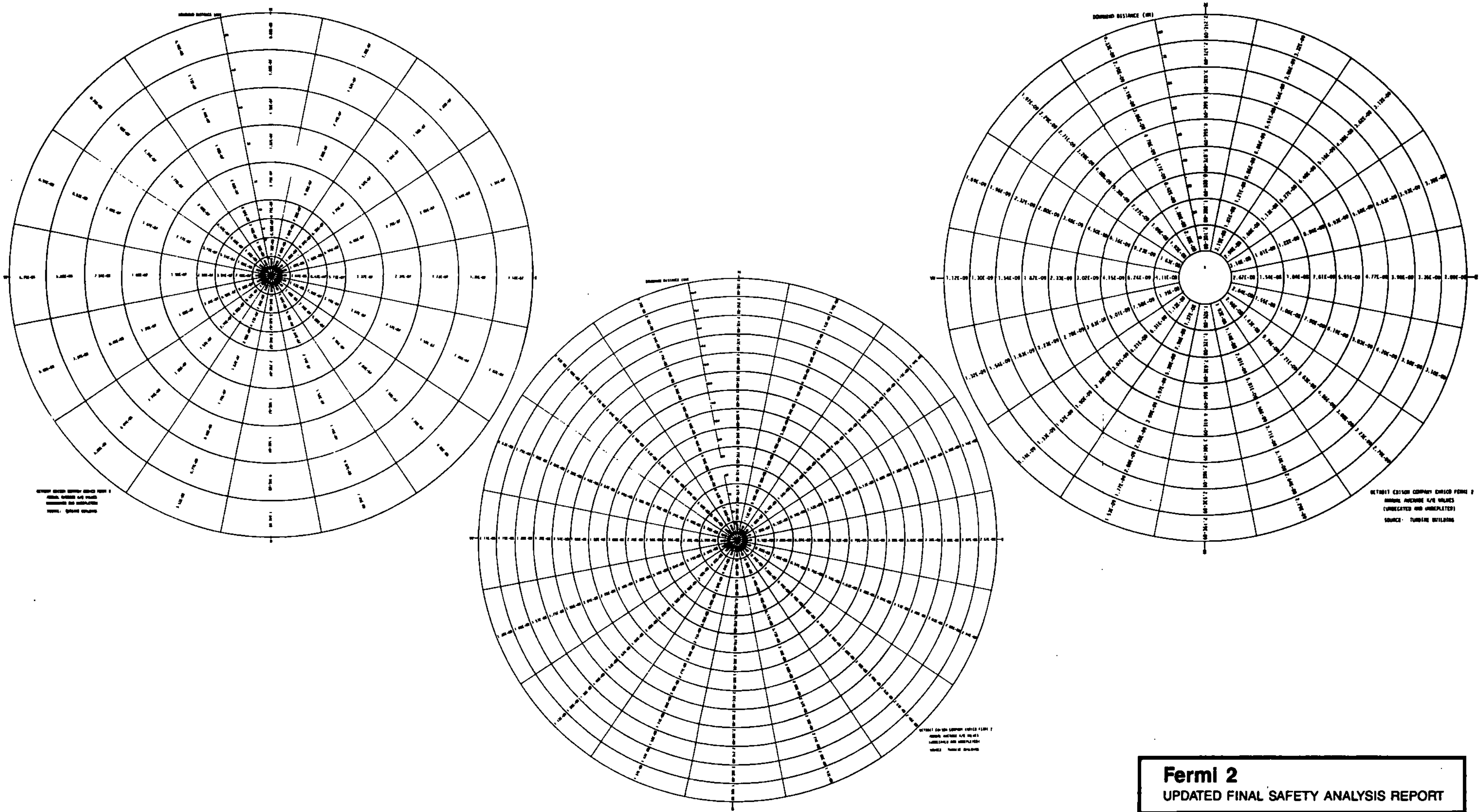

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FIGURE 2.3-64

ANNUAL AVERAGE X/Q VALUES
TURBINE BUILDING SOURCE
(UNDECAYED AND UNDEPLETED)

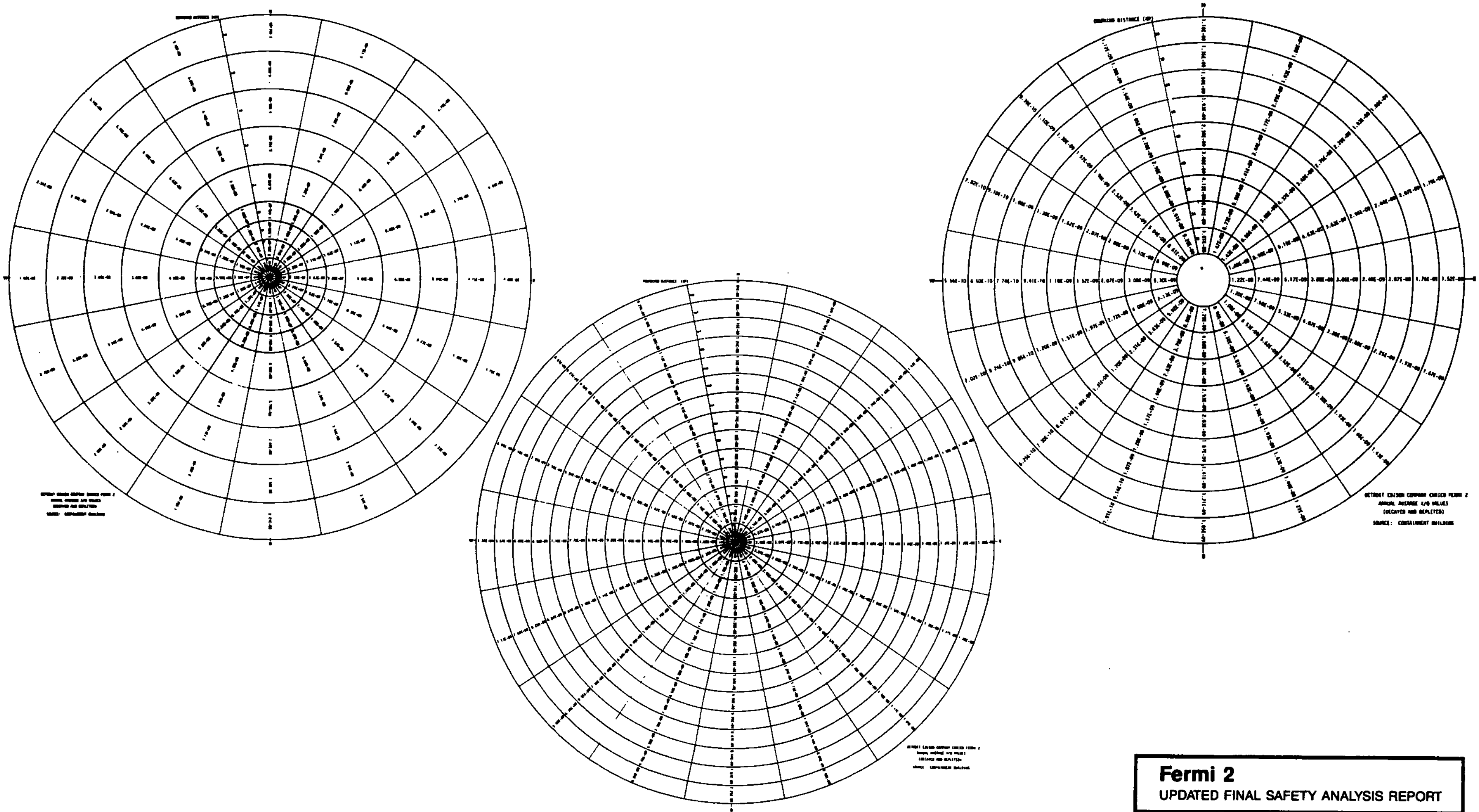

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FIGURE 2.3-55

ANNUAL AVERAGE X/Q VALUES CONTAINMENT BUILDING SOURCE (DECAYED AND DEPLETED)

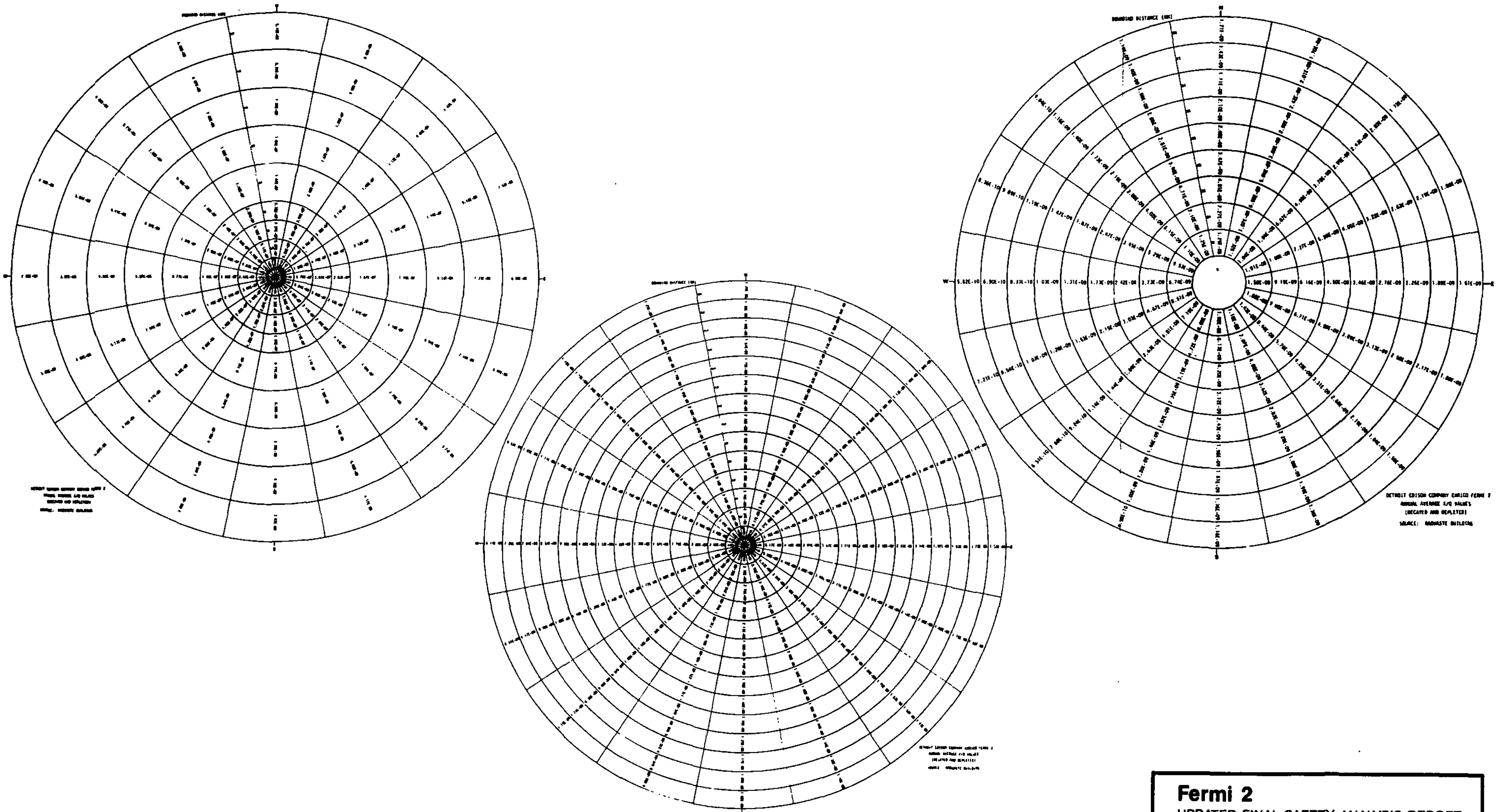

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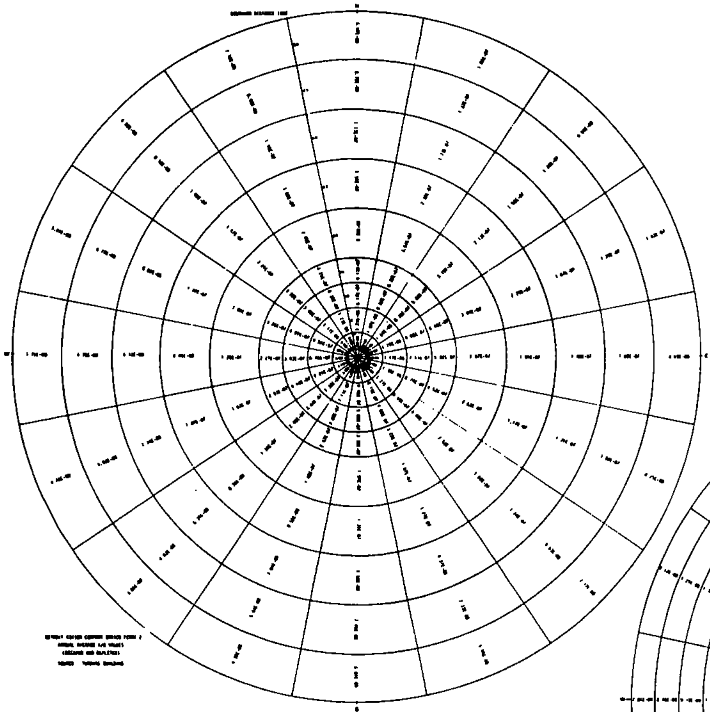
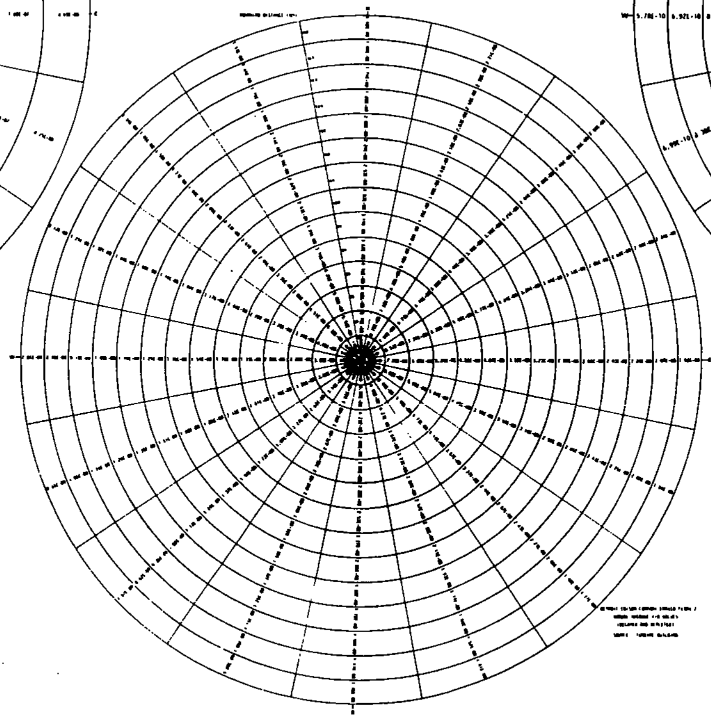
FIGURE 2.3-56

ANNUAL AVERAGE X/Q VALUES
RADWASTE BUILDING SOURCE
(DECAYED AND DEPLETED)





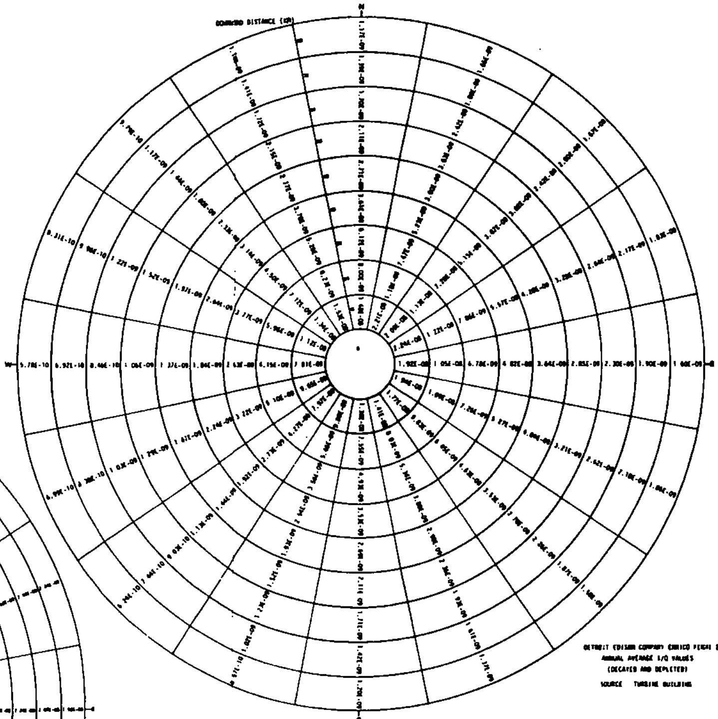


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FIGURE 2.3-57

ANNUAL AVERAGE X/Q VALUES
TURBINE BUILDING SOURCE
(DECAYED AND DEPLETED)

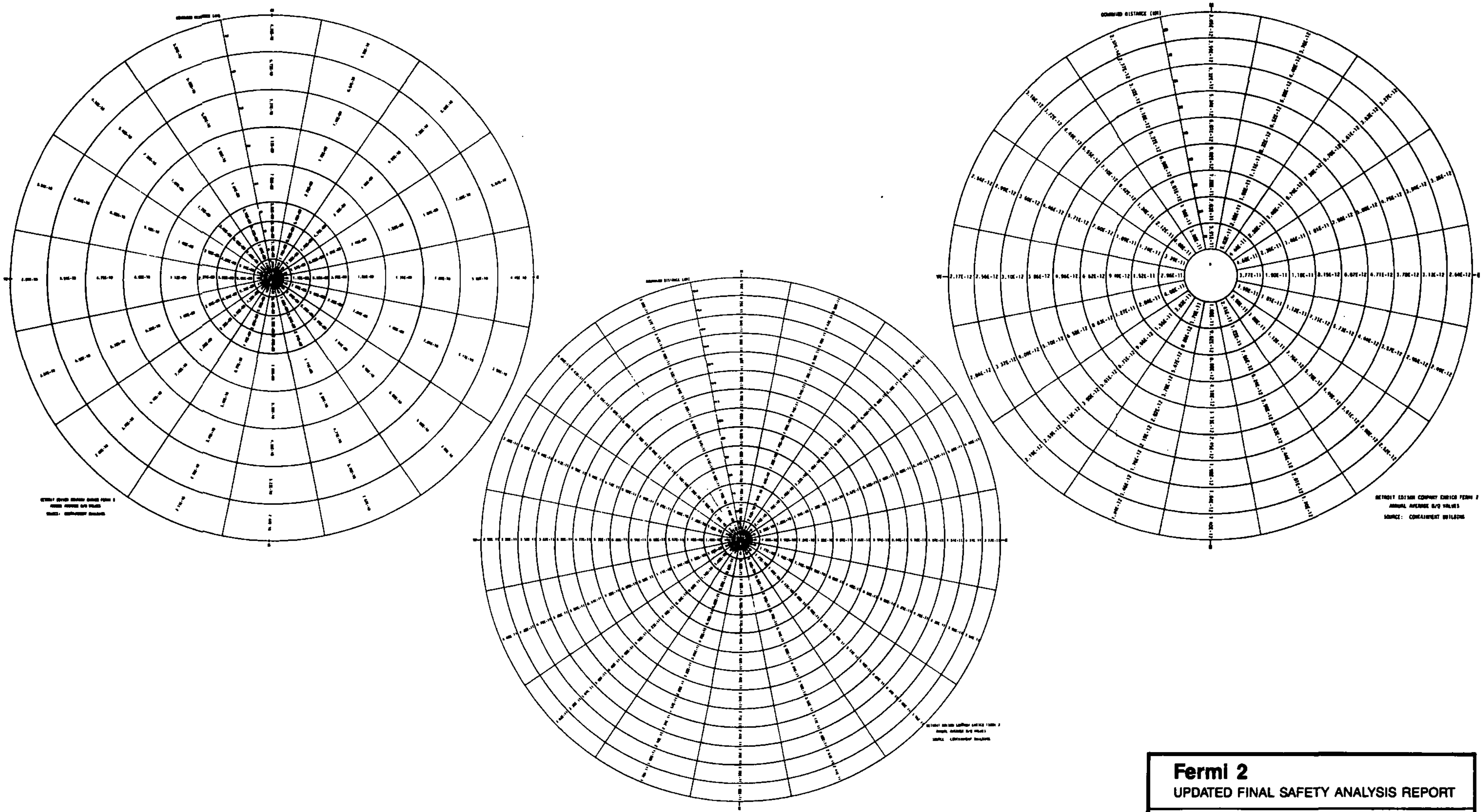

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FIGURE 2.3-58

RELATIVE DEPOSITION D/Q VALUES
CONTAINMENT BUILDING SOURCE

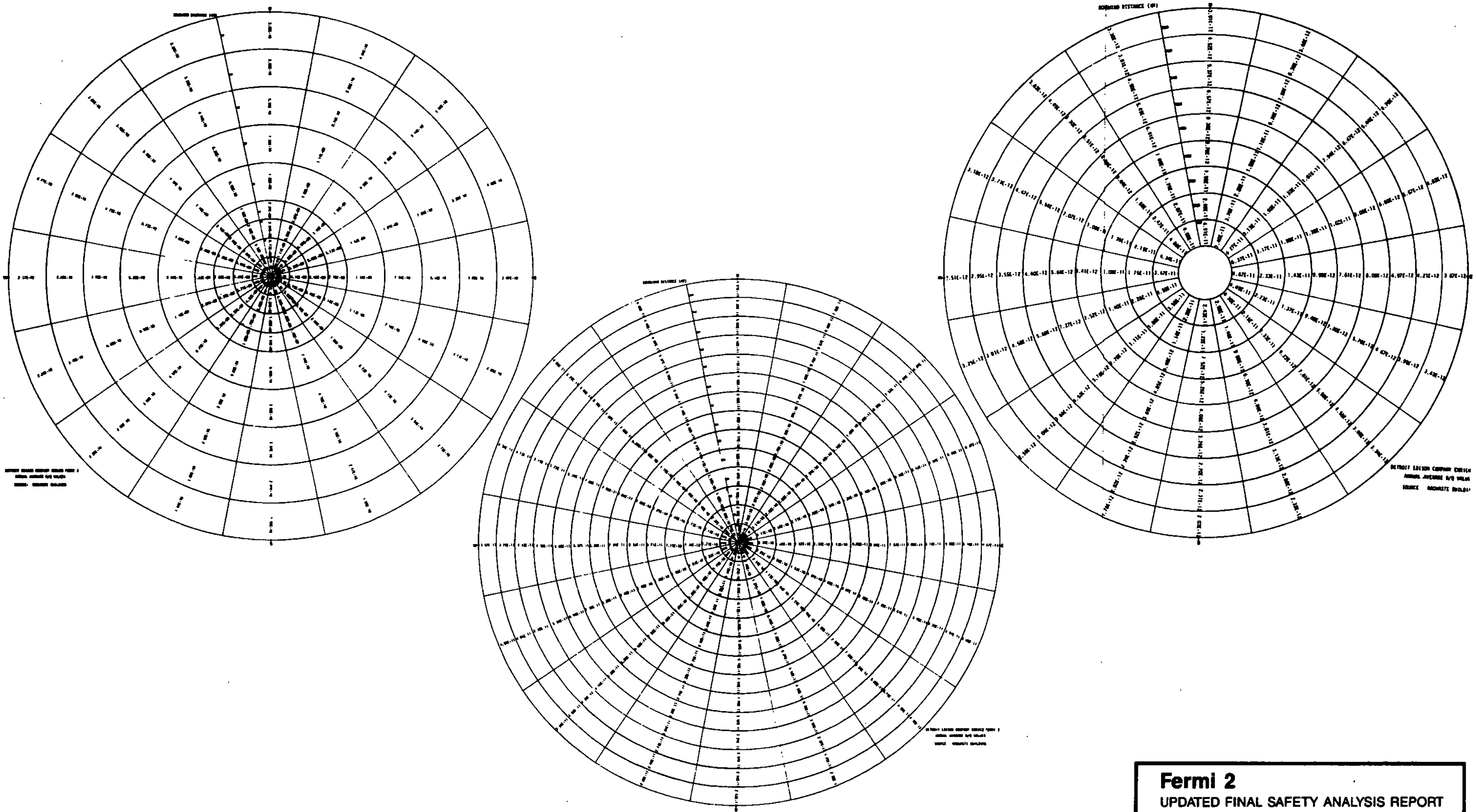

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FIGURE 2.3-59

RELATIVE DEPOSITION D/Q VALUES RADWASTE BUILDING SOURCE

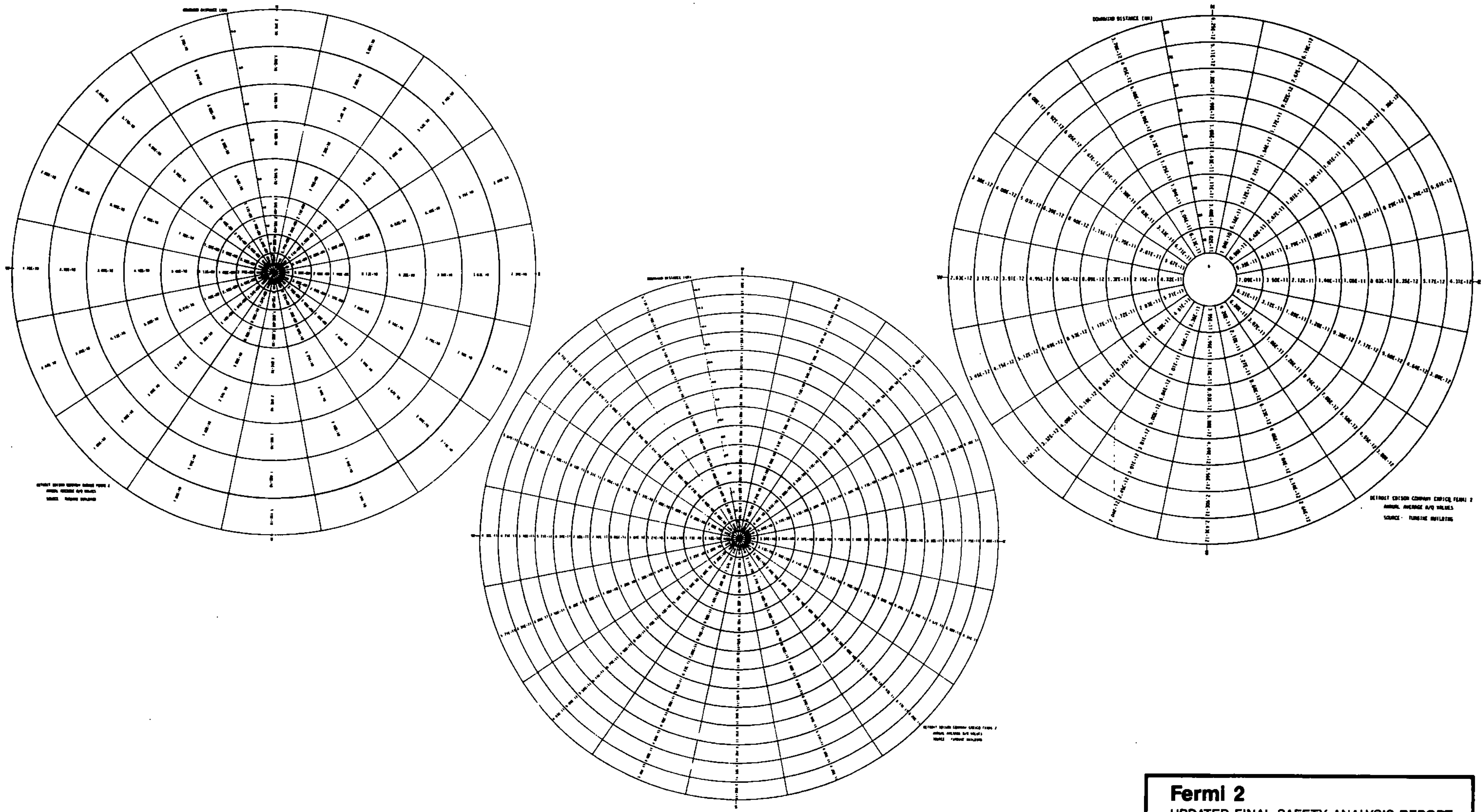

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FIGURE 2.3-60

RELATIVE DEPOSITION D/Q VALUES
TURBINE BUILDING SOURCE

2.4. HYDROLOGIC ENGINEERING

2.4.1. Hydrologic Description

2.4.1.1. Site and Facilities

The Fermi site is located adjacent to the western shore of Lake Erie (Figure 2.4-1). Prior to construction of Fermi 2, the site area was a lagoon separated from Lake Erie by a barrier beach, known as Lagoona Beach, which formed the eastern site boundary. The Fermi 2 preconstruction topography is shown in Figure 2.4-2. The lagoon was connected to Lake Erie by Swan Creek, a perennial stream that discharges into Lake Erie about 1 mile north of the Fermi plant site. The site for Fermi 2 was prepared by excavating soft soils and rock, and constructing rock fill to a nominal plant grade elevation of 583 ft. All elevations refer to New York Mean Tide, 1935. The topography of the developed site as of December 10, 1972, is shown in Figure 2.4-3.

Category I structures housing safety-related equipment consist of the reactor/auxiliary building and the residual heat removal (RHR) complex. These structures are indicated in Figure 2.1-5. The plant site is not susceptible to flooding caused by surface runoff because of the shoreline location and the distance of the site from major streams. Plant grade is raised approximately 11 ft above the surrounding area to further minimize the possibility of flooding. Flooding of the site is conceivable only as the result of an extremely severe storm with a storm-generated rise in the level of Lake Erie. Protection of safety-related structures and equipment against this type of flooding is provided through the location, arrangement, and design of the structures with respect to the shoreline and possible storm-generated waves.

After the excavation of topsoil, peat, and soft clay, construction of the plant site to grade Elevation 583 ft (nominal) was accomplished using the following fill materials:

a. Crushed rock (1-1/2-in. maximum) within 10 ft from the building walls (water has been observed to run off rather than drain through this evenly graded crushed rock)

b. Crushed rock (6-in. maximum) inside the perimeter road (surrounding the plant main structures), except adjacent to buildings (this permits water to drain quite well)

c. Quarry run rock for most fill areas outside the perimeter road (surrounding the plant main structures) (providing good drainage for water under almost all circumstances)

d. Topsoil for grass was placed on a layer of 1-ft-deep crushed-rock fill, 1-1/2-in. maximum, to avoid being washed down.

Roof water that is collected through drainage systems from all structures and catch basins inside the perimeter road is collected and routed to the station storm-water drain system to prevent ponding of water adjacent to structures. Water in the plant storm-water drain system is then discharged into the overflow canal. In grassy areas outside the perimeter road, and in gravel areas, catch basins discharge water into the quarry run fill. In paved areas, the catch basins are usually tied to the storm-water drain system. The plant circulating water is treated within the closed loop circulating water system, which includes the 5.5-acre circulating water reservoir.

2.4.1.2. Hydrosphere

2.4.1.2.1. Regional Conditions

The region of the Fermi site is located within the western part of the Lake Erie drainage basin. The divide between the Lake Michigan and the Lake Erie watersheds lies about 50 miles west of the site. Perennial streams in the region generally flow in a southeasterly direction and discharge into Lake Erie. Tributaries of these streams are intermittent and form a dendritic drainage pattern.

The average precipitation in the region ranges from 30 in. to 36 in./yr (Subsection 2.3.1.2). Average annual runoff ranges from 10 to 16 in. Infiltration is highest in the western part of the region in areas where permeable soils occur in end moraines and beach lacustrine deposits. High runoff coefficients are characteristic of the relatively impermeable lacustrine soils in the eastern part of the region.

2.4.1.2.2. Swan Creek

The Fermi site is in the Swan Creek drainage basin. The watershed is an area of 109 square miles, elongated in shape from northwest to southeast (Figure 2.4-4). The basin is about 25 miles long with a maximum topographic relief of about 130 ft. The drainage area topography is flat to gently undulating and varies from about 700 ft elevation in the upper watershed to about 570 ft elevation at Lake Erie.

Land in the basin is mixed in use for residential, commercial, industrial, and agricultural purposes. The surface soils are primarily lacustrine clay with some lacustrine sand ridges at the head of the watershed. The infiltration capacity of the basin soils is low. Surface drainage is poor and drainage ditch improvements are common in the upper part of the basin. Stream channel flow is retarded by typical vegetative cover of deciduous trees and brush undergrowth. There are no flow-control structures on Swan Creek. Stream level near the site is controlled by the level of Lake Erie.

Gages were placed along Swan Creek in 1971 and the collected data indicate that runoff is greatest during the spring and early summer (Reference 1). Data on the adjacent River Raisin and Huron River also indicate that runoff is highest during spring and summer. However, Swan Creek stream flow is normally too low for water supply use.

2.4.1.2.3. Lake Erie

2.4.1.2.3.1. Lake Characteristics

Lake Erie is approximately 240 miles long and has a mean width of 40 miles. The lake is divided into three principal subbasins: (1) a small, shallow basin at the west end which borders the site and is partially restricted by a chain of barrier beaches and islands; (2) a flat, unrestricted, and rather shallow basin in the center; and (3) a small, relatively deep eastern basin. The average depth of the lake is 61 ft and the maximum depth is 210 ft. The longitudinal axis of the lake trends northeast-southwest, a direction coincident with strong and persistent winds that predominate under normal meteorological conditions. Wind

stresses acting upon the lake surface over a sustained period can have a considerable effect on the level of the lake.

The most significant lake level variations are observed mainly at the western and eastern ends of the lake and are caused by transport of water as a result of sustained wind actions. Historical records show that in about 96 percent of all extreme cases, high water occurred at the eastern end of the lake and low water occurred at the western end. This is a result of the predominantly westerly winds causing the lake to set up at the eastern end.

The lake bottom in the vicinity of the site slopes very gently toward the east, reaching a depth of approximately 12 ft about 1/2 mile offshore. The soil deposits below the west end of the lake consist primarily of sand with intermittent layers of gravel and/or clay.

Two primary current patterns exist in the Lagoona Beach embayment. Winds moving from the northwest clockwise through northeast result in a general southwestward airflow over the entire embayment. This airflow creates the pattern of water movement shown in Figure 2.4-5. When the winds are from east-southeast clockwise through west, northward longshore currents are found to exist with a pronounced clockwise eddy formed south of the Point Mouillee marshes. This current pattern is shown in Figure 2.4-6.

When onshore winds from east clockwise through east-southeast and offshore winds from west-northwest clockwise through northwest occur, phase systems of current flow develop that produce variable patterns. The longshore currents shift from one primary current pattern to the other, reflecting changes in the local wind system. These phase changes are generally of short duration. Under ice cover, variations occur in the southward current flow and result in divergence of the currents immediately south of the existing plant intake and convergence north and east of Pointe Aux Peaux as shown in Figure 2.4-7.

2.4.1.2.3.2. Water Use

The use of potable and agricultural surface water within 10 miles of the plant site is presented in Subsection 2.1.4.2. Surface-water users withdrawing water from intakes in Lake Erie are the only surface-water users subject to the effects of accidental or normal releases of contaminants from the plant into the hydrosphere. The existing intakes along the western shore of Lake Erie have been examined to ensure that the dilution capacity of Lake Erie is sufficient to preclude adverse effects on users from releases of contaminants (Subsection 2.4.12). It is expected that future intakes will be located in the same approximate area and likewise will not be exposed to adverse effects of contaminants.

Municipalities with Lake Erie intakes, listed in Table 2.1-12, are located as shown in Figure 2.1-20. The municipal water intake nearest to the plant is the Monroe intake near Pointe Aux Peaux, approximately 2 miles southeast of the site, as shown in Figure 2.4-1. The Toledo intake is located about 18.6 miles due south of the plant site. The 1972 annual withdrawals at the Monroe and Toledo intakes were 2000×10^6 gal and $29,200 \times 10^6$ gal, respectively.

2.4.1.2.4. Ground Water

Regional ground water features are discussed in Subsection 2.4.13.1.1. Ground water in the site area occurs in a dolomite aquifer, underlying a mantle of relatively impermeable glacial deposits and recent sediments. This mantle ranges up to 40 ft in thickness. Water wells are

of low yield and the water is highly mineralized. The aquifer characteristics and ground water uses are described in more detail in Subsection 2.4.13.2.

2.4.2. Floods

2.4.2.1. Flood History

2.4.2.1.1. Maximum Mean Monthly Lake Levels

Based upon data collected by the U.S. Lake Survey, Detroit, Michigan (Reference 2), the highest observed monthly mean water level during the period of record from 1860 to 1973 was +4.9 ft above Low Water Datum. This level occurred during June 1973, at Monroe, Michigan. During 1973, the monthly mean water level varied between +3.0 and +4.9 ft above Low Water Datum, a vertical variation of 1.9 ft (Figure 2.4-9).

2.4.2.1.2. Maximum Wind Tide

Lake gaging records at Monroe have been collected for the periods from 1932 to 1939 and from 1952 to the present. Data from gages at Gibraltar and Toledo have been in existence since 1897 and have been correlated with records from the Monroe gage. Based on this relationship, the calculated maximum wind tide at Monroe was +4.5 ft on January 30, 1939. In an earlier report covering the period 1886 to 1896, a maximum wind tide of +5.5 ft was reported at Monroe. The description of the easterly gales that produced this wind tide suggests that they were more intense than those reported during the past 77 years. Therefore, it is reasonable to accept +5.5 ft (Elevation 576.0 ft) as the maximum wind tide occurrence since 1886.

2.4.2.1.3. Seiche History

Seiche history is discussed in Subsection 2.4.5.2.

2.4.2.1.4. Swan Creek

Complete flood data are not available for Swan Creek as gages were not installed until 1971. Long-term information exists from gages on adjacent drainage basins. On the River Raisin near Monroe, the largest flood (record begins in 1938) occurred on March 29, 1950, and the second largest on April 6, 1947. On the Huron River at Ann Arbor, the largest flood (record begins in 1918) occurred on April 5, 1947. Maximum annual floods occur principally in April and May. Discharge frequencies at the mouth of Swan Creek, estimated using standard methods (References 3 and 4), are shown in Table 2.4-1.

The estimated 100-year frequency discharge of 9300 cfs on Swan Creek is significantly less than the probable maximum flood (PMF) flow of 89,000 cfs (Subsection 2.4.3.4). In Subsection 2.4.3.5, it is demonstrated that the PMF flow on Swan Creek could not cause flooding at plant grade Elevation 583.0 ft. Therefore, water levels for the estimated discharges in Table 2.4-1 are not pertinent to site flood considerations.

2.4.2.1.5. Recent Storms

2.4.2.1.5.1. April 1966 Storm and Flood Analysis

On April 27, 1966, a persistent storm system moved into the Lake Erie drainage basin. During the month of the storm, the mean lake level at Toledo, Ohio, was 1.7 ft above the Low Water Datum of 570.5 ft. The maximum surge on Lake Erie occurred at Toledo while proportionately smaller surges were measured at distances from Toledo. The water level at Toledo reached 577.50 ft, which was 7.0 ft above the datum. The surge was driven by steady northeast winds with a directional duration of about 48 hr. At the time of peak surge, 1000 hr on the 27th, the maximum wind velocity measured at the Detroit River Light Station was 38 knots. However, a maximum wind velocity of 42 knots from the east-northeast was measured at 1300 hr, by which time the surge elevation had dropped to 575.93 ft.

Wave heights ranging from 6 to 7 ft were reported at the Toledo Harbor Light Station. To supplement the available wave data, a wave hindcast analysis was performed for the Fermi site. As discussed above, the times of peak surge and of peak wind velocity do not coincide, and this was considered in the hindcast analysis. The critical wind speed measured at the Detroit River Light Station was 38 knots from the northeast. This wind speed was increased by a factor of 1.30 to obtain a velocity representative of open-water conditions. The fetch aligned with the wind direction was 51,650 ft long and had associated with it a depth of approximately 13 ft at high water. A significant wave height and period of 3.8 ft and 3.2 sec, and a maximum wave height and period of 6.8 ft and 3.8 sec, would have been generated during this storm. Because the shoreline north of the Fermi site is oriented northeast, the waves that approached the site would have been attenuated by refraction and by the available depth of water over the sloping lake bottom. A conservative approximation of the lake bottom slope in this area is 1:100. Using this slope and the maximum wave period, the maximum supported wave height reaching the beach at the highest water level would have been about 1.3 ft. Waves larger than this would have broken too far seaward of the beach berm to have affected the site. The maximum runup elevation that would have been reached during this storm is 579.6 ft. This elevation is considerably less than the plant grade at the Fermi site of 583.0 ft and the probable maximum meteorological event (PMME) water level of 586.9 ft (Subsection 2.4.5).

2.4.2.1.5.2. November 1972 Storm and Flood Analysis

On November 13, 1972, a sudden storm moved into the Lake Erie drainage basin. The storm produced widespread flooding after the storm winds shifted from south to northeast, resulting in local evacuation within the low-lying areas along the western and southwestern shores. The total effect of the storm was that of a wind tide plus the abnormally high water level of Lake Erie, which existed at the time. In November, the mean lake level at Toledo was 3.6 ft above the Low Water Datum of 570.5 ft. The maximum surge on Lake Erie occurred at Toledo, while proportionately smaller surges were measured at distances from Toledo. The water level at Toledo reached 577.9 ft, which is 7.4 ft above the datum, while the maximum level at the Fermi site was 576.8 ft, which is 6.3 ft above the datum. Marblehead and Cleveland, Ohio, experienced maximum surges to Elevations 577.0 and 576.2 ft, respectively. The surge was driven by northeast winds with a directional duration of approximately 24 hr and a maximum velocity of about 40 knots over the central portion of the lake.

For most of November 12, 1972, winds were light and out of the southwest. Very late on the 12th and throughout the 13th, winds shifted gradually to northwest, then to northeast. By midday on November 13, the northeast winds were established and the velocity increased to 20 knots. The water level began rising at the Fermi site at 0800 hr on November 13. The maximum wind speed at Toledo was 25 knots and was reached early on November 14. By midday on the 14th, when the wind direction was changing to north, the water level at the Fermi site had reached its maximum elevation, 576.8 ft. The water level dropped rapidly, reaching a minimum level of elevation at 1800 hr on the 14th. Wind direction remained northerly throughout the 15th and velocity varied from 5 to 14 knots. Secondary and tertiary seiches were experienced on the 15th, but decayed rapidly from bottom friction. The troughs of these seiches resulted in lake elevations of 573.5 and 573.3 ft at the Fermi site. By November 16, the water level had stabilized at approximately Elevation 574.3 ft.

Waves during this storm were not measured at the site. Sufficient data describing the storm are available to hindcast the probable wave attack at the site. Waves were estimated at the Detroit River Light Station as ranging between 5 and 8 ft. Wind speed reached a maximum of 35 knots from the northeast at the Detroit River Light Station while Toledo Express Airport reported a maximum of 25 knots from direction N50°E. Applying a factor of 1.3 to the Detroit River Light Station yields an over-water wind velocity of 45.5 knots. The fetch aligned with the wind direction was approximately 51,000 ft long and had associated with it a depth of approximately 20 ft at high water. A significant wave height and period of 4.2 ft and 3.3 sec, and a maximum wave height and period of 7.6 ft and 4.0 sec, would have been generated during this storm.

The waves that approached the Fermi site would have been limited in height by the available depth of water over the gradually sloping lake bottom. Figure 2.4-10 shows the bathymetry offshore of the site.

A conservative approximation of the lake bottom slope in this area is 1:100. Using this slope and the maximum wave period, the maximum supported wave height reaching the beach at highest water level would have been 1.7 ft. Waves larger than this would have broken too far seaward of the beach berm to have affected the site.

The maximum runup elevation which would have been reached during this storm is 579.6 ft. This elevation is considerably less than the plant grade at the Fermi site of 583.0 ft and the PMME water level of 586.9 ft.

2.4.2.1.5.3. April 1973 Storm and Flood Analysis

Another storm moved into the Lake Erie Basin on April 9, 1973. Although this storm was less intense than the November 1972 storm, its total impact was nearly equal to the November storm because of the extremely high static lake level at the time.

In April 1973, the mean lake level at Toledo was measured by the U.S. Lake Survey as +4.76 ft above the Low Water Datum of 570.5 ft. The maximum surge associated with this spring storm was measured as +3.3 ft at Toledo, which brought the total stillwater level to 578.6 ft. This is 0.7 ft higher than the level reached by the November 1972 storm.

On April 8, 1973, wind speeds ranged from 15 to 20 knots, blowing steadily from the northeast. On the morning of the 9th, the wind speed increased, reaching a maximum value

of 35 knots and shifting gradually to the east-northeast by 1430 hr. The water level began rising at Toledo, Ohio, at 0100 hr on April 9 and reached maximum Elevation 578.57 ft at 1600 hr on the 9th. The water level dropped rapidly, reaching minimum level Elevation 573.2 ft at 0100 hr on the l0th.

Secondary and tertiary seiches were experienced on the 10th, but decayed rapidly from bottom friction. By April 11, the water level had stabilized at approximate Elevation 574.6 ft. At the height of the storm, an 8-ft wave height was reported at the Detroit River Light Station.

To supplement the available wave data, a wave hindcast analysis was performed for the Fermi site. The maximum wind speed measured at the Detroit River Light Station was 35 knots from direction N67.5°E. This wind speed was increased by a factor of 1.30 to obtain an over-water velocity. The fetch aligned with the wind direction was 66,900 ft long and had associated with it a depth of approximately 20 ft at high water. A significant wave height and period of 4.8 ft and 3.6 sec, and a maximum wave height and period of 8.6 ft and 4.3 sec, would have been generated during this storm.

The waves that approached the Fermi site would have been limited in height by the available depth of water over the gradually sloping lake bottom. A conservative approximation of the slope of the lake bottom is 1:100. Using this slope and the maximum wave period, the maximum supported wave height reaching the beach at highest water level would have been 2.0 ft. Waves larger than this would have broken too far seaward of the beach berm to have affected the site. The maximum runup elevation that would have been reached during this storm is 581.7 ft. This elevation is less than the plant grade at the Fermi site of 583.0 ft and the PMME water level of 586.9 ft.

2.4.2.1.5.4. June 1973 Storm and Flood Analysis

High static lake levels continued through 1973. During June the mean lake level measured at Toledo by the U.S. Lake Survey was approximately 4.9 ft above the Low Water Datum of 570.5 ft. The earlier April 1973 storm occurred at a time when the lake was approximately 4.8 ft above the Low Water Datum. The maximum instantaneous surge associated with this June storm was measured at +3.4 ft at Toledo, which brought the total stillwater level to 578.7 ft. This was 0.1 ft above the April 1973 storm and 0.8 ft higher than the November 1972 storm.

At the Fermi site, maximum stillwater levels recorded by the U.S. Lake Survey reached a peak hourly reading of 577.75 (Low Water Datum) at 0200 hr on June 17, 1973. The Fermi water-level recorder does not record instantaneous water levels; however, interpolation from stations at Toledo, Ohio, and Gibraltar, Michigan, yields an instantaneous high of approximately 578.6 ft. Detroit area newspapers reported a maximum flood stage of 578.4 ft.

Wind speeds with an easterly component at the west end of Lake Erie between June 17 and June 18 were generally light to moderate. The Toledo Express Airport recorded fastest 1-minute velocities of only 9.6 knots, while the Detroit River Light Station recorded velocities between 10 and 15 knots. In addition, the Canadian government reported easterly gusts to 34 knots with an average of 20.9 knots at their Southeast Shoal lighthouse near Pt. Pelee, Ontario. The duration of these easterly winds was about 25 hr with peak velocities reached in the first 6 hr.

Winds at the east end of the lake, at Buffalo, were only slightly higher but maintained an easterly component for approximately 34 hr. It was this long-duration, moderate-wind regime at the east end of Lake Erie that was primarily responsible for the flooding at the west end. Buffalo reported east winds 12 hr before Toledo. The east winds from Buffalo were met by westerly winds from Toledo, which resulted in a temporary water buildup (to Elevation 576.3 ft 4 in.) at Cleveland. When the Toledo winds finally switched from west to east, the light to moderate velocities were enough to push the surge into the western end of the lake.

Wave heights, which were estimated during the storm at the Detroit River Light Station, ranged from 2 to 5 ft. To supplement available data, a wave hindcast analysis was performed at the Fermi site. Assuming a maximum steady-state wind velocity of 21 knots blowing from the east (N90°E), and applying a factor of 1.3, an over-water wind velocity of 27.3 knots is obtained. The maximum fetch aligned with the wind direction was 199,500 ft and had associated with it a depth of approximately 25 ft at high water. A significant wave height and period of 3.9 ft and 3.2 sec, and maximum wave height and period of 7.0 ft and 3.8 sec, would have been generated during this storm.

The waves that approached the Fermi site would have been limited in height by the available depth of water over the gradually sloping lake bottom. A conservative approximation of the slope of the lake bottom is 1:100. Using this slope and the maximum wave period, the maximum supported wave height reaching the beach at highest water level would have been 1.3 ft. Waves higher than this would have broken too far seaward of the beach berm to have affected the site. The maximum runup elevation that would have been reached during this storm is 581.0 ft. This elevation is less than the plant grade at the Fermi site of 583.0 ft and the PMME water level of 586.9 ft.

2.4.2.1.5.5. April 1974 Storm and Flood Analysis

In 1974 the highest water level measured by the U.S. Lake Survey at Toledo occurred on April 8 at 12 noon. The maximum reading was the result of sustained high static lake levels and an early spring storm.

In March and April the mean lake level at Toledo was approximately 4.4 ft above the Low Water Datum of 570.5. The maximum surge associated with the storm that moved through the area on April 7 and 8 was measured at +3.6 ft, which brought the total stillwater level to 578.5 ft. This was 0.2 ft below the June 1973 storm and 0.1 ft below the spring storm of April 1973.

At the Fermi site, the maximum stillwater level recorded by the U.S. Lake Survey was at Elevation 577.6 ft, which occurred at 12 noon on April 8.

Fastest 1-minute wind speeds measured at the Toledo Express Airport had a northeasterly direction and obtained a maximum of 26 knots with an average of 16.3 knots. At the Detroit River Light Station, a maximum wind velocity of 28 knots from the northeast and an estimated wave height of 4 to 5 ft were recorded at 1030 hr on April 8. At 1630 hr on April 8, the light station recorded an east-northeast wind at 25 knots and a wave height of 5 to 6 ft. At this time water levels were already dropping at both Toledo and the Fermi site.

To supplement the available wave data, a wave hindcast analysis was performed for the Fermi site. Assuming a maximum steady-state wind velocity of 28 knots from direction

N67.5°E and applying a factor of 1.3, an over-water wind velocity of 36.4 knots is obtained. The maximum fetch aligned with the wind direction was 66,900 ft long and had associated with it a depth of approximately 20 ft at high water. A significant wave height and period of 3.8 ft and 3.2 sec, and a maximum wave height and period of 6.8 ft and 3.7 sec, would have been generated during this storm.

The waves that approached the Fermi site would have been limited in height by the available depth of water over the gradually sloping lake bottom. A conservative approximation of the slope of the lake bottom is 1:100. Using this slope and the maximum wave period, the maximum supported wave height would have been 1.6 ft. Waves larger than this would have broken too far seaward of the beach berm to have affected the site. The maximum runup elevation that would have been reached during this storm is 581.3 ft. This elevation is less than the plant grade at the Fermi site of 583.0 ft and the PMME water level of 586.9 ft.

2.4.2.2. Flood Design Consideration

2.4.2.2.1. Conditions Considered

The following basic types of hypothetical flooding conditions were considered in the design:

a. The PMF of 89,000 cfs on Swan Creek coincides with the mean monthly maximum water level of 575.3 ft in Lake Erie. In the discussion of backwater computations (Subsection 2.4.3.5), the resulting PMF flow elevation of 577.3 ft would provide a safety margin of 5.7 ft. Even by the use of a conservative slope/area computation (Subsection 2.4.3.5), the PMF elevation would be less than 582 ft, or 1 ft below plant grade at 583 ft and 1.5 ft below the elevation of plant door sills

b. The maximum probable wind tide of 11.6 ft coincides with a maximum monthly mean lake level of 575.3 ft. The resulting stillwater flood elevation at the plant site area in this case is 586.9 ft, or 3.90 ft above the plant grade elevation (Subsection 2.4.5.3)

c. Local probable maximum precipitation (PMP) runoff on the plant site coincident with runoff from the 2-square mile area above the plant site, assuming blockage of plant drainage, would result in no adverse effects on the safety-related (Category I) facilities. The estimated PMF of 25,300 cfs with a corresponding elevation of less than 582 ft, and the 15-minute PMP of 4.9 in. over the plant site with a grade elevation of 583 ft and door sills at 583.5 ft would not result in adverse plant site flooding, as further discussed in Subsection 2.4.2.3. The temporary local water buildup due to the failure of the plant drainage system will flow into the lower land and swamps at the northern end of the plant area and eventually discharge into Lake Erie through estuaries. The local temporary water buildup elevation will be substantially lower than the flood elevation due to the maximum wind tide, as described in item b. above

d. The potential dam failure effect is not applicable, as described in Subsection 2.4.4

e. The water level at the site is controlled by Lake Erie. The PMF flow from Swan Creek has no significant effect on the design water level at the site. The maximum lake stillwater level due to storm surge is Elevation 586.9 ft (Subsection 2.4.5.3). Plant grade is at Elevation 583.0 ft. At plant grade elevation, the lake water would extend approximately 2.5 miles inland from the plant site (Figure 2.4-11) and even further inland at maximum stillwater level.

The case (item b) above is clearly the most critical condition and is defined as the PMME.

2.4.2.2.2. Reactor/Auxiliary Building Flood Criteria

The Category I reactor/auxiliary building, which houses safety-related systems and components, is designed against flooding to Elevation 588.0 ft, or 1.1 ft above the PMME stillwater flood elevation of 586.9 ft. All doors and penetrations through the outside walls below the design flood elevation are of watertight design. All safety-related systems and equipment located inside this Category I structure are protected from the PMME flood. The reactor/auxiliary building is also designed to withstand wave action associated with this flooding. Maximum wave effects and forces are discussed in Subsection 2.4.5.4.

All interior floor drain systems inside the reactor/auxiliary building are not connected to the yard storm drainage system and, therefore, no potential water backflow into the structure is anticipated during the design flood condition. Shore protection is not required to preclude flooding of this structure.

The reactor/auxiliary building has only a few essential penetrations in the exterior walls. All of these penetrations below Elevation 588 ft are watertight.

The presence of the turbine building prevents waves and wave runup above the sill elevations on the east wall of the reactor/ auxiliary building, thereby preventing flooding of the buildings. The south wall of the reactor/auxiliary building has two large openings, two rail pockets with waterproofed seals and several waterproofed pipe-sleeved openings. These large openings are in an air-locked rail-car door and an air-locked personnel door. Both of these doors, however, will be air-locked and completely waterproofed to preclude wave runup flooding.

The reactor/auxiliary building roof is designed for a live load of 30 lb/ft^2. This load is equivalent to approximately 6 in. of water, or its equivalent in snow, or snow and ice load combined. Roof drains are designed for a rainfall of 4 in./hr. The reactor building roof water drains through openings in the parapet wall into scuppers and then down through conductors to the auxiliary building roof. Roof drains in the auxiliary building roof carry the runoff into the buried site drainage system by first passing through the turbine building roof drainage system.

2.4.2.2.3. Residual Heat Removal Complex Flood Criteria

The RHR complex is watertight to Elevation 590.0 ft. The north, south, and west walls have no openings. The east wall has approximately 30 waterproofed pipe-sleeved openings. The east wall also has four sets of double 3 ft by 7 ft doors for access to the building. These doors are normally closed and locked, and have their thresholds at Elevation 590.0 ft and extend to Elevation 597.0 ft. They are of steel construction and are shielded behind

reinforced-concrete missile walls. The east wall also has eight 4" diameter openings with water tight seals located within each of the two RHR cable vaults at elevations above 590'-6".

Waves reaching the east wall of the RHR complex across the flooded site would be diminished considerably by the stairs, the missile wall, and the landing at Elevation 590.0 ft in front of the doors. The insignificant amount of runup above the flooded elevation of 586.9 ft, or generated by the reduced waves, may find its way through the door threshold and door jambs, at Elevation 590.0 ft, and be diverted into the floor drain system in the building. The structure is also designed to withstand the wave action associated with this flooding. Shore protection is not required to preclude flooding of this structure.

The roofs of the RHR complex are provided with an adequate number of drainage pipes to pass runoff resulting from the PMP. The PMP was obtained from U.S. Weather Bureau (National Oceanic and Atmospheric Administration) information (Reference 5). Further, the storm-drainage provisions surrounding the RHR complex are designed to pass the discharge from the drain pipes as well as the runoff from surrounding areas. The plant area drainage system is designed so that there is no possibility of ponding near the RHR complex. The roofs of the RHR complex are designed for a postulated maximum ice and snow load of 70 lb/ft^2. This load is based on the simultaneous accumulation of the most severe postulated ice resulting from the mechanical draft cooling towers drift loss (21 lb/ft^2) plus the seasonal snowpack (30 lb/ ft^2), and on an additional ice load (19 lb/ft^2).

The mechanical draft cooling tower drift loss is based on an assumed drift loss of 0.015 percent, with the fans operating at full speed. For evaluating the ice loading on the RHR complex roof, a conservative value of 0.1 percent for drift loss was used at full speed. Under freezing conditions, the fans operate at half speed or are completely shut off. The total water loss under these conditions is less than 390 gal/hr. Based on the above, it is estimated that, with two towers operating for 30 days with no wind drift, and with the temperature below freezing, the maximum ice accumulation is less than 4-1/2 in. This amount of ice is equivalent to about 21 lb/ft^2 live load.

The seasonal snowpack load is based on results of reported research (Reference 6). According to this reference, the seasonal snowpack load is 30 lb/ft^2.

2.4.2.2.4. <u>Category I Yard Structures Flood Design Criteria</u>

The Category I piping and electrical ducts between the RHR complex and the reactor building are below the site flood elevation of 586.9 ft during the PMME. The RHR supply, RHR return, and emergency equipment service water pipelines to both divisions will continue to function during the flood.

There are two sets of Category I ductbanks between the RHR complex and the Reactor/Auxiliary building, with a Division I and Division II ductbank in each set. In each case, the buried cable ducts between the RHR complex and the Reactor/Auxiliary building provide adequate cable separation to maintain independence of redundant circuits.

The first set of ductbanks was installed during plant construction. The physical separation of the two redundant, below-grade circuits is 30 ft at the point the cable ducts leave the southeast corner of the reactor building. The ducts make a sweeping bend with a minimum

separation of 20 ft between them. After the bend, the ducts parallel the reactor building in a westerly direction, with 24-ft separation. This separation is constant until the ducts pass under the rail-car air lock, where the separation widens until the ducts enter (still below grade) the RHR complex.

Each circuit is separately housed in a cast-in-place, rectangular reinforced-concrete duct. The duct is covered by successive layers of compacted rock fill placed up to the finished site grade of 583.0 ft. The duct runs vary in elevation from 573.0 ft minimum to 580.0 ft maximum. Since maximum ground water elevation is 576.0 ft, the cables are not specifically designed for continuous underwater service. For low voltage power, control and instrumentation cables, there is no long term mechanism for water related insulation degradation due to lack of voltage stressor or a credible common mode failure mechanism. Therefore, low voltage cables perform their design functions while their external surface remains continuously wetted due to surrounding water. 4160-V essential power circuits are not routed within these ductbanks.

The second set of ductbanks, associated manholes, and cable vaults is installed above the maximum ground water elevation of 576.0 ft with ducts sloped to the manholes, such that circuits contained are not subject to continuous wetting. These are also cast-in-place, rectangular reinforced concrete ductbanks, but are located with the ductbank top approximately six inches below the surface and manhole covers at grade level. The ductbanks rise above grade and enter above ground cable vaults at the RHR complex and also rise above grade at the entrance to the Reactor/Auxiliary building cable vaults. 4160-V essential power circuits are routed within these ductbanks.

The minimum elevation for cable termination in either the RHR complex or reactor building is 588.7 ft, which is above the site maximum probable stillwater elevation of 586.9 ft.

2.4.2.2.5. Site Drainage Flood Design Criteria

The storm drainage system is not used to protect Category I structures from local PMP flooding, as further discussed in Subsection 2.4.2.3. Inlet manholes in the immediate plant vicinity are located at the low points of relatively flat roadside and railroad track areas, and in local area depressions. The storm-drainage conduit discharges westward into the existing overflow canal for Fermi 1 and eventually into Lake Erie through estuaries. The storm-drainage system is designed as a gravity system with a minimum velocity of 3 fps flowing full for a rainfall intensity of 4 in./hr. Runoff coefficients used are 1.0 for roofs and paved areas and 0.5 for gravel and grassed areas. The closed storm-drainage system provides the normal means of drainage for the plant site and building roofs.

The sedimentation potential of the site drainage system for anticipated rainfall conditions is negligible since the site consists principally of firmly compacted crushed-rock fill and grassed areas, and the slopes of the ditches feeding the inlet of manholes are relatively flat. The resulting velocity of the drainage flow is nonscouring. Riprap or paving is provided for protection of outlet ends at all discharge points of the storm sewer system.

2.4.2.3. Effects of Local Intense Precipitation

Flooding due to a local PMP on the adjacent 2-square mile drainage area west of the plant site, as shown in Figure 2.4-4, was examined. The local PMP shown in Table 2.4-2 was determined by use of Reference 5. The hourly distribution of the maximum 6-hr rainfall was determined by procedures presented in Reference 7. The shorter 15-minute-duration PMP was extrapolated by use of similar procedures. Due to its small area, the rational formula with a runoff coefficient of 1.0 and concentration time of 15 minutes was applied to compute the peak discharge (Reference 8). The maximum PMP intensity of 15 minutes is assumed to be 4.9 in., as shown in Table 2.4-2. The calculated peak discharge due to the local PMP is 25,000 cfs, which is 10,000 cfs greater than indicated by the PMF peak envelope curve for the Great Lakes region. The Great Lakes PMF peak discharge envelope curve indicates a maximum flow of 15,000 cfs, which represents a more severe flood than would result from the relatively flat 2-square mile local area if determined by the unit hydrograph PMP calculation procedure.

The calculated peak discharge due to the local PMP is 25,000 cfs. Assuming, conservatively, that the peak discharge would pass the plant site only along the axis of the overflow canal (Figure 2.1-5), a hypothetical cross section approximately 1 mile in length and normal to the axis of the overflow canal was constructed to intersect the southernmost chimney on the plant site and the intersection of Langton and Leroux roads to the west of the site (Figure 2.4-3).

Using the slope/area method and conservative values of slope and roughness coefficient, 0.001 ft/ft and 0.07, respectively, a flow of 31,500 cfs was determined as passing through the cross section with a maximum water surface elevation of 582 ft (New York Mean Tide, 1935). The peak flow due to a local PMP, 25,000 cfs, would pass through the cross section at an even lower water surface elevation. In this analysis, channel or cross-section bottom was assumed to be at maximum monthly mean lake level. And, as stated earlier, all flow due to a local PMP was assumed to pass through the hypothetical cross section. Under actual conditions, a peak flow due to the local PMP would flow both south of the plant site and to Lake Erie, as well as through the hypothetical cross section. Water surface elevations due to a local PMP would therefore be lower in actuality than those determined in our analysis.

At a hypothetical water surface elevation of less than 582 ft (New York Mean Tide, 1935), as determined in the above analysis, the maximum water elevation at peak flow due to a local PMP would be more than 1 ft below plant grade (583 ft, New York Mean Tide, 1935) and would not pose a threat to safety-related structures onsite.

With respect to that portion of a local PMP falling on the plant site itself, including roof structures, runoff overflowing the roof parapets and from the downspouts, assuming that the site drainage system was completely blocked, would flow overland under conditions of site gradient (Figure 2.1-5) to lower elevations surrounding the site and then to Lake Erie itself.

All door sills on safety-related structures are at least 6 in. above plant grade. Because there are no downspouts or scuppers located near doors on safety-related structures, ponded water under local PMP conditions, with the event of a blocked site drainage system, should drain overland, as described above, prior to reaching the base of door sills on safety-related structures.

The local PMP is shown in Table 2.4-2, and the description of the runoff model is given in Subsection 2.4.3.3.

The drainage system in the plant site area is designed with inlet manholes located at the low points of relatively flat roadside and railroad ditches and in local area depressions. The storm-drainage system is not used to protect Category I structures from local PMP flooding, as described in Subsection 2.4.2.2.

2.4.3. Probable Maximum Flood on Swan Creek

The PMF is an estimated flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region (References 5 and 7). The PMF on Swan Creek was estimated as the maximum flood runoff resulting from a PMP occurring on the entire drainage basin of 109 square miles, as shown in Figure 2.4-4.

2.4.3.1. Probable Maximum Precipitation

The estimation of a PMP includes both time and areal distributions. Due to its small drainage area (109 square miles), the PMP is assumed uniformly distributed throughout the entire Swan Creek watershed. The time distribution of a PMP is obtained as follows. The PMP for various durations shown in Table 2.4-3 was obtained from the all-season PMP (Reference 5). Its 2-hr time distribution for the maximum 6-hr rainfall and time sequence were based on procedures presented in Reference 7. Table 2.4-3 shows the synthesized PMP for the Swan Creek watershed.

2.4.3.2. Precipitation Losses

An estimate of precipitation losses was obtained using data from References 9 and 10 and studies of other similar areas. Surface soils in the Swan Creek drainage area are largely comprised of lacustrine clays, which have low infiltration capacity (Reference 11). The land use is estimated as follows: 30 percent small grain, 30 percent forage and pasture, 25 percent row crops, and 15 percent wooded land and buildings. Considering the Swan Creek type ground cover and soil surface as compared to similar type areas in other locations where studies have been made, minimum loss rates are higher in the summer months than in the winter months. These minimum losses can be characterized as follows.

a. Winter initial losses vary from 0.0 to 0.2 in., and winter infiltration losses vary from 0.01 to 0.02 in./ hr

b. Summer initial losses vary from 0.5 to 1.2 in., and minimum summer infiltration rates are approximately 0.05 in./hr.

The Swan Creek losses adopted are initial losses of 0.5 in. and an infiltration rate of 0.02 in./hr during the probable maximum storm. This is assumed as occurring during a wet period with the most favorable antecedent conditions when the moisture capacity of the topsoil would be essentially satisfied. The adopted minimum losses for the Swan Creek area assuming the most favorable (to high runoff) antecedent (ground and rainfall) conditions are based on a conservative estimate for these conditions. The Swan Creek rainfall-excess relationships were determined by use of the minimum conservative losses during the PMP

storm as shown in Table 2.4-4. The estimated precipitation losses and runoff are shown in Table 2.4-4.

2.4.3.3. Runoff Model

Because Swan Creek was ungaged prior to 1971, a synthetic unit hydrograph was developed for the 109-square mile basin, as shown in Figure 2.4-4, by using Snyder's method (Reference 12). The runoff was determined at the mouth of Swan Creek north of the site.

Figure 2.4-12 shows the synthetically derived unit hydrograph of 2-hr duration for the Swan Creek watershed. The hydrograph ordinates are shown in Table 2.4-4. Coefficients used in the derivation of the synthetic unit hydrograph are as follows: L = 25.4 miles, L_{ca} = 16.7 miles, C_t = 2.0, W_{50} = 16 hr, and W_{75} = 9 hr. The terms L and L_{ca} are distances measured on the U.S. Geological Survey (USGS) 7.5-minute topographical map for the site area. Time in hours, from start of rise to peak rate, or t_p, was determined using the formula

$$t_p = c_t(L * L_{ca})^{0.3}$$

The value of t_p was determined to be 12.3 hr using a basin parameter C_t of 2.0. Comparison of synthetic unit hydrograph values for Swan Creek with values for nearby stations with similar runoff characteristics as obtained from U.S. Army Corps of Engineers unpublished unit hydrographs is given in Table 2.4-5.

Table 2.4-5 illustrates the conservatism of the coefficients selected for the Swan Creek watershed. For example, a curve enveloping the q_p values would yield a unit hydrograph peak of about 3100 cfs for the 109 square miles as compared to the 4000 cfs peak adopted. The utilization of the extreme coefficient value was intended to include the possible nonlinear runoff response of Swan Creek due to high rainfall intensities.

2.4.3.4. Probable Maximum Flood Flow

The PMF for the 109-square mile watershed of Swan Creek was determined by appropriate application of the preceding analysis described in Subsections 2.4.3.1, 2.4.3.2, and 2.4.3.3. Base flow was assumed to be 100 cfs. The computed PMF hydrograph components are shown in Table 2.4-4.

The calculated basin-wide peak flow in Swan Creek due to the synthesized PMP is 89,000 cfs at the mouth of Swan Creek, as shown in Figure 2.4-13.

There are no dams or other regulating hydraulic structures on Swan Creek that could affect the hydrograph. The exact PMF stream course response cannot be assessed since Swan Creek has not been gaged for a sufficient period of time.

2.4.3.5. Water-Level Determinations

The water level at the site is controlled by Lake Erie. The PMF flow from Swan Creek has no significant effect on the design water level at the site. The maximum lake stillwater level due to storm surge is Elevation 586.9 ft (Subsection 2.4.2.2.1). Plant grade is at Elevation 583.0 ft. At plant grade elevation, the lake water would extend approximately 2.5 miles inland from the plant site (Figure 2.4-11) and even further inland at maximum stillwater level.

To estimate the maximum floodwater level, a section through the east end of the plant site and normal to Swan Creek was selected to compute backwater effects due to the PMF flow on Swan Creek. This section is 3.5 miles wide and is bounded by Port Sunlight Road to the north and Pointe Aux Peaux Road to the south (Figure 2.4-1). Neither of the roads was constructed as a flood-protection levee. In the vicinity of the control section, the land is flat, approximately at Elevation 572.5 ft (Figure 2.4-11).

The backwater calculations were done with the assumptions that the selected section has a water level at Elevation 575.3 ft, mean monthly maximum lake level, and the main plant structures are located 1500 ft west of this section. By applying the Manning formula (Reference 13) on a rectangular channel with a width of 3.5 miles and a bottom elevation of 572.5 ft, with a Manning's roughness coefficient of 0.07, the estimated rise of water level during a peak flood flow of 89,000 cfs is less than 2.0 ft. Therefore, the maximum flood level at the plant site due to the PMF flow from Swan Creek at the mean monthly maximum lake level is at approximately Elevation 577.3 ft, which provides a safety margin of more than 5.7 ft below the established plant grade of Elevation 583.0 ft.

The same procedures were applied using a higher peak flood flow of 115,000 cfs, resulting in an estimated maximum flood level at the plant site at Elevation 579.1 ft, which is 3.9 ft below the plant grade. Therefore, the PMF flow from Swan Creek has no flooding potential with respect to the plant site.

Additional computations, utilizing the slope/area method at a hypothetical cross section through Swan Creek above the plant site (Figure 2.4-4) determined that a flow of 106,000 cfs in Swan Creek would represent a maximum water surface elevation at the cross section of 582 ft (New York Mean Tide, 1935). The PMF of 89,000 cfs on Swan Creek (Subsection 2.4.3.4) should not cause flooding affecting safety-related structures at plant grade Elevation 583 ft (New York Mean Tide, 1935).

In the above computations by the slope/area method, a hypothetical cross section normal to Swan Creek and approximately 1.8 miles in length was chosen. Channel base or the bottom of the cross section was assumed to be at the elevation of the maximum monthly mean lake level. A slope of 0.001 ft/ft and a roughness coefficient of 0.07 were used in the computations.

2.4.3.6. Coincident Wind Wave Activity

A flood on Swan Creek would result in a landward extension of the lake. Therefore, wind activity determined for the lake would apply to the stream flood condition. Wave activity in Lake Erie is described in Subsection 2.4.5.4.

2.4.4. Potential Dam Failures (Seismically Induced)

There are no regulatory structures on Swan Creek. Nor are there dams on other streams or rivers in southeastern Michigan that should failure result because of seismic or other disturbances would affect water levels in Lake Erie along the plant shoreline.

2.4.5. Probable Maximum Surge and Seiche Flooding

2.4.5.1. Probable Maximum Winds and Associated Meteorological Parameters

Extensive studies have been made regarding the effects of wind setup on Lake Erie. Data developed by Platzman (Reference 14), which relate lake levels at Toledo and Buffalo to various wind conditions, were used to establish the wind setup for the site.

The Platzman one-dimensional wind setup model has been verified using four storms producing peak setup at Toledo (Reference 15). The model, valid for setup along the longitudinal axis of Lake Erie, has been shown to consistently calculate peak longitudinal setup greater than the measured peak longitudinal setup at Toledo when using the wind stress and bottom friction coefficients proposed by Platzman. Verification of this model is valid for input winds measured at the Ashtabula Coast Guard Station. The verification for one storm, and possibly a second, indicates that cross-lake wind setup can, at times, be significant and should be considered.

The conservatism of the model in predicting the longitudinal setup increases with increasing wind speed. For a maximum 3-hr average wind speed of 74 knots, the model is estimated to compute a longitudinal wind setup at Toledo 2 ft above the value which would be measured. Whereas an allowance should be made for the possibility of cross-lake setup occurring simultaneously with longitudinal setup at Toledo, an allowance is not required at the Fermi site near Monroe since Monroe is in the vicinity of the nodal point for cross-lake setup. The nodal point is the location where the change in stillwater level due to cross-lake setup is zero.

To establish meteorological conditions appropriate for calculation of the maximum probable wind setup for the site, winds with an easterly or northeasterly component that would be sustained for 6 to 9 hr were examined. The National Weather Records Center in Asheville, North Carolina, was commissioned to examine 25 years of wind records for eight stations in the vicinity of Lake Erie. The eight stations were Toledo, Windsor (Ontario), Sandusky, Cleveland, London (Ontario), Youngstown, Erie, and Buffalo. The National Weather Records Center tabulated (Reference 16) the speed, direction, and date of the fastest 1-minute wind having an easterly component.

The maximum, easterly 1-minute wind speeds observed for the 25-year period at the eastern four stations (London, Youngstown, Erie, and Buffalo) were 65, 37, 60, and 44 mph, respectively. The companion maximum, easterly 1-minute wind speeds observed at the western four stations (Toledo, Windsor, Sandusky, and Cleveland) were 40, 45, 35, and 35 mph respectively. Comprehensive analysis of these and other data (Reference 17) led to the conclusions that:

a. Maximum easterly wind speeds are substantially less than maximum westerly wind speeds

b. Maximum easterly wind speeds over the western portion of Lake Erie are somewhat less than maximum easterly wind speeds over the eastern portion of Lake Erie.

On this basis, a maximum, 1-minute easterly wind speed of 45 mph was selected as representative for the 25-year period of record for the site. This 1-minute value was converted to the probable maximum easterly wind as follows:

a. Overland wind speed was converted to over-water wind speed by multiplying the land value by 1.33. The maximum easterly wind speed over water is thus calculated as 60 mph. This wind speed is assumed to have a probability of once in 25 years

b. The maximum 1-minute easterly wind speed with a probability of once in 1000 years was calculated, using the method of Thom (Reference 18), to be 86 mph

c. A maximum 10-minute wind speed of 74 mph was calculated (Reference 19) by multiplying the maximum 1-minute easterly wind speed by 0.86

d. The 1000-year maximum easterly wind was taken as the maximum 10-minute wind speed of 74 mph.

The PMME data used to calculate the probable maximum wind tide at the Fermi site were obtained from the table of probable maximum wind estimates (over-water wind speeds) supplied by the AEC. The PMME wind speeds over the lake varied with time and distance along the lake axis. The peak 10-minute wind speed was 100 mph. Since the model used to calculate the probable maximum wind tide (Reference 14) is one dimensional, the PMME winds were directed along the axis of Lake Erie (N67.5°E). The PMME had a translational velocity of 20 mph moving from east to west, and duration of 60 hr.

2.4.5.2. Surge and Seiche History

2.4.5.2.1. Maximum Monthly Mean Lake Level

Historical maximum monthly mean water levels are discussed in Subsection 2.4.2.1.1.

2.4.5.2.2. Maximum Wind Tide

Historical maximum wind tides are discussed in Subsection 2.4.2.1.2.

2.4.5.2.3. Seiches

Seiches are periodic oscillations of the lake water level that are caused by changes in wind stress or barometric pressure acting upon the water surface. As the wind stress diminishes, the adverse gradient of the surface water cannot be maintained and an inertial surge of water occurs. Seiches also may result from very rapid changes in barometric pressure, usually associated with squall lines. However, sudden barometric disturbances are very infrequent on Lake Erie.

Analysis of gage records of Lake Erie indicates that the average period of oscillation for a seiche traveling between Toledo, Ohio, and Buffalo, New York, is approximately 14 to 15 hr. As a result of the greater depth of water at the east end of the lake and the generally higher wind speeds associated with the prevailing westerly winds, the maximum amplitudes of a seiche on Lake Erie occur at Buffalo.

Gages at Buffalo and Toledo indicate that the amplitude of the oscillations of a seiche decays rapidly with each subsequent oscillation. The rise in water level induced by the initial wind setup is greater than any subsequent rise associated with the seiche.

In addition to the general seiche that occurs over the entire lake surface, a local seiche may occur between the west end of Lake Erie and Point Pelee. Local seiches with amplitudes of up to 0.8 ft have been detected from gage records at Toledo and Monroe (Reference 20). These seiches can occur when the water body is in a state of equilibrium or constant stillwater level.

The stillwater level of Lake Erie near the Fermi site constantly changes in elevation, with respect to the rest of the lake during the PMME. This difference in water levels effectively damps out any seiche activity near the site. It is unlikely, therefore, that any seiche will occur simultaneously with the PMME. Consequently, for design purposes, no rise in water elevation from a seiche is considered.

2.4.5.3. Surge and Seiche Sources

The maximum PMME wind tide of 11.4 ft was calculated for the Fermi site with the PMME wind speeds as input to the verified Platzman one-dimensional wind setup model of Lake Erie (Reference 15). As an additional conservatism, the previously accepted wind tide of 11.6 ft was used for design purposes. This value does not include an allowance for cross-lake setup as none is required. Monroe is in the vicinity of the nodal point for cross-lake setup, where the change in stillwater level due to cross-lake setup is zero.

A total stillwater elevation of +16.4 ft (586.9 ft) was selected as the design maximum. This was based on the PMME defined by the AEC with a storm path along the axis of Lake Erie (N67.5°E). Elevation +16.4 ft results from a calculated wind tide of +11.6 ft superimposed on a maximum monthly mean lake level of +4.8 ft. This storm surge would occur at the Fermi site approximately 9 hr after the maximum wind reaches the shore. The storm surge hydrograph resulting from the PMME is shown in Figure 2.4-14.

No rise in water elevation resulting from a seiche was used in the design (Subsection 2.4.5.2.3).

2.4.5.4. Wave Action

2.4.5.4.1. Wind-Generated Waves

Wave characteristics are dependent upon wind speed, wind duration, water depth, and fetch length. Generated waves were calculated coincidental with the maximum storm surge hydrograph to determine the maximum flood elevations at the site. Fetch lengths were measured to the site from the axis of the lake (N67.5°E), from N78.75°E, and from due east (Figure 2.4-15). These fetches, hereafter referred to as degrees clockwise from north, have fetch lengths ranging from 11 to 33 nautical miles. Average lake depths range from 32 to 42 ft during probable maximum stillwater levels.

Using the AEC definition of probable maximum winds, component wind velocity profiles were plotted for fetch directions 67.5°, 78.75°, and 90.0° (Figure 2.4-16). Component wind velocities for fetch directions 78.75° and 90.0° were based on the wind velocity profile from 67.5°, the path of the storm.

The shallow water depths over the fetch approaching the Fermi site preclude deep-water wave activity; only shallow-water waves are generated during the PMME. The shallow-

water wave generation curves of Bretschneider (Reference 21) were used to calculate significant wave heights and periods (Figure 2.4-14). The generated wave height and period profiles have a phase shift in time of +1.5 hr over the wind profiles to allow for the generation and travel of waves to the site.

The significant wave height is the normal available parameter from statistical analysis of synoptic weather charts. Approximate relations of the significant wave heights to other parameters of the normal wave spectra in nature have been defined. Assuming that the most probable maximum wave height, H_m, is given by the deep water simplified theoretical solution of Equation 2.4-1, then the ratio of H_m to H_s is 1.8 to 1.

$$H_m = 0.707 H_s \sqrt{\log_e N} \tag{2.4-1}$$

where

N = number of waves during a period of steady-state conditions

H_s = significant wave height

This value is conservative, as the wave spectrum curve is flatter for shallow-water conditions near the Fermi site than for deep-water conditions applicable to the solution. Curves of H_m are presented in Figure 2.4-16.

2.4.5.4.2. Design Waves

2.4.5.4.2.1. Selection Bases

Selection of design waves depends on the wave climate at the site, the structures being considered, and the available water depths fronting the structures. Generated wave conditions during the PMME occurrence, offshore of the site location (Figure 2.4-16), are propagated shoreward to the various plant structures. In selecting design waves for various structures, the possible range of wave periods, heights, and approach directions during various times of the storm are considered to occur at critical conditions.

2.4.5.4.2.2. Incident Wave at Shoreline

The maximum stillwater level and the maximum offshore generated wave height do not occur simultaneously. Therefore, various stillwater levels are considered in selecting the critical wave conditions. The maximum generated wave height, significant wave height, and wave period (offshore of the plant site) are 21.9 ft, 12.2 ft, and 9.0 sec, respectively. These occur during the stillwater level of 582.8 ft, 1.50 hr after the maximum winds have crossed the shoreline (Figure 2.4-14). During the maximum stillwater level of 586.9 ft and 9 hr after the maximum winds have crossed the shoreline, the maximum wave height, significant wave height, and wave period are 14.0 ft, 7.8 ft, and 7.7 sec, respectively.

Design waves were generated offshore of the site location from approach directions 67.5° (path of PMME), 78.75°, and 90.0°. There should be no significant wave action south of 110° (i.e., normal to the shoreline) during the occurrence of the PMME, as this direction is a 42.5° departure from the wind direction. Waves north of 67.5° also are insignificant because of diminishing fetch length, shallow water depths, and change of direction through wave refraction. An 8-sec wave period generated from 67.5° would approach the plant site

shoreline from due east because of refraction effects (Figure 2.4-10). A shorter wave period would not be affected by refraction as much as the 8-sec wave period.

As waves approach the shoreline, they start breaking in water depths approximately equal to their wave heights. Figure 2.4-14 shows breaking wave heights for shoreline toe elevations of 569 ft, 572 ft, and 575 ft. The upper breaking wave height limit considers the effects of wave setup. With continuous heavy wave action breaking against the shoreline, it is possible that the return flow of water lakeward will be slower, thus causing a pileup of water (wave setup) along the shoreline. The possibility of this wave setup was assumed to raise the stillwater level by an amount equal to one-tenth the breaking wave height. With this increase in stillwater level, a slightly higher wave could be supported before breaking.

In selecting the proper design wave that can attack the shoreline, Figure 2.4-14 is used. Design H_s and H_m curves were plotted from the maximum values of Figure 2.4-16. For a particular shoreline or shore barrier toe elevation, the breaking wave height is the controlling factor if it is less than the unbroken wave height during a given stillwater level. In Figure 2.4-14, which includes the storm surge hydrograph, the stillwater level is read off the right-hand ordinate while the wave parameters, H_m, H_s, and H_b, are read off the left-hand ordinate. In using either the significant wave height curve (H_s) or the maximum wave height curve (H_m), the breaking wave height curve (H_b) controls until it intersects (progressing positively from left to right along the TIME axis) the H_m or H_s curve. Thereafter, the unbroken wave height controls.

When using significant wave conditions and a toe elevation of 575.0 ft, the following applies:

a. For a time of +3 hr after the maximum winds reach shore, the design wave is a breaking wave of 7.9 ft to 8.6 ft, with a period of 8.8 sec, during a stillwater elevation of 584.0 ft

b. For a time of +9 hr, the design wave is a significant wave of 7.8 ft

c. The maximum design wave is a wave of 10.2 ft with a period of 8.4 sec and occurs during a stillwater elevation of 585.6 ft at a time of +5.1 hr.

2.4.5.4.2.3. Transmitted Wave

During the occurrence of the PMME, plant grade Elevation 583.0 ft is flooded for approximately 17 hr. Therefore, incident waves attacking the shoreline can be transmitted inland across the flooded plant grade. These transmitted wave heights depend on the available water depth above plant grade, the incident wave characteristics attacking the shoreline, the configuration of the shore barrier, and the location and configuration of other obstacles.

A rock shore barrier has been constructed in front of Fermi 2 along the shore between Plant Coordinate System Grid N6800 and N7800. The rock shore barrier crest elevation is 583 ft nominal; the toe elevation will be 572 ft nominal. For design wave considerations, a design toe elevation of 569.0 ft was used to allow for 3 ft of scour at the toe.

Transmitted wave heights (Reference 20) over the shore barrier are shown in Figure 2.4-17 for maximum and significant incident wave heights at the shore barrier. The incident water

depth at the shore barrier toe and the inland depth of water above a plant grade elevation of 583.0 ft are also indicated in Figure 2.4-17.

Using this inland depth of water caused by flooding of plant grade, a curve indicating the maximum wave height that can be supported over the flooded plant grade, without breaking, is presented in Figure 2.4-17. During the maximum flooding of plant grade, the maximum supported wave height is less than the transmitted wave heights. Therefore, the maximum supported wave height is the controlling factor for plant structures located more than a few hundred feet inland from the shoreline. The maximum inland supported wave heights for plant grade Elevation 583.0 and 580.0 ft are 3.0 and 5.4 ft, respectively. The actual site grade at a given location may vary from the reference elevation of 583.0 ft. However, the resultant difference in the hydrostatic pressure due to the difference of supported wave heights would be insignificant.

Waves that are transmitted over the shore barrier will attack the office service and radwaste buildings of Fermi 2. These buildings are not Category I structures and, therefore, could be damaged during the storm without causing a safety concern to the public.

Small waves can reach the Category I structures by traveling around the northerly and southerly ends of the shore barrier. Waves traveling around the ends of the shore barrier undergo several effects, including the following:

a. Breaking caused by the shallow depths of the flooded plant grade

b. Diffraction around the ends of the other plant structures

c. Reflection off plant structures before reaching the Category I structures

d. Reduction caused by plant grade bottom friction and side friction of obstructing structures.

The significant wave period of 7.7 sec will approach the plant sites from due east, while lower period waves can approach the northerly end of the shore barrier from 65° (N65°E), and possibly approach the southerly end from 110° (E20°S). Waves approaching the north end of the shore barrier will be reduced to the maximum inland support wave heights of 3.0 and 5.4 ft for plant grade Elevations 583.0 and 580.0 ft, respectively, in approaching Category I structures. Waves approaching the southerly end of the shore barrier will be reduced in height approaching Category I structures as a result of the maximum inland supported wave height and the protection provided by the office service and turbine buildings. Neglecting any reduction effects from protection provided by the office service and turbine buildings, waves approaching Category I structures from the south will be reduced to the maximum inland supported wave height of 3.0 ft for the plant grade elevation of 583.0 ft.

2.4.5.4.2.4. Wave Stability

In selecting the proper design wave for wave runup and wave forces against Category I structures, the wave period spectra must be considered since the significant wave period might not control. In calculating minimum wave periods, Equation 2.4-2 was used to determine the limiting wave steepness in shallow water (Reference 22).

$$H/L = 1/7 \tanh\left[\frac{2\pi d}{L}\right] \qquad (2.4\text{-}2)$$

As mentioned in Subsection 2.4.5.4.2.3, waves attacking Category I structures are controlled by the available water depth over the flooded plant grade elevations. For plant grades with very flat slopes, the maximum supported wave height is approximately 0.78 times the water depth. The plant grade of Fermi 2 is Elevation 583 ft 0 in., and therefore a maximum wave height of 3.0 ft can be supported. Where the plant grade elevation is 580 ft 0 in., a maximum wave height of 5.4 ft can be supported. With the plant grade elevation changing from 580.0 ft to 583.0 ft in the vicinity of Grid N8000, it would be possible for either the 3.0-ft or the 5.4-ft wave to strike the north or east sides of Category I structures. Minimum wave periods calculated for wave heights of 3.0 ft and 5.4 ft are 3.4 sec and 4.5 sec, respectively. The maximum wave period of about 9 sec (Reference 22) is for a significant wave height of 7.8 ft and a significant wave period of 7.7 sec.

2.4.5.5. Resonance

Resonance generated by waves can be a problem in enclosed bays or harbors when the natural period of oscillation of the bay is equal to the period of the incident waves. However, the Fermi site is not located in an enclosed embayment. The full exposure of the site to Lake Erie during PMME conditions, plus the flat slopes surrounding the site area, result in a natural period of oscillation of the flooded area that is much greater than that of the incident shallow-water storm waves. Consequently, resonance is not a problem at the site during the PMME occurrence.

2.4.5.6. Runup

2.4.5.6.1. Flood Levels

Refer to Subsection 2.4.2.2 for a discussion of flood levels.

2.4.5.6.2. Maximum Runup Elevations

Maximum runup elevations on the exposed north faces of the reactor/auxiliary building and the RHR complex are 593.0 and 598.0 ft for the 3.0-ft and 5.4-ft waves, respectively. The maximum runup elevation on the exposed south faces of the reactor/ auxiliary building and the RHR complex, the exposed east face of the RHR complex, and the west face of the reactor/auxiliary building is 593.0 ft for the 3.0-ft wave. This wave could possibly reach the west face of the reactor/auxiliary building by reflection from the east face of the RHR complex. The east face of the reactor/auxiliary building is not exposed to waves and wave runup. The west face of the RHR complex is landward of the storm direction and not subject to waves and wave runup. As previously stated, no shore protection is required to preclude flooding of these structures.

2.4.5.6.3. Wave Forces

Maximum wave pressures and forces against Fermi 2 Category I structures can result from a 3.0-ft or possibly a 5.4-ft wave striking the north or east faces of Category I structures. These wave heights are the maximum supported wave heights for plant grade Elevations

583.0 and 580.0 ft. Wave pressures and thrusts against smooth vertical walls have been calculated from nonbreaking, broken, and breaking wave conditions. The wave periods have been varied from the minimum wave period to the maximum wave period. The instantaneous impact forces produced by waves breaking against a structure result in intense shock pressure with a duration in the range of 1/100 to 1/1000 sec. The intense pressures occur when a thin cushion is entrapped by waves breaking on a structure.

The breaking wave conditions are calculated from Minikin's formula. In adapting Minikin's formula, unrealistic results are predicted for very flat slopes (slopes fronting a vertical wall). Therefore, when the actual slope is flatter than 20:1 or even 10:1 (horizontal to vertical), pressures derived from a 20:1 or 10:1 slope should be used. Pressures and thrusts from breaking wave conditions were calculated for both slope conditions. Porous fill material, which can become completely saturated during flooded conditions, is placed from the top of slab elevation of the Category I structure to the plant grade elevation. Therefore, hydrostatic pressures against Category I structures are considered to the depth of the upper surface of the slab of both buildings.

Wave pressure and thrust results for the reactor/auxiliary building and the RHR complex are presented in Figures 2.4-18 and 2.4-19. Wave pressure distribution diagrams are presented in Figures 2.4-20 and 2.4-21. The critical static pressure and thrust occur under the broken wave conditions, whereas the critical dynamic pressure and thrust occur under the breaking wave conditions for an assumed slope of 20:1 and the minimum wave periods of 3.4 to 4.5 sec. All Fermi 2 Category I structures are designed to withstand these forces.

2.4.5.7. Protective Structures

The importance of the shore barrier in providing protection for Category I structures during the PMME has been greatly reduced from the originally approved concept for the following reasons:

a. Category I structures are not susceptible to flooding from storm surge and wave runup

b. Category I structures are largely protected by other plant facilities

c. Category I structures are not subject to damage from transmitted waves behind the barrier

d. Category I structures are not endangered by wave forces from 3.0-ft to 5.4-ft waves

e. Damage to the shore barrier will not enable waves larger than 5.4 ft to break against Category I structures since these structures are located a minimum distance of 800 ft inland from the shoreline. Safety-related structures that are located this distance away would remain safe during the extreme high stillwater levels of the PMME.

The shore barrier design and location are shown in Figure 2.4-22. The parameters used in the shore barrier design are discussed in detail in this section. The shore barrier ends are to be constructed on a side slope of 3:1 (horizontal to vertical) as compared to the design slope of 2:1 used for the shore barrier. The ends of the shore barrier rubble-mound structures are of

the same design as determined for the 2:1 slope. Criteria for construction of the multilayered barrier are shown in Figure 2.4-22. The ends have been flattened to a 3:1 slope to ensure that they can withstand conditions more severe than the design conditions.

A shore-barrier-slope-stability analysis was performed to deter-mine the factor of safety against sliding of the shore barrier, and it was concluded that the shore barrier has a sufficient factor of safety with regard to a sliding failure occurring at any soil layer. A report of this analysis was submitted to the NRC in July 1981.

The shore barrier, which allows for the possibility of 6 to 8 percent stone displacement during the PMME, extends from Grid N6800 to N7800 and preserves the integrity of the plant site fill placed to Elevation 583.0 ft.

The shore barrier, including the ends, consists of a rubble-mound structure using an armor cover of stone. A toe elevation of 572.0 ft, a crest elevation of 583.0 ft, and a lakeward-side slope of 2:1 (horizontal to vertical) were considered in its design. The design wave was based on the probable maximum storm event and a design shore barrier toe elevation of 569 ft, allowing for 3 ft of scour. Hudson's stability equation was used for determining the weights of armor units (Reference 21). Stability coefficients (K_D) listed in Reference 21 were used for significant wave conditions and are conservative values based on zero damage criteria for model studies. By allowing for some shore barrier damage (displacement of armor stones), a higher stability coefficient was used.

An armor cover was calculated using rough angular stone (density 165 lb/ft^3) placed on a 2:1 slope. Using a design toe elevation of 569.0 ft, the maximum significant breaking wave height (Figure 2.4-14) is found to be 12.2 ft during the probable maximum storm event. The possibility of some stone displacement (6 percent to 8 percent) was allowed for, with any displaced stones being replaced after the storm passed. A stability coefficient of 5.0 was used for two layers of stone placed randomly. This results in an armor layer 7.5 ft thick using 3.3-ton to 5-ton stone, as shown in Figure 2.4-22. The secondary layer is 3.5 ft thick with 600-lb to 1000-lb stone, while the filter layer is 1.5 ft thick, consisting of 30-lb to 50-lb stone. Below the filter layer is 1 ft of crushed rock (20 lb and under).

Where the plant grade elevation slopes from 580.0 to 583.0 ft, to the north of the Fermi 2 location, the slope is protected against the possibility of breaking 5.4-ft waves during the maximum stillwater level. Protection of the slope is achieved by lining it with suitable rock.

The NRC evaluated the as-built condition of the shore barrier and concluded that it met the requirements of General Design Criterion (GDC) 2 and was, therefore, acceptable on the basis that the inspection and maintenance program required by the Technical Requirements Manual provided reasonable assurance that the shore barrier would not be allowed to deteriorate significantly from its as-built configuration. The Technical Specifications require that the shore barrier be inspected on an annual basis and after major storms and seismic events exceeding operating-basis earthquake (OBE) intensity and be promptly restored to its prior condition in the event of any significant damage.

2.4.6. Probable Maximum Tsunami Flooding

The Fermi site is located in an area of the United States designated as having potentially minor seismic activity. Any tsunami activity in Lake Erie could only be generated by local seismic disturbances. Based on the history of the area, local seismic disturbances would result only in minor excitations in the lake. No tsunami has been recorded in Lake Erie; the only remotely similar phenomena observed have been low-amplitude seiches resulting from sudden barometric pressure differences. The low-amplitude seiches that could occur would be of negligible concern to the site.

2.4.7. Ice Flooding

Ice flooding is not a design basis at the Fermi site. The grade elevation of the plant site is at least 10 ft above the normal winter level of Lake Erie, and the emergency supply of water for cooling is not dependent upon natural bodies of water or the operation of intakes located where ice flooding could occur.

2.4.8. Cooling Water Canals and Reservoirs

2.4.8.1. Canals

A discharge canal is provided between the natural draft cooling towers and the circulating water reservoir. The canal is not part of a Category I system and is not safety related or necessary for the safe shutdown of the reactor.

2.4.8.2. Reservoirs

An open pond reservoir is provided as a collection basin from the natural draft cooling tower discharge to the circulating water pump house. The reservoir is not part of a Category I system and is not safety related or necessary for the safe shutdown of the reactor.

In addition, a reservoir is provided in the RHR complex. This is a Category I reservoir that is part of a closed cycle system that is not dependent upon natural bodies of water for makeup. The design basis for this complex in relation to water levels is described in Section 3.4.

2.4.9. Channel Diversions

The plant does not use water from channels; therefore, this subsection is not applicable.

2.4.10. Flooding Protection Requirements

All safety-related plant features are designed to withstand combinations of flood conditions and wave runup as discussed in Subsections 2.4.2.2 and 2.4.5.4. Protection of safety-related structures and components, including the effects of floods and waves, is discussed in Section 3.4 and Subsection 2.4.5.7.

2.4.11. Low Water Consideration

2.4.11.1. Low Flow in Rivers and Streams

Plant water sources are not related to the flow of rivers and streams in the area, except to the minor extent that these flows affect the general water level of Lake Erie.

2.4.11.2. Low Water Resulting From Surges, Seiches, or Tsunamis

2.4.11.2.1. Minimum Monthly Mean Lake Level

A summary of the historical minimum monthly mean lake levels was recorded by the U.S. Lake Survey during the period 1860 to 1973 and is presented in Figure 2.4-9. The minimum historic monthly mean lake level was reduced by approximately 40 percent of the recorded range of low water conditions (0.9) to give a minimum monthly mean design lake level of -1.5 ft below Low Water Datum.

2.4.11.2.2. Wind Setdown

Using the computer model prepared by Platzman (Reference 14 and Subsection 2.4.5.1), values were obtained for winds of varying speed from a westerly direction. Calculations based upon U.S. Weather Bureau data at Asheville, North Carolina, indicate that westerly winds of 70 mph sustained over a period of 6 hr would have a recurrence interval of one in 250 years. Using these values, the decrease in water level resulting from wind setdown at the site would be -9.2 ft (Elevation 561.3 ft).

Based upon probable maximum estimates of westerly winds furnished by the AEC, maximum wind setdown of the lake water level was calculated by Platzman's method (Reference 14) as -11.2 ft. The selected design wind setdown is -11.6 ft (Elevation 558.9 ft). This is identical to the calculated design PMME storm surge except with a minus instead of a plus sign.

2.4.11.2.3. Local Seiches and Tsunamis

For the same reasons as given in Subsections 2.4.5.2.3 and 2.4.6, no decrease in water level is assumed to occur from seiche and tsunami activity.

2.4.11.2.4. Design Level

Assuming that the effect of wind setdown occurs simultaneously with extreme minimum monthly lake levels, the resulting design stillwater level is Elevation -13.1 ft (Low Water Datum), or Elevation 557.4 ft.

The cooling water supply for safety-related systems is provided by the RHR complex, which contains its own water reservoir and is independent of ground water or lake-water level conditions. See Subsection 9.2.5 for a discussion of the RHR service water system.

2.4.11.3. Historical Low Water

The lowest observed monthly mean lake level during the period of record (1860 to 1973) was during February 1936, when Elevation -1.2 ft (Low Water Datum) was recorded. Low lake levels are generally recorded during the month of February. The most extreme setdown on

record (1897 to present) was -7.1 ft on March 22, 1955. This level was calculated from gage records obtained at Gibraltar and Toledo.

If coincident occurrence of the minimum historical lake level and setdown is assumed (-8.3 ft), a minimum probable low water elevation of 562.2 ft is obtained. The conservatism of the design values is realized by comparing these figures with the respective -1.5-ft and -11.6-ft values that were combined for the design level elevation of -13.1 ft.

2.4.11.4. Future Control

There is no future control anticipated for Lake Erie (Reference 23). Drainage improvements on Swan Creek have been made, but no additional controls are planned (Reference 24).

2.4.11.5. Plant Requirements

As described in Subsection 9.2.5, the cooling water supply for safety-related systems is provided by the RHR service water system, which contains its own water reservoir and is independent of ground- or lake-water supplies.

The main plant cooling water supply is provided by the circulating water pond (Subsection 10.4.5) and requires only makeup water from Lake Erie.

2.4.11.6. Heat Sink Dependability Requirements

The RHR complex contains the ultimate heat sink for Fermi 2, which is the RHR service water system. The RHR complex includes a man-made structure with a self-contained reservoir and is discussed in Subsection 9.2.5. This service water complex is independent of local water-level conditions.

2.4.12. Environmental Acceptance of Effluents

Discharge of liquid radwaste effluents is through a decant line into Lake Erie. The release point is indicated in Figure 2.1-5. Liquid effluent accidentally released at the surface from the plant eventually flows either eastward into Lake Erie or into the north lagoon after percolation downward through the crushed-rock fill. The configuration of the surface-area drainage pattern does not permit flow westward toward inland areas. Since the lagoon drains into the lake via Swan Creek, liquid surficial discharges would ultimately reach and be diluted by waters of Lake Erie. Any percolation into ground water ultimately reaches Lake Erie (Subsection 2.4.13). The locations and users of surface and ground water pertinent to effluent releases from the plant are provided in Subsections 2.4.1.2 and 2.4.13. The effects of plant effluent releases to Lake Erie were examined by calculating dilution factors at the Monroe intake and the Toledo intake.

Studies of the currents and dilution capacity of Lake Erie were made by Ayers (Reference 25) who found that except under ice-cover conditions there are two primary current patterns, northward and southward, with a velocity range from 0.1 to 0.3 mph. During ice-cover periods, the current is predominantly southerly with a velocity of less than 0.1 mph. The probable percentages of occurrence of the current patterns are 30 percent, southerly; 50

percent, northerly; and 20 percent, phase system. The duration of ice-cover ranges from 1 to 4 months.

Based on Ayers' measurements, dilution factors for the Monroe intake and the Toledo intake were estimated and are summarized in Table 2.4-6. The dilution factors were determined using the plant blowdown discharge line into Lake Erie as the effluent release point.

The annual average dilution factor was calculated on the basis of 40 percent (southerly) and 60 percent (northerly) current directions, with an ice-cover duration of 2 months occurring during southerly current conditions. Current velocities used in the calculations are 0.394 fps under ice-free conditions and 0.117 fps under ice-cover conditions. The worst condition for dilution factors is based on a southerly current under ice-cover conditions with a current velocity of 0.04 fps.

The subsurface diffusion of accidental releases of liquid radioactive effluents is considered in Subsection 2.4.13.

2.4.13. Ground Water

2.4.13.1. Description and Onsite Use

Ground water is not used as a source of water supply for the plant. Ground water features are subsequently described.

2.4.13.1.1. Regional Ground Water Features

The project area is located in the eastern lake section of the central lowlands physiographic province (Figure 2.5-1). Bedrock formations dip northwest into the Michigan Basin. They are generally covered by glacial drift deposits that vary considerably in thickness and composition. The bedrock topography at the base of the drift is irregular as a result of erosion and differential scouring by Pleistocene glaciation.

The drift deposits range from nearly impervious till to coarse channel deposits of gravel and boulders. To the northwest of the site, drift deposits occur that are sufficiently thick and permeable enough to allow development of ground water. To the south, soluble limestone and dolomite formations compose the principal aquifers. The distribution of these regional aquifers, as described by the USGS (Reference 26), is shown in Figure 2.4-23. Regional aquifers capable of furnishing public ground water supplies do not exist near the site because the bedrock formations are not highly pervious and contain poor quality water. The drift is thin and consists of nearly impervious till. Ground water conditions in Monroe County are described by Sherzer (Reference 27) and by Mozola (Reference 11).

Bordering Lake Erie and surrounding the site area are soils associated with former higher stages of Lake Erie. The soils are thin, generally organic, and do not serve as aquifers. The soil units are described in Subsection 2.5.1.1.2. Geologic units in the site region, principally the bedrock formations, are described in detail in Subsection 2.5.1.1.

2.4.13.1.2. Local Ground Water Features

In the site area, geologic units consist of bedrock formations that are overlain by thin and nearly impervious till and lacustrine deposits (Subsection 2.5.1.2). At the site, the lacustrine and till units have been partially excavated and replaced with crushed-rock fill (Subsection 2.4.1.1).

The till and lacustrine deposits are too thin and impervious to serve as aquifers. They are about 14 ft thick at the site. Descriptions of these deposits are given in Subsection 2.5.1.2.7.

The test borings explored the bedrock formations beneath the site to depths of 324.7 ft, penetrating the Bass Islands Group and part of the Salina Group. The formations dip slightly to the northwest (Subsection 2.5.1.2.3.2). The uppermost bedrock formation at the site is the Bass Islands Group; the upper surface of the Bass Islands is erosional and somewhat irregular. It is covered with till and lacustrine deposits less than 20 ft thick. At the site, the upper surface of the Bass Islands is about 550 ft elevation (Subsection 2.5.1.2.2) and exists to a depth of about 100 ft (Figure 2.5-15). It is directly below glacial drift in a 7-mile-wide band bordering Lake Erie (Figure 2.5-5). The Bass Islands Group consists of thin-bedded, fractured, locally vuggy, gray-brown dolomite, with carbonaceous shale partings. The formation is described in greater detail in Subsection 2.5.1.2.2. The Bass Islands Group comprises a confined aquifer at the site. During the exploration borings program, there was artesian flow from a number of borings penetrating the Bass Islands Group (Figures 2.5-24 through 2.5-56). Ground water in the Bass Islands Group is confined by the overlying till and lacustrine deposits. During construction dewatering, the ground water is drawn down below the confining layer.

Below the Bass Islands Group are fractured limestone and dolomite formations of the Salina Group. The Salina Group formations appear to comprise aquifers even in the argillaceous beds because test borings at the plant site encountered artesian flows from them.

Water quality was sampled at various zones. The water is highly mineralized. Sulfate content was similar in all formations. Results of the chemical analyses of the zones tested are shown in Table 2.5-16 and discussed in Subsection 2.5.1.2.4.

The aquifers receive recharge by infiltration of precipitation on higher ground areas west of the site as indicated by a mapping of the regional ground water level, shown in Figure 2.4-24. Because the ground water surface approximates the shape of the land surface, water apparently can percolate through the till. The map was prepared from water levels measured in wells completed within the Bass Islands dolomite. These well locations are shown in Figure 2.4-25. Water-level measurement data for the wells are presented in Table 2.4-7. The slope of the water level toward Lake Erie indicates that the lake comprises the ultimate sink for ground water flow.

The permeability data developed from pressure tests of borings at the Fermi site are described in Subsection 2.5.4.6. Of 29 tests in four borings, permeability varied from 210 to 2220 ft/yr. The average was 763 ft/yr. Because permeability is developed in rock joints and fractures, it can vary considerably from place to place.

Ground water is not a water supply source for the plant or any of its supporting facilities.

2.4.13.2. Sources

All municipal supplies within 25 miles of the site are from streams or lakes (Reference 28). In areas not served by municipal water systems, water supplies for domestic use are generally obtained from private wells. There are no industrial or municipal water wells in the site area (Reference 7). The network of private wells presently in use forms the source of water for domestic and livestock purposes in farms and homes west and north of the site, and for residences in the Stony Point area to the south, where the largest concentration of wells in the area occurs. The distribution of private water wells surrounding the site area is shown in Figure 2.4-26. This figure shows that there are about 4000 wells within 10 miles of the site. A survey of available drillers' records on approximately 400 wells in the site vicinity, filed at the Michigan Department of Natural Resources, shows that well depths generally do not exceed 70 ft. The wells are 4 to 6 in. in diameter, drilled into dolomite bedrock, and cased only through overburden soils into bedrock. Casings are uncemented, and the remainder of the hole below the casings is left open. Pumps are submersible or centrifugal (suction) type, having a capacity of about 10 gpm or less. The pumpage of water per well is probably on the order of 200 to 400 gal per day, typical of residential use. A certain amount of seasonal variation in water use can be expected because in summer months lawns and gardens are irrigated.

There has been virtually no long-term ground water level decline in the site area. The largest concentration of wells is in Stony Point. Pumping there may have lowered the water levels by 5 to 10 ft, on the basis of water levels reported on numerous drillers' logs since the 1940s. The radius of influence of pumping from these wells cannot be detected more than 1 mile away from Stony Point, on the basis of water-level data. Pumping from an onsite rock quarry operation in 1969-1972 caused a temporary lowering of water level. Pumping was terminated in June 1972 and the abandoned quarry was allowed to fill with ground water. The piezometric surface in the vicinity of the quarry returned to its normal level by the summer of 1973. The ground water level was monitored during the quarry dewatering and the data are shown in Table 2.4-7. Water level in the quarry is now approximately at land surface.

At the site, the confining layers have been stripped to permit the excavation for subgrade structures constructed in the aquifer. Backfill around the completed structures will not permit percolation into the aquifer at the site (Subsection 2.4.1.1).

The water use trend in the area is from ground water to surface water. The low transmissibility of the formation will not permit large-yielding water wells. Undesirable water quality is typical. As described in Subsection 2.5.1.2.9 and noted on boring logs, the ground water is high in sulfate content and hydrogen sulfide. Many neighboring communities, for example Woodland Beach and Berlin Township, have recently abandoned individual water wells in favor of a surface-water treatment-distribution system. Because surface water is available from nearby municipal systems for the communities in the area, the trend of increasing surface-water use and decreasing ground water use can be expected to continue in dense population areas. Isolated homesites, as on farms, will probably continue to use ground water.

Because of the trend toward decreasing use of ground water, it is improbable that any significant change in ground water gradient will occur from well pumping. The gradient is to the east, toward Lake Erie. There are no domestic wells downgradient from the site. If, for any reason, a reversal of ground water gradient from the site to the water wells were to occur, it would have to be for some reason other than pumping from the wells. This is true because, in order to create a gradient from the site to the water wells, the water level at the wells would have to be drawn down below their depth. It is therefore considered highly improbable that there will be any ground water condition in the future resulting in gradient reversal from the site toward the water wells.

The regional lakeward gradient is shown on the contour map of Figure 2.4-25. Water-level data used to prepare the map are shown in Table 2.4-7. Water levels at the site were depressed as a result of dewatering for Fermi 2 quarry operation. Prior to construction of Fermi 2, water flowed naturally from many of the borings in the area, as indicated on the boring logs in Figures 2.5-24 through 2.5-56. On the basis of the above-grade static level implied by these flows and water levels in wells in peripheral areas, it is suggested that ground water level at the site is normally above 575 ft.

Water levels in wells fluctuate seasonally, generally highest in spring and lowest in fall. Seasonal fluctuations are not related to Lake Erie fluctuations, although seasonal peaks are somewhat coincidental. The Lake Erie fluctuations are of lower magnitude (Subsection 2.4.2) than ground water fluctuations. It is suggested that the fluctuations coincide because both water bodies respond to the same influences of recharge and evapotranspiration. Water-level fluctuations in the site vicinity since 1970 are provided by the data in Table 2.4-7.

The nearest government agency observation well is approximately 20 miles to the west, in the Dundee area. It is monitored by the USGS. Because the well is completed in glacial drift, water-level fluctuations in the well cannot be considered representative of water-level fluctuations that would occur in the bedrock formation wells in the site area.

Flow rates within the aquifer are highly variable, owing to the fractured and jointed nature of the bedrock. The width, density, and directional pattern of openings can vary from place to place, as indicated by exposures of rock in excavations of the Fermi 2 site and in the onsite rock quarry to the south. An average velocity of flow in the bedrock aquifer is derived on the following basis:

Porosity, $n = 0.01$, conservatively assumed (Reference 29)

Permeability, $k = 2$ ft/day, from tests in borings

Hydraulic gradient, $I = \frac{3\text{ ft}}{2{,}500\text{ ft}} = 0.0012$, determined between wells 17M2 and 17Q1 (12/31/1973)

Velocity, $V = kI/n = 0.24$ ft/day

It is noted that the natural water-level gradient at the site is not available owing to construction dewatering at Fermi 2.

2.4.13.3. Accident Effects

Ground water conditions of the site (Subsection 2.4.13.1) consist of a bedrock aquifer confined under artesian pressure beneath a cap of relatively impervious glacial deposits. Under natural conditions, the ground water gradient is toward Lake Erie. Ground water moves in this direction and eventually discharges into the lake by moving upward through till and lake-bottom sediments.

In the unlikely event of an earthquake, minor cracking in the walls of at least the subgrade portion of the radwaste building structure could occur. The radwaste liquid storage tanks could also undergo stress cracking and leaking to allow fluid flow between the interior of the structure and the surrounding earth. Initially, liquid would be retained within the structure and diluted by inflowing ground water from the dolomite aquifer in contact with the structure. There would be a slow inflow of ground water and the water level inside the structure would rise until it attained the elevation of the piezometric level of the aquifer, approximately Elevation 575.0 ft. At this time, the radioactive material will have been diluted 10:1 or greater.

The time required to fill the structure would be on the order of 3 to 4 weeks. This length of time is determined on the basis of the following information:

a. During construction dewatering of the reactor building basement, pumping was stopped overnight and on weekends. The excavation became flooded up to 3 ft as a result of inflowing ground water. On one such occasion, the water-level rise in the excavation was measured. The rate of rise was 0.0281 ft/hr

b. It is assumed that this same rate of rise could occur in the radwaste building excavation, but adjusted to account for the space occupied by masonry and equipment, which is approximately one-third of the total floor area. The adjusted rate of rise is somewhat higher, almost 0.042 ft/hr

c. The rate of rise decreases continuously as the water level in the structure approaches ground water level. The assumption of a steady rate of water level rise of 0.042 ft/hr is therefore conservative.

During the 3- to 4-week period during which water is rising in the structure, equipment can be mobilized for pumping, storage, processing, and disposal of radioactive material.

If the structure is allowed to fill completely, diluted material would move into and through the aquifer at the same rate of flow and direction of movement as the existing ground water in the aquifer. The direction of movement would be to the east at a rate of 0.24 ft/day (Subsection 2.4.13.2).

The length of time required to travel the 460-ft distance from the structure to the Lake Erie shoreline is 1920 days. By this time, the specific activity of the radioactive material will have been below the limits set forth in 10 CFR 20. (For details of this accident analysis, see Subsection 15.7.3.)

For a discussion of flood protection of the onsite storage building, see Subsection 11.7.2.2.5.

2.4.13.4. Monitoring and Safeguard Requirements

It was demonstrated in Subsection 2.4.13.2 that no water wells are located downgradient from the site. As part of the operational radiological environmental monitoring program, Edison will measure the water level monthly in existing observation wells. The comparison of the data will show flow reversal if it occurs. Should a reversal in flow occur, grab samples would be taken and analyzed for gross beta and gamma isotopes if a path is available from the plant to the ground water. Results would be reported in accordance with the requirements of the Technical Specifications 5.6.2 and 5.6.3.

Under accident conditions, postulated in Subsection 2.4.13.3, monitoring wells will be drilled between the affected structures and the Lake Erie shoreline to monitor subsurface travel and dispersion of radioactive material. Exploratory drilling experience at the Fermi site indicates that truck-mounted drilling rigs are available from Detroit and Toledo and that an observation well could be drilled within several days.

2.4.13.5. Design Bases for Subsurface Hydrostatic Loadings

As described in Subsection 2.4.13.2, the natural ground water level at the site is on the order of 575 ft. As a conservative value for computing normal subsurface hydrostatic loadings, the ground water level is assumed to be 576.0 ft.

Because of the ground-level conditions, construction dewatering is necessary during all major building excavations. In the Fermi 2 construction, dewatering was done by sump pumps placed in the excavations. At the reactor building, grout curtains were installed to minimize ground water inflow and to prevent seepage that would cause falling rock from the walls of the excavations. The Fermi 2 reactor building excavation is 204 by 154 ft, with floor elevations of 540.0 and 551.0 ft.

Bedrock beneath the structure is dolomite, and was pressure grouted for added strength. The dewatering does not affect the structural integrity of the rock. All major safety-related structures have their foundations on bedrock and not within the overburden soils or drift (Subsection 2.5.4.11).

Water supply wells will not be used at the facility.

2.4.14. Technical Specifications and Emergency Operation Requirements

Fermi 2, together with its associated safety-related facilities, is designed to function in a safe manner despite the occurrence of any of the adverse hydrologic events previously discussed. These events have been postulated to occur in appropriate combinations, and such provisions for the safe operation of the plant have been incorporated into the design.

2.4.14.1. Flooding

The probable maximum water levels in Swan Creek resulting from precipitation or flood are discussed in Subsection 2.4.3. These levels are less than those anticipated from the probable maximum surge on Lake Erie.

2.4.14.2. Dam Failures

Potential dam failures are discussed in Subsection 2.4.4. It has been found that there are no regulatory structures on Swan Creek. In addition, there are no dams on other streams and rivers in southeastern Michigan, the failure of which would affect water levels in Lake Erie along the plant shoreline.

2.4.14.3. Surge and Seiche Flooding

The PMME is caused by storm surge. This event, discussed in Subsection 2.4.5, causes a stillwater level at the site of 586.9 ft, or 3.9 ft above plant grade elevation. As described, the Category I structures are designed for the PMME flood level plus runup from small waves generated on the flooded site. The openings in the structures are watertight and designed for the high-water levels.

The water levels associated with the seiche, discussed in Subsection 2.4.5, have been found to be less than the storm surge.

2.4.14.4. Tsunami

Tsunami is discussed in Subsection 2.4.6. Water levels associated with this event have been found to be less than for the storm surge.

2.4.14.5. Ice Flooding

Ice flooding is discussed in Subsection 2.4.7.

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TABLE 2.4-1 ESTIMATED DISCHARGE FREQUENCY - SWAN CREEK

Recurrence Interval (years)	Maximum Discharge (ft^3/sec)
2	2250
5	3500
10	4500
20	5800
50	7700
100	9300

TABLE 2.4-2 SYNTHESIZED LOCAL MAXIMUM PRECIPITATION[a]

Time (hr)	Cumulative Rainfall (in.)	Incremental Rainfall (in.)
1/4	4.9	4.9
1/2	7.0	2.1
3/4	8.8	1.8
1	10.2	1.4
2	14.3	4.1
3	18.0	3.7
4	21.3	3.3
5	24.2	2.9
6	26.9	2.7
12	29.2	2.3
18	31.0	1.8
24	32.4	1.4
30	33.2	0.8
36	33.8	0.6
42	34.3	0.5
48	34.7	0.4

[a] Data from Reference 5.

TABLE 2.4-3 SYNTHESIZED PROBABLE MAXIMUM PRECIPITATION FOR THE SWAN CREEK WATERSHED[a,b]

Time (hr)	Maxima for Durations Indicated: Cumulative Rainfall (in.)	Maxima for Durations Indicated: Incremental Rainfall (in.)	Increments of Storm Sequence (2-hr periods)
2	10.7	10.7	0.2
4	16.0	5.3	0.2
6	20.2	4.2	0.2
8	21.4	1.2	0.2
10	22.0	0.6	0.2
12	22.5	0.5	0.2
14	23.0	0.5	0.2
16	23.4	0.4	0.2
18	23.8	0.4	0.2
20	24.2	0.4	0.2
22	24.5	0.3	0.3
24	24.8	0.3	0.3
26	25.1	0.3	0.3
28	25.4	0.3	0.3
30	25.6	0.2	0.4
32	25.8	0.2	0.5
34	26.0	0.2	0.6
36	26.2	0.2	1.2
38	26.4	0.2	5.3
40	26.6	0.2	10.7
42	26.8	0.2	4.2
44	27.0	0.2	0.5
46	27.2	0.2	0.4
48	27.4	0.2	0.4

[a] Drainage area 109 square miles.

[b] Data from Reference 5.

TABLE 2.4-4 ESTIMATED PRECIPITATION LOSSES AND RUNOFF, PROBABLE MAXIMUM FLOOD, SWAN CREEK[a]

Time (hr)	Unit Hydrograph (ft^3/sec)	PMP	Loss	Runoff	Surface Runoff From Rainfall Excess (ft^3/sec)	Base Flow (ft^3/sec)	Total Discharge (ft^3/sec)
0		0	0	0	0	100	100
2	410	0.2	0.2	0	0	100	100
4	1070	0.2	0.2	0	0	100	100
6	1860	0.2	0.2	0	0	100	100
8	2640	0.2	0.04	0.16	66	100	166
10	3420	0.2	0.04	0.16	236	100	336
12	4000	0.2	0.04	0.16	534	100	634
14	3820	0.2	0.04	0.16	957	100	1,057
16	3440	0.2	0.04	0.16	1,504	100	1,604
18	3010	0.2	0.04	0.16	2,144	100	2,244
20	2520	0.2	0.04	0.16	2,755	100	2,855
22	2060	0.3	0.04	0.26	3,347	100	3,447
24	1710	0.3	0.04	0.26	3,935	100	4,035
26	1410	0.3	0.04	0.26	4,524	100	4,624
28	1160	0.3	0.04	0.26	5,188	100	5,218
30	900	0.4	0.04	0.36	5,775	100	5,875
32	700	0.5	0.04	0.46	6,548	100	6,648
34	510	0.6	0.04	0.56	7,450	100	7,550
36	350	1.2	0.04	1.16	8,741	100	8,841
38	160	5.3	0.04	5.26	12,269	100	12,369
40	22	10.7	0.04	10.66	21,325	100	21,425
42	0	4.2	0.04	4.16	35,034	100	35,134
44		0.4	0.04	0.46	50,805	100	50,905
46		0.4	0.04	0.36	66,564	100	66,664
48		0.4	0.04	0.36	80,588	100	80,688
50					88,432	100	88,532

[a] Drainage area 109 square miles.

TABLE 2.4-5 U.S. ARMY CORPS OF ENGINEERS UNIT HYDROGRAPHS

Basin	Station	Drainage Area (mi^2)	q_p	t_p	C_p 640	C_t	$(LL_{ca})^{0.3}$	L	L_{ca}	t_r (hr)
Swan Creek[a]	Mouth, Michigan	109	36.7	12.3	451	2	6.14	25.4	16.67	2
Cedar River	East Lansing, Michigan	355	7.6	36.5	279	5.1	7.1	37	18	6
Sandusky River	Bucyrus, Ohio	89.8	27.1	21.0	569	3.39	6.2	27.5	16.3	6
Sebewaing River	Sebewaing, Michigan	105	28.46	11.0	313	2.50	4.44	16	9	6
Juscarawas River	Massillon, Ohio	507	8.06	44.4	358	6.34	7.0	41.0	16.0	6
Clinton River	Mt. Clemens, Michigan	733	17.5	22.2	441	3.81	6.62	32	17	6
Grand River	Lansing, Michigan	1230	6.8	38.5	260	3.4	11.2	75	42	6

[a] Synthetic unit hydrograph.

TABLE 2.4-6 DILUTION FACTOR ESTIMATES - LAKE ERIE INTAKES

Location	Normal Conditions				Annual Average	Worst Condition
	South Current		North Current			
	Ice-Free	Ice-Cover	Ice-Free	Ice-Cover		
Monroe intake	320	290	1.6×10^{11}	1.0×10^{10}	770	26
Toledo intake	1.6×10^{16}	9.0×10^{12}	3.1×10^{25}	1.1×10^{22}	5.4×10^{13}	4.3×10^{5}

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
R1	5S/8E-36R1[b]	77	594.0	9/9/64
			597.6	4/28/72
D1	5S/9E-2D1[b]	33	590.0	5/20/65
			588.11	4/28/72
J1	6S/9E-11J1[b]	--	581.22	2/3/72
K1	6S/9E-13K1	--	577.02	12/29/70
			577.25	12/30/70
			576.68	10/22/71
C1	6S/9E-23C1	35	580.74	2/3/72
			583.0	11/13/54
K1	6S/9E-23K1	95	572.0	11/24/69
			570.64	9/8/70
Q1[c]	6S/9E-23Q1	76	572.0	11/6/69
			575.4	9/8/70
			574.65	10/27/70
			576.39	12/29/70
			575.8	2/26/71
			577.0	3/26/71
			576.25	4/30/71
			576.3	5/28/71
			574.8	7/2/71
			573.0	7/30/71
			572.8	8/24/71
			573.52	10/22/71
			572.3	10/30/71
			579.13	4/28/72
C1	6S/9E-24C1	--	576.87	12/29/70
Q1[c]	6S/9E-24Q1	50	575.0	9/19/69
			574.76	9/8/70
			573.84	10/27/70
			575.97	12/29/70
			573.4	11/5/71

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			573.4	12/3/71
			574.4	1/7/72
			575.4	2/4/72
			576.1	3/3/72
			579.8	4/7/72
			580.5	4/21/72
			580.73	4/29/72
			582.15	5/26/72
			578.57	6/23/72
			578.23	7/7/72
			577.73	8/23/72
			578.57	10/6/72
			581.90	11/24/72
			582.07	12/29/72
Q2	6S/9E-24Q2	70	571.0	11/6/53
Q3	6S/9E-24Q3	65	577.0	6/13/53
R1	6S/9E-24R1	127.5	577.0	3/27/51
L1	6S/9E-25L1	32	568.0	8/2/56
L2	6S/9E-25L2	45	572.0	7/9/52
L3	6S/9E-25L3	41.5	570.0	4/28/50
L4	6S/9E-25L4	50.5	565.0	7/3/50
L5	6S/9E-25L5	28.5	572.0	6/17/53
			575.04	2/3/72
M1	6S/9E-25M1	49.5	574.0	4/17/53
M1A	6S/9E-25M1A	37	570.0	10/18/55
M2	6S/9E-25M2	39	575.0	4/12/48
	6S/9E-35H1	34.5	569.0	1/20/49
J1	6S/10E-6J1[b]	52	575.0	8/31/63
Q1	6S/10E-6Q1[b]	55	570.0	10/17/53
Q2	6S/10E-6Q2[b]	56.5	575.0	7/3/47
A1	6S/10E-7A1[b]	55	576.0	9/18/53
A2	6S/10E-7A2[b]	116	570.0	12/12/69

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			570.7	2/3/72
H1	6S/10E-7H1[b]	52	567.0	6/12/56
K1	6S/10E-7K1[b]	67	576.0	6/6/68
L1	6S/10E-7L1[b]	35	572.0	7/1/50
J1	6S/10E-8J1[b]	49	575.0	12/21/55
K1	6S/10E-8K1[b]	36	571.0	11/26/57
R1	6S/10E-8R1[b]	51	571.0	1/30/66
			570.63	9/8/70
			570.03	2/3/72
B1	6S/10E-16B1[b]	52	572.0	
C1	6S/10E-16C1	49	570.0	6/25/54
F1	6S/10E-17F1	59	562.0	2/17/64
			568.91	9/8/70
M2	6S/10E-17M2	--	567.59	10/27/70
			571.75	2/3/72
P1[c]	6S/10E-18P1	60	572.1	9/8/70
			571.84	12/30/70
			576.3	2/26/71
			576.6	1/26/71
			573.2	5/28/71
18P1[c]	6S/10E-19P1	--	574.0	7/2/71
			575.0	7/29/71
			573.25	8/27/71
			573.30	9/24/71
			573.30	10/30/71
			571.2	12/3/71
			573.5	1/7/72
			573.6	2/4/72
			574.0	3/3/72
			577.3	4/7/72
			578.3	4/21/72
			576.67	4/29/72

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			579.00	5/26/72
			576.92	6/23/72
			576.17	7/7/72
			573.50	8/25/72
			576.58	10/6/72
			581.17	11/24/72
			581.50	12/29/72
R1	6S/10E-18R1	80	573.49	9/8/70
			569.24	10/27/70
			569.56	12/29/70
B1	6S/10E-19B1	65	577.0	12/22/64
B2	6S/10E-19B2	65	583.0	2/17/69
			576.86	9/8/70
			571.86	10/27/70
			568.94	12/29/70
			583.0	2/17/69
			576.42	9/8/70
			571.42	10/27/70
			568.3	12/29/70
			571.33	8/6/71
			570.26	8/27/71
			570.21	9/24/71
			570.14	10/30/71
			570.94	12/10/71
			570.94	1/7/72
			571.84	2/4/72
			572.34	3/3/72
			575.02	4/7/72
			578.19	4/21/72
			576.69	4/29/72
			576.76	5/26/72
			574.69	6/23/72

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			573.69	7/7/72
			573.94	10/6/72
			579.11	11/24/72
B3	6S/10E-19B3	45	581.0	10/30/53
G1	6S/10E-19G1	--	591.0	3/2/56
H1[c]	6S/10E-19H1	--	570.7	5/12/71
			570.4	6/1/71
			570.75	7/2/71
			570.32	8/2/71
			570.21	8/27/71
			570.57	10/1/71
			569.8	11/5/71
			569.5	12/3/71
			570.25	12/23/71
			572.0	1/31/72
			571.3	2/25/72
			573.0	3/14/72
			574.4	4/7/72
			578.0	4/21/72
			576.67	4/29/72
			575.58	5/26/72
			573.25	6/23/72
			572.50	7/7/72
			570.67	8/25/72
			572.67	10/6/72
			578.17	11/24/72
			578.92	12/29/72
M1	6S/10E-19M1	56	580.0	5/17/68
			570.03	9/8/70
			572.36	2/3/72
M2	6S/10E-19M2	40.5	580.0	12/8/45
M3	6S/10E-19M3	31	582.0	4/12/49

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
P1	6S/10E-19P1	58	569.0	10/6/64
R1	6S/10E-19R1	45	566.72	9/8/70
			573.94	4/28/72
P1[c]	6S/10E-20P1	84	568.0	3/18/70
			568.0	4/1/70
			567.3	5/6/70
			559.8	8/10/70
			562.2	8/19/70
			563.58	3/1/71
			565.38	4/1/71
			562.58	5/3/71
			554.48	6/1/71
			548.38	7/1/71
			544.78	7/23/71
			Destroyed	--
P2[c]	6S/10E-20P2	--	568.0	3/18/70
			567.2	5/6/70
			564.3	6/25/70
			563.9	7/30/70
			563.8	8/18/70
			566.92	3/1/71
			567.62	4/1/71
			565.92	5/3/71
			564.52	6/1/71
			559.12	7/1/71
			556.77	8/2/71
			552.02	8/27/71
			551.81	10/1/71
			550.94	11/5/71
			549.61	12/3/71
			549.14	12/23/71
E1	6S/10E-20E1	62	583.0	10/27/70

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			585.18	4/28/72
E2	6S/10E-20E2	--	580.51	12/29/70
N1	6S/10E-20N1	53.5	565.0	5/26/50
C1	6S/10E-28C1	58	569.0	12/12/50
D1	6S/10E-28D1	39	568.19	10/22/71
D2	6S/10E-28D2	51.5	571.0	3/12/51
E1[c]	6S/10E-28E1	--	567.97	9/8/70
			567.88	10/27/70
			569.84	12/29/70
			571.5	2/26/71
			572.1	3/26/71
			571.75	4/30/71
			570.4	5/28/71
			568.5	7/2/71
			566.0	7/30/71
			566.17	8/27/71
			565.82	9/24/71
			565.9	10/30/71
			566.17	12/3/71
			567.5	1/7/72
			569.3	2/4/72
			570.84	3/3/72
			572.1	4/7/72
			572.8	4/21/72
			572.42	4/29/72
			571.50	5/26/72
			570.00	6/23/72
			569.58	7/7/72
			569.17	8/25/72
			570.92	10/6/72
			573.00	11/24/72
			573.42	12/29/72

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
E2	6S/10E-28E2	74.5	574.5	6/30/51
E3	6S/10E-28E3	43	577.0	5/1/56
E4	6S/10E-28E4	56.5	575.0	4/19/52
E5	6S/10E-28E5	51	572.0	7/28/65
E6	6S/10E-28E6	--	568.8	10/22/71
E7	6S/10E-28E7	--	569.4	10/22/71
			576.4	5/1/72
F1	6S/10E-28F1	68	573.0	11/20/67
			571.81	10/22/71
M1	6S/10E-28M1	68	572.0	5/17/49
A1	6S/10E-29A1	--	566.52	10/22/71
			570.65	4/28/72
B1[c]	6S/10E-29B1	--	567.45	7/1/70
			567.42	8/3/70
			566.22	9/1/70
			566.37	10/1/70
			566.87	11/2/70
			567.07	12/2/70
			567.17	1/4/71
			566.6	2/1/71
			568.57	3/1/71
			569.57	4/1/71
			568.43	5/3/71
			567.87	6/1/71
			565.97	7/1/71
			564.82	8/2/71
			564.15	8/27/71
			564.15	10/1/71
			563.57	11/5/71
			563.57	12/3/71
			563.77	12/23/71
			564.57	1/31/72

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			563.87	2/25/72
			564.37	3/14/72
			565.27	4/7/72
			566.24	4/21/72
			566.40	4/29/72
			567.07	5/26/72
			564.99	6/23/72
			564.90	7/7/72
			566.24	8/25/72
			567.07	10/6/72
			569.74	11/24/72
			570.07	12/29/72
D1	6S/10E-29D1	28.5	570.0	10/2/54
			563.25	10/22/71
			567.45	4/28/72
E1	6S/10E-29E1	38.5	572.0	7/16/53
E2	6S/10E-29E2	31	567.0	8/31/55
E3	6S/10E-29E3	60.5	572.0	7/13/62
E4	6S/10E-29E4	40	572.2	1970
			562.4	10/22/71
H1	6S/10E-29H1	39	571.0	
H2	6S/10E-29H2	38.5	569.0	10/15/47
J1	6S/10E-29J1	37	570.0	5/27/60
J2	6S/10E-29J2	35	567.0	6/4/56
			570.55	2/3/72
J3	6S/10E-29J3	35	572.0	1/8/53
J4	6S/10E-29J4	74	566.0	11/18/52
J5	6S/10E-29J5	46	568.0	7/25/64
J6	6S/10E-29J6	40	572.0	6/2/52
J7	6S/10E-29J7	45	571.0	6/13/53
J8	6S/10E-29J8	28	572.0	4/12/49
J9	6S/10E-29J9	38	570.0	5/13/50

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
J10	6S/10E-29J10	31	570.0	7/29/53
J11	6S/10E-29J11	36	572.0	6/14/57
K1	6S/10E-29K1	30	575.0	3/19/52
K2	6S/10E-29K2	47	573.0	6/7/63
Q1	6S/10E-29Q1	40	566.0	
R1	6S/10E-29R1	30	573.0	4/18/57
R2	6S/10E-29R2	50	564.0	11/16/54
B1	6S/10E-30B1	60	569.0	10/7/68
C1	6S/10E-30C1	40	569.0	11/26/63
			568.93	2/3/72
E1	6S/10E-30E1	29	571.0	8/8/45
H1	6S/10E-30H1	42.5	570.0	9/18/65
H2	6S/10E-30H2	49	572.0	10/28/57
A1	6S/10E-32A1	49	570.0	6/7/56
A2	6S/10E-32A2	41.5	575.0	6/11/51
P2[c]	6S/10E-20P2		546.94	1/31/72
			547.14	2/25/72
			540.34	3/14/72
			537.99	4/7/72
			540.77	4/21/72
			541.86	4/29/72
			542.94	5/26/72
			539.11	6/23/72
			540.44	7/7/72
			552.86	8/25/72
			557.19	10/6/72
			561.52	11/24/72
			564.69	12/29/72
P3	6S/10E-20P3	62	576.0	12/15/65
			551.55	7/25/72
E1[c]	6S/10E-21E1	42	557.91	7/1/70
			559.59	8/3/70

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date
			555.02	9/1/70
			555.74	10/1/70
			556.74	11/2/70
			556.60	12/2/70
			556.94	1/4/71
			556.1	2/1/71
			557.14	3/1/71
			556.94	4/1/71
			555.49	5/3/71
			556.54	6/1/71
			555.94	7/1/71
			555.99	8/2/71
			556.53	8/28/71
			557.12	10/1/71
			556.24	11/5/71
			556.24	12/3/71
			556.64	12/23/71
			558.14	1/31/72
			559.44	2/25/72
			559.64	3/14/72
			562.16	4/7/72
			562.99	4/21/72
			561.91	4/29/72
			561.99	5/26/72
			564.16	6/23/72
			563.99	7/7/72
			560.32	8/25/72
			560.37	10/6/72
			560.91	11/24/72
			563.74	12/29/72

TABLE 2.4-7 WATER WELL DATA[a]

Map Reference Number	Well Number	Depth (ft)	Elevation of Water Level (ft)	Date

[a] Shown in Figure 2.4-25.

[b] Not shown in Figure 2.4-25.

[c] Monitor wells are underlined.

Explanation of well numbering system:

The well locations are identifiable by the well number. The well numbering system, which is commonly used by water resource agencies, including the U.S. Geological Survey, designates the location of the well within a 40-acre parcel of land. The standard one-square-mile section is subdivided into 40-acre parcels as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

As an example, suppose a given well is located as follows:

a. Township 7 South

b. Range 10 East

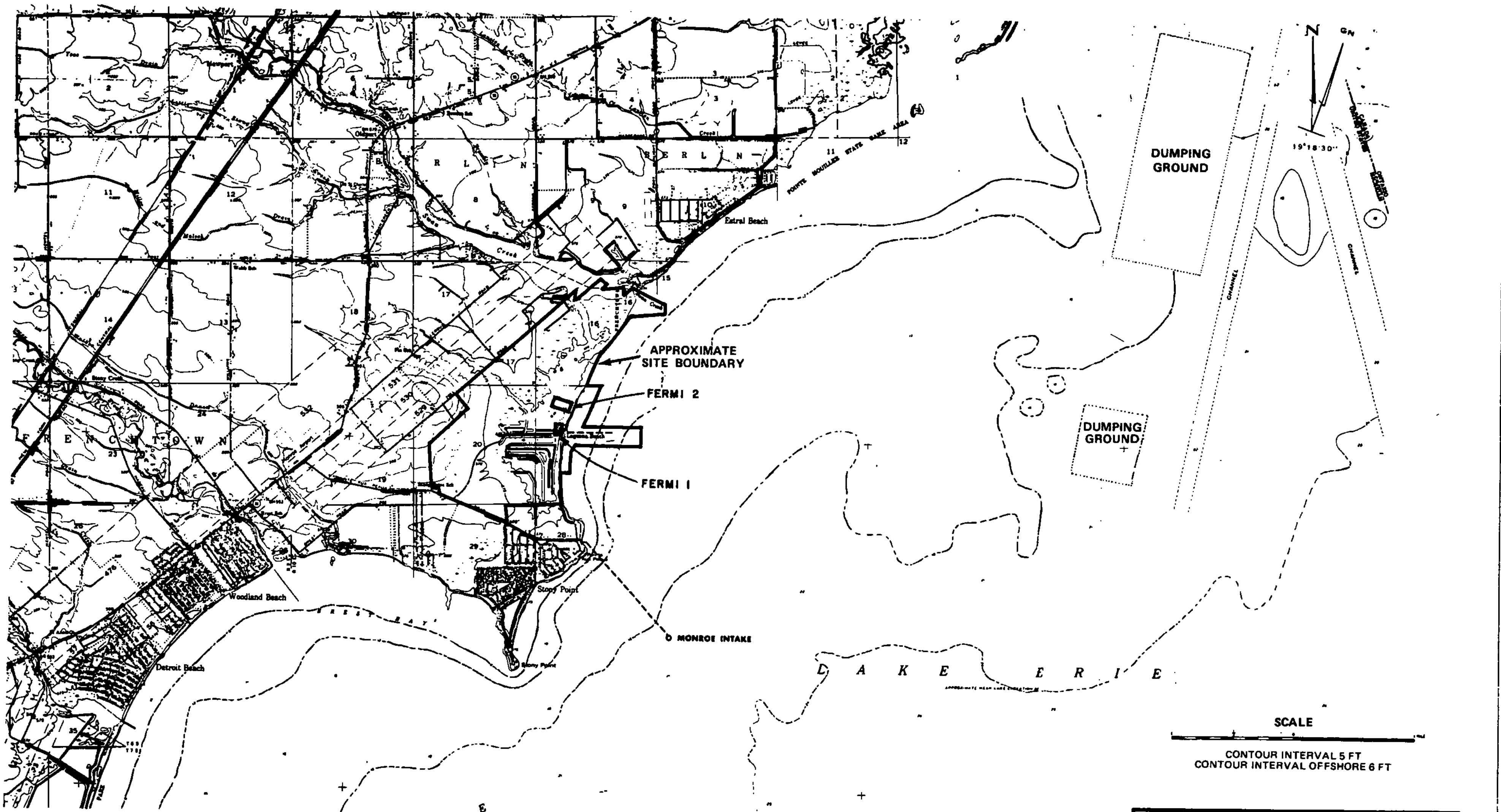
c. Section 32

d. northeast corner.

That well would be given the number, 7S/10E-32A1.

The number 1 following the letter A indicates that this is the first well inventoried in the 40-acre parcel lettered A.

All the wells within the immediate vicinity of the site are shown in Figure 2.4-25. These wells are identified and located by the last two digits of the previously described well numbering system and listed under the heading, "MAP Reference Number."



REFERENCE:
THIS MAP WAS PREPARED FROM PORTIONS OF THE FOLLOWING U.S.G.S. QUADRANGLES: ESTRAL BEACH, MICH., 1942, STONY POINT, MICH., 1952, ROCKWOOD, MICH., 1952, AND FLAT ROCK, MICH., 1952.

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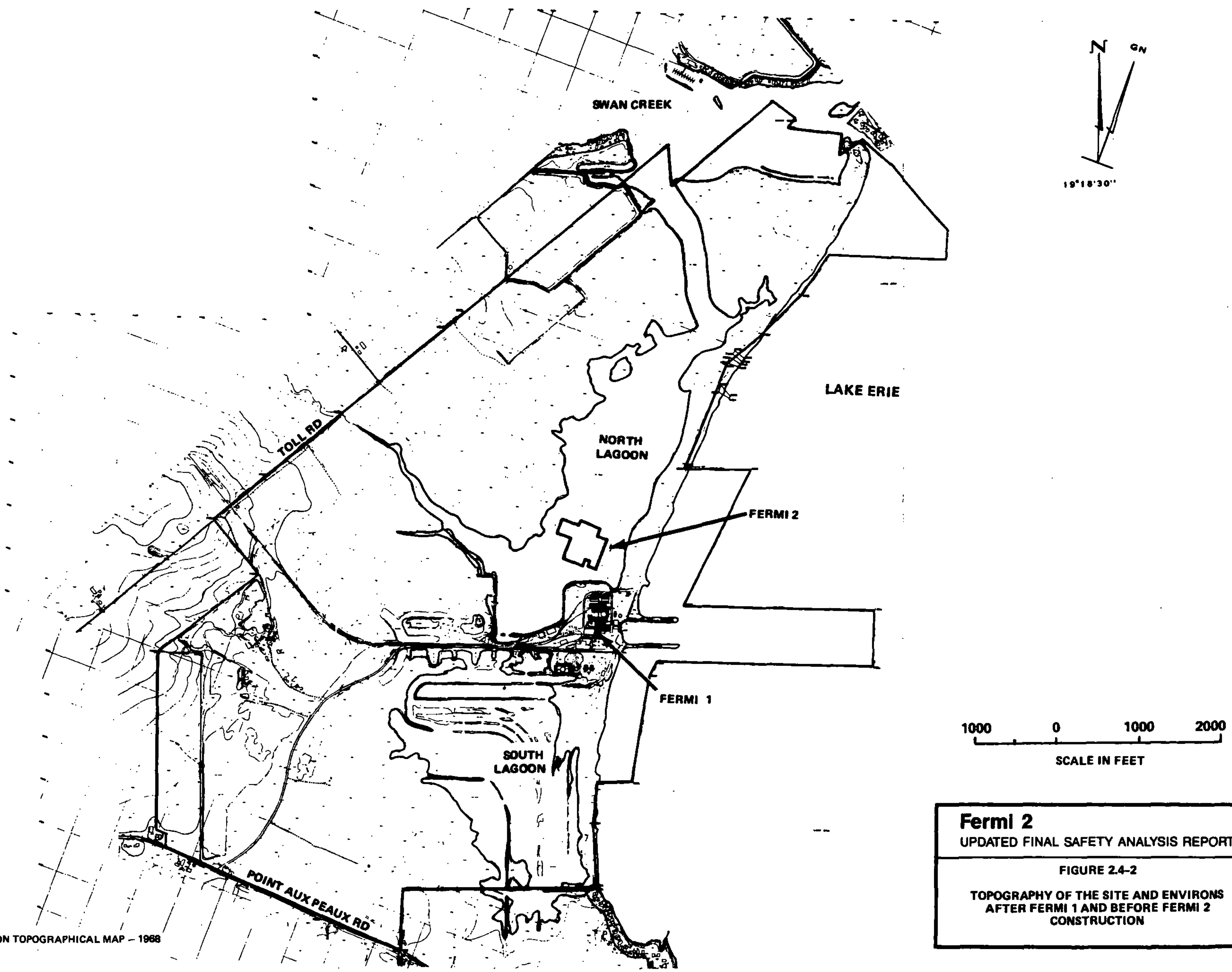
FIGURE 2.4-1

SITE VICINITY MAP



REFERENCE:
PORTION OF THE DETROIT EDISON TOPOGRAPHICAL MAP – 1968

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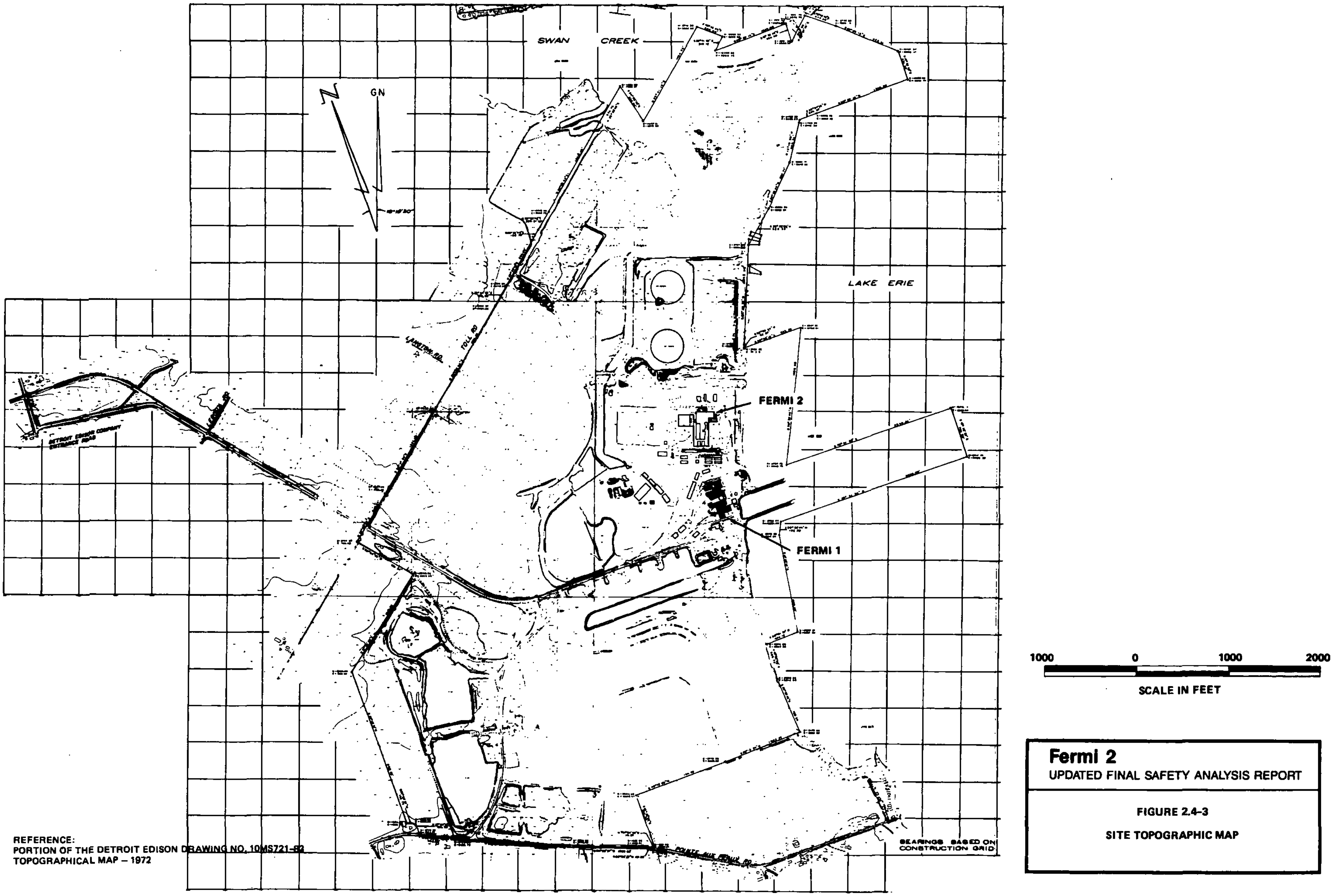
FIGURE 2.4–2

TOPOGRAPHY OF THE SITE AND ENVIRONS AFTER FERMI 1 AND BEFORE FERMI 2 CONSTRUCTION



REFERENCE:
PORTION OF THE DETROIT EDISON DRAWING NO. 10MS721-63
TOPOGRAPHICAL MAP – 1972

Fermi 2
UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.4-3

SITE TOPOGRAPHIC MAP

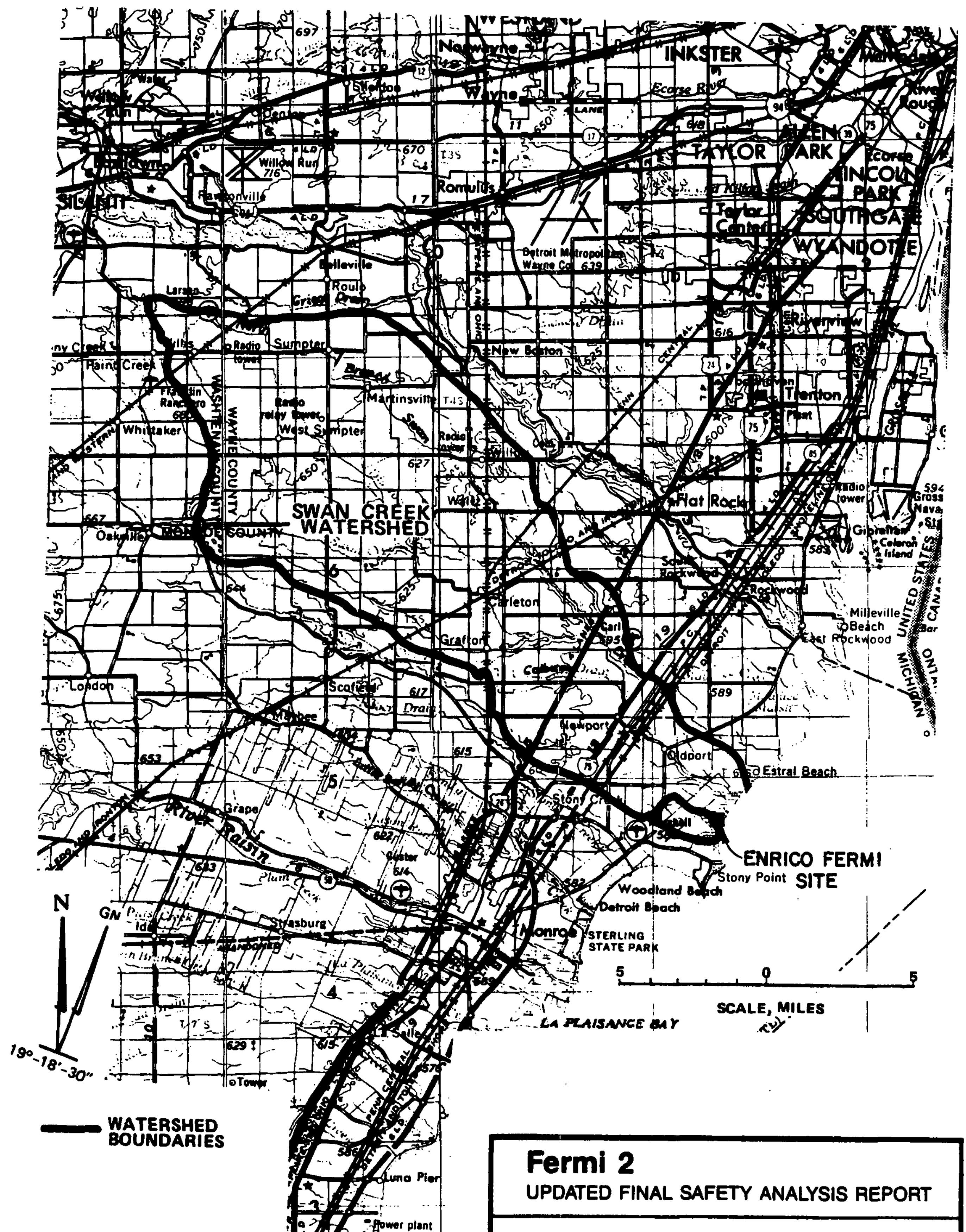


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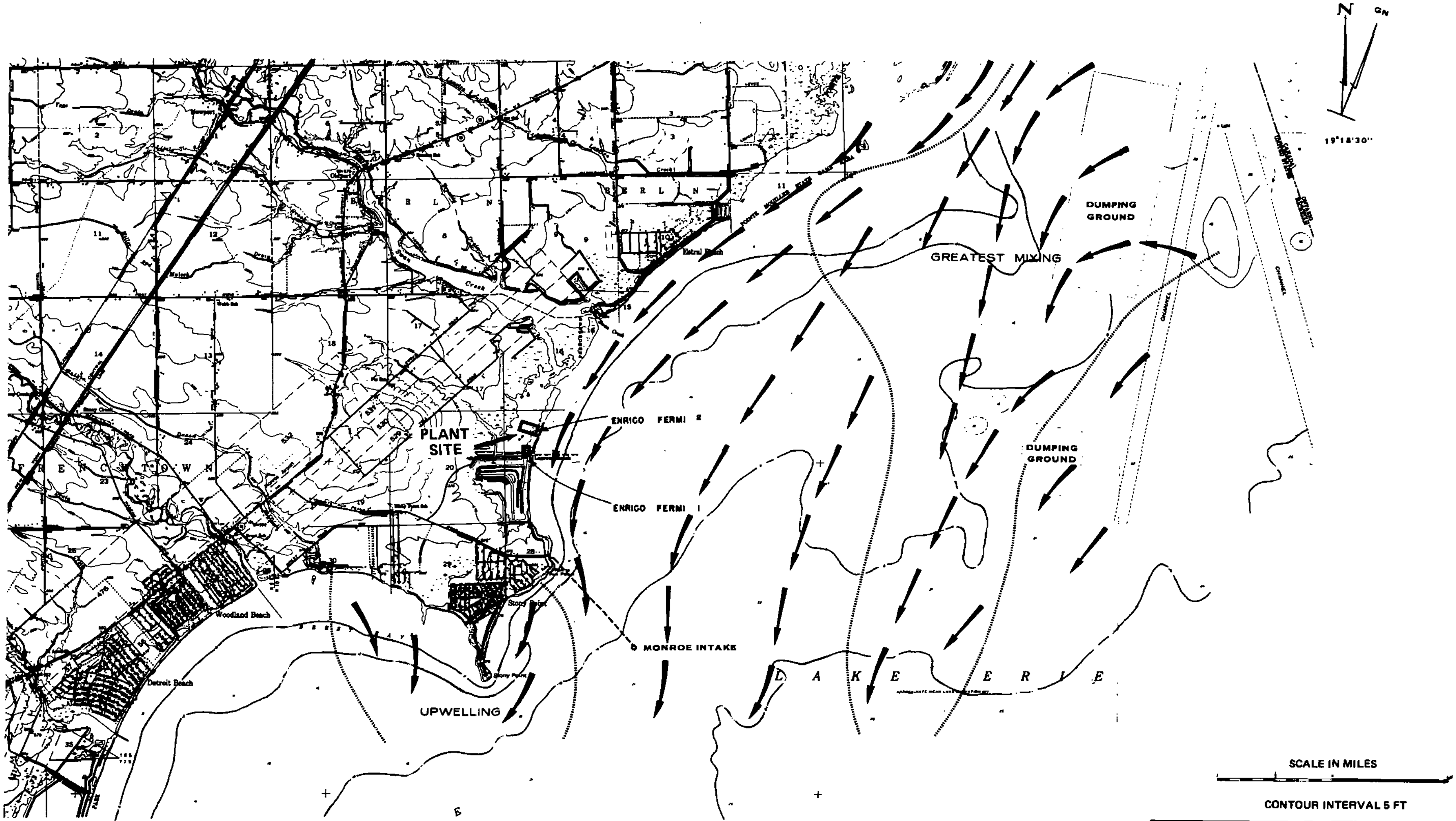
FIGURE 2.4-4

SWAN CREEK WATERSHED

REFERENCE:
PORTIONS OF DETROIT AND TOLEDO
U.S.G.S. TOPOGRAPHIC MAPS.



REFERENCE:
THIS MAP WAS PREPARED FROM PORTIONS OF THE FOLLOWING U.S.G.S. TOPOGRAPHIC QUADRANGLES: ESTRAL BEACH, MICHIGAN, 1942, STONY POINT, MICHIGAN, 1952, ROCKWOOD, MICHIGAN, 1952, AND FLAT ROCK, MICHIGAN, 1952.

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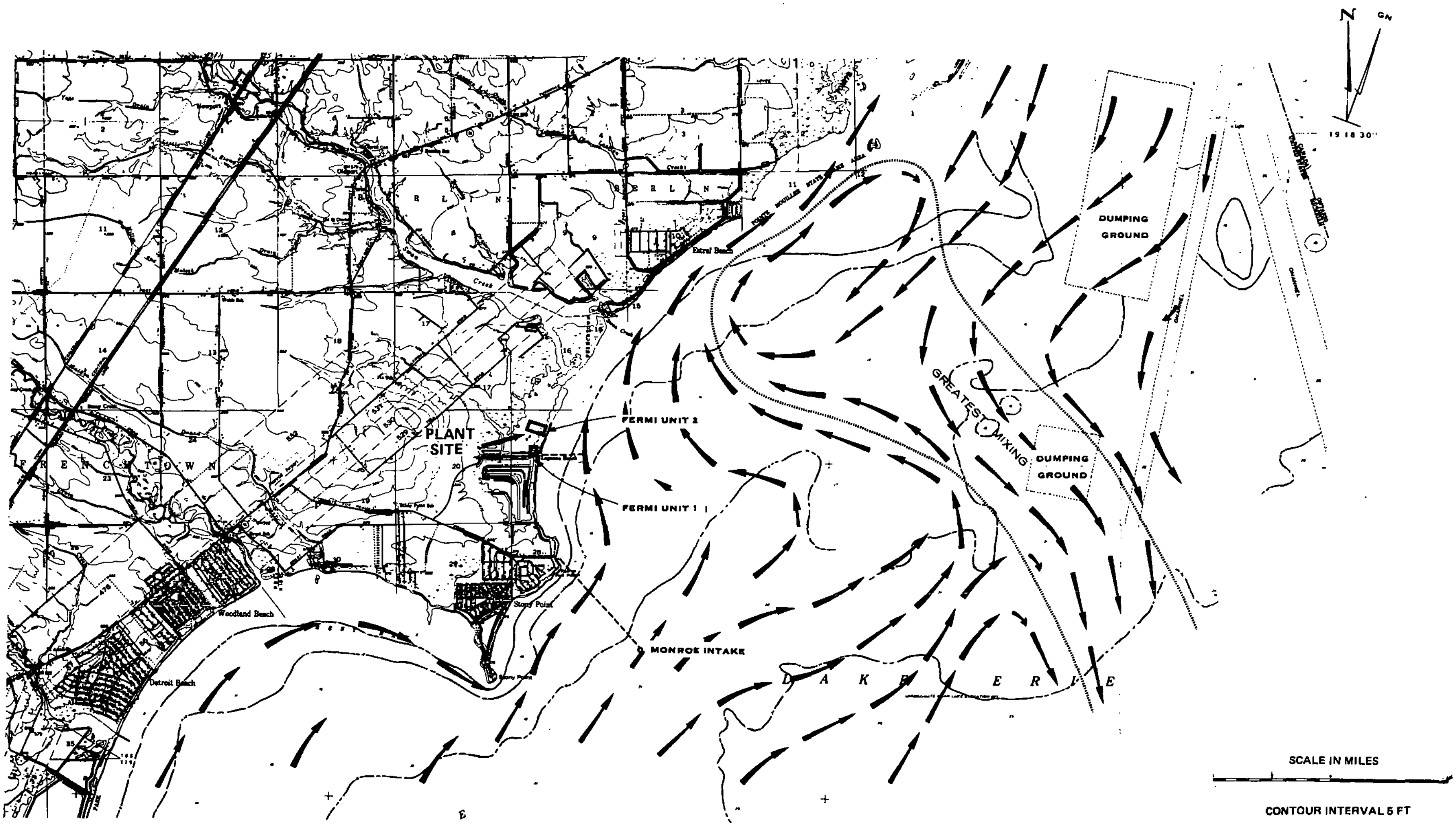
FIGURE 2.4-5

WATER CURRENT PATTERNS WITH WINDS FROM NORTHWEST THROUGH NORTHEAST



REFERENCE:
THIS MAP WAS PREPARED FROM PORTIONS OF THE FOLLOWING U.S.G.S. TOPOGRAPHIC QUADRANGLES: ESTRAL BEACH, MICHIGAN, 1942, STONY POINT, MICHIGAN, 1952, ROCKWOOD, MICHIGAN, 1952, AND FLAT ROCK, MICHIGAN, 1952.

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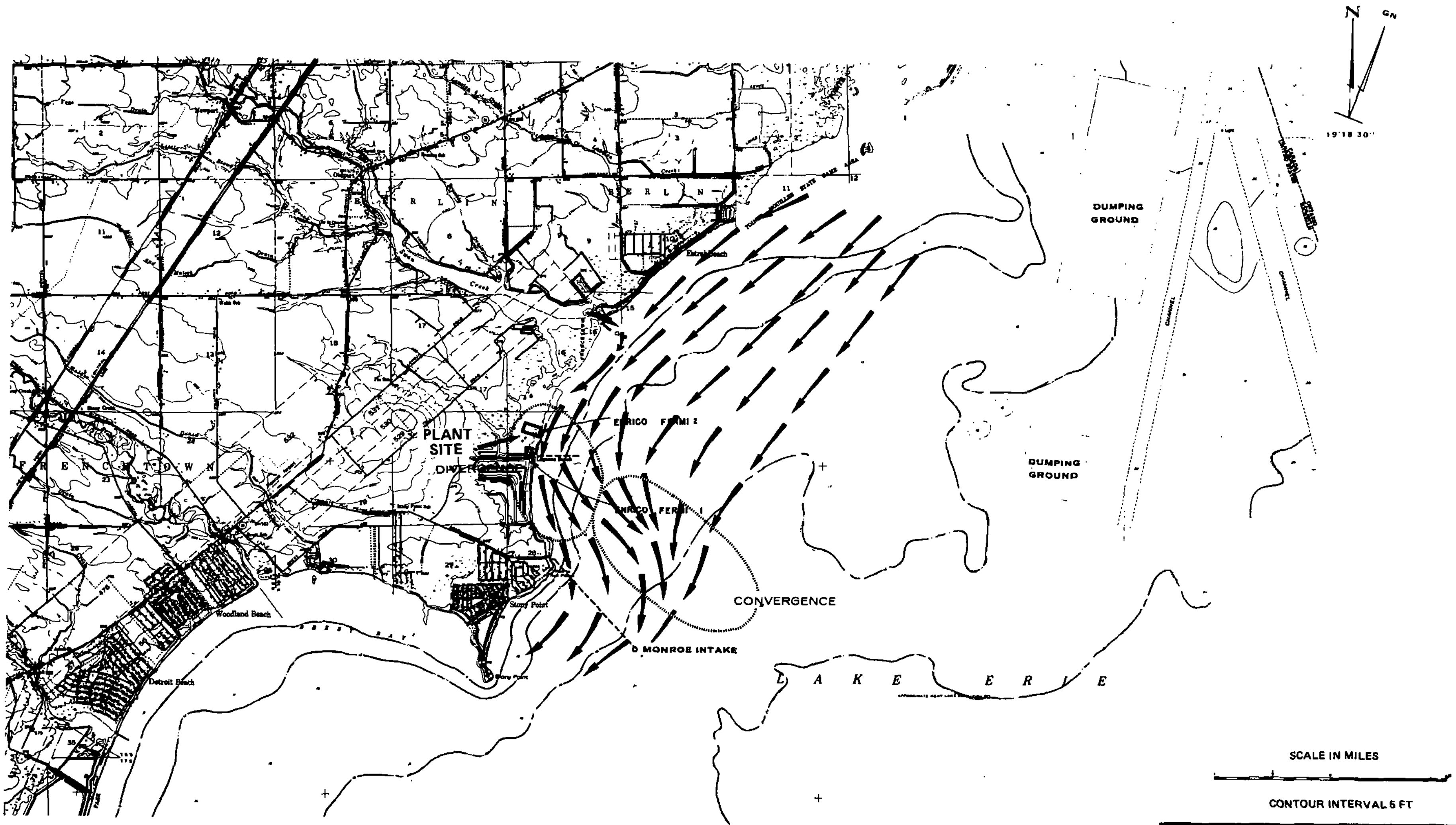
FIGURE 2.4-6

WATER CURRENT PATTERNS WITH WINDS FROM EAST-SOUTHEAST THROUGH WEST



REFERENCE:
THIS MAP WAS PREPARED FROM PORTIONS OF THE FOLLOWING U.S.G.S. TOPOGRAPHIC QUADRANGLES: ESTRAL BEACH, MICHIGAN, 1942, STONY POINT, MICHIGAN, 1952, ROCKWOOD, MICHIGAN, 1952, AND FLAT ROCK, MICHIGAN, 1952.

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FIGURE 2.4-7

WATER CURRENT PATTERNS UNDER ICE CONDITIONS

FIGURE 2.4-8 HAS BEEN DELETED

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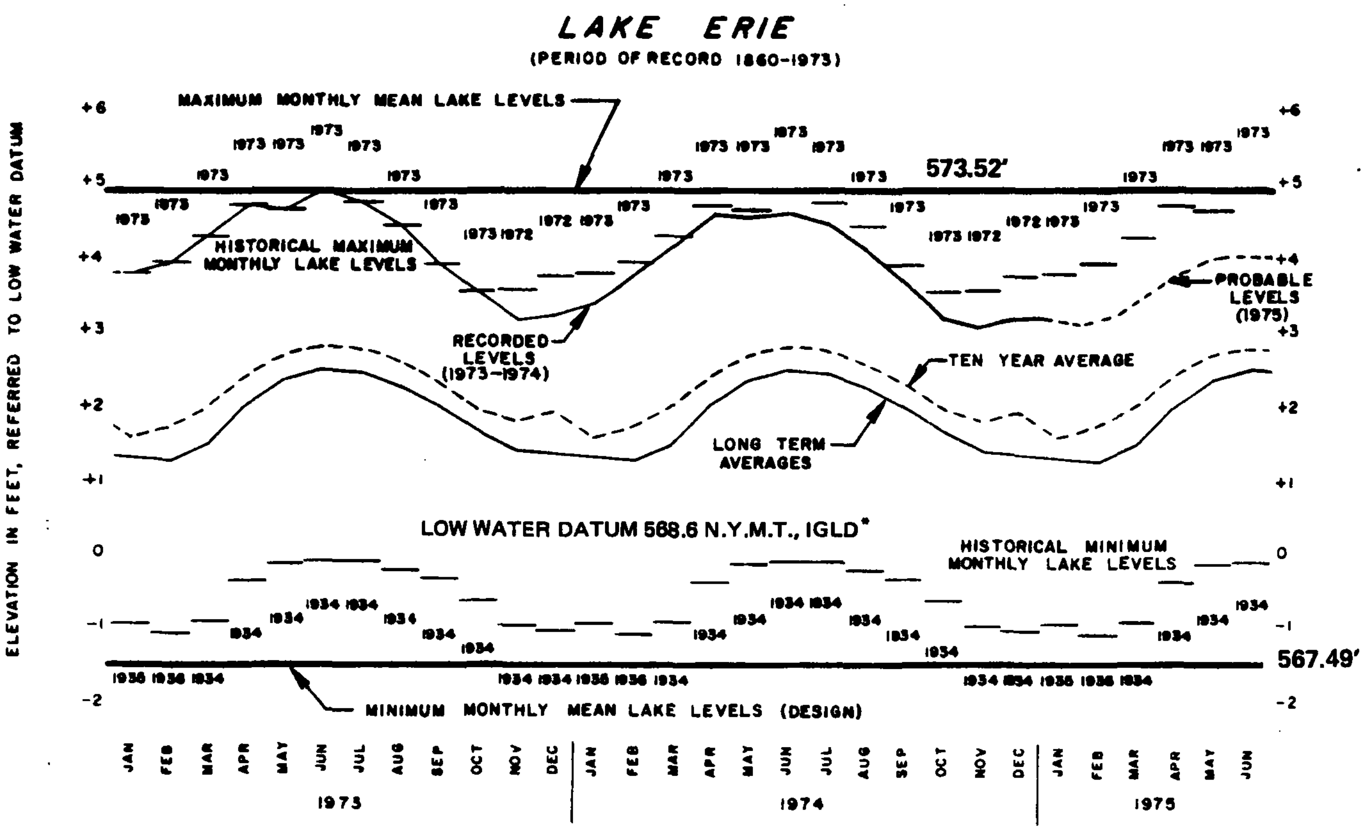

*ADD 1.94' TO CONVERT TO N.Y.M.T., 1935

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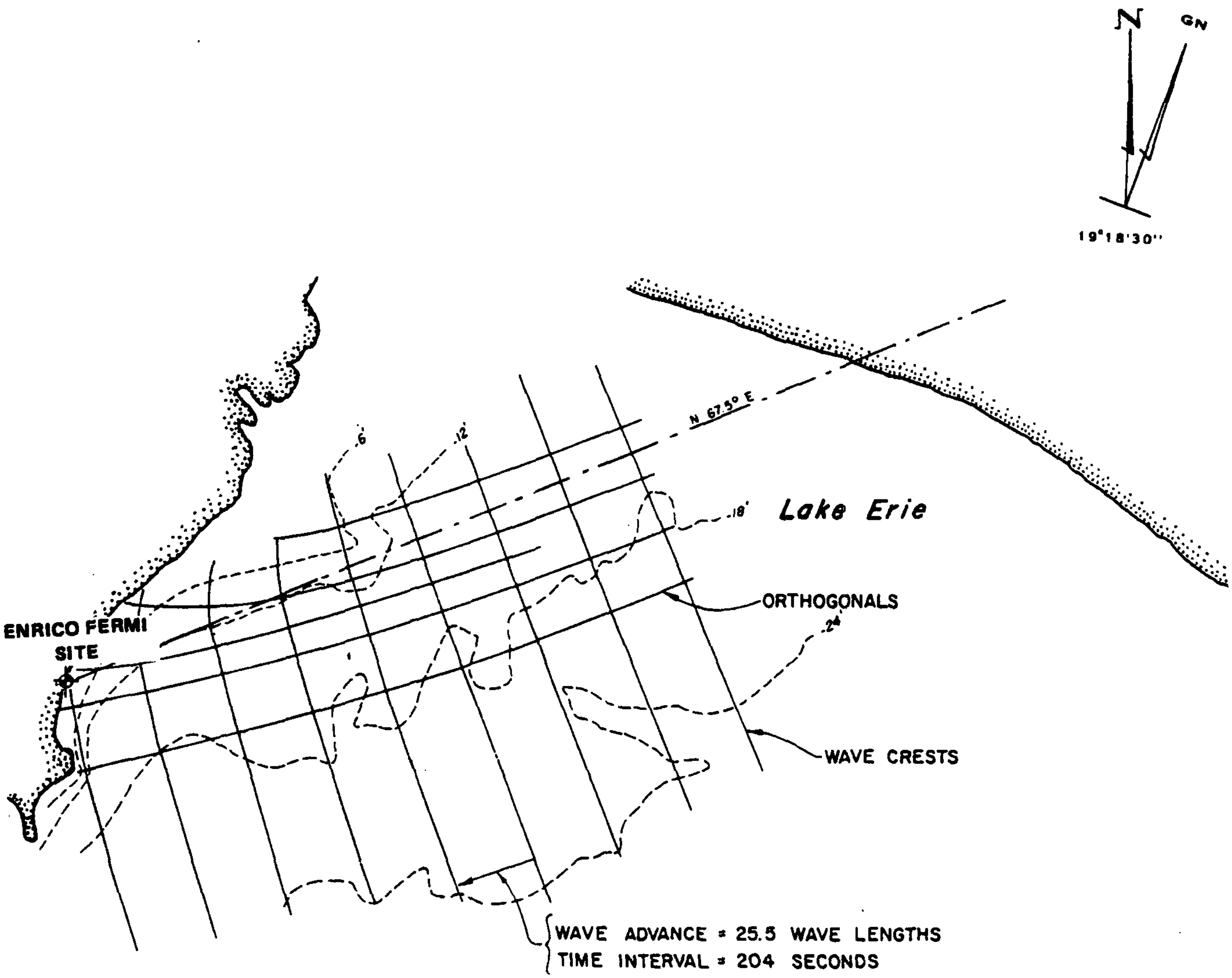
FIGURE 2.4-9

MAXIMUM AND MINIMUM MONTHLY MEAN LAKE LEVELS

REFERENCE:
U.S. DEPARTMENT OF COMMERCE, MONTHLY BULLETIN OF LAKE LEVELS FOR JANUARY 1974, NATIONAL OCEAN SURVEY, LAKE SURVEY CENTER.



LEGEND:
- - - - LAKE BOTTOM CONTOURS
SOUNDING DATUM: NYMT 1935
WAVES REFRACTED DURING TIDE = +16.4 FEET NYMT 1935
WAVE PERIOD = 8.0 SECONDS
WAVE DIRECTION FROM N67.5°E

100,000 50,000 0 100,000
SCALE IN FEET

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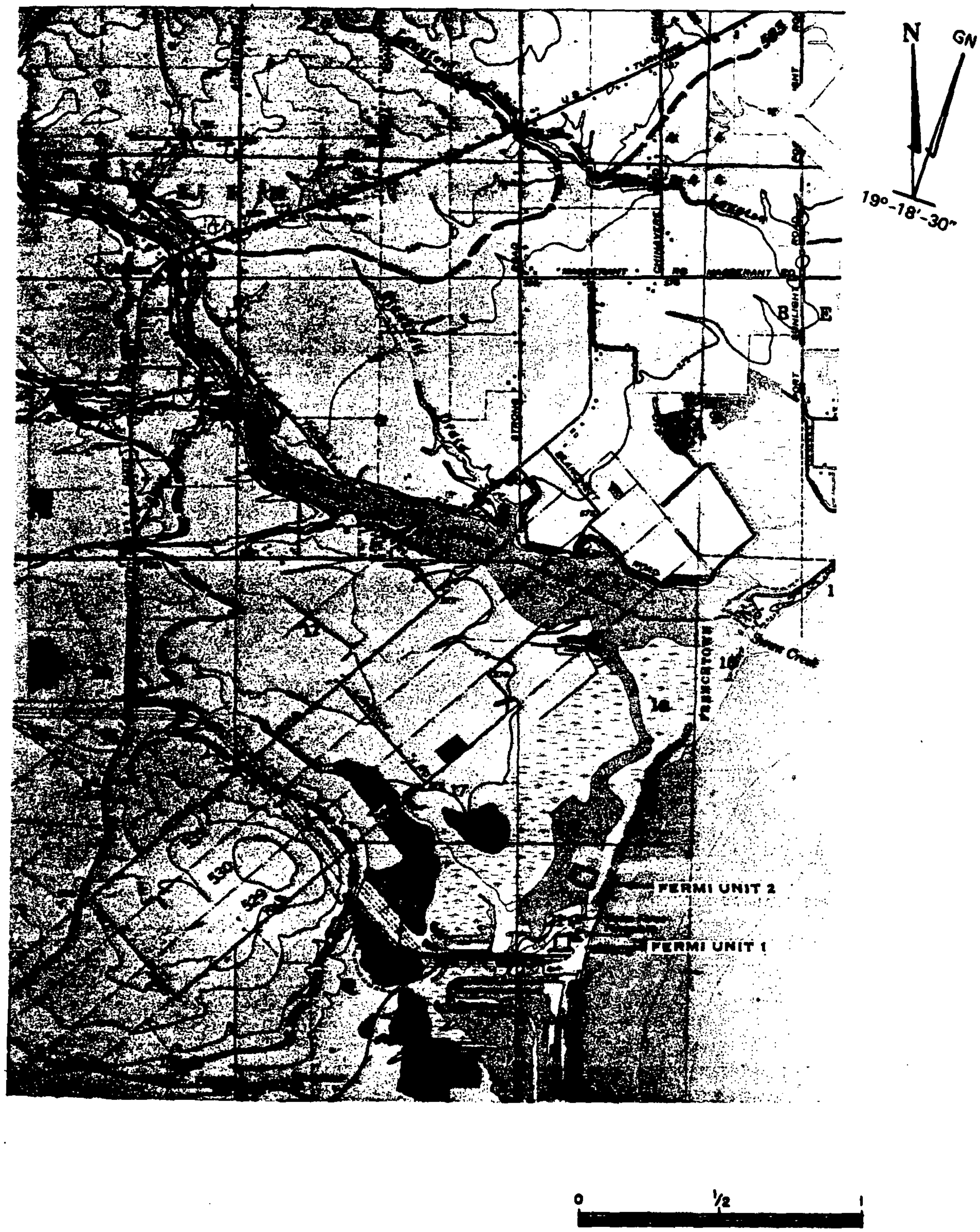
FIGURE 2.4-10
WAVE REFRACTION

REFERENCE:
U.S. LAKE SURVEY, CHART NO. 39, 1968



REFERENCE:
U.S.G.S. TOPOGRAPHIC QUADRANGLE
STONY POINT, MICHIGAN – 1967.

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FIGURE 2.4-11

SITE AREA TOPOGRAPHY SHOWING 583-FT CONTOUR

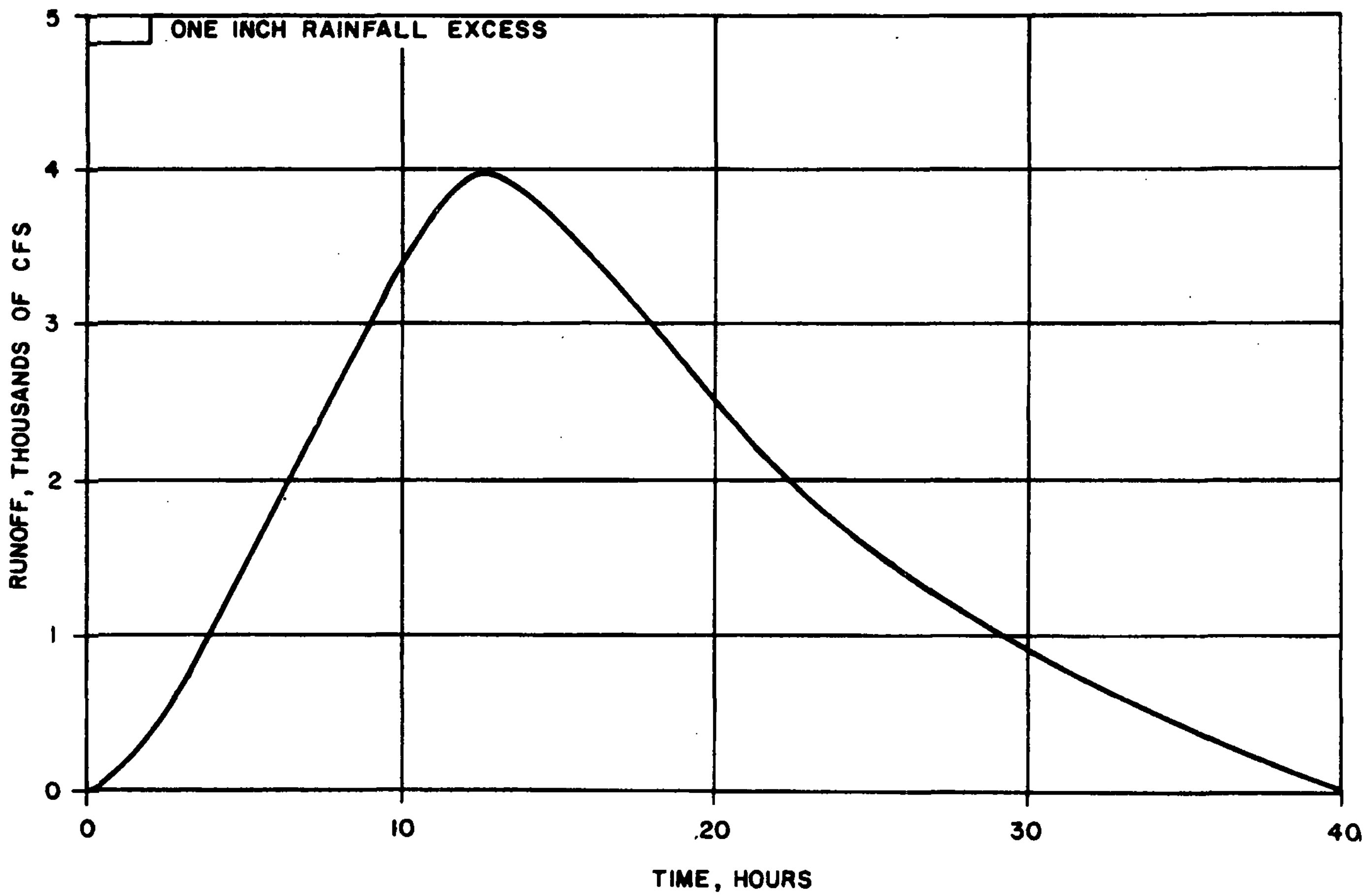

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FIGURE 2.4-12

UNIT HYDROGRAPH – SWAN CREEK AT MOUTH

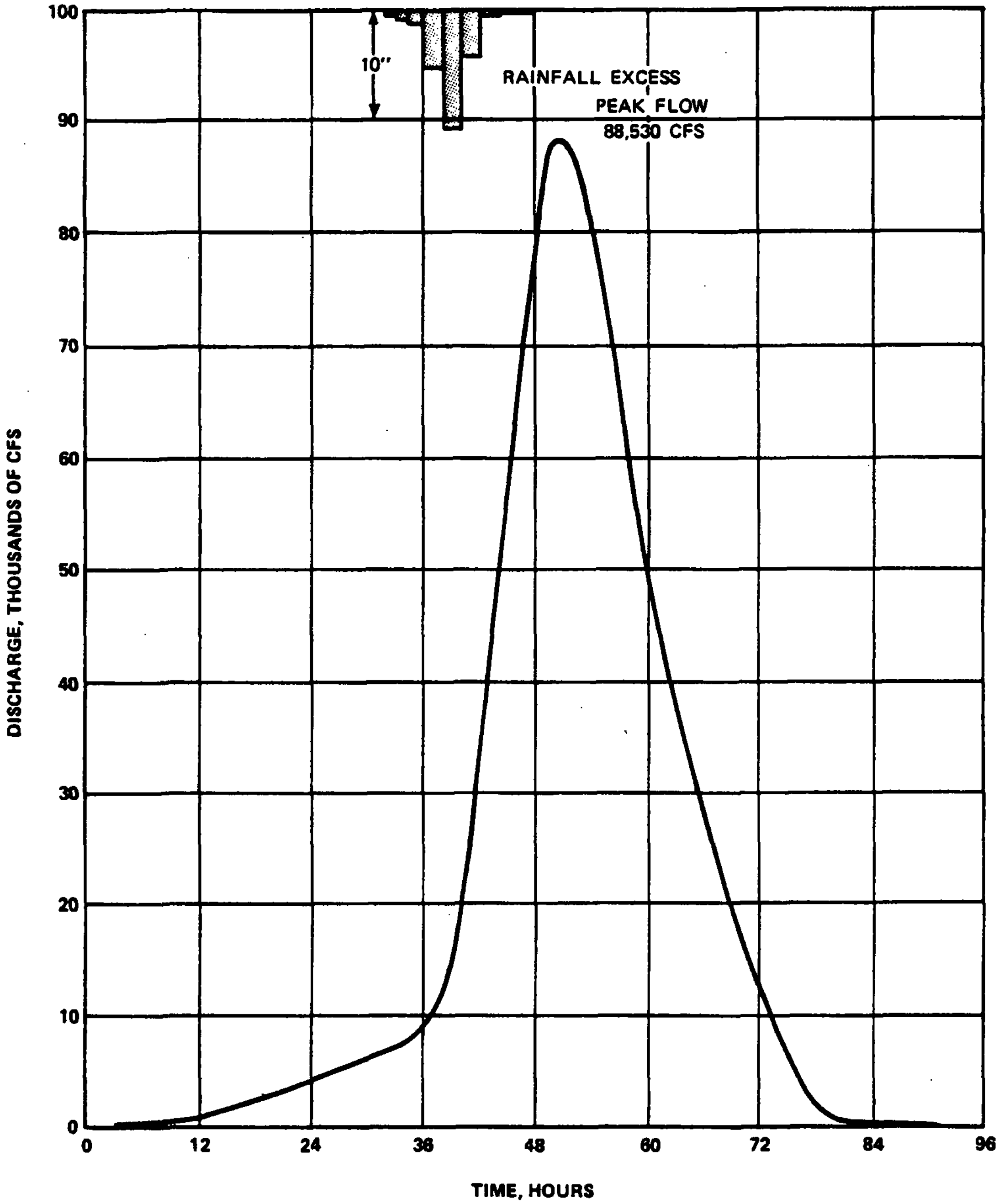

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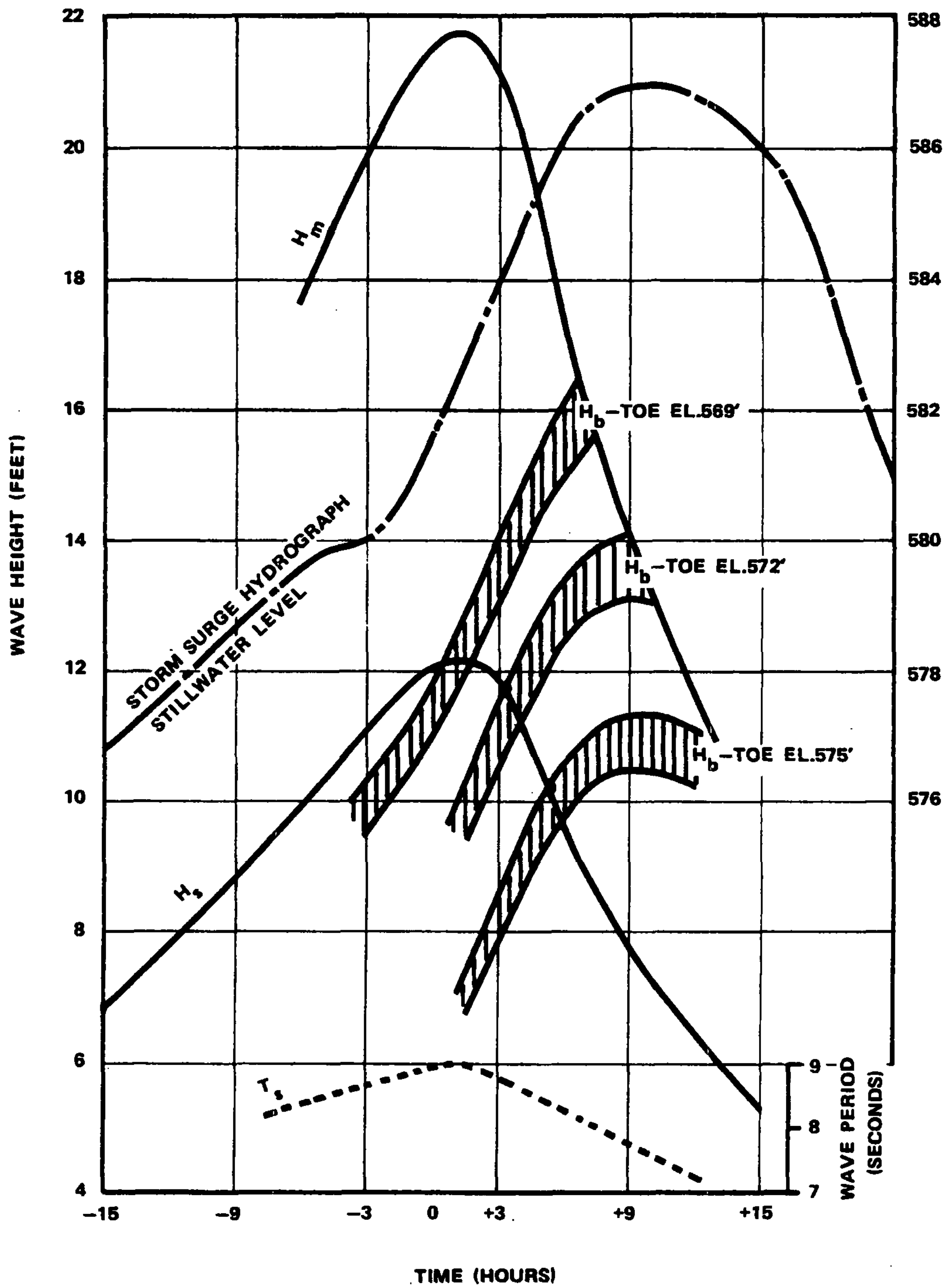
FIGURE 2.4-13

PMF HYDROGRAPH – SWAN CREEK AT MOUTH



LEGEND:

H_m = MAXIMUM HEIGHT

H_s = SIGNIFICANT WAVE HEIGHT

H_b = BREAKING WAVE HEIGHT FOR SHORE BARRIER TOR ELEVATION (UPPER LIMIT CONSIDERS WAVE SETUP)

T_s = SIGNIFICANT WAVE PERIOD

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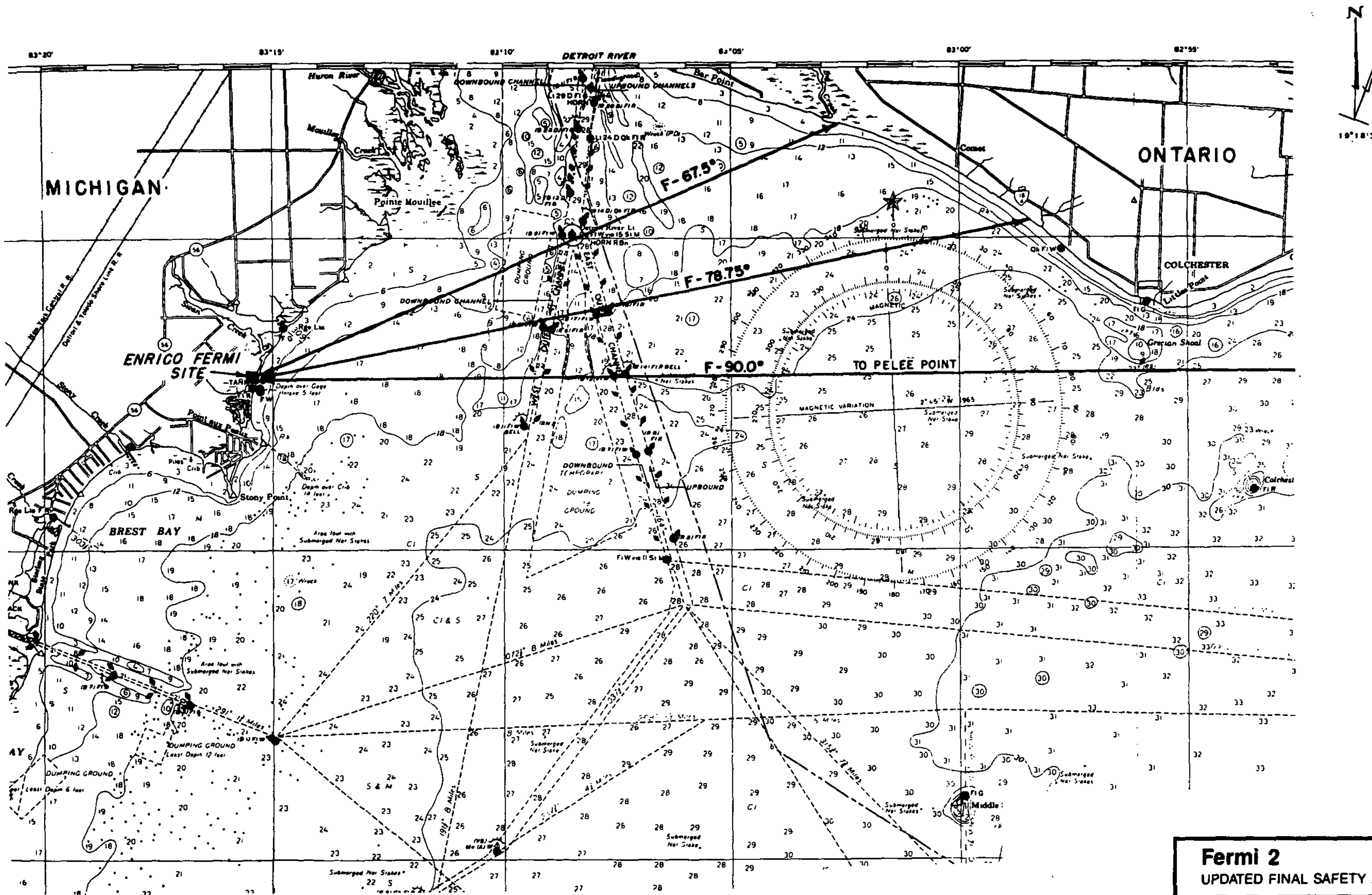
FIGURE 2.4-14

STORM SURGE HYDROGRAPH FOR PMME



REFERENCE:
U.S. LAKE SURVEY, CHART NO. 39, 1968

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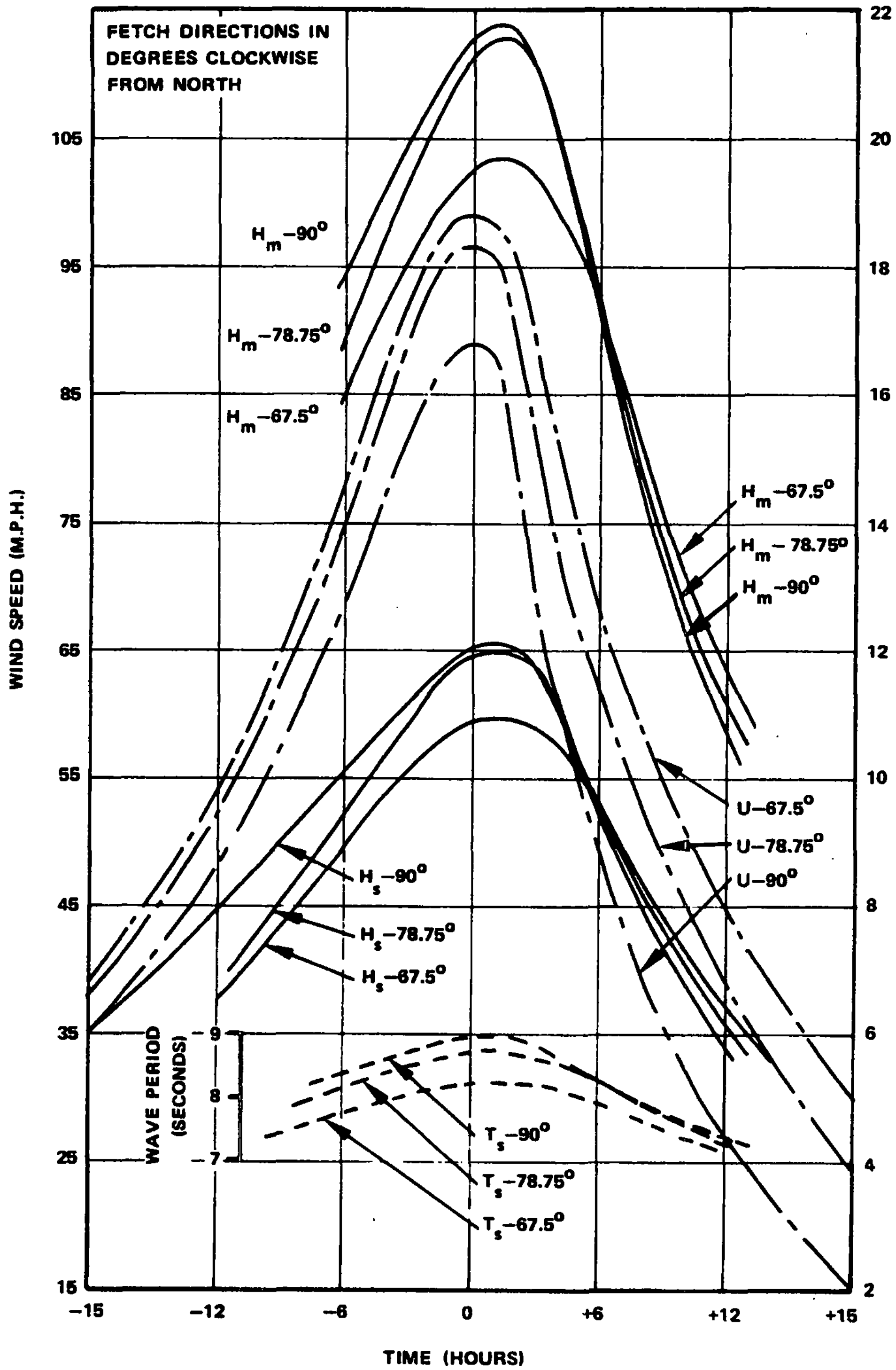
FIGURE 2.4-15
FETCH DIRECTIONS



LEGEND:
H_m = MAXIMUM HEIGHT
H_s = SIGNIFICANT WAVE HEIGHT
T_s = SIGNIFICANT WAVE PERIOD
U = COMPONENT WIND VELOCITY

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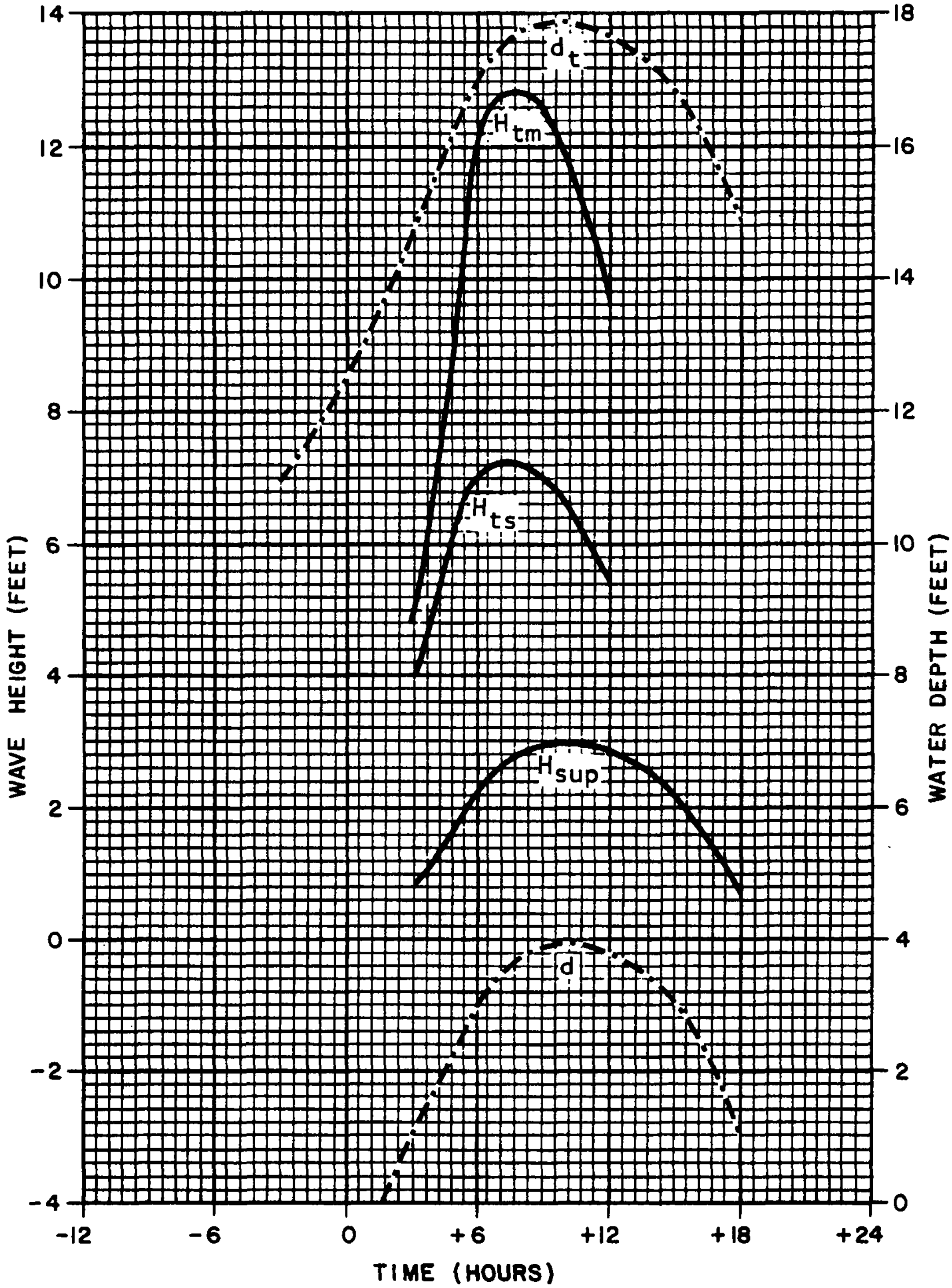
FIGURE 2.4-16

WIND AND WAVE CHARACTERISTICS VERSUS TIME



LEGEND:
ALL ELEVATIONS REFER TO NYMT, 1935.

FOR A SHORE BARRIER TOE ELEVATION OF 569.0 FT AND CREST ELEVATION OF 583.0 FT:

H_{tm} = WAVE HEIGHT TRANSMITTED OVER SHORE BARRIER FOR INCIDENT MAXIMUM WAVE HEIGHTS

H_{ts} = WAVE HEIGHT TRANSMITTED OVER SHORE BARRIER FOR INCIDENT SIGNIFICANT WAVE HEIGHTS

H_{sup} = MAXIMUM WAVE HEIGHT SUPPORTED OVER INLAND FLOODED PLANT GRADE (ELEVATION 583.0 FT) WITHOUT BREAKING

d_t = DEPTH OF WATER AT SHORE BARRIER WITH A TOE ELEVATION OF 569.0 FT

d = INLAND DEPTH OF WATER ABOVE PLANT GRADE ELEVATION OF 583.0 FT.

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FIGURE 2.4-17

TRANSMITTED AND SUPPORTED WAVE HEIGHTS VERSUS TIME

STATIC FORCES		BREAKING WAVE (MINIKIN METHOD)			NON-BREAKING WAVE (1) (SAINFLOU METHOD)			BROKEN WAVE
PRESSURE (PSF)		2,960			2,925			3,060
THRUST (LBS./FT. OF WALL)		70,100			68,700			75,000
DYNAMIC FORCES	WAVE PERIOD (SECONDS)	3.4	7.7	9.0	3.4	7.7	9.0	FORCES ARE INDEPENDENT OF WAVE PERIOD
PRESSURE (PSF)	10% SLOPE	2,460	660	520	150	180	182	122
	5% SLOPE	3,000	900	700				
THRUST (LBS./FT. OF WALL)	10% SLOPE	2,460	660	520	1,125	1,235	1,245	256
	5% SLOPE	3,000	900	700				

CASE 1

D = 46.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF REACTOR SLAB)
d = 3.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)
H = 3.0' (WAVE HEIGHT)

STATIC FORCES		BREAKING WAVE (MINIKIN METHOD)			NON-BREAKING WAVE (1) SAINFLOU METHOD)			BROKEN WAVE
PRESSURE (PSF)		3,100			2,925			3,160
THRUST (LBS./FT. OF WALL)		77,000			68,700			80,100
DYNAMIC FORCES	WAVE PERIOD (SECONDS)	4.5	7.7	9.0	4.5	7.7	9.0	FORCES ARE INDEPENDENT OF WAVE PERIOD
PRESSURE (PSF)	10% SLOPE	4,480	1,870	1,460	268	312	319	215
	5% SLOPE	5,500	2,460	1,950				
THRUST (LBS./FT. OF WALL)	10% SLOPE	8,060	3,360	2,640	3,664	3,900	3,950	814
	5% SLOPE	9,900	4,430	3,520				

(1) DYNAMIC FORCES OF NON-BREAKING WAVES RESULT FROM CLAPOTIS AFFECT.

CASE 2

D = 46.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF REACTOR SLAB)
d = 6.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)
H = 5.4' (WAVE HEIGHT)

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FIGURE 2.4-18

WAVE PRESSURE AND FORCES AGAINST REACTOR BUILDING

STATIC FORCES		BREAKING WAVE (MINIKIN METHOD)			NON-BREAKING WAVE (1) (SAINFLOU METHOD)			BROKEN WAVE
PRESSURE (PSF)		2,334			2,240			2,371
THRUST (LBS./FT. OF WALL)		43,641			40,208			46,049
DYNAMIC FORCES	WAVE PERIOD (SECONDS)	3.4	7.7	9.0	3.4	7.7	9.0	FORCES ARE INDEPENDENT OF WAVE PERIOD
PRESSURE (PSF)	10% SLOPE	2,460	660	520	150	180	182	122
	5% SLOPE	3,000	900	700				
THRUST (LBS./FT. OF WALL)	10% SLOPE	2,460	660	520	1,125	1,235	1,245	256
	5% SLOPE	3,000	900	700				

CASE 1

D = 35.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF RHR SLAB)
d = 3.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)
H = 3.0' (WAVE HEIGHT)

STATIC FORCES		BREAKING WAVE (MINIKIN MMETHOD)			NON-BREAKING WAVE (1) (SAINFLOU METHOD)			BROKEN WAVE
PRESSURE (PSF)		2,409			2,240			2,477
THRUST (LBS./FT. OF WALL)		46,487			40,208			49,174
DYNAMIC FORCES	WAVE PERIOD (SECONDS)	4.5	7.7	9.0	4.5	7.7	9.0	FORCES ARE INDEPENDENT OF WAVE PERIOD
PRESSURE (PSF)	10% SLOPE	4,480	1,870	1,460	268	312	319	215
	5% SLOPE	5,500	2,460	1,950				
THRUST (LBS./FT. OF WALL)	10% SLOPE	8,060	3,360	2,640	3,664	3,900	3,950	814
	5% SLOPE	9,900	4,430	3,520				

(1) DYNAMIC FORCES OF NON-BREAKING WAVES RESULT FROM CLAPOTIS AFFECT.

CASE 2

D = 35.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF RHR SLAB)
d = 6.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)
H = 5.4' (WAVE HEIGHT)

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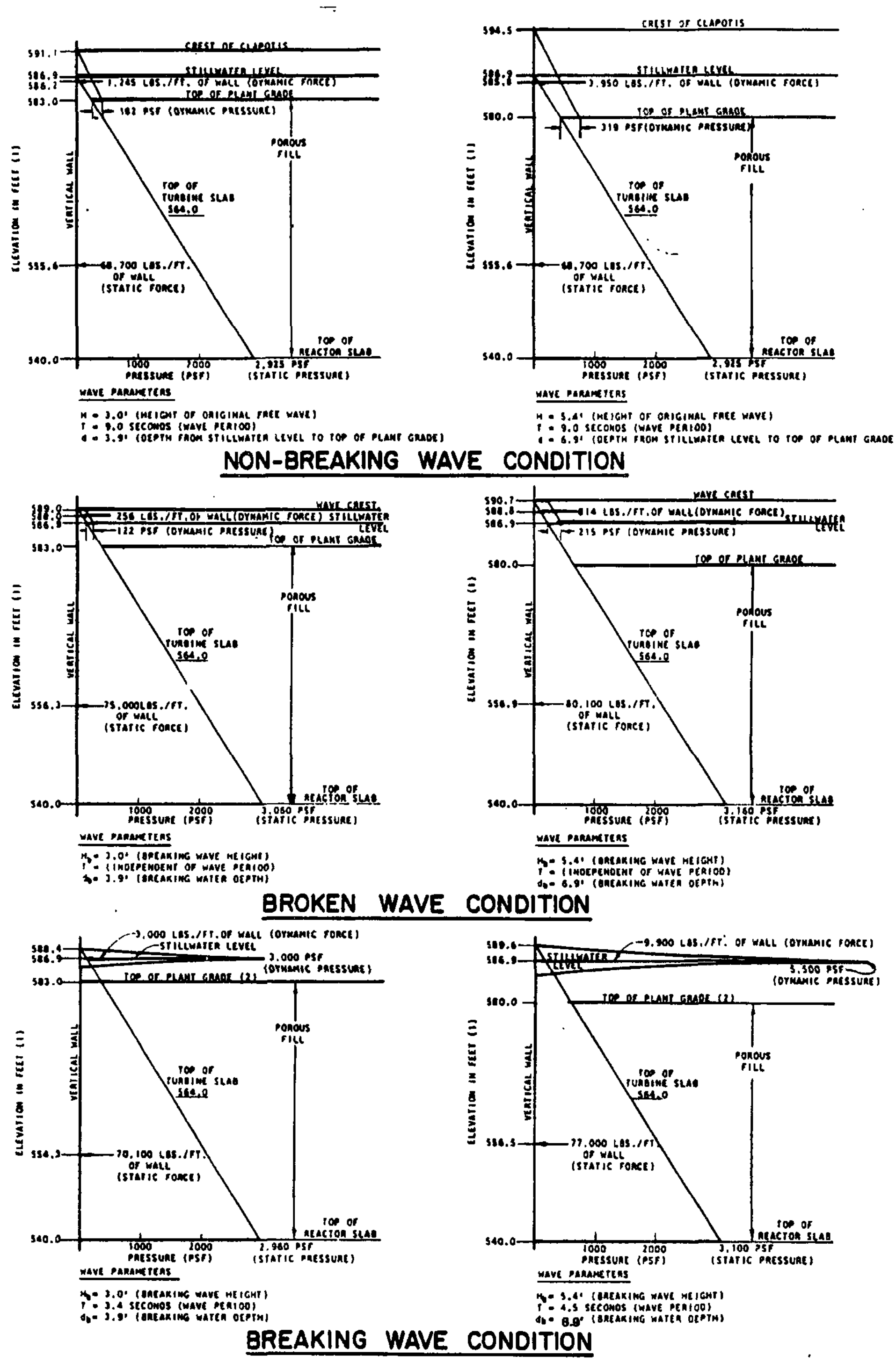
FIGURE 2.4-19

WAVE PRESSURE AND FORCES AGAINST RESIDUAL HEAT REMOVAL COMPLEX



NOTES:
1. ALL ELEVATIONS REFER TO NYMT, 1935 DATUM
2. 5 PERCENT SLOPE ASSUMED

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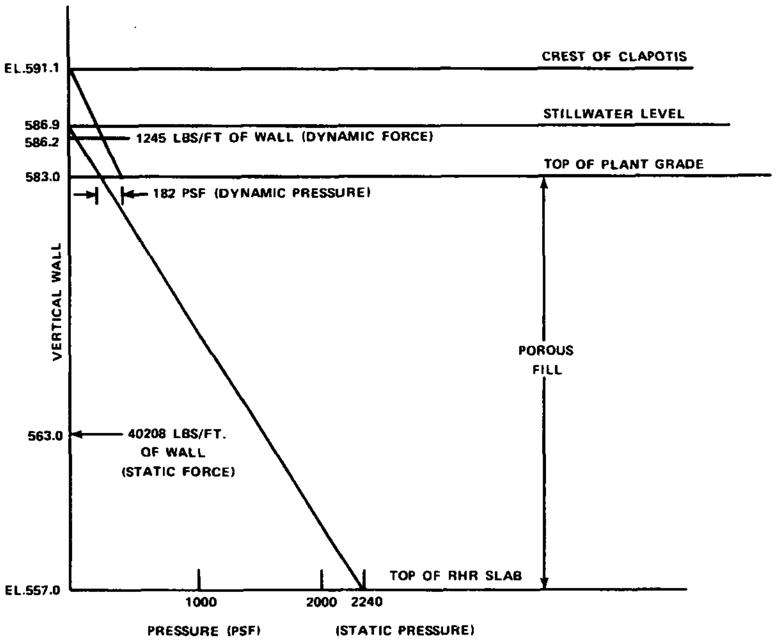
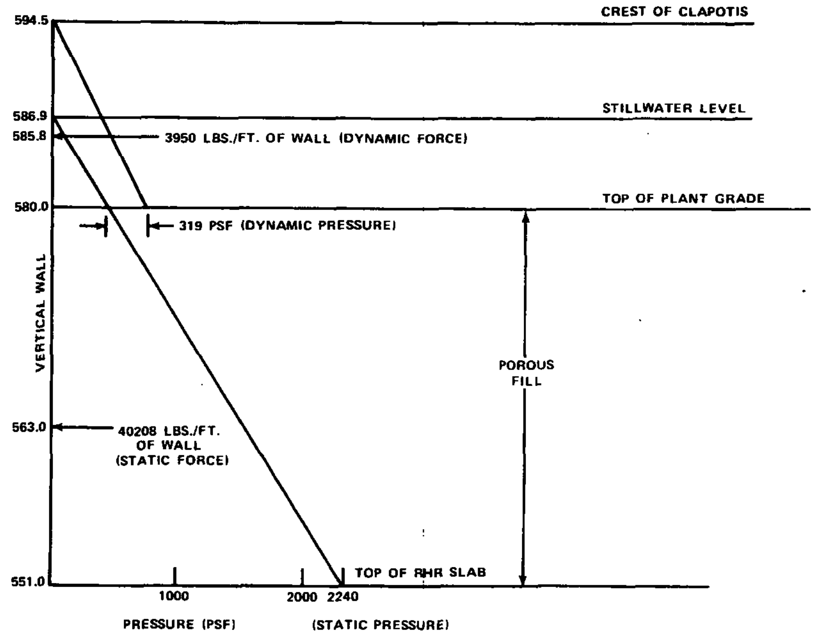
FIGURE 2.4-20

WAVE PRESSURE DISTRIBUTIONS AGAINST REACTOR/AUXILIARY BUILDING



WAVE PARAMETERS

H = 3.0' (HEIGHT OF ORIGINAL FREE WAVE)
T = 9.0 (SECONDS (WAVE PERIOD)
d = 3.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)



WAVE PARAMETERS

H = 5.4' (HEIGHT OF ORIGINAL FREE WAVE)
T = 9.0 SECONDS (WAVE PERIOD)
d = 6.9' (DEPTH FROM STILLWATER LEVEL TO TOP OF PLANT GRADE)

NON–BREAKING WAVE CONDITION

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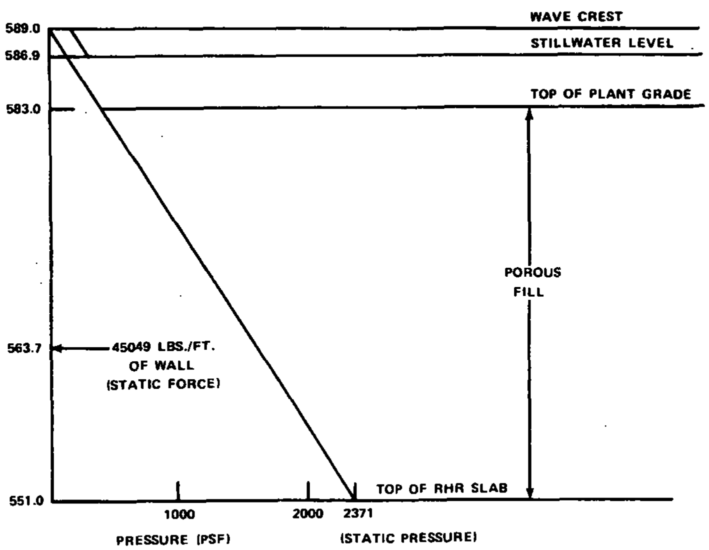
FIGURE 2.4-21, SHEET 1

WAVE PRESSURE DISTRIBUTION AGAINST RESIDUAL HEAT REMOVAL COMPLEX

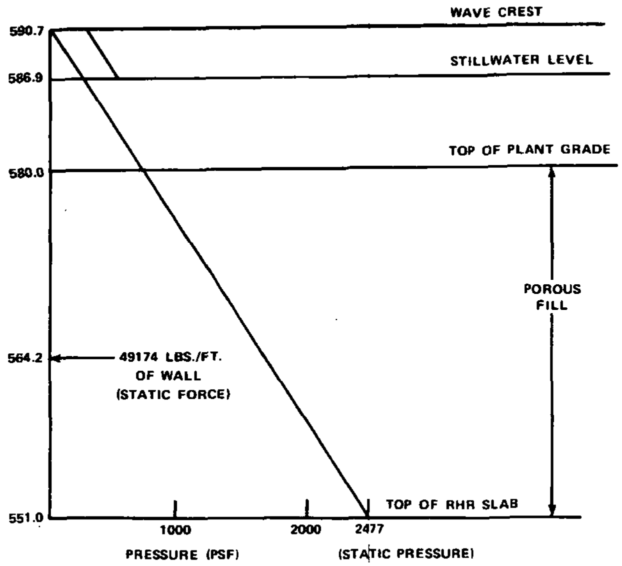


WAVE PARAMETERS

H_b = 3.0' (BREAKING WAVE HEIGHT)

T = (INDEPENDENT OF WAVE PERIOD)

d_b = 3.9' (BREAKING WATER DEPTH)



WAVE PARAMETERS

H_b = 5.4 (BREAKING WAVE HEIGHT)

T = (INDEPENDENT OF WAVE PERIOD)

d_b = 6.9' (BREAKING WATER DEPTH)

BROKEN WAVE CONDITION

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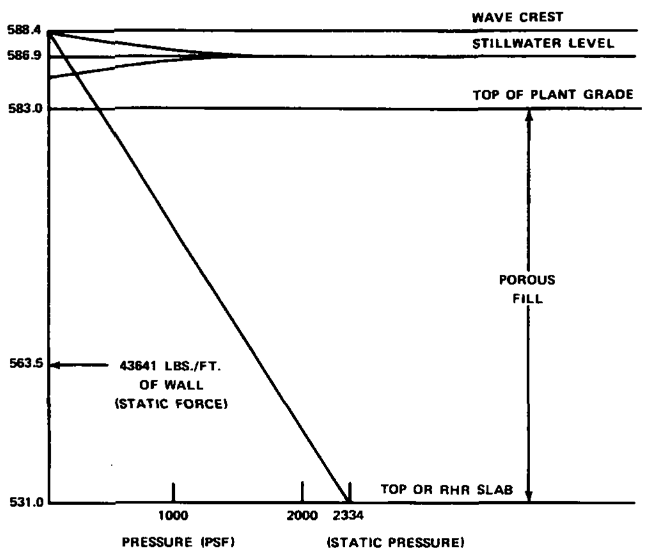
FIGURE 2.4-21, SHEET 2

WAVE PRESSURE DISTRIBUTION AGAINST RESIDUAL HEAT REMOVAL COMPLEX

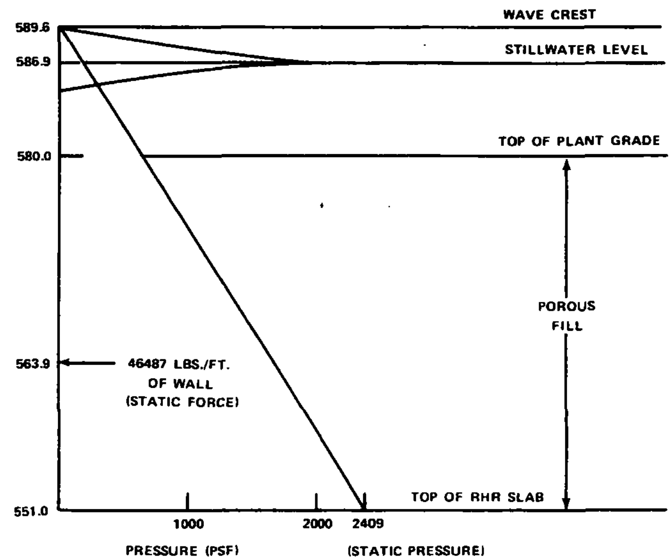


WAVE PARAMETERS

H_b = 3.0' (BREAKING WAVE HEIGHT)

T = 3.4 SECONDS (WAVE PERIOD)

d_b = 3.9' (BREAKING WATER DEPTH)



WAVE PARAMETERS

H_b = 5.4' (BREAKING WAVE HEIGHT)

T = 4.5 SECONDS (WAVE PERIOD)

d_b = 6.9 (BREAKING WATER DEPTH)

BREAKING WAVE CONDITION

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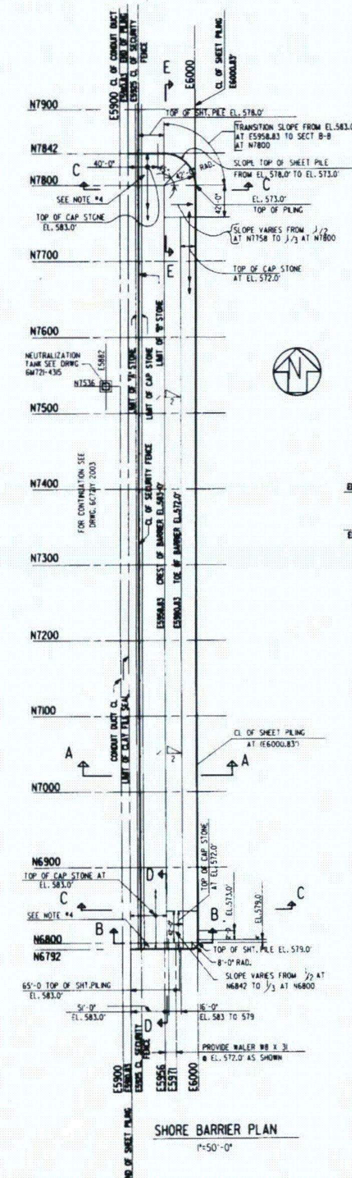
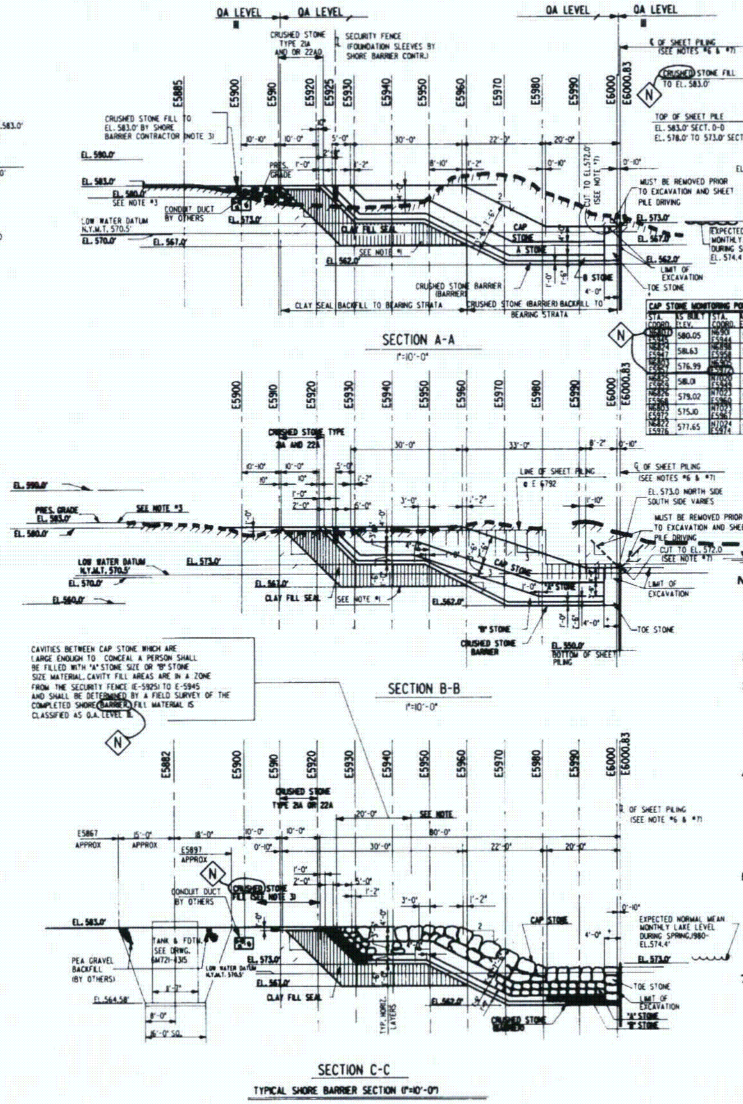
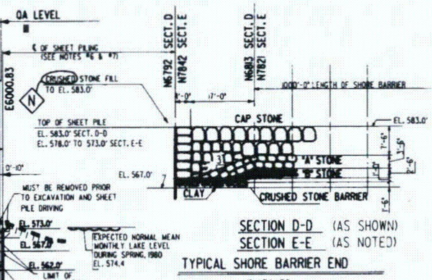
FIGURE 2.4-21, SHEET 3

WAVE PRESSURE DISTRIBUTION AGAINST RESIDUAL HEAT REMOVAL COMPLEX

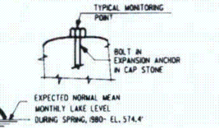






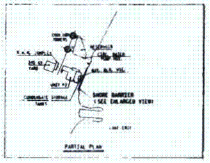
CAP STONE MONITORING POINTS

STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.	STA. COORD.	AS BUILT ELEV.
[illegible]	580.05	N6901 E5944	581.52	N7119 E5947	582.09	N7228 E5966	578.59	N7418 E5957	581.40	N7612 E5937	583.85	N7722 E5971	576.42
[illegible] E5947	581.63	[illegible]	579.89	N7122 E5957	581.45	N7233 E5973	575.59	N7429 E5963	578.12	N7610 E5950	582.21	[illegible]	581.86
[illegible]	576.99	[illegible]	577.08	N7120 E5964	578.72	N7328 E5946	582.22	N7428 E5974	576.53	[illegible]	582.56	[illegible]	[illegible]
[illegible] E5959	581.01	[illegible]	580.92	[illegible] E5974	575.52	N7322 E5958	581.8	N7529 E5948	583.04	[illegible]	576.58	[illegible] E5965	578.88
[illegible] E5968	579.02	N7023 E5960	580.59	N7222 [illegible]	582.54	[illegible] E5966	578.99	[illegible]	582.10	N7721 E5940	583.15	[illegible] E5975	577.81
[illegible] E5972	575.10	[illegible] E5967	578.58	[illegible] E5950	582.70	N7328 E5974	575.09	[illegible] E5965	579.91	N7721 E5956	582.08		
N6822 E5976	577.65	N7024 E5974	575.99	[illegible] E5958	581.22	N7422 E5950	582.6	N7526 E5973	575.13	N7718 E5963	579.82		



LEGEND:

CAP STONE & TOE STONE:	2 LAYERS TOTAL 7.5' THICK AND 4.0' THICK RESP. MIN. SIZE - 3.0 TONS MAX. SIZE - 5.0 TONS 50% BY WEIGHT SHALL CONSIST OF PIECES WEIGHING OVER 4 TONS
"A" STONE:	2 LAYERS, TOTAL 3.5' THICK LESS THAN 10% BY WEIGHT UNDER 600 POUNDS LESS THAN 50% BY WEIGHT UNDER 800 POUNDS LESS THAN 10% BY WEIGHT OVER 2000 POUNDS
"B" STONE:	2 LAYERS TOTAL 1.5' THICK MAX. SIZE - 200 POUNDS NOT LESS THAN 10% NOR MORE THAN 35% BY WEIGHT CONSISTING OF PIECES WEIGHING LESS THAN 20 POUNDS
CRUSHED STONE: (BARRIER)	MINIMUM 1.0' THICK MAX. DIAMETER - 6 INCHES NOT LESS THAN 10% NOR MORE THAN 35% BY WEIGHT CONSISTING OF FINES WITH DIAMETERS LESS THAN 3 INCHES
ALTERNATE:	CAP STONE, TOE STONE AND "A" STONE SUBSTITUTED BY CONCRETE BLOCKS - 4000 PSI TYPE V CEMENT AIR ENTRAINED CONCRETE (SEE SPEC. 3071-176)



NOTES:

1. EXCAVATE PEAT AND OTHER UNSUITABLE MATERIAL TO EXPOSE ACCEPTABLE BEARING STRATA PER SPEC. 3071-176. BORINGS INDICATE THIS STRATA STARTS AT APPROX. 567'.
2. BACKFILL WITH CLAY FILL SEAL OR CRUSHED STONE (BARRIER) PER SECTION A-A.
3. FILL AREAS BETWEEN BARRIER AND EXISTING SITE FILL WITH CRUSHED STONE TO EL. 583.0 FT. A SMOOTH TRANSITION TO THE EXISTING PLANT GRADE IS REQUIRED. CRUSHED STONE SHALL CONFORM TO MDOT STANDARD SPEC. FOR CONSTRUCTION CLASS 21 A. PLACED AT 120 PCF IN 12" LAYERS.
4. REAR SEGMENT OF SHORE BARRIER END SHALL BE FILLED WITH A COMPOSITE OF CAP STONE, "A" STONE, AND "B" STONE WITH THE HEAVIER STONES ON OUTER LAYERS. THE MATERIAL SHALL BE PLACED IN A MANNER TO PROVIDE A SMOOTH TRANSITION BETWEEN THE HORIZONTAL GRADE AT THE REAR OF THE BARRIER AND THE 3 ON 1 SLOPE ON THE FLANK.
5. EXPECTED NORMAL MEANS MONTHLY LAKE LEVEL AND LOW WATER DATUM ARE IN REFERENCE TO NEW YORK MEAN TIDE (N.Y.M.T., 1935).
6. SHEET PILING SHALL BE PZ27 (UNITED STATES STEEL DESIGNATION) OR EQUAL WITH STEEL BRAND OR GRADE OF ASTM-328 AND MINIMUM YIELD POINT OF 38500 PSI.
7. DRIVE SHEET PILING TO BEDROCK OR A MAXIMUM DEPTH OF EL. 550.0' PRIOR TO EXCAVATION WITH TOP AT EL. 575.0'+ AND CUT TO EL. 572.0' AFTER ARMOR UNITS HAVE BEEN PLACED. SHEET PILING LENGTH APPROX. 25'-0" ±.
8. THIS WORK IS GOVERNED BY 3071-176 PRIOR TO EXCAVATION, THE GROUND EITHER SIDE OF THE SHEETING MUST BE EXCAVATED TO ELEV. 572'-0".
9. SHORE BARRIER QA LEVEL SHALL BE AS NOTED ON SECTION A-A.
10. SHEETING MATERIAL & INSTALLATION SHALL BE QA LEVEL III. SEE SPEC. 3071-176 FOR QA REQUIREMENTS.

NOTE*

VARIATIONS BETWEEN THE AS BUILT ELEVATIONS AND DESIGN ELEVATIONS OF CAP STONE EXCEED THE SPECIFIED TOLERANCE OF + 6 INCHES FOR MANY AREAS OF THE SHORE BARRIER. THESE VARIATIONS HAVE BEEN EVALUATED BY THE SHORE BARRIER ENGINEER AND ARE ACCEPTABLE AS REPORTED IN DAMES & MOORE LETTER DMO-01 DATED JULY 16, 1984 AND SARGENT & LUNDY LETTER SLS 2668.

DETROIT EDISON COMPANY DRAWING NO. 6C721-0040, REV. N

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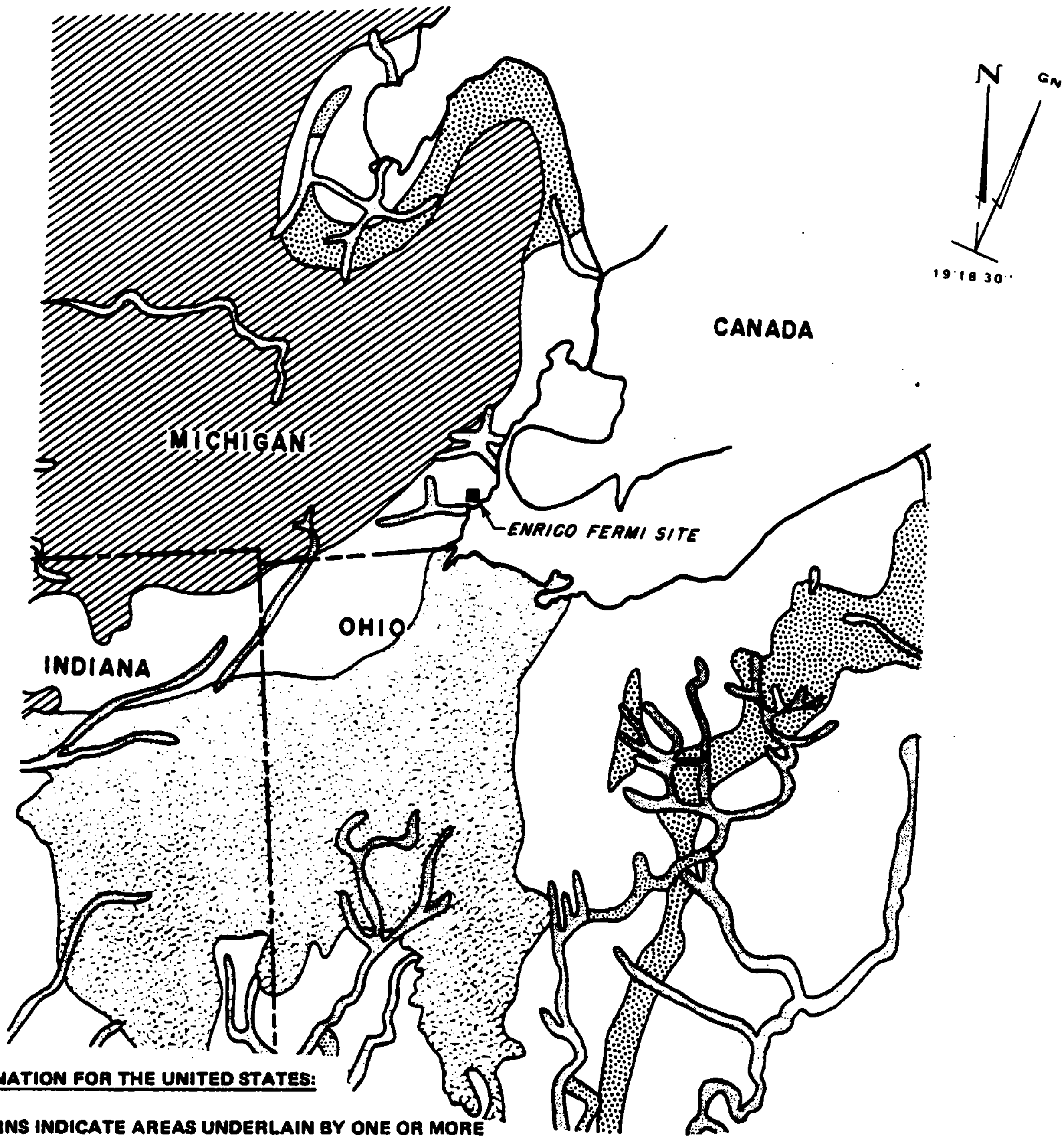
FIGURE 2.4-22

SHORE BARRIER DESIGN



EXPLANATION FOR THE UNITED STATES:

PATTERNS INDICATE AREAS UNDERLAIN BY ONE OR MORE AQUIFERS GENERALLY CAPABLE OF YEILDING TO A WELL AT LEAST 50 gpm OF WATER CONTAINING NOT MOR THAN 2000 ppm OF DISSOLVED SOLIDS (INCLUDING AREAS WHERE MORE HIGHLY MINERALIZED WATER IS ACTUALLY USED).

LEGEND:

UNCONSOLIDATED AND SEMICONSOLIDATED AQUIFERS

- ALLUVIAL SAND AND GRAVEL
- WATERCOURSE – ALLUVIAL VALLEY TRAVERSED BY PERENNIAL STREAM FROM WHICH RECHARGE CAN BE INDUCED
- SURFICIAL ALLUVIAL VALLEY NO LONGER TRAVERSED BY PERENNIAL STREAM (ABANDONED WATERCOURSE), OR BURIED ALLUVIAL VALLEY

CONSOLIDATED – ROCK AQUIFERS

- SANDSTONE (INCLUDES SOME SAND)
- CARBONATE ROCKS (LIMESTONE AND DOLOMITE; LOCALLY INCLUDE GYPSUM)

REFERENCE:
U.S. DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY WATER SUPPLY PAPER NO. 1800, 1963.

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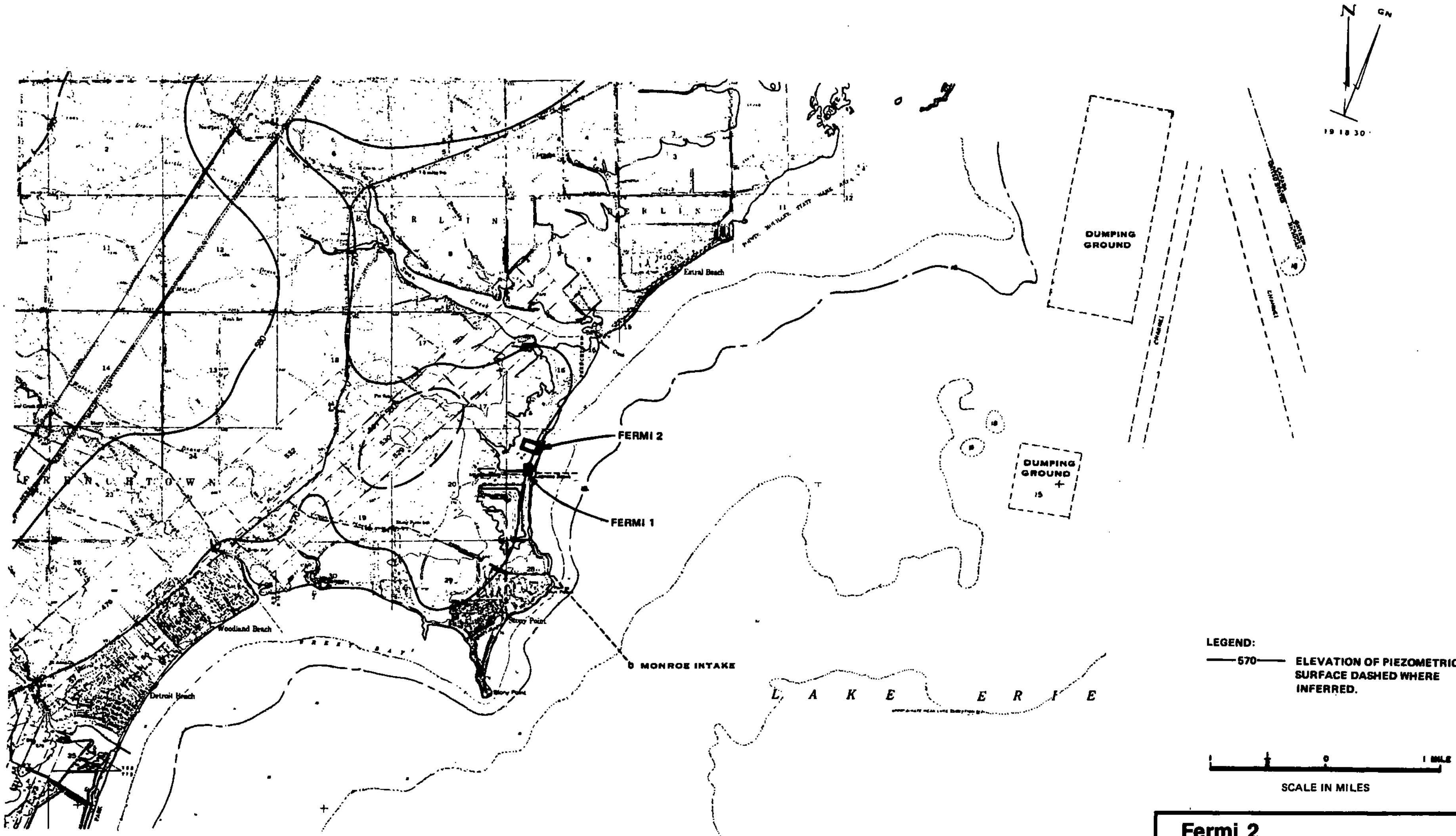
FIGURE 2.4-23

REGIONAL AQUIFER DISTRIBUTION



REFERENCE:
THIS MAP WAS PREPARED FROM PORTIONS OF THE FOLLOWING U.S.G.S. TOPOGRAPHIC QUADRANGLES: ESTRAL BEACH, MICHIGAN, 1942, STONY POINT, MICHIGAN, 1952, ROCKWOOD, MICHIGAN, 1952, AND FLAT ROCK, MICHIGAN, 1952.

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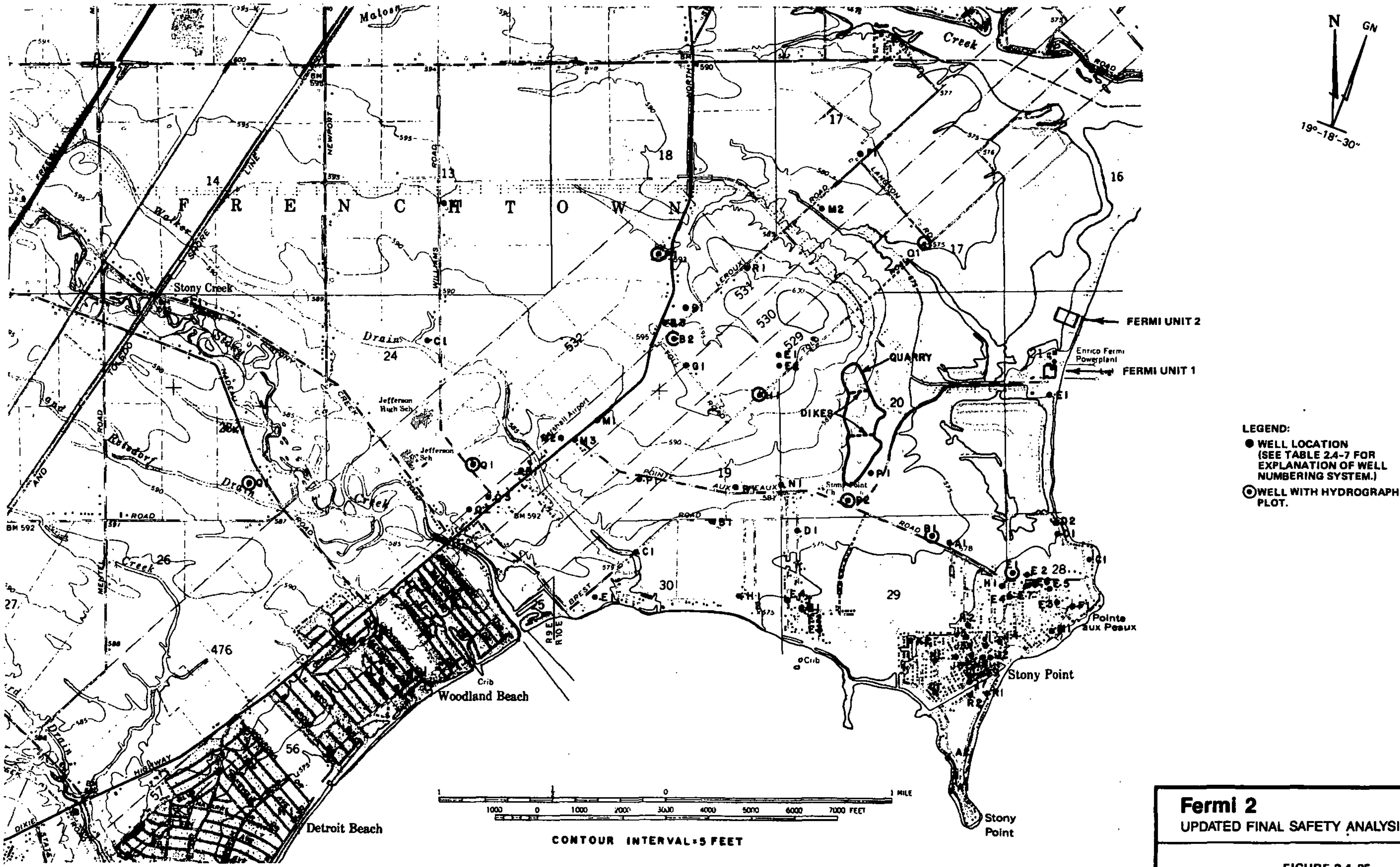
FIGURE 2.4-24

PIEZOMETRIC SURFACE 1961-1966



REFERENCE:
U.S.G.S. TOPOGRAPHIC QUADRANGLE
STONY POINT, MICHIGAN – 1967.

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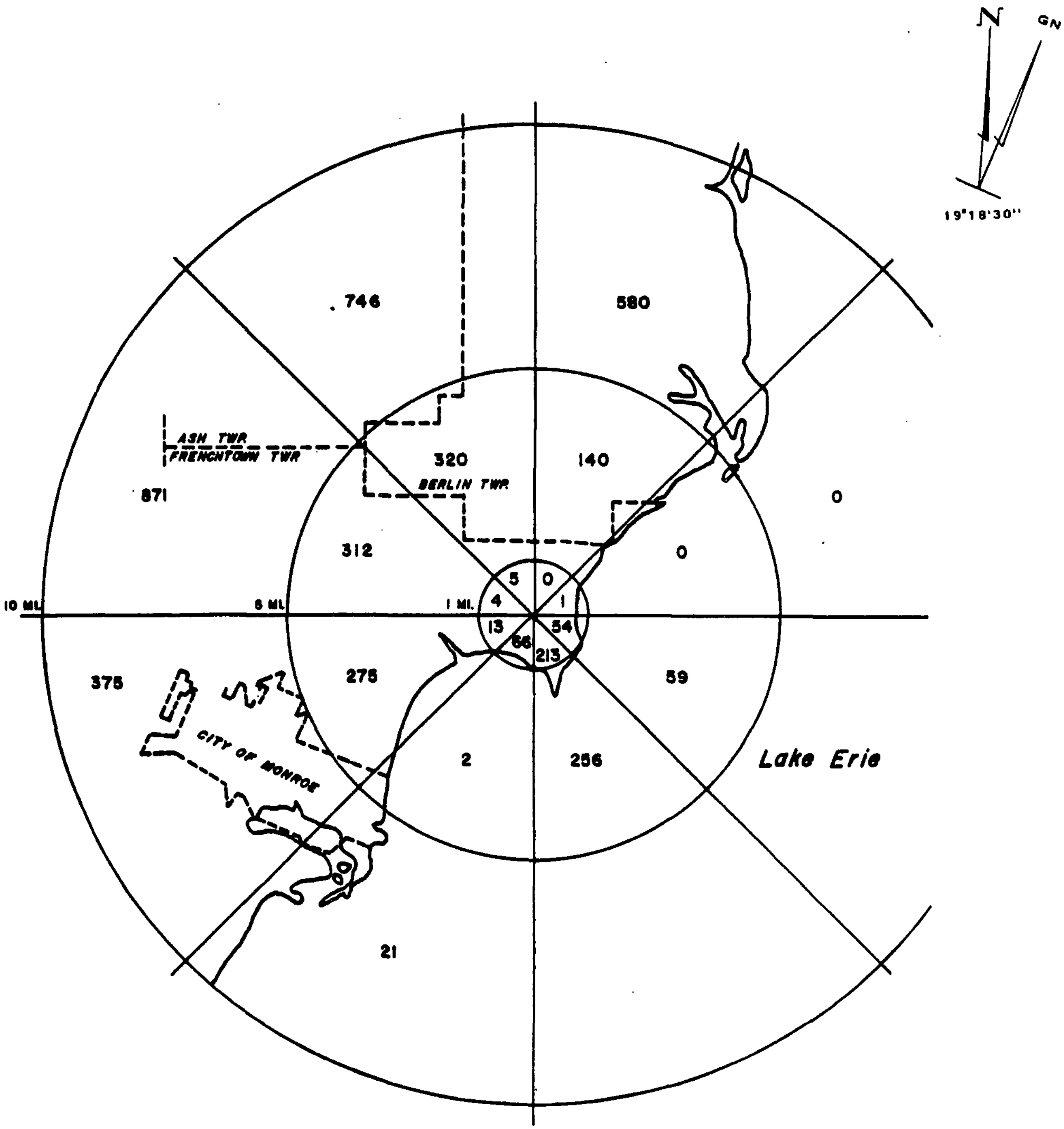
FIGURE 2.4-25

WELL LOCATIONS



LEGEND:
NUMBERS REFER TO NUMBER OF GROUNDWATER WELLS IN EACH SECTOR.

0 1 2 3 4 5
SCALE IN MILES

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FIGURE 2.4-26

WATER WELL DISTRIBUTION

2.5. GEOLOGY AND SEISMOLOGY

The Fermi site is located on the shore of the western end of Lake Erie at Lagoona Beach, Frenchtown Township, Monroe County, Michigan. Geologic and seismic studies of the Fermi site were conducted for Fermi 2 in 1968 and 1969. Detailed foundation studies were performed for the Fermi 2 reactor/auxiliary building in 1969, and rock foundation grouting for these structures was performed in 1970. Detailed foundation studies were performed in 1972 for the Fermi 2 residual heat removal (RHR) complex. Foundation grouting for the RHR complex has been completed. The geologic, seismic, and foundation studies for Fermi 2 were conducted by Dames & Moore (D&M) with the results of a few of the studies presented in the Fermi 2 PSAR. The location of Fermi 2 is shown in Figure 2.4-1. The topography of the site with the location of the principal plant facilities is shown in Figure 2.4-3.

The site is located within the Central Stable Region tectonic province of the North American continent. Some regional faulting and seismic activity is known, but the region is characteristically one of relative stability. There are no known faults within 25 miles of the site and there are no capable faults within 200 miles of the site.

Approximately 3100 ft of Paleozoic sedimentary rocks overlie the Precambrian basement in the area. Overlying the Paleozoic sedimentary rock strata are Pleistocene soils of glacial origin that are less than 20 ft thick at the site. The site is located on the southeast side of the Michigan Basin. The sedimentary rock strata generally dip to the northwest toward the center of the Michigan Basin. The bedrock immediately underlying the site consists of dolomites of the Bass Islands Group of the Silurian System. The Bass Islands Group is competent dolomite with thin shale beds and is variably fractured and contains some vuggy zones. No geologic conditions are known that could have an adverse effect on the safety of plant facilities.

All major Fermi 2 Category I structures are supported in the Bass Islands dolomite. Foundation pressure grouting of the bedrock was performed to improve subsurface conditions. A test blasting program was conducted, and blast monitoring was provided during construction. Criteria for foundation treatment and design were formulated, based on foundation studies performed at the locations of Category I and other major structures.

All Category I structures are designed to respond to peak horizontal ground accelerations of the rock surface at foundation levels of 8 and 15 percent of gravity for the operating-basis earthquake (OBE) and safe-shutdown earthquake (SSE), respectively. Site-related response spectra were used to analyze the response of structures to earthquake ground motion.

The results of the geologic and seismic studies for Fermi 2 are summarized in Subsections 2.5.1 through 2.5.3. The stability of subsurface materials at the locations of Fermi 2 Category I and major structures is summarized in Subsection 2.5.4.

2.5.1. Basic Geologic and Seismic Information

Basic geologic and seismic data were obtained by D&M for the Fermi site from 1968 through 1972 in three major programs:

a. Geologic and seismic studies in 1968 for the Fermi 2 site

b. Foundation studies in 1969 for the reactor/auxiliary building

c. Foundation studies in 1972 for the RHR complex.

The general scope of these studies is outlined in the following paragraphs.

The geologic and seismic program of investigation conducted in 1968 at the Fermi site for Fermi 2 (Reference 1) included the following:

a. A thorough review of pertinent geologic literature (published and unpublished) and interviews with university and state geologists

b. A geologic reconnaissance of the site and surrounding area, and a review of maps and aerial photographs

c. Field explorations that were performed to evaluate the geologic and seismologic characteristics of the site, consisting of the following:

1. Geologic test boring program
2. Geologic inspection of the site and surrounding area
3. Geophysical refraction survey
4. Blast monitoring observations
5. Micromotion measurements
6. Borehole geophysical measurements
7. Ground water observations

d. A laboratory soil- and rock-testing program for Fermi 2 was conducted.

In 1969, a comprehensive foundation investigation was performed at the Fermi 2 reactor/auxiliary building and adjacent structures (Reference 2). The field explorations consisted of the following:

a. Test boring program

b. Water pressure testing in selected borings

c. Ground water observations

d. Ground water sampling.

Laboratory testing during this investigation consisted of density and unconfined compression tests on selected rock cores and chemical analyses of ground water.

In 1972, a comprehensive foundation investigation was performed at the location of the Fermi 2 RHR complex (Reference 3). The field exploration program consisted of the following:

a. Test boring program

b. Water pressure testing

c. Piezometer installation

d. Geologic reconnaissance.

Laboratory testing for this investigation consisted of pulsating load triaxial tests, unconfined compression tests, consolidation tests, moisture-density tests on soil samples, and unconfined compression tests on rock cores.

Supplementary seismic evaluations were completed for the Fermi 2 site in October 1982 by Weston Geophysical Corporation. These evaluations led to the establishment of facility site specific response spectra that were subsequently used to validate the satisfactory nature of the original facility design-basis earthquake provisions. The site-specific earthquake was characterized in terms of Richter magnitude (from 4.9 to 5.9) and epicentral distance (25 km). Site-specific response spectra were developed from real-time histories for the appropriate magnitude and distance, and foundation conditions similar to the Fermi site. (Weston Geophysical Corporation, Draft Site Specific Response Spectra for Enrico Fermi 2; October 1982.)

2.5.1.1. Regional Geology

2.5.1.1.1. Physiography

The Fermi site is located in the northern portion of the midwestern United States in the Central Lowlands Physiographic Province. This physiographic province has been subdivided into eight physiographic sections. Michigan is located in the Eastern Lake Section (Figure 2.5-1).

The Eastern Lake Section is characterized by glacial landforms (including end moraines, ground moraines, outwash plains, kames, eskers, and drumlins) and by beach and lacustrine deposits formed during the fluctuations of the Great Lakes. The glacial deposits overlie maturely dissected bedrock cuestas and broad areas of relatively flat-lying bedrock. The bedrock is exposed locally. The bedrock surface was dissected prior to being covered with glacial drift. The rock surface tends to be gently rolling with well-developed valley systems.

The Fermi site is located on a lake plain formed during the high-water stages of Lake Erie. There is little topographic relief on the lake plain, which results in poor surface drainage. It has been dissected by eastward-flowing creeks and rivers. The relief on the lake plain within the vicinity of the project area is approximately 25 ft.

2.5.1.1.2. Stratigraphy

2.5.1.1.2.1. Soil Units

The soil units in the region include Pleistocene-aged deposits consisting of alluvium, lacustrine materials, peats, tills, outwash, glaciofluvial materials, glaciolacustrine materials, and residual soil. Figure 2.5-2 shows the distribution of surface Pleistocene glacial deposits of the southern peninsula of Michigan and portions of surrounding states. The site area is located in a glaciolacustrine section on the western edge of Lake Erie. The distribution of surface soil units within eastern Monroe County is shown in Figure 2.5-3. The soil deposits in Monroe County range in thickness from 0 to over 150 ft (Reference 4).

2.5.1.1.2.2. Rock Units

The distribution of the rock units that form the bedrock surface within the region is shown in Figure 2.5-4 and the stratigraphic sequence of the various-aged rock units is shown in the legend. The rock units in the Michigan Basin consist of sedimentary strata of Jurassic, Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian ages, as well as an igneous and/or metamorphic complex of Precambrian-aged rocks.

The sedimentary sequence in the Monroe County area includes Devonian- through Cambrian-aged strata. The local distribution of these strata is shown in Figure 2.5-5. These strata consist of 2500 to 3500 ft of limestones, dolomites, sandstones, and shales. The Precambrian basement in southeastern Michigan consists of crystalline rocks of igneous and metamorphic origin (Reference 4) and occurs at a depth of about 3100 ft.

2.5.1.1.3. Structural Geology

The Fermi site is located within the Central Stable Region tectonic province of the North American continent. This tectonic province is characterized by a thick sequence of sedimentary strata overlying the Precambrian basement. The Precambrian basement is exposed in Wisconsin, Minnesota, and the upper peninsula of Michigan. During Paleozoic and early Mesozoic time, the area was subjected to a series of vertical crustal movements that formed broad basins and arches. The arches and basins have been modified by local folding and faulting. Major geologic structures are shown in Figures 2.5-6 and 2.5-7. The relation between structures and gravimetric and magnetic anomalies is discussed in Subsection 2.5.1.1.5.2.

2.5.1.1.3.1. Folding

The distribution of major folds in the region is shown in Figure 2.5-6 and the characteristics of these folds are presented in Table 2.5-1. The Fermi site is located on the southeast side of the Michigan Basin, which corresponds to the northwest flank of the northeast-trending Findlay Arch. Ells (Reference 5) has proposed the name "Washtenaw Anticlinorium" to describe a broad northwesterly plunging structure in southeast Michigan that is composed of several smaller folds. This broad structural feature covers about 4500 square miles within Michigan and continues into Ohio, Ontario, and Lake Erie. Local structures within this broad structurally high region include the Howell Anticline, the Freedom Anticline, and the Lucas Monocline. The northwest-trending Howell Anticline is located north and northwest of the project area. The northwest-trending Freedom Anticline is located west of the project area, and the north-to-northwest-trending Lucas Monocline lies southeast of the project area and along the projected trend of the Bowling Green Fault.

The direction and amount of regional dip of the strata in south-eastern Michigan are variable. In the vicinity of the site, the strata dip northwest toward the Michigan Basin at 0.5° or less (Reference 4).

The Howell Anticline approaches to within about 25 miles north of the site and extends approximately 80 miles to the northwest. The northwest-southeast-trending fold is located on the southeast flank of the Michigan Basin and has a maximum structural relief, in the early Paleozoic rocks, of about 1000 ft (Reference 22 in Reference 5). The relief is less

pronounced in the younger strata. It has been suggested that faulting is associated with the Howell Anticline (References 5, 6, and 7) as discussed in Subsection 2.5.1.1.3.2.

The Lucas Monocline is a north-to-northwest-trending series of folds in southeastern Michigan located approximately 30 miles southwest of the site. It has been inferred by Ells (Reference 5) that the Lucas Monocline may connect with or be associated with the Bowling Green Fault, which is mapped in northwest Ohio (References 6 and 8). Other researchers (Reference 9) have inferred that the Lucas Monocline is actually a fault structure. The folds bend northwestward in southern Michigan where they join the Freedom Anticline. The early Paleozoic rocks in this folded area have a maximum structural relief on the order of 500 ft.

The Chatham Sag (References 5 and 10) is a broad, gentle northwest-trending syncline that has been mapped as far south as the north shore of Lake Erie. The axis of the syncline lies about 50 miles northeast of the site. The Chatham Sag crosses the Findlay-Algonquin Arch System and is virtually unrecognizable in the early Paleozoic strata. A system of small faults, the most prominent of which is the Electric Fault, is associated with this structure.

Several small earthquakes have occurred near the juncture of the Findlay, Cincinnati, and Kankakee Arches. These earthquakes cannot be associated with any known structures, but are believed to have occurred along a zone of structural weakness that separates the three arches.

A portion of the U.S. Geological Survey (USGS) tectonic map of the United States is shown in Figure 2.5-8. This map shows the detail of some of the structural features in the Michigan Basin area.

2.5.1.1.3.2. Faulting

The distribution of major faults in the region is shown in Figure 2.5-7, and their characteristics are presented in Table 2.5-2. The Bowling Green, Electric, Tekonsha Trend, and Albion-Scipio Trend faults are the four major faults within 100 miles of the project area.

The Bowling Green Fault is located approximately 35 miles southwest of the site. It has been inferred by some workers (Reference 9) that faulting extends northward into southeast Michigan. Some (Reference 5) have inferred that major faulting is not present in this area in Michigan and have interpreted the structure to be a result of folding. Others (Reference 11) believe no major faulting to be affiliated with the structure at all, and interpret it as being a monocline.

Since the very existence of the fault is in question, no clear-cut evidence is available that would either indicate age of last movement or definition of the fault. For purposes of conservatism, the Bowling Green structure is assumed to be a fault. The fault is not believed to extend into Michigan (Reference 12). The evidence available for faulting is described as follows (Reference 7):

> A drop by faulting of more than 200 feet in the top of the Trenton Limestone is indicated between well locations in the vicinity of Findlay, Cygnet, and Bowling Green, Ohio. The fault which is down-thrown on the west extends northward and connects with the Lucas County (Ohio) - Monroe County (Michigan) monocline.

Thus, the only evidence of the age of last faulting is Middle Ordovician (based upon evidence in the Trenton Limestone).

Evidence of faulting along the west flank of the Howell Anticline has been presented (References 7 and 13) and it has been suggested that total vertical displacement may be as much as 1000 ft (Reference 13). The type of faulting, amount of displacement, and orientation have not been absolutely determined. More recent work (Reference 5) has revealed that faults of major displacement are not believed to exist in connection with the immediate west flank of the Howell Anticline and it is shown that, although minor faulting may have occurred along the west flank or across the structure, it is not of the magnitude generally described by earlier investigators. Developments of the Howell Anticline associated with major faulting may have begun as early as Late Ordovician and continued throughout most of the Paleozoic. If the presence of Jurassic-aged rock in the Michigan Basin is considered, developments may have taken place as late as Cretaceous time. The age of last faulting within the State of Michigan, however, appears to be Paleozoic (Reference 14).

A system of faults located 45 miles northeast of the site is associated with the Chatham Sag. The Electric Fault in this fault system has a reported maximum vertical displacement of 300 ft (Reference 15). Maximum displacements of less than 100 ft have been reported for other faults in this system (Reference 15).

Faulting has been postulated along the Tekonsha oil field structure, and several small seismic events have been tentatively correlated to these. The structure trends northwest-southeast for an inferred length of 60 miles. Only limited, minor structural indications of this fault have been recorded.

The age of the faulting in the southeastern portion of the Michigan Basin is assumed to be Ordovician, although some evidence exists of minor movement in post-Ordovician time (Ells, personal communication).

The Keweenawan-Lake Owen Fault System lies northwest of the Michigan Basin, approximately 430 miles northwest of the site. It has a northeast trend on the Keweenawan Peninsula in Lake Superior. Vertical displacements on this fault system of a few thousand feet to more than 9000 ft are known (Reference 16). This fault system is not associated with the Michigan Basin.

The Rough Creek-Kentucky River Fault System in southern Illinois and central Kentucky is approximately 350 miles south of the site.

2.5.1.1.3.3. Pop-up and Affiliated Structural Features

Pop-up features in bedrock have been identified in various parts of western New York State, and in Canada. The existence of several of these features has been documented (Reference 17) in various parts of the North American continent and their existence has been attributed to the release of postglacial horizontal compressive stresses. In addition to occurring in regions where activities of Man have been limited, these and affiliated phenomena have been seen in man-made structures such as excavations into bedrock.

Actual pop-ups have not been noted in southeastern Michigan or adjacent portions of Ohio, Indiana, or Canada, but surficial folding of Devonian shales has been observed in northwestern Ohio.

Although pop-ups have not been specifically documented in the site region, pop-ups or "heave" are fairly common occurrences in quarries in a wide range of localities due to a reduction of lithostatic load.

The small mound-like features noted during the mapping of excavation at the site are believed to be of organic origin. During the excavation process, no rockbursts, pop-ups, or heaves were seen. This can be attributed to a lack of compressive stresses as described in Reference 17 and insufficient depth of excavation to reduce lithostatic loading sufficiently to cause such features to occur.

2.5.1.1.4. Ground Water

In the region surrounding the site, ground water aquifers are present in two types of material: glacial outwash deposits and Paleozoic bedrock. An expanded discussion of regional ground water conditions is found in Subsection 2.4.13.

2.5.1.1.5. Geologic History

2.5.1.1.5.1. General

The study of geologic history provides an insight as to the tectonic stability of a region and a better understanding of stratigraphic relationships between various soil and rock units. It also furnishes correlative data that assist in the interpretation of events in adjacent regions.

An accurate interpretation of geologic history is the result of years of cumulative effort. It is based on numerous examinations of soil and rock units in exposures, and from borings with regard to lithology and fossil content.

The generalized stratigraphic succession and the distribution of the bedrock units in Michigan are presented in Figure 2.5-4. They are composite in nature. The entire series of stratigraphic units is not likely to be encountered at any given locality; however, it is a graphic illustration of the changing geologic history. Individual time units are discussed in the following paragraphs, and the tectonic and structural features mentioned are shown in Figures 2.5-6 and 2.5-7.

2.5.1.1.5.2. Precambrian

The basement rocks of Michigan are Precambrian in age. They include granite, felsic and mafic gneiss, volcanics, metavolcanics, metasediments, mafic volcanics, and mafic intrusives (Reference 18). Radiometric dates range from approximately 600 to 3500 million years (Reference 19). These rocks represent a complex series of geologic events that include sedimentation, uplift and erosion, subsidence and deposition, mountain building, volcanism, and igneous intrusions followed by erosion, which have produced an irregular surface upon which the overlying Paleozoic sediments have been unconformably deposited.

The regional Bouguer gravity map (Figure 2.5-9) and the regional magnetic map (Figure 2.5-10) of the Southern Peninsula of Michigan substantiate the conclusion that the basement

rocks are both structurally and lithologically complex. The Mid-Michigan Anomaly, the dominant feature of the gravity map and to a lesser degree of the magnetic map, has been interpreted by Hinze (Reference 20) as originating from the mafic rocks of Keweenawan age similar to those that outcrop in the Lake Superior region. This feature consists of a positive gravity anomaly and a correlative magnetic high. Pirtle (Reference 21) states, "...it is believed that the principal folds now existing in the later sediments are controlled by trends of folding or lines of structural weakness which existed in the basement rocks." This opinion is still the prevalent one shared by most workers (Reference 20). The most obvious example of this correlation is the alignment of the Washtenaw Anticlinorium with the Mid-Michigan Anomaly in Washtenaw and Livingston Counties.

2.5.1.1.5.3. Cambrian

At the beginning of the Cambrian Period, a mountainous belt extended across most of the Upper Peninsula of Michigan. Erosion of topographic highs dominated while clastic sediments accumulated in the surrounding lowlands.

Paleozoic deposition in southern Michigan began when Late Cambrian seas spread across the interior of the continent, depositing clean sandstones, dolomites, and limestones characteristic of shallow, clear seas with bordering land masses of low relief.

The accumulation of sediments in the Michigan Basin originated with Late Cambrian subsidence. During this period of geologic history, the Michigan and Illinois Basins were not separated. This early, undifferentiated basin is known as the Eastern Interior Basin.

2.5.1.1.5.4. Ordovician

The Ordovician was the period during which Paleozoic seas became fully established in Michigan.

The variable nature of the rocks in southern Michigan, as revealed by deep-boring data, suggests fluctuating marine conditions. Deposition of Lower Ordovician dolomite and sandstone indicates that seas were present in the Lower Peninsula while absent in the Upper Peninsula. Two regressions of the sea during the Ordovician are indicated by unconformities within the sedimentary sequence of southern Michigan, one at the top of the Prairie du Chien Group during the Early Ordovician and the other at the top of the Eden Group during the Late Ordovician.

2.5.1.1.5.5. Silurian

Seas persisted in Michigan from Ordovician into Silurian time. Apparently, the entire state was occupied by offshore waters so that the Silurian marine deposits in Michigan are mainly chemical precipitates formed in clear seas. Locally, shallow banks supported reefs. It is believed that coral reef formations along the margins of the Michigan Basin effectively isolated the basin area from the main marine body and formed an evaporation basin. Great accumulations of Silurian salt, anhydrite, and gypsum were formed.

The Silurian was a time of accelerated downwarping of the Michigan Basin. Slight expressions of the Findlay and Kankakee Arches are seen in the Upper Silurian sediments in the southeast and southwest corners of Michigan, respectively.

Near the close of the Silurian Period, the seas withdrew from the Michigan Basin.

2.5.1.1.5.6. Devonian

During Early Devonian time, the southeastern portion of the Michigan Basin was subjected to erosion and/or nondeposition. To the north and northwest, however, marine sedimentation continued.

By Middle Devonian time, the Michigan Basin was fully occupied by the sea, which deposited limestones and, finally, shales in a relatively shallow-water environment.

2.5.1.1.5.7. Mississippian

Marine waters that existed since Middle Devonian time continued into Early Mississippian time. Alternating shales, siltstones, and sandstones are representative of sediments of Mississippian age.

Tilting of the Michigan Basin area is believed to have occurred in Early Mississippian time, resulting in a marked expression of the Findlay Arch and possibly the northeast-southwest trending folds in the central portion of the Michigan Basin. Toward the close of Early Mississippian time, a major regression of the sea maintained much of southern Michigan as a near-shore and beach environment.

Middle Mississippian rocks are absent, which indicates that either there was no deposition due to a complete withdrawal of the sea from Michigan, or there was deposition and subsequent erosion.

Upper Mississippian deposits indicate a transgression of the sea. Some evaporite deposits similar to those found in Silurian sediments are present. Near the close of the period, the seas freshened and limestone was deposited.

In latest Mississippian time, the Michigan Basin was subjected to uplifting and folding that involved the Precambrian basement features. This activity produced many of the structures in Paleozoic rocks of the Michigan Basin in which gas and oil later accumulated (References 19 and 22).

2.5.1.1.5.8. Pennsylvanian

The pattern of alternating sedimentation established during the Mississippian Period continued into Pennsylvanian time and reached its peak with a characteristic cyclical sedimentation of alternating marine, brackish-water, and terrestrial deposits. Organic accumulation in the brackish-water swamps formed widespread coal beds.

From Pennsylvanian time to the Pleistocene Epoch, the area remained above sea level.

Erosion prevailed in post-Pennsylvanian time with the exception of some terrestrial sandstone and shale deposition during the Jurassic Period. The entire Mesozoic Era was relatively inactive, although broad uplift and some erosion did occur. Minor fault activity is believed to have taken place along the Keweenawan Fault System into Cretaceous time.

Geologic evidence suggests that southern Michigan existed as a low stable land mass for over 200,000,000 years, while the Appalachian Mountains, Rocky Mountains, and other structural features in North America were being formed or were undergoing additional movements.

2.5.1.1.5.9. Jurassic

The geologic record is almost completely missing from the end of Pennsylvanian time until the Pleistocene. The only rocks representing this long span of time are some sedimentary strata that for many years were referred to simply as "red beds." Their age was long uncertain but was thought to be Pennsylvanian. Early maps showed them as such. In recent years, fossilized microscopic plant spores have been found in well samples from the red beds. They have been identified as being Late Jurassic in age (Reference 19). Surface exposures of the rocks have not been found, and their presence beneath the glacial drift has been demonstrated only by well samples. The Jurassic red beds are normally about 100 ft thick, but in places attain thicknesses of 300 to 400 ft (References 19 and 22). The rock consists mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

2.5.1.1.5.10. Pleistocene

Glaciation began during Pleistocene time some 1,000,000 years ago. In general, four distinct glacial advances are recognized throughout North America during this division of geologic history. From oldest to youngest, these are known as the Nebraskan, Kansan, Illinoian, and Wisconsinan glacial stages. There is positive evidence in Michigan for only the Wisconsinan glacial advance. However, Illinoian and Kansan glacial deposits are found to the south of Michigan in Ohio and Indiana. Therefore, it is reasonable to assume that Michigan was overridden by at least these two earlier advances as well (Reference 19).

The Wisconsinan glacial deposits blanket large portions of Michigan (Figure 2.5-2). These deposits represent a complex series of ice lobes that advanced and retreated a number of times. The ice sheets modified the Great Lakes basin and are responsible for almost all of the present-day surface topography.

2.5.1.2. Site Geology

2.5.1.2.1. Physiography

The site area (Figure 2.4-3) is located on a featureless lacustrine plain (Figure 2.4-1) along the western shore of Lake Erie. The plain was formed during the high-water stages of Lake Erie. It is essentially flat lying and generally poorly drained, but it has been slightly dissected along Swan Creek, which flows into Lake Erie at the northern edge of the Fermi site. The plain slopes gently to the east. The average elevation of the lacustrine plain is about 660 ft above mean sea level, or approximately 90 ft above mean lake level. The relief within the site boundaries is approximately 9 ft.

2.5.1.2.2. Stratigraphy

2.5.1.2.2.1. Soil Units

Local sand deposits are encountered in an old channel of Swan Creek at the north end of the site, and in the barrier beach, which forms the shoreline of Lake Erie at the site. Other sand deposits are encountered offshore. The maximum thickness of sand encountered in the lake is 25 ft. More recent surficial deposits of silt, peat, and clay are encountered in the lower, swampy areas at the site. A compact, relatively impermeable till mantles the rock throughout the site area. Occasional boulders, up to 3 ft in diameter, are encountered near the bedrock surface. The till is approximately 14 ft thick and is overlain by about 7 ft of impermeable stratified lacustrine clay.

Approximately 5 ft of lacustrine peaty silts and clay had been removed from the site area at the time of the Fermi 2 foundation investigation. The surface of glacial till was exposed at an average elevation of 566 ft, which is approximately 6 ft below the water surface of adjacent Lake Erie. The till consists of nearly impermeable silty to sandy clays with varying amounts of gravel and cobbles.

The thickness of the till deposit on top of bedrock within the immediate Fermi 2 plant area, as determined from the borings, ranges from a minimum of 8 ft to a maximum of 15.5 ft, and has an average thickness of approximately 14 ft. Wider variations may be present since both the upper and lower surfaces of the till are erosional surfaces.

2.5.1.2.2.2. Rock Units

The bedrock strata in the site area range in age from Silurian to Precambrian as shown in Figure 2.5-11. The bedrock surface is shown in Figure 2.5-12. A total of 40 test borings were drilled at the site for Fermi 2 detailed foundation studies. The locations of these borings are shown in Figures 2.5-13 and 2.5-14. The deepest boring at the site extended 109 ft into the Unit C bed of the Salina Group. Relationships between the units encountered during the drilling program are shown in the subsurface sections, Figures 2.5-15 through 2.5-20.

The description of the stratigraphic units below Unit C of the Salina Group is based on published reports. The estimated thicknesses of these deeper units are based on logs of boreholes drilled in the general area and on interpretation of structural geologic maps of the general area.

Bass Islands Group - Dolomite of the Bass Islands Group forms the uppermost bedrock stratum at the site and overlies the Salina Group. In the borings at Fermi 2, the Bass Islands dolomite is a gray-brown, thinly bedded rock of dense, finely crystalline character. Black shale partings about 1/8 in. in thickness are interspersed throughout the dolomite at spacings of about 4 in. Both the dolomite bedding and the shale partings are essentially horizontal. Occasional soft gray clay seams between 1/4 in. and 8 in. in thickness occur at random in the dolomite and are usually associated with fractured zones and vugs. Two marker beds in the Bass Islands Group were penetrated by the borings and have been correlated throughout the site. The upper marker bed is an oolitic dolomite ranging from 1.8 to 3.5 ft in thickness. The lower marker bed is a soft black shale. Recovered thickness of the shale among the several

borings ranges from 0.2 to 1.2 ft; however, its in-place thickness is greater than the amounts recovered.

Fractures are present to a variable degree in the Bass Islands Group; joints are relatively tight and discontinuous, and usually display only very minor solution activity. The dominant trends of joints are N45°-60°W and N40°-50°E and are nearly vertical in dip (Reference 23). Where the rock is densely fractured, intervals have closely spaced joints that form fragmented zones. Fractures are oriented from 0° (horizontal) to 90° (vertical), and the thickness and depths of these zones are variable throughout the site. The fragmented zones range in thickness from a few inches to as much as 4.5 ft, and average about 1 ft.

Small vugs are present throughout the Bass Islands Group. They range from barely visible to 2 in. in maximum dimension. The amount of open space created by vugs ranges from about 0 to 30 percent of the total rock mass, with an average of 5 percent to 10 percent. Numerous vugs are also present which are lined with crystals of the mineral celestite. Fractures connect some of the vuggy zones, which increases the permeability to the rock mass.

The thickness of the Bass Islands Group, where fully penetrated by the borings, increases from 13.5 ft at boring 20 where part has been removed by erosion, to 101 ft at boring 201 (Figures 2.5-13 and 2.5-14).

<u>Salina Group</u> - The Salina Group at the site is subdivided into five beds referred to as:

a. Unit G, shales and argillaceous dolomite

b. Unit E, argillaceous dolomite

c. Unit C, dolomite

d. Unit A-2, dolomite

e. Unit A-1, dolomite.

Borings at the site encountered only the lower portion of the Bass Islands Group and extended as deep as Unit C of the Salina. Beds of the Salina Group in the site area consist of alternating layers of dark gray dolomite and shale. The maximum thickness of Salina Group strata penetrated during drilling was 224 ft in boring 79. None of the borings passed through the Salina Group into lower strata. Some brecciation was noted at the Bass Islands-Salina contact.

No salt beds were encountered in the vicinity of the site. Figure 2.5-21 is an isopach map of the Salina salt beds in southeastern Michigan. Salt present in Wayne County thins to the south and is absent in Monroe County. The only salt underlying the site is an insignificant quantity in the form of very small salt crystals (1/16-in. in diameter) disseminated through several feet of a dense dolomite in the Unit G, E, and C formations.

The shale intervals of the Salina Group, as observed in recovered core, range from soft to hard and from 0.01 ft to 2.2 ft in thickness. Gray clay seams in the sequence are soft and occur predominantly in fractured and vuggy zones, and are responsible for the lower percentages of core recovery. The vugs are sedimentary features caused by decay of fossil matter or other depositional and consolidation features and do not indicate karst conditions at the site. Little of this material was recovered during drilling, but the maximum clay thicknesses are believed not to exceed 1 ft.

Unit G - Unit G directly overlies Unit E and consists of gray, hard and soft shales, dolomitic shales, and argillaceous dolomites with occasional traces of anhydrite. Unit G was observed to be about 60 ft thick at the site.

Unit E - Unit E, which directly overlies Unit C, consists of gray to brownish-gray, vuggy, shaly dolomite, dolomitic limestone, and limestone breccias. All vugs encountered in the borings were less than 2 in. in diameter. Due to the vugged zones, the unit is highly permeable and shows minor artesian ground water flow. Unit E is uniformly about 60 ft thick in the vicinity of the site.

Unit C - Unit C directly overlies the A-2 dolomite unit and consists of a buff to gray, hard, thin- to medium-bedded dolomite with thin seams of shaly dolomite and anhydrite. Generally, anhydrite layers were less than 6 in. in thickness and the thickest layer encountered was a 6-ft layer in boring 209 at approximate Elevation 295 ft. The base of Unit C was not penetrated in the borings drilled for this study. Unit C is estimated to be about 140 ft thick at the site.

Units A-2 and A-1 - The A-2 and A-1 units are buff-white to brownish-gray, very finely to finely crystalline dolomite. Stylolites, argillaceous thin layers, and partings are present. Although the test borings at the site did not go as deep as the A units, the units are considered to be present below the site.

Niagaran Group - The Niagaran Group consists of buff, gray, and light brown, fossiliferous, finely to coarsely crystalline dolomite. This group is stratigraphically equivalent to the Clinton and Guelph-Lockport Groups of southeastern Ontario, and has an estimated thickness of 425 ft near the site (Reference 24).

Cataract Group - This group is a buff to gray, fossiliferous dolomite with thin layers and partings of green to gray shale. Traces of pyrite and glauconite are present. Estimated thickness near the site, based on Michigan well logs, is 100 ft.

Richmond Group - The Richmond Group contains approximately 625 ft of shale and dolomite, based on Monroe County well logs. The shale is gray to green with some brick-red units throughout the section. Dolomite occurs as stringers within the shale and as gray to buff, fossiliferous beds containing red and gray shale seams.

Trenton-Black River Group - The Trenton Group is generally undivided in subsurface from the underlying Black River Group. These rocks consist of gray-brown to buff, fossiliferous dolomite and dolomitic limestone with noticeable oil stains and gas shows. Estimated thickness near the site is 825 to 850 ft. Several thin layers of metabentonitic clay occur within a 1-ft zone at the bottom of the Trenton Group. These layers have been noticed in drillers' logs of Monroe County and are discussed by Hussey (Reference 25). The Trenton-Black River Group unconformably overlies the St. Croixan Series at the site due to the local absence of Lower Ordovician deposits (Reference 16).

St. Croixan Series - The St. Croixan Series comprises dolomite, sandstone, and minor amounts of shale in approximately 475 ft of section. The dolomite is buff, white to gray, slightly glauconitic, finely crystalline, and occasionally shaly. The dolomite occurs in the upper section of the series and is underlain by buff, white to gray, fine- to coarse-grained sandstone. Gray shale layers occur throughout the sandstone as partings or more uncommonly as beds several feet in thickness.

Precambrian - The Precambrian basement is a metamorphic-igneous complex composed of granite and granitic gneiss (Reference 18). Estimated depth near the site to the Precambrian rock is about 3100 ft.

2.5.1.2.3. Structural Geology

The borings have not disclosed faulting at the site. Differential elevations in the bedrock strata were investigated and are interpreted as a shallow synclinal fold. The axis of the fold trends approximately N60°W and passes through the Fermi 2 area, as shown in Figures 2.5-22 and 2.5-23. The strata dip toward the axis of the fold at about 4° and 1.5° to the north and south sides, respectively. The axis of the synclinal fold plunges to the northwest at about 1.5°.

Several marker beds were used to trace the folding and to determine the configuration and continuity of the rock structures. The primary marker bed used was the lower oolitic horizon in the Bass Islands dolomite. Other marker beds were a thin continuous shale seam within the Bass Islands Group, and the contact between the Bass Islands Group and the Salina Group.

Small local folds of the shale, encountered at the site area, are quite common in southeastern Michigan and are not necessarily related to regional tectonic trends. Many have been detected through oil and gas exploration in Monroe and Wayne Counties.

2.5.1.2.3.1. Jointing

The Bass Islands dolomite is highly jointed. The vertical joints range from open to closed. Some are filled with gypsum, anhydrite, or selenite. The nature of this jointing has been observed in excavations for Fermi 2 and in a quarry located less than 1 mile west of Fermi 2. This quarry has been allowed to fill with water, and excavations for Fermi 2 have been filled so that observation of these joints has been obliterated. Nevertheless, mapping of the joints has been accomplished in the excavation for the reactor/auxiliary buildings (Reference 24) and more recently in the excavation for the RHR complex. Mapping of the excavation for the reactor/auxiliary building indicated trends of N45°-60°W and N60°-50°E. The RHR complex excavation exhibits joint trends of N21°-35°W and N54°-72°E. Quantity and degree of openness of jointing tends to decrease with depth in all excavations encountered at the site.

2.5.1.2.3.2. Folding

The regional structure at the site indicates a northwest dip of less than 0.5°. Local warpings superimposed on the regional dip are known to be present. Contour maps drawn using the base of an oolitic horizon marker bed within the Bass Islands Group indicate a shallow synclinal fold (Figures 2.5-22 and 2.5-23). The axis of the fold trends approximately N60°W and passes through the Fermi 2 area, as shown in Figures 2.5-22 and 2.5-23. The fold is asymmetrical and the strata on the northeast side dip southwest at about 4°. The strata on the southwest side dip northeast at about 1.5°. The axis of the syncline plunges northwest at about 1.5°. A small anticlinal feature superimposed on this shallow synclinal fold is indicated on Figure 2.5-23 on the basis of boring data. During the course of mapping of the

excavation, this feature was also observed. It was noted that, in general, foundation surface bedding planes are higher in the east-central region of the excavation and gently dip to the south, west, and north, implying a slight doming of the bedding planes in this region of the excavation.

2.5.1.2.3.3. Faulting

There are no reported faults within 25 miles of the site. All reported regional faults are tabulated in Table 2.5-2 and are shown in Figure 2.5-7.

2.5.1.2.4. Ground Water

The surficial deposits at the site consist of low-permeability glacial till, lacustrine clay, and peat. Some fine sand is present along the shoreline of Lake Erie. The surficial deposits locally act as a confining layer above the Paleozoic bedrock aquifer, and a slight artesian pressure exists at the site. More detailed information on ground water conditions at the site is found in Subsections 2.4.13 and 2.5.4.6.

The rate of flow of artesian ground water was noted at varying depths during the 1968 and 1969 boring operations for Fermi 2 Category I structures and is shown in Table 2.5-3. Similarly, any noticeable odor of hydrogen sulfide gas was noted. These observations are presented on the boring logs. Chemical analyses of ground water were made and the results are given in Subsection 2.5.4.6.

2.5.1.2.5. Geologic History

The geologic history of the region is discussed in Subsection 2.5.1 and includes the history as represented by the geologic units from the Precambrian to the Pleistocene. At the site, the borings penetrated only the Middle and Early Silurian rocks (Niagaran and Cayugan Series) indicated on the site stratigraphic column, Figure 2.5-11. The presence of Precambrian, Cambrian, and Ordovician rocks underlying the Silurian sequence shown on the legend of the regional geologic map, Figure 2.5-4, has been proven by borings in areas adjacent to the site, and these rocks are probably present at the site. Those portions of the regional geologic history that are applicable to the site are the Precambrian, Cambrian, Ordovician, Silurian, and Pleistocene.

2.5.1.2.6. Hydrocarbon Production and Subsurface Gas Storage Potential

Neither hydrocarbon production nor subsurface gas storage is believed to have great potential within the site vicinity.

2.5.1.2.6.1. Hydrocarbon Production Potential

As mentioned in Subsection 2.5.1.2.2.2, oil stains and gas shows have been noted in the Trenton-Black River Group of Middle Ordovician age.

The Trenton-Black River Group does hold distinct possibilities for future hydrocarbon production. Virtually all Ordovician hydrocarbons have come from the eight-county area which includes Monroe and surrounding counties. Of this production, the AlbionScipio Trend, which crosses Calhoun, Hillsdale, and Jackson Counties, accounts for nearly 74

percent of the productive drilled acreage and most of the cumulative Ordovician hydrocarbons (Reference 26).

The eight-county area has been analyzed for hydrocarbon yield per square mile and has been thought to have been adequately drilled to assess its future potential.

Ells (Reference 26) says:

> For the purpose of estimating the amount of undiscovered hydrocarbons in the Middle Ordovician Trenton-Black River rocks, it is assumed that the eight-county area has been completely explored, that no additional fields will be found and that the total production from this area amounted to 92,694,457 bbl.

From this standpoint, although the majority of Ordovician oil is presently obtained from this eight-county area and primarily from the Albion-Scipio Trend, significant future hydrocarbon development is unlikely and the remainder of the Michigan Basin holds more promise for increased future development.

2.5.1.2.6.2. Subsurface Gas Storage Potential

Subsurface storage of gas has been successfully carried out in the State of Michigan and has been largely restricted to converted gas fields.

The nearest such field that has been used for subsurface storage of gas is the Northville Field in Wayne County. Other fields affiliated with subsurface gas storage are found in St. Clair and Macomb Counties at some distance from the site.

Monroe, Lenawee, and Washtenaw Counties and most of Wayne County are not considered prime candidates for gas storage. Increased gas storage is far more likely in regions of converted gas fields (Reference 27). This would preclude any great potential for subsurface storage of gas in isolated anticlinal structures as may occur in the site region.

2.5.1.2.7. Engineering Geology

Geologic conditions at the site are considered satisfactory for the support of the foundations of the Fermi 2 facilities. The foundations for all Category I structures are established into the Bass Islands dolomite beneath the glacial till and lacustrine deposits.

Fracturing is present to a variable degree in the Bass Islands Group. It ranges from sparse to dense. In the former case, the fractures occur as singular, isolated structures of different lengths and orientations. Other intervals are characterized by closely spaced fractures that form fragmented zones. The fragmented zones range in thickness from a few inches to as much as 4.5 ft. They average about 1 ft in thickness. The thicknesses and depths of these zones are variable. Occasionally they occur at similar elevations, but the extent of lateral continuity is difficult to ascertain.

Vuggy zones are present throughout the Bass Islands Group and range from barely visible size to 2 in. in maximum dimension. The amount of open space created by vugs ranges as high as 30 percent of the total rock mass with an average of 5 percent to 10 percent. Fractures connect some of the vuggy zones, the connections thereby increasing the permeability of the rock mass. Comprehensive subsurface explorations, careful inspection of all excavations, and monitoring of foundation grouting (Subsection 2.5.4) ensure that no cavities of

detrimental size underlie the plant structures. Several sinkholes are known in Whiteford, Bedford, and Ida Townships of Monroe County (about 15 to 20 miles from the site), but none are reported or have been encountered in the site area (Reference 4). Nearly all occur in rocks of the Detroit River Group, which lie stratigraphically above the Bass Islands Group and are not present at the site.

A study of older published reports of drillers' logs and of four modern reports, including detailed study of well logs and cuttings conducted by Eschman, indicates that no salt deposits underlie the Fermi site (Reference 1).

Figure 2.5-21 indicates the thickness of salt deposits in the Salina Group in southeastern Michigan. The contours shown represent points of equal thickness. The 0 isopach line or contour, therefore, represents the outer margin of the salt beds. The Fermi site is outside the salt area. The nearest occurrence of salt is shown to be about 10 to 15 miles north of the site.

There is no solution mining within 17 miles of the site and the local geology indicates that there is no likelihood of future solution-mining activity in the site area, because minable salt does not occur within 15 miles.

The closest reported salt-mining operation was in Wayne County about 17 miles north-northeast of the Fermi site (Reference 28). This is the same general area of current active mining operations that was studied in detail in the D&M report of the River Rouge Generating Plant site (Reference 29).

Accidental gas blowouts, associated with oil and gas exploration activity, have occurred to the north in the region (Reference 30). In blowouts, gas has been known to travel several miles along permeable horizons from the source well and cause damage in the outcrop area of the permeable stratum. However, there is no anticipated danger of gas blowouts at the site since the highest relatively permeable stratum in the area is the Salina E formation, which outcrops beyond the shoreline in Lake Erie.

The results of ground water chemical analyses show that ground water at the site contains concentrations of sulfates that are potentially deleterious to portland cement, concrete, or grout. The potential for sulfates affecting cement, concrete, or grout stems from their chemical composition.

When certain alumina-bearing compounds are present in the cement of a hardened concrete, its exposure to water containing sulfate ions results in the formation of ettringite, accompanied by a volumetric expansion within the fabric of the hardened paste, which can result in disruption of the gel structure. Hence, for concretes that will be exposed to sulfate containing soils or waters, low tricalcium aluminate ($3\ CaO \bullet Al_2O_3$) cements are often specified (Reference 31). For this reason, Type V, modified Type II, and Canadian Standards Association (CSA) A5-1971 cement was used for grouting and for all subsurface concrete construction that would come into contact with the ground water. Since there is no known tricalcium aluminate present within the Category I crushed-rock backfill and it is not bonded like a concrete or cement grout, there would be no similar deleterious effect upon the crushed-rock backfill. Consolidation characteristics are described in Subsection 2.5.4.

2.5.1.2.8. Test Borings

Geologic borings were drilled at the Fermi 2 site in 1968, 1969, and 1972 to determine the details of the lithology, structure, and physical properties of the subsurface strata. Borings were drilled in 1970 to determine static and dynamic soil and rock properties. The borings range in depth from 12.1 to 324.7 ft below the ground surface and were drilled at the locations indicated in Figures 2.5-13 and 2.5-14.

Detailed descriptions of the soil and rock encountered in the borings are presented in Figures 2.5-24 to 2.5-56. The soils were classified. The Unified Soil Classification System is described in Figure 2.5-57.

Rock was cored utilizing NX and BX coring equipment and samples of the overburden soils were obtained. The field exploration program was conducted under the technical direction and supervision of D&M. Rock core from other borings drilled under the supervision of Soil and Foundations Associates was carefully examined by D&M.

Five of the borings were utilized for pressure tests to obtain water leakage data as an aid in establishing criteria for dewatering and foundation grouting. The results of pressure testing are shown to the right of boring logs 201, 203, 209, 210, and RHR-3 in Figures 2.5-33, 2.5-35, 2.5-42, 2.5-43, and 2.5-50.

2.5.1.2.9. Geophysical Explorations

Geophysical investigations performed at the site in 1968 consisted of a seismic refraction survey and a borehole geophysical survey. The velocity of compressional wave propagation and other dynamic properties of the natural subsurface materials were determined by these studies, and were used in evaluating the response of the materials to earthquake loading. The results of the field geophysical studies are presented in Figures 2.5-58 through 2.5-61. Micromotions were measured to indicate the pattern of vibration at the site based on ambient background vibration analyses. These measurements, given in Table 2.5-4, are of assistance in estimating any predominant natural period of vibration at the site.

Poisson's ratio and other dynamic moduli for the various materials (crushed-rock fill, glacial till, Bass Islands Group) in the stratigraphic section at the site were estimated based on computed and/or empirical data for similar materials. Shear wave velocities for the upper bedrock at the site were computed using the measured compressional wave velocities from the refraction survey and estimated Poisson's ratio. The computed shear wave velocities were then confirmed by the data developed in the borehole geophysical survey. In general, relatively good agreement was obtained from these two methods of evaluating shear wave velocity.

Compressional wave velocities for the deeper rock strata have been measured in the region. These data were used to compute shear wave velocities for the deeper rock strata, based on estimates of Poisson's ratio measured in similar materials.

Measured and computed geophysical data for the stratigraphic section at the site are presented in Figure 2.5-58.

2.5.1.2.9.1. Geophysical Borehole Logging

Borehole geophysical measurements were made in three deep borings by the Birdwell Division of Seismograph Service Corporation. Four types of logs were run, providing the following categories of reduced data:

a. Compressional wave velocity (in situ) (Figure 2.5-58) at each 1-ft interval

b. Shear wave velocity (in situ) (Figure 2.5-58) at each 1-ft interval. (In these three borings the shear velocity was not measured directly, but was calculated from an empirical relationship between compressional velocity and bulk density)

c. Poisson's ratio (Figure 2.5-58) computed from compressional wave velocity and shear wave velocity

d. Bulk density, derived from density log (Figure 2.5-58).

Representative logs are shown graphically in Figures 2.5-59 and 2.5-60.

2.5.1.2.9.2. Seismic Refraction Survey

Two seismic refraction surveys, shown in Figure 2.5-61, were conducted to evaluate the bedrock characteristics at the site during the 1968 Fermi 2 investigation. The seismic lines were located along the barrier beach at the east edge of the site, as shown in Figure 2.5-22. One line was 250 ft long and the other was 500 ft long with some overlap in coverage. The results of the seismic refraction surveys were used to obtain dynamic properties of the foundation materials. Permanent records of the compressional waves generated from this survey were obtained using an Electro- Technical Labs ER75012 Seismic Timer, a 12-trace refraction seismograph. Geophone spacing was 25 and 50 ft, respectively, for the two lines. The compressional velocities measured during these studies are presented in Figures 2.5-58 and 2.5-61. Access to additional geophysical refraction work in southeastern Michigan was provided by others. The compressional wave velocities measured in other regional surveys were slightly higher than the results obtained during this study. The other profiles were in slightly different material, higher in the geologic column.

During the refraction surveys, the vibration levels within the existing Fermi 1 plant, and wave data generated in the foundation materials by the explosive charges, were monitored by a blast monitoring program.

2.5.1.2.9.3. Ambient Vibration Measurements

Ambient vibration measurements were made at two locations during the 1968 Fermi 2 investigation using D&M Micromotion Equipment (Hosaka Recording System). This equipment, which measures ambient ground displacements, has a magnification of up to 150,000. The equipment is capable of recording ground displacements ranging in frequency from 1 cycle per second to 30 cycles per second. The ambient vibration records can be used to indicate predominant periods of ground motion at the site, under the test strain levels.

Ambient station measurement No. 1 was obtained on 2 ft of soil covering a rock outcrop in an old quarry located in the northwest portion of the site. The second measurement was on

approximately 20 ft of soil overlying rock. At the first location, the intensity of ground motion was very low with only a slight suggestion of predominant periods, indicative of hard rock. At the second observation point, the intensity of ground motion was so low that it was obscured by machinery noise. The depth of bedrock at each location and the predominant ground periods observed are indicated in Table 2.5-4.

2.5.1.2.10. Laboratory Tests

During the 1968 investigations of Fermi 2, representative rock cores that were extracted from certain borings were subjected to a laboratory testing program to evaluate the physical properties of the rock encountered at the site (References 1 and 2). The depths of the rock cores that were tested and tabulated in Table 2.5-5 and in Appendix 2D represent depths from the original ground surface. In some cases the rock samples tested were from above the foundation level. Testing of rock samples from this zone was carried out in order to arrive at conservative foundation design parameters since the rock above foundation level is more weathered and less competent than the rock below. Laboratory tests included the following:

a. Density tests

b. Unconfined compression tests

c. Shockscope tests

d. Resonant column tests.

The density and unconfined compression tests were performed in accordance with ASTM standards. The shockscope and resonant column tests were performed according to generally accepted methods. There are no ASTM standards for these tests.

Chemical analyses of ground water samples were performed during the 1969 investigation.

Additional laboratory testing was performed in 1972 on soil samples and rock core obtained from borings at the Fermi 2 RHR complex (Reference 3).

2.5.1.2.10.1. Static Tests

Density Tests - Density tests were performed on representative rock cores that were selected from 1968 and 1969 borings made during the investigation of Fermi 2. The results of these tests are given in Table 2.5-5.

Unconfined Compression Tests - During the 1968 and 1969 Fermi 2 boring program, several representative unconfined compression tests were performed on selected rock samples to evaluate the strength and elasticity characteristics of the bedrock. The tests on the rock cores were performed by the Robert W. Hunt Company in accordance with ASTM standards. The results of the rock compression tests and associated density determinations are presented in Table 2.5-5.

Later, during the 1972 foundation investigation for the RHR complex, additional unconfined compression tests were performed by the Robert W. Hunt Company. The results of these tests are given in Table 2.5-6.

2.5.1.2.10.2. Dynamic Tests

Shockscope Tests - Several samples of the rock materials underlying the site were tested in the shockscope during the 1968 and 1969 studies. The shockscope is an instrument developed by D&M to measure the velocity of propagation of compressional waves in the material tested. The velocity of compressional wave propagation observed in the laboratory is used for correlation purposes with the field velocity measurements obtained in the geophysical refraction and borehole surveys.

In the shockscope test, samples are subjected to a physical shock under a range of confining pressures, and the time necessary for the shock wave to travel the length of the samples is measured using an oscilloscope. The velocity of compressional wave propagation is then computed. Since this velocity is proportional to the dynamic modulus of elasticity of the sample, the data also are used in evaluating dynamic elastic properties. The results of the tests are presented in Table 2.5-7.

Resonant Column Tests - Resonant column tests were performed on two representative samples of rock from the 1968 boring program to determine the shear modulus of rigidity of these materials. The samples are subjected to steady-state, sinusoidal, torsional forces applied to the top of the sample. The frequency of the force application is varied until the resonant frequency (the frequency associated with the maximum steady-state amplitude) is attained. The shear modulus is computed from the resonant frequency of the sample. The results of the resonant column tests are presented in Table 2.5-8.

2.5.1.2.11. Static and Dynamic Properties of Foundation Materials

Static and dynamic soil and rock properties of foundation materials for Fermi 2 were determined for the reactor/auxiliary building and adjacent turbine and office service buildings and are presented in Table 2.5-9 (Reference 32). The properties were modified for the Fermi 2 RHR complex in order to be representative of the local soil and rock conditions. The properties used for design criteria for the RHR complex are presented in Table 2.5-10 (Reference 3).

2.5.2. Vibratory Ground Motion

Basic Fermi 2 site vibratory ground-motion evaluations were conducted by D&M in 1968. A reaffirmation of the acceptability of this early work was provided by Weston Geophysical in 1982. The following paragraphs of this section present the data summarized from the original D&M investigation. However, any recent data of significance are identified and appropriately noted.

2.5.2.1. Geologic Conditions of the Site

A complete discussion of the regional stratigraphy, structure, and geologic history is found in Subsection 2.5.1. This site is located within the Central Stable Region of North America, an area in which the geologic structure is relatively simple. The region is characterized by a system of broad, circular to oblong sedimentary basins that include the Michigan, Appalachian, and Illinois Basins. Stable regions, including the Cincinnati Arch Complex

(including the Findlay, Algonquin, and Kankakee Arches), separate the basins. Numerous secondary features are superimposed on these broad structures. The site lies along the southeast edge of the Michigan Basin and northwest of the axis of the Findlay Arch.

Precambrian crystalline basement rock lies about 3100 ft below the ground surface in the vicinity of the site. The crystalline basement complex is mantled by sedimentary rocks of Paleozoic age (Subsection 2.5.1.1.2.2). The bedrock surface at the site ranges in depth from approximately 15 to 30 ft below the existing ground surface. The overburden materials consist of sands, silts, and clays of Pleistocene age.

The uppermost bedrock unit at the site consists of the Bass Islands dolomite of Late Silurian age. Prior to glaciation, the Bass Islands Group was covered by deeply weathered and jointed rocks that experienced solution activity. Glacial advance and retreat scoured the younger rocks, and exposed the hard and relatively unweathered Bass Islands Group. The Bass Islands dolomite is on the order of 80 ft thick in the site area. The Salina Group underlies the Bass Islands and is about 525 ft thick near the site. This material consists of interbedded shales, limestones, and dolomites and is underlain by the Niagaran dolomite.

Faults have not been identified within the basement rocks or overlying sedimentary strata at the site. The closest fault, the Bowling Green Fault, is postulated approximately 35 miles southwest of the site. The vertical displacement of this fault is thought to be several hundred feet. Other known faults in the area are more distant from the site. Most faults in the region are believed to have been dormant since late Paleozoic time, at least 200 million years ago (Subsection 2.5.1). Folding is known throughout southeastern Michigan. The most prominent secondary feature is the Howell Anticline, located in the southeastern portion of the Michigan Basin. Since the area has undergone multiple Pleistocene glaciation, it may be inferred that this region has been subjected to repeated slight bending in the last few hundred thousand years (Subsection 2.5.1).

2.5.2.2. Underlying Tectonic Structures

A discussion of tectonic structures in the region surrounding the site is found in Subsection 2.5.1. The most significant structural features are listed below:

a. The Bowling Green Fault trends north-south in north-western Ohio. An inferred extension of this fault lies approximately 35 miles southwest of the site (Subsection 2.5.1.1.3.2)

b. The Howell Anticline, the most prominent fold in the region, approaches to within about 25 miles north of the site and extends approximately 80 miles to the northwest (Subsection 2.5.1.1.3.1)

c. The Chatham Sag is a broad, gentle, northwest-trending syncline that has been mapped as far south as the north shore of Lake Erie. The axis of the syncline lies about 50 miles northeast of the site. A system of faults, including the Electric Fault, is associated with this structure (Subsection 2.5.1.1.3.1)

d. The Keweenawan Fault System, which is characterized by vertical displacements from a few thousand feet to more than 9000 ft, lies northwest of the Michigan Basin approximately 430 miles northwest of the site. It has a

northeast trend on the Keweenawan Peninsula in Lake Superior (Subsection 2.5.1.1.3.2)

e. The Rough Creek-Kentucky River fault complex in southern Illinois and central Kentucky approaches to within about 350 miles south of the site (Subsection 2.5.1.1.3.2).

2.5.2.3. Behavior During Prior Earthquakes

Although a few distant earthquakes have been felt at the site, detailed onsite studies suggest that their intensities have not been sufficient to affect local surface or subsurface materials. There is no physical evidence at the site to indicate that the area has experienced seismic activity at any time.

2.5.2.4. Engineering Properties of Materials Underlying the Site

The engineering properties of unconsolidated surficial deposits and bedrock are presented in Subsections 2.5.1 and 2.5.4. Seismic wave velocities are presented in Subsections 2.5.1.2.9, 2.5.1.2.9.2, and 2.5.4.2; density values are presented in Subsections 2.5.1.2.9.1, 2.5.1.2.10, and 2.5.4.2; water contents are indicated by wet and dry density values given in Subsection 2.5.1.2.10; rock quality designation is presented below and in Subsection 2.5.4.2; and strength characteristics are given in Subsections 2.5.1.2.9.1 and 2.5.4.2.

2.5.2.5. Earthquake History

2.5.2.5.1. 1968 Evaluation

The site is located in one of the most seismically stable regions in the United States. No earthquake epicenter has been located closer than about 25 miles and only seven earthquakes have been reported within 50 miles of the site since the beginning of the 19th century. None of these shocks were greater than Intensity V on the Modified Mercalli Scale.* Eleven earthquake epicenters of Intensity V to VIII have been reported within 50 to 100 miles of the site and another 24 of Intensity V to VII are located at distances between 100 and 200 miles. The closest Intensity VII shock was located at 90 miles and the closest Intensity VIII shock was located at 100 miles from the site.

A list of larger earthquakes located 200 or more miles from the site is presented in Table 2.5-12.

A list of earthquakes with epicenters located within a distance of about 200 miles from the site is presented in Table 2.5-13. This list presents all reported earthquakes within 50 miles of the site and significant shock (Intensity V and greater) within 200 miles of the site. The epicenters of these shocks are shown in Figure 2.5-62.

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* All intensity values in this subsection refer to the Modified Mercalli Scale. The intensity scale, which is described in Table 2.5-11, is a means of indicating the relative size of an earthquake in terms of its perceptible effect.

Although at least six shocks have been felt at the site within the past two centuries, the maximum intensity at the site has not exceeded Intensity IV. None of the recorded earthquakes caused any damage at or near the site.

Since the beginning of the 19th century, twelve earthquakes of Intensity V or greater have been reported within 100 miles of the site, and only 37 earthquakes of Intensity V or greater have been reported within about 200 miles of the site. The 1776 and 1925 events have not been located precisely enough to plot on the figure. Few were of high enough intensity to cause structural damage to reasonably well-built structures. None of these shocks were greater than Intensity VIII and only six can be considered more than minor disturbances. These earthquakes occurred in 1875 (Intensity VII), 1930 (Intensity VI and VII), 1931 (Intensity VII), and two in 1937 (Intensity VII and VIII). The epicenter of the closest of these shocks was about 100 miles from the site. These six earthquakes, along with a number of smaller shocks, are concentrated in a 40-mile-long northeast-southwest-trending zone extending south of Lima, Ohio. This zone of earthquake activity is located near the juncture of the Findlay, Cincinnati, and Kankakee Arches.

The earthquakes closest to the site were four Intensity III and IV shocks near Toledo, Ohio (about 30 miles distance), an 1877 Intensity V shock west of Detroit, Michigan (about 30 miles from the site), and a 1961 Intensity V shock in northern Ohio (about 55 miles south of the site). The several Intensity III and IV shocks were reported in the Toledo newspapers. These shocks were not felt at the site. The 1961 earthquake occurred near the Bowling Green Fault and/or the confluence of the Bowling Green Fault with the axis of the Findlay Arch. The 1877 Detroit shock has not been related to any specific geologic structure. Although one or more of these small shocks may have been felt in the vicinity of the site, there were no reports of disturbance near the site, and no damaging effects were experienced. It is estimated that intensities at the site due to these shocks were on the order of III or less. The other five earthquakes within 50 miles of the site were Intensity V or smaller and probably were not felt at the site.

For purposes of this study, it is considered that the most significant earthquakes in the region were the 1937 Intensity VII to VIII earthquakes south of Lima, Ohio; the 1947 Intensity VI earthquake in south-central Michigan; the 1943 Intensity V earthquake in Lake Erie, about 100 miles east of the site; and the 1961 Intensity V earthquake in northern Ohio. This evaluation has been made considering such factors as epicentral intensity (with regard to both damage to structures and perceptible area), distance from the site, and geologic structure (with regard to the possible relationship of geologic structure near the earthquake epicenter to structure near the site). A discussion of each of these significant earthquakes follows.

The earthquake of March 8, 1937, was the single most significant shock recorded within 200 miles of the site during the period of record. The shock occurred in an area that has experienced the most concentrated earthquake activity within the region.

The area is located at the south end of the Findlay Arch near the confluence of the Cincinnati and Kankakee Arches. Residual stress fields from late Mississippian time may still be slightly active in this area and this locality is probably weaker than the surrounding region due to the confluence of structural features. Earthquakes in the region were generally located at the transition between major tectonic features, rather than within a structural block. The earthquake was felt in an area of about 150,000 square miles. The shock was reported in the

Detroit newspapers and was felt near the site with about Intensity IV. The effect in Michigan was not great and no damage resulted.

The earthquake of August 9, 1947, occurred at approximately 8:47 p.m. northeast of Kalamazoo, Michigan. The effects near the epicenter were minor, consisting primarily of damage to a few brick chimneys. There also were reports of loose plaster shaken from ceilings and loose bricks shaken from a few buildings. Based on the damage reports, the epicentral intensity of this earthquake was Intensity VI. The earthquake was felt within an area almost 200 miles in radius. The shock was felt in the vicinity of the site with Intensity III or less. This shock may be related to the Tekonsha oil field structure (see Subsection 2.5.1.1.3.2).

The earthquake of March 8, 1943, occurred at about 11:26 p.m. The maximum intensity of this shock was probably Intensity V and the duration of shaking was only several seconds. It was felt in a relatively large and irregular area extending from Toronto, Ontario, as far south as Zanesville, Ohio. The total perceptible area of this shock was on the order of 40,000 square miles. Its location in the middle of Lake Erie reduced the area likely to sustain damage. The damage from this earthquake was trivial, with the highest intensity (VI) reported in Cleveland, Ohio. In Detroit, houses shook and windows rattled, but there were no reports of damage or of tall-building disturbance which is usual for more distant larger shocks. The shock was felt in the vicinity of the site and was reported to be about Intensity III. This shock may be related to an extension of the Chatham Sag into the northern part of Lake Erie.

The Intensity V earthquake of February 22, 1961, was the largest and most recent shock within 55 miles of the site. The epicenter of this shock has been located near the southern end of the Bowling Green Fault. Since only one seismograph recorded this shock, its specific location is somewhat tenuous. The shock was felt only in the local area and no damage resulted. The shock was not felt in the vicinity of the site. The limited perceptibility of this recent earthquake, indicating a rather low energy release, minimizes its significance in this study.

2.5.2.5.2. 1986 Reaffirmation

Earthquake reassessment activities, in which new site-specific earthquakes were defined and which provided documentation of the satisfactory conclusions reached from evaluation of the preceding earthquake history, were completed in 1982.

Additional seismic activity has occurred since 1968 and is summarized through July of 1986 in the following paragraphs.

Six more earthquakes have occurred within 200 miles of the site. Two of these were minor disturbances located near Colechester, Ontario, with epicentral intensities of III and IV. One occurred in 1968 near Attica, Michigan, with an epicentral intensity of V. The three others were located in Ohio near Celina, Perry, and St. Mary's and had intensities of VI, VI, and V respectively.

Six other earthquakes can be added to the list of earthquakes located 200 or more miles from the site. A 1975 earthquake was located near Wellston, Ohio (Intensity V), about 215 miles from the site. A major earthquake shook Sharpsburg, Kentucky (Intensity VII) in July 1980,

about 300 miles from the site. A 1984 earthquake was located near Sudbury, Ontario (Intensity V), about 350 miles from the site. Two other 1984 earthquakes of Intensity V were located about 285 miles from the site near Clay City, Indiana. Finally, one 1985 earthquake near Edgebrook, Illinois, which is located about 250 miles from the site also had an intensity of V.

Documentation for all these earthquakes has been provided in Tables 2.5-12 and 2.5-13 and their epicenters are shown in Figure 2.5-62.

The most significant earthquakes since 1968 are the 1977 Ohio earthquake, the 1980 Kentucky earthquake, and the 1986 Perry earthquake.

The June 1977 earthquake was located near Celina, Ohio, and had a Richter magnitude of 3.2. The earthquake was felt over about 550 sq km^2 of western Ohio from Celina, south to Chickasaw, west to Fort Recovery, and north to Rockford. Several instances of slight damage were reported in the area. The maximum intensity reported was a VI near Celina, Coldwater, Fort Recovery, and Rockford, Ohio.

Damage ranged from sidewalk cracks to plaster cracks and hairline cracks in exterior walls. The estimated intensity at the site is a II.

The shock of July 27, 1980, is the strongest earthquake to be centered in Kentucky and the strongest earthquake to be felt in this region since the southern Illinois earthquake of 1968. It was felt over an area of approximately 600,000 km^2 of the central United States and Canada. The epicenter was located near Sharpsburg, Kentucky, and the epicentral magnitude and intensity were 5.1 and VII respectively. The worst damage was at Maysville, Kentucky, approximately 50 km north of the epicenter, where 37 business structures and 269 residences suffered damage of some degree. Most of the significant damage to structures occurred in the older downtown section of the city. The damage was mostly to older brick structures probably built during the middle 1800s.

Ground cracks were reported to have occurred about 12 km from the epicenter at Owingsville and Little Rock, Kentucky. Reports of the duration of ground vibration were about 15 sec of strong motions and up to several minutes for sensible vibrations.

The intensity in Michigan varied from II to IV and was reported to be at II in Monroe, Michigan.

The earthquake of January 1986, was located about 11 miles south of the Perry Nuclear Power Plant site and had a Richter magnitude of 4.96.

The earthquake was rated as a Modified Mercalli Intensity of VI. Seventeen people were treated for minor injuries. Structural damage was confined to slightly damaged chimneys, cracks in concrete and under blockwalls, some cracked and fallen plaster, a few broken windows, and some well-water silting.

The January 31, 1986, Ohio earthquake was felt at the Fermi site as a Mercalli Intensity IV event. No unusual conditions were observed. The earthquake was not strong enough to be designated an event at Fermi. However, detailed earthquake instrumentation evaluations were completed and evaluation procedures and instrumentation interpretation techniques were verified.

2.5.2.6. Correlation of Epicenters With Geologic Structures

The majority of the significant earthquakes in the region can be associated with well-defined geologic structural zones (Figure 2.5-62). The major geologic structures are described in Subsection 2.5.1.1.3 and are shown in Figures 2.5-6 and 2.5-7. As indicated by Tables 2.5-1 and 2.5-2, the folding and faulting in the central stable region are principally Paleozoic. Recent investigations (References 33 and 34) have indicated that the present seismic activity is not related to surface faulting. Seismic activity occurs in regions bounded by structures of Paleozoic age. The random nature of epicentral locations is the result of stress release in randomly distributed Precambrian crustal blocks (Subsection 2.5.1.1.5.2 contains a more complete discussion). Any present seismic activity occurring near a fault or fold of Paleozoic age does not indicate that the structure is active.

To the north and west of the site, earthquakes are rare and appear to occur near anticlinal structures in northern Michigan. To the west of the site, earthquake activity has consisted of infrequent minor shocks that occur in the random epicentral region of southern Wisconsin and northern and central Illinois. To the south, at Anna, Ohio, recent investigations (Reference 35) conducted in the area indicate that earthquake activity is associated with complex Precambrian basement structures. Geologic conditions in this area are unique and the seismic events that occurred here cannot be considered random. However, as described in Subsection 2.5.2.9, in defining the maximum earthquake, an event similar to the Anna event was considered to be able to occur along the axis of the Findlay Arch at its closest approach to the site. These recent studies only indicate that the acceleration values used in design are more conservative than had previously been assumed.

The zone of major earthquake activity closest to the site is in the vicinity of New Madrid, Missouri, more than 500 miles to the southwest. Earthquakes near New Madrid in 1811 and 1812 are considered among the largest ever to have occurred in the United States. It is reported that these shocks (possible Intensity XI) were felt in an area of 2 million square miles and changed the surficial topography in an area of about 30,000 to 50,000 square miles. The structural damage resulting from these earthquakes was small due to the lack of construction and habitation in the region.

It is estimated that intensities felt in the vicinity of the Fermi site due to these shocks were probably on the order of III to IV. Their influence would be predominant only at low frequencies and is enveloped by existing design criteria. These earthquakes occurred within the extensively faulted New Madrid (Reel Foot) seismographic region (Reference 36). The geologic structure in southern Illinois and western Kentucky is not related to the geologic structure in the vicinity of the site. The Rough Creek fault complex crosses major regional structures and probably forms a boundary separating the stable continental interior to the north from the seismogenic upper Mississippi Embayment. There is no geologic evidence to relate this fault system with structure or faulting within the continental interior. Thus, the seismically active region at the boundary and to the south should be considered dissimilar and distinct from the seismically quiet region to the north.

Another area of concentrated earthquake activity is in the vicinity of Cleveland, Ohio. Since the turn of the century, five Intensity V shocks have been reported in this area. No shock larger than Intensity V has been reported and none of these earthquakes were large enough to

have been felt in Michigan. These shocks have not been related to a known tectonic feature. Several small shocks in southern Michigan, northern Indiana, and in Lake Erie, similarly, cannot be positively related to known faults. The 1947 southern Michigan shock apparently is coincident with the alignment of the Tekonsha oil field and may be associated with oil field structures. Structure and faulting is inferred for the oil field. The validity of an Intensity VI shock in 1883 in southern Michigan has been questioned. Although the magnitude of this earthquake is dubious, its location may indicate a relation to oil field structures.

The 1947 Intensity VI south-central Michigan shock and the 1943 Intensity V Lake Erie shock are the largest earthquakes in the region that cannot be positively related to specific tectonic features. Since the geologic structures in the region are believed to have been dormant since Paleozoic time, earthquake activity in the area may represent final crustal readjustment to Pleistocene glacial advance and retreat. Glacial rebound in the site area is nonexistent as far as is known.

2.5.2.7. Identification of Capable Faults

No known capable faults occur within 200 miles of the site. Significant tectonic structures that occur within 200 miles of the site, however, are described in Subsection 2.5.2.2 and their locations are shown in Figure 2.5-7. A description of these structures is included in Subsection 2.5.1.1.3 and a summary of the major faults is given in Table 2.5-2. Information on the activity of the structures is included in Subsections 2.5.2.5 and 2.5.2.6.

2.5.2.8. Description of Capable Faults

No known capable faults occur within 200 miles of the site. For a description of regional faulting, see Subsection 2.5.3.

2.5.2.9. Maximum Earthquake

The effect at the site of a possible future earthquake similar to a large historical shock has been investigated. For this evaluation, the first shock considered was the March 8, 1937, Intensity VIII earthquake near Lima, Ohio. Should a shock similar to this earthquake occur in the vicinity of the confluence of the Findlay, Cincinnati, and Kankakee Arches, the attenuated ground acceleration at the site would be less than 5 percent of gravity.

A review of the regional seismic history indicates that the shocks occurring near Lima, Ohio, have been localized within a very small area. The epicentral areas generally trend north-south and are quite limited in extent. An additional shock (1961) was located near the confluence of the Bowling Green Fault and the axis of the Findlay Arch. Even if a shock as large as the 1937 Lima shock were to occur at this location, or at the closest approach of the Bowling Green Fault, or the axis of the Findlay Arch to the site, the maximum expected ground acceleration would be less than 10 percent of gravity.

The 1811-1812 Intensity XII New Madrid, Missouri, series of earthquakes was also studied. Should a shock as large occur as close to the site as the closest approach of the Rough Creek-Kentucky River fault complex (about 350 miles), the attenuated ground acceleration at the site would be less than 5 percent of gravity.

It is also concluded that either of these occurrences would result in ground motion at the site significantly less than that selected for the safe-shutdown earthquake (SSE).

Small earthquakes similar to the 1947 and 1943 shocks (Subsection 2.5.2.6) could occur in the vicinity of the site. On this basis, the effect of a shock similar to the 1947 south-central Michigan or the 1943 Lake Erie earthquake with an epicenter near the site has been considered. A conservative estimate of the maximum horizontal ground acceleration at the rock surface, due to such a shock, is less than 10 percent of gravity.

Confirmatory site-specific earthquake evaluations were completed in 1982 to reaffirm the acceptability of the established Fermi 2 facility seismic design bases. This site-specific evaluation was completed assuming a Richter magnitude 4.9 to 5.9 quake with an epicenter less than 25 km from the site. This assumption is consistent with a quake at the Fermi 2 site similar to that which occurred in Anna, Ohio, in March 1937, and which would also account for a quake at the site such as the July 27, 1980, Kentucky experience in the Central Stable Region as well as the recent January 31, 1986, Perry, Ohio, event.

Site-specific spectra were derived directly from representative real-time histories for the appropriate magnitude and distance, and foundation conditions similar to the Fermi site. The 84 percentile of such spectra represented the comparative evaluation level for which the facility seismic design capability was reaffirmed.

2.5.2.10. Safe-Shutdown Earthquake

Category I structures at the plant are founded on rock and are designed so that they can be safely shut down in the event ground accelerations at the site exceed those that are operationally tolerable. Consequently, an evaluation has been made of the degree of ground motion that is remotely possible, considering both seismic history and geologic structure. In developing the SSE evaluation, consideration was given to the fact that there is a history of minor to moderate earthquake activity in the region that cannot be related directly to known tectonic features. Category I structures, systems, and components are designed for a safe shutdown due to horizontal zero period ground accelerations at the rock surface at foundation level, of 15 percent of gravity (0.15g).

2.5.2.11. Site-Specific Earthquake

In response to a request from the Geosciences Branch, a site- specific earthquake ground response spectrum (essentially per Regulatory Guide 1.60 pegged at 0.15g horizontal) was developed, exhibiting a significantly higher ground response than the SSE ground response. Reevaluation of structures, systems, and components required for cold shutdown was presented to the NRC in the Supplementary Seismic Evaluation Report, Detroit Edison Report No. EF2-53332, Revision 1, dated July 15, 1981. Also see Subsection 3.7.1.2.1.

2.5.2.12. Operating-Basis Earthquake

On the basis of the seismic history of the area, it does not appear likely that the site will be subjected to significant earthquake ground motion during the life of the plant. However, Category I structures are conservatively designed to respond, within elastic limits, and with no loss of function, to a horizontal ground acceleration on the rock surface at foundation

level of 8 percent of gravity (0.08g). Subsequent review by Weston Geophysical demonstrated that the operating-basis earthquake (OBE) peak horizontal ground acceleration of 0.08g has a return period, as a minimum, of the order of 100 to 300 years.

2.5.3. Surface Faulting

No faults are known within 25 miles of the site. Detailed information concerning faulting on a regional and site basis is included in Subsections 2.5.1.1.3 and 2.5.2.7.

2.5.3.1. Geologic Conditions of the Site

Details of the stratigraphy, structure, and geologic history of the site are found in Subsection 2.5.1.2.

2.5.3.2. Evidence of Fault Offset

No faults are known within 25 miles of the site (Subsection 2.5.1.1.3).

2.5.3.3. Identification of Capable Faults

No faults are known within 25 miles of the site (Subsection 2.5.1.1.3).

2.5.3.4. Earthquakes Associated With Capable Faults

No faults are known within 25 miles of the site, and no earthquakes have been reported closer than 25 miles from the site (Subsections 2.5.1.1.3 and 2.5.2.5).

2.5.3.5. Correlation of Epicenters With Capable Faults

No faults or earthquake epicenters have been reported within 25 miles of the site (Subsections 2.5.1.1.3 and 2.5.2.5).

2.5.3.6. Description of Capable Faults

No faults are known within 25 miles of the site (Subsection 2.5.1.1.3).

2.5.3.7. Zone Requiring Detailed Faulting Investigation

There is no known geologic basis for the possible existence of faulting in the site area. Therefore a detailed faulting investigation is not warranted.

2.5.3.8. Results of Faulting Investigation

A review of all available literature, conferences with geological organizations, and onsite investigations revealed that no surface or subsurface faults exist within 25 miles of the site (Subsection 2.5.1.1.3.2).

2.5.3.9. Design Basis for Surface Faulting

Surface faulting at the site is not considered for design.

2.5.4. Stability of Subsurface Materials

2.5.4.1. Geologic Features

Pertinent geologic features of the site are discussed in detail in Subsection 2.5.1.2. Competent bedrock strata underlie the site and there are no major solution cavities or zones of solution weathering in the site area. However, due to the presence of zones of extensively fractured or highly vugged rock, pressure grouting was used to provide assurance that zones of this type are not horizontally continuous across the site. The foundation rock will satisfactorily support all static and dynamic loads imposed by all Category I and other heavy settlement sensitive structures.

2.5.4.2. Properties of Underlying Materials

A description of the site geology is given in Subsection 2.5.1.2. Test boring data are presented in Subsection 2.5.1.2.8. Grain- size classification is presented in Subsection 2.5.1.2.8; consolidation characteristics are given in Subsection 2.5.4.5.2; water content is indicated by wet and dry densities given in Subsection 2.5.1.2.10; unit weight values are given in Subsection 2.5.1.2.9; shear moduli are presented below; damping is considered below; and Poisson's ratio values are given below and in Subsection 2.5.1.2.9. Seismic wave velocities are given below and in Subsection 2.5.1.2.8. Density values are given below. Rock quality designations are considered below and in Subsection 2.5.2.4. Strength characteristics are given below.

Based on an analysis of the results of laboratory testing together with a review of published data and a comparative evaluation of the soil and rock materials at the residual heat removal (RHR) complex (Reference 3) with those determined for the reactor site (Reference 2), design parameters were developed and are presented in Tables 2.5-9 and 2.5-10.

The parameters presented in Tables 2.5-9 and 2.5-10 are discussed below. A brief description of the method of determining the values is given, and the range of variation is discussed.

2.5.4.2.1. Density

The densities given for the rock fill material were determined from large-scale density tests performed in a compacted test fill (Reference 2). In determining the submerged density, the rock fill material was assumed to have a specific gravity equivalent to that of dolomite. The range of variation given is considered appropriate for a controlled compacted fill of 1.5 in. and smaller crusher-run rock. The densities for the in situ glacial till and their range of variation were assessed from the moisture- density tests performed on relatively undisturbed samples. An appropriate specific gravity was used in calculating the submerged density.

Bedrock density and its range of variation were determined from the results of measured densities of representative rock cores.

2.5.4.2.2. Wave Velocities

The compression and shear wave velocities presented in Table 2.5-9 for the crushed-rock fill, glacial till, and in situ rock are measured values (References 1, 2, and 3). The range of variation of wave velocities has been estimated with consideration for the inherent uncertainties in methods of measurement and variations in grain size, density, and strength of the various materials.

2.5.4.2.3. Poisson's Ratio

The tabulated values of Poisson's ratio for the compacted rock fill and glacial till were computed from the shear and compression wave velocities. Where possible, the load-settlement data from plate load tests were compared to provide a further check on the values computed from the wave velocities. Values for in situ rock were estimated from the seismic investigation (Reference 1).

The range of variation for Poisson's ratio was estimated with consideration for probable differences in wave velocities, grain size, density, and strength of the materials being considered.

2.5.4.2.4. Static Modulus of Elasticity

The tabulated static moduli of elasticity for the rock fill and glacial till were computed from the results of load-settlement behavior recorded during plate load testing and, for the glacial till, from unconfined compression tests performed on relatively undisturbed samples (References 1, 2, and 3).

Laboratory values for static modulus of elasticity were derived from unconfined compression tests. Based on certain empirical formulae (Reference 37) and literature research (References 38 and 39), combined with experience, knowledge, or rock characteristics such as Rock Quality Designation (RQD), vugs, discontinuities, and clay seams and tempered with conservatism, a factor of 0.25 was applied to the average laboratory values. This figure was then taken to be the in situ static modulus of elasticity. A range of ±50 percent was utilized in presenting this value to account for the expected variability of characteristics within the Bass Islands Group.

2.5.4.2.5. Dynamic Modulus of Elasticity

The dynamic moduli for the glacial till were determined from elastic analysis of the data provided by the Pulsating Load Triaxial Tests. The dynamic moduli of the compacted rock fill and the bedrock were determined by elastic analysis of the results of the field seismic studies (References 2 and 3).

The range of values presented reflects the accuracy of field measurement and analysis together with the anticipated variations in grain size, density, and/or strength of the various materials.

2.5.4.2.6. Shear Moduli

The shear moduli of the till maerials were computed from the results of Pulsating Load Triaxial Tests. For the compacted rock fill and the bedrock, the shear moduli were computed using the elastic relationship between the shear modulus, modulus of elasticity, and Poisson's ratio. The range of values reflects inherent uncertainties in methods of analysis and anticipated variations in grain size, density, and/or strength of the various materials.

2.5.4.2.7. Damping Values

The tabulated values of damping are based largely on a review of available published data. The values of damping presented for the glacial till were computed from the results of Pulsating Load Triaxial testing. The damping capacity of the bedrock was developed from various dynamic tests (Reference 1). All of the tabulated damping values are expressed as a percentage of critical damping.

2.5.4.2.8. Rock Quality

The quality of the rock as observed in recovered drill core was evaluated by measuring:

a. Rock quality designation

b. Fragmented zones

c. Fracture density.

The data are included on the core boring logs (Figures 2.5-33 through 2.5-55).

The average RQD in the upper 15 to 20 ft of bedrock in all borings at the RHR complex was 47 percent, or the "poor" quality classification. The average core recovery throughout this depth interval was 92.4 percent, sufficiently high to yield reliable RQD values.

Fragmented zones are present. They range in thickness from 6 in. to 3 ft and occur at different elevations in each boring. The lack of depth and thickness correlation between borings suggests that the fragmented zones are not continuous laterally across the site.

Fracture density ranged typically from very close (less than 2 in.) to close (2 to 6 in.) in the upper 15 to 20 ft of bedrock at both the RHR complex and the reactor site. The fracture density is directly influenced by the spacing of shale partings along with the core separates during drilling operations and subsequent handling.

2.5.4.2.9. Rock Strength

Corrected values for ultimate compressive strength and modulus of elasticity of bedrock, as determined by laboratory unconfined compression tests, are presented in Table 2.5-5. Elastic moduli values were computed from plots of unit axial stress versus unit axial strain derived from laboratory test results. Records of these laboratory test results are contained in Appendix 2D. Results of unconfined compression tests on rock from borings taken from the reactor site and from the RHR complex are presented in Tables 2.5-5 and 2.5-6.

2.5.4.3. Plot Plan

A topographic map of the site showing the location of Fermi 2 facilities is given in Figure 2.4-3. The plant facilities are shown in relation to bedrock topography in Figure 2.5-12. The boring plan in relation to plant facility locations is given in Figures 2.5-13 and 2.5-14. Subsurface sections in relation to plant facilities are presented in Figures 2.5-15 through 2.5-20.

Structural geology in relation to facility location is shown in Figures 2.5-22 and 2.5-23.

2.5.4.4. Soil and Rock Characteristics

A table and profiles of a compressional and shear wave velocity survey are presented in Subsection 2.5.1 and in Figures 2.5-58 through 2.5-61. Graphic core boring logs are presented in Subsection 2.5.1 and in Figures 2.5-24 through 2.5-56. Compressional and shear wave velocities are presented in Subsections 2.5.1.2.9, 2.5.1.2.10, and 2.5.4.2.

2.5.4.5. Excavations and Backfill

2.5.4.5.1. Rock Excavation

Early in the reactor building excavation, a test blasting program was conducted to control the excavation blasting at Fermi 2 relative to Fermi 1 (References 13, 40, 41, and 42). Ground motions were measured at varying distances from test blasts for a selected range of blast loads, and attenuation data were developed as shown in Figure 2.5-63. The blasting criteria for limiting onsite seismic disturbances were (a) particle velocity limited to 1 in./sec, and (b) particle acceleration limited to 5 percent of gravity. The blasting program was carefully supervised by qualified engineering personnel and was monitored with instruments.

Subsequent to blasting operations, the exposed foundation bedrock was sluiced with high-pressure water jets and carefully examined by a qualified geologist to ensure that no excessive natural fracturing or blasting back-break existed that might be unsuitable for foundation support. All heavily fractured rock, clay seams, weathered shale, and other unsuitable materials exposed at final foundation grade were removed.

Based on the limiting criteria, the production shot loads for the reactor/auxiliary building foundation excavation were as follows.

Pounds per Delay	Minimum Distance From Fermi 1 (ft)
25	400
40	500
50	600
65	700
80	800
100	900
150	1000
175	1100
200	1200

The charge limitation for the initial blasting to excavate for the RHR complex foundation was based on the distance to Fermi 2 facilities, as follows:

Pounds per Delay	Distance to the Nearest 144-in.-Diameter Circulating Water Pipe (ft)
0.30	60
0.60	75
1.40	100
3.50	150
6.25	200

On the basis of blast-induced ground or structure motions measured during initial blasts (Reference 43), the charge limitation was increased as follows:

Pounds per Delay	Distance to the Circulating Water Pipe (ft)
1.0	60
1.0	75
1.4	100
3.5	150
6.25	200

2.5.4.5.2. Earthwork

Fill materials required to raise the site to required final grade were obtained from an onsite rock quarry and supplemented by offsite quarry-supplied rock. Fill placed at the site and properly compacted was used for the support of minor structures. All Category I and other major structures are supported on competent bedrock; the walls were framed and placed on the structural base slab. Crushed rock was then compacted in layers between the walls and the blast-excavated rock face.

A test section of compacted stone fill material was constructed to permit onsite plate load testing and seismic studies of the fill material (Reference 3). Plate load tests were performed on both the compacted crushed-rock fill and the in situ glacial till. The locations of the plate load tests are indicated in Figure 2.5-14. The results of the plate load tests are given in Table 2.5-14. A seismic investigation of the compacted crushed- rock test area was also performed. The results of the compression wave velocity measurements are shown in Figure 2.5-64.

Information on compaction criteria, gradation criteria, methods of placing and compacting, and thickness of lifts of the crushed- rock structural backfill is found in Detroit Edison specification 3071-37, Fill Materials, Placement and Compaction (Appendix 2C), and in Building Work specification for RHR Complex 3071-142.

Because of the difficulty of preparing representative samples for laboratory testing, there were no laboratory static or dynamic tests performed on samples of the crushed-stone compacted fill material. Crushed-stone compacted fill material obtained a high degree of density when placed in accordance with specifications 3071-37 and 3071-142. This dense compacted-rock fill with its select gradation was further reinforced by the interlocking mechanism of the angular, well-graded particle sizes of the rock fragments and afforded

resistance to penetration by conventional sampling methods. Field plate load and seismic tests were used as the basis for deriving the values presented in Table 2.5-9.

Consolidation tests were done on relatively undisturbed samples of glacial till (Reference 3). The results of the tests are shown in Figure 2.5-65.

There are no Category I buildings placed directly on crushed-rock fill. Additional testing on the in-place structural backfill after its placement in accordance with the specification for such placement was not performed. The onsite quality control program required constant inspection to ensure that the work was being performed in accordance with the referenced specification. Since the test results taken from the large compacted test fill area formed the basis for developing the specification, assurance that specification objectives throughout the site were being met was obtained by using trained personnel in a continuously monitored quality control (QC) program.

Fill that did not meet the specification requirements was rejected. Construction supervision and constant QC inspection were utilized to ensure that all work was continuously performed in accordance with the specifications.

During the course of safety evaluation review, the NRC requested additional information regarding backfill (drawings) for structures and components. This information was provided to the NRC with Reference 32 in June 1981, wherein it was mentioned that the following representative drawings show the backfill at the site: 6C721-2106, 6C721-2324, 6M721-2680, and 6M721-4232.

2.5.4.6. Ground Water Conditions

A summary of ground water conditions appears in Subsection 2.4.13. The history of ground water conditions at the site is summarized below.

The natural surficial deposits at the site consist of low- permeability glacial till, lacustrine clay, and peat. The surficial deposits locally act as a confining layer above the Paleozoic bedrock aquifer, and a slight artesian pressure exists at the site.

Various parameters were investigated and their relationships to local ground water features have been noted.

Pressure tests were conducted in borings 201, 203, 209, and 210 in 1969 during the comprehensive foundation investigation for the reactor/auxiliary building. Test data are shown in Table 2.5-15. The results of these tests are presented to the right of the boring logs as shown on Figures 2.5-33, 2.5-35, 2.5-42, and 2.5-43. Pressure testing was accomplished by means of inflatable packers set in the area to be tested. Water under pressure was forced into this area and the rate of take of the water at various pressures was recorded in gallons per minute. From these data, permeability of the rock was calculated by use of the following formula:

$$K = C_p \frac{Q}{H} \qquad (2.5\text{-}1)$$

where

K = permeability in feet per year

Q = flow in gallons per minute

H = head of water in feet of water acting on the test section

C_p = a constant of 4900 for nx-sized hole and a 10-ft test section (Reference 44)

Ground water observations were made by observing the rate of artesian flow at varying depths. These observations were made by drilling to a certain depth and collecting water as it flowed from the top of the boring and timing the rate of filling of a container of known volume in gallons. It was then possible to determine rate of artesian flow in gallons per minute at various levels in the boring.

Further ground water observations were made after completion of the borings by inserting standpipes in the borings, allowing the water to rise to its static level, and measuring the elevation of the top of the water. Other observations were made at this time in regard to water quality. These observations ranged from simply noting the odor of H_2S gas (shown on the boring logs) to collecting ground water samples for chemical analyses of the ground water.

In 1972, foundation investigations for the RHR complex included the installation of six piezometers in borings RHR 1, 2, 5, 6, 7, and 8. The installation of these piezometers and data gathered from them refute the 1969 water-level data in that water levels are generally much lower and artesian flow is not noted. This is due exclusively to construction dewatering. The overall result has been to reverse the ground water gradient at the plant site from toward the lake to away from the lake.

During quarry operations between 1969 and 1972, a decline in ground water level occurred. Also, during this period a decline occurred because of a regional drought condition. After the spring of 1971, the quarry operation was restricted to the southern end. The northern part was diked and functioned as a ground water recharge pit, with the water level maintained full at about Elevation 570 ft. Quarry operations ceased on June 30, 1972. Water-level observations were made during and after the quarry operations in several observation wells, as shown in Figure 2.4-25. Water-level data are given in Table 2.4-7.

As mentioned above, dewatering was carried out specifically for rock excavation. Conventional dewatering by pumping from sumps was employed. A grout curtain was constructed around the reactor/auxiliary building rock excavation to decrease the extent of dewatering required and to minimize the extent of depression of the surrounding ground water level.

The curtain wall grout plan for the excavation of the Fermi 2 reactor/auxiliary building (References 45 and 46) delineated 96 grout holes spaced at 12-ft centers and located as shown in Figure 2.5-66. A grout curtain was not used for the RHR complex excavation.

Grouting of the rock mass under the plant facilities will force that moving ground water which would have flowed through the grouted rock to be diverted around it. This diversion will increase slightly the ground water flow rate in the rock immediately outside and below the grout curtain and might increase slightly the solutioning of the carbonate rocks in that zone. In view of the low flow rate of the ground water in the bedrock aquifer (see Subsection 2.4.13.2), the minor expected increase in flow rate through diversion of ground water around the grout curtain is not expected to significantly accelerate solutioning at the site.

Water samples for laboratory analyses were obtained from stratigraphic horizons within the site area during the 1969 boring program. The elevations at which water samples were obtained are noted in the boring logs. Some water samples were obtained from artesian flows at various depths during the borings, usually after the boring had flowed for several hours. After completion of the boring, the remaining samples were obtained from borings 210 and 209 at 10-ft intervals between double-inflatable packers from artesian flow through a 3/4-in. discharge pipe. At each sample interval, the water flowed a minimum of 20 minutes before a sample was taken.

Selected ground water samples were tested to determine pH, sulfate content, and chloride content. These tests were performed by Mr. Bernard Erlin, Materials and Concrete Consultant. The results of chemical analyses of ground water samples are shown in Table 2.5-16. All of the ground water tested had a relatively high sulfate content, in the range of 1168 to 1865 ppm. The depth at which ground water samples were obtained varied from the rock surface to more than 200 ft below the rock surface. No marked variation of sulfate content with depth was observed.

The chloride content of the ground water, as sampled, ranged from 21 to 1164 ppm. The random and occasional high chloride contents measured were affected by boring operations where salt was used as an additive to the boring fluid. Salt was used with the boring fluid in borings 209 and 210 and in zones of close fractures; this would have affected the chloride content of ground water sampled from adjacent borings. Based on the results of measured chloride content of samples that should not have been affected by salt in the boring fluid, the natural ground water at the site appears to have a chloride content of less than 100 ppm.

The hydrogen ion concentration (pH) of the ground water ranged from 7.3 to 8.1; thus, the ground water is not acidic.

Although the ground water was not tested for the presence of free carbon dioxide, it can reasonably be assumed that the water has been saturated with calcium carbonate by its passage through limestone and dolomitic bedrock.

2.5.4.7. Response of Soil and Rock To Dynamic Loading

Response spectra for the SSE and the OBE are presented in Figures 2.5-67 and 2.5-68 respectively.

The SSE (originally designated design-basis earthquake or DBE on the project) was anchored at the zero period acceleration level previously described and configured to match the shape of existing spectra for similar site conditions. At the time the facility design bases were established, spectra from El Centro 1940, Olympia 1949, El Centro 1934, Helena 1935, and Taft 1952 were used in developing envelope spectra for design bases purposes.

The OBE was similarly shaped but anchored at a zero period acceleration approximately half the SSE. In the decade since the Fermi design bases were established, more conservative assumptions have been made regarding the shape of facility site response spectra in intermediate frequency ranges. For this reason, the Fermi project developed a site-specific earthquake response spectrum, incorporating all potential conservatisms, and reevaluated those items in the facility necessary for shutdown with a loss of offsite power, to ensure the

acceptability of the plant with respect to site-specific earthquake excitation. These activities reaffirmed the Fermi 2 seismic design adequacy.

Soil structure interaction phenomena were evaluated at the Fermi site, and found to be negligible. Category I structures at Fermi 2 are founded in bedrock. A study completed for the Fermi 2 structures founded on rock showed that it can be safely assumed in accordance with existing studies and the unique finite element analysis undertaken for Fermi, that the Fermi 2 foundation behaves as a rigid medium, and that soil structure interaction effects are negligible. Therefore, the site earthquake response spectra developed for the bedrock represent the base excitation to be experienced by facility Category I structures.

Category I buried piping and electrical ducting runs between Category I structures at the Fermi site. These buried pipes and ducts have been subjected to a rigorous dynamic analysis including the effects of interaction with the supporting foundation material. Flexibility has been provided at all building and manhole intersection points to minimize potential concrete strains. The design integrity of these buried components is proven by evaluation of anticipated earthquake wave propagation phenomena.

The response spectra indicate the estimated response of a structure subjected to earthquake ground motion. The spectra are presented over a range of frequencies corresponding to the natural frequencies of the various structural elements. The spectra represent the maximum amplitude of motion in the various elements of the structure for typical degrees of damping. Response spectra are also discussed in Section 3.7.

2.5.4.8. Liquefaction Potential

All Category I structures are supported within the Bass Islands dolomite, which is not susceptible to liquefaction.

2.5.4.9. Earthquake Design Basis

The earthquake design basis is presented in Subsection 2.5.2.

2.5.4.10. Static Analyses

The strength of the foundation rock was evaluated in the laboratory by means of unconfined compression tests (Subsection 2.5.1.2.10). Considering these values to be appropriate for rock with an RQD of 100, a reduction factor was selected based on an assessment of the measured RQD values, information on vug volume and size, fracture orientation and spacing, and presence of clay and shale seams (Subsection 2.5.1.2.2.2). On this basis, the ultimate bearing capacity of the rock mass in the plant and RHR complex is considered to be on the order of 300,000 lb/ft^2. Using a factor of safety of 12, the recommended design bearing capacity is 25,000 lb/ft^2. However, no credit was taken for a possible increase in the recommended bearing capacity by rock grouting.

Settlement was computed using the elastic moduli information with modifications based on experience, RQD, vugs, discontinuities, and clay seams to produce conservative deformation moduli appropriate for the in situ rock. The total settlement of the RHR complex is estimated to be on the order of 0.25 in. for an assumed applied pressure of 3000 lb/ft^2. The

total settlement of the reactor /auxiliary building is conservatively estimated to be on the order of 0.3 to 0.5 in. for an assumed applied pressure of 25,000 lb/ft^2.

Computed lateral pressures are presented in Table 2.5-17. In computing lateral pressures appropriate for the compacted rock fill, it was necessary to estimate the probable angle of internal friction of this material. Based on observation of the material placed in the field and on research of available published data, the angle of internal friction was assumed to be 40°.

All static lateral pressure data presented in Table 2.5-17 are expressed as equivalent fluid pressures. For rigid walls, the tabulated values of lateral pressures are derived for the case of earth pressure "at rest." For cantilever walls, the tabulated values are derived for the case of "active" earth pressure.

Dynamic lateral pressure increments due to rock fill were determined using methods described in Reference 47. The dynamic increments of lateral pressure on the walls of the substructures due to ground water were obtained using Westergard's Theory (Reference 48), modified by Matuo and Ohara (Reference 49). These lateral pressure increments for the RHR complex and reactor/auxiliary building are provided in Figures 3.8-48 and 3.8-49, respectively.

Static pressures imposed by rock on rigid or cantilever walls above the ground water level will be negligible. The lateral pressure in rock cuts below the water table will be limited to hydrostatic water pressure.

2.5.4.11. Criteria and Design Methods

2.5.4.11.1. Foundations

The criteria for foundation support are based on the properties of the underlying materials (Subsection 2.5.4.2) and soil and rock characteristics (Subsection 2.5.4.4).

The ultimate bearing capacity of the rock mass in the plant area is estimated to be on the order of 300,000 lb/ft^2 (Subsection 2.5.4.10). Assuming a combined static and dynamic maximum loading as high as 25,000 lb/ft^2, the factor of safety against further foundation failure could exceed 12. Considering the rock to be strengthened by the grouting operations, the factor of safety is considerably in excess of 12. The average foundation load data for Category I and other structures are given in Table 2.5-18. The average foundation loads are considerably less than the assumed 25,000 lb/ft^2; therefore, the factor of safety will be larger than 12.

The criteria for seismic design are presented in Subsections 2.5.2.10 and 2.5.2.11. Seismic design methods are presented in Section 3.7.

2.5.4.11.2. Cement

In consideration of the high sulfate content of the natural ground water, sulfate-resistant cement was used for all cement grout and subsurface concrete that will be in contact with the ground water. Type V portland cement conforming to the requirements of ASTM Designation C150-68 was used. In concrete work above Elevation 573.0 ft, Type II portland cement conforming to the requirements of ASTM Designation C150-68 was used. As stated in Subsection 2.5.1.2.7, CSA A5-1971 cement was also used.

The use of calcium chloride or other chlorides as admixtures incorporated into concrete or grout mixtures was prohibited as such admixtures reduce the resistance of the concrete or grout to sulfate attack.

2.5.4.12. Techniques To Improve Subsurface Conditions

2.5.4.12.1. Grouting - Reactor/Auxiliary Building

Rock strata below the foundation levels of the Category I structures were pressure grouted. It ensured that no continuous open zones existed across the excavation in the bedrock. The complete grouting program for the reactor/auxiliary building was successfully carried out (References 50, 51, and 52).

The sequence of grouting operations for the reactor/auxiliary building consisted of drilling, washing, pressure testing, and grouting each grout hole. The elevations of the bases of grout holes were selected for the reactor/auxiliary building at elevations of 483 and 499 ft, respectively. These elevations were chosen on careful study of RQD, core recovery, and fracture data, modified after visual inspection of the rock core itself. Since the in situ rock was judged to be sufficiently sound to support the vertical loads and grouting was performed only to provide a more homogeneous rock mass beneath the structures, it was judged that grouting into the underlying Salina Group would have no effect on foundation stability. Grouting was performed in two stages, herein referred to as first and second zones, extending to depths of 6 and 50 ft below the rock surface, respectively. Initial or primary holes within each zone were spaced 30 ft on centers, and final closure was achieved by subsequently grouting all intermediate holes (secondary, tertiary, and quaternary holes). The locations of all holes are presented in Figures 2.5-69 and 2.5-70.

During grouting operations, two additional grout holes were drilled (Nos. 75A and 76A). Hole 75A was drilled to replace hole 75, which was abandoned when a drill bit was lodged in the hole. Hole 76A was drilled because of the low grout take (1.5 ft^3) in hole 77. The relatively low grout take in hole 76A indicated that intermediate holes were probably not necessary when low grout takes are recorded.

All grout holes were drilled with percussion drilling equipment, and any anomalies in the general rate of penetration of drilling were noted. On some holes, detailed logs of rate of penetration were recorded. These records assisted in delineating the extent of rock fracturing and thus assisted the planning of grout mixes. In general, the rate of penetration of rock varied between 20 and 50 sec/ft. Very few voids were encountered; the largest was a 20-in. void observed in hole 67. All grout holes penetrated to an elevation of 515 ft, with the exception of holes 51 and 27, which extended to 518 and 526 ft, respectively. These two holes were terminated short because of drilling difficulties.

Subsequent to drilling operations, holes were washed and pressure tested. On many holes, the drilling operations combined with a relatively large flow of ground water provided clean holes. Consequently, no additional washing was required. Each hole was pressure tested at a selected pressure and the steady water take was recorded. The results of pressure testing were used in determining the initial grout mixes for each particular hole.

Grout mixes injected into the grout holes all contained a 2:1 ratio of cement to flyash. The ratio of water to cement plus flyash varied from 3:1 to slightly less than 1:1. For holes with

high grout takes, final grout mixes included sand, which was added to give a sand-to-cement ratio of 1:1 or 1.5:1. All holes were pressure grouted in one stage. The grouting of each hole was started with a water-to-cement plus flyash ratio of 3:1 or 2:1. If the pressure did not increase after approximately 10 ft^3 of grout had been pumped, then the mix was thickened initially by decreasing the water-to-cement ratio and then further, if necessary, by adding sand to the mix. All holes were grouted to refusal. Individual grout takes for various mixes are summarized in Table 2.5-19.

A total of 1644 ft^3 of pressure grout was injected into the grout holes. An additional 72.5 ft^3 of grout was used to backfill the upper portion of the holes above the packer. Table 2.5-20 summarizes the grout take for each zone. Detailed descriptions of the foundation rock encountered in five exploratory borings, drilled following completion of the grouting program, are presented in Figures 2.5-71 through 2.5-75. Grout encountered in rock cores is noted in the logs of borings. Only one void of 0.3 ft was encountered in the post-grout exploratory boring in boring 216. Since boring 216 was drilled within 5 ft of a secondary grout hole and the void contained no grout, it was not an interconnected void, but an isolated feature. Upon completion, all five of the exploratory borings were tremie grouted.

Subsequent to grouting operations, a complete rock subgrade inspection of the reactor/auxiliary building was carried out; the results of this inspection are summarized in Figure 2.5-76.

2.5.4.12.2. Grouting - Residual Heat Removal Complex

The sequence of grouting operations (References 53 and 54) for the RHR complex consisted of drilling, washing, and grouting each grout hole. The elevation of the bases of the holes was selected at 530 ft. Grouting was performed in two zones extending to depths of 6 and 20 ft below a concrete leveling mat placed over the original rock surface at Elevation 550 ft. Initial or primary holes within each zone were spaced 30 ft on centers and final closure was achieved by subsequently grouting all intermediate holes (secondary, tertiary, and a few quaternary holes). Figures 2.5-77 through 2.5-81 show locations of all holes, as well as amounts of grout taken.

Prior to drilling and grouting operations, eight exploratory holes were core drilled to depths of 20 ft, and then washed and pressure tested. The logs of these borings are shown in Figures 2.5-82 through 2.5-85. Each interval was tested at a selected pressure and the steady water take was recorded.

All grout holes were drilled with percussion drilling equipment and then washed prior to grouting. Grout mixes injected into the grout holes contained a 1:1 to 1.5:1 ratio of cement to flyash. The ratio of water to cement plus flyash varied from 3:1 to approximately 1:1. The grouting of each hole was generally started with a water-to-cement plus flyash ratio of 3:1 and if the pressure did not increase after approximately 10 minutes, the mix was thickened by decreasing the water-to-cement ratio. All holes were grouted to refusal.

Table B1, Appendix 2B, summarizes the grout take for each zone. Detailed descriptions of the foundation rock encountered in eight exploratory borings drilled following completion of the grouting program are presented in Figures 2.5-86 through 2.5-89, and water-pressure test results are shown in Table B2, Appendix 2B.

Subsequent to cleaning the exposed rock surface, and prior to placement of the concrete mat, a complete rock subgrade inspection was carried out. A map summarizing the results of this inspection is shown in Figure 2.5-90. In addition, photographs were taken completely covering the side walls of the excavation and are available for inspection.

A detailed report on the results of the foundation treatment is found in Appendix 2B.

2.5.4.12.3. Effectiveness of Grouting Program

The grouting program was intended to seal cracks in the foundation bedrock that may have been horizontally continuous. As part of the preliminary explorations and later the grouting program, observations were made during drilling with respect to water losses and dropping of drill rods. It was observed that water losses were generally not great and that there were no instances of drill rod drop. Based on these observations, no areas of major or continuous solution activity were detected. However, the core recovered did show vugs, indicating that minor solution activity was present. To ensure that no continuous horizontal zones could be present below Category I structures, pressure grouting was undertaken. The grouting program has the further benefit of enhancing the bearing capacity of the rock.

The grouting program consisted of drilling primary, secondary, and, where necessary, tertiary grout holes until the requirements for discontinuing grouting were achieved. Subsequent to grouting, a number of holes were drilled to ascertain the effectiveness of the grouting program. The borings drilled after grouting generally produced the same results as the exploratory holes prior to grouting. That is, the core recovery and RQD showed no appreciable difference. Furthermore, the postgrouting borings showed very little evidence of grout in the core or drill water.

The lack of grout in postgrouting borings is attributed to the nonexistence of open or continuous solutioning in the bedrock. The low grout takes during consolidation grouting and the lack of grout in postgrouting borings provide evidence of the noncontinuity of any open features. In addition, the lack of both drill rod drops and water losses in postgrouting borings further indicates that no open channels exist in the bedrock foundation.

2.5.4.12.4. Base Slab Construction

The reactor/auxiliary building base slab is a 4-ft-thick reinforced-concrete slab consisting of 4000 psi concrete at 28 days with ASTM A-615 grade 60 reinforcing steel. The slab is supported by a leveling slab also constructed of 4000 psi concrete that is in turn supported by pressure-grouted competent bedrock. Shortly after placement of the base slab, radial superficial cracks appeared. A report covering the investigation and treatment of these cracks is documented in Reference 55.

All possibilities that may have caused the cracking of the slab were considered. However, after a review of all of the postulated potential causes for the surface hairline cracks, and a detailed observation and mapping of the location, arrangement, depth, and thickness of the cracks themselves, it is concluded that the cracks were most probably caused by the restraint of the slab at its perimeter during temperature fluctuations and by shrinkage strains that developed during the curing of the thick and heavily reinforced concrete slab. The cracks were very thin, and most of them did not penetrate the full depth of the slab. The lack of differential vertical displacement on both sides of a crack indicated that vertical shear planes

resulting from upheaval or settlement of the underlying concrete level slab or grouted bedrock had not occurred. The radial symmetry of the cracks further supported the belief that vertical displacement, local, random, or general in orientation, did not occur. As stated on page A7 of the D&M report "Results of Rock Foundation Treatment," dated January 12, 1975 (Reference 23), "No zones of excessive fracturing or highly vugged material exist in horizontal layers across the site; localized openings in the foundation rock have been adequately treated; and the near surface fractures have been filled." Part B of the same referenced report outlines the careful attention placed on preparing the rock surface to receive the 2- to 4-ft-thick level mat and then the 4-ft-thick structural slab that later developed thin radial superficial cracks.

After reviewing these data, reviewing the conclusions presented by consultants, and observing and investigating the extent and orientation of the cracking, it is concluded that the source of the cracking is not the solutioning or jointing in the bedrock. The placement of crushed-rock fill outside the subbasement walls and at an elevation higher than the slab was not related to the cracking. The schedule for fill placement was done one section at a time and generally followed the initial observation of radial cracking.

2.5.5. Slope Stability

During the excavation for the reactor/auxiliary building and RHR complex, which included blasting, there were no instances of instability of the excavation slopes and therefore no need for stabilization measures.

There are no excavation or natural slopes whose failure could adversely affect the safe operation of the plant. However, a shore barrier was erected at the east end of the plant bordering on Lake Erie. For a discussion of the shore barrier, see Subsections 2.4.5 and 3.4.4.5.

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2.5 GEOLOGY AND SEISMOLOGY

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TABLE 2.5-1 SUMMARY OF MAJOR FOLDS IN REGION OF FERMI 2

Name	Identification[a]	Major Movement
Kankakee Arch	S, B, G	Ordovician or Devonian to Late Mississippian
Michigan Basin	S, B, G	Early to Late Paleozoic
Appalachian Basin	S, B, G	Early to Late Paleozoic
Valley & Ridge	S, B, G	Late Paleozoic
Cincinnati Arch	B	Ordovician to Post - Pennsylvanian
Findlay Arch	B	Cambrian to Devonian
Algonquin Arch	B	Cambrian to Devonian
Waverly Arch	B	Early Ordovician
Howell Anticline	B, G	Ordovician through Mississippian
Lucas Monocline	B, G	Ordovician through Mississippian
Freedom Anticline	B, G	Ordovician through Mississippian
Chatham Sag	B	Late Silurian and Post-Silurian
Washtenaw Anticlinorium	B	Middle Ordovician through Late Mississippian
Logansport Sag	B	Ordovician or Devonian to Late Mississippian
Francisville Arch	B	Mississippian

[a] S = Surface.
B = Borehole.
G = Geophysical.

TABLE 2.5-2 SUMMARY OF MAJOR FAULTS

Fault Name	Identification[a]	Displacement	Last Movement
Bowling Green Fault	S, B, G	West side down	Post-Middle Ordovician to Pre-Devonian
Electric Fault	B	South side down	Post-Silurian
Tekonsha Trend	B, G	(Fracture zone)	Post-Ordovician
Rough Creek- Kentucky River Fault System	G S, B, G	North side down (Except Kentucky River Fault, south side down)	Cretaceous (Rough Creek) Post-Ordovician to Pre-Mississippian (Kentucky River)
Keweenawan-Lake Owen Fault System	S, B, G	South side down	Keweenawan and Post - Keweenawan
Albion-Scipio Trend	B, G	(Fracture zone)	Post-Middle Ordovician to Pre-Pennsylvanian
Royal Center Fault	B	Southeast side down	Post-Devonian
Fortville Fault	B	Southeast side down	Post-Devonian

[a] S = Surface.
B = Borehole.
G = Geophysical.

TABLE 2.5-3 OBSERVED WATER FLOW AND WATER LEVEL DATA

Boring Number	Surface Elevation	Boring Bottom Elevation	Artesian Flow From Elevation 550-510 (gpm)	Artesian Flow From Bottom of Boring (gpm)	Piezometric Surface 12-19-69 (lake level at Fermi 1, 573.0)	Piezometric Surface 12-19-69 (lake level at Fermi 1, 572.8)
201	565.0	451.4	5	20	569.5	570.0
202	564.3	438.0	5	36	568.4	569.9
203	565.4	448.9	3	22	569.8	569.8
204	564.9	452.4	3	10	568.9	569.7
205	565.8	448.6	3	50	570.0	569.9
206	567.2	455.9	0	3	570.1	569.7
207	566.8	454.8	5	17	569.9	569.6
208	566.9	454.2	0.5	0.5	569.9	569.9
209	567.0	253.1	2	60	571.9	571.1
210	566.6	451.6	0.5	20	569.9	569.8
211	567.4	452.4	0	10	570.2	569.8
212	567.2	410.4	4	43	569.4	569.7
213	568.0	452.5	0	0	570.0	569.8
214	565.6	453.2	5	5	569.0	569.6

TABLE 2.5-4 AMBIENT VIBRATION MEASUREMENTS

Ambient Station Number	Depth of Bedrock (ft)	Predominant Period of Ground Motion (sec)
1	2	0.7 to 1.1
2	20	0.10

TABLE 2.5-5 ROCK COMPRESSION TEST RESULTS FERMI 2 REACTOR/AUXILIARY BUILDING SITE

Boring Number	Depth Below Original Surface (ft)	Elevation (ft)	Formation[a]	Density (lb/ft^3)	Ultimate Compressive Strength (lb/ft^2)	Modulus of Elasticity (lb/ft^2)
20	27.0	546.7	BI	154	2.26×10^6	9.0×10^8
32A	52.0	527.6	BI	145	1.39×10^6	6.28×10^8
28	106.0	466.5	S	162	1.30×10^6	3.75×10^8
4	58.0	514.5	BI	138	1.12×10^6	6.51×10^8
201	50.7	514.3	BI	151	1.29×10^6	5.75×10^8
201	73.2	491.8	BI	169	1.62×10^6	5.04×10^8
202	49.2	515.1	BI	146	1.41×10^6	3.89×10^8
203	58.2	507.2	BI	154	1.31×10^6	3.17×10^8
208	16.2	550.7	BI	145	0.62×10^6	3.29×10^8
210	20.6	546.0	BI	153	0.99×10^6	2.2×10^8
211	18.4	549.0	BI	170	2.70×10^6	1.8×10^8
211	35.1	532.3	BI	146	0.85×10^6	2.5×10^8
213	24.6	543.4	BI	149	0.82×10^6	7.2×10^8

[a] BI = Bass Islands Group.
S = Salina Group.

TABLE 2.5-6 ROCK COMPRESSION TEST RESULTS - FERMI 2 RHR COMPLEX

Boring Number	Depth (ft)	Formation[a]	Ultimate Compressive Strength (lb/ft^2)
RHR-2	39.1	BI	1.31×10^6
RHR-3	29.2	BI	1.18×10^6
RHR-4	31.0	BI	1.46×10^6
RHR-5	40.5	BI	1.20×10^6
RHR-6	29.2	BI	1.49×10^6
RHR-7	33.9	BI	1.06×10^6
RHR-8	36.3	BI	1.09×10^6

[a] BI = Bass Islands Group.

TABLE 2.5-7 SHOCKSCOPE TEST RESULTS

Boring Number	Depth (ft)	Formation[a]	Velocity of Compressional Wave Propagation (ft/sec)
4	28.5	BI	12,500
4	36	BI	10,500
4	42	BI	10,000
4	58.5	BI	11,000
18	29	BI	14,000
18	40	BI	14,500
79	30	BI	11,500
79	97	BI	12,500
79	240	S	14,500

[a] BI = Bass Islands Group.
S = Salina Group.

TABLE 2.5-8 RESONANT COLUMN TEST RESULTS

Boring Number	Depth (ft)	Formation[a]	Rock Type	Shear Modulus (lb/ft^2)
32A	25	BI	Dolomite	150 x 10^6
25	96	S	Calcareous Shale	30 x 10^6

[a] BI = Bass Islands Group.
S = Salina Group.

TABLE 2.5-9 STATIC AND DYNAMIC SOIL AND ROCK PROPERTIES - REACTOR/AUXILIARY BUILDING

Property	Crushed-Rock Fill	In Situ Glacial Till	Bass Islands Bedrock
Density (lb/ft^3):			
Dry density	139 + 4%	125 + 4%	150 + 10%
Wet density	144 + 5%	140 + 5%	--
Submerged density	90 + 3%	80 + 3%	110 + 10%
Wave velocities (ft/sec):			
Compression wave	2,500 + 15%	7,700 + 7%	13,000 + 10%
Shear wave	900 + 25%	2,200 + 5%	7,600 + 15%
Poisson's Ratio:			
Static or dynamic	0.4 + 10%	0.45 + 10%	0.24 + 10%
Modulus of elasticity (lb/ft^2):			
Static	1.2×10^6 + 25%	0.5×10^6 + 20%	120×10^6 + 50%
Dynamic	4.0×10^6 + 30%	1.2×10^6+ 30%	180×10^6 + 50%
Increase per foot of depth	0.48×10^6 + 25%	0.48×10^6 + 20%	0
Shear modulus (lb/ft^2):			
Dynamic	1.4×10^6 + 30%	0.4×10^6 + 30%	72×10^6 + 50%
Increase per foot of depth	0.17×10^6 + 25%	0.17×10^6 + 20%	0
Damping values (percent of critical):			
Within earthquake levels	7% to 10%	5% to 8%	1%

TABLE 2.5-10 STATIC AND DYNAMIC SOIL AND ROCK PROPERTIES - RHR COMPLEX

	Crushed-Rock Fill	Glacial Till[a]	Bass Islands Bedrock
Density (lb/ft^3)			
Dry density	139 + 4%	124 + 2%	150 + 10%
Wet density	144 + 5%	139 + 2%	
Submerged density	90 + 3%	77 + 2%	110 + 10%
Wave velocities (ft/sec)			
Compression wave	2500 + 15%	7700 + 7%	13000 + 10%
Shear wave	900 + 25%	2200 + 15%	7600 + 15%
Poisson's Ratio			
Static or dynamic	0.4 + 10%	0.45 + 10%	0.24 + 10%
Static modulus of elasticity (lb/ft^2)	1.2×10^6 + 25%	4.0×10^5 + 30%	120×10^6 + 50%
Dynamic modulus of elasticity (lb/ft^2)			
Single 1.0%		1.2×10^5 + 50%	
Amplitude shear 0.01%	$4.0 \times 10^6 \pm 30\%$	$4 \times 10^5 \pm 50\%$	$180 \times 10^6 \pm 50\%$
Strain 0.01%		$13 \times 10^5 \pm 50\%$	
Static modulus of rigidity (lb/ft^2)	4.0×10^5 + 30%	1.4×10^5 + 30%	48×10^6 + 50%
Dynamic modulus of rigidity (lb/ft^2)			
Single 1.0%		0.7×10^5 + 50%	
Amplitude shear 0.1%	1.4×10^6 + 30%	2.5×10^5 + 50%	72×10^6 + 50%
Strain 0.01%		7.5×10^5 + 50%	
Damping values (percent of critical damping)			
Single 1.0		19.0	
Amplitude shear 0.1	7 to 10	17.0	1
Strain 0.01		9.0	
Modulus of subgrade reaction (lb/ft^3)	1.0×10^6 + 25%		6.5×10^5 + 50%

[a] Values reported were determined specifically for in situ conditions. However, the glacial till, compacted to at least 95 percent of maximum dry density, is expected to exhibit static and dynamic properties that fall within the ranges of variation reported in this table.

TABLE 2.5-11 MODIFIED MERCALLI INTENSITY (DAMAGE) SCALE OF 1931 (Abridged)

I. Not felt except by a very few under especially favorable circumstances (I, Rossi-Forel Scale)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing (I to II, Rossi-Forel Scale)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated (III, Rossi-Forel Scale)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably (IV to V, Rossi-Forel Scale)

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop (V to VI, Rossi-Forel Scale)

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight (VI to VII, Rossi-Forel Scale)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars (VII, Rossi-Forel Scale)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed (VII+ to IX-, Rossi-Forel Scale)

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken (IX+, Rossi-Forel Scale)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks (X, Rossi-Forel Scale)

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly

XII. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown upward into the air

TABLE 2.5-12 DISTANT EARTHQUAKE EPICENTERS (200 OR MORE MILES FROM THE SITE) (1800-1986)

Date	Time	Maximum Intensity	Location	North Latitude	West Longitude	Affected Area (square miles)	Approx. Distance From Site (miles)	Estimated Intensity at Site
1811 Dec 16	0200	XII	New Madrid, Missouri	36.6	89.6	2,000,000	530	III - IV
1812 Jan 23	-	XII	New Madrid, Missouri	36.6	89.6	2,000,000	530	III - IV
1812 Feb 7	-	XII	New Madrid, Missouri	36.6	89.6	2,000,000	530	III - IV
1870 Oct 20	1125	IX	Montreal-Quebec, Canada	47.4	70.5	1,000,000	730	IV
1886 Aug 31	2159	X	Charleston, South Carolina	32.9	80.0	2,000,000	650	IV
1895 Oct 31	0508	VIII	Charleston, Missouri	37.0	89.4	1,000,000	460	III
1905 Mar 13	1030	V	Menominee	45.0	87.7	Local	300	-
1909 Jan 22	2115	V	Houghton, Michigan	47.2	88.6	Local	435	0
1909 May 26	0842	VII	Beloit, Wisconsin	42.5	89.0	500,000	290	0
1909 Sep 27	0345	VII	Indiana	39.0	87.7	30,000	310	0
1925 Feb 28	0919	IX	St. Lawrence River	47.6	70.1	1,000,000	780	II
1926 Nov 5	0953	VII	Southeast Ohio	39.1	82.1	350	205	0
1929 Aug 12	0625	IX	Attica, New York	42.9	78.3	100,000	270	II
1935 Nov 1	0104	VI	Timiskaming, Ontario	46.8	79.1	1,000,000	340	III - IV
1944 Sep 5	0039	VIII	Cornwall-Massena	44.9	74.5	175,000	480	II
1963 Feb 27	0600	IV	Grimsby, Ontario	43.2	79.5	-	220	0
1968 Nov 9	1203	VIII	Southeast Illinois	38.5	88.0	1,000,000	350	II
1975 Feb 16	2321	V	Near Wellston, Ohio	39.0	82.4	Local	215	0
1980 Jul 27	1852	VII	Sharpsburg, Kentucky	37.8	83.7	260,000	300	II
1984 Jul 6	1724	V	Near Sudbury, Ontario	46.5	81.2	Local	350	0
1984 Jul 28	2339	V	Near Clay City, Indiana	39.2	87.1	Local	285	0
1984 Aug 29	0650	V	Near Clay City, Indiana	39.4	87.2	Local	285	0
1985 Sep 9	2206	V	Near Edgebrook, Illinois	41.9	88.0	Local	250	0

TABLE 2.5-13 EARTHQUAKE EPICENTERS WITHIN 200 MILES OF THE SITE[a] (1776-1986)

Date	Time	Maximum Intensity	Location	North Latitude	West Longitude	Affected Area (square miles)	Approx. Distance From Site (miles)	Estimated Intensity at Site
1776 Summer	0800	VI	Near Muskingum River	-	-	-	170	-
1833 Feb 4	-	VI	Near Kalamazoo, Michigan	42.3	85.6	-	125	-
1857 Mar 1	-	V	Near Eastlake, Ohio	41.7	81.2	-	110	-
1872 Feb 6	0800	V	Wenona, Michigan	43.5	83.5	Local	110	0
1875 Jun 18	0743	VII	Urbana and Sidney, Ohio	40.2	84.0	40,000	130	-
1877 Aug 17	1050	V	SE Michigan near Detroit	42.3	83.3	200	25	0
1882 Feb 9	1500	V	Swandors and Dodkins near Anna, Ohio	40.5	84.0	Local	110	0
1883 Feb 4	0500	VI	Indiana and Michigan, felt at Kalamazoo	42.3	85.6	8,000	125	-
1884 Sep 19	1414	VI	Near Lima, Ohio	40.7	84.1	125,000	95	IV
1900 Apr 9	1400	VI	Near Brunswick, Ohio	41.4	81.8	-	95	III
1901 May 17	0100	VI	Southeast Ohio	39.3	82.5	7,000	190	0
1902 Jun 14	0700	V	Near Dover, Ohio	40.3	81.4	-	150	0
1906 Apr 23	0712	V	Near Ada, Ohio	40.7	83.6	-	90	II
1906 Jun 27	1610	V	Fairport, Ohio	41.4	81.6	400	95	0
1925 Mar 27	2306	V	Southwestern Ohio	-	-	-	170	-
1926 Oct 28	0240	III	East Toledo, Ohio	41.6	83.6	Local	30	0
	0500	IV	Toledo, Ohio	41.6	83.6	Local	30	0
1927 Oct 29	-	V	Near Alliance, Ohio	40.9	81.2	-	125	-
1928 Sep 9	1500	V	Lorain and Cleveland, Ohio	41.5	82.0	1,500	70	0
1929 Mar 8	0406	V	Bellefontaine, Ohio	40.4	84.2	5,000	130	0
1930 Sep 20	1440	VI	Anna, Ohio	40.3	84.3	-	125	0
1930 Sep 30	1440	VII	Anna, Ohio	40.3	84.3	-	130	-
1930 Nov 20	-	III	Near Brighton, Michigan	42.6	83.4	-	45	II
1931 Jun 10	0330	V	Malinta, Ohio	41.6	84.0	-	55	-
1931 Sep 20	1805	VII	Anna, Sidney, Houston, Ohio	40.2	84.3	40,000	130	0
1932 Jan 22	-	V	Near Akron, Ohio	41.1	81.5	-	110	0
1937 Mar 2	0948	VII	Anna, Sidney, Ohio	40.7	84.0	90,000	110	III

TABLE 2.5-13 EARTHQUAKE EPICENTERS WITHIN 200 MILES OF THE SITE[a] (1776-1986)

Date	Time	Maximum Intensity	Location	North Latitude	West Longitude	Affected Area (square miles)	Approx. Distance From Site (miles)	Estimated Intensity at Site
1937 Mar 3	0450	V	Anna, Sidney, Ohio	40.5	84.0	Local	110	0
1937 Mar 9	2445	VIII	Anna, Sidney, Ohio	40.6	84.0	150,000	100	IV
1938 Mar 13	1040	II	Detroit River	42.3	83.1	Local	25	II
1943 Mar 9	2226	V	Lake Erie	42.2	80.9	40,000	120	IV
1947 Aug 9	2047	VI	South-Central Michigan	42.0	85.0	50,000	90	III
1948 Jan 18	Night	III	Toledo, Ohio	41.6	83.6	Local	30	-
1952 Jun 20	0438	VI	Zanesville, Ohio	39.8	82.2	10,000	170	0
1953 Jun 12	2345	IV	Toledo, Ohio	41.6	83.6	Local	30	0
1955 May 26	1309	V	Cleveland, Ohio	41.5	81.7	Local	85	0
1955 Jun 28	2016	V	Cleveland, Ohio	41.5	81.7	Local	85	0
1956 Jan 27	1103	V	West-Central Ohio	40.5	84.0	Local	110	0
1957 Jun 29	0525	V	Southeast of London, Ontario	42.9	81.2	Local	120	0
1958 May 1	1647	V	Cleveland, Ohio	41.3	81.4	Local	110	0
1961 Feb 22	0344	V	Findlay, Ohio	41.2	83.4	Local	55	0
1967 Apr 7	2340	V	Columbus, Ohio	39.6	82.5	3,000	165	0
1968 Oct 31		V	Attica, Michigan	43.0	83.0	Local	80	II
1976 Feb 2	2114	III	Colechester, Ontario	42.0	82.7	Local	25	II
1977 Jun 17	1539	VI	Near Celina, Ohio	40.7	84.6	200	110	II
1980 Aug 20	0934	IV	Near Colechester, Ontario	41.9	83.0	Local	15	III
1986 Jan 31	1646	VI	Near Perry, Ohio	41.7	81.2	-	110	IV
1986 Jul 12	0819	V	St. Mary's Ohio	40.6	84.4	Local	115	0

a. Earthquakes of Intensity V or greater only are tabulated beyond a distance of 50 miles from the site. All known shocks within 50 miles of the site are indicated.

TABLE 2.5-14 RESULTS OF PLATE LOAD TESTS ON FILL AND TILL

Material	Plate Diameter (in.)	Average Movement of Plate For a Contact Stress of 10,000 lb/ft	
		Initial Load Cycle (in.)	Average of Rebound Cycle (in.)
Fill	12	0.035	0.006
	24	0.091	0.027
	30	0.097	0.040
Till	12	0.050	0.040
	24	0.092	0.049
	30	0.101	0.052

TABLE 2.5-15 WATER PRESSURE TEST DATA

Boring Number	Test Section Depth (ft)	Water Pressure (psi)	Period of Steady Flow (minutes)	Water Intake (gpm)	Calculated Permeability (ft/yr)
201	23-1/2 - 33-1/2	25	20	2.5	211
	33 - 43	30	20	8.0	564
	43-1/2 - 53-1/2	45	10	7.0	327
	53 - 64	75	10	6.0	169
	63-1/2 - 73-1/2	70	10	8.0	240
203	15 - 25	13	20	8.5	1380
	21 - 31	17	20	12.4	1540
	30 - 40	30	20	9.0	635
	39 - 49	37	20	24.0	1370
	48 - 58	55	20	10.5	404
	57 - 67	55	20	6.5	250
	66 - 76	55	20	5.5	210
	75 - 85	55	20	23.0	884
	84 - 94	55	20	22.0	845
	93 - 103	55	20	22.0	845
	102 - 112	65	20	19.0	616
209	36 - 46	30	20	11.5	810
	43 - 53	30	20	19.0	1340
	52 - 62	40	5	6.0	316
	61 - 71	40	10	13.0	685
	70 - 80	40	10	13.0	685
	79 - 89	40	10	2.0	105
	88 - 98	40	10	10.0	526
	97 - 107	40	10	3.0	158
	106 - 116	40	20	17.6	930
	115 - 125	40	15	16.6	875

TABLE 2.5-15 WATER PRESSURE TEST DATA

Boring Number	Test Section Depth (ft)	Water Pressure (psi)	Period of Steady Flow (minutes)	Water Intake (gpm)	Calculated Permeability (ft/yr)
	124 - 134	40	15	16.0	845
	133 - 143	40	20	15.0	790
	142 - 152	40	20	9.5	500
210	14 - 24	15	15	15.8	2220
	23 - 33	30	20	15.5	1090
	45 - 55	50	20	11.5	486
	54 - 64	50	20	16.5	697
	63 - 73	50	15	21.0	888
	72 - 82	50	20	21.0	888
	81 - 91	50	20	20.0	845
	90 - 100	50	20	15.0	634

Note: Permeabilities were calculated using the method outlined in Reference 4; i.e., using the formula $K = Cp\ (Q/H)$

where K = permeability in feet per year

Cp = a constant dependent on hole size

Q = flow in gallons per minute

H = applied pressure in feet of water units

TABLE 2.5-16 CHEMICAL ANALYSES OF GROUND WATER

Boring Number	Depth (ft)	Formation[a]	pH	Chloride (C1-, ppm)	Sulfate (SO_4--, ppm)
201	30.0	BI	7.65	33	1685
201	85.0	BI	7.60	34	1747
204	18.0	BI	8.00	43	1661
205	17.4	BI	8.10	45	1865
205	27.4	BI	8.00	43	1733
205	117.0	S	7.30	424	1790
207	19.8	BI	7.40	356	1776
207	20.0	BI	7.70	51	1747
208	27.2	BI	7.90	1164	1168
208	110.0	S	8.10	183	1282
209	92.0-102.0	BI-S	8.10	102	1771
209	97.0-107.0	BI-S	8.05	156	1738
209	102.0-112.0	S	8.00	91	1738
209	132.0-142.0	S	7.80	116	1757
209	147.0-152.0	S	8.10	122	1800
209	151+	S	8.10	115	1757
209	210+	S	7.90	162	1771
210	20.4-30.5	BI	7.60	603	1738
210	30.4-40.5	BI	7.65	547	1728
210	40.4-50.5	BI	8.00	1145	1709
210	50.4-60.5	BI	8.00	362	1742
210	60.4-70.5	BI	8.10	198	1709
210	70.4-80.5	BI	7.70	65	1752
210	80.4-90.5	BI-S	8.00	156	1699
210	90.4-100.0	S	7.50	21	1718
210	67+	BI	7.70	48	1747

[a] BI = Bass Islands Group.
S = Salina Group.

TABLE 2.5-17 LATERAL PRESSURE VALUES[a]

Lateral Pressure (lb/ft^2/ft)	Crushed-Rock Fill	Bass Islands Bedrock
Static-rigid wall above water	96[b]	0
Static-rigid wall submerged	122[b]	63
Static-cantilever wall above water	32[b]	0
Static-cantilever wall submerged	80[b]	63
Dynamic-rigid wall above water	c	-
Dynamic-rigid wall below water	c	-

[a] During the course of safety evaluation review, the NRC requested additional information regarding the technique for the dynamic lateral pressure computation. This information was provided to the NRC as Reference 32.

[b] A factor of safety of 1.5 is applied to these values when the foundation walls are required to perform safety-related functions.

[c] See Figures 3.8-48 and 3.8-49.

TABLE 2.5-18 FOUNDATION DATA

	Approximate Plan Dimensions (ft x ft)	Foundation Elevations[a] (ft)	Approximate Uniform Applied Foundation Load (lb/ft^2)
Category I			
Reactor building	120 x 155	536	7500
Auxiliary building	80 x 155	536	4000 to 5000
RHR Complex	120 x 310	547	4000 to 5000
Other structures			
Turbine house	210 x 375	558	5000
Radwaste building	100 x 190	552	2500

[a] USGS datum.

TABLE 2.5-19 CURTAIN WALL GROUTING SUMMARY OF GROUT TAKES

Hole Number[a]	Grout Take in Cubic Feet[b]				Observed Horizontal Distance of Grout Travel (ft)
	Mix A[c]	Mix B[d]	Mix C[e]	Total	
1	3		10	13	12
2	1.5	10.5		12	
3	6	3		9	12
4	3			3	
5	9			9	
6	6			6	
7		18		18	
8		6		6	
9	6			6	
10	6	9		15	
11	9			9	
12	4.5			4.5	
13	10.5			10.5	
14	1.5			1.5	
15	10.5	6		16.5	
16	3			3	
17	18	3		21	36
18	3			3	
19	6	4.5		10.5	24
20	3	3		6	
21	3	1.5		4.5	
22	12	18		30	12
23	6	10.5		16.5	24
24	10.5	6		16.5	12
25	9	12		21	12
26	9	3		12	
27	12	24		36	24
28	9	9		18	12
29	9	18	10	37	
30	6	15	7.5	28.5	24
31	9	27	10	46	12
32	12	3		15	12
33	9	12		21	12
34	6	12		18	12
35	10.5	21	5	36.5	12

TABLE 2.5-19 CURTAIN WALL GROUTING SUMMARY OF GROUT TAKES

Hole	Grout Take in Cubic Feet[b]				Observed Horizontal Distance of
Number[a]	Mix A[c]	Mix B[d]	Mix C[e]	Total	Grout Travel (ft)
36	1.5			1.5	12
37		18	27	45	12
38		1.5		1.5	
39		21	44	65	24
40	9	24	26	59	24
41	12	18		30	12
42	12	21		33	12
43	7.5	3		10.5	
44	1.5			1.5	
45	12	9		21	
46	12	21		33	12
47	12	3		15	24
48	12	10.5		22.5	12
49	12	12		24	
50	12	18		30	
51	12	30	5	47	12
52	9	10.5		19.5	24
53	6	12		18	12
54	12	27		39	12
55	7.5	3		10.5	
56	1.5			1.5	
57	12	15		27	12
58	9	12		21	12
59	1.5			1.5	
60	10.5	18		28.5	12
61	7.5	18	5	30.5	
62	7.5	15		22.5	
63		9	18	27	24
64	9		21	30	24
65		21	46	67	24
66	15	30	15	60	36
67	24	6		30	12
68	15			15	
69	22.5	3		25.5	
70	19.5			19.5	

TABLE 2.5-19 CURTAIN WALL GROUTING SUMMARY OF GROUT TAKES

Hole Number[a]	Grout Take in Cubic Feet[b] Mix A[c]	Mix B[d]	Mix C[e]	Total	Observed Horizontal Distance of Grout Travel (ft)
71	1.5			1.5	12
72	15	12	10	37	12
73	18	7.5		25.5	24
74	15	9		24	12
75	Abandoned - Driller Lost Drill Bit in Hole				
75A	9	12		21	24
76		12		12	
76A		6		6	
77		1.5		1.5	
78		7.5		7.5	12
79		21		21	24
80		15		15	

[a] All grout holes were brought to refusal with a grout pressure ranging from 8 psi to 20 psi with the exception of holes 2, 3, and 68 in which there was a heavy grout return through the surface of the rock which was highly fractured above packer.

[b] An additional 72-1/2 ft^3 of grout was used for filling inside the casing subsequent to pressure grouting.

[c] Mix A – Water:cement + flyash ratio of 2:1 or greater.

[d] Mix B - Water:cement + flyash ratio of 1.5:1 or less

[e] Mix C - Water:cement + flyash ratio of 1:1 or less plus a water:sand ratio of 1:1.

TABLE 2.5-20 SUMMARY OF GROUTING FIRST ZONE GROUTING

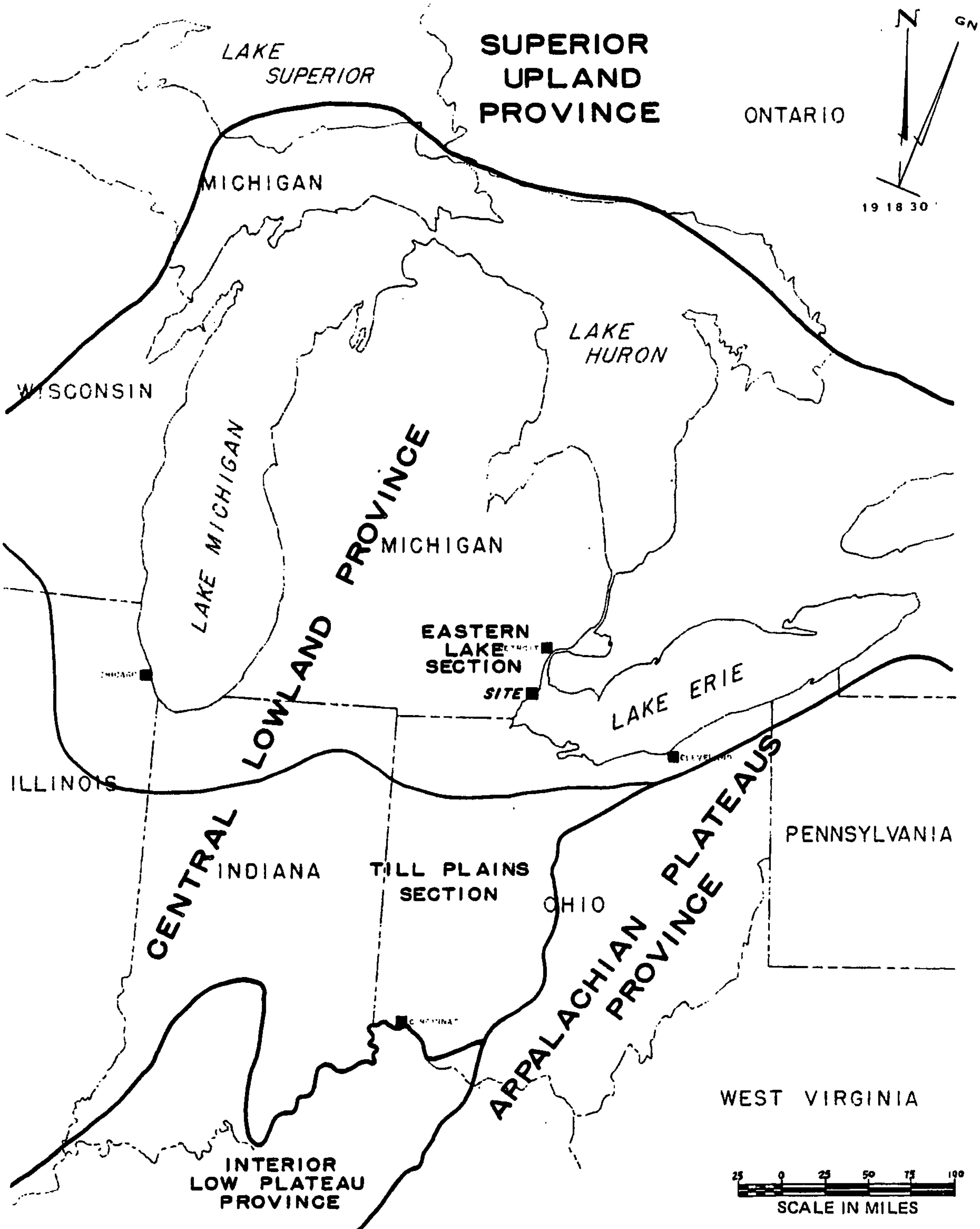
(holes drilled 10 ft into rock)

Holes Drilled	Holes With Take	Percent Holes With Take	Sacks Cement and Flyash	Unit Take (sacks per foot of hole)
Primary	75	87	1629.00	3.17
Secondary	65	75	1066.25	2.08
Tertiary	39	29	174.00	0.21
Quaternary	7	27	109.25	0.84
Total	186	--	2978.00	--
Average		52.75		1.58

SECOND ZONE GROUTING

(holes drilled approximately 50 ft into rock)

Holes Drilled	Holes With Take	Percent Holes With Take	Sacks Cement and Flyash	Unit Take (sacks per foot of hole)
Primary	91	99	1340.25	0.46
Secondary	89	100	652.50	0.31
Tertiary	47	98	357.75	0.18
Quaternary	9	100	106.50	0.27
Total	236	--	2457.00	--
Average		99.22		0.31



REFERENCE:
MODIFIED FROM FENNEMAN, N. 1946; PHYSICAL DIVISIONS OF THE UNITED STATES IN COOPERATION WITH THE PHYSIOGRAPHIC COMMITTEE OF THE U. S. GEOLOGICAL SURVEY.

MODIFIED FROM: BASEMENT ROCK MAP OF THE UNITED STATES, COMPILED BY RICHARD W. BAYLEY, UNITED STATES GEOLOGICAL SURVEY, AND WILLIAM MUEHLBERGER, UNIVERSITY OF TEXAS, 1968.

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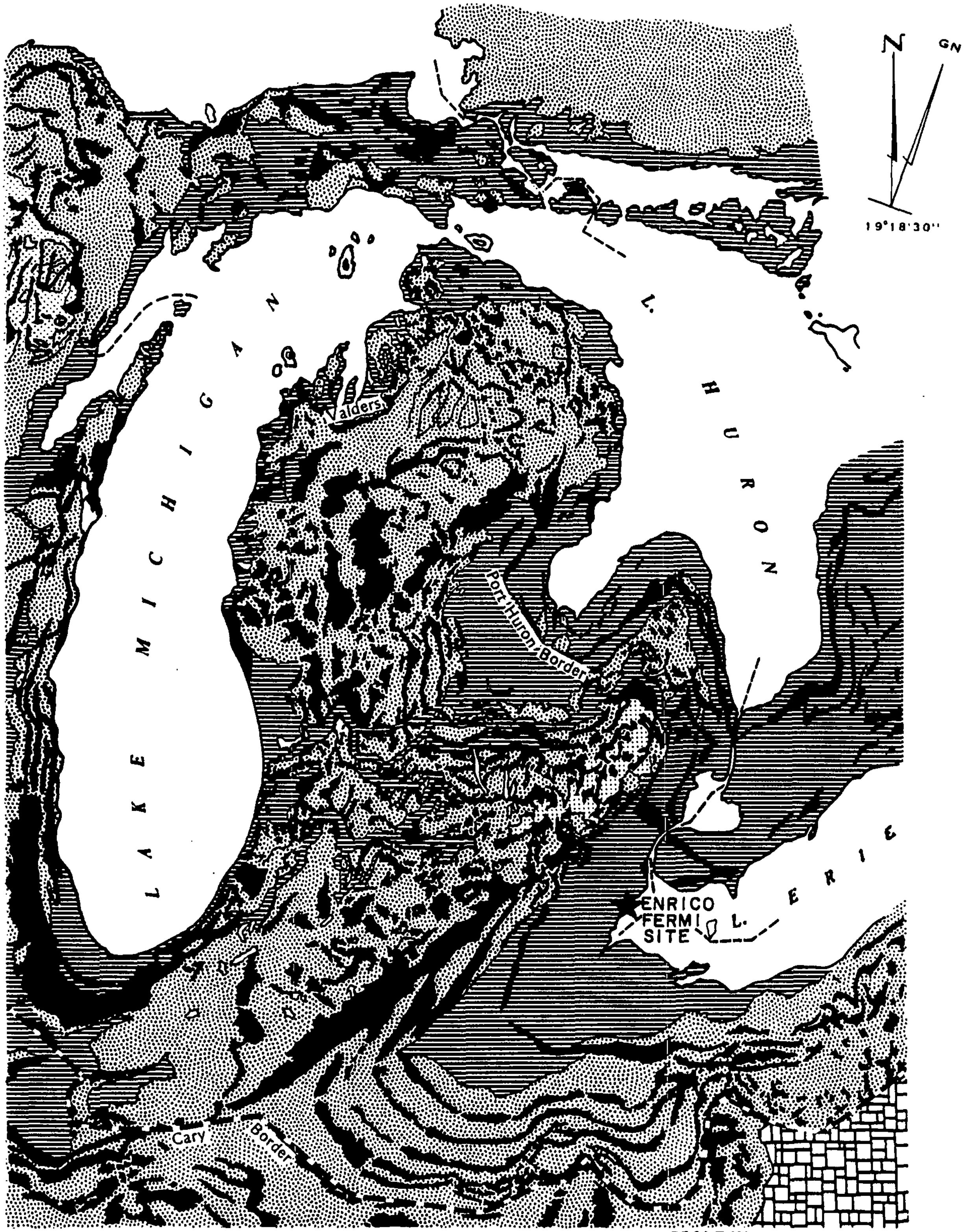
FIGURE 2.5-1

CENTRAL LOWLAND PROVINCE
REGIONAL PHYSIOGRAPHIC MAP



LEGEND:

LAKE SEDIMENTS

WISCONSIN END MORAINES

NO GLACIAL DEPOSITS

GROUND MORAINES AND OUTWASH PLAINS

ICE CONTACT STRATIFIED DRIFT

SCALE IN MILES

50 0 50

REFERENCE:

GEOLOGICAL SOCIETY OF AMERICA 1959, GLACIAL MAP OF THE UNITED STATES EAST OF THE ROCKY MOUNTAINS.

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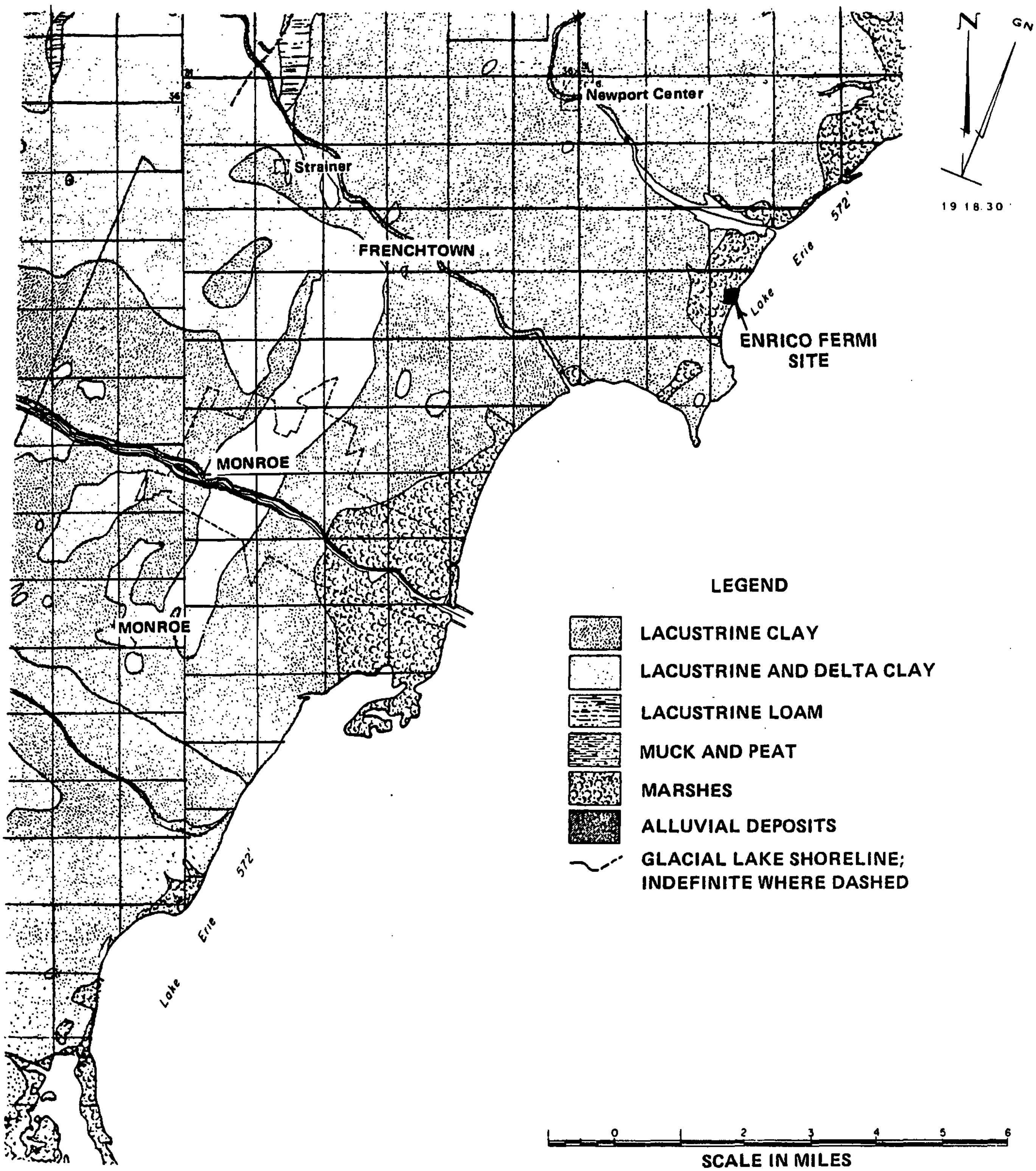
FIGURE 2.5-2

REGIONAL SURFACE GEOLOGICAL MAP



REFERENCE:
MAZOLA, A. J., 1969, GLACIAL DEPOSITS OF MONROE COUNTY, MICHIGAN; FROM REPORT OF INVESTIGATION 13, GEOLOGY FOR ENVIRONMENTAL PLANNING IN MONROE COUNTY, MICHIGAN; GEOLOGICAL SURVEY DIVISION, DEPARTMENT OF NATURAL RESOURCES.

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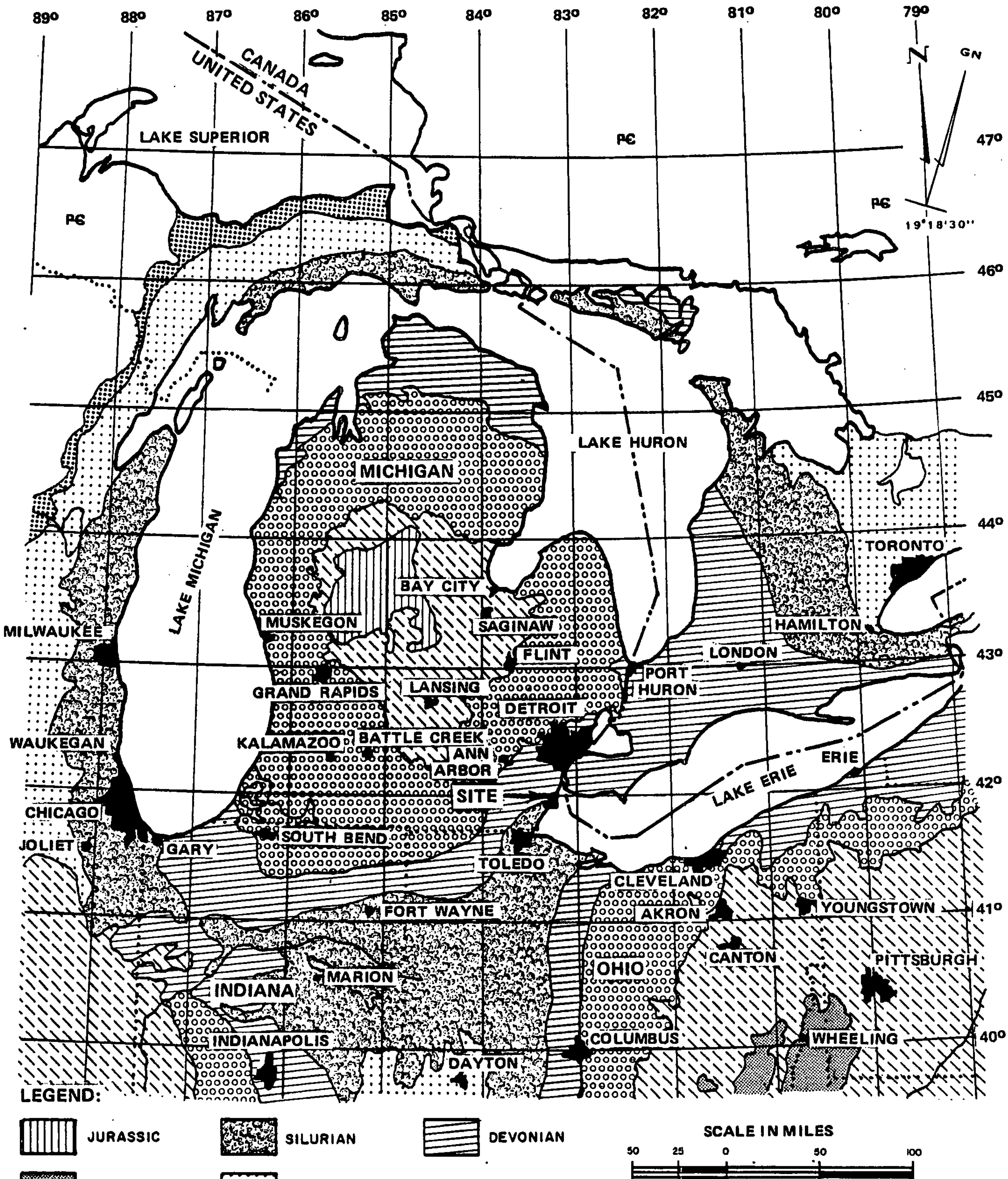
FIGURE 2.5-3

AREA SURFACE GEOLOGICAL MAP



REFERENCE:

THIS MAP WAS PREPARED FROM:
A) "GEOLOGIC MAP OF NORTH AMERICA" BY THE U.S.G.S., 1965
B) "BEDROCK OF MICHIGAN" BY THE MICHIGAN STATE GEOLOGICAL SURVEY, 1968

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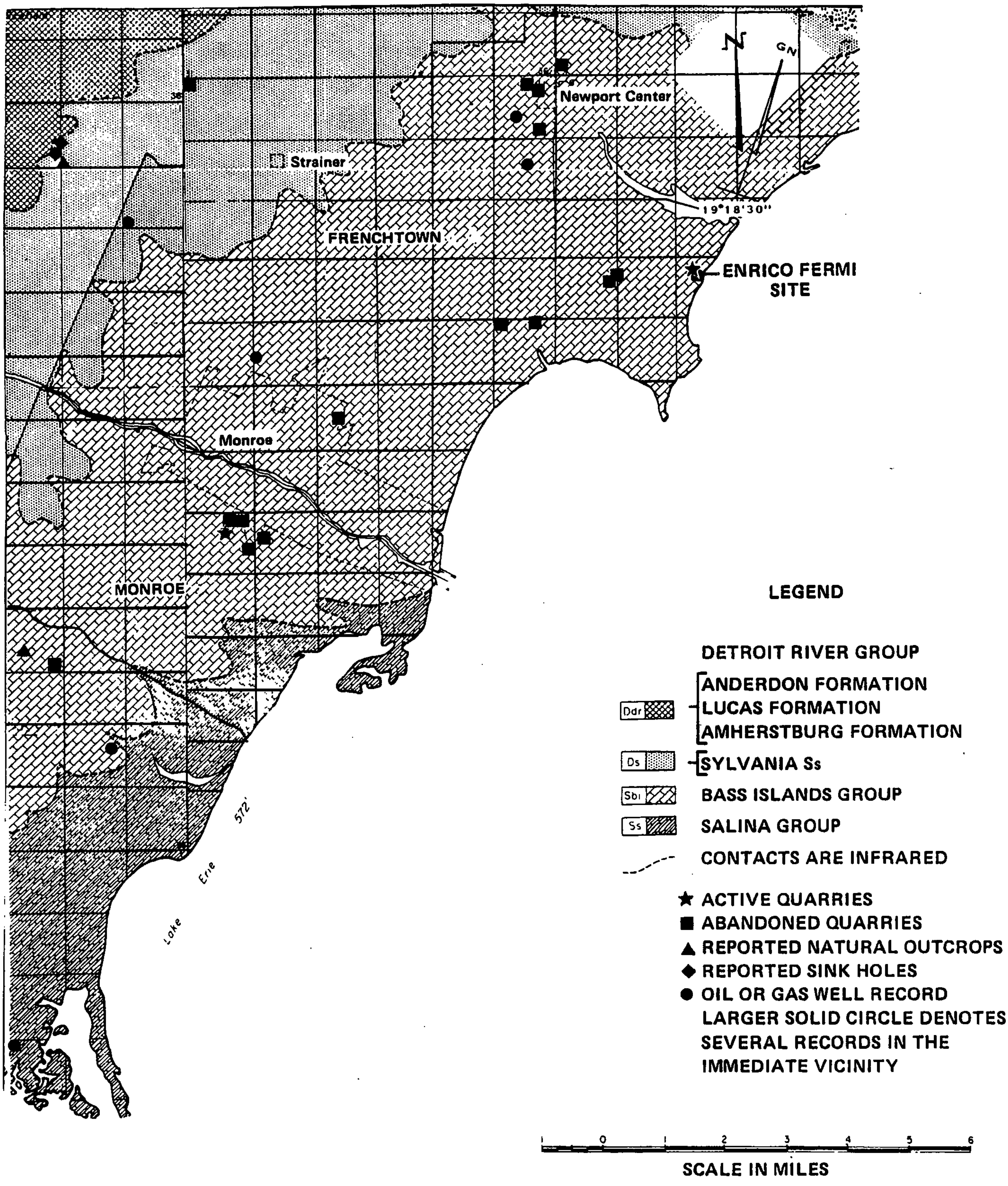
FIGURE 2.5-4

REGIONAL BEDROCK GEOLOGICAL MAP



REFERENCE:
MAZOLA, A. J., 1969, BEDROCK GEOLOGIC MAP OF MONROE COUNTY, MICHIGAN: FROM REPORT OF INVESTIGATION 13, GEOLOGY FOR ENVIRONMENTAL PLANNING IN MONROE COUNTY, MICHIGAN; GEOLOGICAL SURVEY DIVISION, DEPARTMENT OF NATURAL RESOURCES, 1970.

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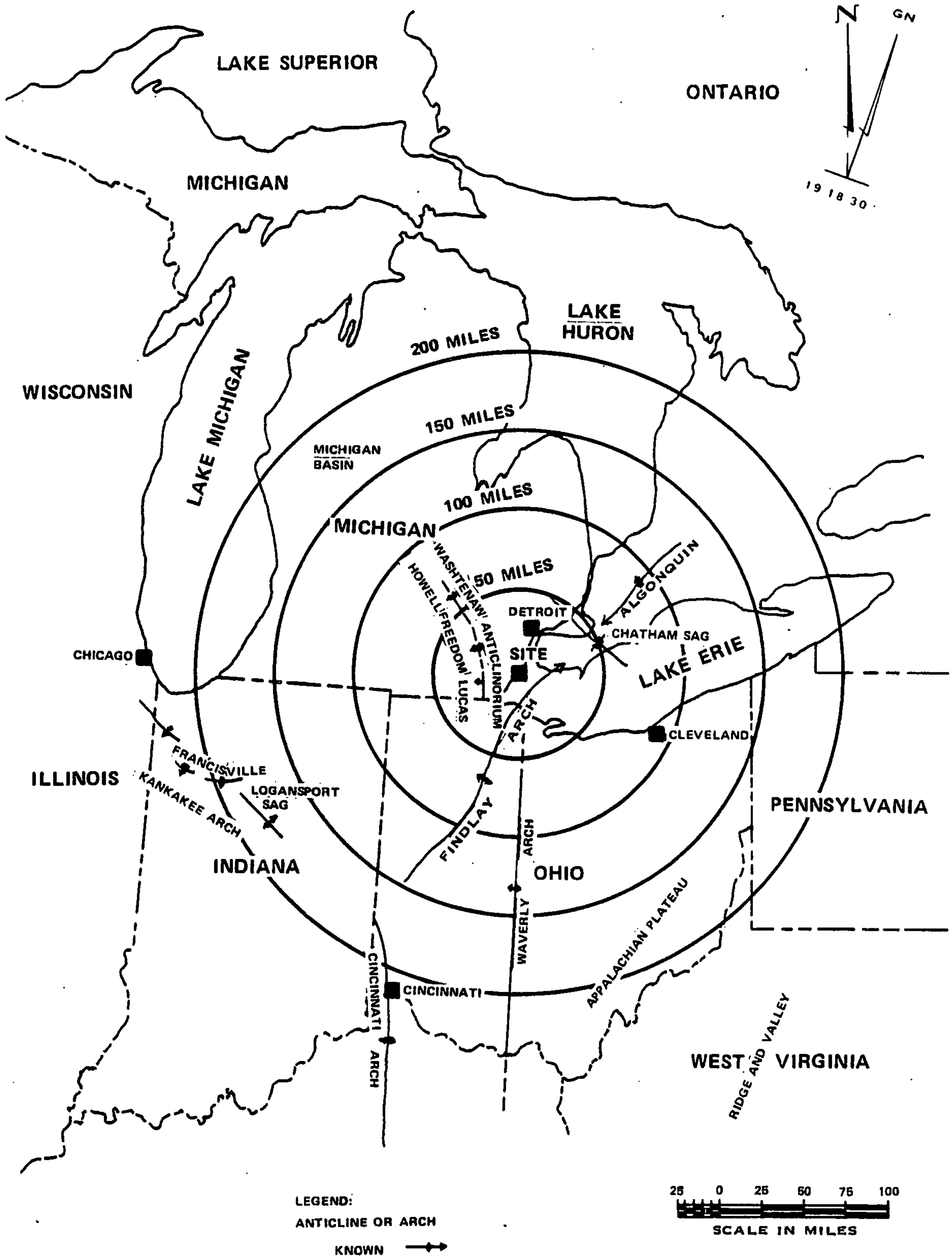
FIGURE 2.5-5

AREA BEDROCK GEOLOGICAL MAP



REFERENCE:
ELLS, G. D., 1969, ARCHITECTURE OF THE MICHIGAN BASIN IN STUDIES OF THE PRECAMBRIAN OF THE MICHIGAN BASIN: MICHIGAN BASIN GEOLOGICAL SOCIETY.

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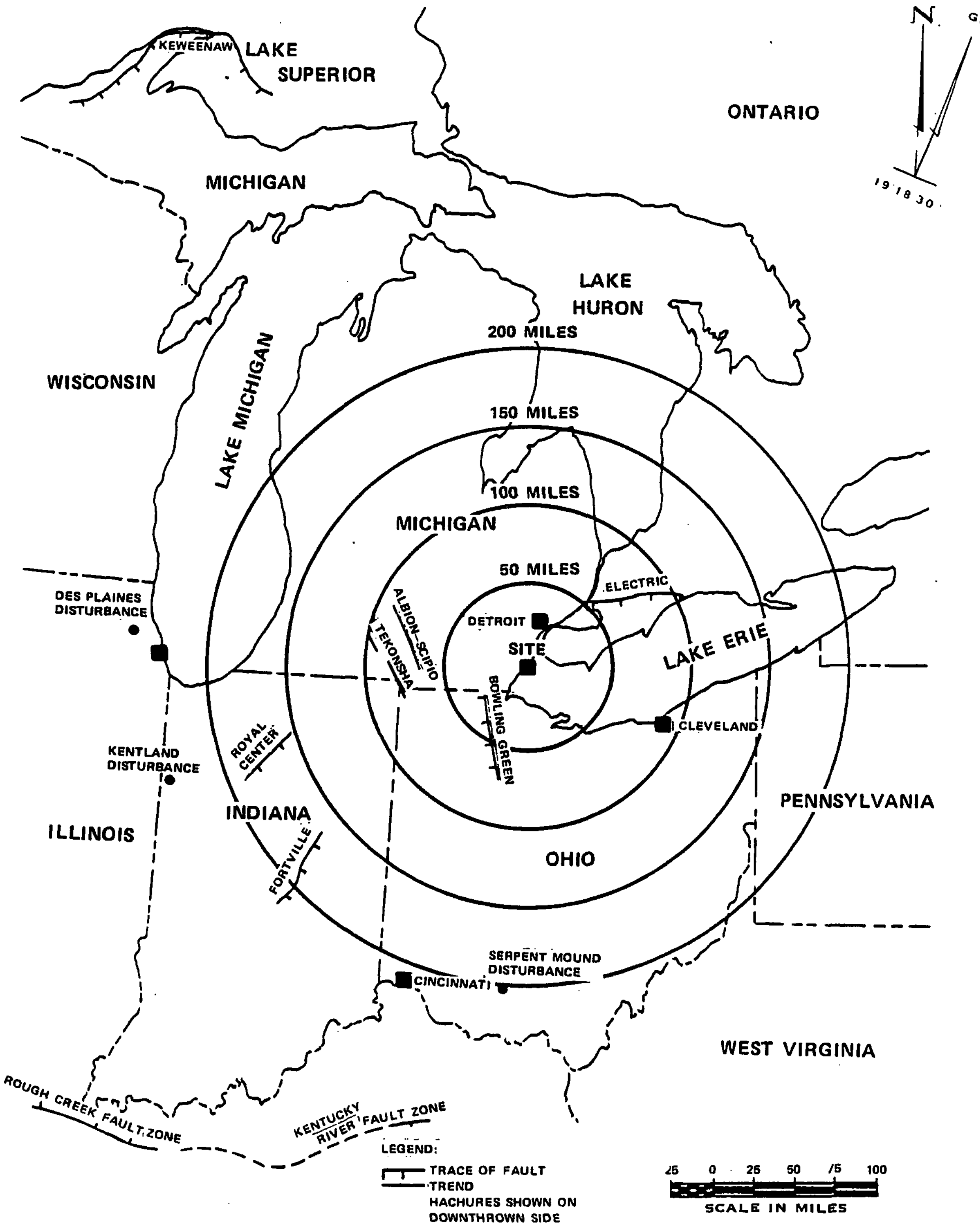
FIGURE 2.5-6

MAJOR FOLDS MAP



REFERENCE:
BRIGHAM, R. J., 1972, STRUCTURAL GEOLOGY OF SOUTHWESTERN ONTARIO AND SOUTHEASTERN MICHIGAN, ONTARIO MINES AND NORTHERN AFFAIRS AFFAIRS. PETROLEUM RESOURCES SECTION PAPER 71-2.
BRISTOL, H. M., AND T. C. BUSHBACH, 1971, STRUCTURAL FEATURES OF THE EASTERN INTERIOR REGION OF THE UNITED STATES IN ILLINOIS GEOLOGICAL SURVEY, ILLINOIS PETROLEUM PUB 96.

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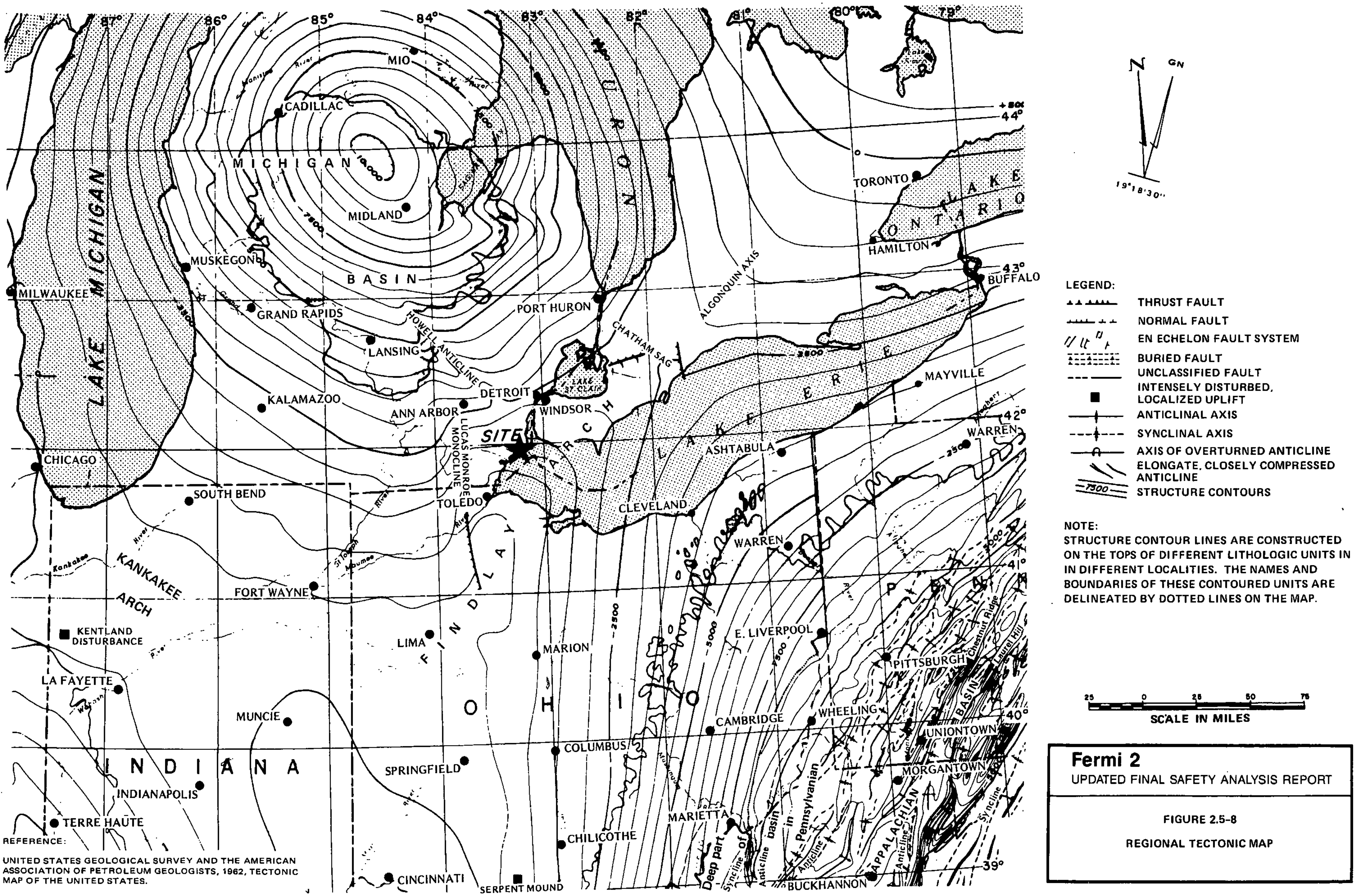
FIGURE 2.5-7

MAJOR FAULTS MAP



REFERENCE:

UNITED STATES GEOLOGICAL SURVEY AND THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, 1962, TECTONIC MAP OF THE UNITED STATES.

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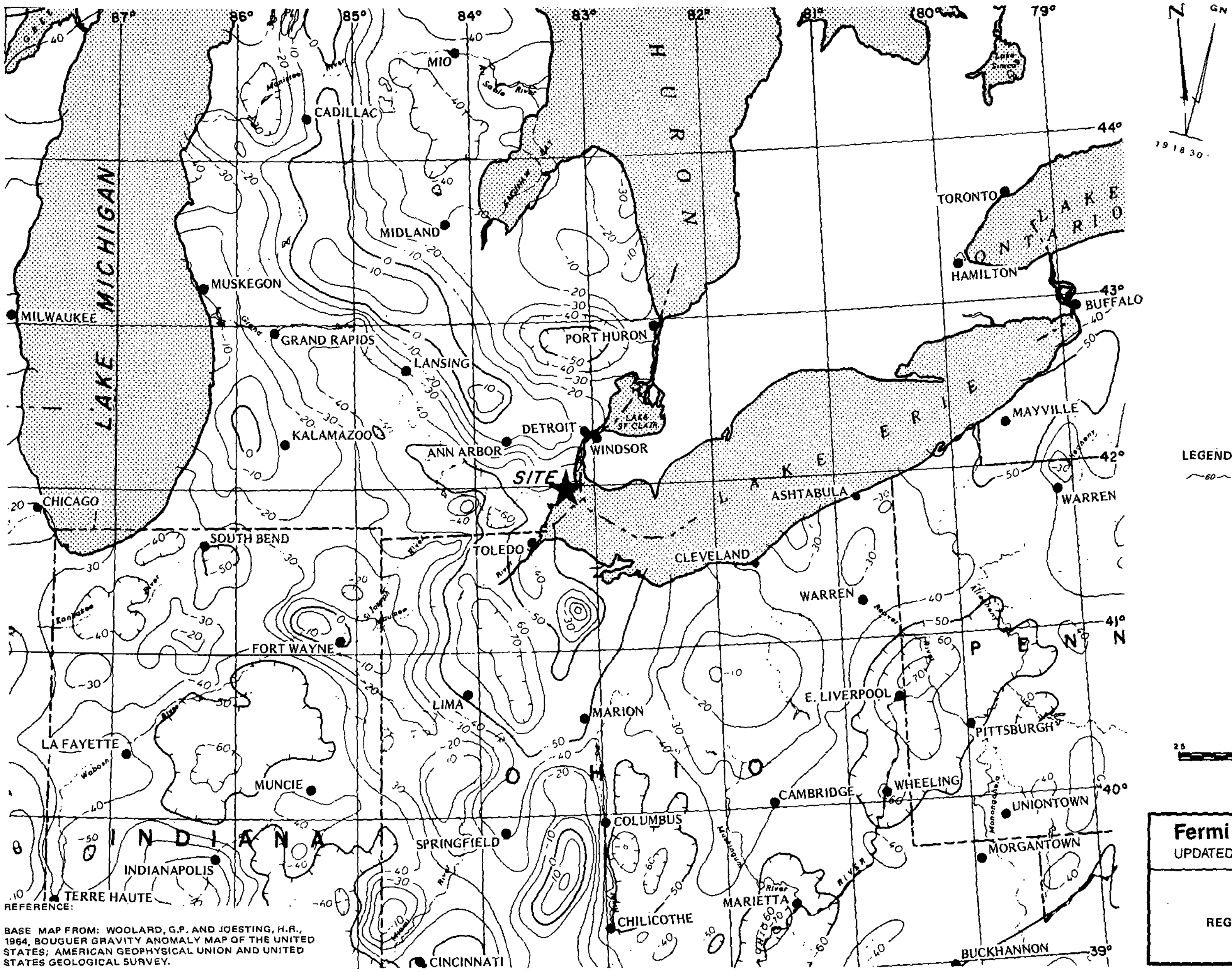
FIGURE 2.5-8

REGIONAL TECTONIC MAP



REFERENCE:

BASE MAP FROM: WOOLARD, G.P. AND JOESTING, H.R., 1964, BOUGUER GRAVITY ANOMALY MAP OF THE UNITED STATES; AMERICAN GEOPHYSICAL UNION AND UNITED STATES GEOLOGICAL SURVEY.

LEGEND:

—60— BOUGUER GRAVITY CONTOUR (CONTOUR INTERVAL 10 MILLIGALS)

25 0 25 50 75

SCALE IN MILES

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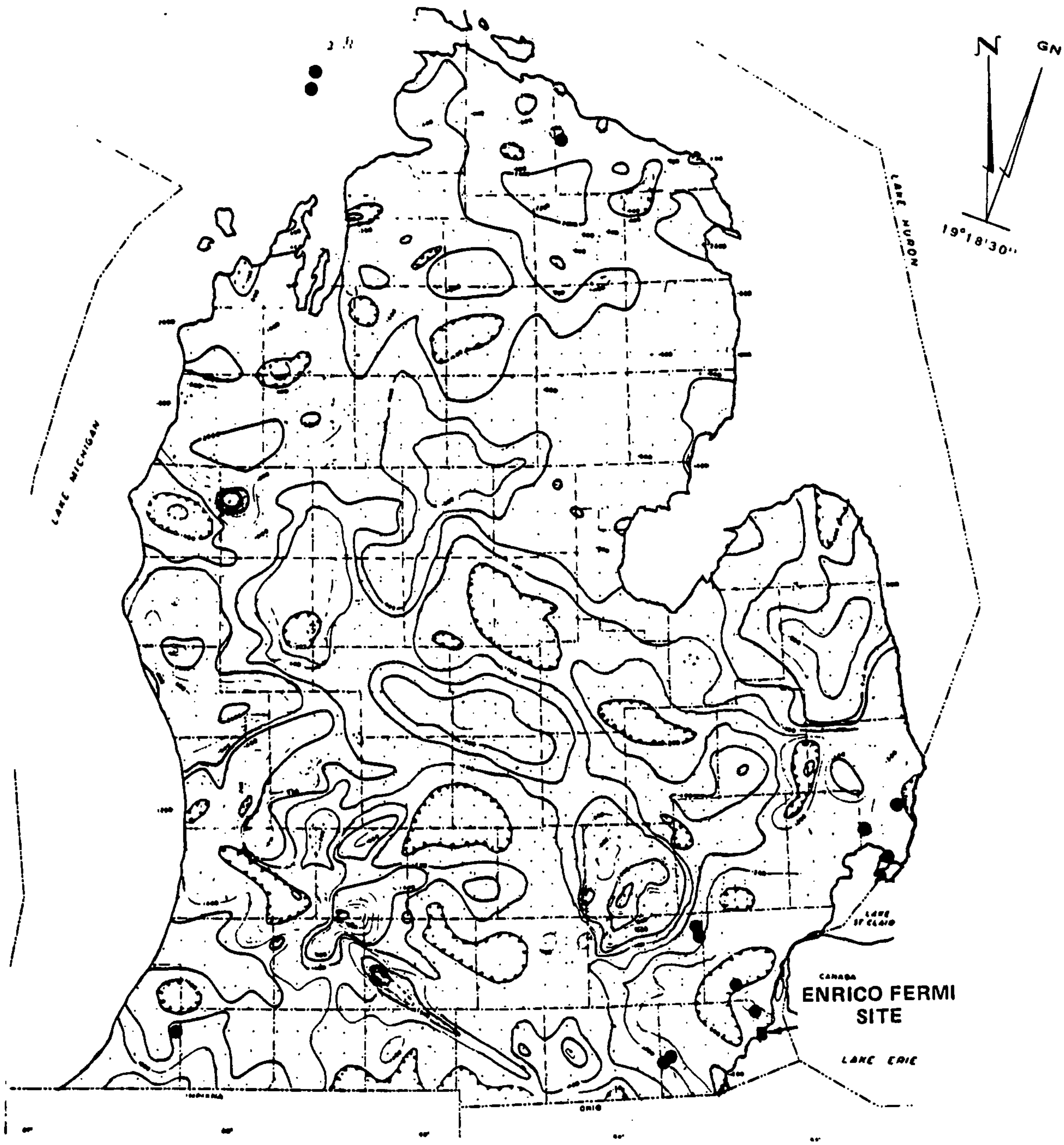
FIGURE 2.5-9

REGIONAL BOUGUER GRAVITY MAP



KEY:
● INDICATES PRECAMBRIAN SAMPLE
CONTOUR INTERVAL = 100 GAMMAS

SCALE IN MILES

REFERENCE:

MAGNETIC MAP –
A) HINZE, W.J., AND MERRITT, D.W., 1969, BASEMENT ROCKS OF THE SOUTHERN PENINSULA OF MICHIGAN IN STUDIES OF THE PRECAMBRIAN OF THE MICHIGAN BASIN: MICHIGAN BASIN GEOLOGICAL SOCIETY
B) THE PRECAMBRIAN WELL LOCATIONS ARE FROM THE MICHIGAN GEOLOGICAL SURVEY, 1968, MICHIGAN'S OIL AND GAS FIELDS, 1967: ANNUAL STATISTICAL SUMMARY NO. 8.

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FIGURE 2.5-10

REGIONAL MAGNETIC MAP

SYSTEM	STRATIGRAPHIC NOMENCLATURE	GRAPHIC LOG	AVERAGE THICKNESS (FEET)	BEDS	LITHOLOGY
QUAT.	Recent and Pleistocene		15–30		Lake Deposits and Glacial Till
SILURIAN	Bass Islands Group		80		Dolomite
SILURIAN	Salina Group		525	G	Shales and Shaly Dolomite
				E	Shaly Dolomite, Limestone and Limestone Breccias
				C	Dolomite and Shaly Dolomite
				A	Limestone and Dolomite
SILURIAN	Niagaran Group		425		Dolomite
SILURIAN	Cataract Group		100		Shale and Dolomite
ORDOVICIAN	Richmond Group		625		Shale and Dolomite
ORDOVICIAN	Trenton – Black River Group		825–850		Dolomites and Shales
CAMBRIAN	St. Croixian Series		475		Sandstones (with some Dolomites)
PRE-CAMBRIAN					Granitic Gneiss

NOTE:
THICKNESS OF THE BASS ISLANDS GROUP AND PART OF THE SALINA GROUP BASED ON SITE EXPLORATORY BORINGS. OTHER THICKNESSES BASED ON MICHIGAN WELL LOGS, BRIGHAM, (1972) FISHER, (1969) AND ELLS, (ORAL COMMUNICATION)

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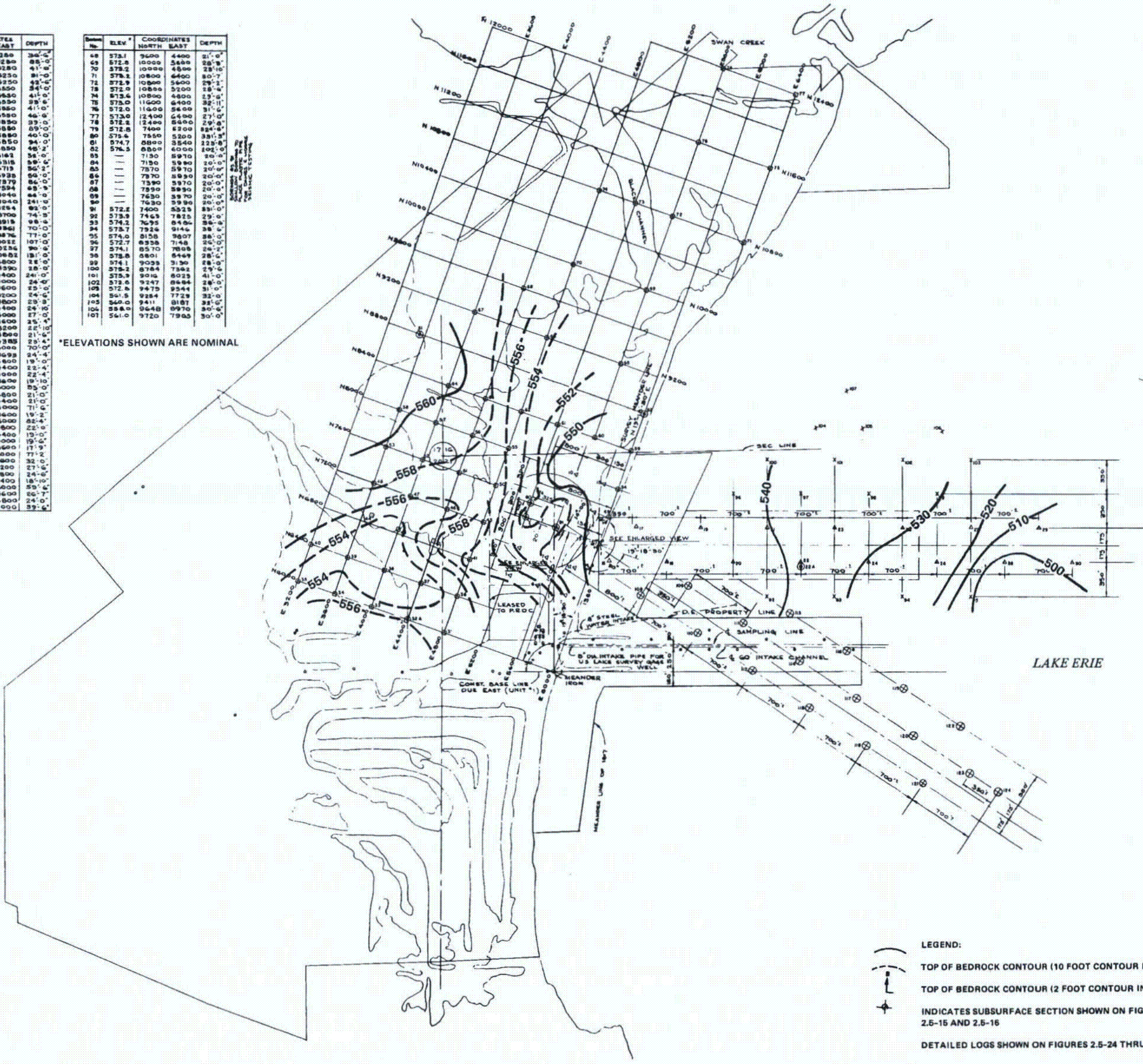
FIGURE 2.5-11

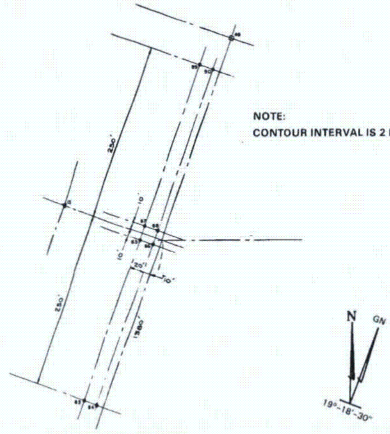
SITE STRATIGRAPHIC COLUMN

Boring No.	Elev.*	Coordinates North	Coordinates East	Depth
1	573.0	6780	5280	36'-6"
2	571.7	7080	5280	85'-0"
3	572.4	7580	5280	41'-0"
4	572.5	7680	5250	81'-0"
5	573.4	7980	5250	42'-6"
6	573.5	6780	5550	34'-0"
7	572.7	7080	5530	41'-0"
8	572.3	7380	5530	39'-6"
9	575.4	7680	5550	41'-0"
10	569.9	7980	5580	46'-6"
11	573.6	6780	5850	33'-0"
12	572.6	7080	5880	89'-0"
13	572.6	7580	5880	40'-0"
14	571.6	7680	5850	94'-0"
15	578.2	7980	5850	48'-2"
16	571.8	7251	6162	58'-0"
17	570.0	7674	6315	59'-6"
18	572.5	7448	6713	56'-2"
19	572.0	7892	6938	56'-0"
20	573.7	7678	7379	86'-0"
21	574.2	8124	7594	63'-3"
22	574.3	7903	8040	64'-0"
22A	577.3	7903	8040	241'-0"
23	574.3	8283	8254	82'-0"
24	573.5	8141	8700	74'-5"
25	573.8	8587	8915	98'-6"
26	572.8	8372	9361	70'-0"
27	571.8	8818	9876	77'-0"
28	573.0	8604	10022	107'-0"
29	572.7	9050	10236	90'-6"
30	573.1	8835	10682	131'-0"
31	572.7	6000	4800	28'-0"
32	579.7	5990	4390	28'-0"
32A	579.7	5990	4400	241'-0"
33	573.5	6000	4000	24'-0"
34	574.2	6000	3600	25'-0"
35	573.1	6000	3200	24'-6"
36	572.9	6400	4800	25'-3"
37	572.7	6400	4400	24'-10"
38	573.4	6400	4000	27'-0"
39	573.0	6400	3600	25'-4"
40	573.3	6400	3200	22'-10"
41	572.1	6800	4800	21'-6"
42	572.8	6855	4385	25'-4"
43	573.1	6850	4000	70'-0"
44	575.0	6892	3693	24'-4"
45	575.1	7200	4800	19'-0"
46	573.1	7200	4400	22'-4"
47	573.6	7200	4000	22'-4"
48	574.1	7200	3600	19'-10"
49	574.1	7680	6000	55'-0"
50	573.7	7800	4800	21'-0"
51	573.1	7800	4400	21'-0"
52	573.6	7800	4000	71'-6"
53	574.1	7800	3600	19'-2"
54	577.0	7980	6000	82'-4"
55	573.0	8000	4800	22'-0"
56	573.0	8000	4400	13'-0"
57	573.0	8000	4000	19'-6"
58	574.0	8000	3600	17'-9"
59	574.8	8400	6000	77'-2"
60	573.0	8400	5600	32'-0"
61	573.2	8400	5200	27'-6"
62	573.2	8400	4800	24'-6"
63	572.7	8400	4400	18'-10"
64	573.0	8400	4000	55'-6"
65	571.7	9200	5600	26'-7"
66	573.5	9200	4800	24'-0"
67	573.0	9200	4000	39'-6"

Boring No.	Elev.*	Coordinates North	Coordinates East	Depth
68	573.1	9600	4400	21'-0"
69	572.8	10000	5600	28'-3"
70	573.2	10000	4800	28'-10"
71	573.2	10800	6400	30'-7"
72	572.9	10800	5600	29'-2"
73	572.0	10800	5200	28'-6"
74	573.6	10800	4800	29'-6"
75	573.0	11600	6400	32'-11"
76	572.0	11600	5600	31'-6"
77	573.0	12400	6400	27'-0"
78	572.2	12400	5600	29'-8"
79	572.8	7400	5200	324'-6"
80	575.6	7550	5200	331'-3"
81	574.7	8800	3540	223'-8"
82	576.3	8800	6000	202'-0"
83	—	7130	5970	20'-0"
84	—	7150	5990	20'-0"
85	—	7370	5970	20'-0"
86	—	7370	5990	20'-0"
87	—	7390	5970	20'-0"
88	—	7390	5990	20'-0"
89	—	7630	5970	20'-0"
90	—	7630	5990	20'-0"
91	572.2	7400	5525	331'-0"
92	573.9	7463	7825	29'-0"
93	574.2	7695	8486	36'-6"
94	573.7	7926	9146	38'-6"
95	574.0	8158	9807	38'-0"
96	572.7	8338	7148	26'-0"
97	574.1	8570	7808	26'-2"
98	573.8	8801	8469	28'-6"
99	574.1	9033	9130	28'-0"
100	573.2	8784	7362	29'-6"
101	573.3	9016	8023	41'-0"
102	572.6	9247	8684	28'-0"
103	572.6	9475	9344	31'-0"
104	561.5	9284	7729	32'-0"
105	560.0	9411	8187	35'-6"
106	558.0	9648	8970	30'-6"
107	561.0	9720	7905	30'-0"

*ELEVATIONS SHOWN ARE NOMINAL

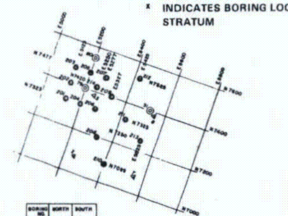




ENLARGED VIEW OF SEISMIC STUDY BORINGS

NOTE:
CONTOUR INTERVAL IS 2 FEET

- o INDICATES PROPOSED BORING LOCATIONS FOR UNIT NO. 2 (201-21)
- ⊕ INDICATES PROPOSED BORING LOCATIONS FOR UNIT NO. 2 (108-124)
- • INDICATES BORING LOCATION TAKEN FOR UNIT NO. 1
- ▲ INDICATES PROPOSED BORING LOCATIONS FOR UNIT 2 (1-31)
- ⊘ INDICATES PROPOSED INLAND BORING LOCATIONS FOR UNIT 2 (31-78
- ⊛ INDICATES DEEP BORING LOCATION
- • INDICATES BORING LOCATIONS FOR SEISMIC SOIL RESPONSE STUDY
- x INDICATES BORING LOCATIONS TO BOTTOM OF SAND STRATUM



Boring No.	North	South
201	7323	5123
202	7400	5123
203	7477	5123
204	7323	5200
205	7477	5200
206	7323	5277
207	7477	5277
208	7200	5367
209	7400	5367
210	7089	5400
211	7323	5423
212	7523	5423
213	7250	5523
214	7430	5280

ENLARGED VIEW FOR ADDITIONAL BORINGS IN REACTOR, AUX. BLDG, TURBINE AND RADWASTE BLDGS

LEGEND:

- TOP OF BEDROCK CONTOUR (10 FOOT CONTOUR INTERVAL)
- TOP OF BEDROCK CONTOUR (2 FOOT CONTOUR INTERVAL)
- INDICATES SUBSURFACE SECTION SHOWN ON FIGURES 2.5-15 AND 2.5-16

DETAILED LOGS SHOWN ON FIGURES 2.5-24 THRU 2.5-56.

DETROIT EDISON COMPANY DRAWING NO. 6MS721-40, REV. I

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UPDATED FINAL SAFETY ANALYSIS REPORT

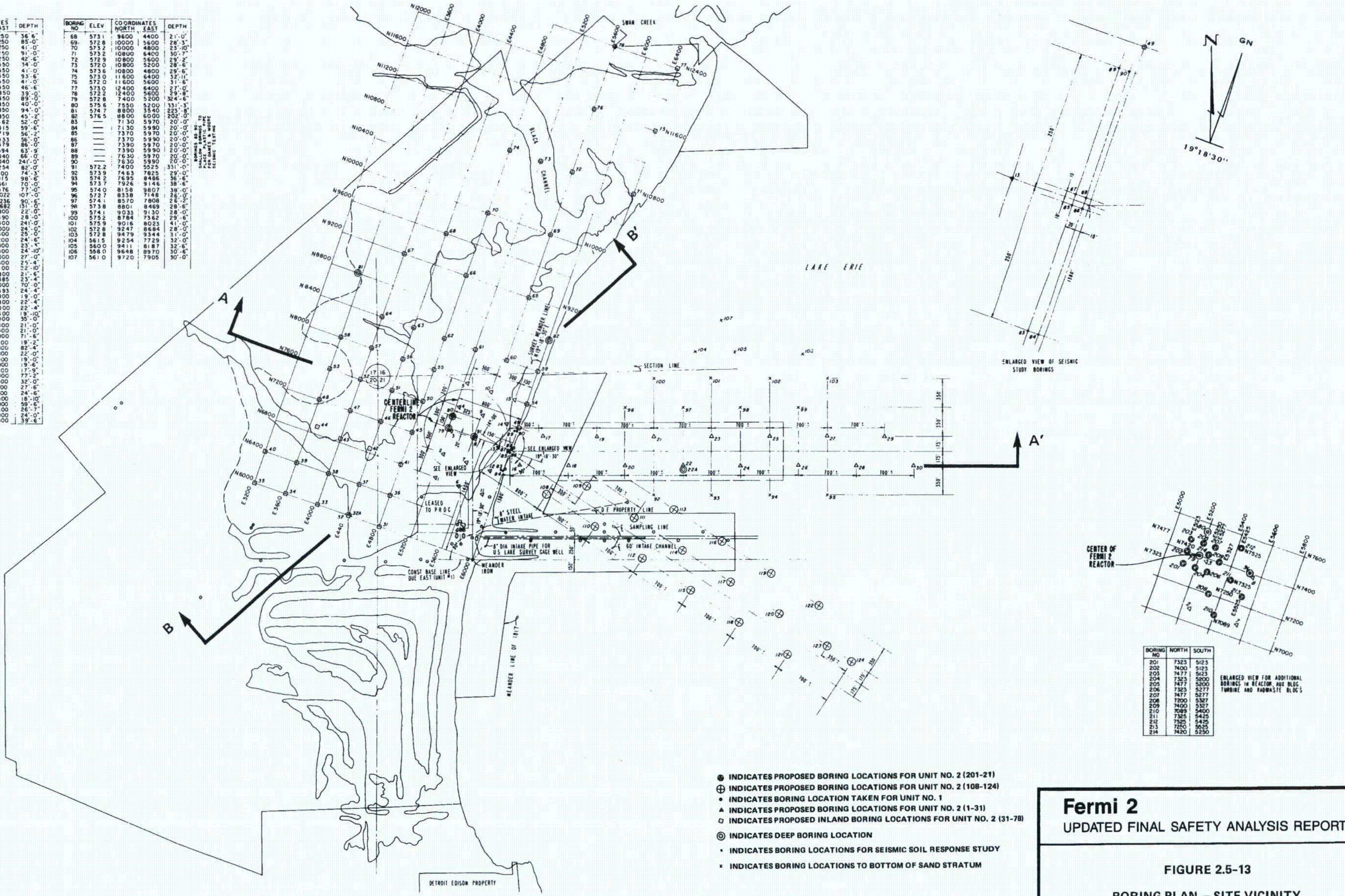
FIGURE 2.5-12

BEDROCK TOPOGRAPHIC MAP – SITE

BORING NO	ELEV	COORDINATES NORTH	EAST	DEPTH
1	5730	6780	5250	36 6"
2	5717	7080	5250	85-0"
3	5724	7380	5250	41'-0"
4	5725	7680	5250	91'-0"
5	5734	7980	5250	42'-6"
6	5735	6780	5550	34'-0"
7	5727	7080	5550	41'-0"
8	5723	7380	5550	93'-6"
9	5734	7680	5550	41'-0"
10	5699	7980	5550	46'-6"
11	573.8	6780	5850	39'-0"
12	5726	7080	5850	89'-0"
13	5726	7380	5850	40'-0"
14	5716	7680	5850	94'-0"
15	5732	7980	5850	45'-2"
16	571.8	7251	6162	52'-0"
17	5700	7676	6315	59'-6"
18	5725	7446	6719	56'-2"
19	5720	7892	6933	56'-0"
20	5737	7678	7379	86'-0"
21	5742	8124	7594	63'-9"
22	5743	7909	8040	66'-0"
22A	5773	7909	8040	241'-0"
23	5743	8355	8254	82'-0"
24	5735	8141	8700	74'-3"
25	5738	8587	8915	98'-6"
26	5728	8372	9361	70'-0"
27	5718	8818	9576	77'-0"
28	5730	8604	10022	107'-0"
29	5727	9050	10236	90'-6"
30	5731	8835	10682	131'-0"
31	5727	6000	4800	22'-0"
32	5797	5990	4390	28'-0"
32A	5797	5990	4400	241'-0"
33	5733	6000	4000	24'-0"
34	5742	6000	3600	25'-0"
35	5731	6000	3200	24'-6"
36	5729	6400	4800	23'-3"
37	572.7	6400	4400	24'-10"
38	5734	6400	4000	27'-0"
39	5730	6400	3600	25'-4"
40	5733	6400	3200	22'-10"
41	5721	6800	4800	21'-6"
42	572.8	6855	4385	23'-4"
43	5731	6850	4000	70'-0"
44	5730	6892	3693	24'-4"
45	5731	7200	4800	19'-0"
46	5731	7200	4400	22'-4"
47	5736	7200	4000	22'-4"
48	5741	7200	3600	19'-10"
49	5741	7680	6000	35'-0"
50	5737	7600	4800	21'-0"
51	5731	7600	4400	21'-0"
52	5736	7600	4000	71'-6"
53	5741	7600	3600	19'-2"
54	5770	7980	6000	82'-4"
55	5730	8000	4800	22'-0"
56	5730	8000	4400	19'-0"
57	5730	8000	4000	19'-6"
58	5740	8000	3600	17'-9"
59	5768	8400	6000	77'-2"
60	5730	8400	5600	32'-0"
61	5732	8400	5200	27'-6"
62	5732	8400	4800	24'-6"
63	5727	8400	4400	18'-10"
64	5730	8400	4000	59'-6"
65	5717	9200	5600	26'-7"
66	5733	9200	4800	24'-0"
67	5730	9200	4000	39'-6"

BORING NO	ELEV	COORDINATES NORTH	EAST	DEPTH
68	5731	9600	4400	21'-0"
69-	5728	10000	5600	28'-3"
70	5732	10000	4800	23'-10"
71	5732	10800	6400	30'-7"
72	5729	10800	5600	29'-2"
73	5720	10800	5200	28'-6"
74	5736	10800	4800	29'-6"
75	5730	11600	6400	32'-11"
76	5720	11600	5600	31'-6"
77	5730	12400	6400	27'-0"
78	5722	12400	5600	29'-8"
79	5728	7400	5200	324'-6"
80	5756	7550	5200	331'-3"
81	5747	8800	3540	223'-8"
82	5765	8800	6000	202'-0"
83	—	7130	5970	20'-0"
84	—	7130	5990	20'-0"
85	—	7370	5970	20'-0"
86	—	7370	5990	20'-0"
87	—	7390	5970	20'-0"
88	—	7390	5990	20'-0"
89	—	7630	5970	20'-0"
90	—	7630	5990	20'-0"
91	572.2	7400	5525	331'-0"
92	5739	7463	7825	29'-0"
93	5742	7695	8486	36'-6"
94	5737	7926	9146	38'-6"
95	5740	8158	9807	38'-0"
96	5727	8338	7148	26'-0"
97	5741	8570	7808	26'-2"
98	5738	8801	8469	28'-6"
99	5741	9033	9130	28'-0"
100	5752	8784	7362	29'-6"
101	5759	9016	8023	41'-0"
102	5728	9247	8684	28'-0"
103	5728	9479	9344	31'-0"
104	5615	9254	7729	32'-0"
105	5600	9411	8187	32'-6"
106	5580	9648	8970	30'-6"
107	5610	9720	7905	30'-0"

BORINGS 83-90 SHALLOW BORINGS TO PLACE PLASTIC PIPE FOR DAMES & MOORE SEISMIC TESTING



BORING NO	NORTH	SOUTH
201	7323	5123
202	7400	5123
203	7477	5123
204	7323	5200
205	7477	5200
206	7323	5277
207	7477	5277
208	7200	5327
209	7400	5327
210	7089	5400
211	7325	5425
212	7525	5425
213	7250	5525
214	7420	5250

ENLARGED VIEW FOR ADDITIONAL BORINGS IN REACTOR, AUX BLDG, TURBINE AND RADWASTE BLDG'S

- ⊛ INDICATES PROPOSED BORING LOCATIONS FOR UNIT NO. 2 (201-21)
- ⊕ INDICATES PROPOSED BORING LOCATIONS FOR UNIT NO. 2 (108-124)
- • INDICATES BORING LOCATION TAKEN FOR UNIT NO. 1
- ▲ INDICATES PROPOSED BORING LOCATIONS FOR UNIT NO. 2 (1-31)
- ◻ INDICATES PROPOSED INLAND BORING LOCATIONS FOR UNIT NO. 2 (31-78)
- ◎ INDICATES DEEP BORING LOCATION
- ▪ INDICATES BORING LOCATIONS FOR SEISMIC SOIL RESPONSE STUDY
- × INDICATES BORING LOCATIONS TO BOTTOM OF SAND STRATUM

DETROIT EDISON COMPANY DRAWING 6MS721-40

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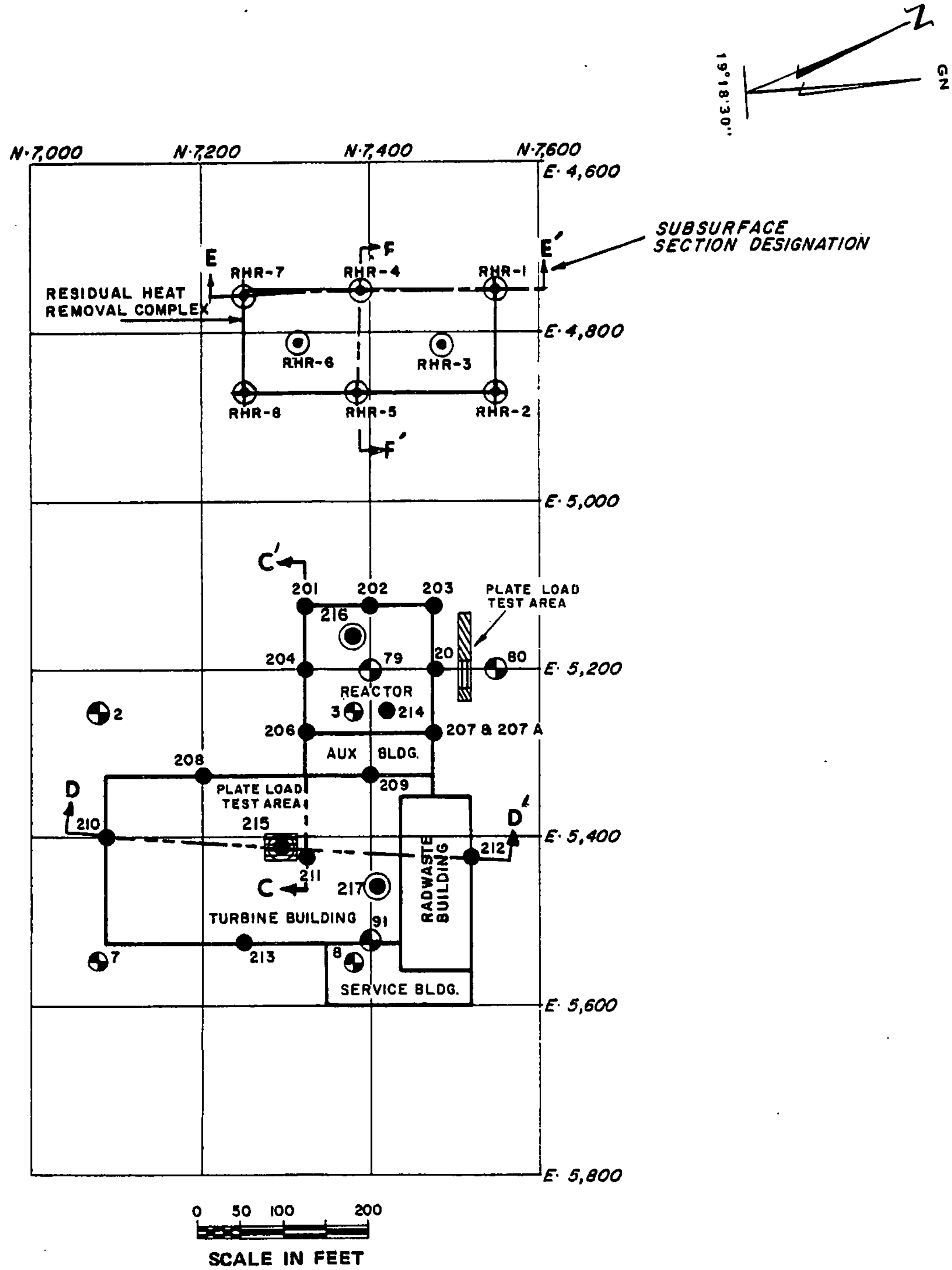
FIGURE 2.5-13

BORING PLAN – SITE VICINITY



KEY:

- BORINGS DRILLED FOR P.S.A.R. (1968)
- BORINGS DRILLED FOR SUPPLEMENT TO P.S.A.R. (1969)
- BORINGS DRILLED FOR SOIL AND ROCK STUDIES (1970)
- BORINGS DRILLED FOR RHR COMPLEX FOUNDATION INVESTIGATION (1972)

SOURCE DRAWING REFERENCE:
REFERENCE 3, PLATE 2

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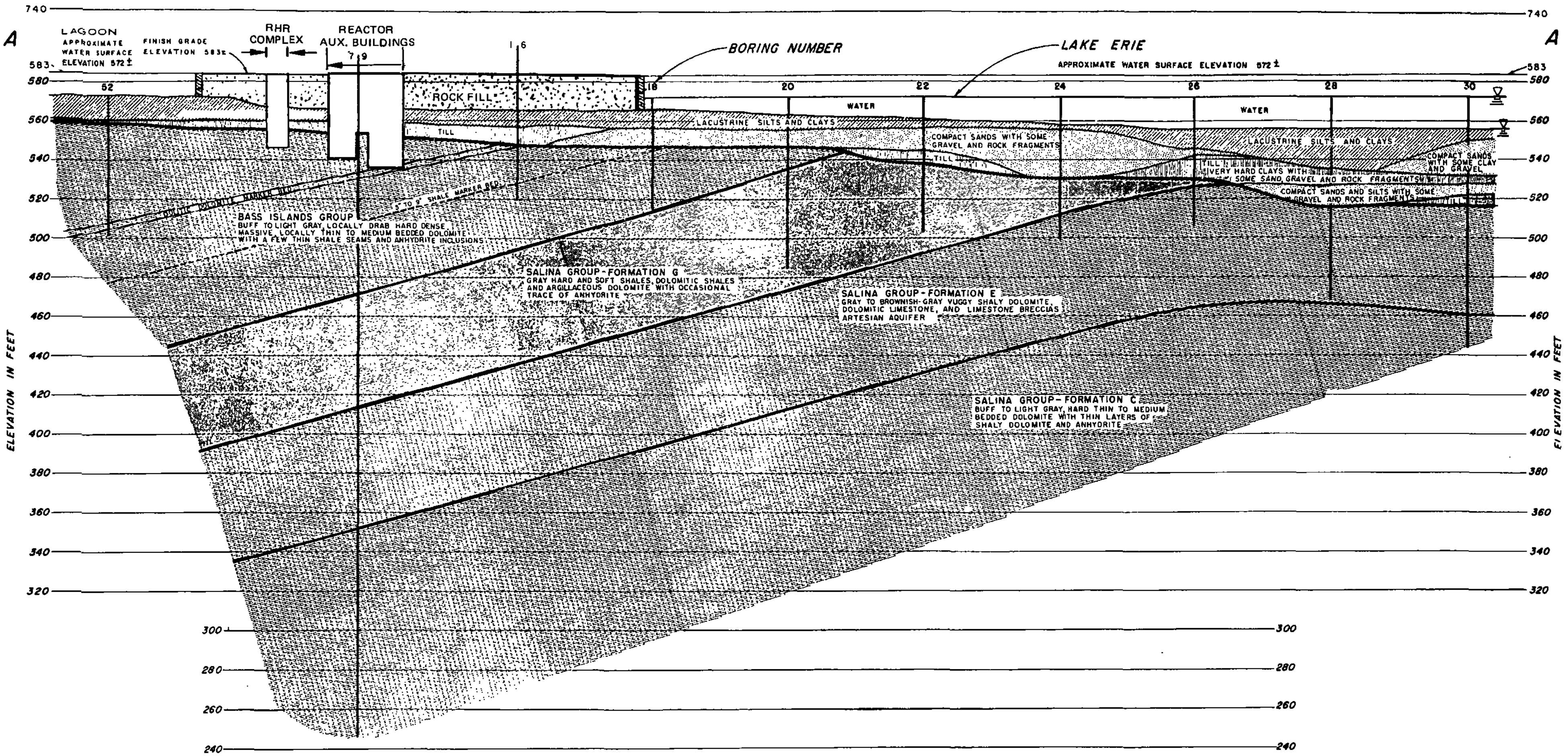
FIGURE 2.5-14

BORING PLAN – REACTOR/AUXILIARY BUILDING, RHR COMPLEX, TURBINE RADWASTE BUILDING, AND SERVICE BUILDING



NOTES:

ELEVATIONS REFER TO GREAT LAKES SURVEY DATUM.

GROUND SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SOIL STRATA AND THE DEPTH OF THE ROCK STRATA INDICATED ON THE SUBSURFACE SECTION WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORING LOCATIONS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

SECTION A - A'

100 0 100 200 300 400 500

SCALE IN FEET

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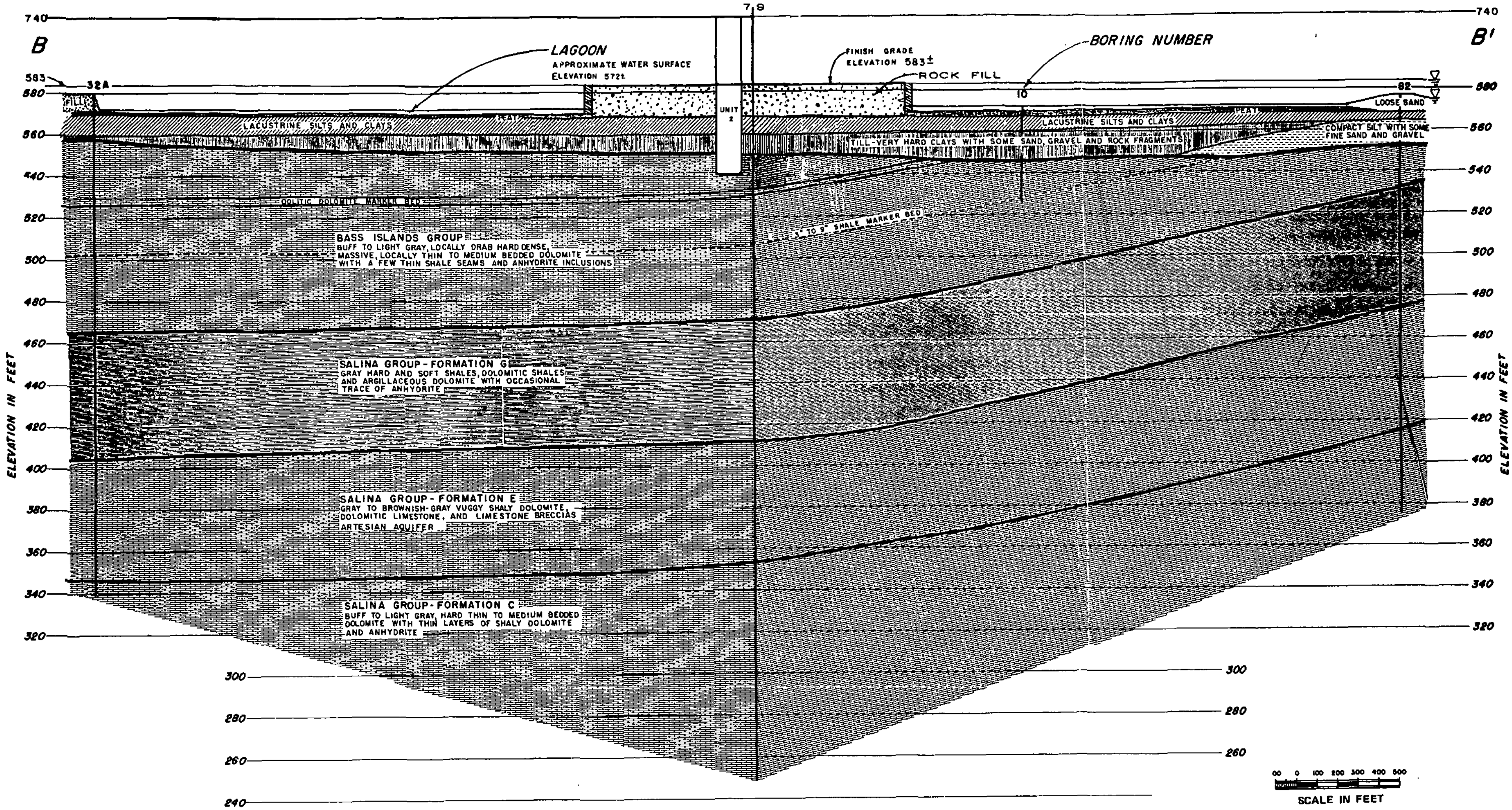
FIGURE 2.5-15

SUBSURFACE SECTION A-A' FROM FIGURE 2.5-13



SECTION B - B'

NOTES:

ELEVATIONS REFER TO GREAT LAKES SURVEY DATUM.

GROUND SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SOIL STRATA AND THE DEPTH OF THE ROCK STRATA INDICATED ON THE SUBSURFACE SECTION WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORING LOCATIONS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

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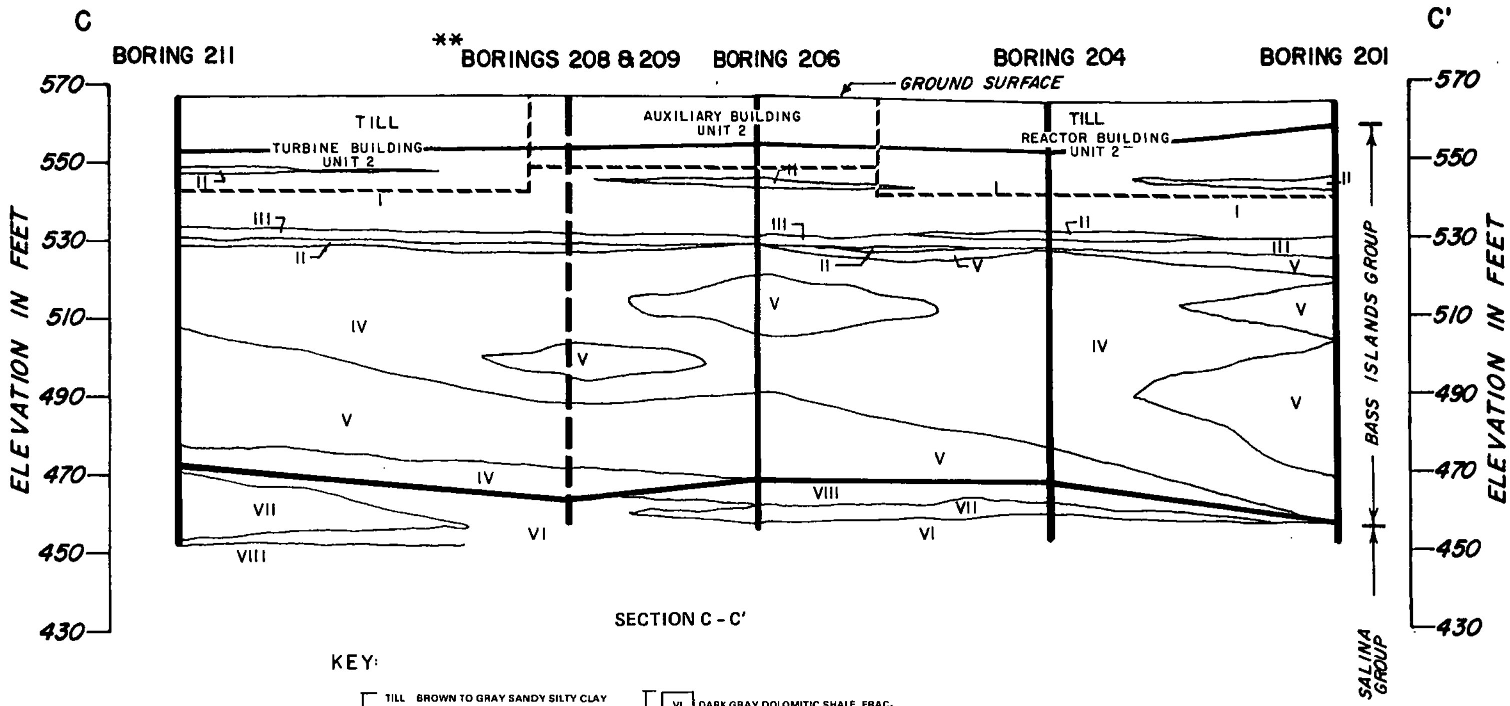
FIGURE 2.5-16

SUBSURFACE SECTION B-B' FROM FIGURE 2.5-13



KEY:

BASS ISLANDS GROUP

- TILL — BROWN TO GRAY SANDY SILTY CLAY WITH SOME COBBLES AND BOULDERS (TILL).
- I — GRAY TO BROWN MICROCRYSTALLINE ARGILLACEOUS DOLOMITE. FRACTURES VERY CLOSE TO MODERATELY CLOSE, 0°-90°. VUGS LESS THAN 10% WITH ZONES OF 20-40%, 1/16 TO 1/2 INCH.
- II — GRAYISH BLUE TO GRAY WITH BLUE STREAKED MICROCRYSTALLINE DOLOMITE. FRACTURES VERY CLOSE TO CLOSE, NEAR HORIZONTAL WITH SOME 90°. VUGS 5-10% WITH SOME ZONES UP TO 40%, 1/32 TO 1/2 INCH.
- III — LIGHT GRAY TO BROWN OOLITIC DOLOMITE. FRACTURES CLOSE TO MODERATELY CLOSE, 0°-45° AND 40° TO 90°. SOME FRAGMENTED ZONES. VUGS UP TO 10% WITH ZONES OF UP TO 40%, 1/32 TO 1/2 INCH.
- IV — LIGHT GRAY TO TAN MICROCRYSTALLINE ARGILLACEOUS DOLOMITE. THINLY BEDDED WITH DARK GRAY SHALE PARTINGS AND LAMINAE. FRACTURES VARY FROM ZONES OF FRAGMENTED AND VERY CLOSE, 0°-90° TO ZONES OF MODERATELY CLOSE TO WIDE, 0° TO 20° AND 30°-70°. VUGS LESS THAN 10% WITH THIN ZONES OF 10 TO 20%, 1/32 TO 1/2 INCH.
- V — LIGHT GRAY TO BROWN ARGILLACEOUS DOLOMITE. FRACTURES CLOSE TO VERY CLOSE, 0° TO 90°. VUGS LESS THAN 10%, 1/16 TO 1-1/2 INCHES.

SALINA GROUP

- VI — DARK GRAY DOLOMITIC SHALE. FRACTURES CLOSE TO VERY CLOSE, 0° TO 60° WITH OCCASIONAL FRAGMENTED ZONES. VUGS IN DOLOMITIC MATERIAL UP TO 10%, 1/32 TO 1/2 INCH.
- VII — GRAY ARGILLACEOUS DOLOMITE. FRACTURES CLOSE TO VERY CLOSE WITH FRAGMENTED ZONES, 0° TO 90°. VUGS LESS THAN 10%, 1/16 TO 1/2 INCH.
- VIII — GRAYISH-BLUE BRECCIATED DOLOMITE HEALED WITH BLUISH GRAY CLAY MATRIX. FRACTURES VERY CLOSE TO FRAGMENTED, 0° TO 90°. VUGS IN DOLOMITE FRAGMENTS LESS THAN 10%, 1/8 TO 1/2 INCH.

NOTES:

GROUND SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SOIL AND ROCK STRATA INDICATED ON THE GENERALIZED SUBSURFACE SECTIONS WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORINGS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

**EXTRAPOLATED TO CROSS-SECTION LINE FROM MORE THAN 80 FEET

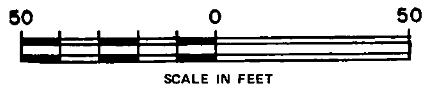


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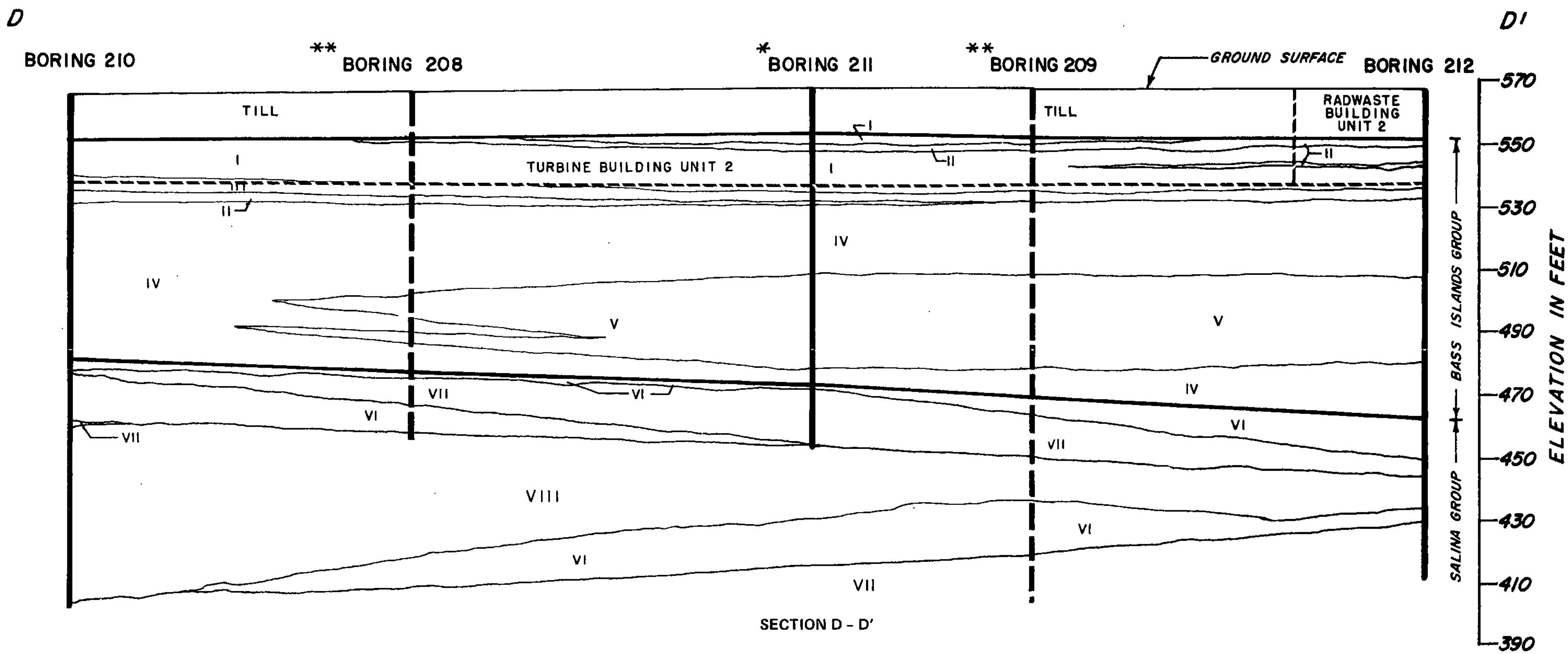
FIGURE 2.5-17

SUBSURFACE SECTION C-C' FROM FIGURE 2.5-14



SECTION D - D'

NOTES:

GROUND SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SOIL AND ROCK STRATA INDICATED ON THE GENERALIZED SUBSURFACE SECTIONS WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORINGS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

**EXTRAPOLATED TO CROSS SECTION LINE FROM MORE THAN 80 FEET
*EXTRAPOLATED TO CROSS SECTION LINE FROM LESS THAN 20 FEET

KEY

BASS ISLANDS GROUP

- TILL — BROWN TO GRAY SANDY SILTY CLAY WITH SOME COBBLES AND BOULDERS (TILL)
- I — GRAY TO BROWN MICROCRYSTALLINE ARGILLACEOUS DOLOMITE. FRACTURES VERY CLOSE TO MODERATELY CLOSE, 0°-90°. VUGS LESS THAN 10% WITH ZONES OF 20-40%, 1/16 TO 1/2 INCH
- II — GRAYISH BLUE TO GRAY WITH BLUE STREAKED MICROCRYSTALLINE DOLOMITE. FRACTURES VERY CLOSE TO CLOSE. NEAR HORIZONTAL WITH SOME 90°. VUGS 6-10% WITH SOME ZONES UP TO 40%. 1/32 TO 1/2 INCH
- III — LIGHT GRAY TO BROWN OOLITIC DOLOMITE. FRACTURES CLOSE TO MODERATELY CLOSE, 0°-45° AND 40 TO 90°. SOME FRAGMENTED ZONES. VUGS UP TO 10% WITH ZONES OF UP TO 40%. 1/32 TO 1/2 INCH
- IV — LIGHT GRAY TO TAN MICROCRYSTALLINE ARGILLACEOUS DOLOMITE THINLY BEDDED WITH DARK GRAY SHALE PARTINGS AND LAMINAE. FRACTURES VARY FROM ZONES OF FRAGMENTED AND VERY CLOSE, 0-90° TO ZONES OF MODERATELY CLOSE TO WIDE, 0° TO 20° AND 30°-70°. VUGS LESS THAN 10% WITH THIN ZONES OF 10 TO 20%. 1/32 TO 1/2 INCH

SALINA GROUP

- V — LIGHT GRAY TO BROWN ARGILLACEOUS DOLOMITE. FRACTURES CLOSE TO VERY CLOSE, 0° TO 80°. VUGS LESS THAN 10%, 1/16 TO 1-1/2 INCHES
- VI — DARK GRAY DOLOMITIC SHALE. FRACTURES CLOSE TO VERY CLOSE. 0° TO 60° WITH OCCASIONAL FRAGMENTED ZONES. VUGS IN DOLOMITIC MATERIAL UP TO 10%, 1/32 TO 1/2 INCH
- VII — GRAY ARGILLACEOUS DOLOMITE. FRACTURES CLOSE TO VERY CLOSE WITH FRAGMENTED ZONES. 0° TO 80°. VUGS LESS THAN 10%, 1/16 TO 1/2 INCH.
- VIII — GRAYISH-BLUE BRECCIATED DOLOMITE HEALED WITH BLUISH GRAY CLAY MATRIX. FRACTURES VERY CLOSE TO FRAGMENTED, 0° TO 90°. VUGS IN DOLOMITE FRAGMENTS LESS THAN 10%, 1/8 TO 1/2 INCH

50 0 50

SCALE IN FEET

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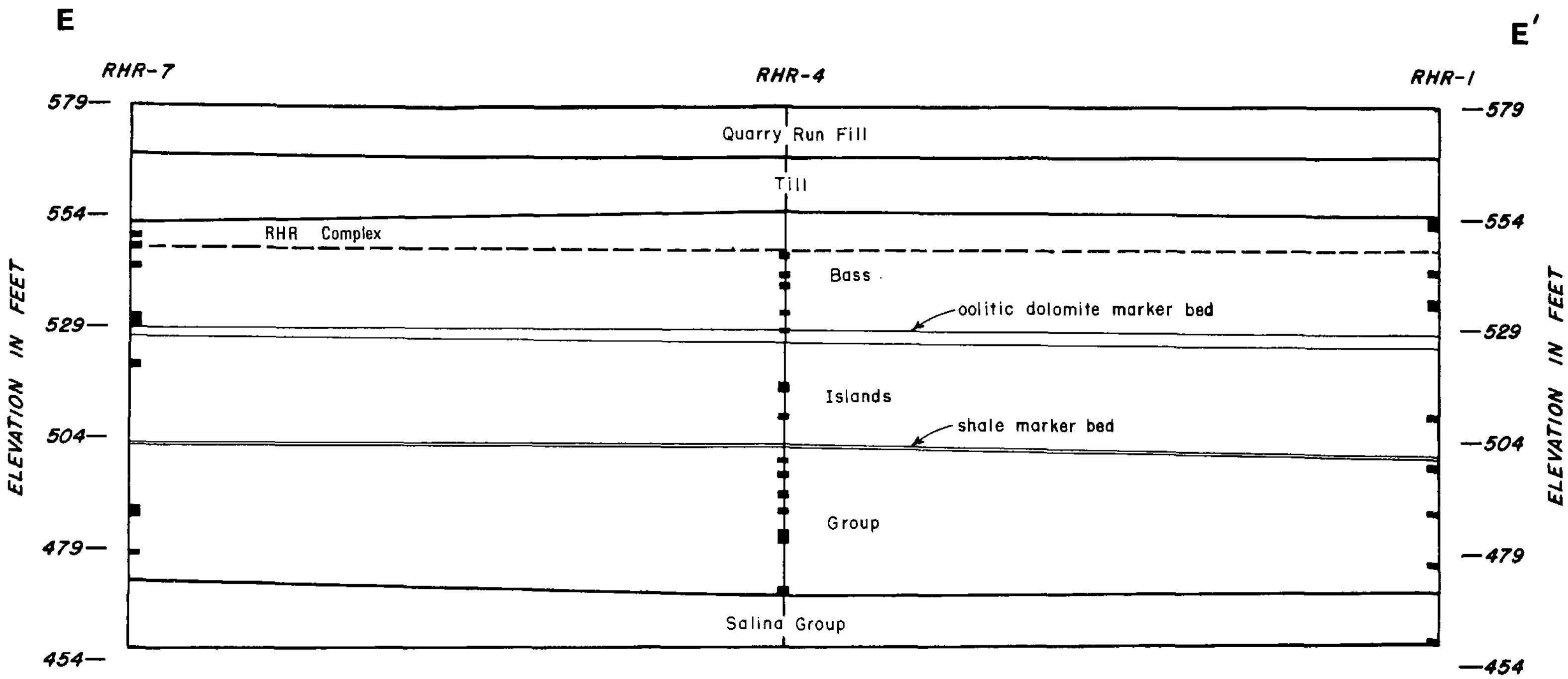
FIGURE 2.5-18

SUBSURFACE SECTION D-D' FROM FIGURE 2.5-14



SECTION E - E'

LEGEND:
■ FRAGMENTED ZONE

NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935.
SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.
THE DEPTH AND THICKNESS OF THE SOIL STRATA AND THE DEPTH OF THE ROCK STRATA INDICATED ON THE SUBSURFACE SECTION WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORING LOCATIONS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

25 0 25
SCALE IN FEET

REFERENCE
PLATE 6A

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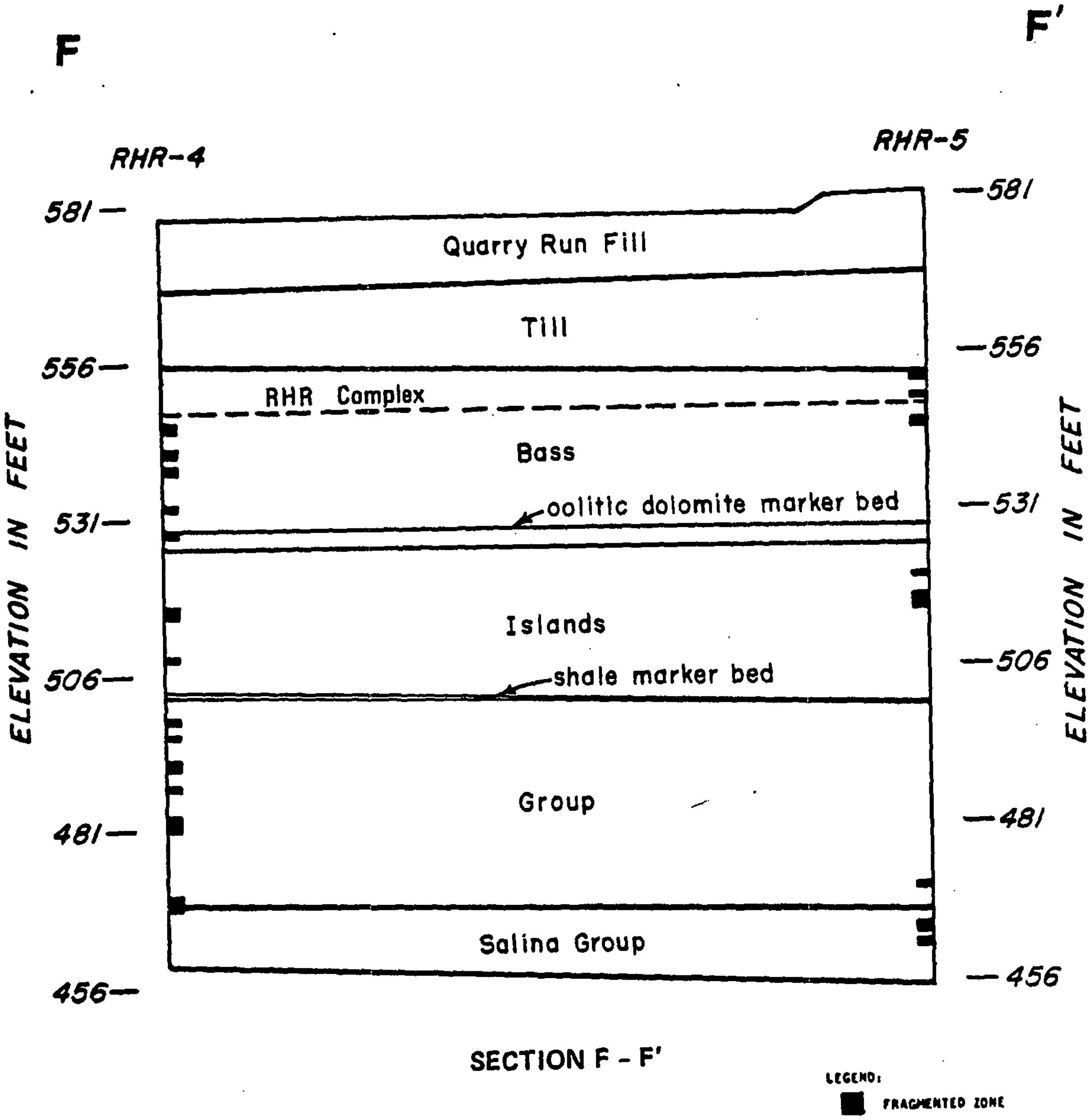
FIGURE 2.5-19

SUBSURFACE SECTION E-E' FROM FIGURE 2.5-14

REV 1 3/88



SECTION F - F'

NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935.

SURFACE ELEVATIONS ARE CORRECT ONLY AT TEST BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SOIL STRATA AND THE DEPTH OF THE ROCK STRATA INDICATED ON THE SUBSURFACE SECTION WERE OBTAINED BY INTERPOLATING BETWEEN TEST BORINGS. INFORMATION ON ACTUAL SOIL AND ROCK CONDITIONS EXISTS ONLY AT THE TEST BORING LOCATIONS AND IT IS POSSIBLE THAT THE SOIL AND ROCK CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

SCALE IN FEET

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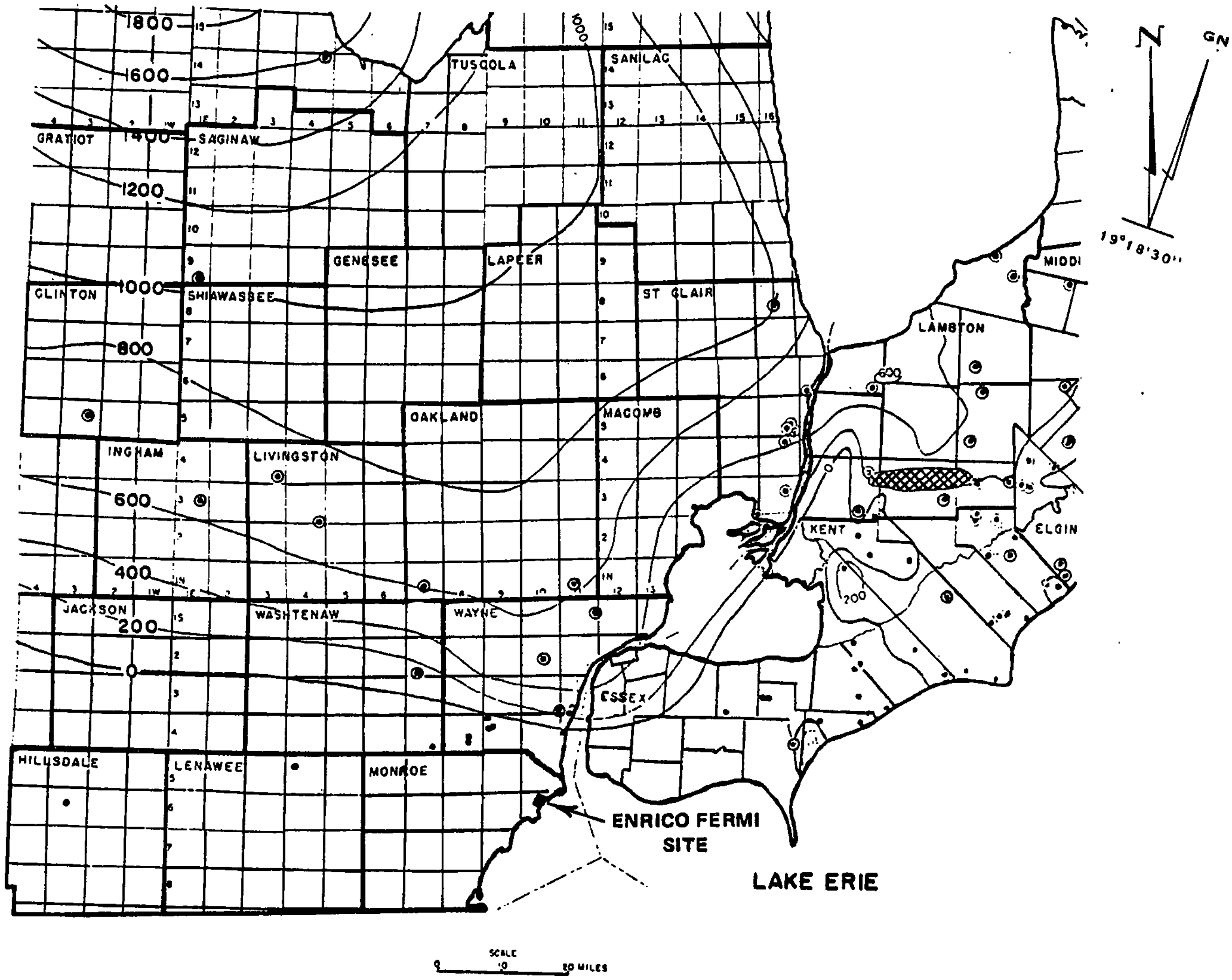
FIGURE 2.5-20

SUBSURFACE SECTION F-F' FROM FIGURE 2.5-14

REFERENCE 3
PLATE 6D



LEGEND:
ISOPACH SHOWING TOTAL THICKNESS OF SALT. ISOPACH INTERVAL 200 FEET.

- WELL REPORTING SALT IN SALINA FORMATION
- WELL WITH NO SALT IN SALINA FORMATION
- DAWN GAS FIELD, SALT 0 TO OVER 300 FEET THICK

0 10 20
SCALE IN MILES

REFERENCE:
LANDES, K. K., 1945, THE SALINA AND BASS ISLANDS ROCK IN THE MICHIGAN BASIN: USGS., PRELIMINARY DM-40, OIL AND GAS INV. SER.

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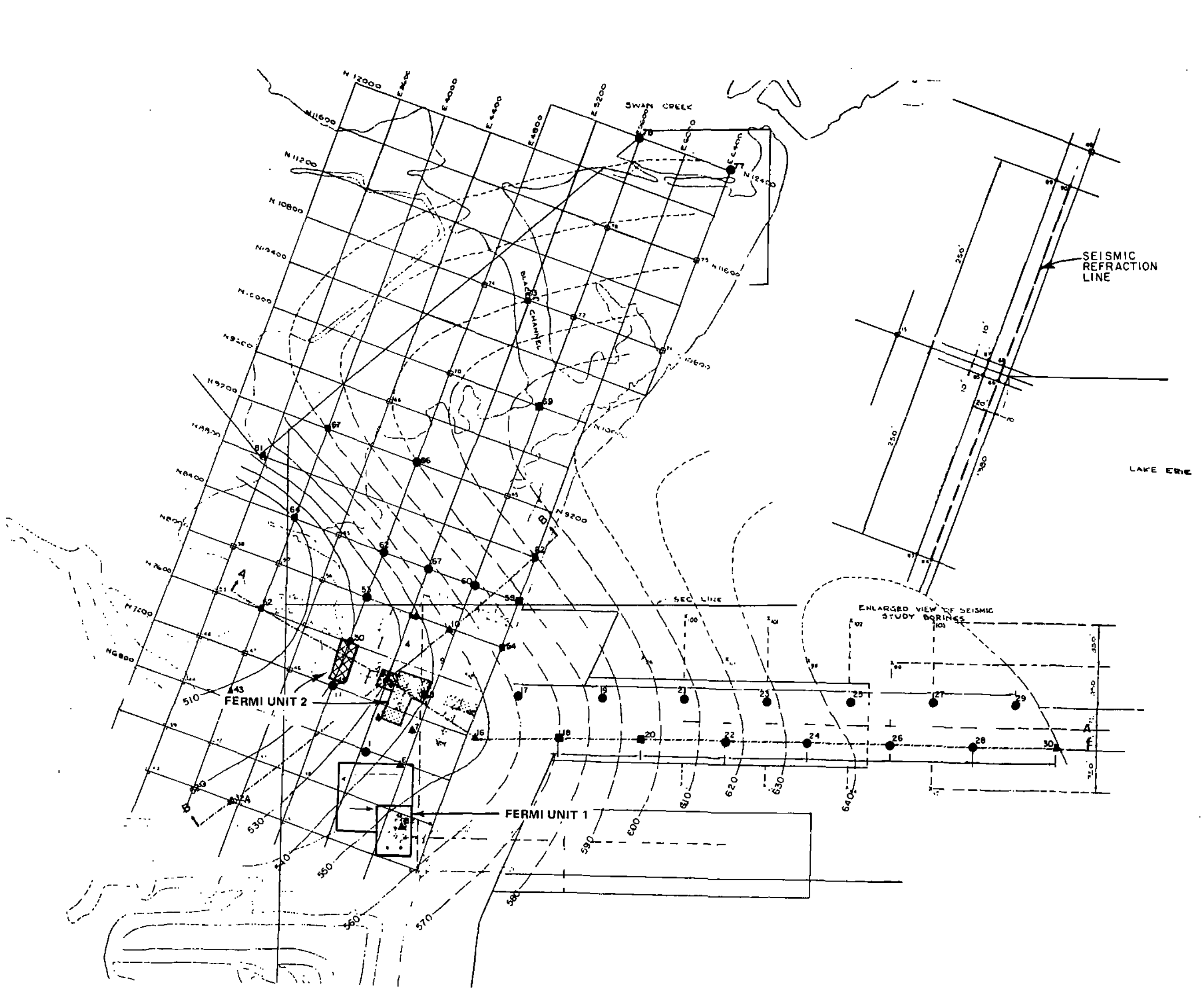
FIGURE 2.5-21

ISOPACH MAP – TOTAL THICKNESS OF SALT IN SALINA FORMATION IN SOUTHEASTERN MICHIGAN



LEGEND:

STRUCTURAL CONTOURS ON BASE OF OOLITIC DOLOMITE MARKER MARKER BED OF THE BASS ISLANDX S GROUP

- ——— COUNTOURS DRAWN FROM DIRECT OOLITIC MARKER BED CONTROL
- — — — CONTOURS PROJECTED TO OOLITIC MARKER BED FROM OTHER RECOGNIZABLE STRATIGRAPHIC CONTACTS
- ------ INFERRED CONTOURS
- ▲ BORINGS IN WHICH OOLITIC DOLOMITE MARKER BED IS ENCOUNTERED
- ■ BORINGS IN WHICH A RECOGNIZABLE CONTACT OR MARKER BED IS ENCOUNTERED
- ● BORINGS IN WHICH A RECOGNIZABLE STRATIGRAPHIC INTERVAL IS ENCOUNTERED
- -.-.-.- INDICATES SUBSURFACE SECTION SHOWN ON FIGURES 2.5-15 AND 2.5-16.

NOTE:
CONTOUR INTERVAL IS 10 FEET.
GRID SYSTEM IS THAT USED FOR PLANT AREA BY DETROIT EDISON COMPANY.

REFERENCE:
MAP PREPARED FROM DRAWING 6MS721-40 BY THE DETROIT EDISON COMPANY ENGINEERING DESIGN AND SERVICES DEPARTMENT.

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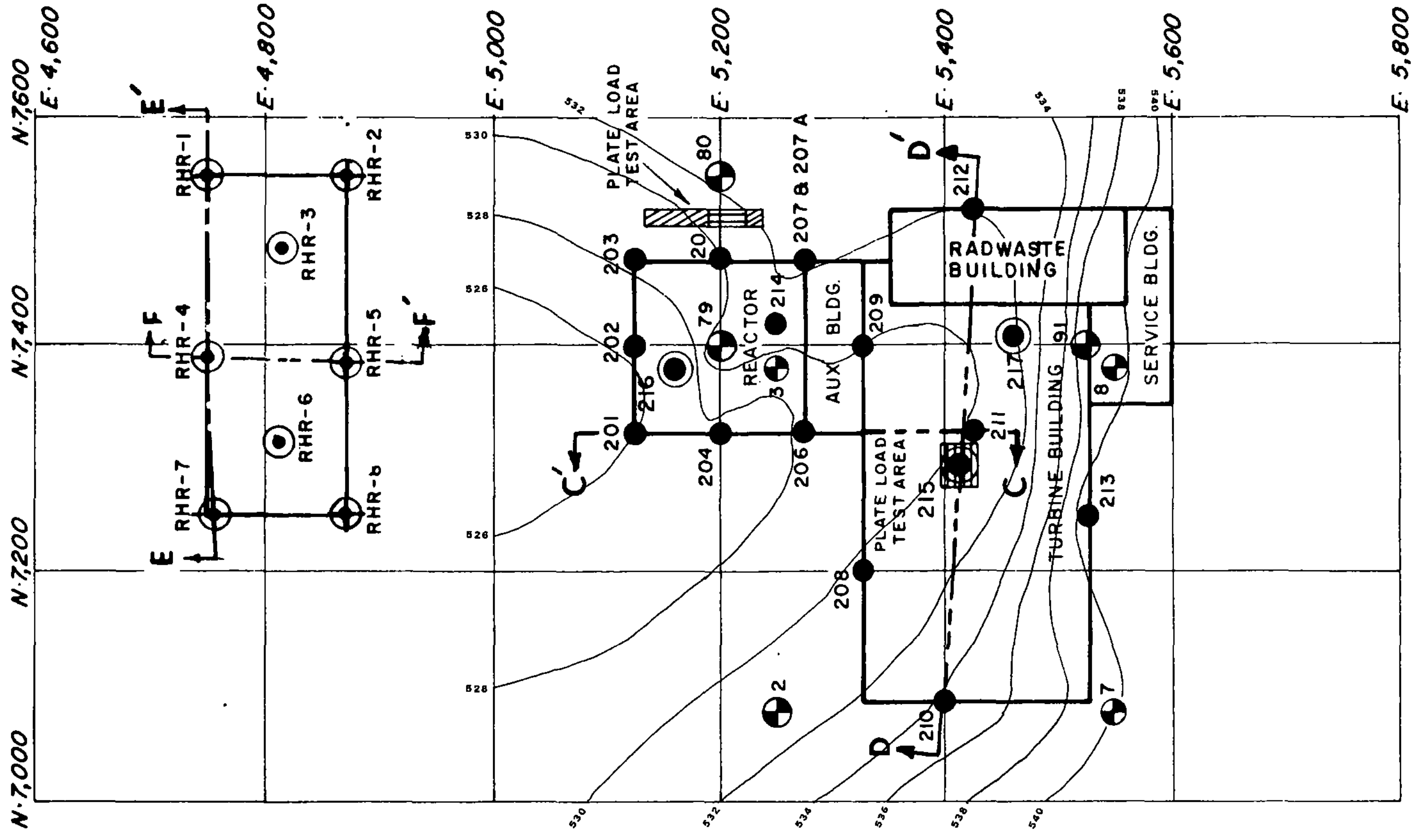
FIGURE 2.5-22

STRUCTURAL CONTOUR MAP OF SITE VICINITY



LEGEND:

540 STRUCTURAL CONTOURS ON THE BASE OF THE OOLITIC DOLOMITE MARKER BED OF THE BASS ISLANDS GROUP

BORINGS DRILLED IN 1968; OOLITIC MARKER BED ENCOUNTERED

BORINGS DRILLED IN 1969; OOLITIC MARKER BED ENCOUNTERED

INDICATES SUBSURFACE SECTION

△ BORINGS DRILLED IN 1968 (LOG NOT PRESENTED WITH REPORT)

0 50 100 200

SCALE IN FEET

NOTE:

CONTOUR INTERVAL IS TWO FEET
ELEVATIONS REFER TO U.S.G.S. DATUM

REFERENCE 45
PLATE 1

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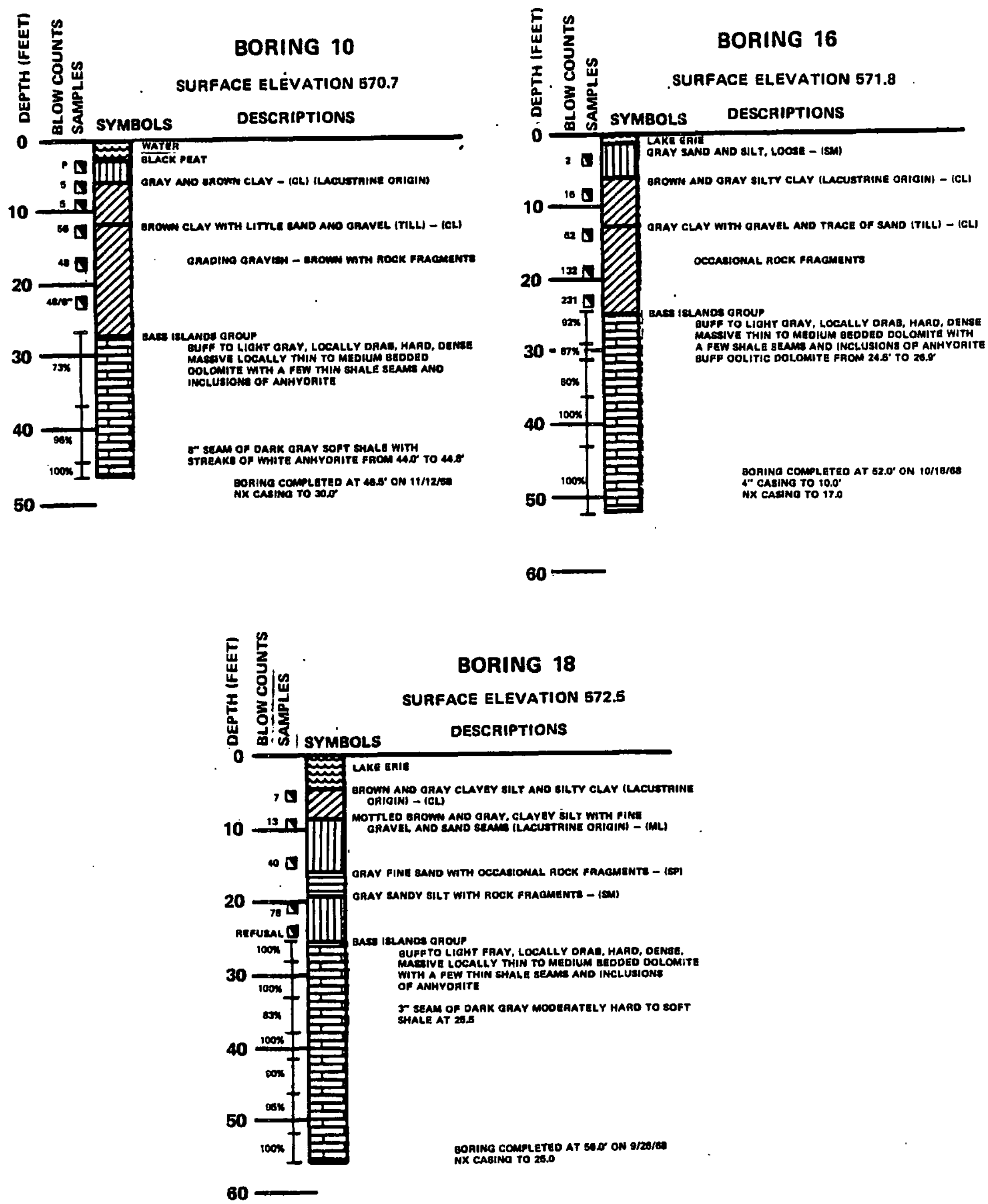
UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-23

STRUCTURAL CONTOUR MAP OF SPECIFIC SITE AREA



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER TO TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS NX SIZE EXCEPT WHERE NOTED.

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FIGURE 2.5-24

LOGS OF BORINGS 10, 16, AND 18

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.1

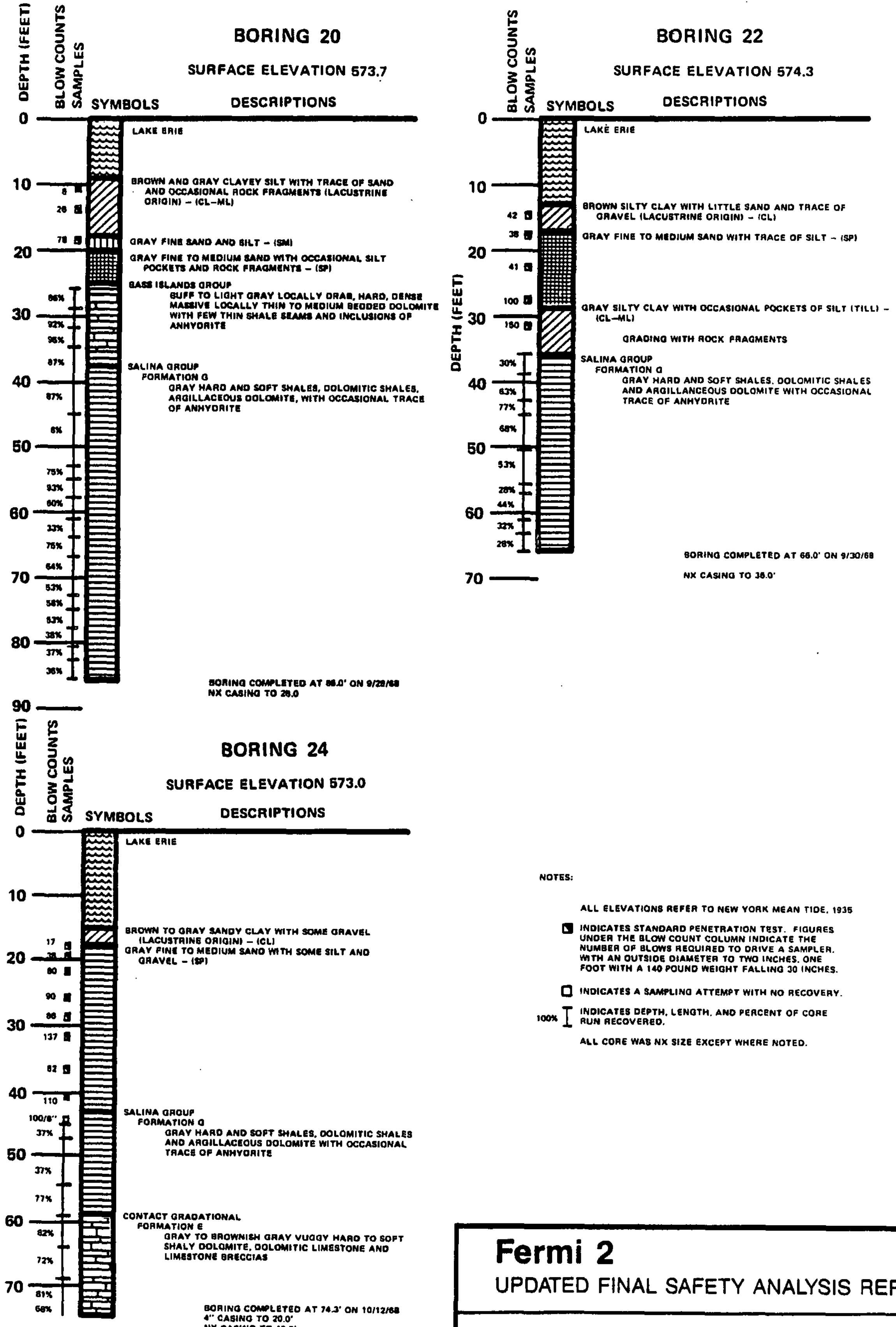

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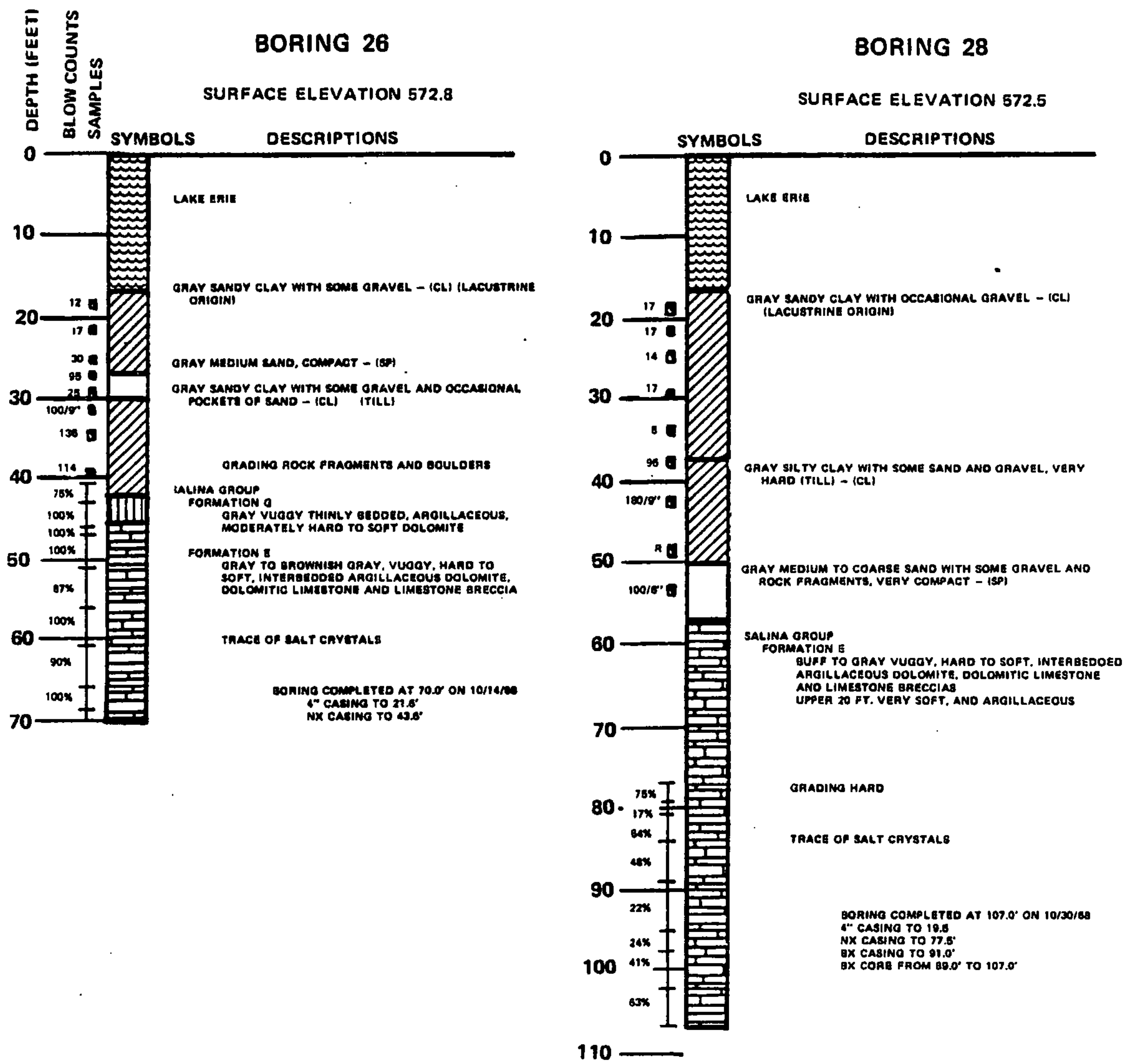
FIGURE 2.5-25

LOGS OF BORINGS 20, 22, AND 24

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.2



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS NX SIZE EXCEPT WHERE NOTED.

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.3

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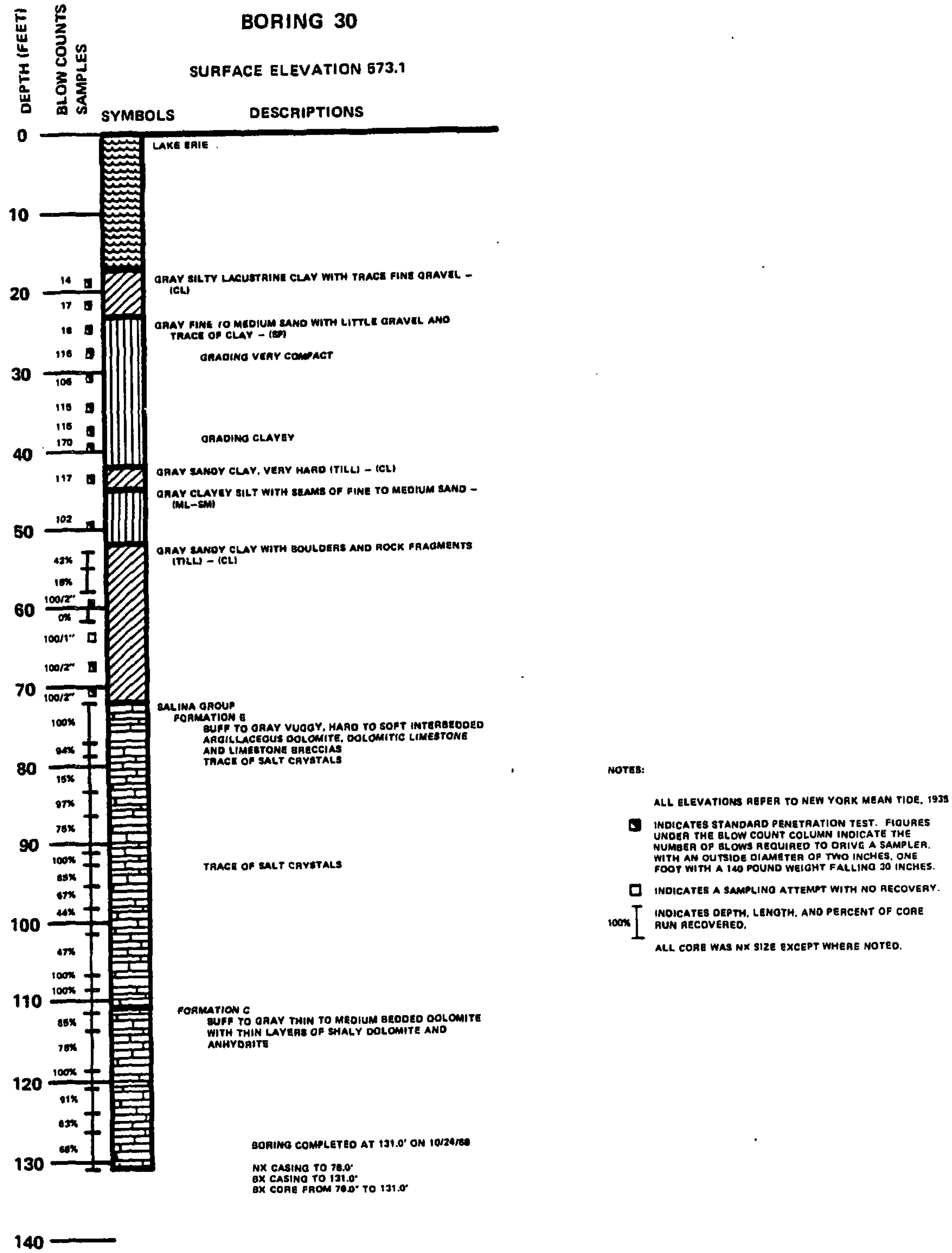
FIGURE 2.5-26

LOGS OF BORINGS 26 AND 28



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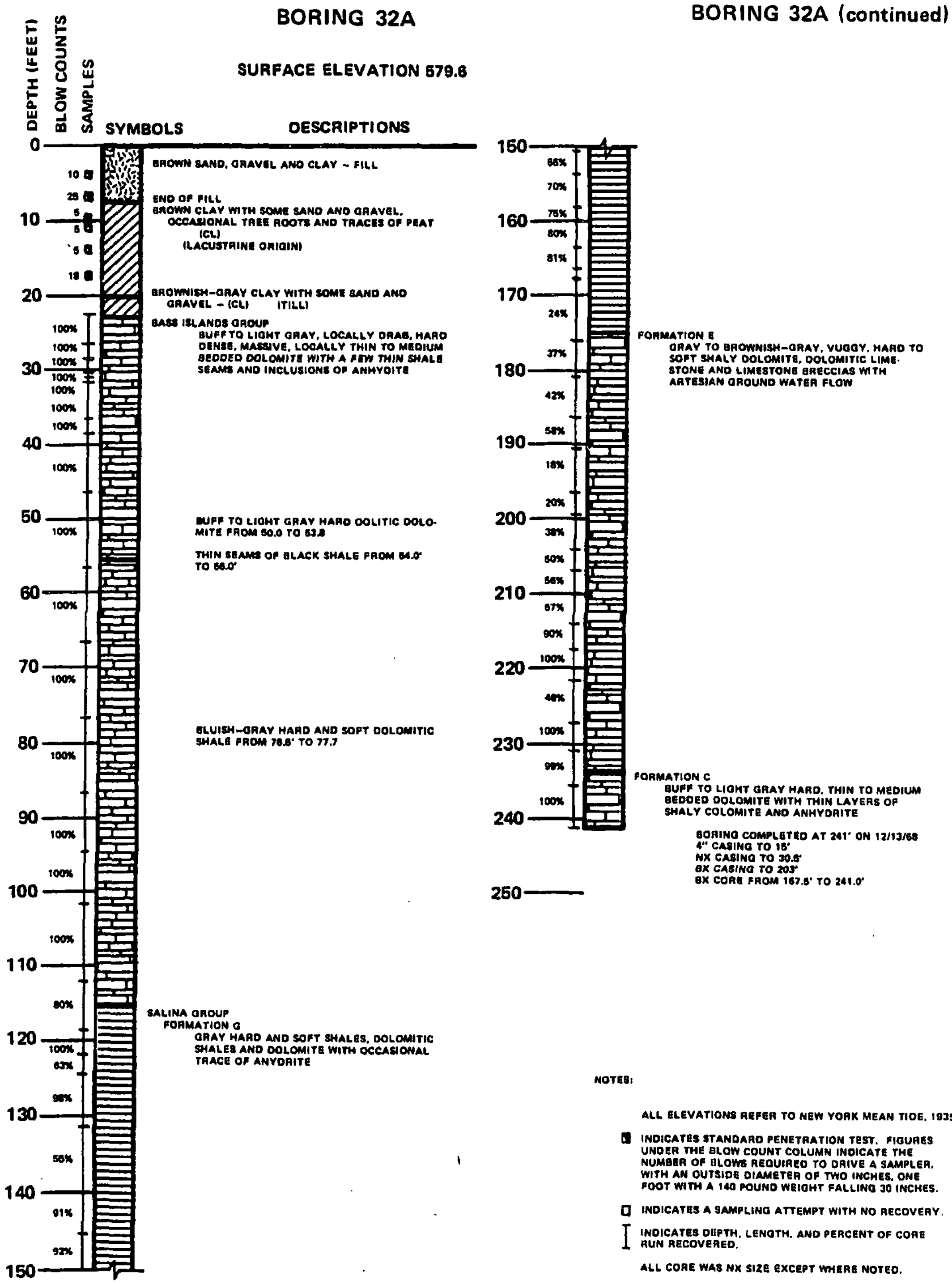
UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-27

LOG OF BORING 30

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.4



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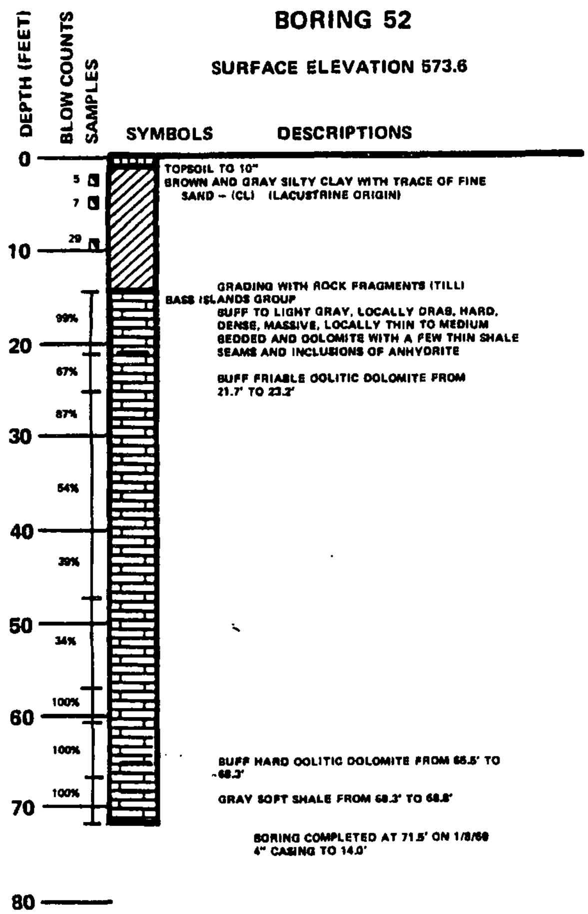
UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-28

LOG OF BORING 32A

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.5



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST, FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS NX SIZE EXCEPT WHERE NOTED.

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.6

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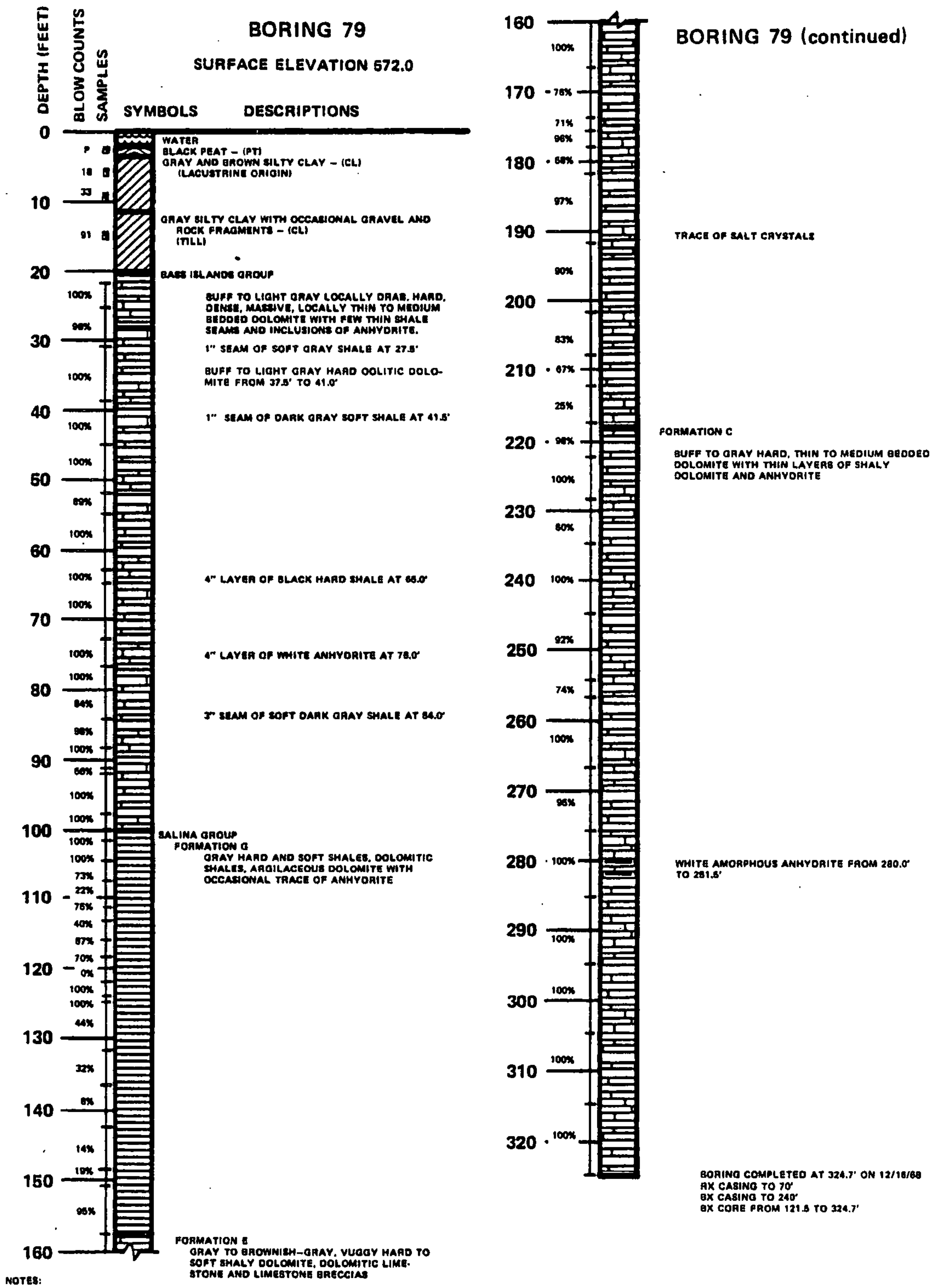
FIGURE 2.5-29

LOG OF BORING 52



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER TO TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS NX SIZE EXCEPT WHERE NOTED.

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.7

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FIGURE 2.5-30

LOG OF BORING 79

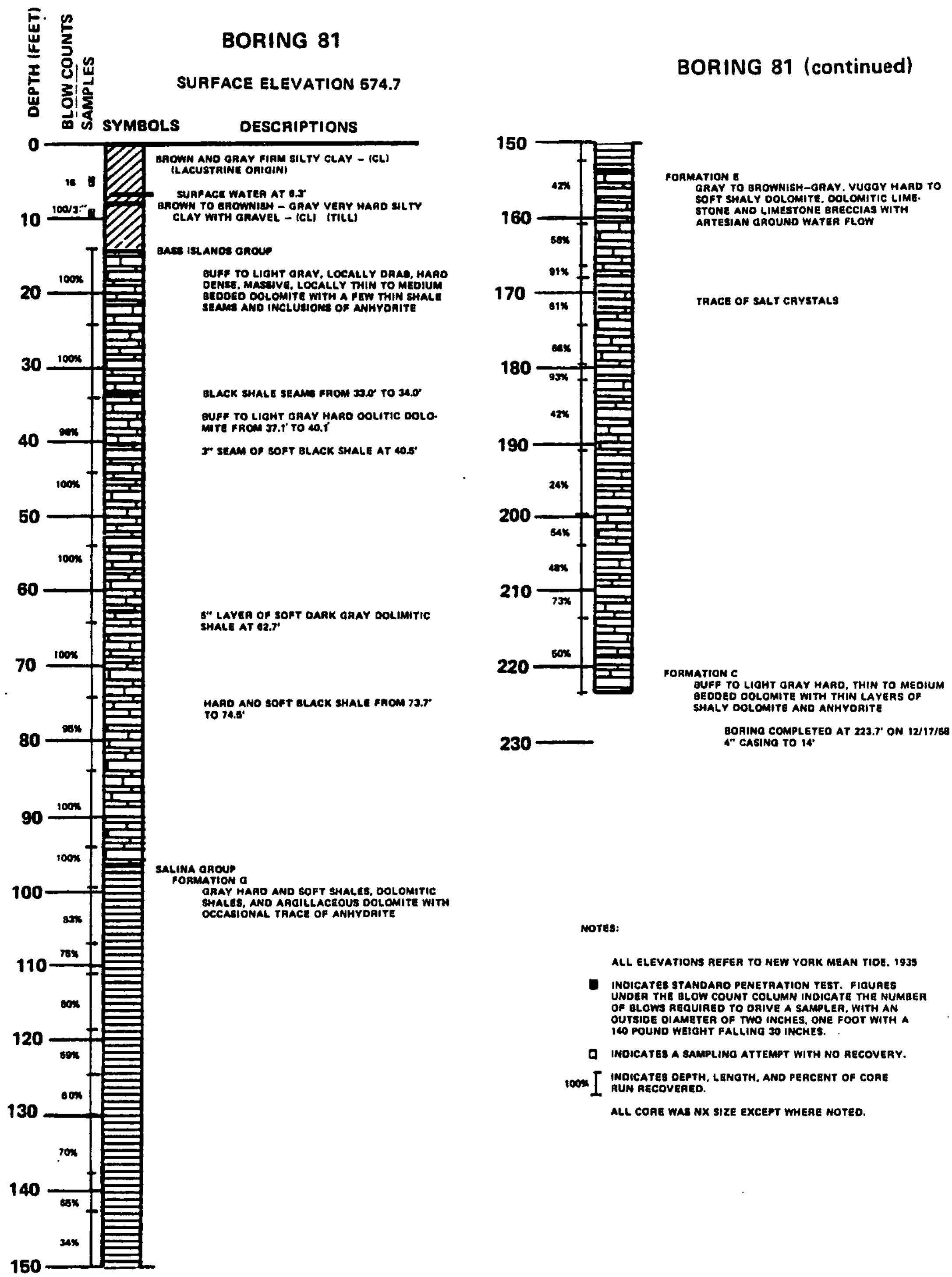

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FIGURE 2.5-31

LOG OF BORING 81

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.8

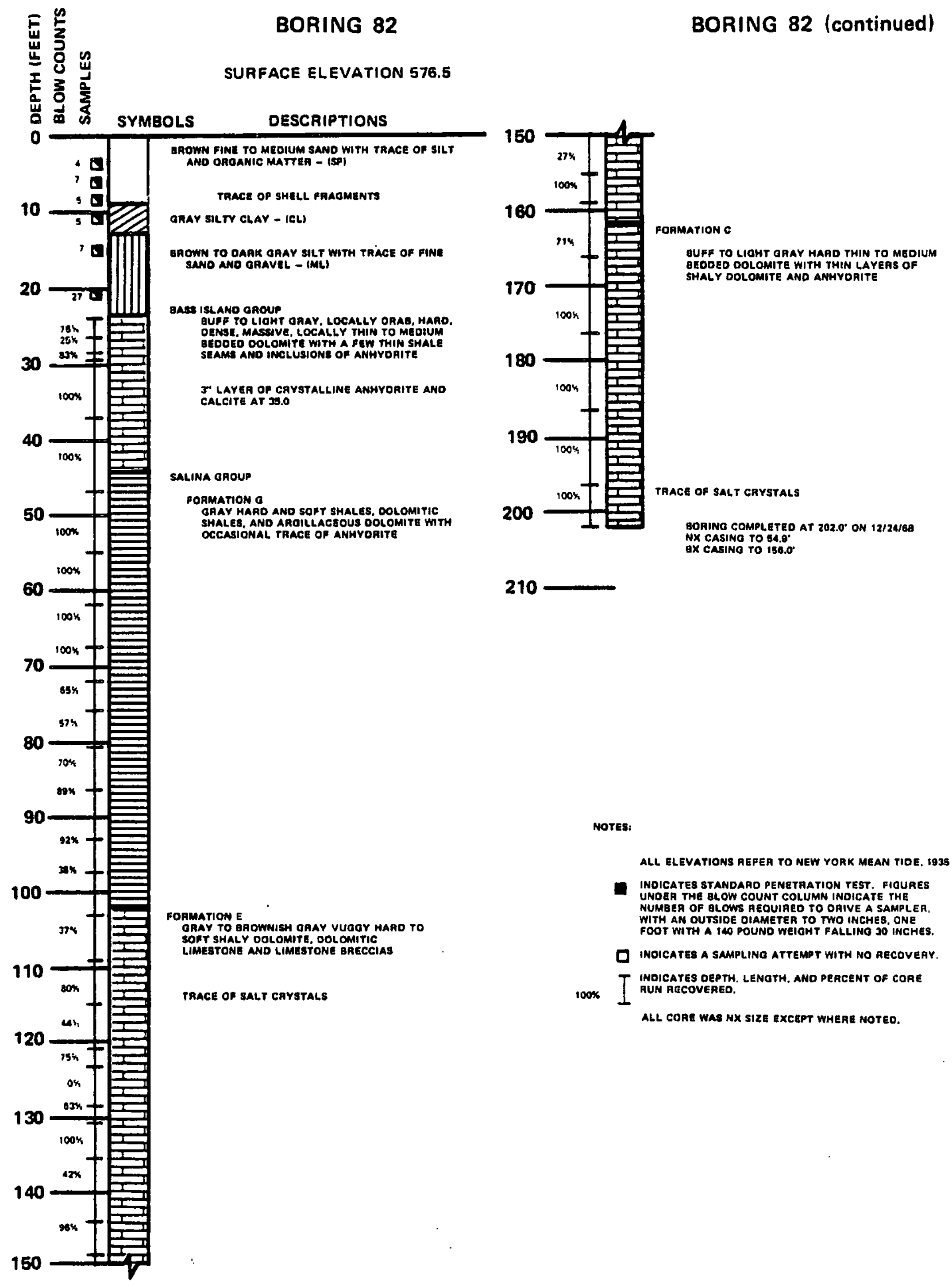

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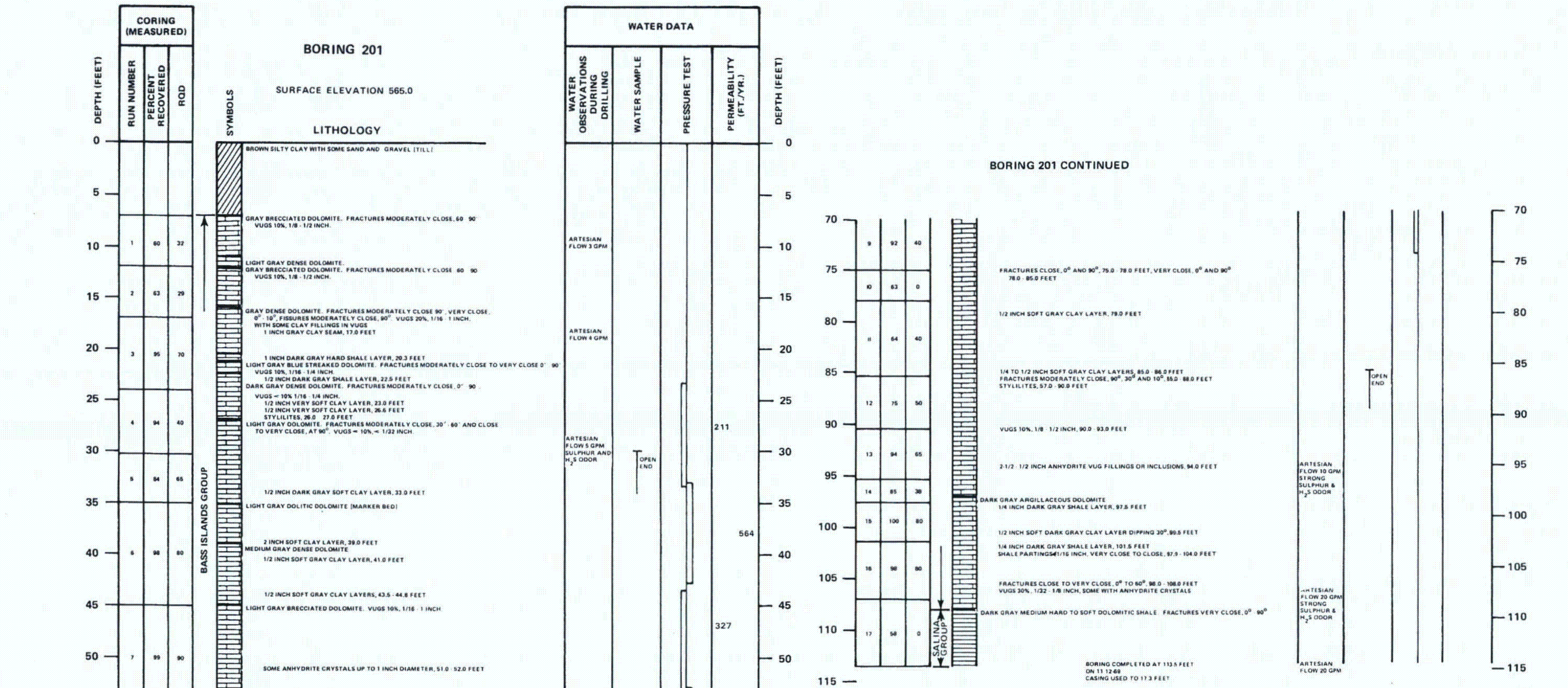
FIGURE 2.5-32

LOG OF BORING 82

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-4.9



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.10 AND 2.5-22.11 REVISED

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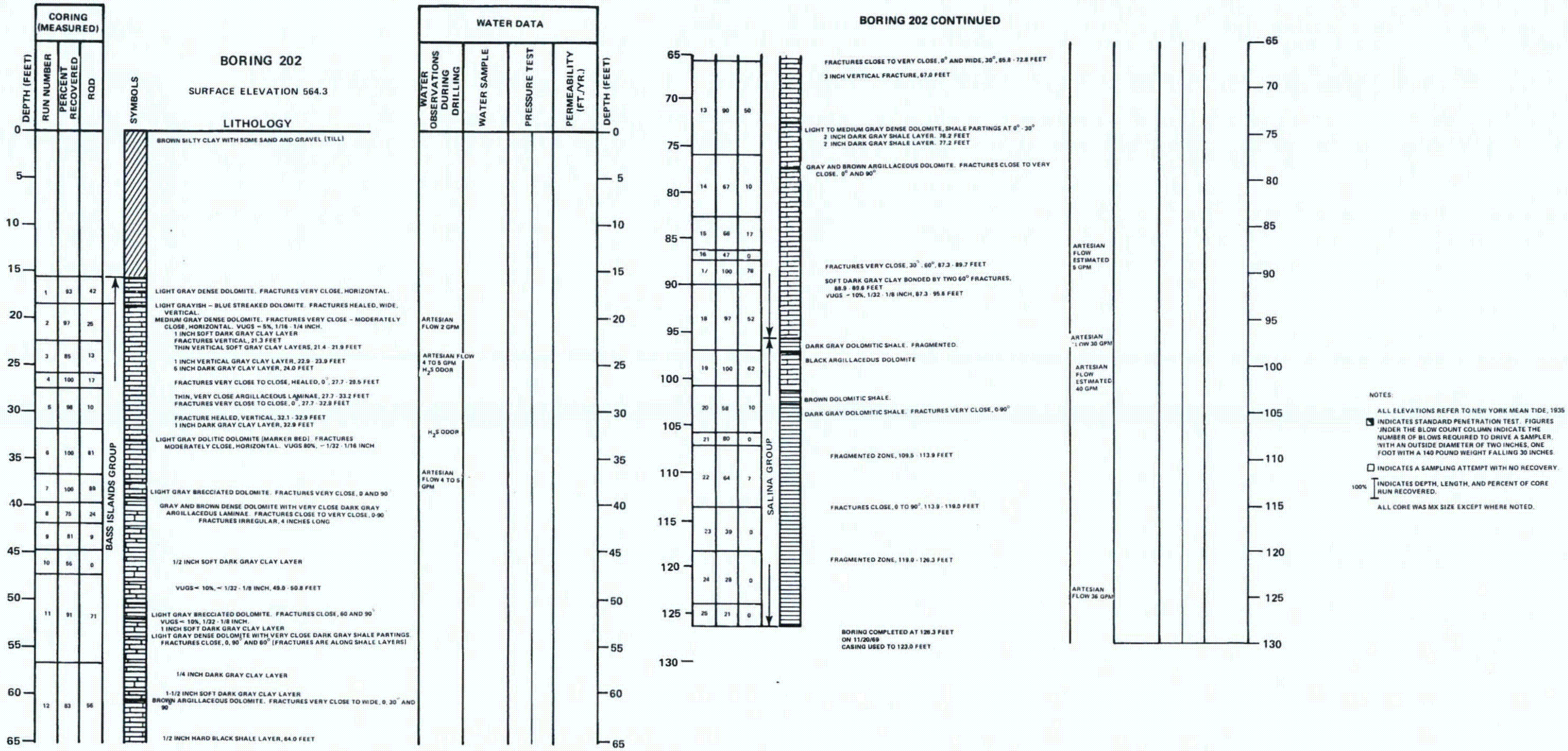
FIGURE 2.5-33

LOG OF BORING 201



Fermi 2

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FIGURE 2.5-34

LOG OF BORING 202

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.12 AND 2.5-22.13

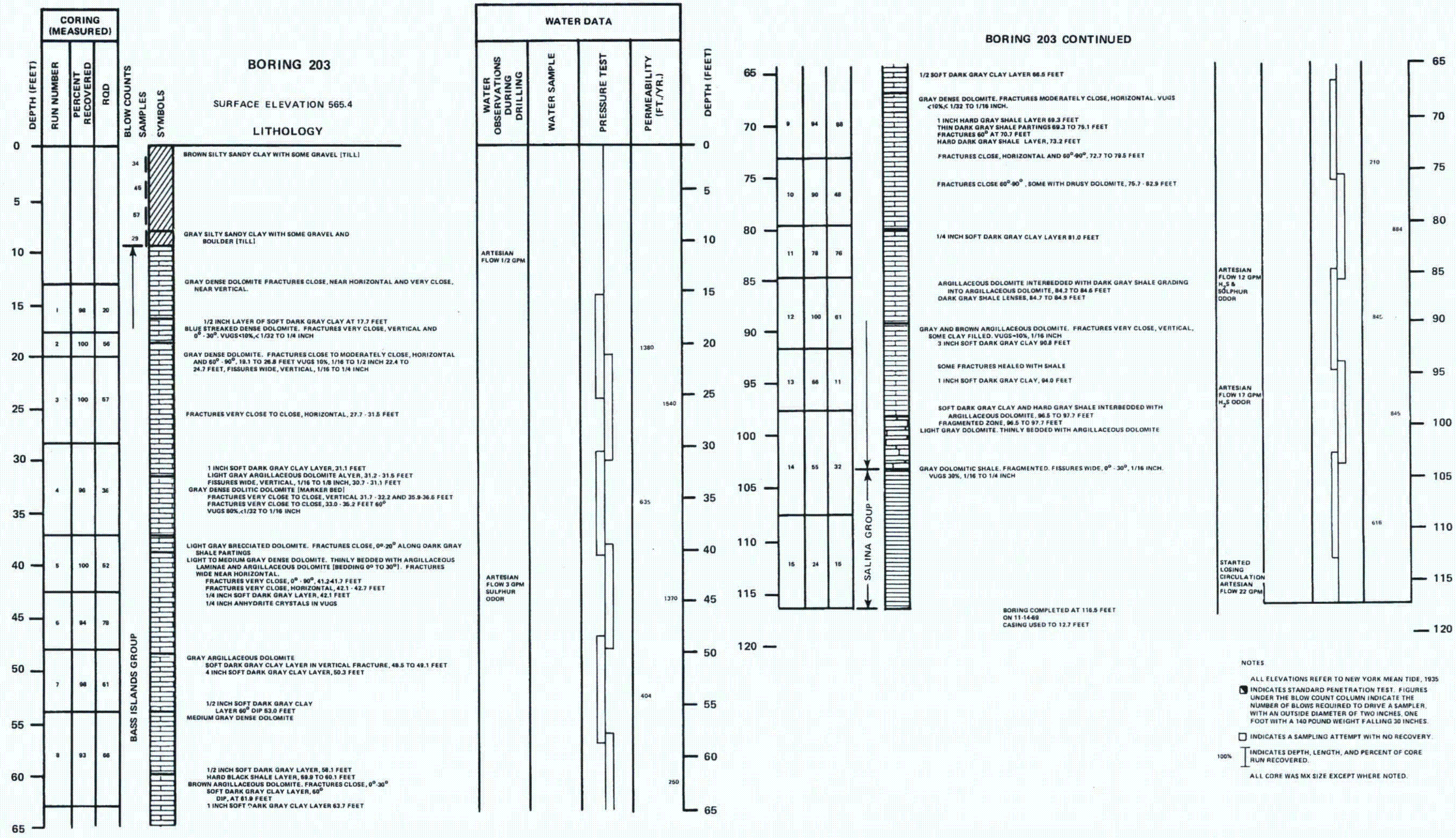

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FIGURE 2.5-35

LOG OF BORING 203

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.14 AND 2.5-22.15

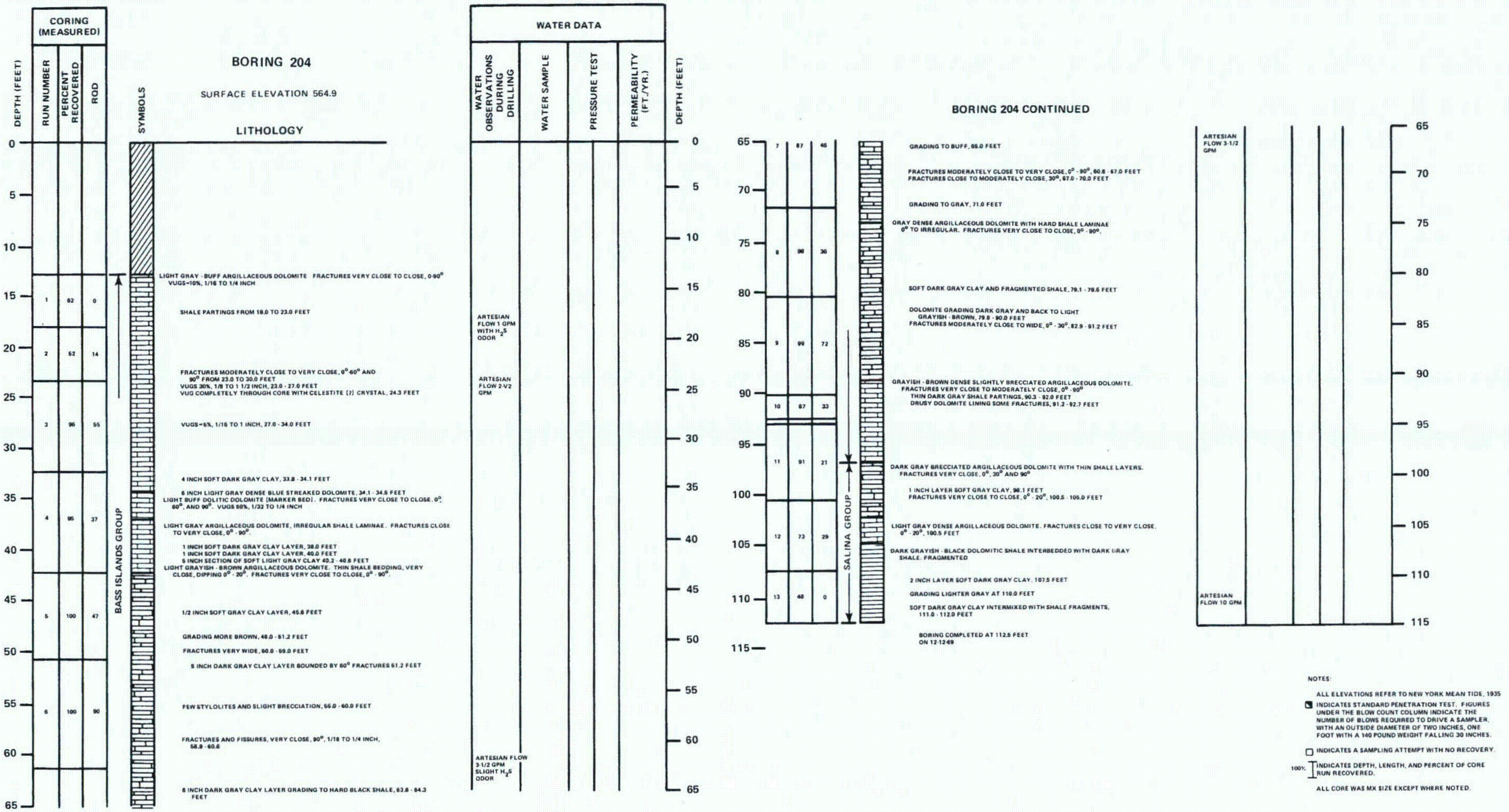

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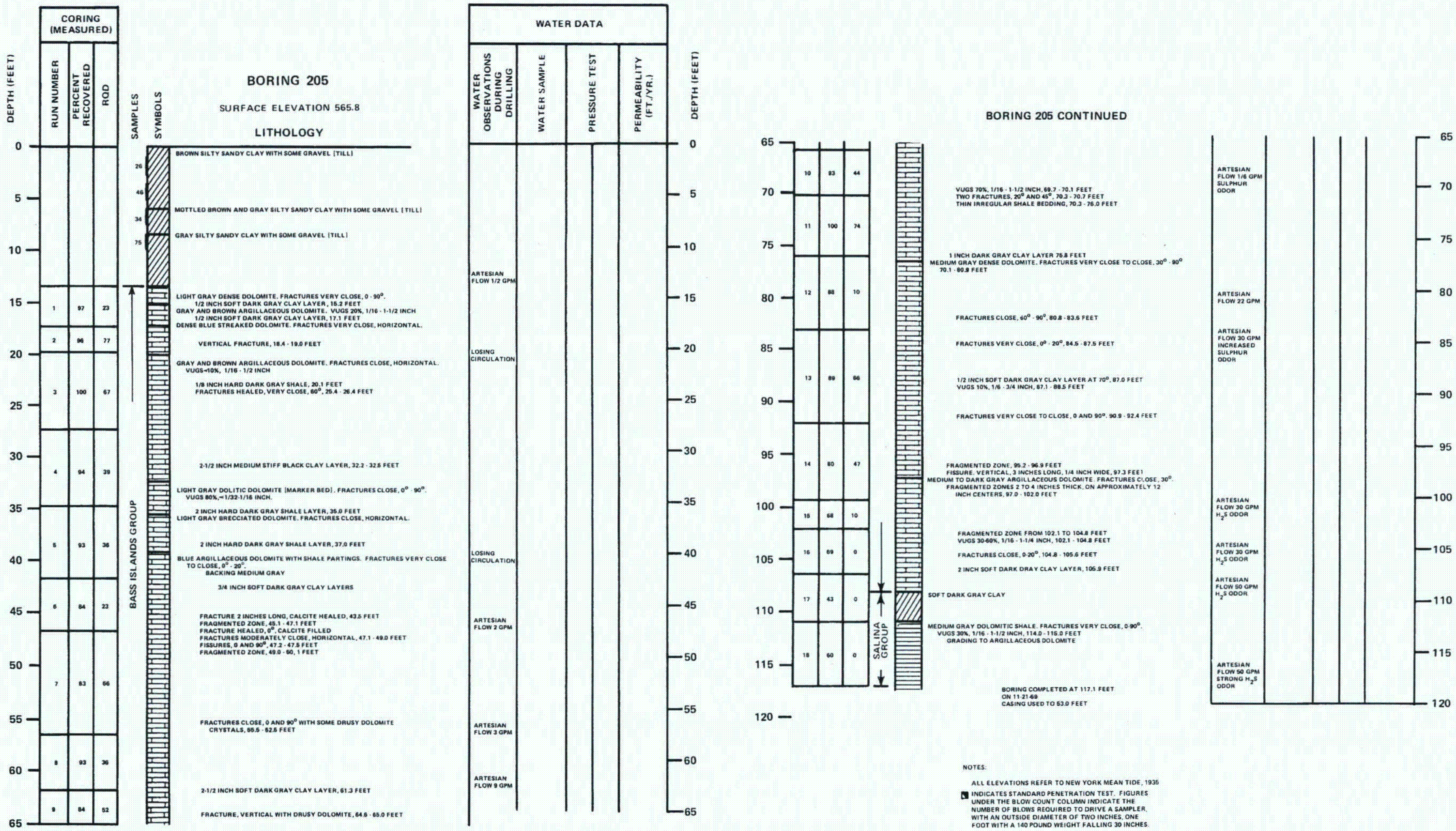
FIGURE 2.5-36

LOG OF BORING 204

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.16 AND 2.5-22.17



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.18 AND 2.5-22.19

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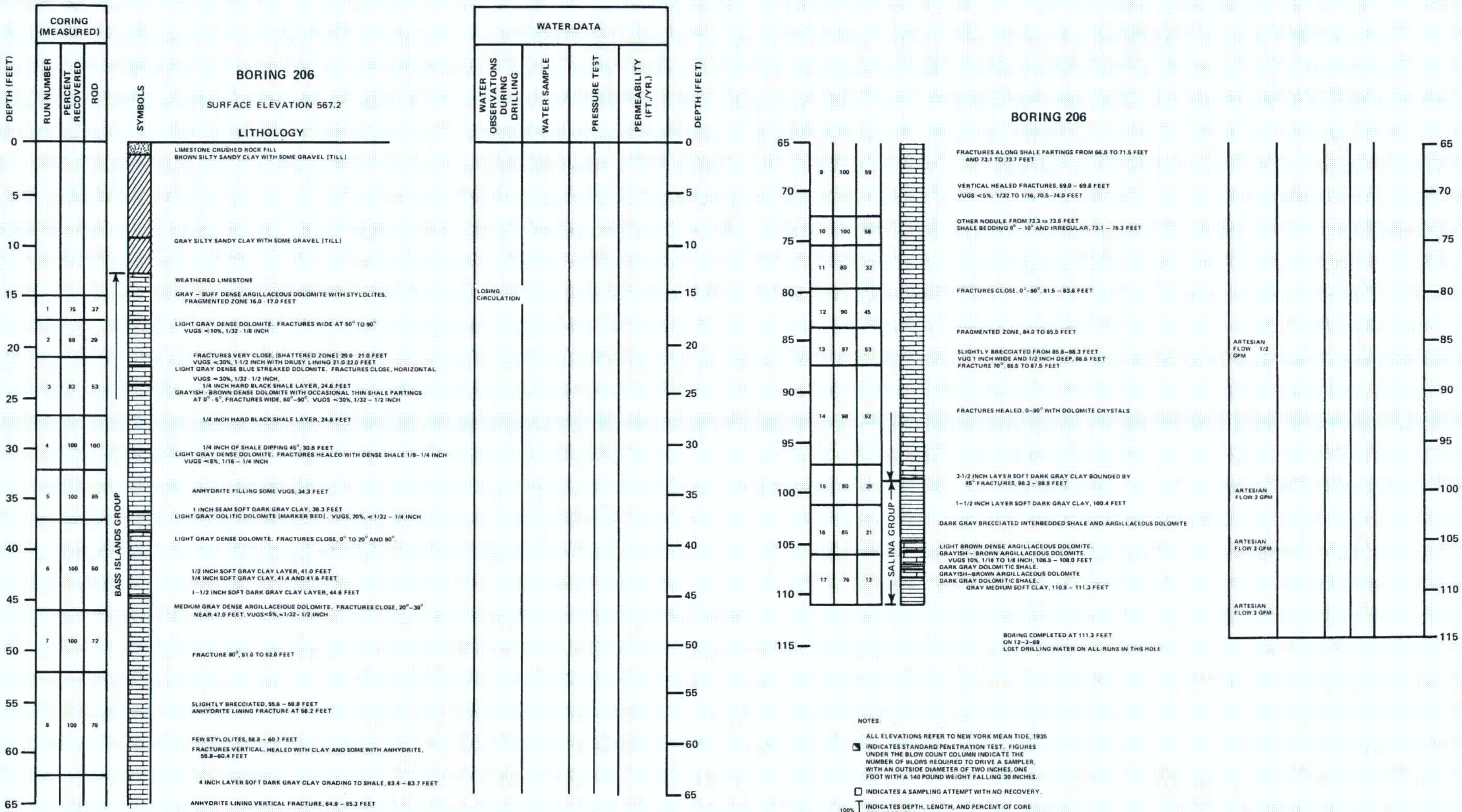
FIGURE 2.5-37

LOG OF BORING 205



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.20 AND 2.5-22.21

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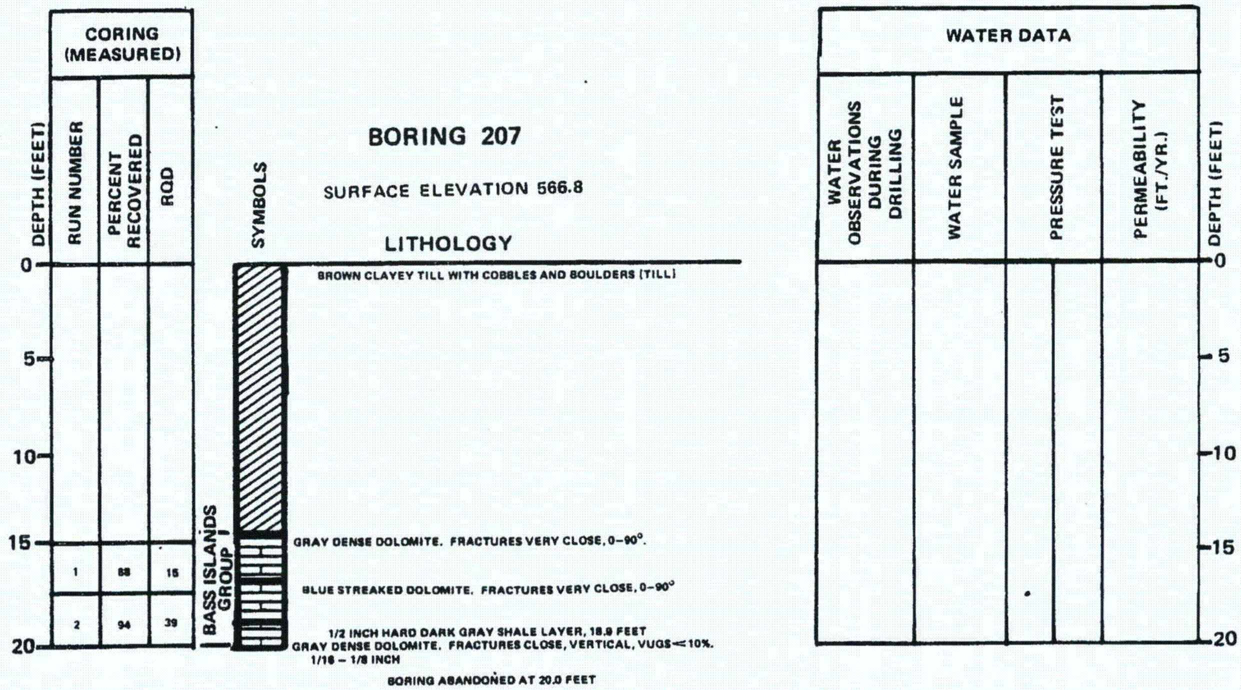
FIGURE 2.5-38

LOG OF BORING 206



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS NX SIZE EXCEPT WHERE NOTED

REFERENCE:
DAMES & MOORE FIGURE 2.5-22.22

Fermi 2
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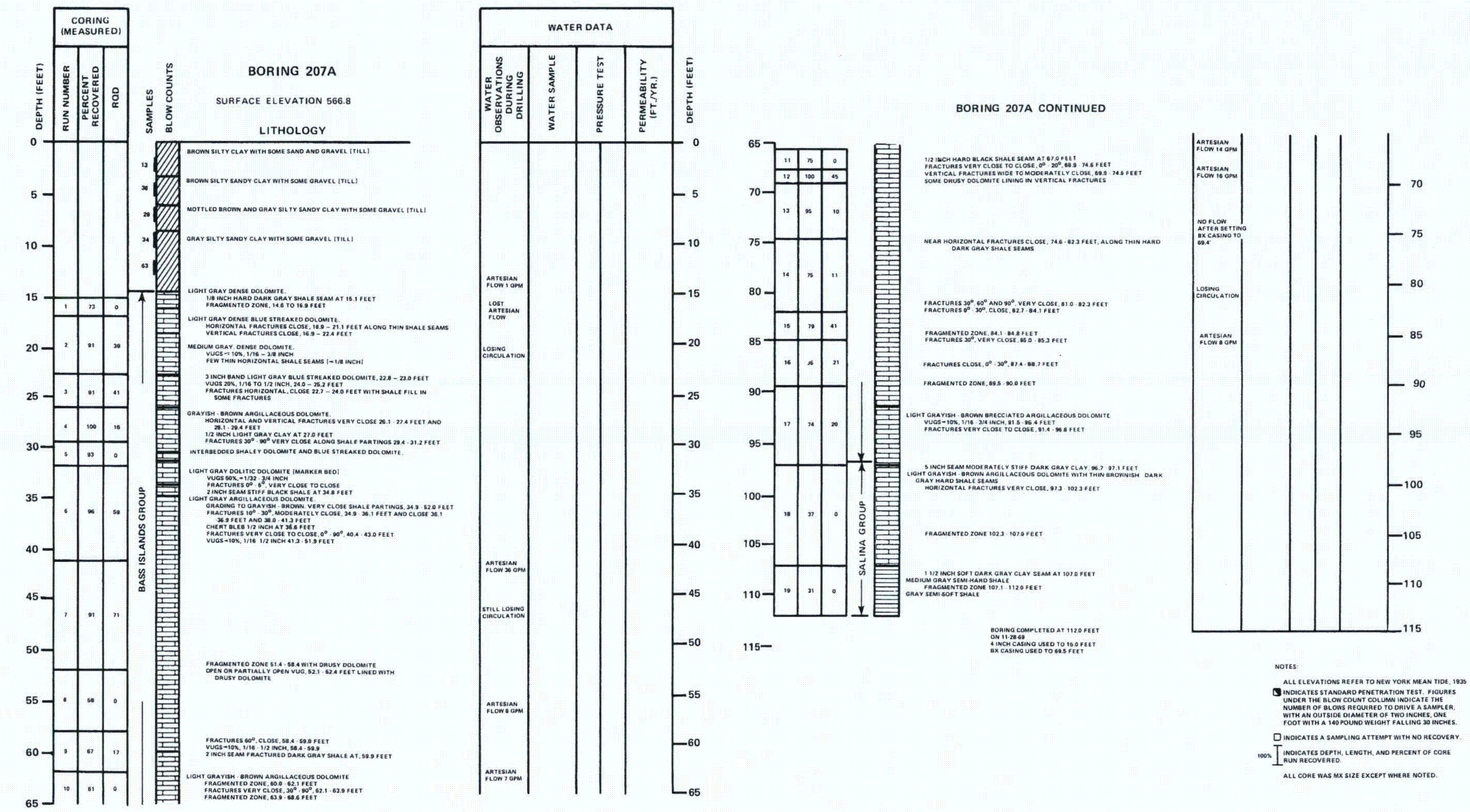
FIGURE 2.5-39

LOG OF BORING 207



REFERENCE:
DAMES & MOORE FIGURES 2.5-22.23 AND 2.5-22.24

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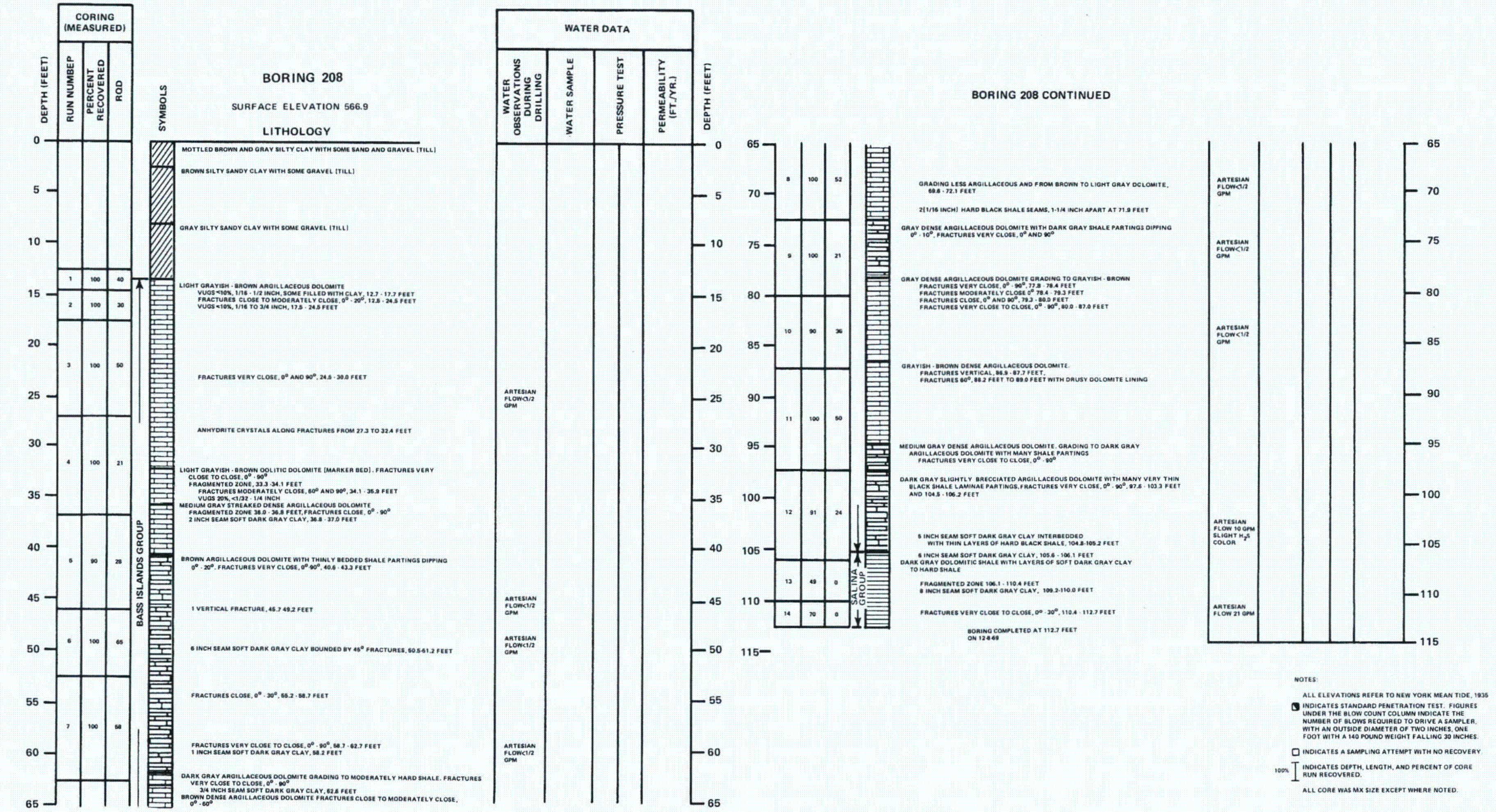
FIGURE 2.5-40

LOG OF BORING 207A



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

■ INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

□ INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY

100% I INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.25 AND 2.5-22.26

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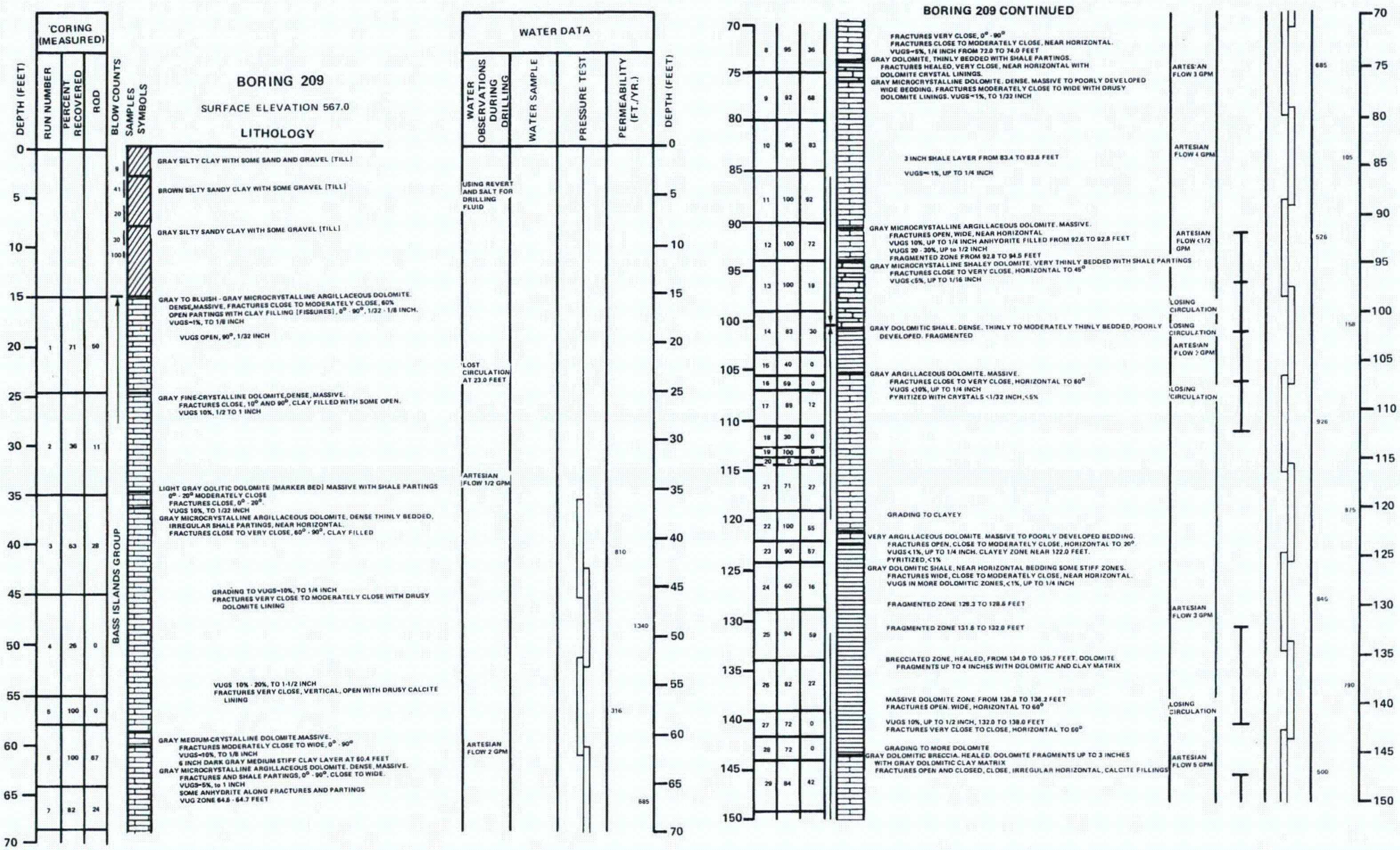
FIGURE 2.5-41

LOG OF BORING 208



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.27 AND 2.5-22.28

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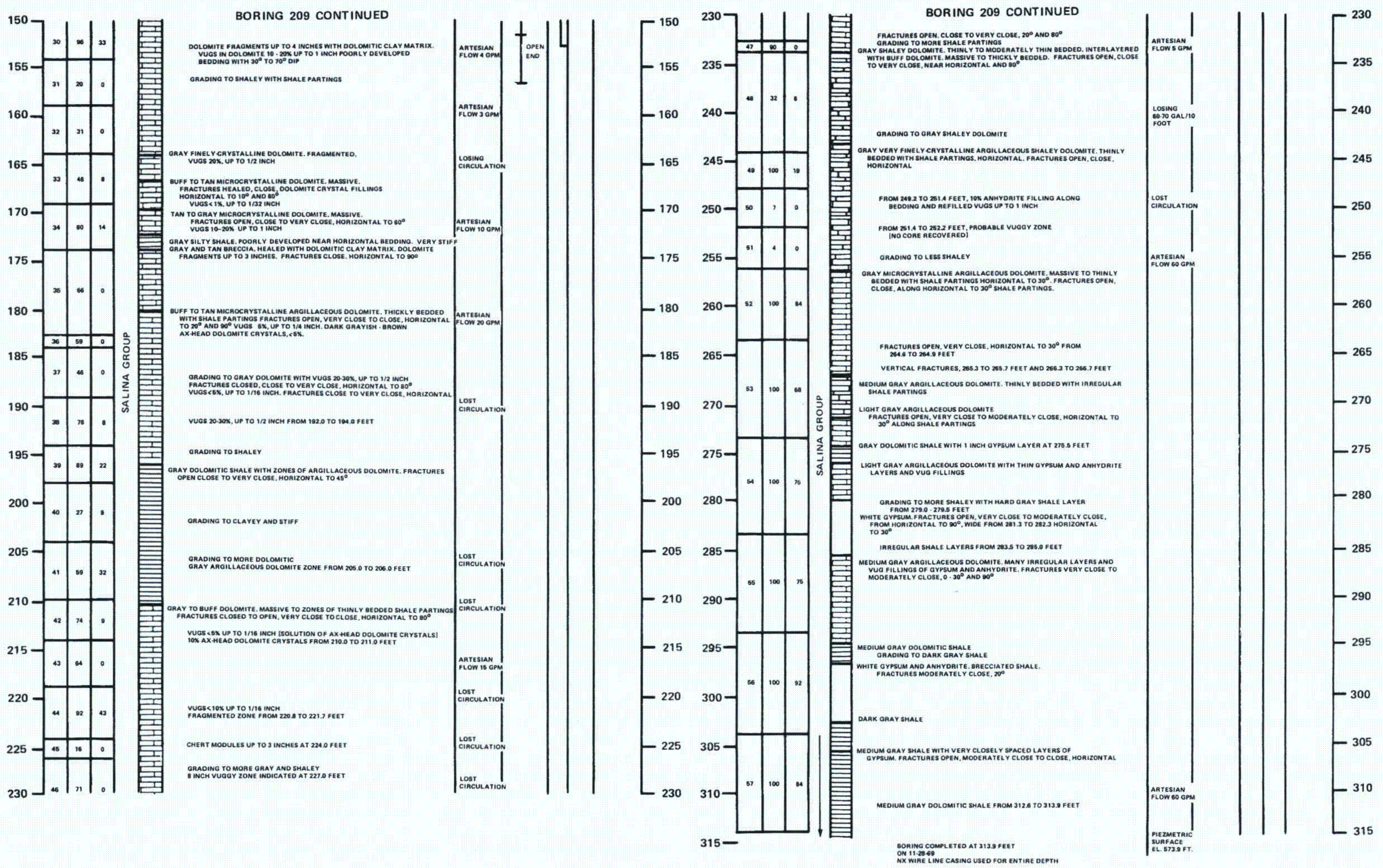
FIGURE 2.5-42, SHEET 1

LOG OF BORING 209



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

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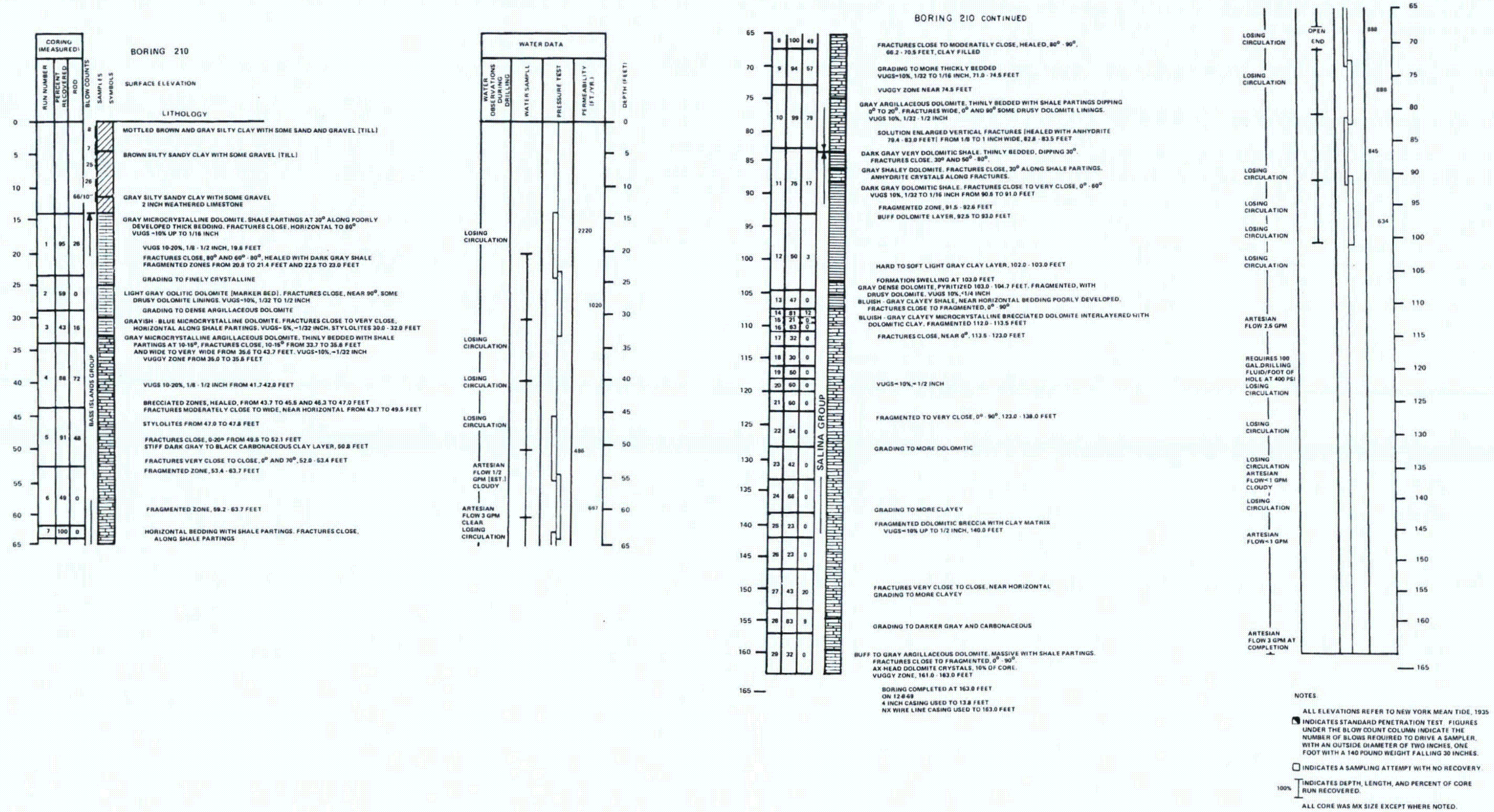
FIGURE 2.5-42, SHEET 2

LOG OF BORING 209

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.29 AND 2.5-22.30



Fermi 2

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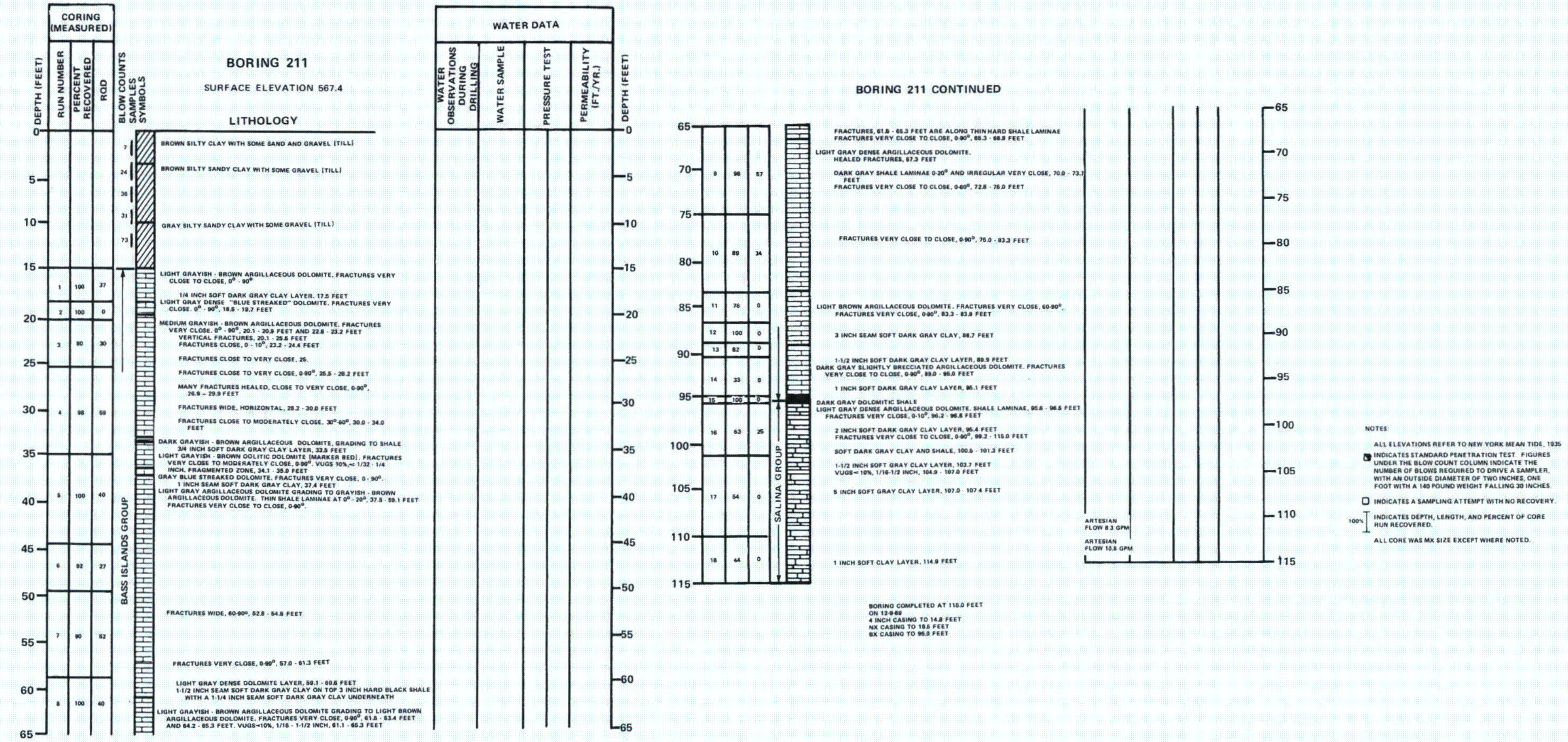
FIGURE 2.5-43

LOG OF BORING 210

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.31, 2.5-22.32 AND 2.5-22.33



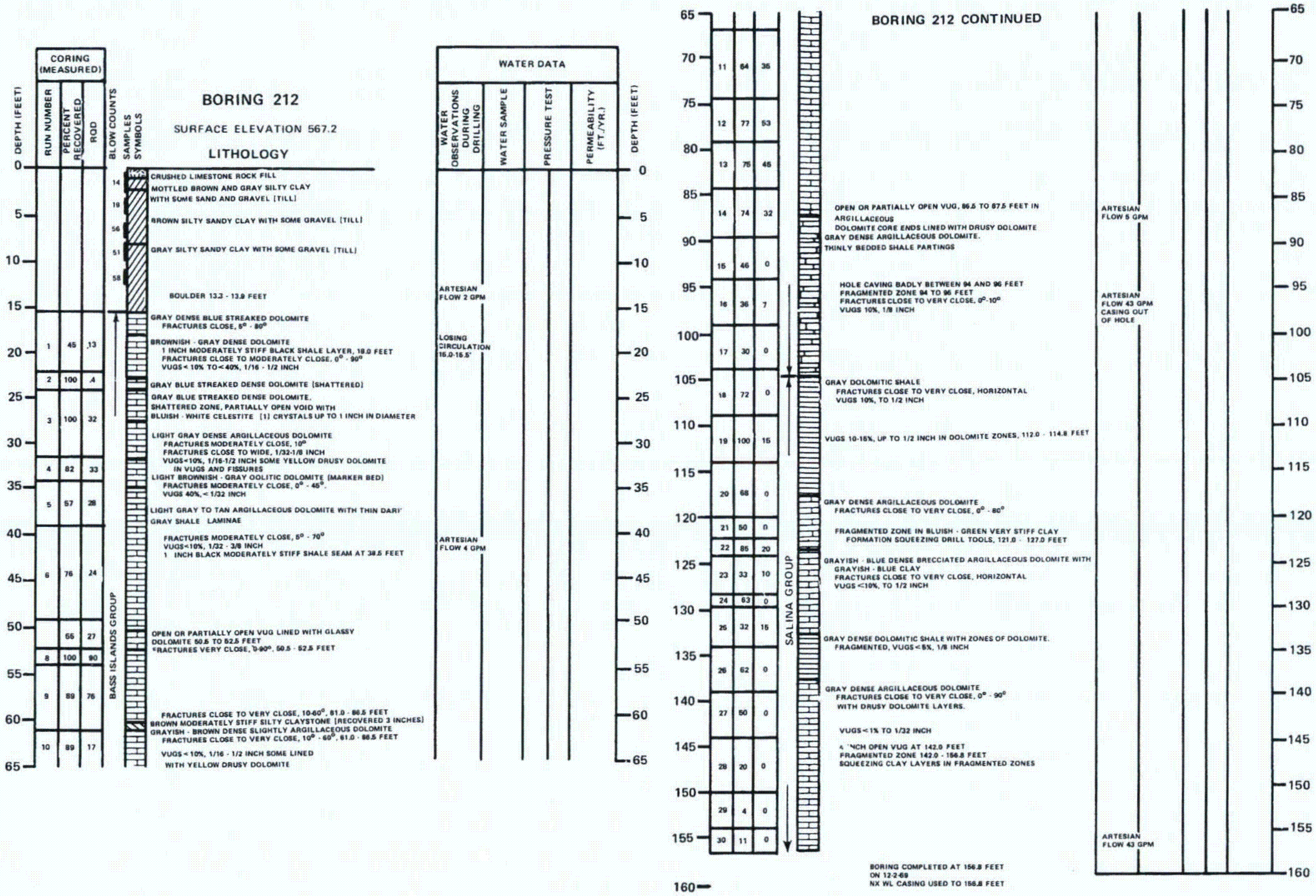
Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-44

LOG OF BORING 211

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.34 AND 2.5-22.35



NOTES

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.36, 2.5-22.37 AND 2.5-22.38

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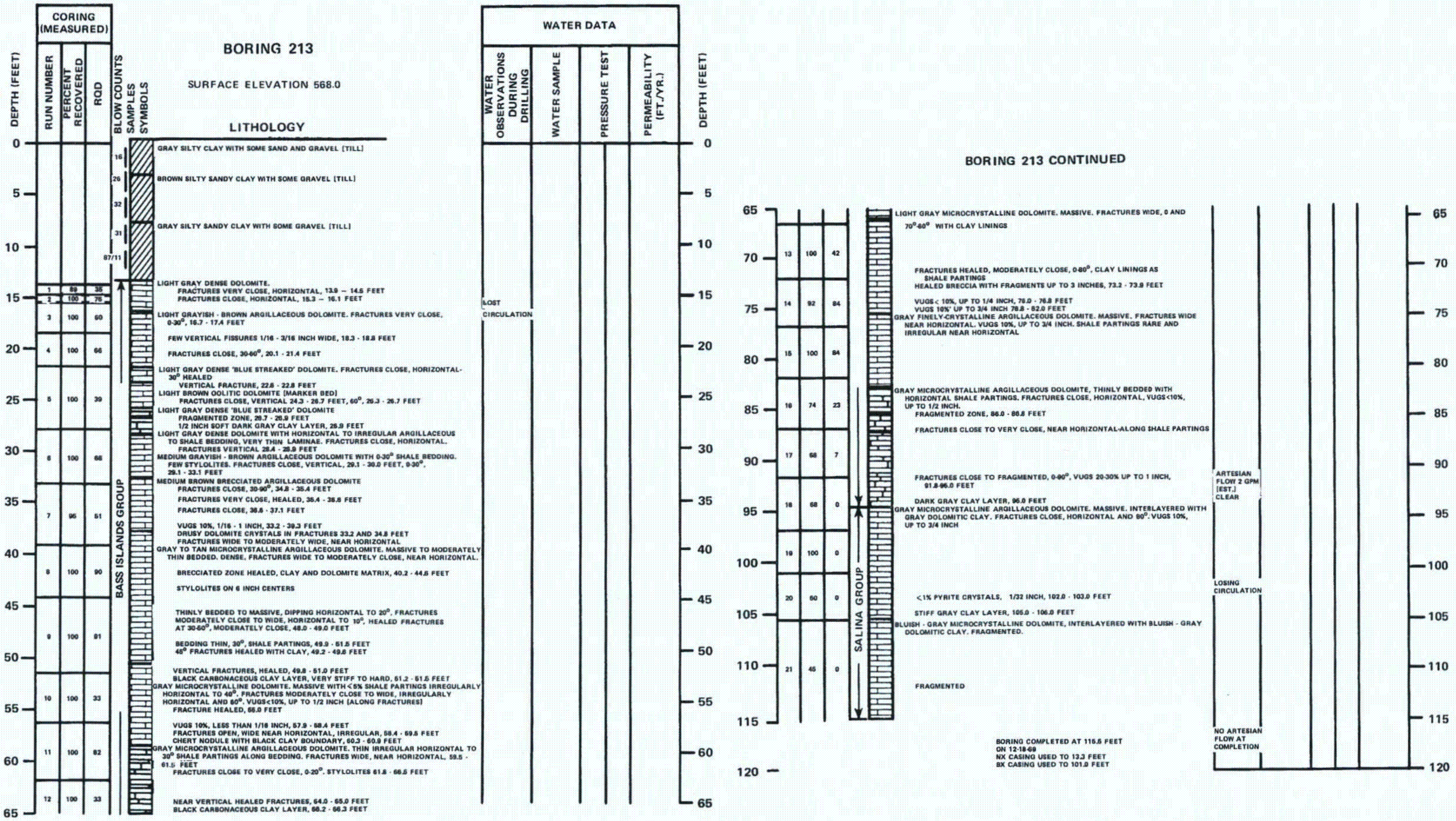
FIGURE 2.5-45

LOG OF BORING 212



Depth (feet)	Run number	Percent recovered	RQD
13.9–15	1	89	35
15–16	2	100	76
16–19	3	100	60
19–22	4	100	66
22–28	5	100	39
28–33	6	100	66
33–39	7	95	51
39–44	8	100	90
44–51	9	100	91
51–56	10	100	33
56–61	11	100	82
61–65	12	100	33
66–72	13	100	42
72–77	14	92	84
77–83	15	100	84
83–88	16	74	23
88–92	17	58	7
92–97	18	68	0
97–101	19	100	0
101–106	20	60	0
106–115	21	45	0

NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.39 AND 2.5-22.40

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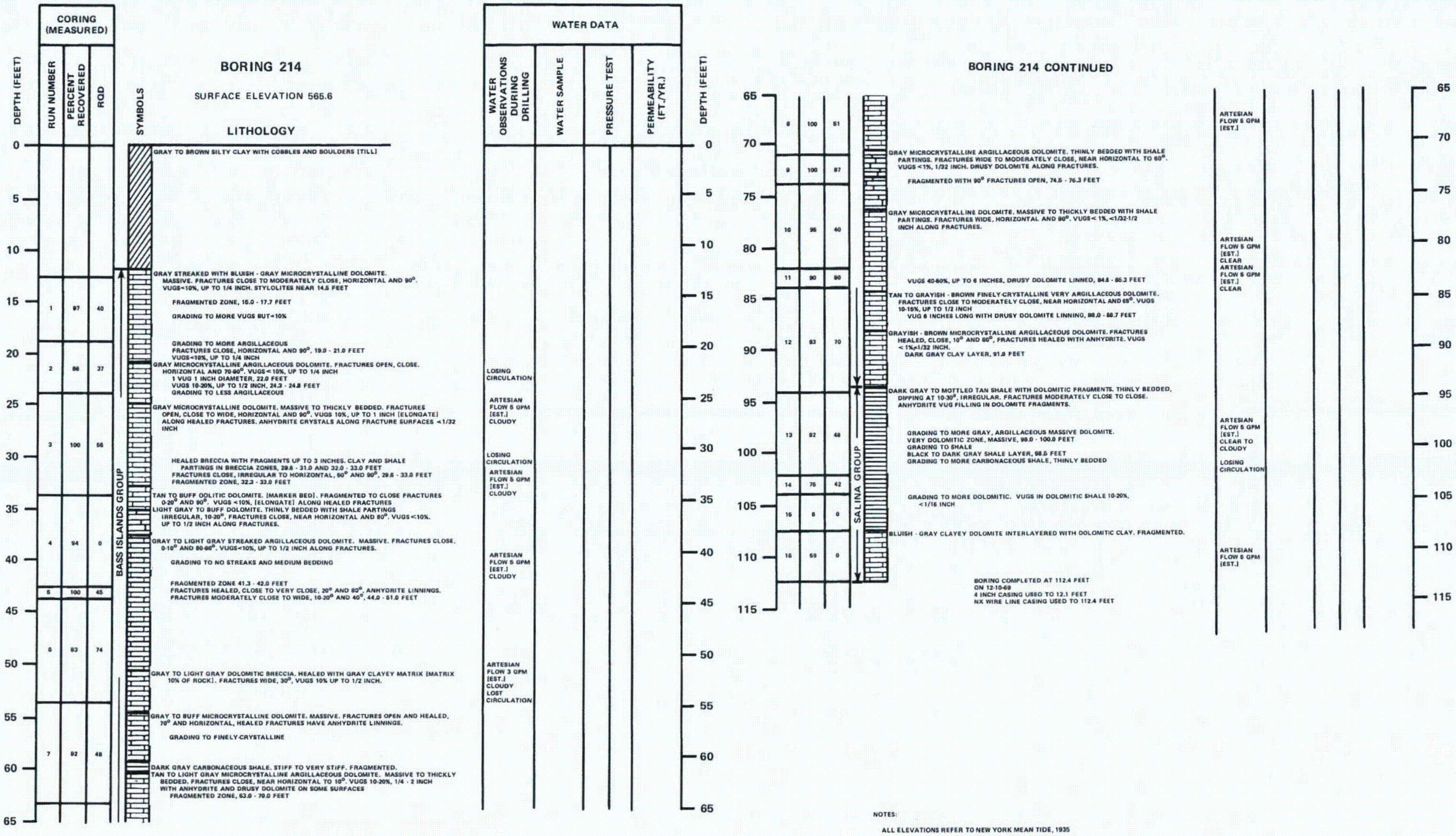
FIGURE 2.5-46

LOG OF BORING 213



NOTES:

ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

INDICATES STANDARD PENETRATION TEST. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE A SAMPLER, WITH AN OUTSIDE DIAMETER OF TWO INCHES, ONE FOOT WITH A 140 POUND WEIGHT FALLING 30 INCHES.

INDICATES A SAMPLING ATTEMPT WITH NO RECOVERY.

100% INDICATES DEPTH, LENGTH, AND PERCENT OF CORE RUN RECOVERED.

ALL CORE WAS MX SIZE EXCEPT WHERE NOTED.

REFERENCE:
DAMES & MOORE FIGURES 2.5-22.41 AND 2.5-22.42

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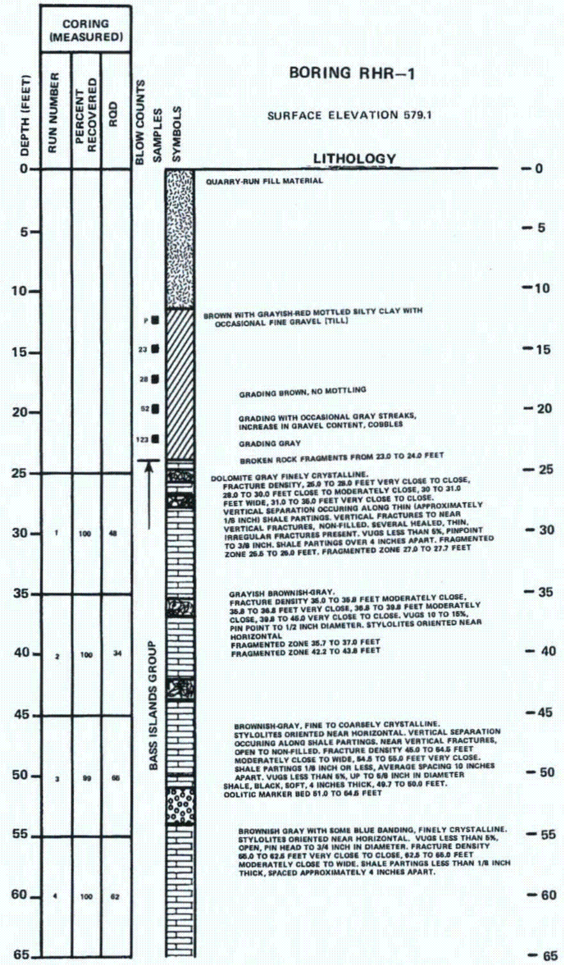
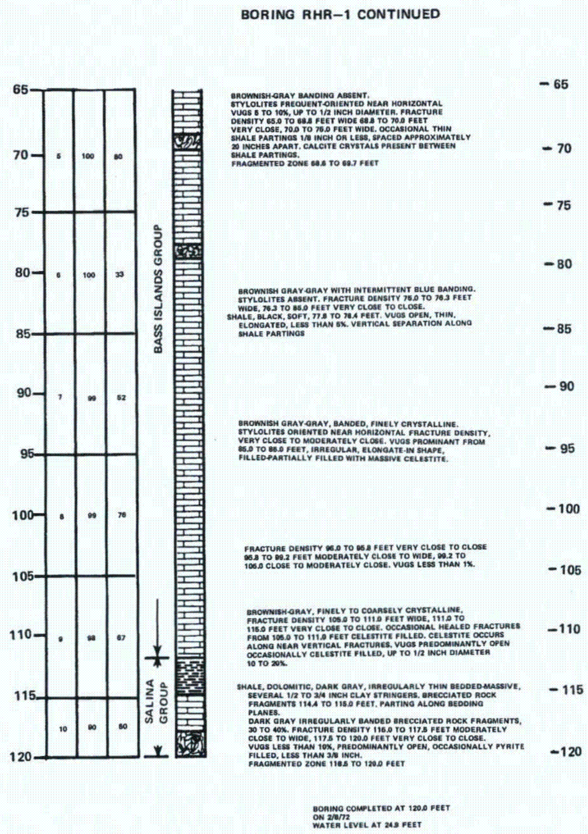
FIGURE 2.5-47

LOG OF BORING 214





NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

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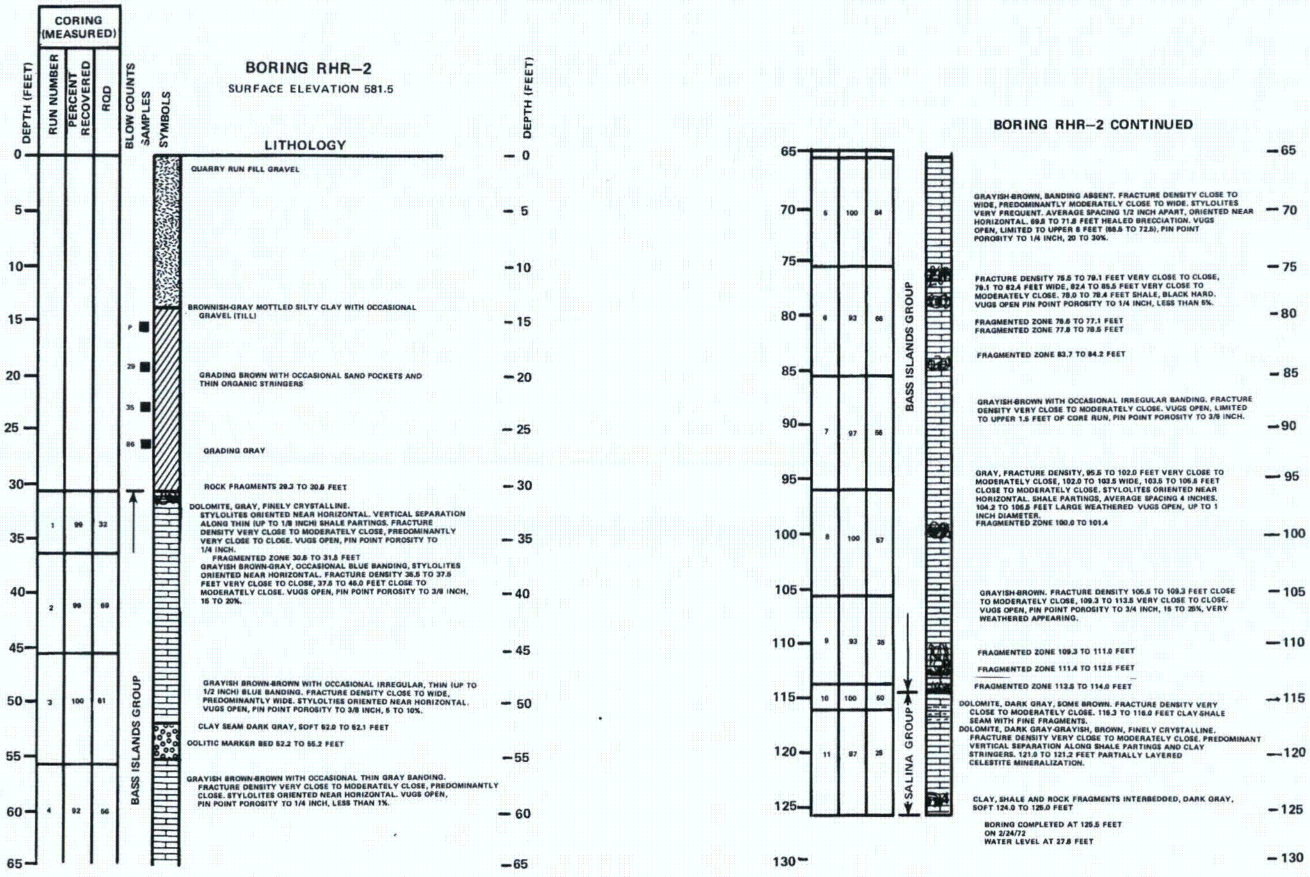
FIGURE 2.5-48

LOG OF BORING RHR-1

REFERENCE:
DAMES & MOORE PLATES A-1A AND A-1B



NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

REFERENCE:
DAMES & MOORE PLATES A-1C AND A-1D

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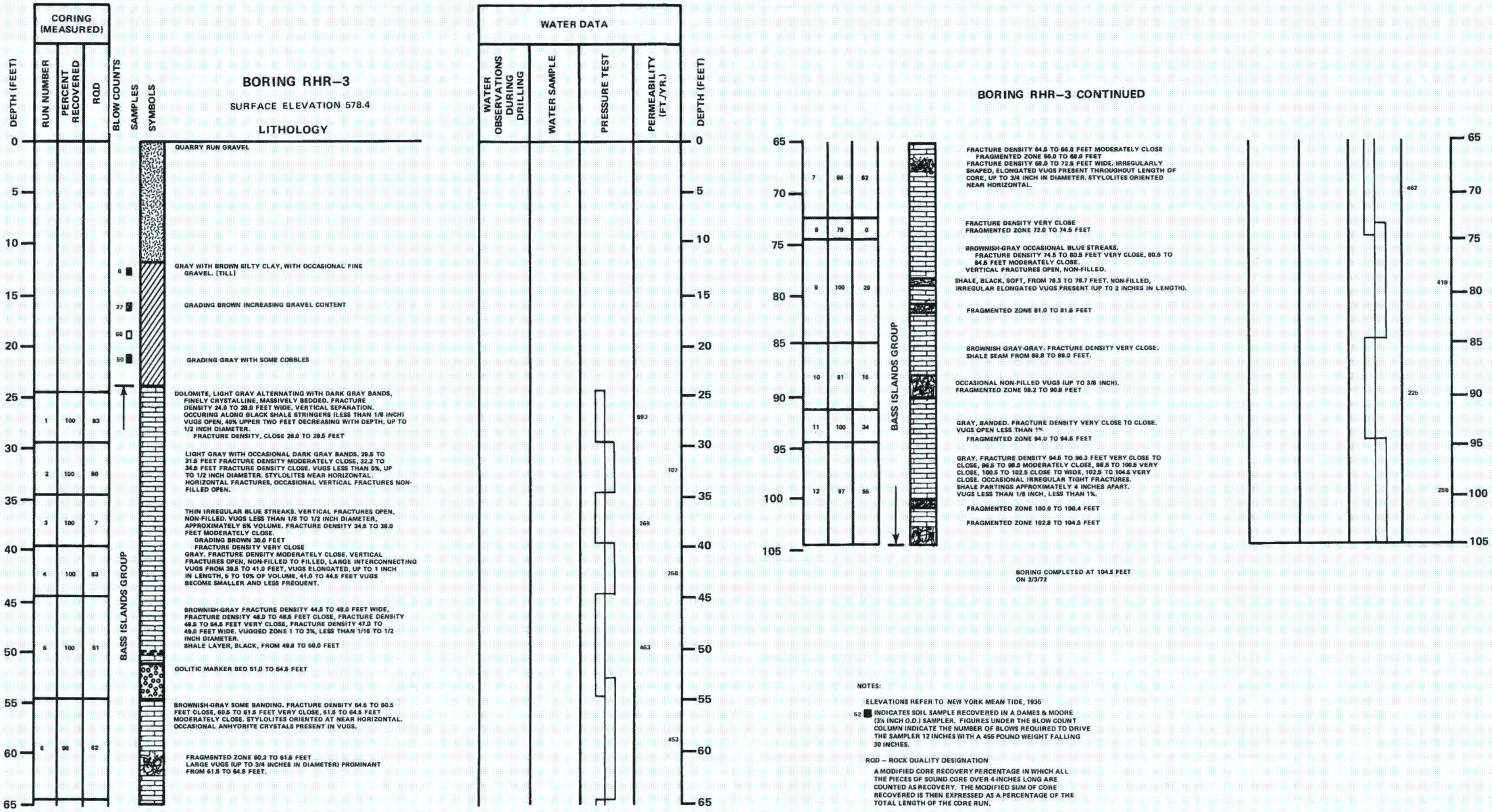
FIGURE 2.5-49

LOG OF BORING RHR-2



NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

REFERENCE:
DAMES & MOORE PLATES A-1E AND A-1F

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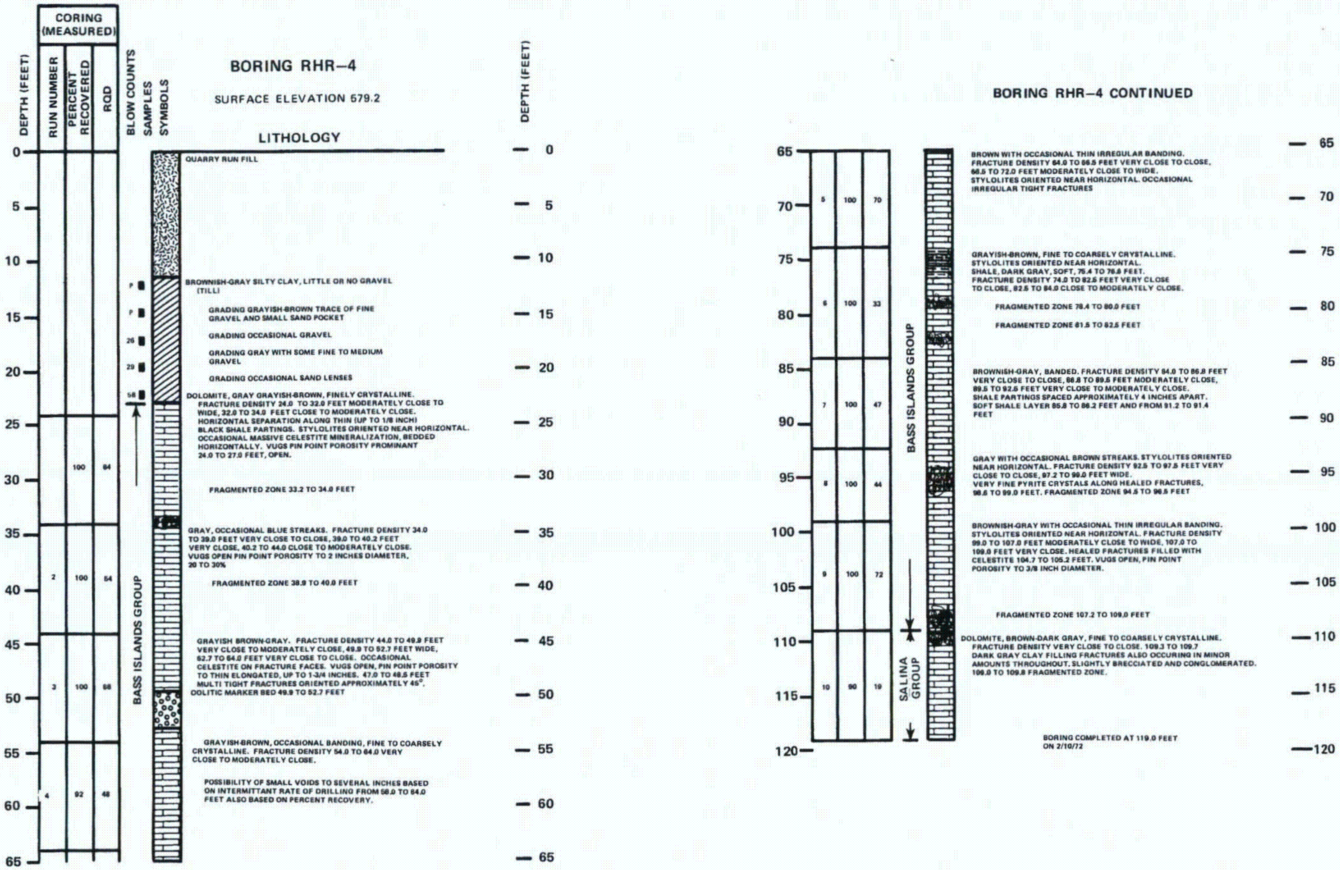
FIGURE 2.5-50

LOG OF BORING RHR-3



NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ▮ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

REFERENCE:
DAMES & MOORE PLATES A-1G AND A-1H

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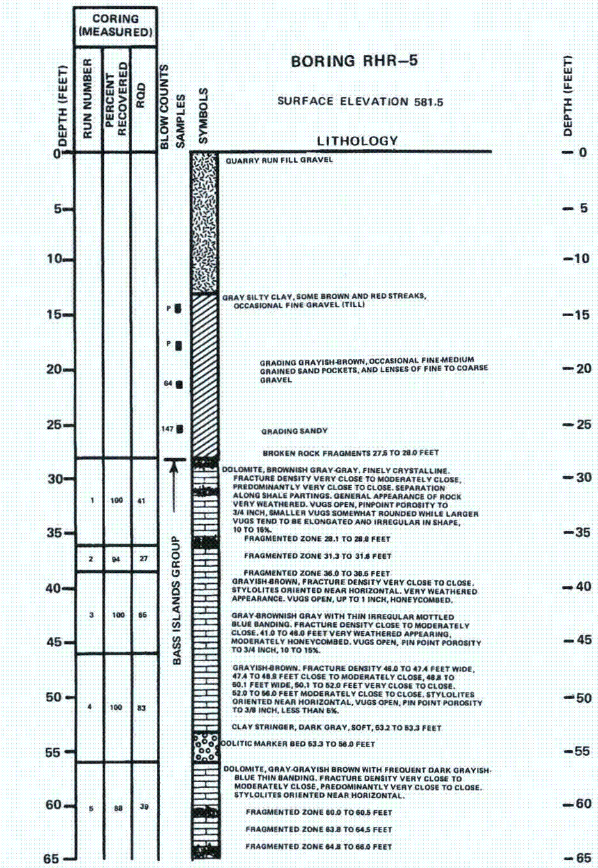
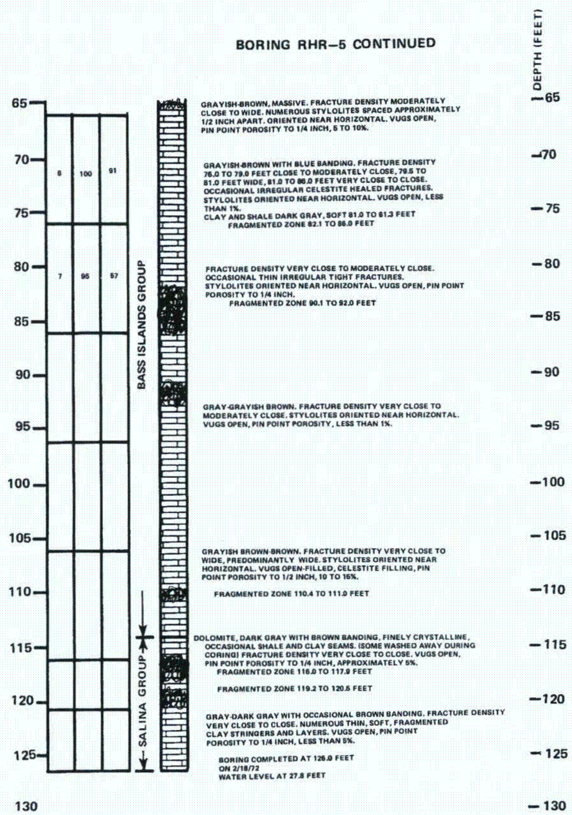
FIGURE 2.5-51

LOG OF BORING RHR-4





NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3½ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

REFERENCE:
DAMES & MOORE PLATES A-1I AND A-1J

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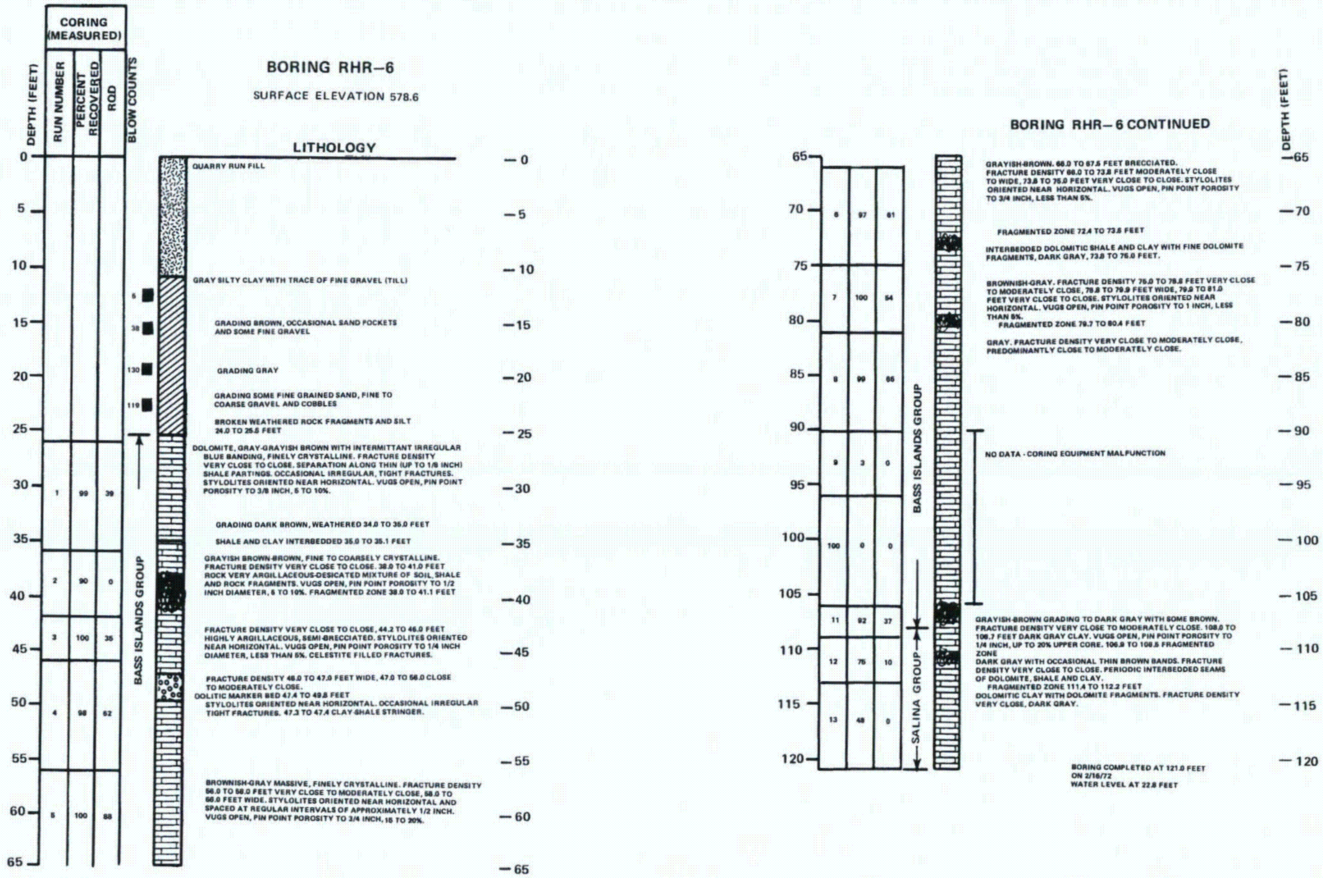
FIGURE 2.5-52

LOG OF BORING RHR-5



NOTES:

ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

52 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 455 POUND WEIGHT FALLING 30 INCHES.

RQD – ROCK QUALITY DESIGNATION

A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4-INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

5% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY:

VERY CLOSE – LESS THAN 2 INCHES APART
CLOSE – 2 TO 6 INCHES
MODERATELY CLOSE – 6 TO 12 INCHES
WIDE – GREATER THAN 12 INCHES

REFERENCE:
DAMES & MOORE PLATES A-1K AND A-1L

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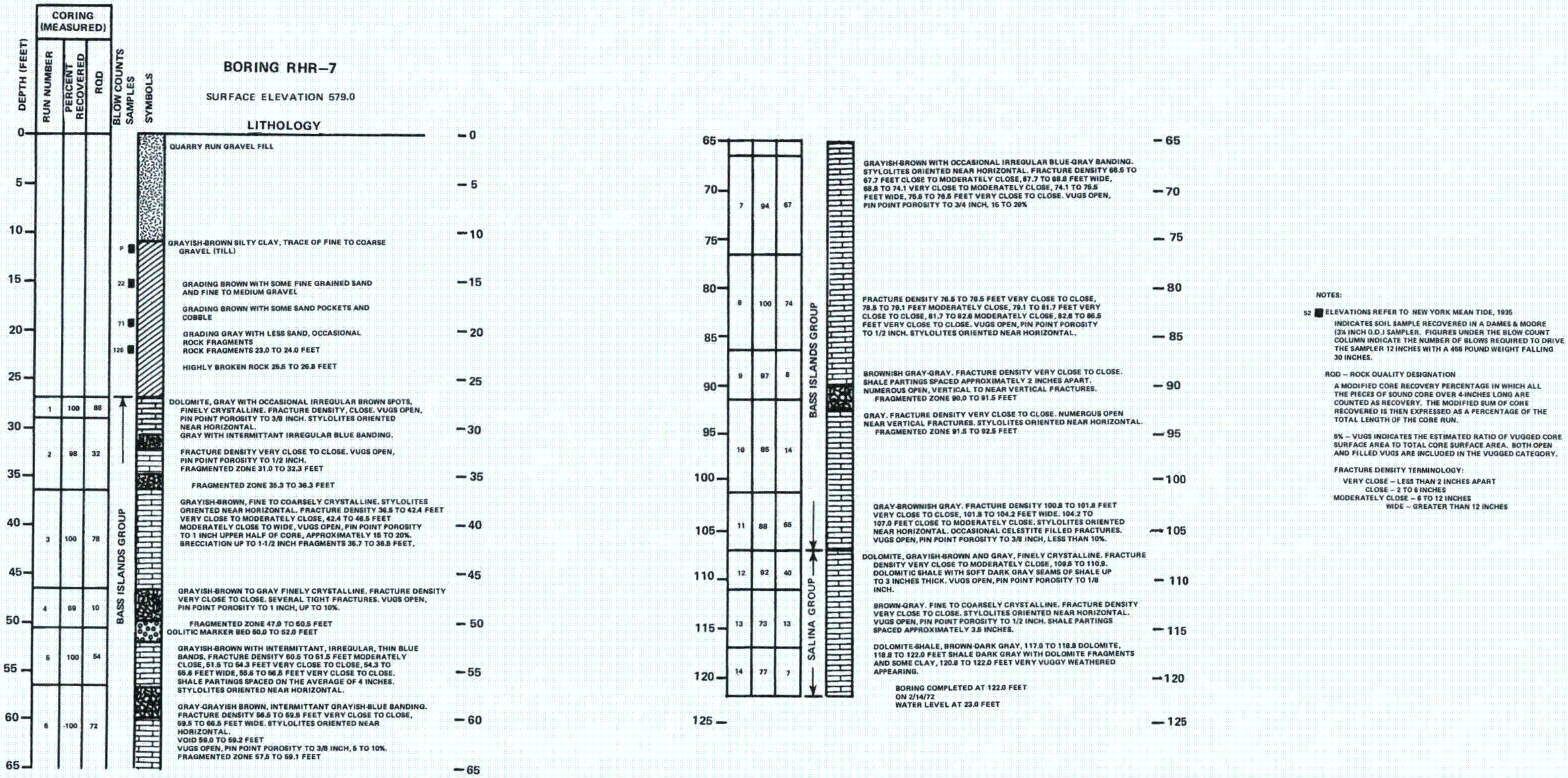
FIGURE 2.5-53

LOG OF BORING RHR-6



REFERENCE:
DAMES & MOORE PLATES A-1M AND A-1N

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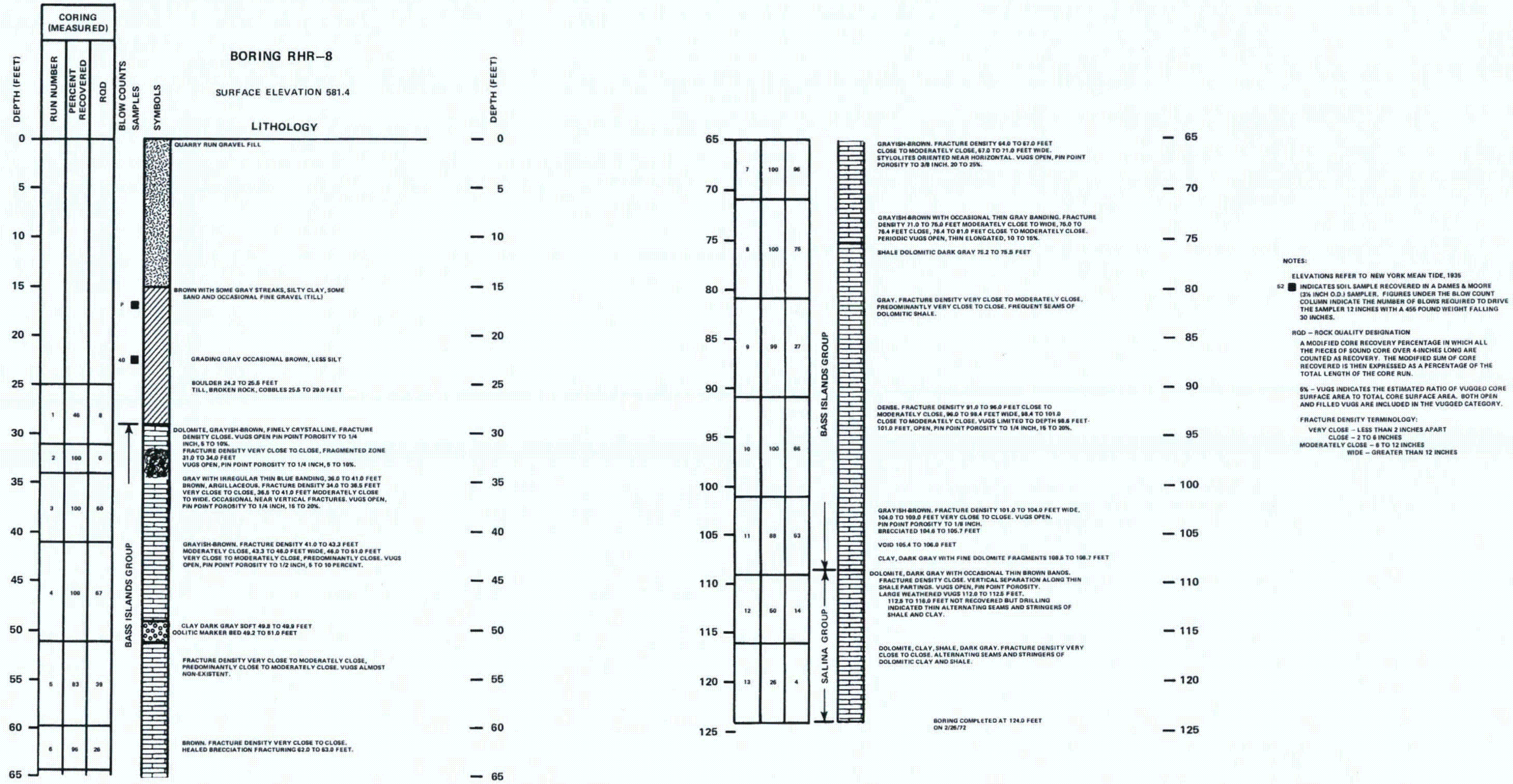
FIGURE 2.5-54

LOG OF BORING RHR-7



REFERENCE:
DAMES & MOORE PLATES A-1O AND A-1P

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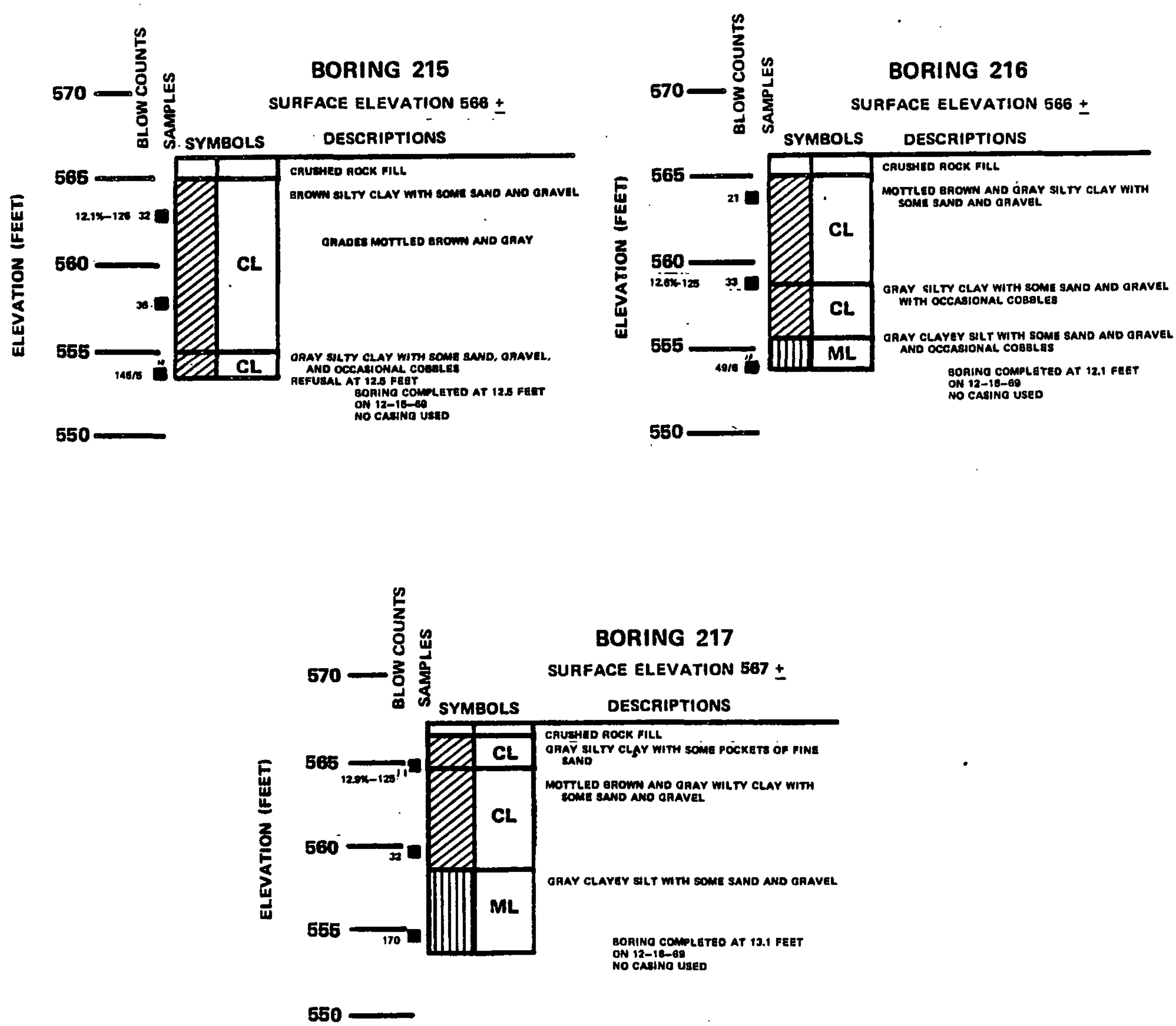
FIGURE 2.5-55

LOG OF BORING RHR-8



NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

12.1% – 126 INDICATES FIELD MOISTURE CONTENT OF 12.1 PERCENT AND DRY DENSITY OF 126 POUNDS PER CUBIC FOOT.

32 ■ INDICATES SOIL SAMPLE RECOVERED IN A DAMES & MOORE (3¼ INCH O.D.) SAMPLER. FIGURES UNDER THE BLOW COUNT COLUMN INDICATE THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SAMPLER 12 INCHES WITH A 350 POUND WEIGHT FALLING 30 INCHES

REFERENCE:
REFERENCE 32, PLATE A-1

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FIGURE 2.5-56

LOGS OF BORINGS 215, 216, AND 217

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO 200 SIEVE SIZE				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICTY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

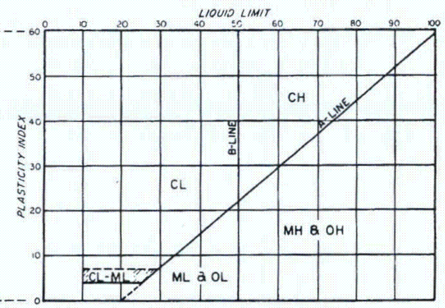
FOR LABORATORY CLASSIFICATION OF FINE-GRAINED SOILS

SOIL CLASSIFICATION CHART

MATERIAL SIZE	PARTICLE SIZE			
	LOWER LIMIT		UPPER LIMIT	
	MILLIMETERS	SIEVE SIZE	MILLIMETERS	SIEVE SIZE●
SAND				
FINE	.074	#200●	0.42	#40●
MEDIUM	0.42	#40●	2.00	#10●
COARSE	2.00	#10●	4.76	#4●
GRAVEL				
FINE	4.76	#4●	19.1	3/4"•
COARSE	19.1	3/4"•	76.2	3"•
COBBLES	76.2	3"•	304.8	12"•
BOULDERS	304.8	12"•	914.4	36"

● U.S. STANDARD • CLEAR SQUARE OPENINGS

GRADATION CHART



PLASTICITY CHART

NOTES:
1. DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE CLASSIFICATIONS.
2. WHEN SHOWN ON THE BORING LOGS, THE FOLLOWING TERMS ARE USED TO DESCRIBE THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE COMPACTNESS OF COHESIONLESS SOILS.

COHESIVE SOILS

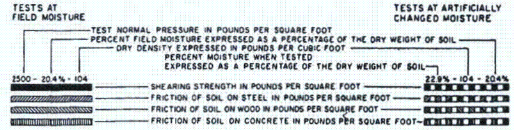
	(APPROXIMATE SHEARING STRENGTH IN KSF)
VERY SOFT	LESS THAN 25
SOFT	0.25 TO 0.5
MEDIUM STIFF	0.5 TO 1.0
STIFF	1.0 TO 2.0
VERY STIFF	2.0 TO 4.0
HARD	GREATER THAN 4.0

COHESIONLESS SOILS

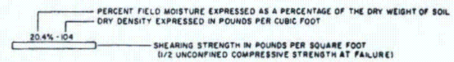
VERY LOOSE
LOOSE
MEDIUM DENSE
DENSE
VERY DENSE

THESE ARE USUALLY BASED ON AN EXAMINATION OF SOIL SAMPLES, PENETRATION RESISTANCE, AND SOIL DENSITY DATA.

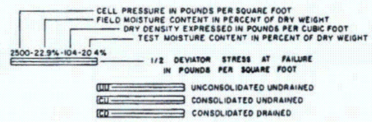
KEY TO TEST DATA



DIRECT SHEAR AND FRICTION TESTS



UNCONFINED COMPRESSION TESTS



TRIAXIAL COMPRESSION TESTS

YIELD, PEAK OR ULTIMATE STRENGTHS ARE IDENTIFIED ON SHEAR TEST DATA ON THE BORING LOGS AS FOLLOWS:

- • YIELD STRENGTH
- •• PEAK STRENGTH
- ••• ULTIMATE STRENGTH

SHEAR TEST RESULTS

■ INDICATES UNDISTURBED SAMPLE
⊠ INDICATES DISTURBED SAMPLE
□ INDICATES SAMPLING ATTEMPT WITH NO RECOVERY

I INDICATES LENGTH OF CORING RUN

NOTE
DEFINITIONS OF ANY ADDITIONAL DATA REGARDING SAMPLES ARE ENTERED ON THE FIRST LOG ON WHICH THE DATA APPEAR.

SAMPLES

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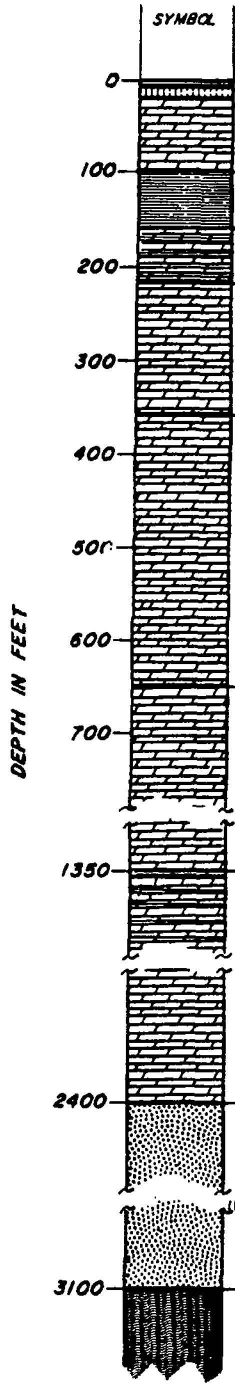
FIGURE 2.5-57

UNIFIED SOIL CLASSIFICATION SYSTEM

REFERENCE:
REFERENCE 32, PLATE A-2



DESCRIPTION	COMPRESSIONAL WAVE VELOCITY (FT./SEC.)	POISSON'S RATIO (ESTIMATED)	SHEAR WAVE VELOCITY (FT./SEC.) (COMPUTED)	TOTAL UNIT WEIGHT (LBS./CU. FT.)
RECENT LAGOON DEPOSITS	1000	.46	300	95
GLACIAL TILL	6500	.40	2650	130
BASS ISLANDS DOLOMITE	13,000	.24	7600	158
SALINA GROUP G FORMATION (SHALES AND SHALY DOLOMITE)	8000	.34	3900	138
E FORMATION (SHALY DOLOMITE, LIMESTONE AND LIMESTONE BRECCIAS)	9000	.30	4600	142
C FORMATION (DOLOMITE AND SHALY DOLOMITE)	14,000	.24	8200	160
A FORMATION (LIMESTONE AND DOLOMITE)	15,600	.24	9100	168
MIDDLE AND EARLY SILURIAN SEDIMENTS (PREDOMINANTLY DOLOMITES AND LIMESTONES)	15,600	.20	9800	168
ORDOVICIAN SEDIMENTS (SHALE, SHALY DOLOMITES AND DENSE DOLOMITES)	15,600	.20	9800	168
CAMBRIAN SEDIMENTS (PREDOMINANTLY SANDSTONES)	15,600	.20	9800	168
PRECAMBRIAN (GRANITIC GNEISS)	19,200	.15	12,300	170

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-14

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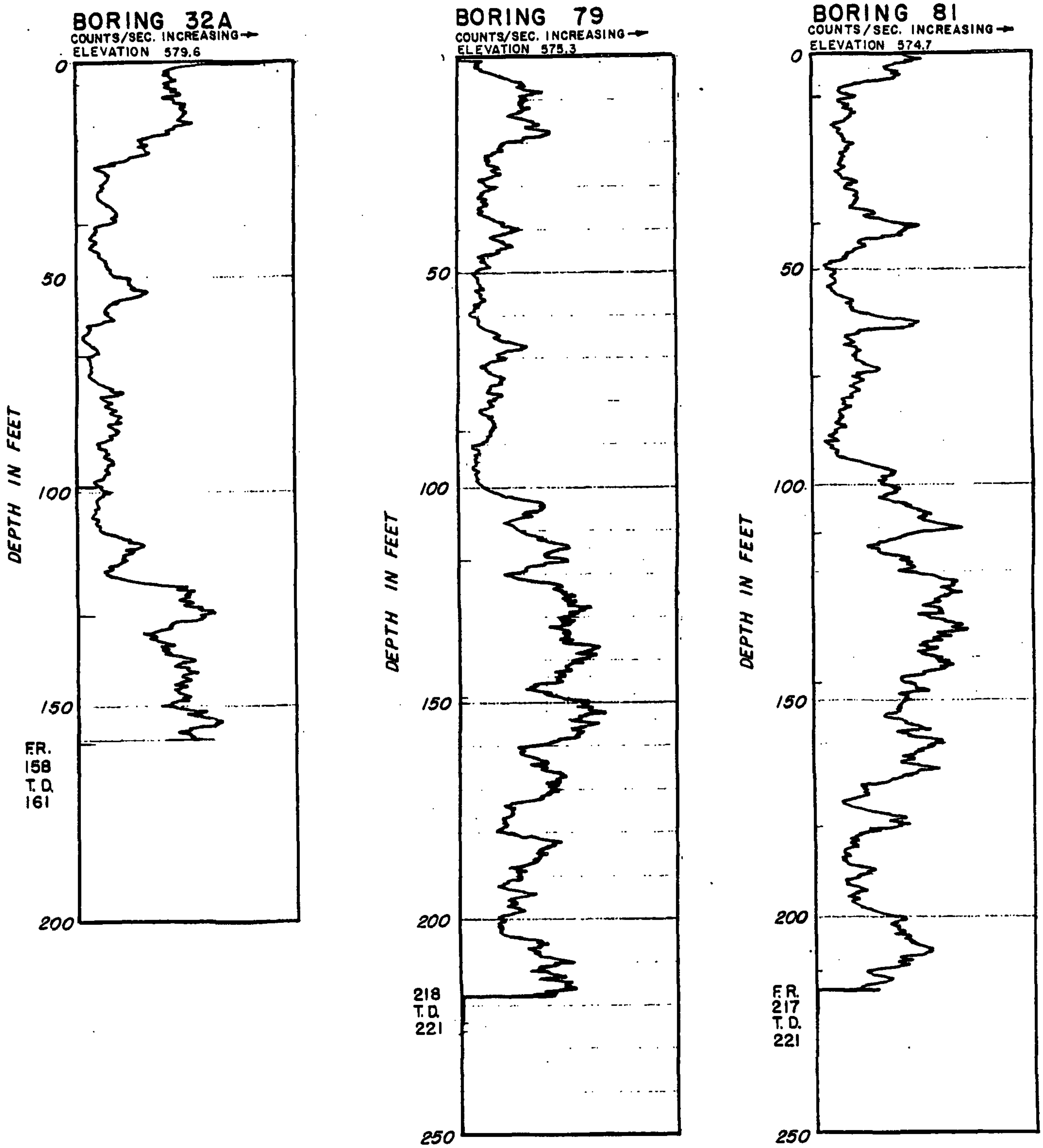
FIGURE 2.5-58

STRATIGRAPHIC COLUMN SHOWING GEOPHYSICAL DATA



NOTE:
GEOPHYSICAL LOGS BY THE BIRDWELL DIVISION
OF SEISMOGRAPHIC SERVICE CORPORATION

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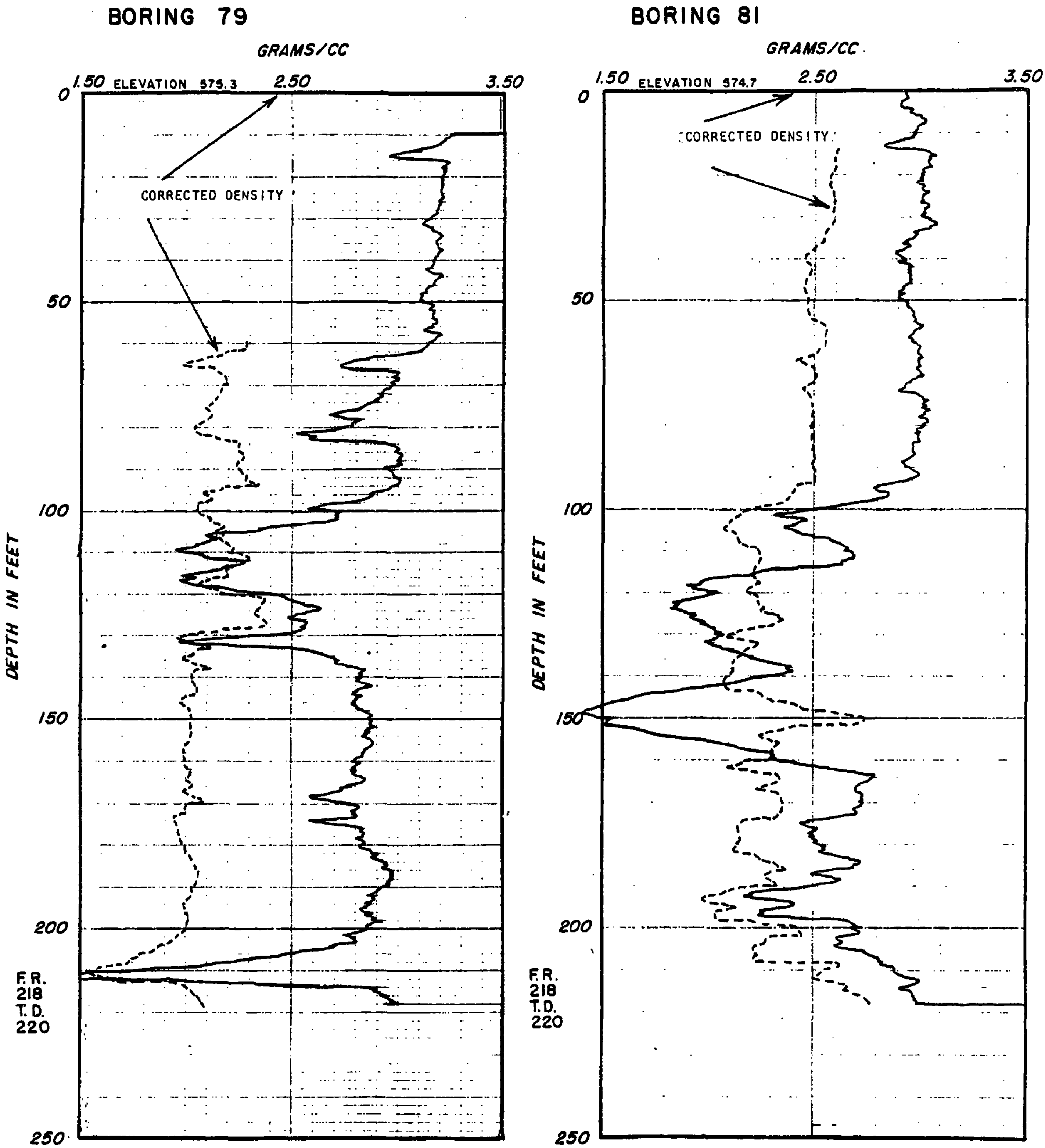
FIGURE 2.5-59

BOREHOLE GEOPHYSICAL MEASUREMENTS
GAMMA RAY LOGS – BORINGS 32A, 79, AND 81

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-13.1



NOTE:
GEOPHYSICAL LOGS BY THE BIRDWELL DIVISION OF SEISMOGRAPHIC SERVICE CORPORATION

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-13.2

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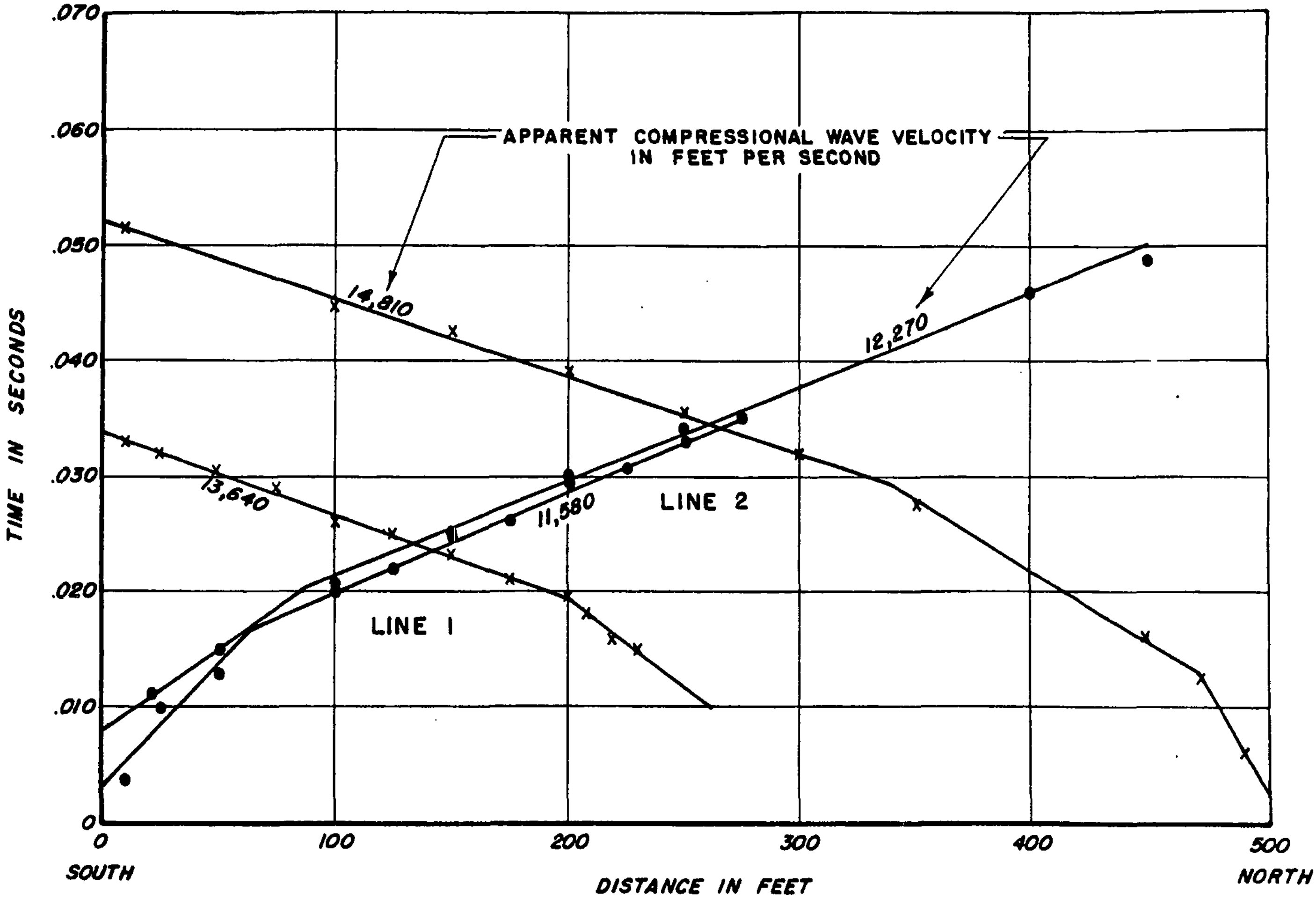
FIGURE 2.5-60

BOREHOLE GEOPHYSICAL MEASUREMENTS
DENSITY LOGS – BORINGS 79 AND 81



V_1 = 1000 FPS, 0 - 3FT
V_2 = 6500 ± 1000 FPS, 3 - 23 FT
V_3 = 13,000 ± 500 FPS, 20+ FT

REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-5

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FIGURE 2.5-61

SEISMIC REFRACTION SURVEY

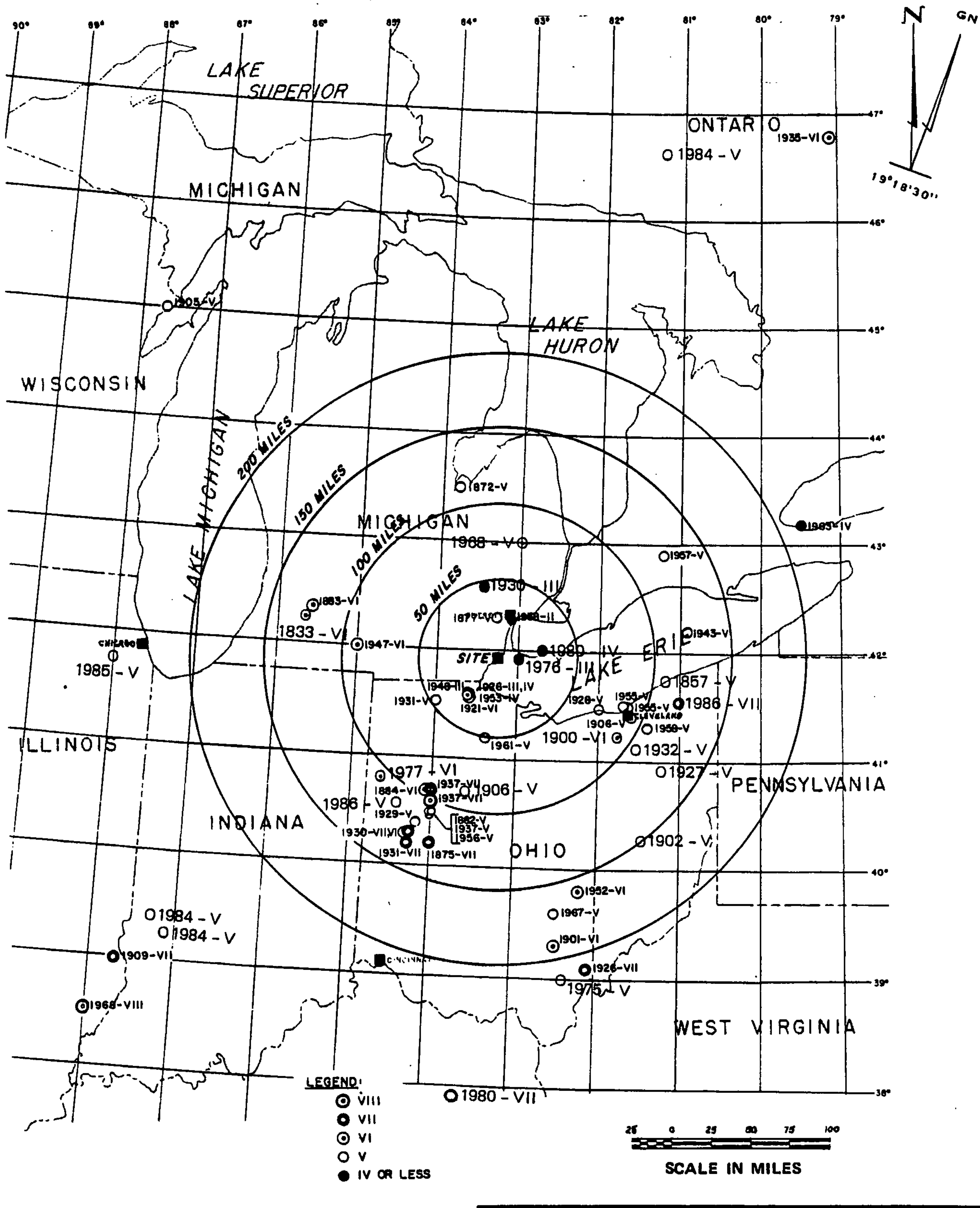

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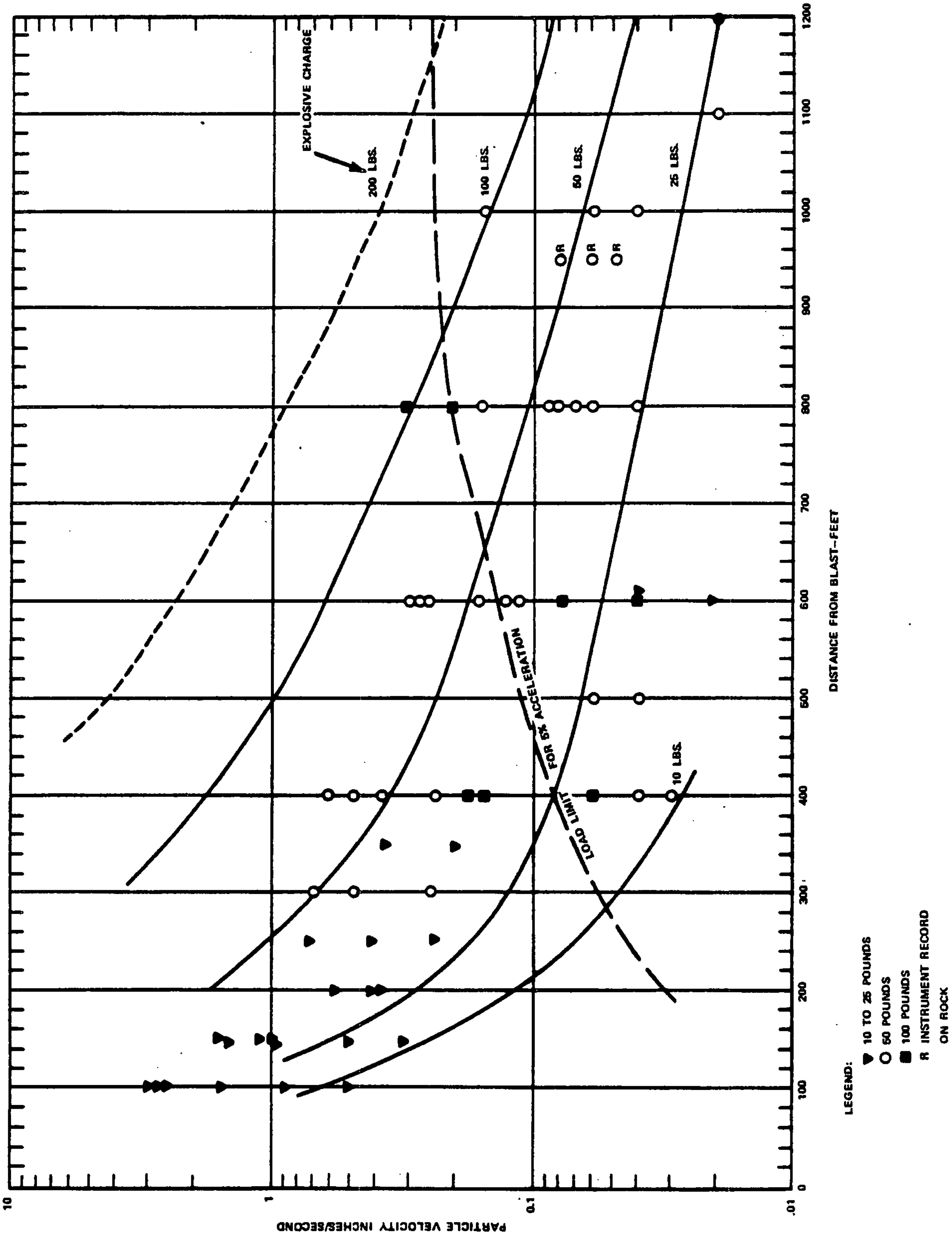
FIGURE 2.5-62

EPICENTER MAP

REFERENCE:
MODIFIED FROM: BASEMENT ROCK MAP OF THE UNITED STATES, COMPILED BY RICHARD W. BAYLEY, UNITED STATES GEOLOGICAL SURVEY, AND WILLIAM MUEHLBERGER, UNIVERSITY OF TEXAS, 1968.



REFERENCE:
FERMI 2 PSAR – FIGURE 2.5-17
DAMES & MOORE FIGURE 2.5-22.8

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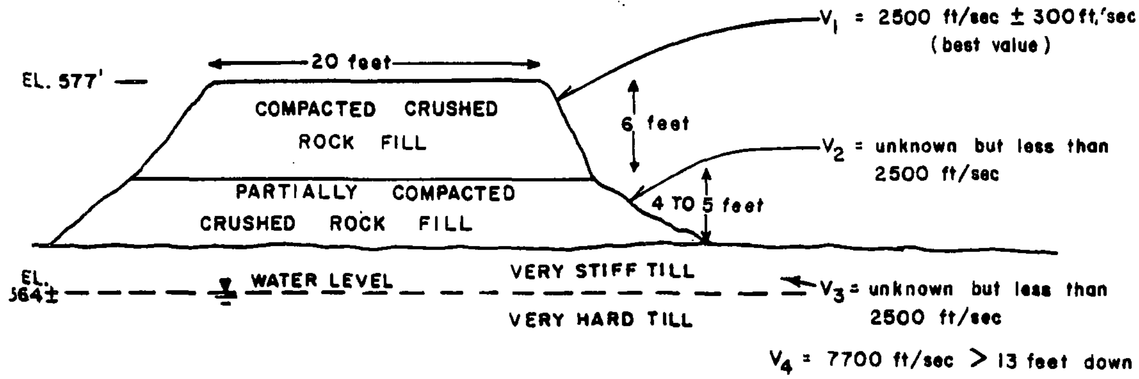
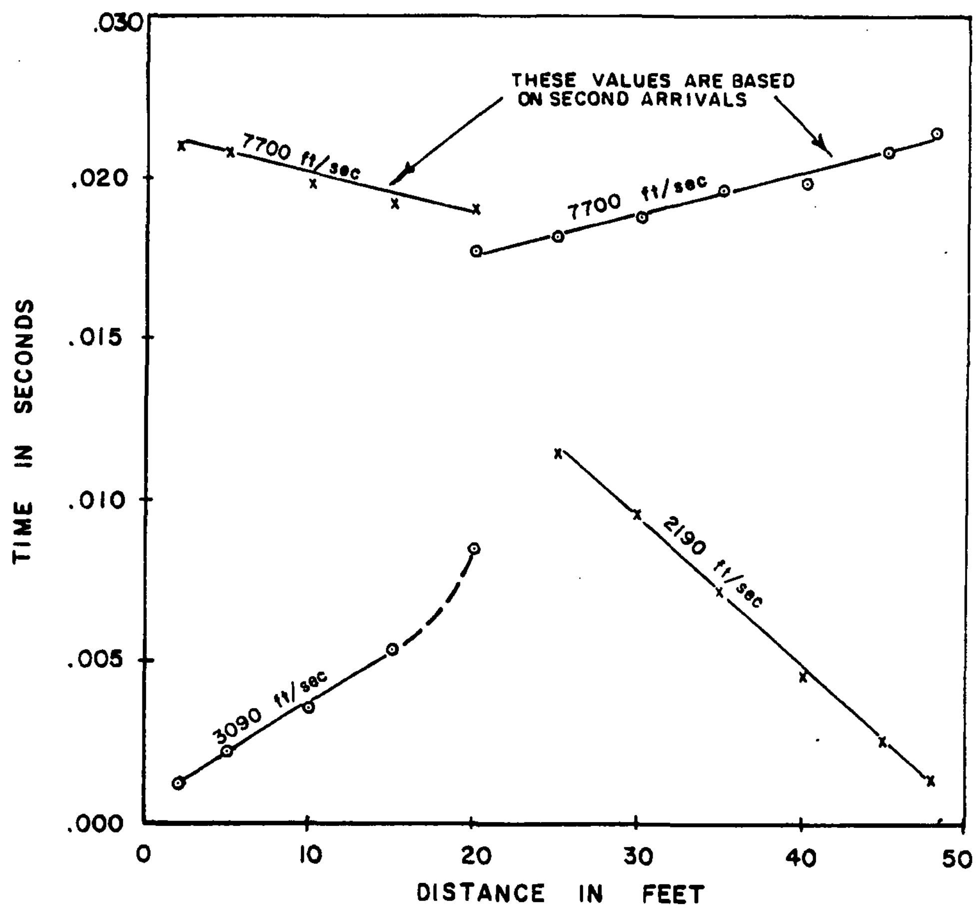
FIGURE 2.5-63

ATTENUATION CURVES



TYPICAL CROSS SECTION OF FILL



NOTE:
ALL ELEVATIONS REFER TO NEW YORK MEAN TIDE, 1935

REFERENCE:
REFERENCE 32, PLATE A-3

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FIGURE 2.5-64

SEISMIC REFRACTION SURVEY OF FILL

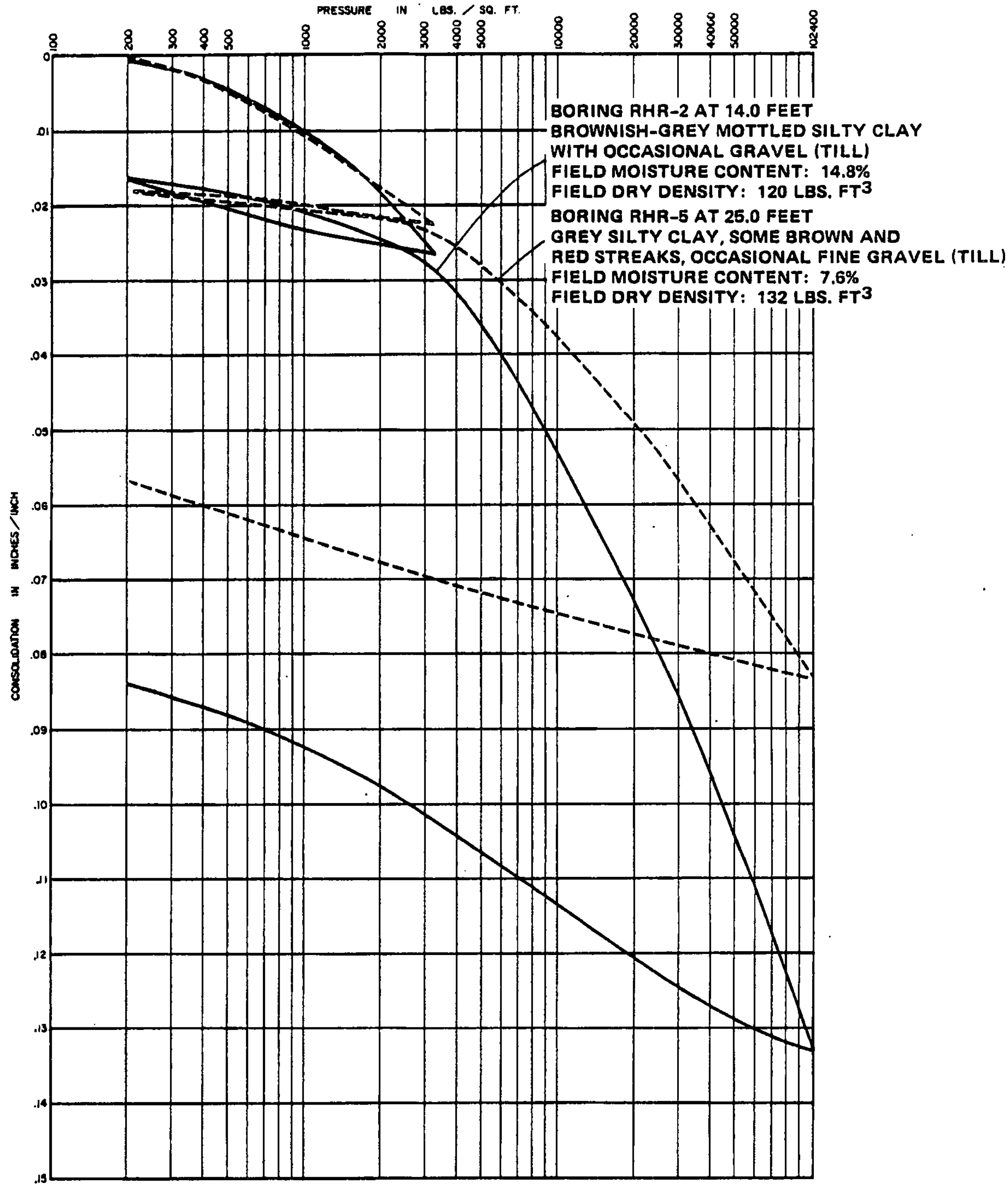

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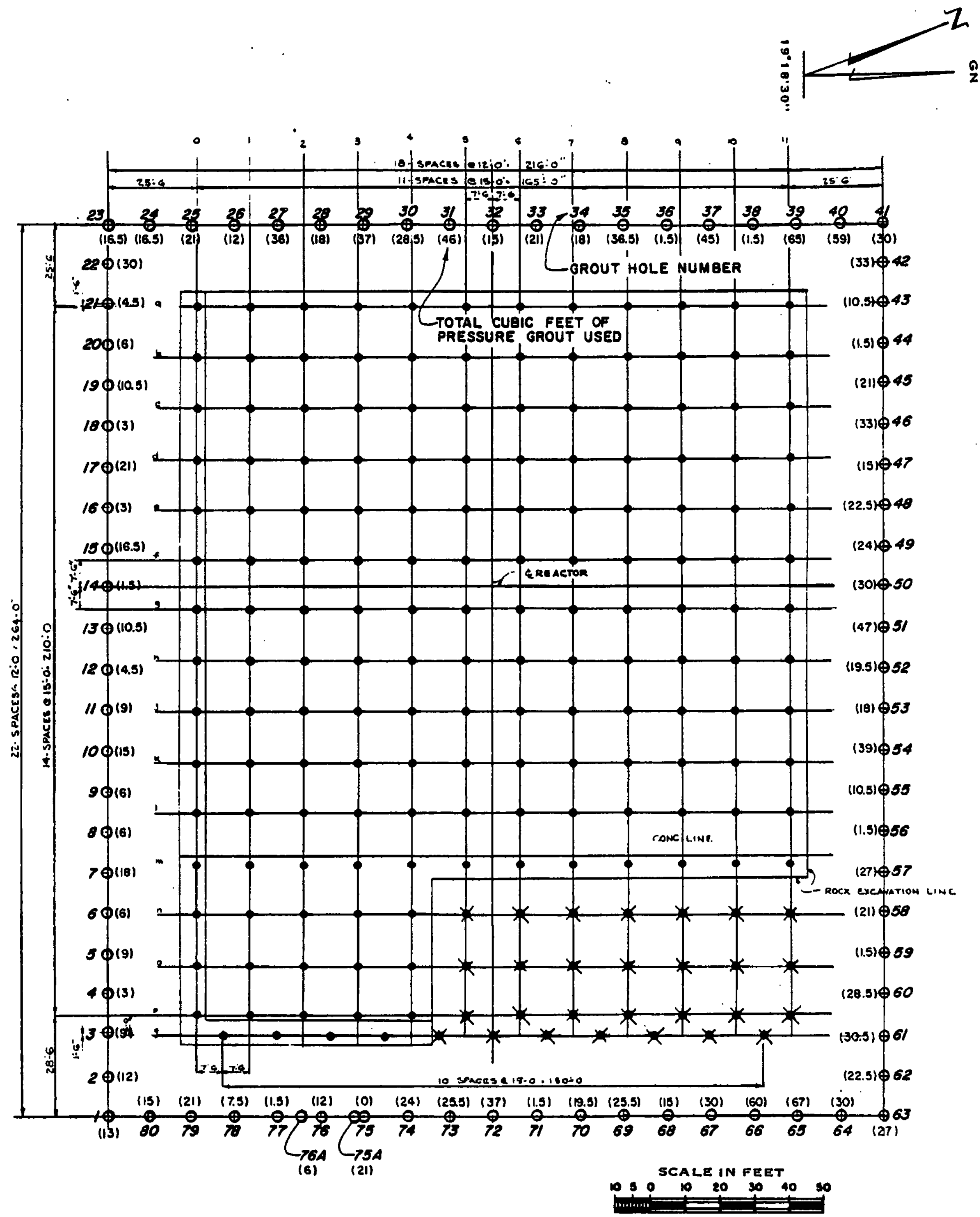
FIGURE 2.5-65

CONSOLIDATION TEST DATA

REFERENCE:
REFERENCE 3, PLATE A-6



KEY TO GROUT HOLES:

- ○ CURTAIN WALL GROUT HOLES TO EL. 515± DRILLED FROM TOP OF GLACIAL TILL
- ● FOUNDATION GROUT HOLES TO EL. 483± DRILLED FROM ROCK SURFACE
- ✱ FOUNDATION GROUT HOLES TO EL. 499± DRILLED FROM ROCK SURFACE

REFERENCE:
REFERENCE 46, PLATE 1

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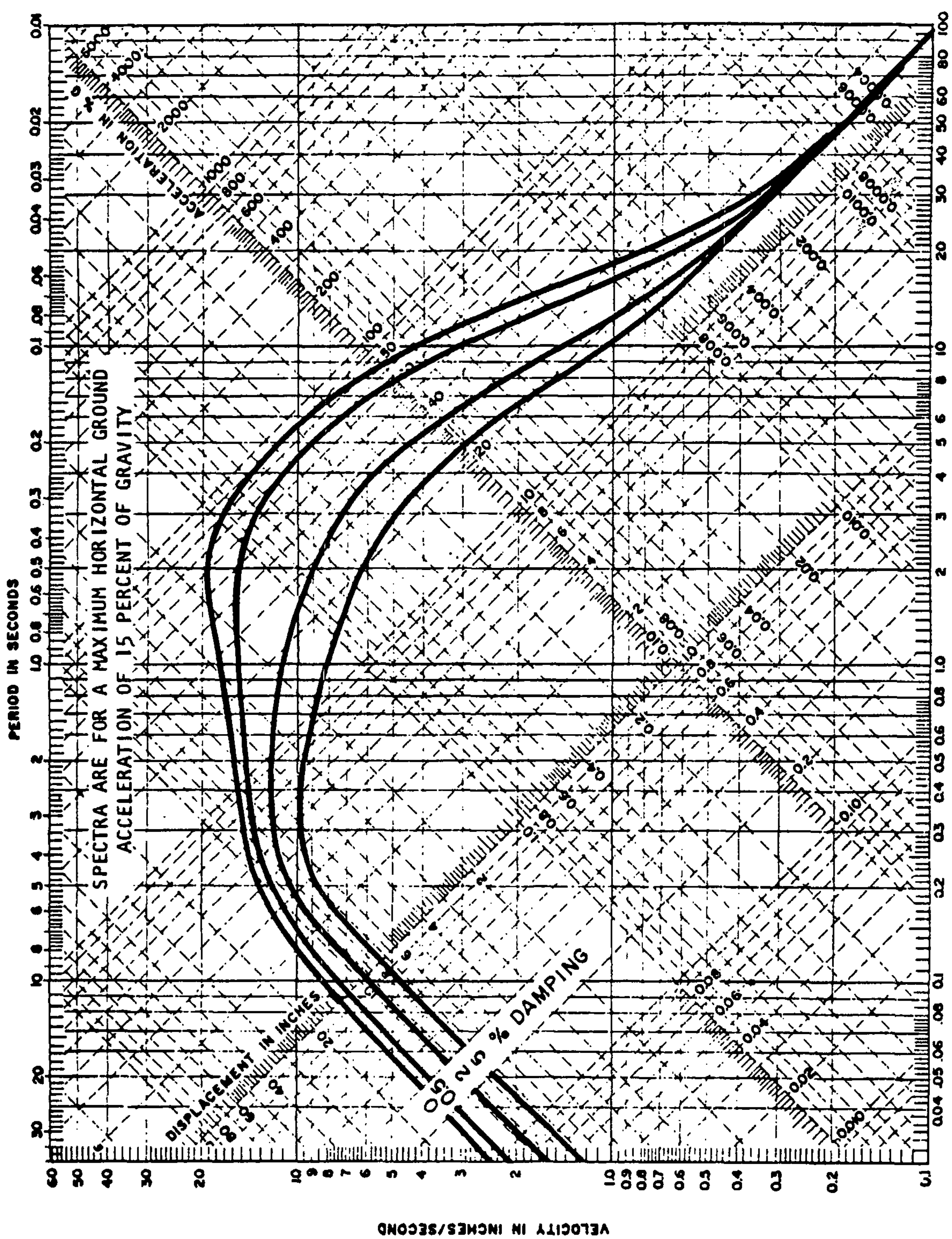
FIGURE 2.5-66

GROUT HOLE LOCATION PLAN
REACTOR/AUXILIARY BUILDING



REFERENCE:
DAMES & MOORE REPORT, REFERENCE 3

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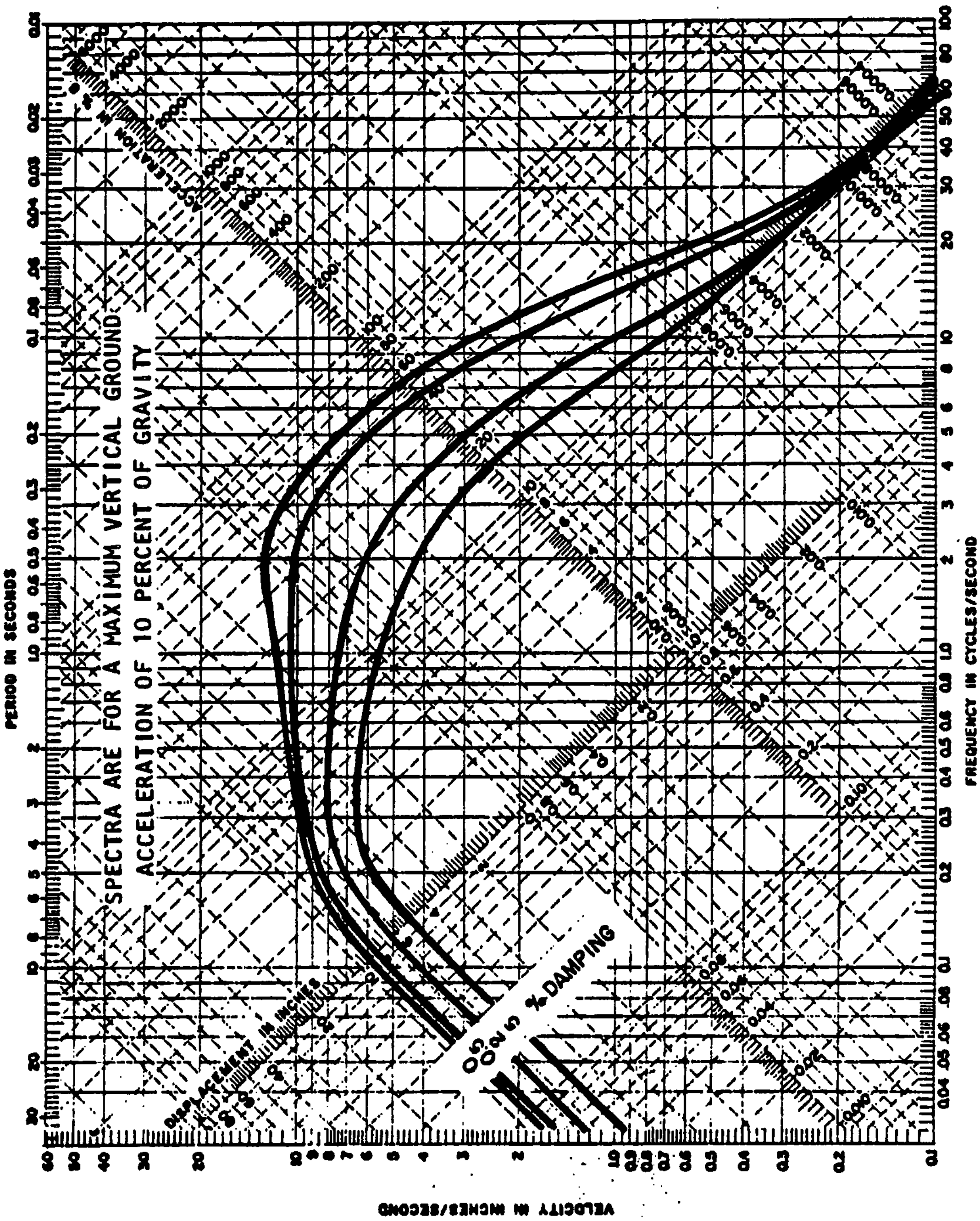
FIGURE 2.5-67, SHEET 1

RESPONSE SPECTRA FOR SAFE-SHUTDOWN EARTHQUAKE – ROCK FOUNDATION (HORIZONTAL)



REFERENCE:
DAMES & MOORE REPORT, REFERENCE 3

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FIGURE 2.5-67, SHEET 2

RESPONSE SPECTRA FOR SAFE-SHUTDOWN EARTHQUAKE – ROCK FOUNDATION (VERTICAL)

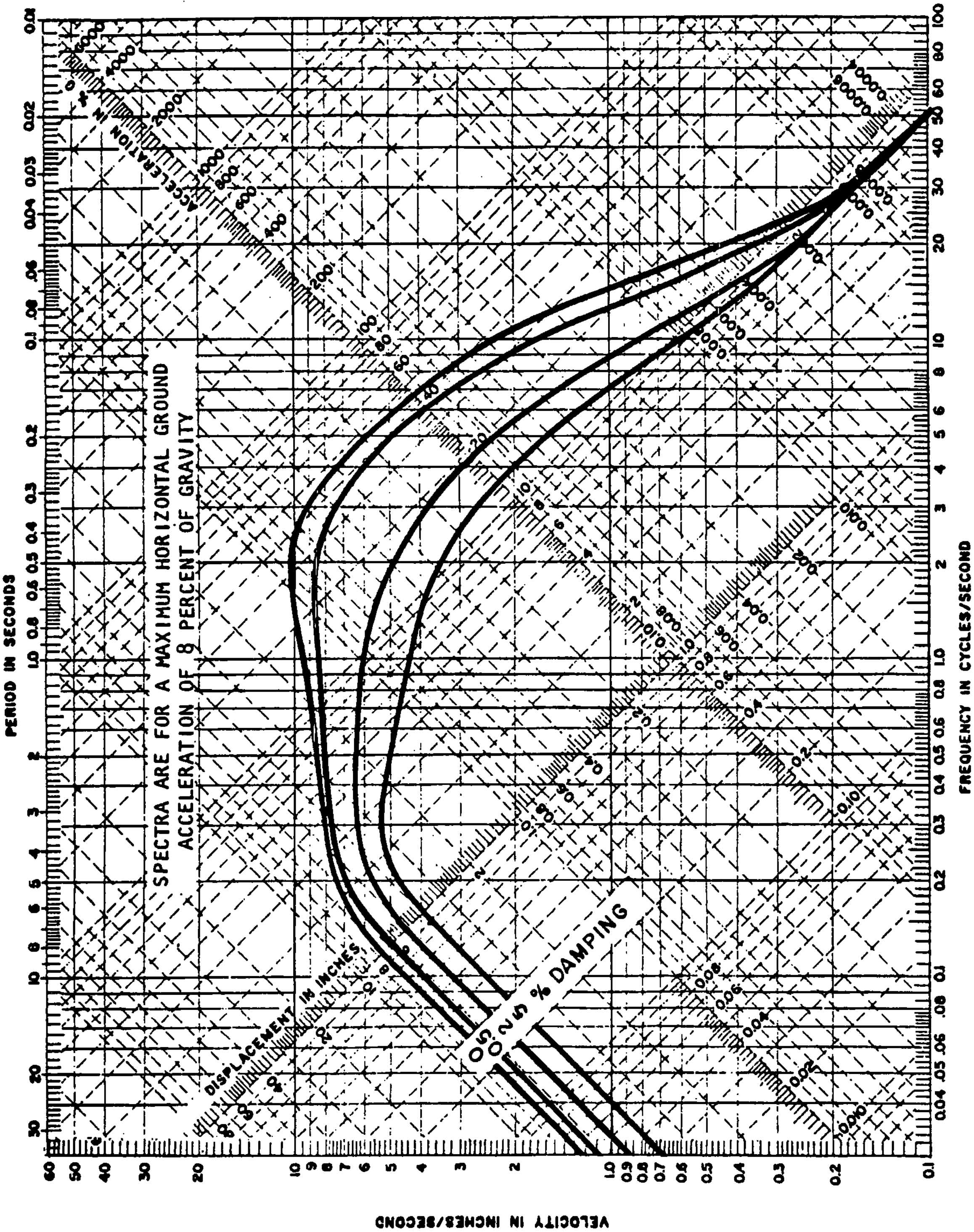

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FIGURE 2.5-68, SHEET 1

RESPONSE SPECTRA FOR OPERATING BASIS EARTHQUAKE – ROCK FOUNDATION (HORIZONTAL)

REFERENCE:
DAMES & MOORE REPORT, REFERENCE 3

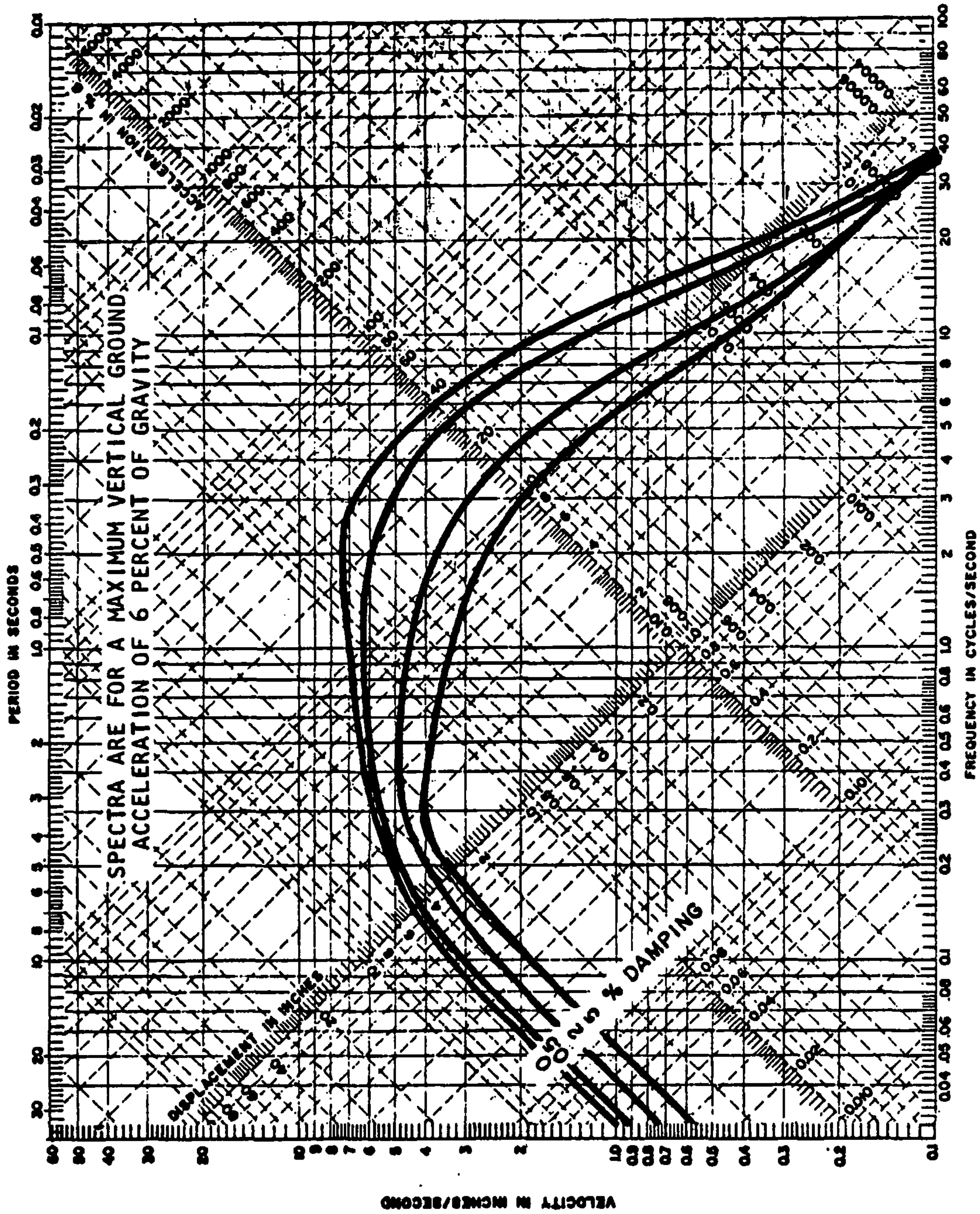

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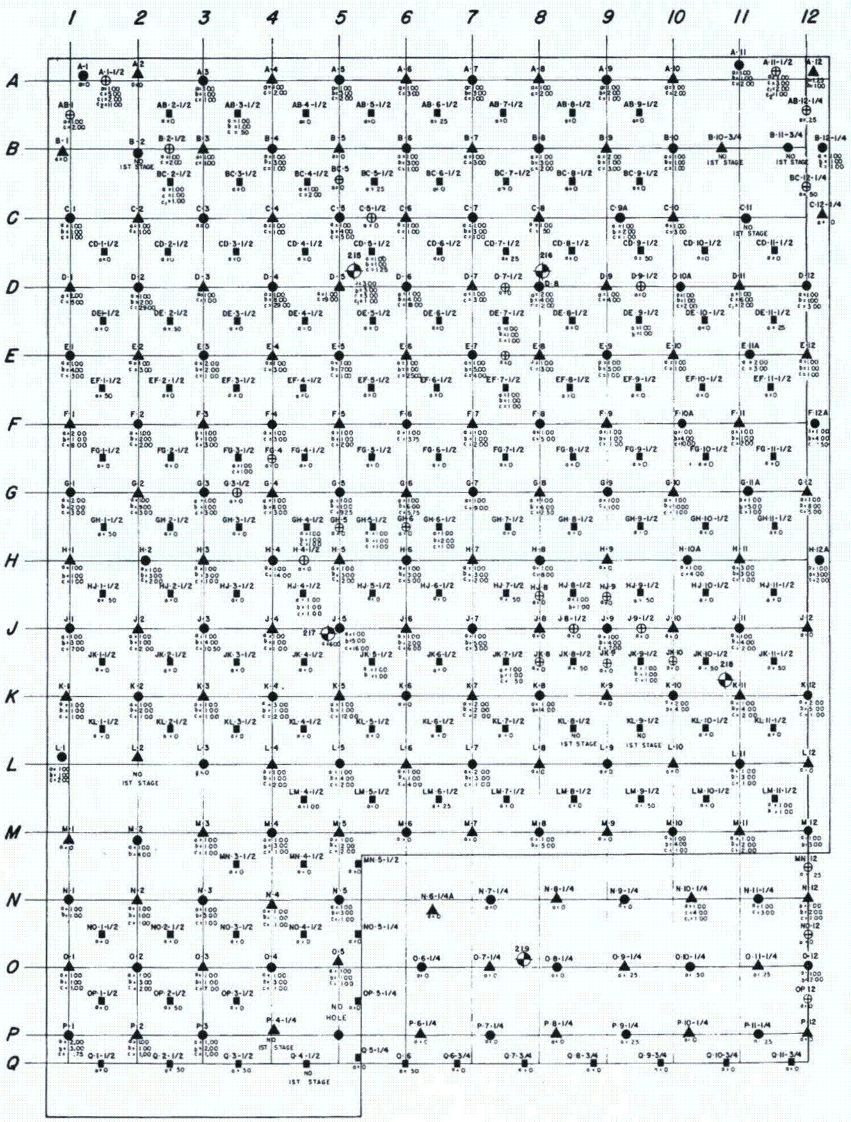
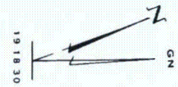
FIGURE 2.5-68, SHEET 2

RESPONSE SPECTRA FOR OPERATING-BASIS EARTHQUAKE – ROCK FOUNDATION (VERTICAL)

REFERENCE:
DAMES & MOORE REPORT, REFERENCE 3





KEY:
- ● PRIMARY HOLE
- ▲ SECONDARY HOLE
- ■ TERTIARY HOLE
- ⊕ QUATERNARY HOLE
- CORE HOLE (SAME VALUES INDICATED 1ST AND 2ND STAGE)

BATCH LEGEND:

a = NUMBER OF BATCHES 3:1 MIX
b = NUMBER OF BATCHES 1.5:1 MIX
c = NUMBER OF BATCHES .67:1 MIX
c_1 = NUMBER OF BATCHES .67:1+ 1 C.F. SAND MIX
c_2 = NUMBER OF BATCHES .67:1+ 2 C.F. SAND MIX

NOTES:

1. ANY OF THE ABOVE SYMBOLS (a, b, c, c_1, c_2) FOLLOWED BY ZERO (0) INDICATES AN ATTEMPT TO GROUT WITH THE INDICATED MIX BUT RESULTED IN A "NO TAKE".
2. NO ATTEMPT AT GROUTING IS INDICATED BY "NO 1ST STAGE" IMMEDIATLY UNDER HOLE.

5 0 5 10 15 20 25
SCALE IN FEET

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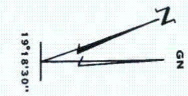
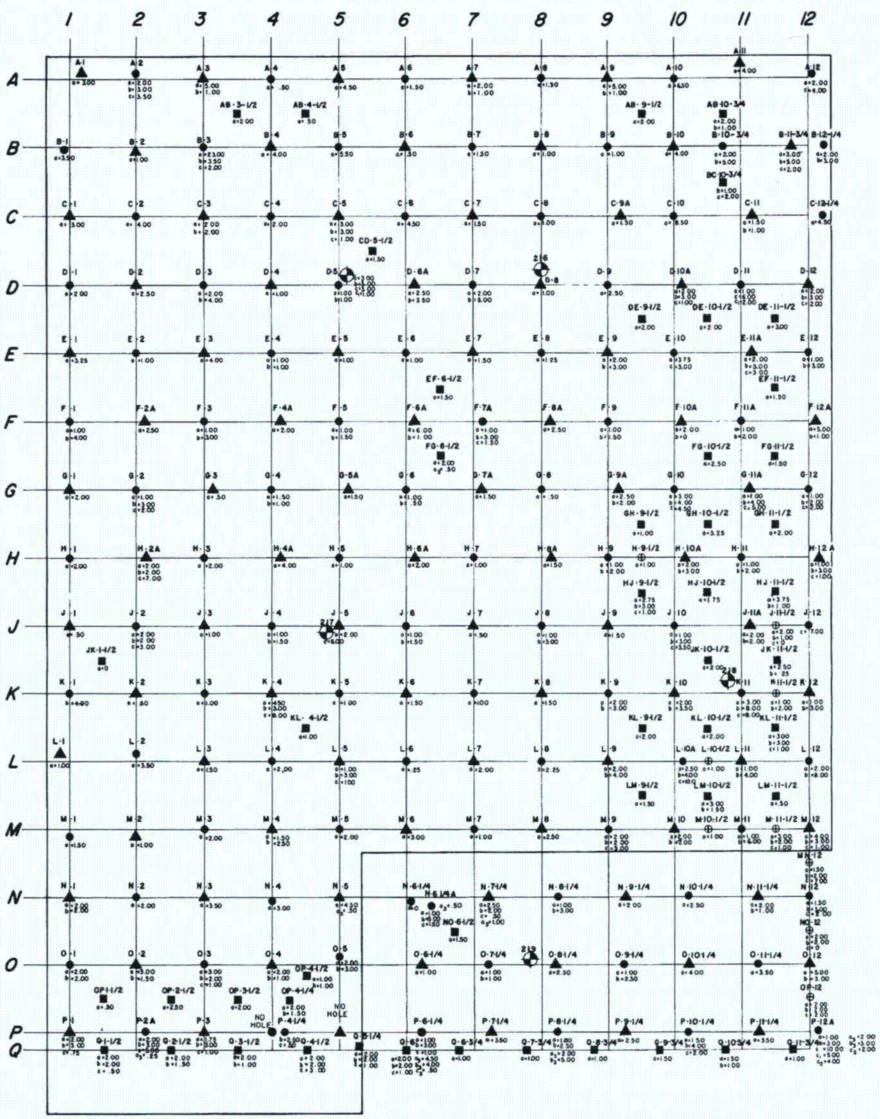
FIGURE 2.5-69

FOUNDATION TREATMENT
FIRST ZONE GROUTING
REACTOR/AUXILIARY BUILDING

REFERENCE:
REFERENCE 23, PLATE A-1





KEY:
- ● PRIMARY HOLE
- ▲ SECONDARY HOLE
- ■ TERTIARY HOLE
- ⊕ QUATERNARY HOLE
- CORE HOLE (SAME VALUES INDICATED 1ST AND 2ND STAGE)

BATCH LEGEND (2ND STAGE):

a = NUMBER OF BATCHES 3:1 MIX
b = NUMBER OF BATCHES 1.5:1 MIX
c = NUMBER OF BATCHES .67:1 MIX
c_1 = NUMBER OF BATCHES .67:1+ 1 C.F. SAND MIX
c_2 = NUMBER OF BATCHES .67:1+ 2 C.F. SAND MIX

BATCH LEGEND (3RD STAGE):

a_3 = NUMBER OF BATCHES 3:1 MIX
b_3 = NUMBER OF BATCHES 1.5:1 MIX
c_3 = NUMBER OF BATCHES .67:1 MIX

NOTES:

1. ANY OF THE ABOVE SYMBOLS (a, b, c, c_1, c_2) FOLLOWED BY ZERO (0) INDICATES AN ATTEMPT TO GROUT WITH THE INDICATED MIX BUT RESULTED IN A "NO TAKE".

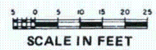


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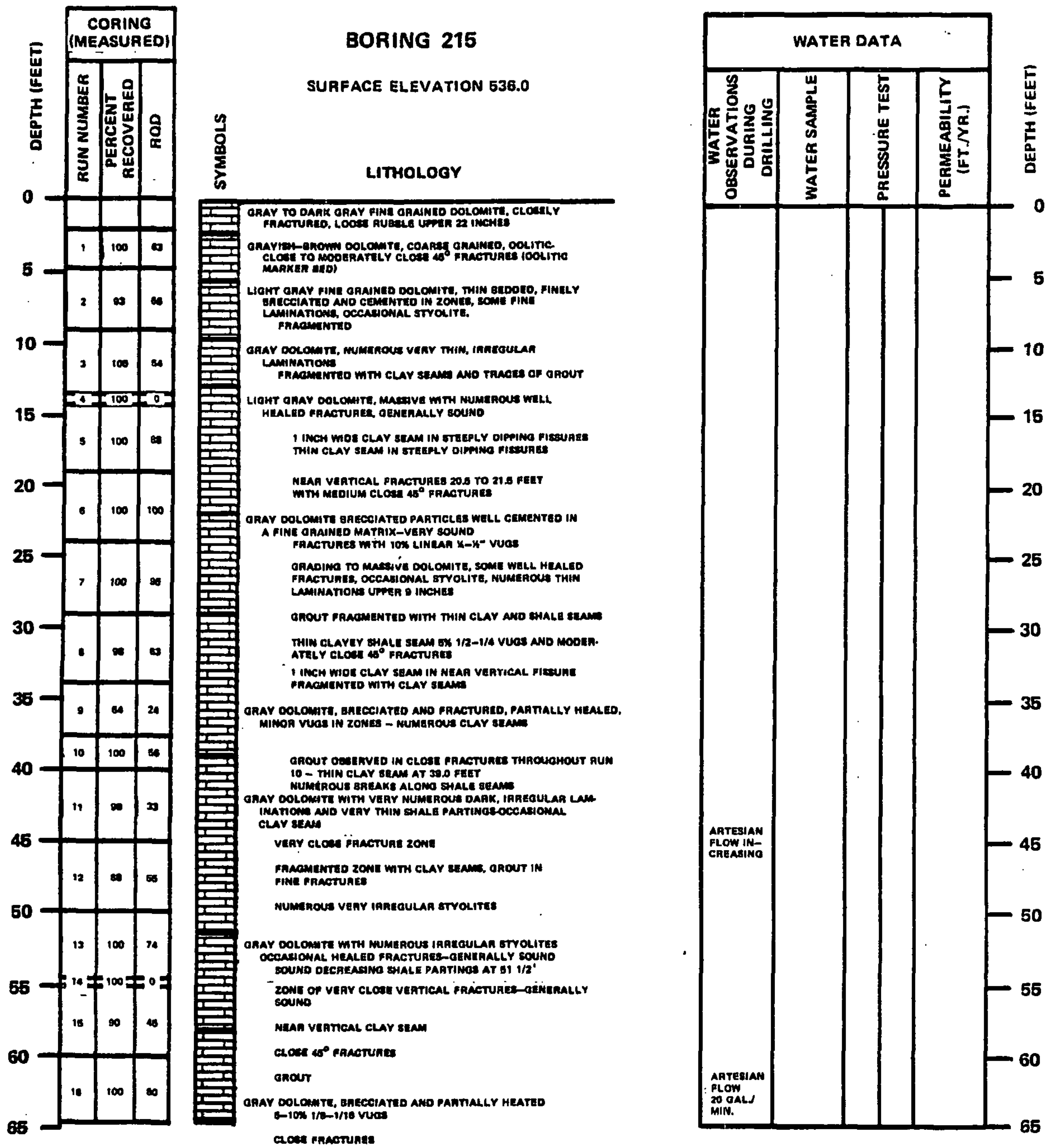
FIGURE 2.5-70

FOUNDATION ZONE TREATMENT
SECOND ZONE GROUTING
REACTOR/AUXILIARY BUILDING

REFERENCE:
REFERENCE 23, PLATE A-2



BORING COMPLETED AT 64.9 FEET ON 9-16-70
CASING USED TO A DEPTH OF 64.0 FEET.
NO DRILLING MUD USED
ARTESIAN WATER FROM 10.0 FEET

NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

RQD – ROCK QUALITY DESIGNATION
A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4 INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY
VERY CLOSE–LESS THAN 2 INCHES APART
CLOSE–2 TO 6 INCHES
MODERATELY CLOSE–6 TO 12 INCHES
WIDE –GREATER THAN 12 INCHES

REFERENCE:
REFERENCE 23, PLATE A-3A

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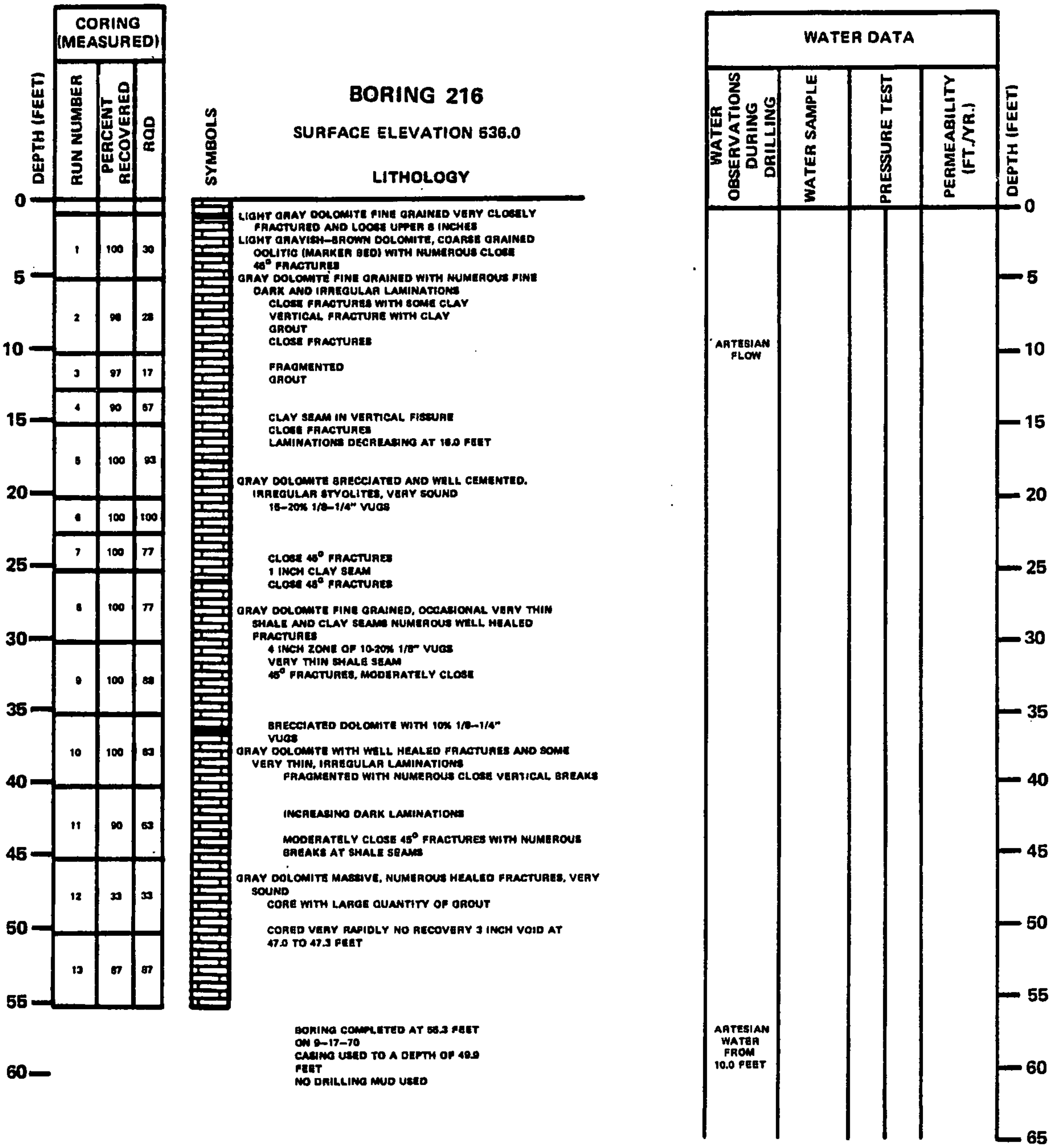
FIGURE 2.5-71

LOG OF BORING 215



NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

RQD – ROCK QUALITY DESIGNATION
A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4 INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY
VERY CLOSE–LESS THAN 2 INCHES APART
CLOSE–2 TO 6 INCHES
MODERATELY CLOSE–6 TO 12 INCHES
WIDE–GREATER THAN 12 INCHES

REFERENCE:
REFERENCE 23, PLATE A-3B

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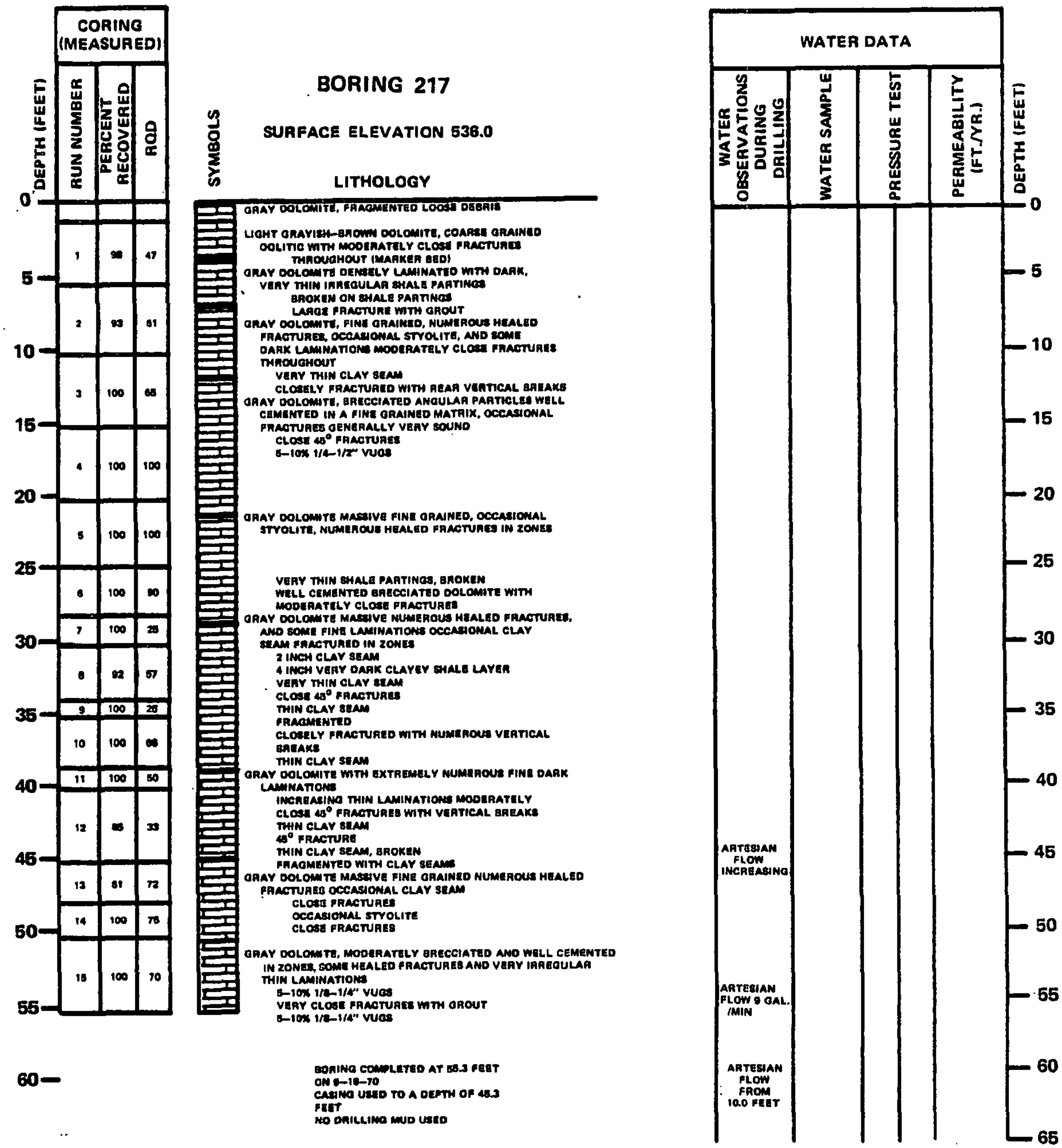
FIGURE 2.5-72

LOG OF BORING 216



NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

RQD – ROCK QUALITY DESIGNATION
A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4 INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY
VERY CLOSE–LESS THAN 2 INCHES APART
CLOSE–2 TO 6 INCHES
MODERATELY CLOSE–6 TO 12 INCHES
WIDE –GREATER THAN 12 INCHES

REFERENCE:
REFERENCE 23, PLATE A-3C

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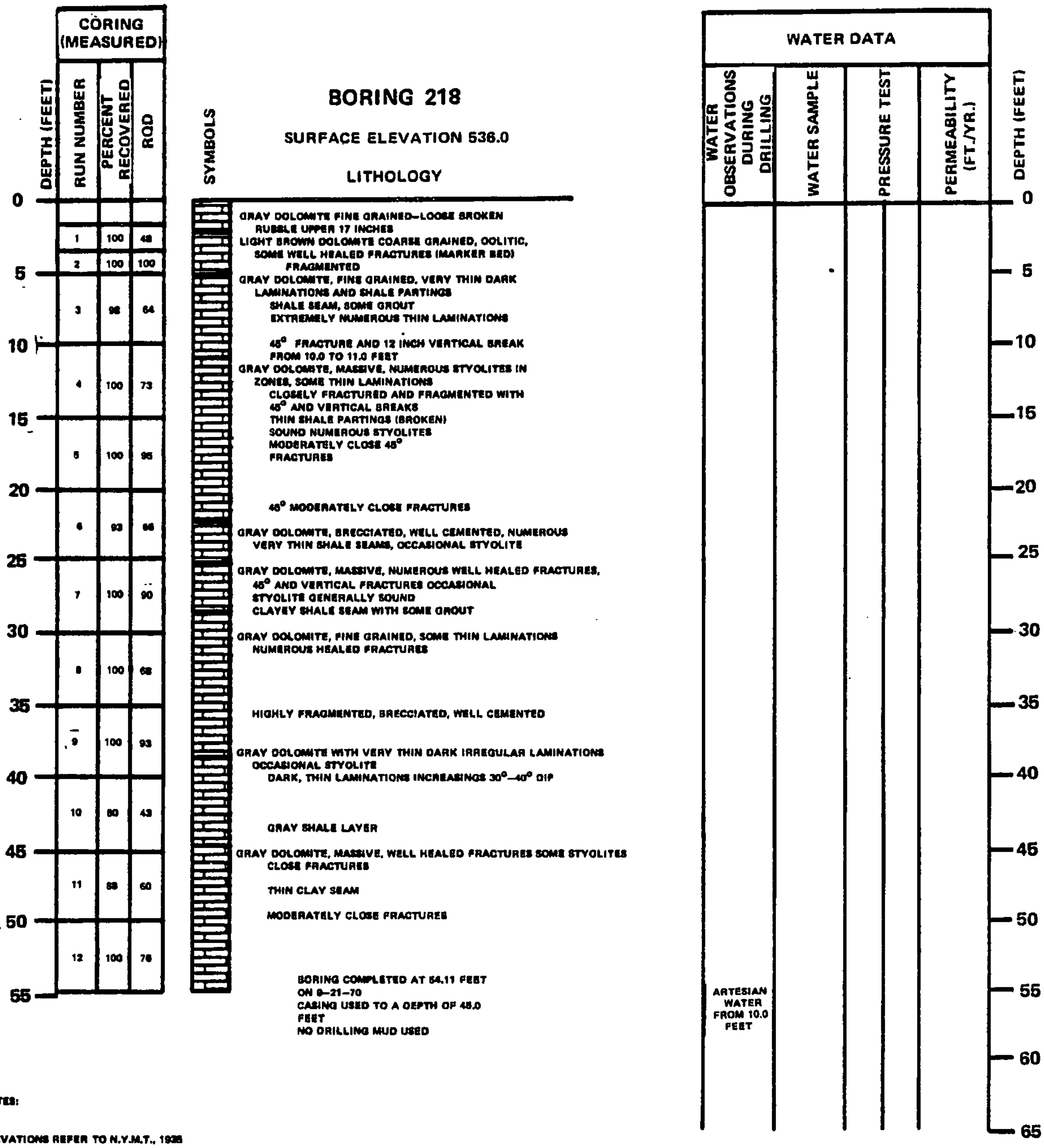
FIGURE 2.5-73

LOG OF BORING 217



NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

RQD – ROCK QUALITY DESIGNATION
A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4 INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY
VERY CLOSE–LESS THAN 2 INCHES APART
CLOSE–2 TO 6 INCHES
MODERATELY CLOSE–6 TO 12 INCHES
WIDE–GREATER THAN 12 INCHES

REFERENCE:
REFERENCE 23, PLATE A-3D

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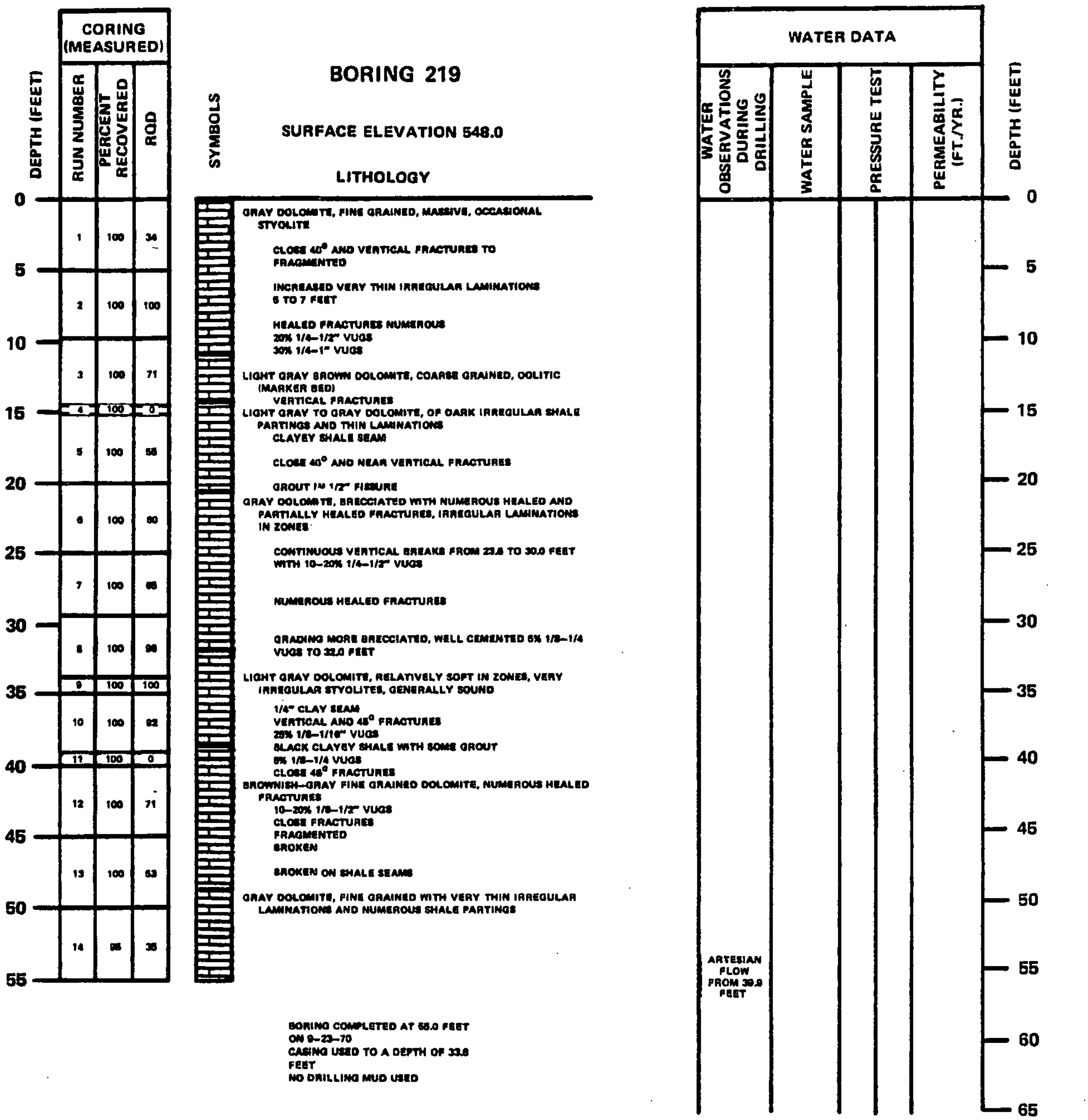
FIGURE 2.5-74

LOG OF BORING 218



NOTES:

ELEVATIONS REFER TO N.Y.M.T., 1935

RQD – ROCK QUALITY DESIGNATION
A MODIFIED CORE RECOVERY PERCENTAGE IN WHICH ALL THE PIECES OF SOUND CORE OVER 4 INCHES LONG ARE COUNTED AS RECOVERY. THE MODIFIED SUM OF CORE RECOVERED IS THEN EXPRESSED AS A PERCENTAGE OF THE TOTAL LENGTH OF THE CORE RUN.

% – VUGS INDICATES THE ESTIMATED RATIO OF VUGGED CORE SURFACE AREA TO TOTAL CORE SURFACE AREA. BOTH OPEN AND FILLED VUGS ARE INCLUDED IN THE VUGGED CATEGORY.

FRACTURE DENSITY TERMINOLOGY
VERY CLOSE–LESS THAN 2 INCHES APART
CLOSE–2 TO 6 INCHES
MODERATELY CLOSE–6 TO 12 INCHES
WIDE –GREATER THAN 12 INCHES

REFERENCE:
REFERENCE 23, PLATE A-3E

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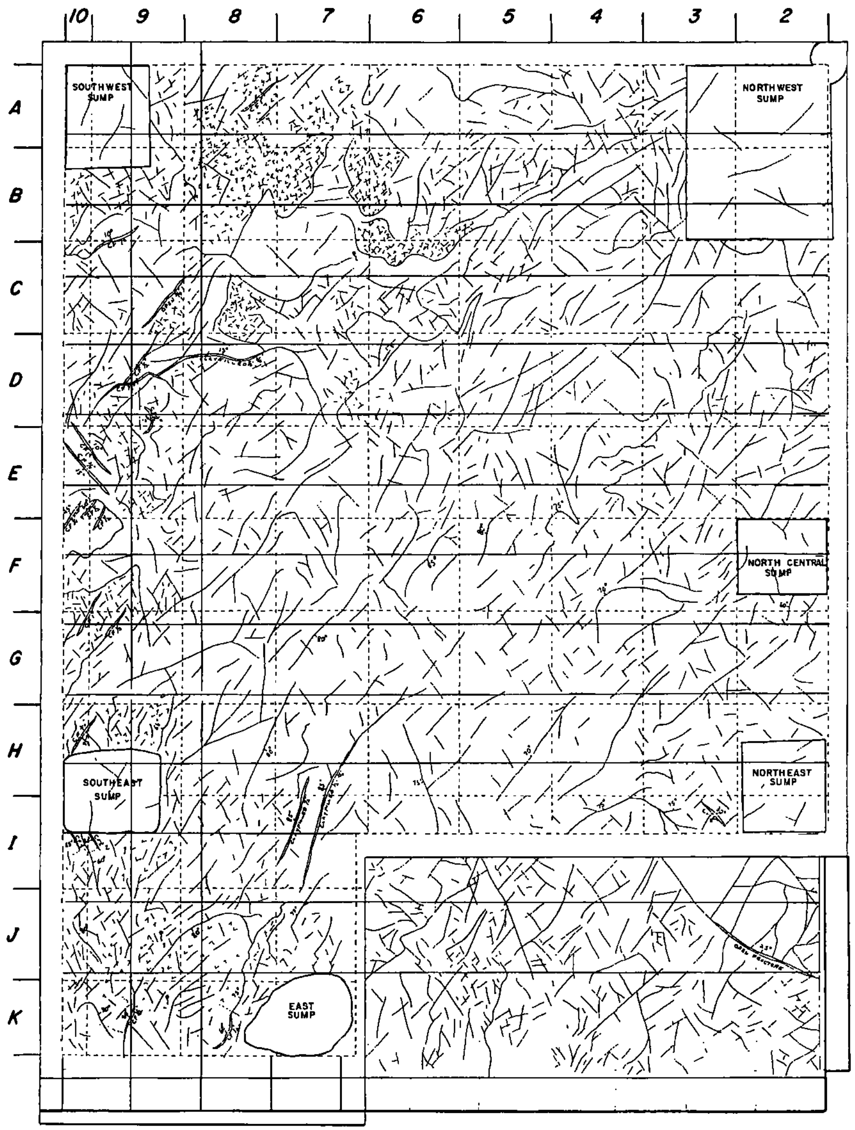
FIGURE 2.5-75

LOG OF BORING 219



- BRECCIATED ROCK (CEMENTED)
- CLOSED FRACTURE
- OPEN FRACTURE
- CLAY SEAM OR CLAY FILLED FRACTURE AND WIDTH OF CLAY
- PROJECTION OF CLAY SEAM OR CLAY FILLED FRACTURE
- INDICATES DIRECTION OF AND ANGLE OF DIP
- VERTICAL FRACTURE OR CLAY SEAM
- FRENCH DRAIN CENTER LINE
- ARTESIAN FLOW

5 0 5 10 15 20 25

SCALE IN FEET

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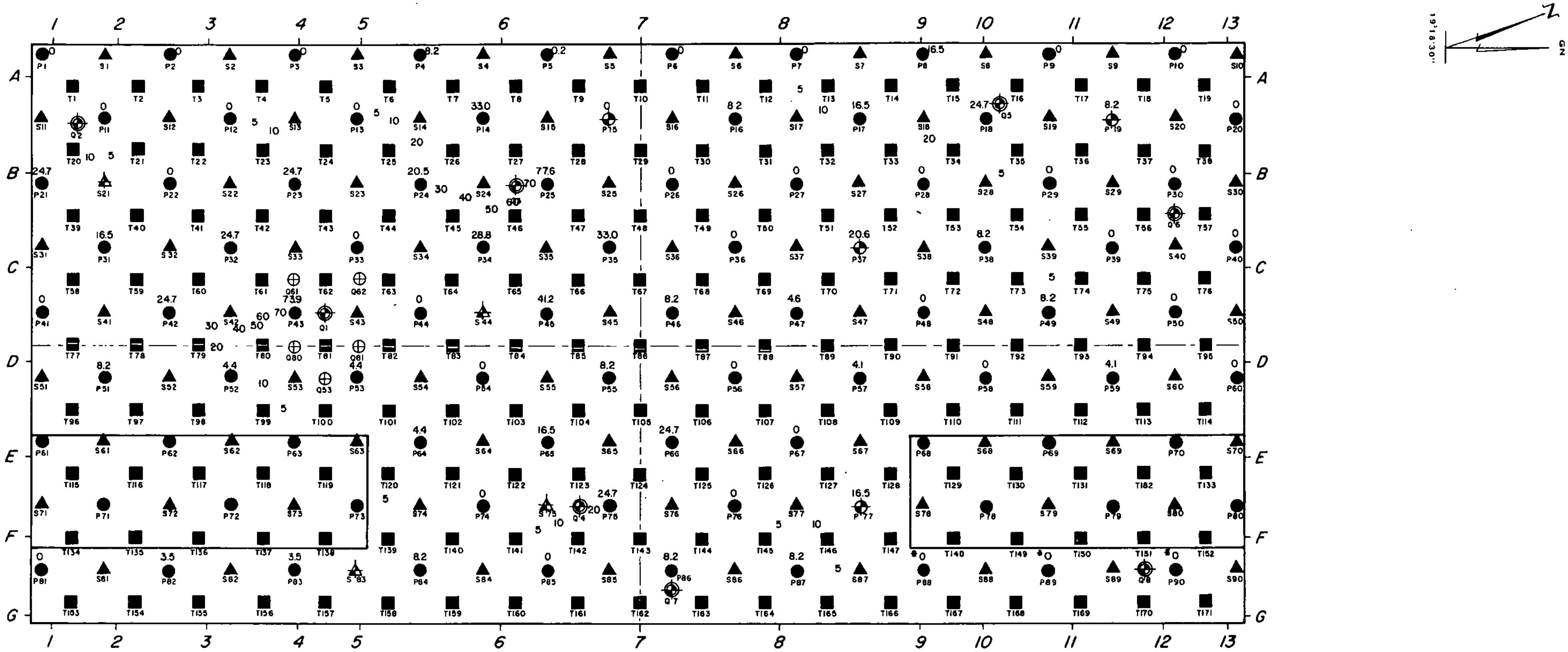
FIGURE 2.5-76

FOUNDATION RACK SURFACE FEATURES REACTOR/AUXILIARY BUILDING

REFERENCE:
REFERENCE 23, PLATE B-1



EXPLANATION

- PRIMARY GROUT HOLES
- SECONDARY GROUT HOLES
- TERTIARY GROUT HOLES
- QUATERNARY GROUT HOLES
- 8.2 GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.6:1 (WATER: CEMENT PLUS FLY ASH)
- *8.2 MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)
- 0 NO GROUT TAKEN BY ROCK
- PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)
- POST-GROUTING EXPLORATORY HOLES
- BUILDING COLUMN LINES
- APPROXIMATE BUILDING AND EXCAVATION LINES
- BUILDING CENTER LINE

0 10 20 30 40 50
SCALE IN FEET

REFERENCE:
MODIFIED FROM LEE TURZILLO CONTRACTING COMPANY
DRAWING NO. 2410-1, FEBRUARY 19, 1974

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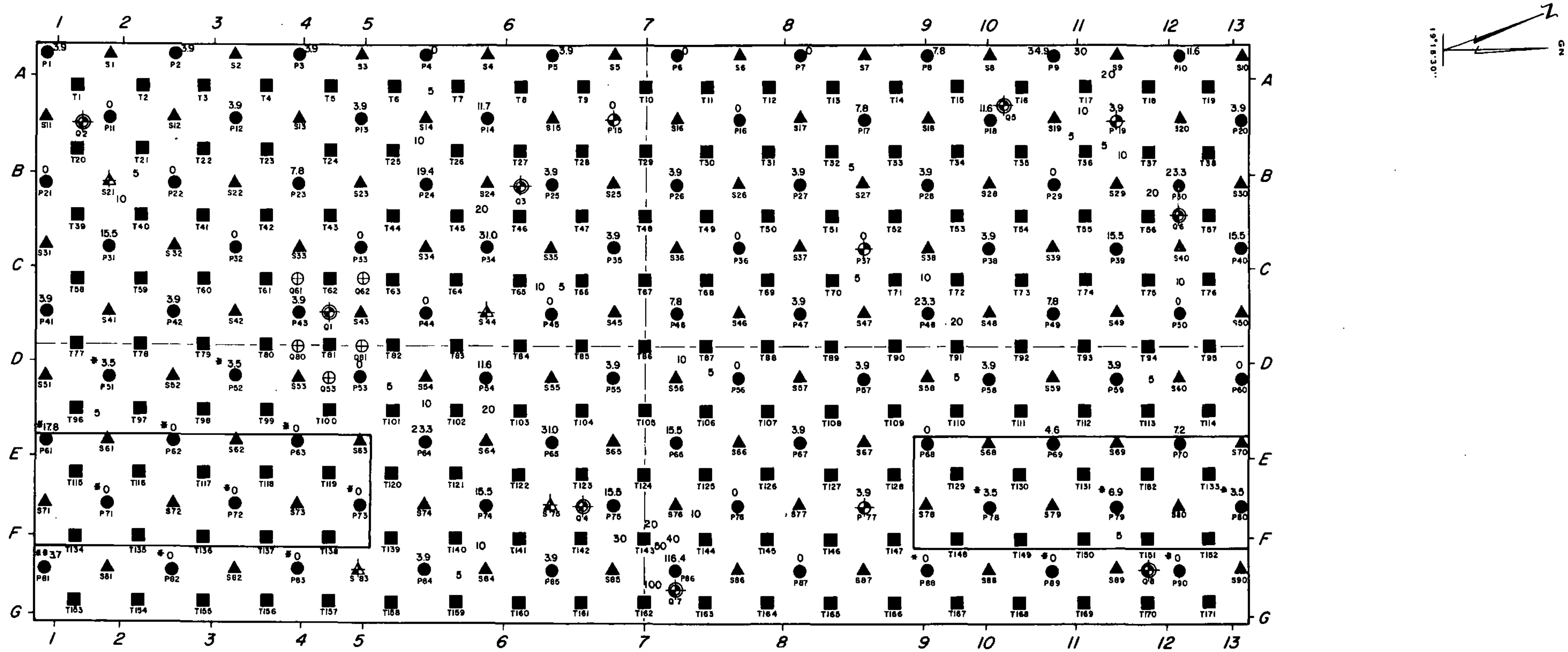
FIGURE 2.5-77

PRIMARY HOLES – FIRST ZONE GROUTING (0-6 FT) RESIDUAL HEAT REMOVAL COMPLEX



- ● PRIMARY GROUT HOLES
- ▲ SECONDARY GROUT HOLES
- ■ TERTIARY GROUT HOLES
- ⊕ QUATERNARY GROUT HOLES

3.9 ● GROUT VOLUME IN CUBIC FEET-MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 2:1 (WATER: CEMENT PLUS FLY ASH)

*3.9 ● MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)

**3.9 ● MIX WITH 1:1 (CEMENT:FLY ASH) AND 1:1 (WATER:CEMENT PLUS FLY ASH)

0 ● NO GROUT TAKEN BY ROCK

PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)

POST-GROUTING EXPLORATORY HOLES

BUILDING COLUMN LINES

APPROXIMATE BUILDING AND EXCAVATION LINES

BUILDING CENTER LINE

0 10 20 30 40 50

SCALE IN FEET

REFERENCE:
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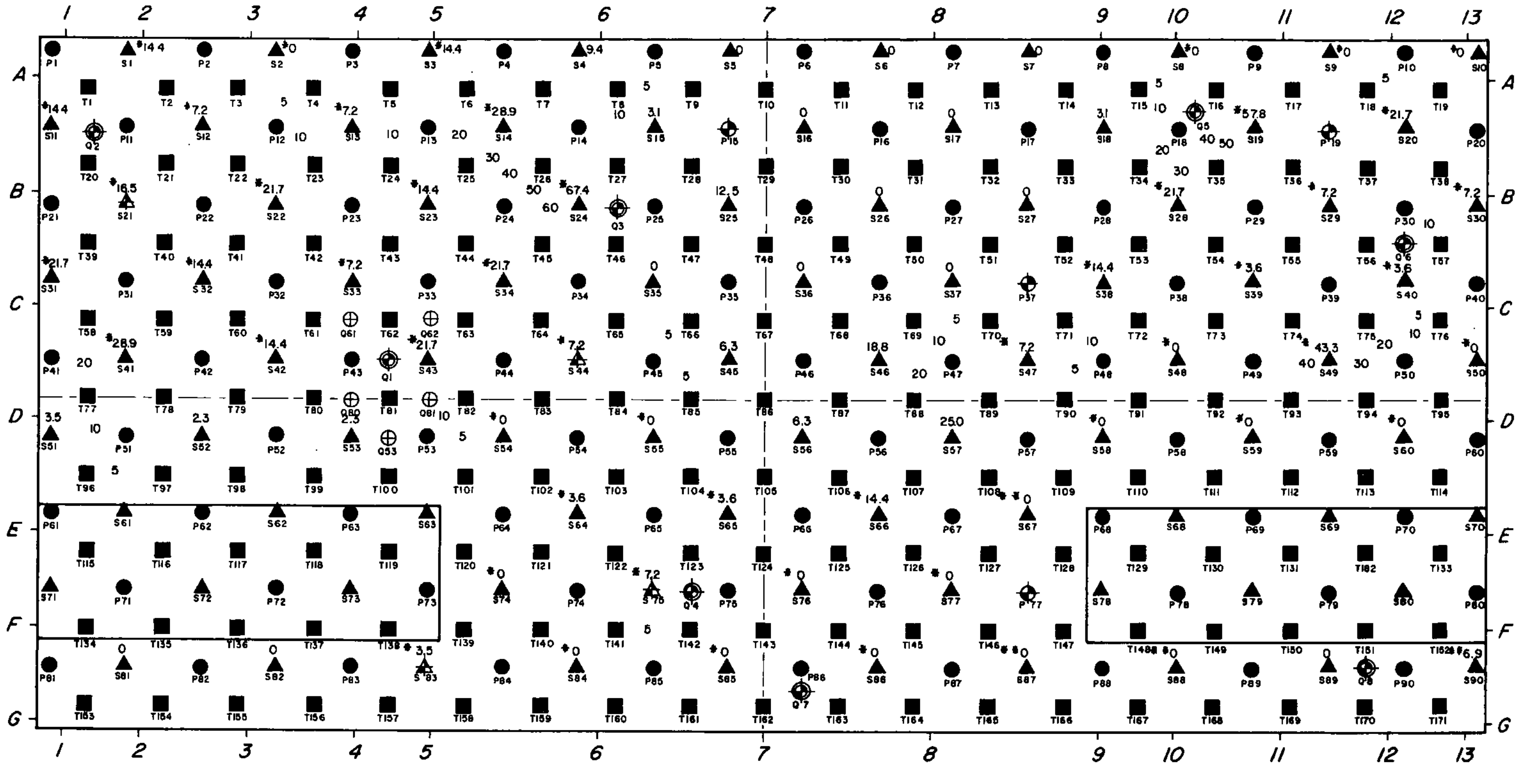
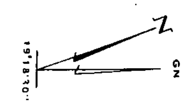
FIGURE 2.5-78

PRIMARY HOLES – SECOND ZONE GROUTING (6-20 FT) RESIDUAL HEAT REMOVAL COMPLEX



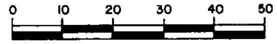


EXPLANATION

- PRIMARY GROUT HOLES
- SECONDARY GROUT HOLES
- TERTIARY GROUT HOLES
- QUATERNARY GROUT HOLES

- 7.2 GROUT VOLUME IN CUBIC FEET-MIX WITH 2:1 (CEMENT:FLY ASH) AND 3:1 (WATER: CEMENT PLUS FLY ASH)
- *7.2 MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 1.8:1 (WATER:CEMENT PLUS FLY ASH)
- **7.2 MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)
- 0 NO GROUT TAKEN BY ROCK

- PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)
- POST-GROUTING EXPLORATORY HOLES
- BUILDING COLUMN LINES
- APPROXIMATE BUILDING AND EXCAVATION LINES
- BUILDING CENTER LINE



SCALE IN FEET

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FIGURE 2.5-79

SECONDARY HOLES – FIRST ZONE GROUTING (0-6 FT) RESIDUAL HEAT REMOVAL COMPLEX

REFERENCE:
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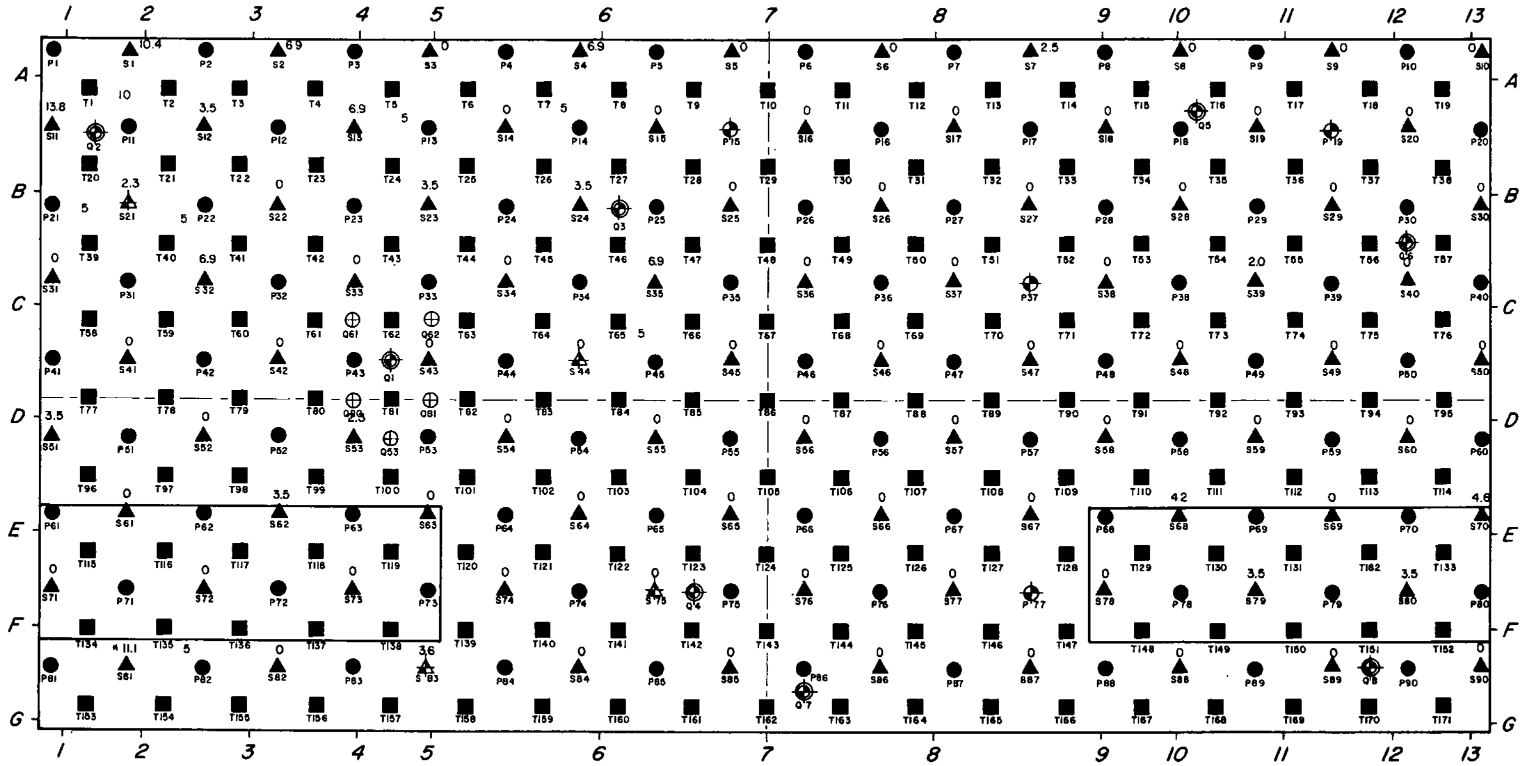
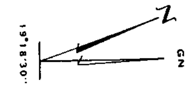
DRAWING NO. 2410-1, FEBRUARY 19, 1974





EXPLANATION

- ● PRIMARY GROUT HOLES
- ▲ SECONDARY GROUT HOLES
- ■ TERTIARY GROUT HOLES
- ⊕ QUATERNARY GROUT HOLES

- 3.5 ▲ GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER: CEMENT PLUS FLY ASH)
- *3.5 ▲ MIX WITH 1:1 (CEMENT:FLY ASH) AND 1:1 (WATER:CEMENT PLUS FLY ASH)
- 0 ▲ NO GROUT TAKEN BY ROCK

- PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)
- POST-GROUTING EXPLORATORY HOLES
- 2 A BUILDING COLUMN LINES
- APPROXIMATE BUILDING AND EXCAVATION LINES
- BUILDING CENTER LINE

0 10 20 30 40 50

SCALE IN FEET

REFERENCE:
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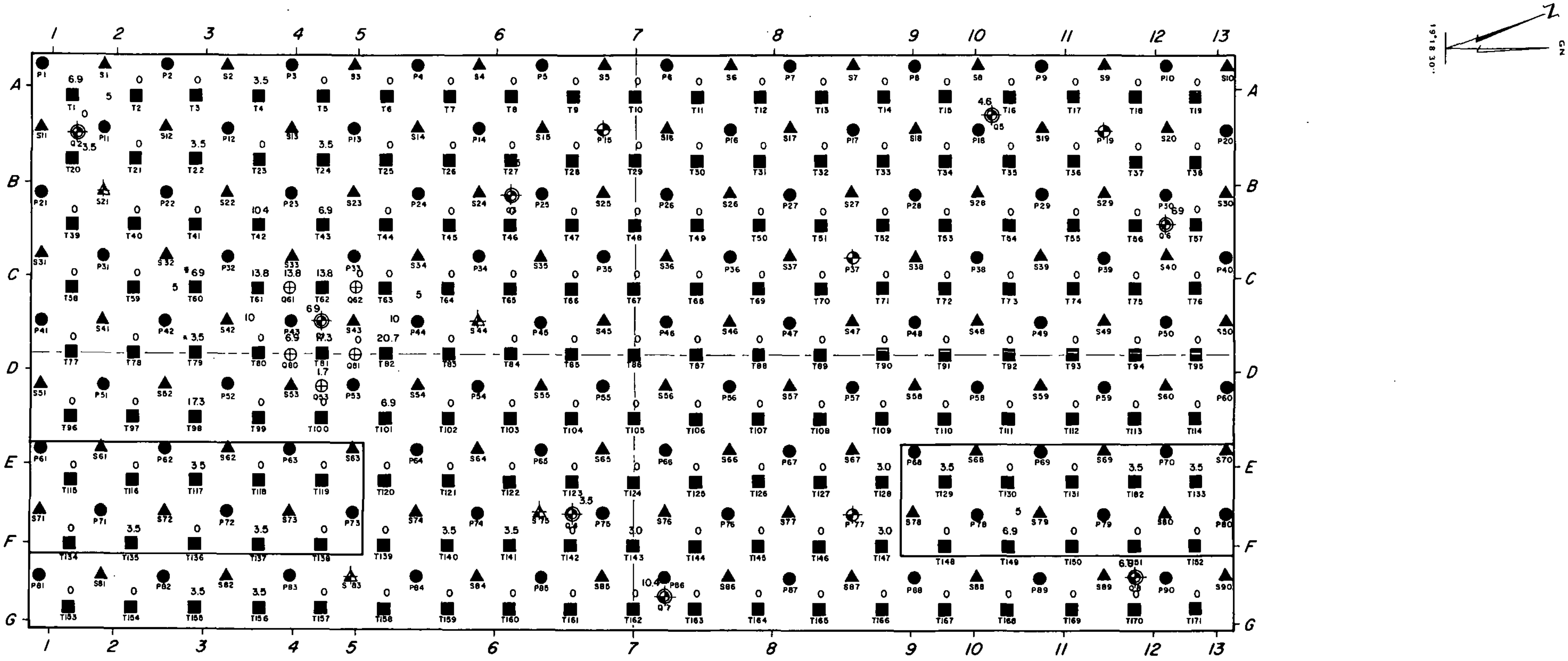
FIGURE 2.5-80

SECONDARY HOLES – SECOND ZONE GROUTING (6-20 FT) RESIDUAL HEAT REMOVAL COMPLEX



EXPLANATION

- PRIMARY GROUT HOLES
- SECONDARY GROUT HOLES
- TERTIARY GROUT HOLES
- QUATERNARY GROUT HOLES

6.9 OR 6.9 OR 6.9 GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER: CEMENT PLUS FLY ASH)

*6.9 MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 1.5:1 (WATER:CEMENT PLUS FLY ASH)

0 NO GROUT TAKEN BY ROCK

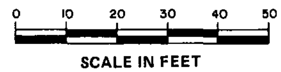
OR PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)

POST-GROUTING EXPLORATORY HOLES

2 A BUILDING COLUMN LINES

APPROXIMATE BUILDING AND EXCAVATION LINES

BUILDING CENTER LINE



REFERENCE:
MODIFIED FROM LEE TURZILLO CONTRACTING COMPANY
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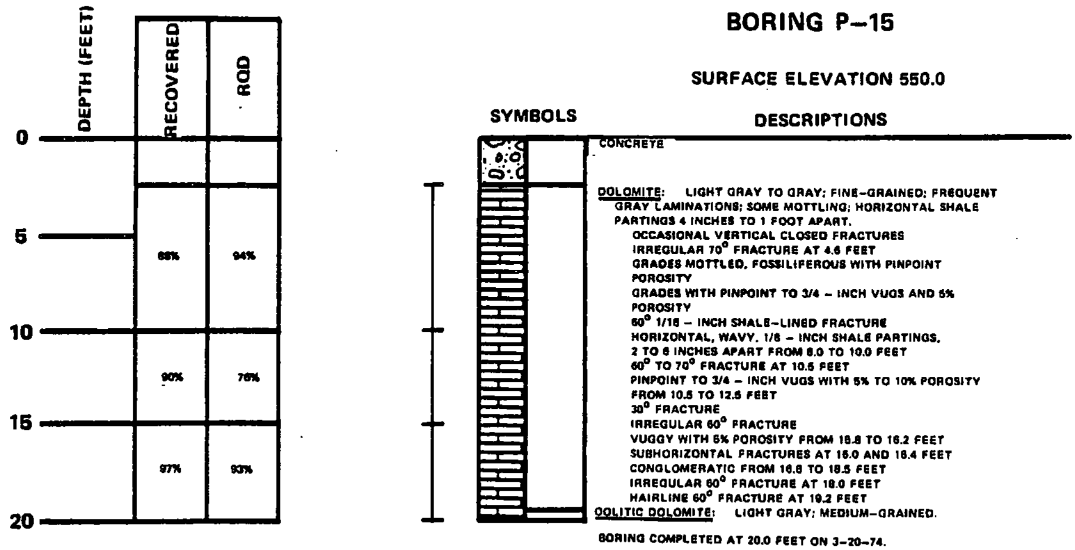
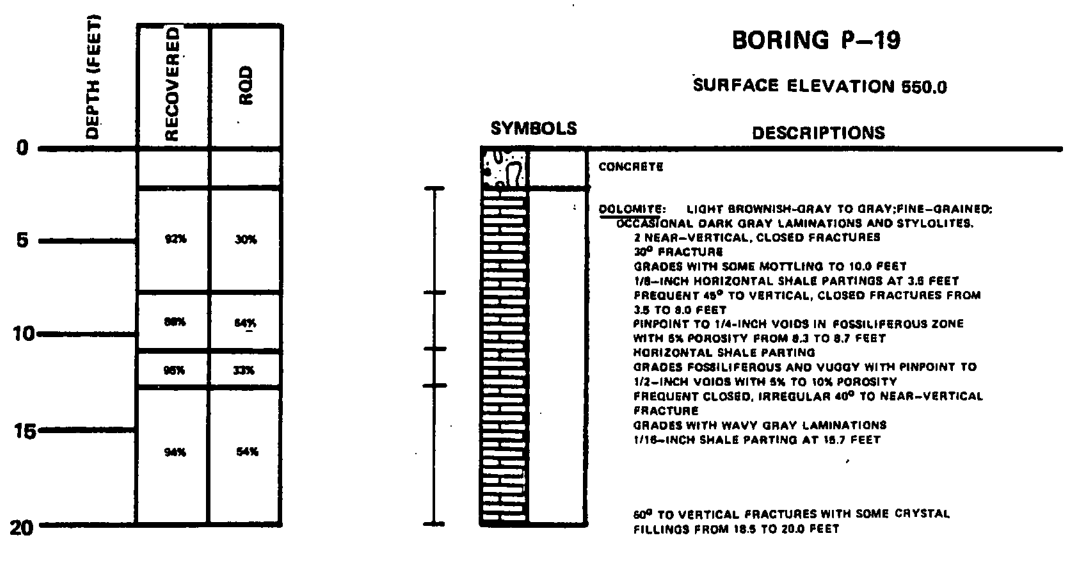
FIGURE 2.5-81

TERTIARY AND QUATERNARY HOLES
SINGLE ZONE GROUTING (0-20 FT)
(CONTOURS ON TERTIARY GROUTING ONLY)
RESIDUAL HEAT REMOVAL COMPLEX





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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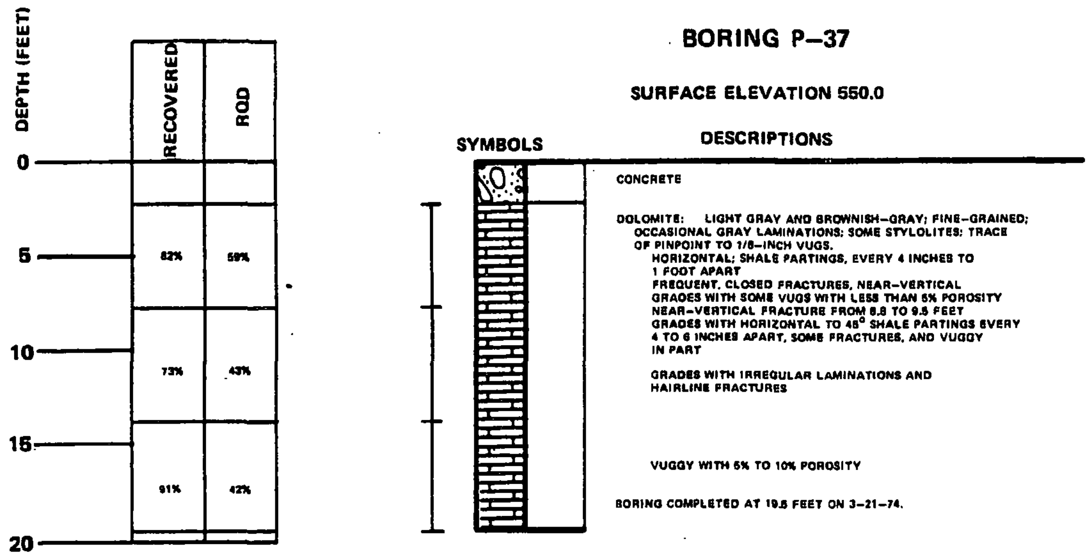
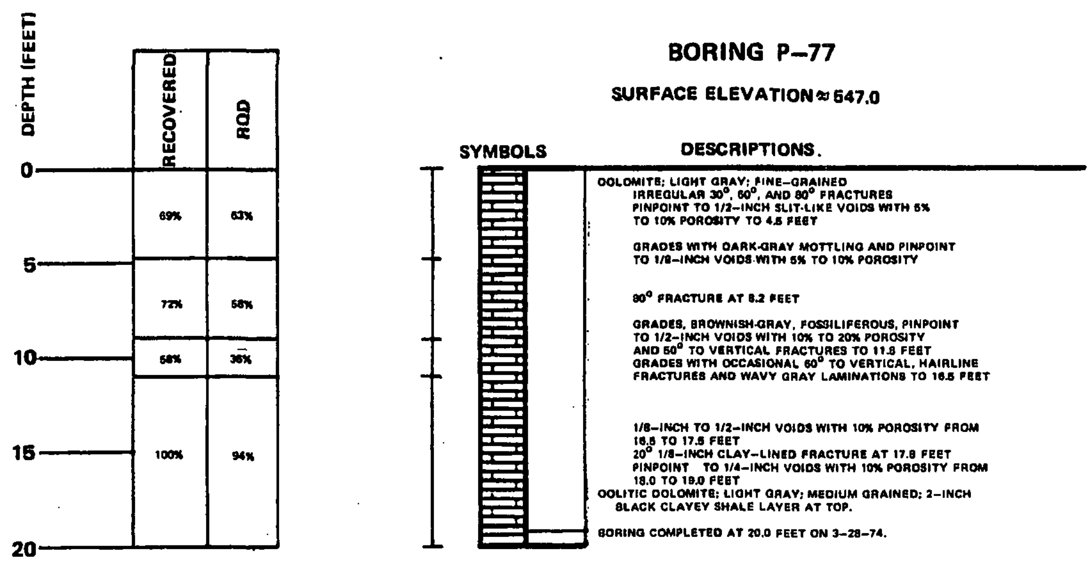
FIGURE 2.5-82

LOG OF BORINGS P-15 AND P-19





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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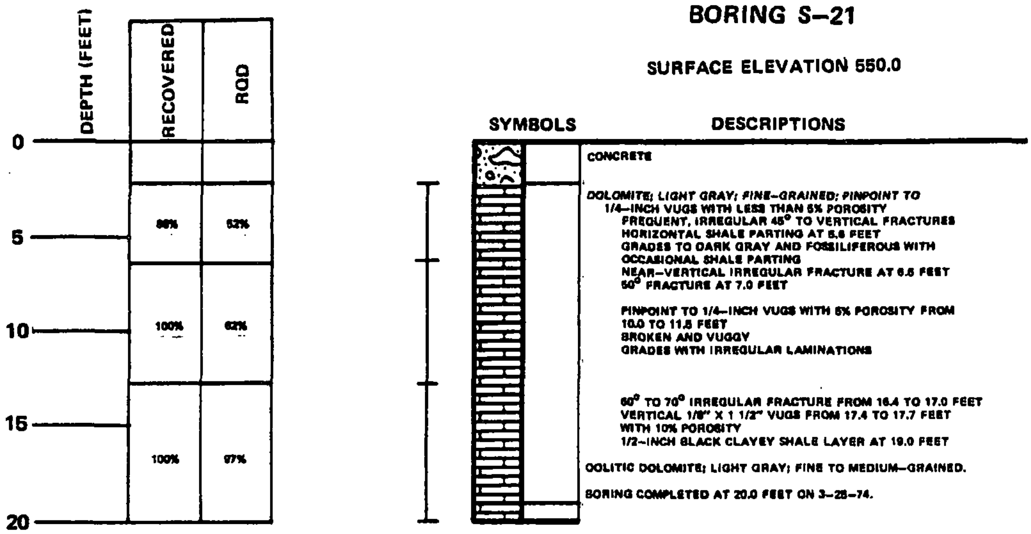
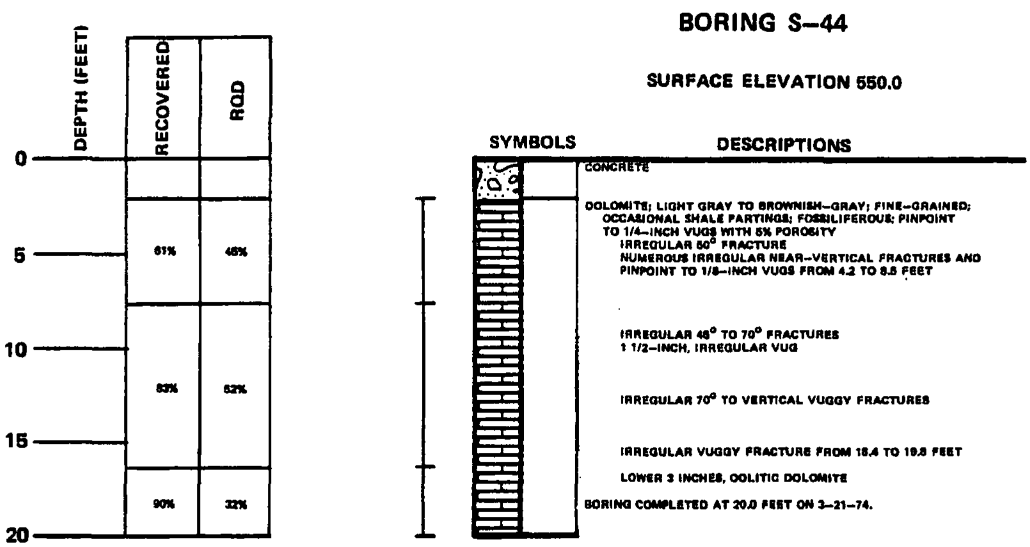
FIGURE 2.5-83

LOG OF BORINGS P-37 AND P-77





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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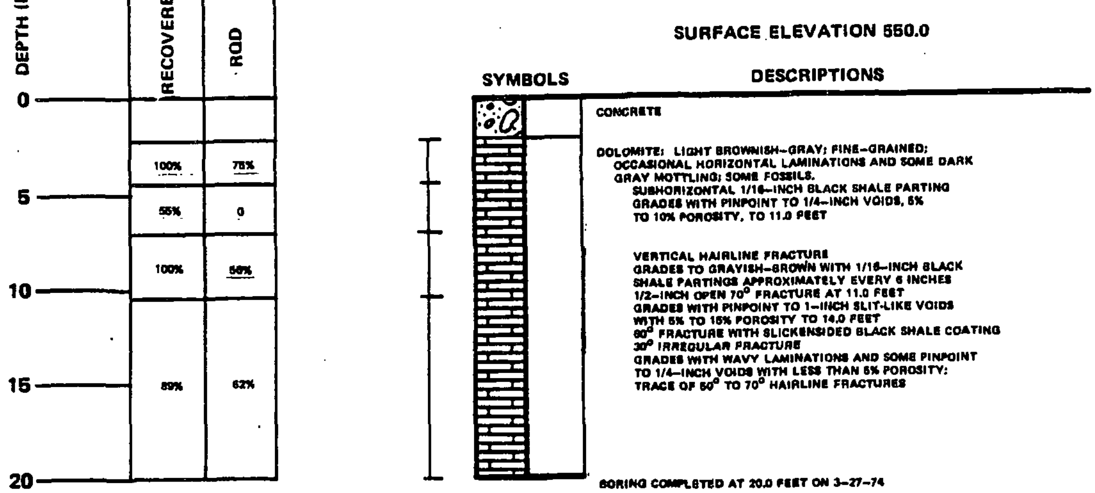
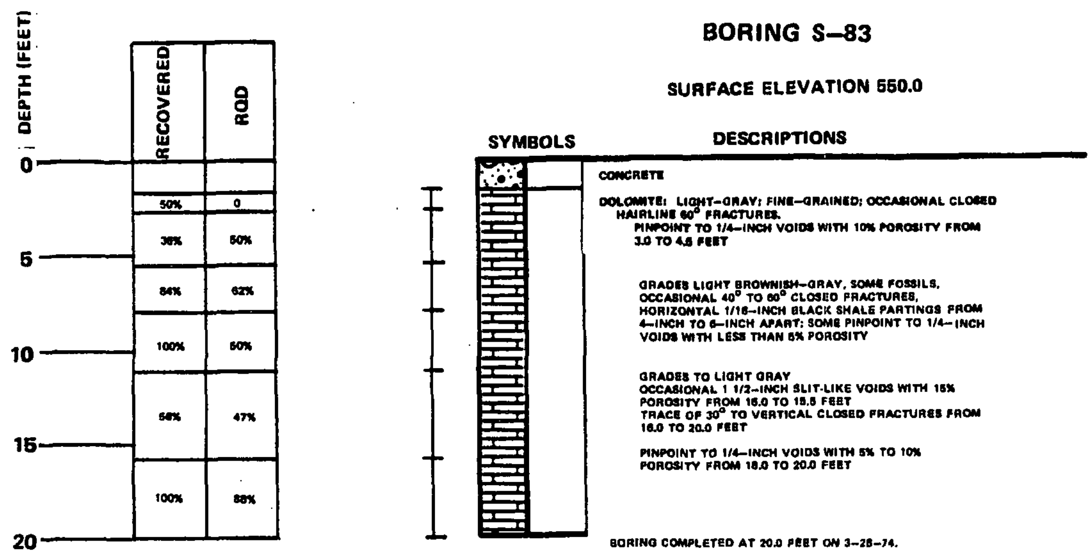
FIGURE 2.5-84

LOG OF BORINGS S-21 AND S-44

BORING S–75



BORING S–83



REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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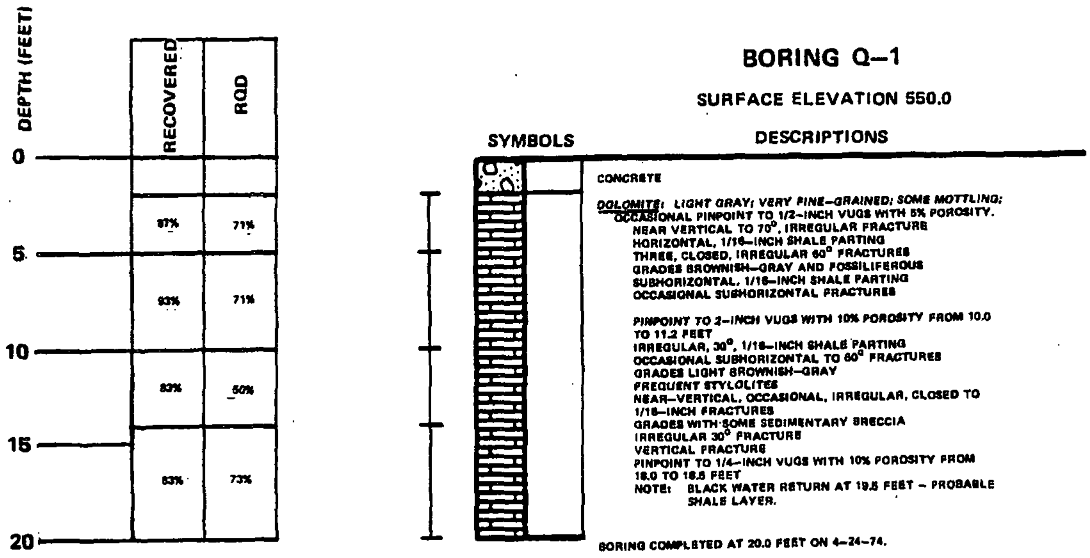
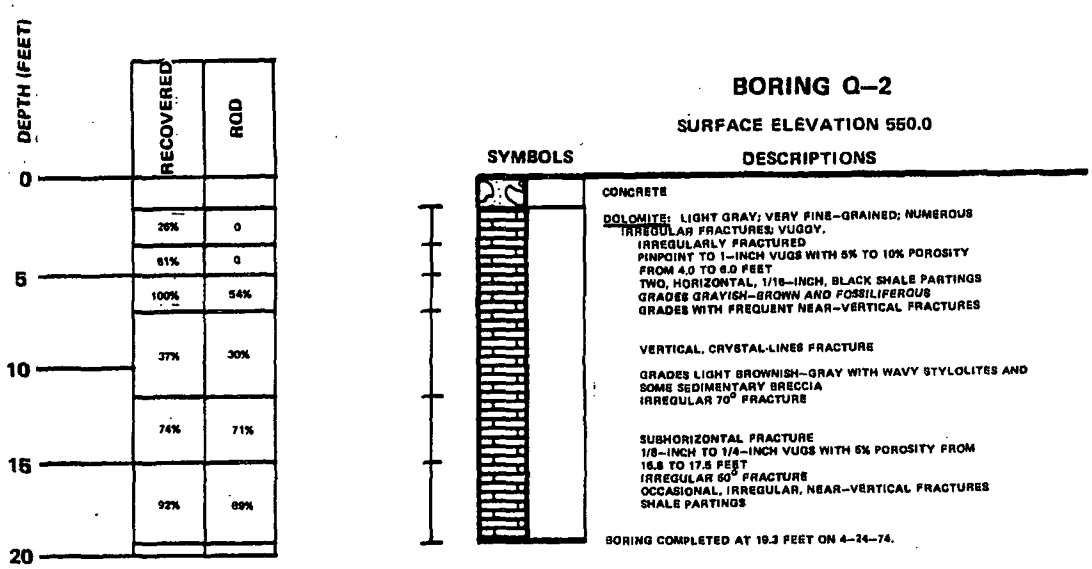
FIGURE 2.5-85

LOG OF BORINGS S-75 AND S-83





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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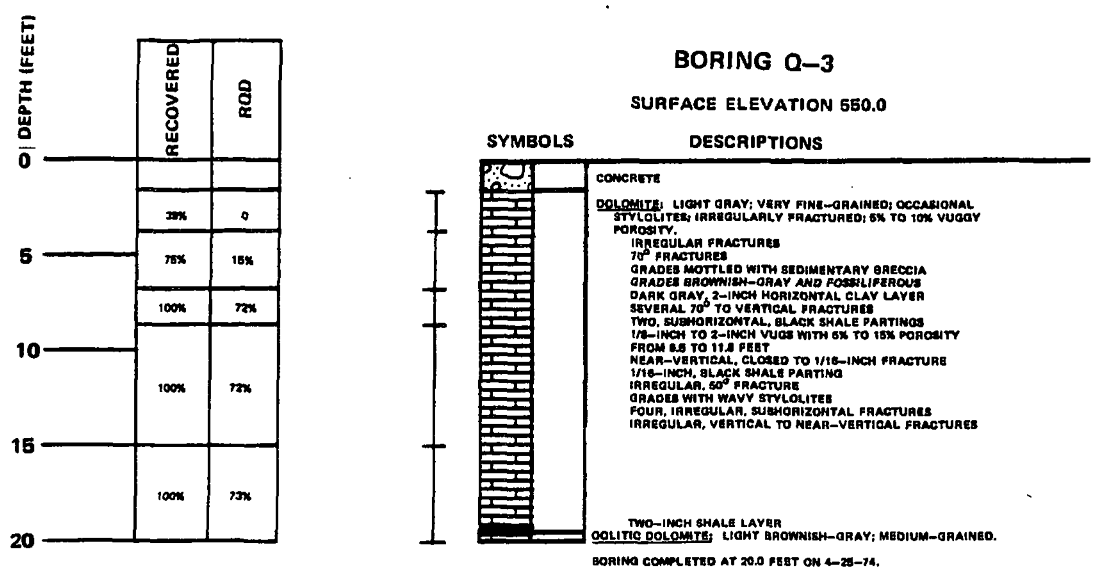
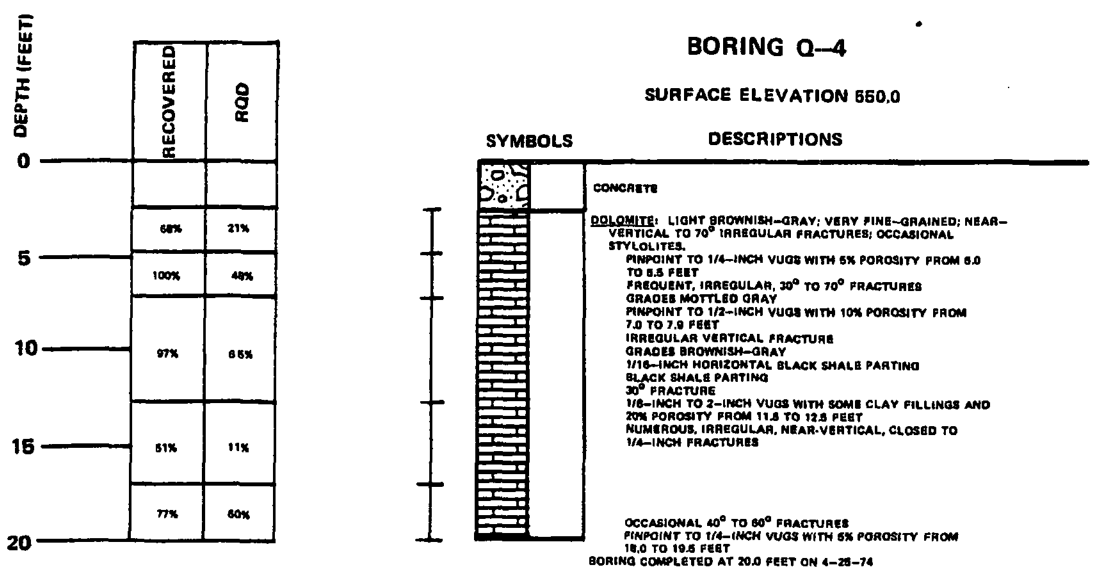
FIGURE 2.5-86

LOG OF BORINGS Q-1 AND Q-2





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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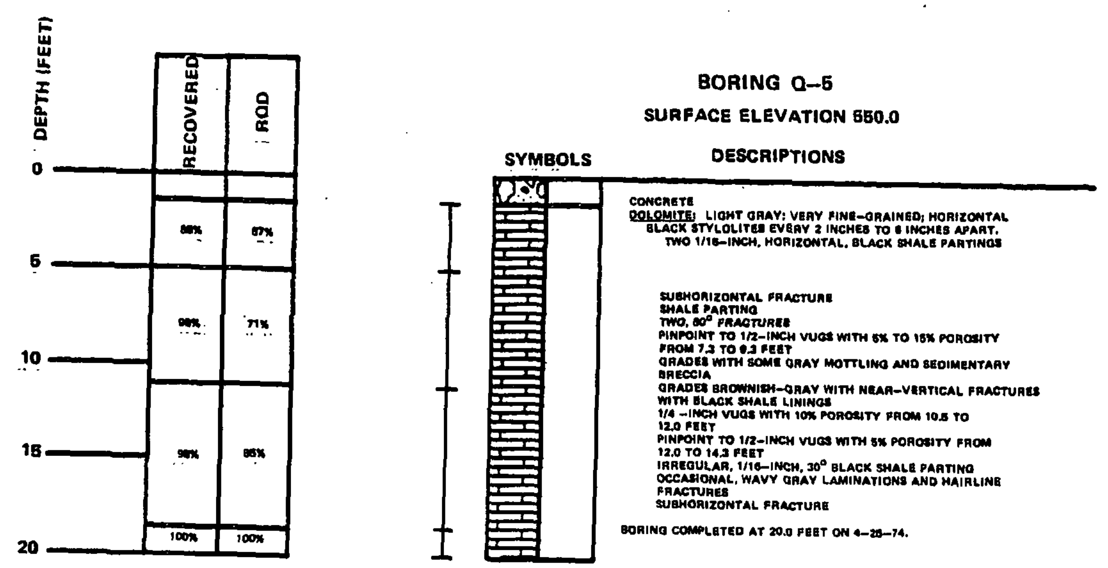
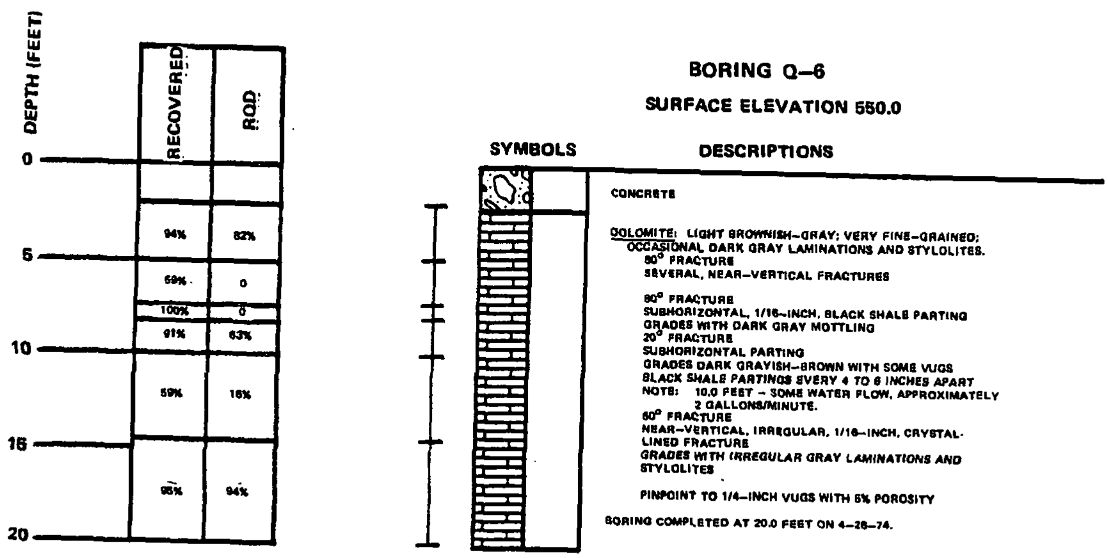
FIGURE 2.5-87

LOG OF BORINGS Q-3 AND Q-4





REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

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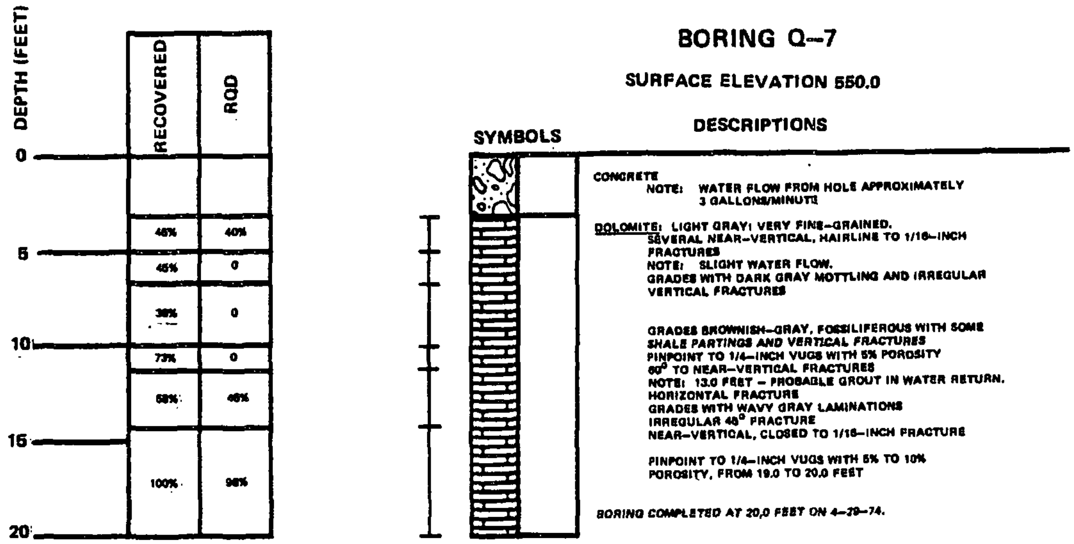
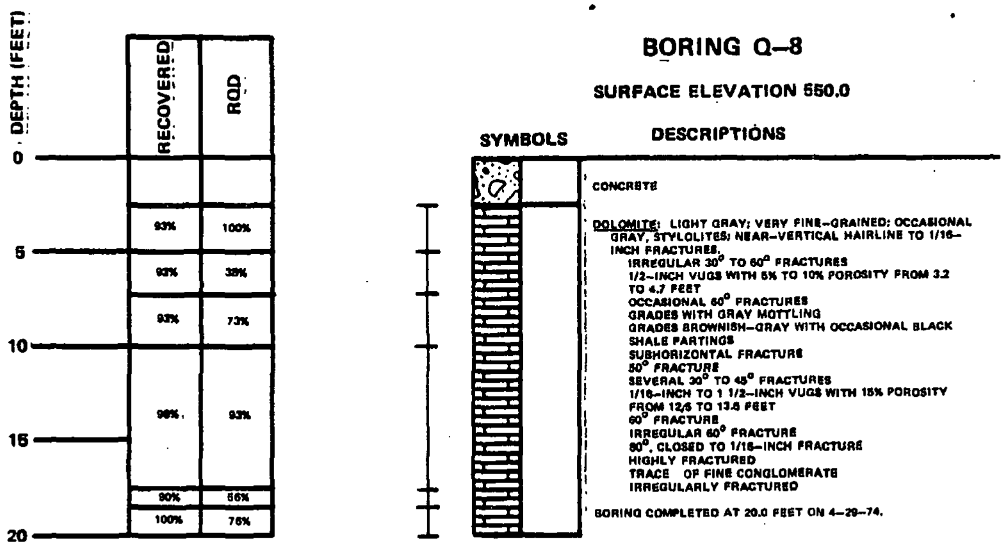
FIGURE 2.5-88

LOG OF BORINGS Q-5 AND Q-6



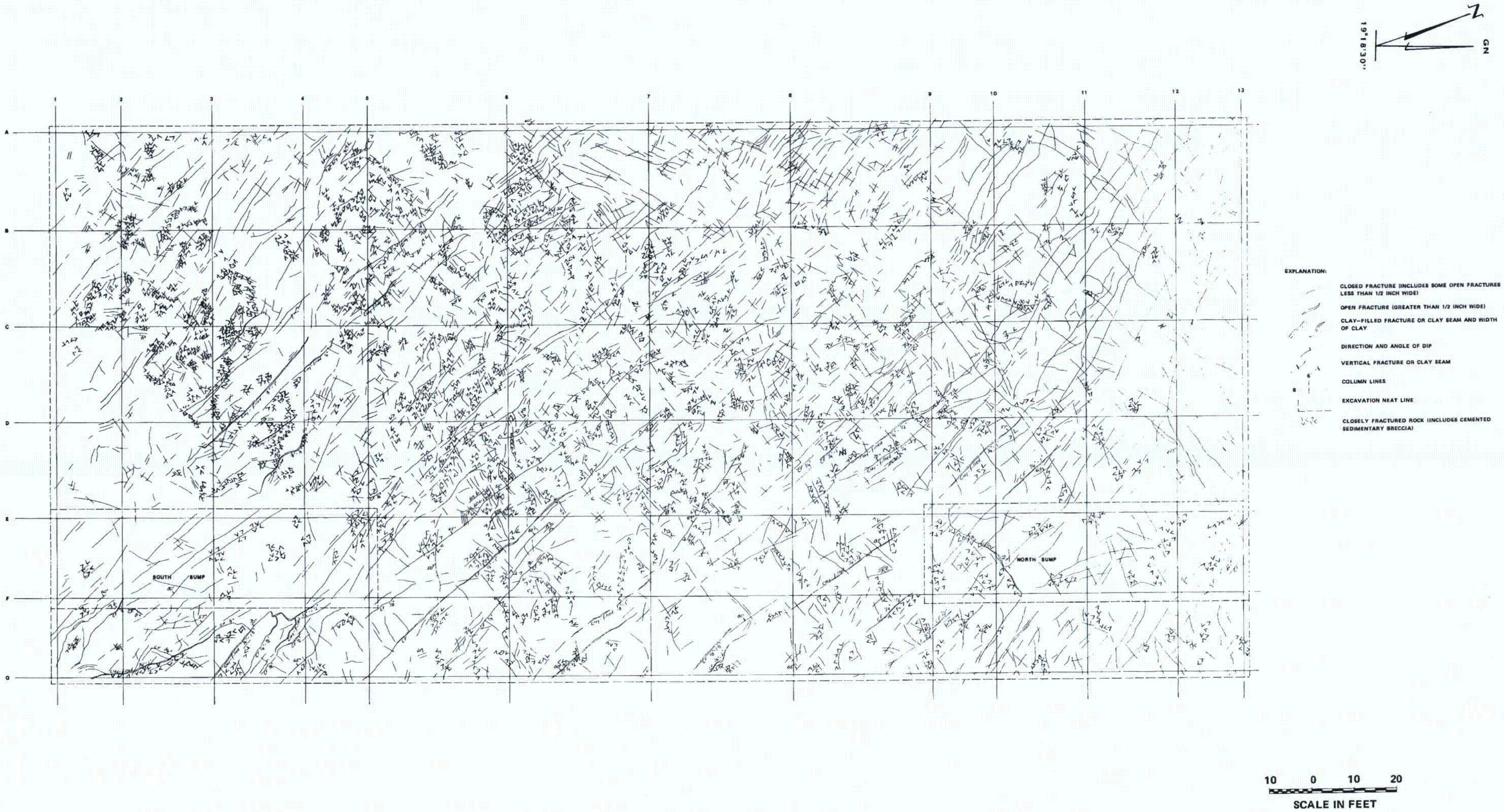


REFERENCE:
DAMES & MOORE REPORT – RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, FERMI 2, JUNE 1974

Fermi 2
UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-89

LOG OF BORINGS Q-7 AND Q-8



Fermi 2

UPDATED FINAL SAFETY ANALYSIS REPORT

FIGURE 2.5-90

FOUNDATION ROCK SURFACE FEATURES
RESIDUAL HEAT REMOVAL COMPLEX

APPENDIX 2A

ANNUAL AVERAGE X/Q VALUES

(UNDECAYED AND UNDEPLETED)

(DEPLETED AND DECAYED)

AND

RELATIVE DEPOSITION D/Q VALUES

FOR THE

CONTAINMENT BUILDING

RADWASTE BUILDING

TURBINE BUILDING

BY

DISTANCE AND SECTOR

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM)				
	0.4	0.8	1.2	1.6	2.4
NNE	1.31E-06	4.16E-07	2.68E-07	2.03E-07	1.37E-07
NE	1.06E-06	3.50E-07	2.28E-07	1.75E-07	1.21E-07
ENE	1.02E-06	3.49E-07	2.30E-07	1.78E-07	1.24E-07
E	7.40E-07	2.54E-07	1.77E-07	1.39E-07	9.88E-08
ESE	7.18E-07	2.45E-07	1.67E-07	1.30E-07	9.13E-08
SE	6.75E-07	2.28E-07	1.54E-07	1.19E-07	8.29E-08
SSE	5.11E-07	1.67E-07	1.14E-07	8.80E-08	6.19E-08
S	4.86E-07	1.52E-07	1.02E-07	7.88E-08	5.45E-08
SSW	3.76E-07	1.27E-07	8.70E-08	6.78E-08	4.78E-08
SW	3.96E-07	1.48E-07	1.05E-07	8.24E-08	5.78E-08
WSW	5.41E-07	1.98E-07	1.35E-07	1.05E-07	7.25E-08
W	4.76E-07	1.64E-07	1.08E-07	8.17E-08	5.49E-08
WNW	6.68E-07	2.15E-07	1.39E-07	1.04E-07	6.97E-08
NW	7.03E-07	2.25E-07	1.51E-07	1.17E-07	8.12E-08
NNW	7.47E-07	2.31E-07	1.52E-07	1.16E-07	8.00E-08
N	7.84E-07	2.52E-07	1.66E-07	1.28E-07	8.86E-06

Source: Containment Building

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	3.2	4.0	4.8	5.6	6.4
NNE	1.04E-07	8.27E-08	6.84E-08	5.80E-08	5.01E-08
NE	9.30E-08	7.51E-08	6.26E-08	5.34E-08	4.63E-03
ENE	9.53E-08	7.69E-08	6.41E-08	5.47E-08	4.75E-08
E	7.65E-08	6.20E-08	5.18E-08	4.43E-08	3.85E-08
ESE	7.08E-08	5.76E-08	4.84E-08	4.15E-08	3.63E-08
SE	6.38E-08	5.16E-08	4.32E-08	3.69E-08	3.22E-08
SSE	4.81E-08	3.92E-08	3.30E-08	2.84E-08	2.49E-08
S	4.20E-08	3.42E-08	2.87E-08	2.47E-08	2.16E-08
SSW	3.70E-08	3.01E-08	2.52E-08	2.16E-08	1.88E-08
SW	4.40E-08	3.50E-08	2.88E-08	2.43E-08	2.09E-08
WSW	5.47E-08	4.34E-08	3.56E-08	3.00E-08	2.57E-08
W	4.09E-08	3.23E-08	2.64E-08	2.22E-08	1.91E-08
WNW	5.20E-08	4.12E-08	3.38E-08	2.85E-08	2.45E-08
NW	6.20E-08	4.96E-08	4.10E-08	3.47E-08	2.99E-08
NNW	6.11E-08	4.92E-08	4.10E-08	3.49E-08	3.03E-08
N	6.78E-08	5.45E-08	4.53E-08	3.86E-08	3.34E-08

Source: Containment Building

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	7.2	8.0	8.8	9.6	10.4
NNE	4.39E-08	3.90E-08	3.49E-08	3.16E-08	2.88E-08
NE	4.08E-08	3.63E-08	3.27E-08	2.96E-08	2.70E-08
ENE	4.18E-08	3.72E-08	3.35E-08	3.04E-08	2.77E-08
E	3.40E-08	3.03E-08	2.73E-08	2.48E-08	2.26E-08
ESE	3.21E-08	2.87E-08	2.60E-08	2.37E-08	2.17E-08
SE	2.85E-08	2.55E-08	2.30E-08	2.09E-08	1.92E-08
SSE	2.21E-08	1.98E-08	1.80E-08	1.64E-08	1.51E-08
S	1.92E-08	1.72E-08	1.56E-08	1.42E-08	1.31E-08
SSW	1.66E-08	1.49E-08	1.34E-08	1.22E-08	1.12E-08
SW	1.82E-08	1.61E-08	1.43E-08	1.29E-08	1.17E-08
WSW	2.24E-08	1.97E-08	1.76E-08	1.58E-08	1.43E-08
W	1.66E-08	1.47E-08	1.31E-08	1.18E-08	1.07E-08
WNW	2.14E-08	1.90E-08	1.70E-08	1.53E-08	1.39E-08
NW	2.62E-08	2.32E-08	2.07E-08	1.87E-08	1.70E-08
NNW	2.66E-08	2.37E-08	2.13E-08	1.93E-08	1.77E-08
N	2.94E-08	2.61E-08	2.34E-08	2.12E-08	1.93E-08

Source: Containment Building

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	11.2	12.0	12.8	13.6	14.4
NNE	2.63E-08	2.43E-08	2.25E-08	2.09E-08	1.95E-08
NE	2.48E-08	2.29E-08	2.12E-08	1.97E-08	1.84E-08
ENE	2.54E-08	2.35E-08	2.18E-08	2.03E-08	1.90E-08
E	2.08E-08	1.92E-08	1.79E-08	1.66E-08	1.56E-08
ESE	2.00E-08	1.86E-08	1.73E-08	1.62E-08	1.52E-08
SE	1.77E-08	1.64E-08	1.52E-08	1.42E-08	1.34E-08
SSE	1.39E-08	1.29E-08	1.20E-08	1.13E-08	1.06E-08
S	1.21E-08	1.12E-08	1.05E-08	9.81E-09	9.23E-09
SSW	1.03E-08	9.52E-09	8.86E-09	8.27E-09	7.75E-09
SW	1.06E-08	9.77E-09	9.01E-09	8.34E-09	7.76E-09
WSW	1.30E-08	1.19E-08	1.10E-08	1.02E-08	9.44E-09
W	9.74E-09	8.94E-09	8.25E-09	7.65E-09	7.12E-09
WNW	1.27E-08	1.17E-08	1.08E-08	1.01E-08	9.37E-09
NW	1.55E-08	1.43E-08	1.32E-08	1.22E-08	1.14E-08
NNW	1.62E-08	1.50E-08	1.39E-08	1.29E-08	1.21E-08
N	1.77E-08	1.63E-08	1.51E-08	1.41E-08	1.31E-08

Source: Containment Building

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	1.82E-08	1.71E-08	1.03E-08	7.13E-09	5.33E-09
NE	1.73E-08	1.62E-08	9.85E-09	6.84E-09	5.13E-09
ENE	1.78E-08	1.67E-08	1.02E-08	7.14E-09	5.37E-09
E	1.46E-08	1.38E-08	8.46E-09	5.93E-09	4.48E-09
ESE	1.43E-08	1.35E-08	8.50E-09	6.09E-09	4.67E-09
SE	1.26E-08	1.19E-08	7.46E-09	5.32E-09	4.07E-09
SSE	1.00E-08	9.45E-09	6.03E-09	4.34E-09	3.35E-09
S	8.70E-09	8.23E-09	5.26E-09	3.79E-09	2.93E-09
SSW	7.28E-09	6.86E-09	4.27E-09	3.02E-09	2.30E-09
SW	7.24E-09	6.78E-09	4.00E-09	2.74E-09	2.03E-09
WSW	8.80E-09	8.23E-09	4.31E-09	3.25E-09	2.39E-09
W	6.65E-09	6.23E-09	3.69E-09	2.53E-09	1.88E-09
WNW	8.77E-09	8.23E-09	4.95E-09	3.43E-09	2.57E-09
NW	1.06E-08	9.98E-09	5.96E-09	4.10E-09	3.06E-09
NNW	1.13E-08	1.07E-08	6.53E-09	4.57E-09	3.44E-09
N	1.23E-08	1.15E-08	6.98E-09	4.84E-09	3.62E-09

Source: Containment Building

TABLE 2A-1 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	48.0	56.0	64.0	72.0	80.0
NNE	4.19E-09	3.42E-09	2.86E-09	2.44E-09	2.11E-09
NE	4.04E-09	3.30E-09	2.76E-09	2.36E-09	2.05E-09
ENE	4.24E-09	3.47E-09	2.91E-09	2.49E-09	2.16E-09
E	3.55E-09	2.91E-09	2.45E-09	2.10E-09	1.82E-09
ESE	3.75E-09	3.11E-09	2.64E-09	2.27E-09	1.99E-09
SE	3.26E-09	2.70E-09	2.28E-09	1.97E-09	1.72E-09
SSE	2.70E-09	2.24E-09	1.90E-09	1.65E-09	1.44E-09
S	2.36E-09	1.96E-09	1.66E-09	1.44E-09	1.26E-09
SSW	1.83E-09	1.51E-09	1.27E-09	1.09E-09	9.53E-10
SW	1.59E-09	1.29E-09	1.07E-09	9.13E-10	7.90E-10
WSW	1.86E-09	1.50E-09	1.24E-09	1.05E-09	9.06E-10
W	1.47E-09	1.19E-09	9.92E-10	8.44E-10	7.29E-10
WNW	2.02E-09	1.65E-09	1.38E-09	1.18E-09	1.03E-09
NW	2.40E-09	1.95E-09	1.63E-09	1.39E-09	1.20E-09
NNW	2.73E-09	2.23E-09	1.87E-09	1.60E-09	1.40E-09
N	2.85E-09	2.33E-09	1.95E-09	1.66E-09	1.44E-09

Source: Containment Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM) 0.4	0.8	1.2	1.6	2.4
NNE	3.04E-06	1.05E-06	6.17E-07	4.40E-07	2.73E-07
NE	2.45E-06	8.69E-07	5.21E-07	3.76E-07	2.38E-07
ENE	2.41E-06	8.70E-07	5.21E-07	3.76E-07	2.38E-07
E	1.70E-06	6.21E-07	3.94E-07	2.89E-07	1.36E-07
ESE	1.73E-06	6.12E-07	3.82E-07	2.79E-07	1.80E-07
SE	1.55E-06	5.45E-07	3.39E-07	2.47E-07	1.58E-07
SSE	1.22E-06	4.15E-07	2.61E-07	1.91E-07	1.24E-07
S	1.10E-06	3.71E-07	2.33E-07	1.69E-07	1.09E-07
SSW	8.68E-07	3.13E-07	1.94E-07	1.42E-07	9.10E-08
SW	8.93E-07	3.51E-07	2.20E-07	1.60E-07	1.01E-07
WSW	1.12E-06	4.24E-07	2.65E-07	1.92E-07	1.21E-07
W	1.06E-06	3.72E-07	2.25E-07	1.60E-07	9.87E-08
WNW	1.58E-06	5.26E-07	3.18E-07	2.26E-07	1.40E-07
NW	1.50E-06	5.19E-07	3.30E-07	2.39E-07	1.52E-07
NNW	1.68E-06	5.63E-07	3.49E-07	2.51E-07	1.59E-07
N	1.63E-06	5.73E-07	3.58E-07	2.60E-07	1.65E-07

Source: Radwaste Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	3.2	4.0	4.8	5.6	6.4
NNE	1.93E-07	1.47E-07	1.17E-07	9.62E-08	8.12E-08
NE	1.70E-07	1.31E-07	1.05E-07	8.68E-08	7.35E-08
ENE	1.70E-07	1.31E-07	1.05E-07	8.72E-08	7.41E-08
E	1.34E-07	1.04E-07	8.38E-08	6.97E-08	5.94E-08
ESE	1.30E-07	1.01E-07	8.21E-08	6.86E-08	5.87E-08
SE	1.14E-07	8.86E-08	7.18E-08	5.99E-08	5.12E-08
SSE	9.02E-08	7.02E-08	5.71E-08	4.79E-08	4.11E-08
S	7.93E-08	6.17E-08	5.02E-08	4.21E-08	3.61E-08
SSW	6.59E-08	5.11E-08	4.13E-08	3.45E-08	2.94E-08
SW	7.12E-08	5.41E-08	4.30E-08	3.53E-08	2.97E-08
WSW	8.55E-08	6.49E-08	5.16E-08	4.24E-08	3.56E-08
W	6.93E-08	5.25E-08	4.16E-08	3.42E-08	2.87E-08
WNW	9.90E-08	7.50E-08	5.96E-08	4.90E-08	4.13E-08
NW	1.08E-07	8.25E-08	6.58E-08	5.42E-08	4.57E-08
NNW	1.14E-07	8.78E-08	7.06E-08	5.85E-08	4.96E-08
N	1.18E-07	9.05E-08	7.26E-08	6.01E-08	5.09E-08

Source: Radwaste Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	7.2	8.0	8.8	9.6	10.4
NNE	6.99E-08	6.10E-08	5.39E-08	4.82E-08	4.34E-08
NE	6.35E-08	5.56E-08	4.93E-08	4.41E-08	3.98E-08
ENE	6.41E-08	5.62E-08	4.99E-08	4.47E-08	4.04E-08
E	5.15E-08	4.53E-08	4.03E-03	3.62E-08	3.27E-08
ESE	5.11E-08	4.51E-08	4.03E-08	3.63E-08	3.30E-08
SE	4.46E-08	3.93E-08	3.51E-08	3.16E-08	2.87E-08
SSE	3.58E-08	3.17E-08	2.84E-08	2.56E-08	2.33E-08
S	3.15E-08	2.79E-08	2.50E-08	2.26E-08	2.05E-08
SSW	2.56E-08	2.25E-08	2.01E-08	1.81E-08	1.64E-08
SW	2.55E-08	2.22E-08	1.96E-08	1.74E-08	1.57E-08
WSW	3.05E-08	2.66E-08	2.34E-08	2.08E-08	1.87E-08
W	2.46E-08	2.15E-08	1.89E-08	1.69E-08	1.52E-08
WNW	3.54E-08	3.09E-08	2.73E-08	2.43E-08	2.19E-08
NW	3.93E-08	3.43E-08	3.03E-08	2.70E-08	2.43E-08
NNW	4.29E-08	3.76E-08	3.34E-08	2.99E-08	2.70E-08
N	4.39E-08	3.85E-08	3.41E-08	3.05E-08	2.75E-08

Source: Radwaste Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	11.2	12.0	12.8	13.6	14.4
NNE	3.94E-08	3.59E-08	3.30E-08	3.05E-08	2.82E-08
NE	3.62E-08	3.31E-08	3.04E-08	2.81E-08	2.61E-08
ENE	3.68E-08	3.37E-08	3.11E-08	2.87E-08	2.67E-08
E	2.99E-08	2.74E-08	2.53E-08	2.34E-08	2.18E-08
ESE	3.02E-08	2.78E-08	2.57E-08	2.39E-08	2.23E-08
SE	2.63E-08	2.42E-08	2.24E-08	2.08E-08	1.94E-08
SSE	2.14E-08	1.97E-08	1.83E-08	1.70E-08	1.59E-08
S	1.88E-08	1.74E-08	1.61E-08	1.50E-08	1.40E-08
SSW	1.50E-08	1.38E-08	1.27E-08	1.18E-08	1.10E-08
SW	1.42E-08	1.29E-08	1.19E-08	1.09E-08	1.01E-08
WSW	1.69E-08	1.54E-08	1.41E-08	1.30E-08	1.20E-08
W	1.37E-08	1.25E-08	1.15E-08	1.06E-08	9.80E-09
WNW	1.98E-08	1.81E-08	1.66E-08	1.53E-08	1.42E-08
NW	2.21E-08	2.01E-08	1.85E-08	1.71E-08	1.58E-08
NNW	2.46E-08	2.25E-08	2.07E-08	1.92E-08	1.78E-08
N	2.50E-08	2.29E-08	2.11E-08	1.95E-08	1.81E-08

Source: Radwaste Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM) 15.2	16.0	24.0	32.0	40.0
NNE	2.63E-08	2.46E-08	1.42E-08	9.63E-09	7.09E-09
NE	2.43E-08	2.28E-08	1.33E-08	9.03E-09	6.67E-09
ENE	2.49E-08	2.33E-08	1.37E-08	9.38E-09	6.95E-09
E	2.03E-08	1.90E-08	1.13E-08	7.75E-09	5.76E-09
ESE	2.09E-08	1.96E-08	1.20E-08	8.35E-09	6.29E-09
SE	1.82E-08	1.71E-08	1.03E-08	7.20E-09	5.41E-09
SSE	1.49E-08	1.40E-08	8.59E-09	6.02E-09	4.55E-09
S	1.31E-08	1.23E-08	7.56E-09	5.30E-09	4.00E-09
SSW	1.03E-08	9.64E-09	5.79E-09	4.00E-09	2.99E-09
SW	9.42E-09	8.79E-09	5.06E-09	3.41E-09	2.50E-09
WSW	1.11E-08	1.04E-08	5.90E-09	3.94E-09	2.87E-09
W	9.11E-09	8.50E-09	4.88E-09	3.28E-09	2.40E-09
WNW	1.32E-08	1.24E-08	7.16E-09	4.84E-09	3.57E-09
NW	1.47E-08	1.37E-08	7.95E-09	5.37E-09	3.95E-09
NNW	1.66E-08	1.56E-08	9.15E-09	6.24E-09	4.63E-09
N	1.68E-08	1.57E-08	9.20E-09	6.25E-09	4.62E-09

Source: Radwaste Building

TABLE 2A-2 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM) 48.0	56.0	64.0	72.0	80.0
NNE	5.51E-09	4.45E-09	3.70E-09	3.14E-09	2.71E-09
NE	5.19E-09	4.20E-09	3.49E-09	2.97E-09	2.56E-09
ENE	5.43E-09	4.40E-09	3.66E-09	3.11E-09	2.69E-09
E	4.51E-09	3.66E-09	3.06E-09	2.60E-09	2.25E-09
ESE	4.97E-09	4.07E-09	3.42E-09	2.92E-09	2.54E-09
SE	4.27E-09	3.49E-09	2.92E-09	2.50E-09	2.17E-09
SSE	3.61E-09	2.96E-09	2.48E-09	2.13E-09	1.85E-09
S	3.17E-09	2.59E-09	2.18E-09	1.86E-09	1.62E-09
SSW	2.35E-09	1.92E-09	1.60E-09	1.37E-09	1.19E-09
SW	1.94E-09	1.57E-09	1.30E-09	1.10E-09	9.48E-10
WSW	2.21E-09	1.77E-09	1.46E-09	1.24E-09	1.06E-09
W	1.86E-09	1.50E-09	1.24E-09	1.05E-09	9.04E-10
WNW	2.77E-09	2.24E-09	1.86E-09	1.58E-09	1.36E-09
NW	3.07E-09	2.48E-09	2.05E-09	1.74E-09	1.50E-09
NNW	3.61E-09	2.93E-09	2.44E-09	2.07E-09	1.79E-09
N	3.60E-09	2.91E-09	2.42E-09	2.06E-09	1.78E-09

Source: Radwaste Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	0.4	0.8	1.2	1.6	2.4
NNE	6.10E-06	2.05E-06	1.07E-06	7.30E-07	4.25E-07
NE	5.27E-06	1.80E-06	9.37E-07	6.39E-07	3.75E-07
ENE	5.75E-06	1.97E-06	1.02E-06	6.91E-07	4.05E-07
E	4.81E-06	1.61E-06	8.43E-07	5.73E-07	3.37E-07
ESE	4.36E-06	1.43E-06	7.56E-07	5.15E-07	3.07E-07
SE	4.32E-06	1.40E-06	7.39E-07	5.02E-07	2.96E-07
SSE	3.16E-06	1.01E-06	5.38E-07	3.67E-07	2.19E-07
S	3.33E-06	1.04E-06	5.63E-07	3.84E-07	2.29E-07
SSW	2.38E-06	7.81E-07	4.13E-07	2.82E-07	1.67E-07
SW	2.33E-06	8.12E-07	4.08E-07	2.74E-07	1.57E-07
WSW	2.88E-06	9.90E-07	4.98E-07	3.34E-07	1.92E-07
W	2.26E-06	7.42E-07	3.84E-07	2.59E-07	1.50E-07
WNW	3.27E-06	1.05E-06	5.51E-07	3.72E-07	2.17E-07
NW	3.94E-06	1.28E-06	6.62E-07	4.47E-07	2.60E-07
NNW	4.17E-06	1.35E-06	7.10E-07	4.81E-07	2.83E-07
N	3.97E-06	1.33E-06	6.92E-07	4.71E-07	2.75E-07

Source: Turbine Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	2.89E-07	2.14E-07	1.67E-07	1.36E-07	1.13E-07
NE	2.57E-07	1.91E-07	1.50E-07	1.22E-07	1.02E-07
ENE	2.76E-07	2.05E-07	1.61E-07	1.31E-07	1.09E-07
E	2.31E-07	1.72E-07	1.35E-07	1.10E-07	9.18E-08
ESE	2.12E-07	1.59E-07	1.26E-07	1.03E-07	8.69E-08
SE	2.04E-07	1.52E-07	1.20E-07	9.82E-08	8.24E-08
SSE	1.52E-07	1.15E-07	9.07E-08	7.45E-08	6.28E-08
S	1.58E-07	1.18E-07	9.34E-08	7.64E-08	6.42E-08
SSW	1.15E-07	8.60E-08	6.77E-08	5.53E-08	4.64E-08
SW	1.05E-07	7.74E-08	6.01E-08	4.85E-08	4.03E-08
WSW	1.29E-07	9.49E-08	7.37E-08	5.95E-08	4.94E-08
W	1.02E-07	7.51E-08	5.86E-08	4.75E-08	3.95E-08
WNW	1.47E-07	1.09E-07	8.53E-08	6.91E-08	5.76E-08
NW	1.77E-07	1.31E-07	1.02E-07	8.29E-08	6.90E-08
NNW	1.93E-07	1.44E-07	1.13E-07	9.16E-08	7.65E-08
N	1.87E-07	1.39E-07	1.09E-07	8.82E-08	7.36E-08

Source: Turbine Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	7.2	8.0	8.8	9.6	10.4
NNE	9.62E-08	8.32E-08	7.30E-08	6.48E-08	5.80E-08
NE	8.70E-08	7.54E-08	6.63E-08	5.90E-08	5.29E-08
ENE	9.33E-08	8.10E-08	7.12E-08	6.33E-08	5.68E-08
E	7.85E-08	6.81E-08	5.99E-08	5.33E-08	4.79E-08
ESE	7.46E-08	6.51E-08	5.75E-08	5.14E-08	4.63E-08
SE	7.06E-08	6.14E-08	5.42E-08	4.83E-08	4.35E-08
SSE	5.40E-08	4.72E-08	4.17E-08	3.73E-08	3.36E-08
S	5.50E-08	4.79E-08	4.23E-08	3.77E-08	3.39E-08
SSW	3.97E-08	3.46E-08	3.05E-08	2.71E-08	2.44E-08
SW	3.42E-08	2.95E-08	2.58E-08	2.29E-08	2.05E-08
WSW	4.19E-08	3.61E-08	3.16E-08	2.80E-08	2.50E-08
W	3.36E-08	2.91E-08	2.55E-08	2.26E-08	2.02E-08
WNW	4.90E-08	4.24E-08	3.72E-08	3.30E-08	2.95E-08
NW	5.87E-08	5.07E-08	4.45E-08	3.94E-08	3.53E-08
NNW	6.53E-08	5.66E-08	4.97E-08	4.42E-08	3.96E-08
N	6.27E-08	5.43E-08	4.77E-08	4.24E-08	3.80E-08

Source: Turbine Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

Sector	Downwind Distance (KM) 11.2	12.0	12.8	13.6	14.4
NNE	5.24E-08	4.76E-08	4.35E-08	4.00E-08	3.70E-08
NE	4.78E-08	4.35E-08	3.99E-08	3.67E-08	3.39E-08
ENE	5.13E-08	4.68E-08	4.28E-08	3.94E-08	3.65E-08
E	4.33E-08	3.95E-08	3.62E-08	3.33E-08	3.08E-08
ESE	4.20E-08	3.84E-08	3.53E-08	3.26E-08	3.03E-08
SE	3.94E-08	3.60E-08	3.30E-08	3.05E-08	2.83E-08
SSE	3.06E-08	2.80E-08	2.57E-08	2.38E-08	2.21E-08
S	3.08E-08	2.81E-08	2.58E-08	2.38E-08	2.21E-08
SSW	2.21E-08	2.02E-08	1.85E-08	1.71E-08	1.58E-08
SW	1.84E-08	1.67E-08	1.53E-08	1.40E-08	1.30E-08
WSW	2.25E-08	2.04E-08	1.86E-08	1.71E-08	1.57E-08
W	1.82E-08	1.65E-08	1.51E-08	1.39E-08	1.28E-08
WNW	2.67E-08	2.42E-08	2.22E-08	2.04E-08	1.88E-08
NW	3.18E-08	2.89E-08	2.64E-08	2.43E-08	2.24E-08
NNW	3.58E-08	3.26E-08	2.98E-08	2.75E-08	2.54E-08
N	3.43E-08	3.12E-08	2.85E-08	2.63E-08	2.43E-08

Source: Turbine Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	3.43E-08	3.19E-08	1.31E-08	1.21E-08	8.86E-09
NE	3.15E-08	2.94E-08	1.68E-08	1.13E-08	8.27E-09
ENE	3.39E-08	3.16E-08	1.81E-08	1.22E-08	8.94E-09
E	2.87E-08	2.67E-08	1.54E-08	1.04E-08	7.61E-09
ESE	2.82E-08	2.64E-08	1.55E-08	1.06E-08	7.90E-09
SE	2.63E-08	2.46E-08	1.43E-08	9.74E-09	7.21E-09
SSE	2.06E-08	1.93E-08	1.14E-08	7.81E-09	5.81E-09
S	2.06E-08	1.92E-08	1.12E-08	7.63E-09	5.65E-09
SSW	1.47E-08	1.37E-08	7.96E-09	5.39E-09	3.97E-09
SW	1.20E-08	1.12E-08	6.31E-09	4.21E-09	3.07E-09
WSW	1.46E-08	1.35E-08	7.58E-09	5.01E-09	3.63E-09
W	1.19E-08	1.11E-08	6.24E-09	4.15E-09	3.02E-09
WNW	1.75E-08	1.63E-08	9.23E-09	6.16E-09	4.50E-09
NW	2.08E-08	1.93E-08	1.09E-08	7.27E-09	5.30E-09
NNW	2.36E-08	2.20E-08	1.26E-08	8.42E-09	6.17E-09
N	2.25E-08	2.10E-08	1.20E-08	8.02E-09	5.87E-09

Source: Turbine Building

TABLE 2A-3 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (UNDECAYED AND UNDEPLETED)

	Downwind Distance (KM)				
Sector	48.0	56.0	64.0	72.0	80.0
NNE	6.85E-09	5.51E-09	4.56E-09	3.86E-09	3.32E-09
NE	6.40E-09	5.16E-09	4.28E-09	3.62E-09	3.12E-09
ENE	6.93E-09	5.59E-09	4.63E-09	3.93E-09	3.39E-09
E	5.91E-09	4.77E-09	3.96E-09	3.35E-09	2.89E-09
ESE	6.19E-09	5.03E-09	4.20E-09	3.58E-09	3.10E-09
SE	5.63E-09	4.56E-09	3.80E-09	3.23E-09	2.79E-09
SSE	4.56E-09	3.71E-09	3.10E-09	2.64E-09	2.29E-09
S	4.41E-09	3.58E-09	2.98E-09	2.53E-09	2.19E-09
SSW	3.09E-09	2.50E-09	2.08E-09	1.77E-09	1.53E-09
SW	2.37E-09	1.90E-09	1.57E-09	1.33E-09	1.14E-09
WSW	2.78E-09	2.23E-09	1.83E-09	1.54E-09	1.32E-09
W	2.33E-09	1.87E-09	1.54E-09	1.30E-09	1.12E-09
WNW	3.48E-09	2.80E-09	2.32E-09	1.96E-09	1.69E-09
NW	4.08E-09	3.28E-09	2.71E-09	2.29E-09	1.97E-09
NNW	4.78E-09	3.85E-09	3.19E-09	2.70E-09	2.33E-09
N	4.55E-09	3.66E-09	3.03E-09	2.57E-09	2.21E-09

Source: Turbine Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM)				
	0.4	0.8	1.2	1.6	2.4
NNE	1.23E-06	3.81E-07	2.45E-07	1.84E-07	1.24E-07
NE	9.96E-07	3.20E-07	2.08E-07	1.59E-07	1.10E-07
ENE	9.65E-07	3.20E-07	2.11E-07	1.63E-07	1.13E-07
E	6.98E-07	2.33E-07	1.63E-07	1.28E-07	9.06E-08
ESE	6.76E-07	2.25E-07	1.53E-07	1.19E-07	8.34E-08
SE	6.37E-07	2.10E-07	1.42E-07	1.09E-07	7.57E-08
SSE	4.81E-07	1.54E-07	1.05E-07	8.07E-08	5.64E-08
S	4.58E-07	1.39E-07	9.34E-08	7.15E-08	4.94E-08
SSW	3.55E-07	1.17E-07	8.01E-08	6.23E-08	4.37E-08
SW	3.75E-07	1.37E-07	9.74E-08	7.64E-08	5.33E-08
WSW	5.12E-07	1.83E-07	1.26E-07	9.70E-08	6.66E-08
W	4.50E-07	1.52E-07	9.99E-08	7.50E-08	4.99E-08
WNW	6.31E-07	1.98E-07	1.28E-07	9.51E-08	6.28E-08
NW	6.67E-07	2.08E-07	1.39E-07	1.07E-07	7.43E-08
NNW	7.06E-07	2.12E-07	1.39E-07	1.06E-07	7.26E-08
N	7.42E-07	2.32E-07	1.53E-07	1.17E-07	8.07E-08

Source: Containment Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	9.27E-08	7.36E-08	6.06E-08	5.13E-08	4.42E-08
NE	8.40E-08	6.76E-08	5.62E-08	4.79E-08	4.15E-08
ENE	8.65E-08	6.96E-08	5.79E-08	4.93E-08	4.27E-08
E	6.98E-08	5.64E-08	4.71E-08	4.02E-08	3.49E-08
ESE	6.44E-08	5.23E-08	4.38E-08	3.75E-08	3.27E-08
SE	5.79E-08	4.67E-08	3.89E-08	3.33E-08	2.89E-08
SSE	4.37E-08	3.55E-08	2.99E-08	2.57E-08	2.24E-08
S	3.79E-08	3.07E-08	2.58E-08	2.21E-08	1.93E-08
SSW	3.37E-08	2.73E-08	2.28E-08	1.95E-08	1.70E-08
SW	4.03E-08	3.20E-08	2.62E-08	2.20E-08	1.88E-08
WSW	4.99E-08	3.94E-08	3.22E-08	2.70E-08	2.30E-08
W	3.69E-08	2.89E-08	2.36E-08	1.97E-08	1.68E-08
WNW	4.64E-08	3.65E-08	2.99E-08	2.51E-08	2.15E-08
NW	5.63E-08	4.49E-08	3.70E-08	3.12E-08	2.68E-08
NNW	5.52E-08	4.42E-08	3.67E-08	3.12E-08	2.70E-08
N	6.14E-08	4.92E-08	4.08E-08	3.46E-08	2.99E-08

Source: Containment Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	7.2	8.0	8.8	9.6	10.4
NNE	3.87E-08	3.42E-08	3.06E-08	2.76E-08	2.51E-08
NE	3.65E-08	3.25E-08	2.91E-08	2.64E-08	2.40E-08
ENE	3.75E-08	3.34E-08	3.00E-08	2.72E-08	2.48E-08
E	3.07E-08	2.73E-08	2.46E-08	2.23E-08	2.03E-08
ESE	2.89E-08	2.59E-08	2.34E-08	2.13E-08	1.95E-08
SE	2.55E-08	2.28E-08	2.06E-08	1.87E-08	1.71E-08
SSE	1.99E-08	1.78E-08	1.61E-08	1.47E-08	1.35E-08
S	1.71E-08	1.53E-08	1.39E-08	1.26E-08	1.16E-08
SSW	1.50E-08	1.34E-08	1.21E-08	1.10E-08	1.00E-08
SW	1.64E-08	1.44E-08	1.28E-08	1.15E-08	1.04E-08
WSW	2.00E-08	1.76E-08	1.56E-08	1.40E-08	1.26E-08
W	1.46E-08	1.29E-08	1.14E-08	1.03E-08	9.28E-09
WNW	1.87E-08	1.65E-08	1.47E-08	1.32E-08	1.20E-08
NW	2.33E-08	2.06E-08	1.83E-08	1.65E-08	1.49E-08
NNW	2.37E-08	2.11E-08	1.89E-08	1.71E-08	1.56E-08
N	2.62E-08	2.33E-08	2.08E-08	1.88E-08	1.71E-08

Source: Containment Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM) 11.2	12.0	12.8	13.6	14.4
NNE	2.29E-08	2.11E-08	1.95E-08	1.81E-08	1.68E-08
NE	2.20E-08	2.03E-08	1.87E-08	1.74E-08	1.62E-08
ENE	2.27E-08	2.09E-08	1.94E-08	1.80E-08	1.68E-08
E	1.87E-08	1.72E-08	1.60E-08	1.49E-08	1.39E-08
ESE	1.79E-08	1.66E-08	1.54E-08	1.44E-08	1.35E-08
SE	1.57E-08	1.46E-08	1.35E-08	1.26E-08	1.18E-08
SSE	1.24E-08	1.15E-08	1.08E-08	1.01E-08	9.44E-09
S	1.07E-08	9.94E-09	9.26E-09	8.67E-09	8.14E-09
SSW	9.20E-09	8.50E-09	7.89E-09	7.36E-09	6.88E-09
SW	9.45E-09	8.64E-09	7.95E-09	7.34E-09	6.81E-09
WSW	1.15E-08	1.05E-08	9.61E-09	8.87E-09	8.22E-09
W	8.44E-09	7.72E-09	7.10E-09	6.56E-09	6.09E-09
WNW	1.09E-08	1.00E-08	9.24E-09	8.55E-09	7.95E-09
NW	1.36E-08	1.25E-08	1.15E-08	1.06E-08	9.87E-09
NNW	1.43E-08	1.32E-08	1.22E-08	1.13E-08	1.06E-08
N	1.57E-08	1.44E-08	1.33E-08	1.24E-08	1.15E-08

Source: Containment Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM)				
	15.2	16.0	24.0	32.0	40.0
NNE	1.57E-08	1.47E-08	8.73E-09	5.96E-09	4.41E-09
NE	1.52E-08	1.43E-08	8.55E-09	5.88E-09	4.37E-09
ENE	1.58E-08	1.48E-08	8.95E-09	6.19E-09	4.63E-09
E	1.30E-08	1.22E-08	7.44E-09	5.17E-09	3.88E-09
ESE	1.27E-08	1.20E-08	7.50E-09	5.33E-09	4.07E-09
SE	1.11E-08	1.05E-08	6.53E-09	4.62E-09	3.52E-09
SSE	8.89E-09	8.40E-09	5.32E-09	3.81E-09	2.93E-09
S	7.67E-09	7.25E-09	4.60E-09	3.30E-09	2.53E-09
SSW	6.46E-09	6.09E-09	3.75E-09	2.63E-09	1.99E-09
SW	6.34E-09	5.92E-09	3.43E-09	2.31E-09	1.70E-09
WSW	7.64E-09	7.13E-09	4.08E-09	2.72E-09	1.97E-09
W	5.67E-09	5.30E-09	3.08E-09	2.07E-09	1.52E-09
WNW	7.42E-09	6.95E-09	4.10E-09	2.80E-09	2.07E-09
NW	9.21E-09	8.61E-09	5.04E-09	3.42E-09	2.52E-09
NNW	9.89E-09	9.29E-09	5.61E-09	3.88E-09	2.90E-09
N	1.08E-08	1.01E-08	6.01E-09	4.12E-09	3.06E-09

Source: Containment Building

TABLE 2A-4 ANNUAL AVERAGE X/Q VALUES FOR THE CONTAINMENT BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	48.0	56.0	64.0	72.0	80.0
NNE	3.44E-09	2.77E-09	2.29E-09	1.93E-09	1.66E-09
NE	3.42E-09	2.76E-09	2.29E-09	1.93E-09	1.66E-09
ENE	3.63E-09	2.94E-09	2.44E-09	2.07E-09	1.79E-09
E	3.06E-09	2.48E-09	2.07E-09	1.76E-09	1.52E-09
ESE	3.26E-09	2.68E-09	2.25E-09	1.93E-09	1.67E-09
SE	2.81E-09	2.30E-09	1.93E-09	1.65E-09	1.43E-09
SSE	2.35E-09	1.93E-09	1.63E-09	1.40E-09	1.22E-09
S	2.03E-09	1.67E-09	1.41E-09	1.21E-09	1.05E-09
SSW	1.57E-09	1.28E-09	1.07E-09	9.14E-10	7.91E-10
SW	1.31E-09	1.05E-09	8.67E-10	7.30E-10	6.25E-10
WSW	1.51E-09	1.20E-09	9.85E-10	8.24E-10	7.02E-10
W	1.18E-09	9.41E-10	7.74E-10	6.50E-10	5.56E-10
WNW	1.62E-09	1.30E-09	1.08E-09	9.10E-10	7.82E-10
NW	1.96E-09	1.57E-09	1.30E-09	1.10E-09	9.39E-10
NNW	2.28E-09	1.85E-09	1.54E-09	1.30E-09	1.12E-09
N	2.39E-09	1.93E-09	1.59E-09	1.35E-09	1.16E-09

Source: Containment Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM)				
	0.4	0.8	1.2	1.6	2.4
NNE	2.86E-06	9.58E-07	5.59E-07	3.94E-07	2.40E-07
NE	2.30E-06	7.94E-07	4.74E-07	3.39E-07	2.11E-07
ENE	2.26E06	7.95E-07	4.75E-07	3.40E-07	2.12E-07
E	1.60E-06	5.70E-07	3.61E-07	2.63E-07	1.67E-07
ESE	1.63E-06	5.61E-07	3.49E-07	2.53E-07	1.61E-07
SE	1.46E-06	5.01E-07	3.11E-07	2.24E-07	1.41E-07
SSE	1.15E-06	3.80E-07	2.39E-07	1.73E-07	1.11E-07
S	1.04E-06	3.39E-07	2.12E-07	1.53E-07	9.71E-08
SSW	8.17E-07	2.87E-07	1.78E-07	1.29E-07	8.15E-08
SW	8.42E-07	3.23E-07	2.03E-07	1.46E-07	9.06E-08
WSW	1.05E-06	3.91E-07	2.44E-07	1.76E-07	1.09E-07
W	1.00E-06	3.42E-07	2.06E-07	1.45E-07	8.77E-08
WNW	1.49E-06	4.83E-07	2.89E-07	2.03E-07	1.24E-07
NW	1.41E-06	4.78E-07	3.03E-07	2.18E-07	1.36E-07
NNW	1.58E-06	5.17E-07	3.18E-07	2.27E-07	1.42E-07
N	1.54E-06	5.27E-07	3.27E-07	2.36E-07	1.47E-07

Source: Radwaste Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	3.2	4.0	4.8	5.6	6.4
NNE	1.67E-07	1.25E-07	9.90E-08	8.08E-08	6.77E-08
NE	1.49E-07	1.13E-07	9.04E-08	7.43E-08	6.27E-08
ENE	1.50E-07	1.14E-07	9.12E-08	7.52E-08	6.35E-08
E	1.19E-07	9.16E-08	7.35E-08	6.09E-08	5.17E-08
ESE	1.16E-07	8.91E-08	7.18E-08	5.97E-08	5.09E-08
SE	1.01E-07	7.78E-08	6.27E-08	5.21E-08	4.43E-08
SSE	7.98E-08	6.18E-08	5.00E-08	4.17E-08	3.56E-08
S	6.98E-08	5.39E-08	4.36E-08	3.63E-08	3.10E-08
SSW	5.84E-08	4.49E-08	3.61E-08	3.00E-08	2.55E-08
SW	6.34E-08	4.77E-08	3.76E-08	3.07E-08	2.56E-08
WSW	7.61E-08	5.73E-08	4.52E-08	3.69E-08	3.08E-08
W	6.07E-08	4.54E-08	3.57E-08	2.90E-08	2.43E-08
WNW	8.57E-08	6.41E-08	5.04E-08	4.10E-08	3.42E-08
NW	9.56E-08	7.22E-08	5.71E-08	4.66E-08	3.91E-08
NNW	1.00E-07	7.62E-08	6.07E-08	5.00E-08	4.22E-08
N	1.04E-07	7.93E-08	6.31E-08	5.19E-08	4.38E-08

Source: Radwaste Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM)				
	7.2	8.0	8.8	9.6	10.4
NNE	5.79E-08	5.03E-08	4.42E-08	3.93E-08	3.52E-08
NE	5.38E-08	4.69E-08	4.14E-08	3.70E-08	3.32E-08
ENE	5.47E-08	4.78E-08	4.23E-08	3.78E-08	3.41E-08
E	4.46E-08	3.91E-08	3.47E-08	3.11E-08	2.80E-08
ESE	4.41E-08	3.88E-08	3.46E-08	3.11E-08	2.82E-08
SE	3.84E-08	3.38E-08	3.01E-08	2.71E-08	2.45E-08
SSE	3.10E-08	2.73E-08	2.44E-08	2.20E-08	2.00E-08
S	2.70E-08	2.38E-08	2.13E-08	1.92E-08	1.74E-08
SSW	2.21E-08	1.94E-08	1.73E-08	1.55E-08	1.40E-08
SW	2.19E-08	1.90E-08	1.67E-08	1.48E-08	1.32E-08
WSW	2.63E-08	2.28E-08	2.00E-08	1.77E-08	1.58E-08
W	2.07E-08	1.79E-08	1.57E-08	1.39E-08	1.25E-08
WNW	2.92E-08	2.53E-08	2.22E-08	1.97E-08	1.76E-08
NW	3.34E-08	2.90E-08	2.55E-08	2.26E-08	2.03E-08
NNW	3.62E-08	3.16E-08	2.80E-08	2.50E-08	2.24E-08
N	3.76E-08	3.28E-08	2.89E-08	2.58E-08	2.32E-08

Source: Radwaste Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	11.2	12.0	12.8	13.6	14.4
NNE	3.18E-08	2.88E-08	2.63E-08	2.42E-08	2.23E-08
NE	3.00E-08	2.74E-08	2.50E-08	2.30E-08	2.13E-08
ENE	3.09E-08	2.82E-08	2.58E-08	2.38E-08	2.20E-08
E	2.55E-08	2.33E-08	2.14E-08	1.97E-08	1.83E-08
ESE	2.57E-08	2.36E-08	2.18E-08	2.02E-08	1.88E-08
SE	2.24E-08	2.05E-08	1.89E-08	1.75E-08	1.63E-08
SSE	1.83E-08	1.68E-08	1.55E-08	1.44E-08	1.34E-08
S	1.59E-08	1.46E-08	1.35E-08	1.25E-08	1.17E-08
SSW	1.27E-08	1.17E-08	1.07E-08	9.94E-09	9.23E-09
SW	1.19E-08	1.08E-08	9.87E-09	9.06E-09	8.36E-09
WSW	1.42E-08	1.29E-08	1.18E-08	1.08E-08	9.92E-09
W	1.12E-08	1.02E-08	9.28E-09	8.51E-09	7.84E-09
WNW	1.58E-08	1.44E-08	1.31E-08	1.20E-08	1.11E-08
NW	1.83E-08	1.66E-08	1.51E-08	1.39E-08	1.28E-08
NNW	2.03E-08	1.85E-08	1.70E-08	1.56E-08	1.44E-08
N	2.10E-08	1.91E-08	1.75E-08	1.61E-08	1.49E-08

Source: Radwaste Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	2.06E-08	1.92E-08	1.07E-08	6.99E-09	5.00E-09
NE	1.98E-08	1.84E-08	1.04E-08	6.87E-09	4.95E-09
ENE	2.05E-08	1.91E-08	1.09E-08	7.27E-09	5.28E-09
E	1.70E-08	1.59E-08	9.19E-09	6.16E-09	4.50E-09
ESE	1.76E-08	1.65E-08	9.80E-09	6.71E-09	4.98E-09
SE	1.52E-08	1.43E-08	8.44E-09	5.76E-09	4.25E-09
SSE	1.25E-08	1.18E-08	7.07E-09	4.86E-09	3.62E-09
S	1.09E-08	1.02E-08	6.13E-09	4.20E-09	3.12E-09
SSW	8.61E-09	8.06E-09	4.72E-09	3.19E-09	2.35E-09
SW	7.74E-09	7.19E-09	4.01E-09	2.63E-09	1.89E-09
WSW	9.17E-09	8.51E-09	4.67E-09	3.03E-09	2.15E-09
W	7.26E-09	6.74E-09	3.73E-09	2.42E-09	1.73E-09
WNW	1.03E-08	9.53E-09	5.29E-09	3.45E-09	2.47E-09
NW	1.19E-08	1.10E-08	6.15E-09	4.02E-09	2.88E-09
NNW	1.34E-08	1.25E-08	7.10E-09	4.71E-09	3.40E-09
N	1.38E-08	1.29E-08	7.27E-09	4.81E-09	3.47E-09

Source: Radwaste Building

TABLE 2A-5 ANNUAL AVERAGE X/Q VALUES FOR THE RADWASTE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM)				
	48.0	56.0	64.0	72.0	80.0
NNE	3.80E-09	2.99E-09	2.42E-09	2.01E-09	1.70E-09
NE	3.78E-09	2.99E-09	2.43E-09	2.03E-09	1.72E-09
ENE	4.05E-09	3.22E-09	2.63E-09	2.19E-09	1.86E-09
E	3.46E-09	2.76E-09	2.26E-09	1.89E-09	1.61E-09
ESE	3.89E-09	3.13E-09	2.58E-09	2.17E-09	1.86E-09
SE	3.31E-09	2.66E-09	2.19E-09	1.84E-09	1.58E-09
SSE	2.83E-09	2.28E-09	1.88E-09	1.59E-09	1.36E-09
S	2.43E-09	1.96E-09	1.61E-09	1.36E-09	1.16E-09
SSW	1.82E-09	1.46E-09	1.20E-09	1.00E-09	8.58E-10
SW	1.44E-09	1.14E-09	9.24E-10	7.68E-10	6.51E-10
WSW	1.63E-09	1.28E-09	1.03E-09	8.54E-10	7.21E-10
W	1.31E-09	1.03E-09	8.33E-10	6.90E-10	5.82E-10
WNW	1.87E-09	1.47E-09	1.19E-09	9.89E-10	8.36E-10
NW	2.19E-09	1.73E-09	1.40E-09	1.16E-09	9.84E-10
NNW	2.61E-09	2.06E-09	1.68E-09	1.40E-09	1.19E-09
N	2.65E-09	2.10E-09	1.71E-09	1.43E-09	1.21E-09

Source: Radwaste Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	0.4	0.8	1.2	1.6	2.4
NNE	5.74E-06	1.87E-06	9.56E-07	6.39E-07	3.61E-07
NE	4.95E-06	1.64E-06	8.35E-07	5.60E-07	3.19E-07
ENE	5.40E-06	1.79E-06	9.06E-07	6.05E-07	3.44E-07
E	4.52E-06	1.47E-06	7.51E-07	5.02E-07	2.87E-07
ESE	4.10E-06	1.30E-06	6.74E-07	4.52E-07	2.62E-07
SE	4.06E-06	1.27E-06	6.59E-07	4.40E-07	2.52E-07
SSE	2.97E-06	9.19E-07	4.80E-07	3.22E-07	1.87E-07
S	3.13E-06	9.46E-07	5.02E-07	3.36E-07	1.94E-07
SSW	2.23E-06	7.11E-07	3.69E-07	2.47E-07	1.42E-07
SW	2.19E0-6	7.38E-07	3.64E-07	2.40E-07	1.34E-07
WSW	2.71E-06	9.01E-07	4.44E-07	2.93E-07	1.63E-07
W	2.12E-06	6.76E-07	3.43E-07	2.27E-07	1.28E-07
WNW	3.07E-06	9.56E-07	4.91E-07	3.26E-07	1.84E-07
NW	3.70E-06	1.17E-06	5.90E-07	3.92E-07	2.21E-07
NNW	3.92E-06	1.23E-06	6.32E-07	4.21E-07	2.40E-07
N	3.73E-06	1.21E-06	6.17E-07	4.13E-07	2.34E-07

Source: Turbine Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	2.39E-07	1.73E-07	1.33E-07	1.06E-07	8.72E-08
NE	2.13E-07	1.55E-07	1.20E-07	9.64E-08	7.97E-08
ENE	2.29E-07	1.67E-07	1.29E-07	1.03E-07	8.53E-08
E	1.91E-07	1.40E-07	1.08E-07	8.69E-08	7.20E-08
ESE	1.77E-07	1.31E-07	1.02E-07	8.25E-08	6.88E-08
SE	1.69E-07	1.24E-07	9.63E-08	7.77E-08	6.45E-08
SSE	1.27E-07	9.37E-08	7.33E-08	5.95E-08	4.96E-08
S	1.31E-07	9.60E-08	7.45E-08	6.01E-08	4.99E-08
SSW	9.56E-08	7.01E-08	5.44E-08	4.39E-08	3.65E-08
SW	8.76E-08	6.31E-08	4.83E-08	3.85E-08	3.16E-08
WSW	1.07E-07	7.74E-08	5.93E-08	4.72E-08	3.88E-08
W	8.45E-08	6.12E-08	4.70E-08	3.75E-08	3.09E-08
WNW	1.22E-07	8.82E-08	6.77E-08	5.41E-08	4.45E-08
NW	1.47E-07	1.06E-07	8.16E-08	6.52E-08	5.36E-08
NNW	1.60E-07	1.16E-07	8.96E-08	7.18E-08	5.93E-08
N	1.55E-07	1.13E-07	8.70E-08	6.97E-08	5.74E-08

Source: Turbine Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	7.2	8.0	8.8	9.6	10.4
NNE	7.33E-08	6.28E-08	5.46E-08	4.80E-08	4.26E-08
NE	6.73E-08	5.79E-08	5.05E-08	4.45E-08	3.96E-08
ENE	7.21E-08	6.20E-08	5.40E-08	4.77E-08	4.24E-08
E	6.09E-08	5.24E-08	4.58E-08	4.04E-08	3.60E-08
ESE	5.85E-08	5.07E-08	4.45E-08	3.95E-08	3.54E-08
SE	5.48E-08	4.73E-08	4.14E-08	3.67E-08	3.27E-08
SSE	4.23E-08	3.67E-08	3.23E-08	2.87E-08	2.57E-08
S	4.23E-08	3.65E-08	3.20E-08	2.83E-08	2.53E-08
SSW	3.09E-08	2.67E-08	2.33E-08	2.06E-08	1.84E-08
SW	2.65E-08	2.27E-08	1.97E-08	1.73E-08	1.54E-08
WSW	3.25E-08	2.78E-08	2.41E-08	2.12E-08	1.88E-08
W	2.60E-08	2.22E-08	1.93E-08	1.70E-08	1.51E-08
WNW	3.74E-08	3.20E-08	2.78E-08	2.44E-08	2.17E-08
NW	4.51E-08	3.86E-08	3.35E-08	2.94E-08	2.61E-08
NNW	5.00E-08	4.29E-08	3.74E-08	3.29E-08	2.93E-08
N	4.84E-08	4.16E-08	3.62E-08	3.19E-08	2.83E-08

Source: Turbine Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM) 11.2	12.0	12.8	13.6	14.4
NNE	3.80E-08	3.43E-08	3.10E-08	2.83E-08	2.59E-08
NE	3.55E-08	3.21E-08	2.91E-08	2.66E-08	2.45E-08
ENE	3.81E-08	3.44E-08	3.12E-08	2.86E-08	2.62E-08
E	3.23E-08	2.92E-08	2.66E-08	2.43E-08	2.24E-08
ESE	3.19E-08	2.90E-08	2.65E-08	2.43E-08	2.25E-08
SE	2.94E-08	2.67E-08	2.43E-08	2.23E-08	2.06E-08
SSE	2.32E-08	2.11E-08	1.93E-08	1.77E-08	1.64E-08
S	2.27E-08	2.06E-08	1.88E-08	1.72E-08	1.58E-08
SSW	1.66E-08	1.50E-08	1.37E-08	1.25E-08	1.15E-08
SW	1.37E-08	1.24E-08	1.12E-08	1.02E-08	9.36E-09
WSW	1.68E-08	1.51E-08	1.36E-08	1.24E-08	1.14E-08
W	1.35E-08	1.21E-08	1.10E-08	1.00E-08	9.18E-09
WNW	1.94E-08	1.74E-08	1.58E-08	1.44E-08	1.32E-08
NW	2.33E-08	2.09E-08	1.90E-08	1.73E-08	1.58E-08
NNW	2.62E-08	2.36E-08	2.14E-08	1.96E-08	1.79E-08
N	2.53E-08	2.29E-08	2.08E-08	1.89E-08	1.74E-08

Source: Turbine Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	2.39E-08	2.21E-08	1.18E-08	7.47E-09	5.23E-09
NE	2.26E-08	2.09E-08	1.13E-08	7.28E-09	5.15E-09
ENE	2.42E-08	2.24E-08	1.22E-08	7.86E-09	5.57E-09
E	2.07E-08	1.92E-08	1.05E-08	6.78E-09	4.82E-09
ESE	2.08E-08	1.94E-08	1.09E-08	7.26E-09	5.27E-09
SE	1.90E-08	1.77E-08	9.83E-09	6.45E-09	4.63E-09
SSE	1.52E-08	1.41E-08	8.03E-09	5.34E-09	3.88E-09
S	1.47E-08	1.36E-08	7.55E-09	4.93E-09	3.53E-09
SSW	1.06E-08	9.89E-09	5.46E-09	3.56E-09	2.54E-09
SW	8.62E-09	7.97E-09	4.27E-09	2.73E-09	1.92E-09
WSW	1.05E-08	9.65E-09	5.10E-09	3.22E-09	2.24E-09
W	8.45E-09	7.81E-09	4.15E-09	2.63E-09	1.84E-09
WNW	1.21E-08	1.12E-08	5.96E-09	3.77E-09	2.64E-09
NW	1.46E-08	1.34E-08	7.12E-09	4.50E-09	3.14E-09
NNW	1.65E-08	1.53E-08	8.23E-09	5.26E-09	3.70E-09
N	1.60E-08	1.48E-08	8.00E-09	5.12E-09	3.61E-09

Source: Turbine Building

TABLE 2A-6 ANNUAL AVERAGE X/Q VALUES FOR THE TURBINE BUILDING (DECAYED AND DEPLETED)

Sector	Downwind Distance (KM) 48.0	56.0	64.0	72.0	80.0
NNE	3.90E-09	3.03E-09	2.42E-09	1.98E-09	1.65E-09
NE	3.87E-09	3.02E-09	2.42E-09	2.00E-09	1.67E-09
ENE	4.20E-09	3.28E-09	2.64E-09	2.17E-09	1.83E-09
E	3.64E-09	2.85E-09	2.30E-09	1.90E-09	1.60E-09
ESE	4.04E-09	3.21E-09	2.62E-09	2.18E-09	1.85E-09
SE	3.53E-09	2.78E-09	2.26E-09	1.87E-09	1.58E-09
SSE	2.98E-09	2.36E-09	1.93E-09	1.61E-09	1.37E-09
S	2.69E-09	2.11E-09	1.71E-09	1.42E-09	1.20E-09
SSW	1.93E-09	1.52E-09	1.23E-09	1.02E-09	8.57E-10
SW	1.44E-09	1.13E-09	9.03E-10	7.44E-10	6.24E-10
WSW	1.67E-09	1.29E-09	1.03E-09	8.38E-10	6.99E-10
W	1.37E-09	1.06E-09	8.46E-10	6.92E-10	5.78E-10
WNW	1.97E-09	1.52E-09	1.22E-09	9.96E-10	8.31E-10
NW	2.33E-09	1.80E-09	1.44E-09	1.17E-09	9.79E-10
NNW	2.77E-09	2.15E-09	1.72E-09	1.41E-09	1.18E-09
N	2.71E-09	2.11E-09	1.70E-09	1.39E-09	1.17E-09

Source: Turbine Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

Sector	Downwind Distance (KM) 0.4	0.8	1.2	1.6	2.4
NNE	1.40E-08	5.71E-09	3.26E-09	2.11E-09	1.15E-09
NE	1.27E-08	5.11E-09	2.90E-09	1.87E-09	1.02E-09
ENE	1.20E-08	4.94E-09	2.89E-09	1.89E-09	1.05E-09
E	7.55E-09	3.32E-09	2.06E-09	1.40E-09	8.13E-10
ESE	7.96E-09	3.36E-09	2.03E-09	1.37E-09	7.84E-10
SE	7.06E-09	3.15E-09	1.95E-09	1.32E-09	7.64E-10
SSE	5.05E-09	2.21E-09	1.35E-09	9.07E-10	5.21E-10
S	3.93E-09	1.73E-09	1.04E-09	7.00E-10	4.01E-10
SSW	3.63E-09	1.57E-09	9.66E-10	6.56E-10	3.80E-10
SW	5.56E-09	2.57E-09	1.61E-09	1.10E-09	6.38E-10
WSW	7.55E-09	3.48E-09	2.18E-09	1.48E-09	8.61E-10
W	6.09E-09	2.77E-09	1.68E-09	1.13E-09	6.40E-10
WNW	7.64E-09	3.36E-09	1.99E-09	1.32E-09	7.38E-10
NW	7.50E-09	3.60E-09	2.21E-09	1.48E-09	8.51E-10
NNW	6.84E-09	3.04E-09	1.78E-09	1.17E-09	6.52E-10
N	8.96E-09	4.02E-09	2.36E-09	1.54E-09	8.51E-10

Source: Containment Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	7.39E-10	5.26E-10	3.99E-10	3.07E-10	2.43E-10
NE	6.53E-10	4.65E-10	3.53E-10	2.72E-10	2.15E-10
ENE	6.83E-10	4.90E-10	3.75E-10	2.89E-10	2.28E-10
E	5.38E-10	3.92E-10	3.03E-10	2.34E-10	1.85E-10
ESE	5.16E-10	3.75E-10	2.90E-10	2.24E-10	1.77E-10
SE	5.04E-10	3.67E-10	2.84E-10	2.19E-10	1.73E-10
SSE	3.44E-10	2.50E-10	1.94E-10	1.50E-10	1.18E-10
S	2.64E-10	1.92E-10	1.48E-10	1.15E-10	9.07E-11
SSW	2.51E-10	1.83E-10	1.41E-10	1.09E-10	8.62E-11
SW	4.23E-10	3.09E-10	2.40E-10	1.85E-10	1.46E-10
WSW	5.68E-10	4.13E-10	3.20E-10	2.47E-10	1.95E-10
W	4.18E-10	3.02E-10	2.32E-10	1.79E-10	1.42E-10
WNW	4.80E-10	3.46E-10	2.65E-10	2.05E-10	1.62E-10
NW	5.58E-10	4.04E-10	3.11E-10	2.41E-10	1.91E-10
NNW	4.22E-10	3.02E-10	2.31E-10	1.78E-10	1.41E-10
N	5.50E-10	3.93E-10	3.00E-10	2.31E-10	1.83E-10

Source: Containment Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

Sector	Downwind Distance (KM) 7.2	8.0	8.8	9.6	10.4
NNE	1.97E-10	1.64E-10	1.39E-10	1.19E-10	1.04E-10
NE	1.75E-10	1.45E-10	1.23E-10	1.05E-10	9.16E-11
ENE	1.85E-10	1.54E-10	1.30E-10	1.11E-10	9.67E-11
E	1.50E-10	1.24E-10	1.05E-10	9.00E-11	7.83E-11
ESE	1.43E-10	1.19E-10	1.00E-10	8.60E-11	7.48E-11
SE	1.41E-10	1.17E -10	9.85E-11	8.45E-11	7.36E-11
SSE	9.57E-11	7.94E-11	6.70E-11	5.74E-11	5.00E-11
S	7.37E-11	6.12E-11	5.17E-11	4.44E-11	3.87E-11
SSW	6.99E-11	5.80E-11	4.90E-11	4.20E-11	3.65E-11
SW	1.19E-10	9.87E-11	8.34E-11	7.15E-11	6.23E-11
WSW	1.58E-10	1.31E-10	1.11E-10	9.52E-11	8.29E-11
W	1.15E-10	9.57E-11	8.09E-11	6.95E-11	6.06E-11
WNW	1.32E-10	1.09E-10	9.25E-11	7.94E-11	6.92E-11
NW	1.56E-10	1.30E-10	1.10E-10	9.43E-11	8.24E-11
NNW	1.15E-10	9.58E-11	8.11E-11	6.97E-11	6.09E-11
N	1.49E-10	1.24E-10	1.05E-10	9.04E-11	7.89E-11

Source: Containment Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

Sector	Downwind Distance (KM) 11.2	12.0	12.8	13.6	14.4
NNE	9.14E-11	8.14E-11	7.30E-11	6.59E-11	5.99E-11
NE	8.08E-11	7.20E-11	6.46E-11	5.83E-11	5.30E-11
ENE	8.53E-11	7.59E-11	6.80E-11	6.14E-11	5.57E-11
E	6.91E-11	6.14E-11	5.50E-11	4.97E-11	4.51E-11
ESE	6.59E-11	5.86E-11	5.25E-11	4.74E-11	4.30E-11
SE	6.49E-11	5.77E-11	5.18E-11	4.67E-11	4.24E-11
SSE	4.41E-11	3.92E-11	3.52E-11	3.17E-11	2.88E-11
S	3.42E-11	3.04E-11	2.73E-11	2.47E-11	2.25E-11
SSW	3.22E-11	2.86E-11	2.57E-11	2.31E-11	2.10E-11
SW	5.50E-11	4.90E-11	4.40E-11	3.98E-11	3.61E-11
WSW	7.32E-11	6.51E-11	5.84E-11	5.28E-11	4.79E-11
W	5.35E-11	4.77E-11	4.28E-11	3.87-E11	3.52E-11
WNW	6.12E-11	5.46E-11	4.90E-11	4.43E-11	4.03E-11
NW	7.30E-11	6.52E-11	5.87E-11	5.31E-11	4.84E-11
NNW	5.39E-11	4.81E-11	4.33E-11	3.92E-11	3.57E-11
N	6.99E-11	6.25E-11	5.62E-11	5.09E-11	4.64E-11

Source: Containment Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	5.47E-11	5.02E-11	2.55E-11	1.59E-11	1.11E-11
NE	4.84E-11	4.44E-11	2.26E-11	1.40E-11	9.74E-12
ENE	5.09E-11	4.66E-11	2.36E-11	1.46E-11	1.01E-11
E	4.11E-11	3.77E-11	1.90E-11	1.18E-11	8.15E-12
ESE	3.92E-11	3.59E-11	1.81E-11	1.12E-11	7.71E-12
SE	3.88E-11	3.55E-11	1.80E-11	1.12E-11	7.76E-12
SSE	2.63E-11	2.41E-11	1.22E-11	7.56E-12	5.24E-12
S	2.05E-11	1.88E-11	9.62E-12	6.00E-12	4.18E-12
SSW	1.92E-11	1.76E-11	8.85E-12	5.47E-12	3.78E-12
SW	3.30E-11	3.03E-11	1.55E-11	9.65E-12	6.71E-12
WSW	4.38E-11	4.02E-11	2.04E-11	1.27E-11	8.83E-12
W	3.22E-11	2.96E-11	1.52E-11	9.49E-12	6.62E-12
WNW	3.69E-11	3.39E-11	1.74E-11	1.09E-11	7.60E-12
NW	4.43E-11	4.08E-11	2.12E-11	1.34E-11	9.42E-12
NNW	3.27E-11	3.00E-11	1.56E-11	9.81E-12	6.90E-12
N	4.25E-11	3.91E-11	2.03E-11	1.28E-11	9.02E-12

Source: Containment Building

TABLE 2A-7 ANNUAL AVERAGE D/Q VALUES FOR THE CONTAINMENT BUILDING

Sector	Downwind Distance (KM) 48.0	56.0	64.0	72.0	80.0
NNE	8.32E-12	6.52E-12	5.28E-12	4.40E-12	3.76E-12
NE	7.30E-12	5.70E-12	4.61E-12	3.83E-12	3.27E-12
ENE	7.56E-12	5.89E-12	4.75E-12	3.94E-12	3.35E-12
E	6.07E-12	4.71E-12	3.78E-12	3.13E-12	2.64E-12
ESE	5.73E-12	4.44E-12	3.57E-12	2.95E-12	2.49E-12
SE	5.78E-12	4.49E-12	3.61E-12	2.98E-12	2.52E-12
SSE	3.90E-12	3.03E-12	2.44E-12	2.01E-12	1.70E-12
S	3.13E-12	2.45E-12	1.98E-12	1.64E-12	1.40E-12
SSW	2.32E-12	2.19E-12	1.76E-12	1.46E-12	1.24E-12
SW	5.01E-12	3.90E-12	3.13E-12	2.59E-12	2.19E-12
WSW	6.58E-12	5.10E-12	4.09E-12	3.37E-12	2.84E-12
W	4.96E-12	3.86E-12	3.10E-12	2.56E-12	2.17E-12
WNW	5.71E-12	4.46E-12	3.60E-12	2.99E-12	2.54E-12
NW	7.10E-12	5.55E-12	4.49E-12	3.72E-12	3.16E-12
NNW	5.22E-12	4.10E-12	3.32E-12	2.77E-12	2.37E-12
N	6.81E-12	5.34E-12	4.32E-12	3.59E-12	3.05E-12

Source: Containment Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM) 0.4	0.8	1.2	1.6	2.4
NNE	3.01E-08	1.11E-08	5.93E-09	3.67E-09	1.88E-09
NE	2.56E-08	9.38E-09	5.01E-09	3.10E-09	1.59E-09
ENE	2.52E-08	9.33E-09	5.03E-09	3.13E-09	1.62E-09
E	1.57E-08	6.16E-09	3.46E-09	2.19E-09	1.16E-09
ESE	1.62E-08	6.15E-09	3.40E-09	2.14E-09	1.12E-09
SE	1.45E-08	5.68E-09	3.18E-09	2.01E-09	1.06E-09
SSE	1.07E-08	4.06E-09	2.25E-09	1.42E-09	7.44E-10
S	8.28E-09	3.23E-09	1.80E-09	1.14E-09	6.00E-10
SSW	8.03E-09	3.09E-09	1.72E-09	1.08E-09	5.68E-10
SW	1.10E-08	4.50E-09	2.57E-09	1.64E-09	8.74E-10
WSW	1.39E-08	5.71E-09	3.25E-09	2.07E-09	1.10E-09
W	1.19E-08	4.69E-09	2.60E-09	1.63E-09	8.54E-10
WNW	1.52E-08	5.94E-09	3.26E-09	2.05E-09	1.07E-09
NW	1.45E-08	6.07E-09	3.45E-09	2.18E-09	1.16E-09
NNW	1.41E-08	5.56E-09	3.06E-09	1.92E-09	9.98E-10
N	1.71E-08	6.73E-09	3.69E-09	2.31E-09	1.20E-09

Source: Radwaste Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	1.17E-09	8.15E-10	6.06E-10	4.64E-10	3.66E-10
NE	9.96E-10	6.92E-10	5.14E-10	3.94E-10	3.11E-10
ENE	1.01E-09	7.06E-10	5.26E-10	4.02E-10	3.17E-10
E	7.34E-10	5.16E-10	3.88E-10	2.97E-10	2.34E-10
ESE	7.10E-10	4.98E-10	3.73E-10	2.85E-10	2.25E-10
SE	6.72E-10	4.72E-10	3.54E-10	2.72E-10	2.14E-10
SSE	4.70E-10	3.30E-10	2.47E-10	1.89E-10	1.49E-10
S	3.80E-10	2.67E-10	2.01E-10	1.54E-10	1.21E-10
SSW	3.59E-10	2.52E-10	1.89E-10	1.44E-10	1.14E-10
SW	5.57E-10	3.93E-10	2.96E-10	2.27E-10	1.79E-10
WSW	6.98E-10	4.92E-10	3.70E-10	2.84E-10	2.23E-10
W	5.39E-10	3.78E-10	2.83E-10	2.17E-10	1.71E-10
WNW	6.73E-10	4.72E-10	3.53E-10	2.71E-10	2.13E-10
NW	7.37E-10	5.20E-10	3.92E-10	3.01E-10	2.37E-10
NNW	6.30E-10	4.41E-10	3.30E-10	2.53E-10	2.00E-10
N	7.56E-10	5.29E-10	3.96E-10	3.03E-10	2.39E-10

Source: Radwaste Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM)				
	7.2	8.0	8.8	9.6	10.4
NNE	2.97E-10	2.46E-10	2.08E-10	1.78E-10	1.55E-10
NE	2.52E-10	2.09E-10	1.77E-10	1.51E-10	1.32E-10
ENE	2.57E-10	2.13E-10	1.80E-10	1.54E-10	1.34E-10
E	1.89E-10	1.57E-10	1.32E-10	1.13E-10	9.82E-11
ESE	1.82E-10	1.51E-10	1.27E-10	1.09E-10	9.47E-11
SE	1.73E-10	1.44E-10	1.21E-10	1.04E-10	9.02E-11
SSE	1.21E-10	1.00E-10	8.43E-11	7.22E-11	6.27E-11
S	9.81E-11	8.13E-11	6.86E-11	5.87E-11	5.10E-11
SSW	9.22E-11	7.64E-11	6.44E-11	5.52E-11	4.79E-11
SW	1.45E-10	1.20E-10	1.01E-10	8.66E-11	7.52E-11
WSW	1.81E-10	1.50E-10	1.26E-10	1.08E-10	9.40E-11
W	1.39E-10	1.15E-10	9.71E-11	8.32E-11	7.24E-11
WNW	1.73E-10	1.44E-10	1.21E-10	1.04E-10	9.04E-11
NW	1.92E-10	1.59E-10	1.35E-10	1.15E-10	1.00E-10
NNW	1.62E-10	1.34E-10	1.13E-10	9.72E-11	8.46E-11
N	1.94E-10	1.61E-10	1.36E-10	1.17E-10	1.02E-10

Source: Radwaste Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM) 11.2	12.0	12.8	13.6	14.4
NNE	1.37E-10	1.21E-10	1.09E-10	9.78E-11	8.87E-11
NE	1.16E-10	1.03E-10	9.20E-11	8.29E-11	7.51E-11
ENE	1.18E-10	1.05E-10	9.36E-11	8.43E-11	7.64E-11
E	8.64E-11	7.67E-11	6.86E-11	6.18E-11	5.60E-11
ESE	8.33E-11	7.39E-11	6.61E-11	5.95E-11	5.39E-11
SE	7.94E-11	7.05E-11	6.31E-11	5.68E-11	5.15E-11
SSE	5.52E-11	4.90E-11	4.38E-11	3.94E-11	3.57E-11
S	4.49E-11	3.99E-11	3.57E-11	3.21E-11	2.91E-11
SSW	4.22E-11	3.74E-11	3.35E-11	3.01E-11	2.73E-11
SW	6.62E-11	5.88E-11	5.26E-11	4.74E-11	4.30E-11
WSW	8.28E-11	7.36E-11	6.59E-11	5.94E-11	5.39E-11
W	6.38E-11	5.67E-11	5.08E-11	4.58E-11	4.16E-11
WNW	7.96E-11	7.08E-11	6.34E-11	5.72E-11	5.19E-11
NW	8.85E-11	7.88E-11	7.07E-11	6.38E-11	5.80E-11
NNW	7.46E-11	6.64E-11	5.95E-11	5.37E-11	4.87E-11
N	8.96E-11	7.98E-11	7.15E-11	6.46E-11	5.86E-11

Source: Radwaste Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM) 15.2	16.0	24.0	32.0	40.0
NNE	8.08E-11	7.40E-11	3.70E-11	2.28E-11	1.58E-11
NE	6.84E-11	6.27E-11	3.13E-11	1.92E-11	1.33E-11
ENE	6.96E-11	6.37E-11	3.17E-11	1.95E-11	1.35E-11
E	5.10E-11	4.67E-11	2.33E-11	1.43E-11	9.98E-12
ESE	4.91E-11	4.49E-11	2.23E-11	1.37E-11	9.48E-12
SE	4.69E-11	4.30E-11	2.15E-11	1.33E-11	9.22E-12
SSE	3.25E-11	2.98E-11	1.48E-11	9.08E-12	6.30E-12
S	2.66E-11	2.43E-11	1.22E-11	7.52E-12	5.26E-12
SSW	2.49E-11	2.28E-11	1.14E-11	6.98E-12	4.85E-12
SW	3.92E-11	3.59E-11	1.80E-11	1.11E-11	7.70E-12
WSW	4.91E-11	4.50E-11	2.26E-11	1.40E-11	9.70E-12
W	3.79E-11	3.47E-11	1.75E-11	1.08E-11	7.52E-12
WNW	4.73E-11	4.34E-11	2.19E-11	1.35E-11	9.41E-12
NW	5.29E-11	4.86E-11	2.47E-11	1.55E-11	1.08E-11
NNW	4.45E-11	4.08E-11	2.07E-11	1.29E-11	9.04E-12
N	5.35E-11	4.91E-11	2.49E-11	1.55E-11	1.09E-11

Source: Radwaste Building

TABLE 2A-8 ANNUAL AVERAGE D/Q VALUES FOR THE RADWASTE BUILDING

Sector	Downwind Distance (KM) 48.0	56.0	64.0	72.0	80.0
NNE	1.19E-11	9.36E-12	7.59E-12	6.36E-12	5.46E-12
NE	1.01E-11	7.94E-12	6.47E-12	5.44E-12	4.70E-12
ENE	1.02E-11	8.08E-12	6.60E-12	5.57E-12	4.82E-12
E	7.61E-12	6.05E-12	4.97E-12	4.21E-12	3.67E-12
ESE	7.20E-12	5.70E-12	4.67E-12	3.95E-12	3.43E-12
SE	7.01E-12	5.56E-12	4.55E-12	3.85E-12	3.34E-12
SSE	4.80E-12	3.81E-12	3.13E-12	2.66E-12	2.32E-12
S	4.06E-12	3.26E-12	2.70E-12	2.31E-12	2.03E-12
SSW	3.69E-12	2.92E-12	2.39E-12	2.02E-12	1.76E-12
SW	5.78E-12	4.52E-12	3.65E-12	3.04E-12	2.59E-12
WSW	7.27E-12	5.68E-12	4.58E-12	3.81E-12	3.25E-12
W	5.64E-12	4.40E-12	3.55E-12	2.95E-12	2.51E-12
WNW	7.07E-12	5.54E-12	4.47E-12	3.73E-12	3.18E-12
NW	8.24E-12	6.51E-12	5.30E-12	4.45E-12	3.83E-12
NNW	6.91E-12	5.49E-12	4.50E-12	3.81E-12	3.30E-12
N	8.30E-12	6.57E-12	5.37E-12	4.52E-12	3.91E-12

Source: Radwaste Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

	Downwind Distance (KM)				
Sector	0.4	0.8	1.2	1.6	2.4
NNE	5.08E-08	1.75E-08	9.00E-09	5.49E-09	2.75E-09
NE	4.36E-08	1.50E-08	7.70E-09	4.70E-09	2.36E-09
ENE	4.55E-08	1.57E-08	8.05E-09	4.91E-09	2.46E-09
E	3.40E-08	1.18E-08	6.05E-09	3.70E-09	1.86E-09
ESE	3.00E-08	1.03E-08	5.33E-09	3.26E-09	1.64E-09
SE	2.92E-08	1.01E-08	5.22E-09	3.19E-09	1.61E-09
SSE	2.04E-08	7.02E-09	3.61E-09	2.21E-09	1.11E-09
S	1.88E-08	6.49E-09	3.34E-09	2.04E-09	1.03E-09
SSW	1.59E-08	5.50E-09	2.84E-09	1.74E-09	8.77E-10
SW	2.19E-08	7.56E-09	3.90E-09	2.38E-09	1.20E-09
WSW	2.70E-08	9.39E-09	4.84E-09	2.96E-09	1.49E-09
W	1.99E-08	6.95E-09	3.60E-09	2.21E-09	1.12E-09
WNW	2.69E-08	9.31E-09	4.80E-09	2.93E-09	1.48E-09
NW	3.08E-08	1.08E-08	5.58E-09	3.42E-09	1.73E-09
NNW	2.92E-08	1.01E-08	5.23E-09	3.19E-09	1.61E-09
N	3.31E-08	1.15E-08	5.93E-09	3.63E-09	1.83E-09

Source: Turbine Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

Sector	Downwind Distance (KM) 3.2	4.0	4.8	5.6	6.4
NNE	1.70E-09	1.16E-09	8.57E-10	6.55E-10	5.18E-10
NE	1.45E-09	9.99E-10	7.36E-10	5.62E-10	4.44E-10
ENE	1.52E-09	1.04E-09	7.68E-10	5.87E-10	4.64E-10
E	1.15E-09	7.89E-10	5.82E-10	4.45E-10	3.51E-10
ESE	1.02E-09	7.01E-10	5.17E-10	3.96E-10	3.13E-10
SE	9.96E-10	6.86E-10	5.06E-10	3.88E-10	3.06E-10
SSE	6.87E-10	4.73E-10	3.49E-10	2.67E-10	2.11E-10
S	6.36E-10	4.38E-10	3.23E-10	2.47E-10	1.96E-10
SSW	5.42E-10	3.74E-10	2.76E-10	2.11E-10	1.67E-10
SW	7.43E-10	5.12E-10	3.78E-10	2.89E-10	2.28E-10
WSW	9.20E-10	6.33E-10	4.66E-10	3.57E-10	2.52E-10
W	6.90E-10	4.75E-10	3.51E-10	2.69E-10	2.12E-10
WNW	9.12E-10	6.28E-10	4.63E-10	3.54E-10	2.80E-10
NW	1.07E-09	7.39E-10	5.46E-10	4.18E-10	3.30E-10
NNW	9.90E-10	6.81E-10	5.02E-10	3.84E-10	3.03E-10
N	1.13E-09	7.77E-10	5.73E-10	4.38E-10	3.47E-10

Source: Turbine Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

Sector	Downwind Distance (KM) 7.2	8.0	8.8	9.6	10.4
NNE	4.21E-10	3.49E-10	2.95E-10	2.53E-10	2.20E-10
NE	3.61E-10	3.00E-10	2.53E-10	2.17E-10	1.89E-10
ENE	3.77E-10	3.13E-10	2.65E-10	2.27E-10	1.97E-10
E	2.86E-10	2.37E-10	2.00E-10	1.72E-10	1.49E-10
ESE	2.54E-10	2.11E-10	1.78E-10	1.53E-10	1.33E-10
SE	2.49E-10	2.07E-10	1.75E-10	1.50E-10	1.30E-10
SSE	1.71E-10	1.42E-10	1.20E-10	1.03E-10	8.98E-11
S	1.59E-10	1.32E-10	1.12E-10	9.57E-11	8.32E-11
SSW	1.35E-10	1.12E-10	9.50E-11	8.15E-11	7.09E-11
SW	1.86E-10	1.54E-10	1.30E-10	1.12E-10	9.72E-11
WSW	2.29E-10	1.90E-10	1.61E-10	1.38E-10	1.20E-10
W	1.73E-10	1.43E-10	1.21E-10	1.04E-10	9.06E-11
WNW	2.28E-10	1.89E-10	1.60E-10	1.37E-10	1.19E-10
NW	2.69E-10	2.23E-10	1.89E-10	1.62E-10	1.41E-10
NNW	2.47E-10	2.05E-10	1.73E-10	1.48E-10	1.29E-10
N	2.82E-10	2.34E-10	1.98E-10	1.70E-10	1.48E-10

Source: Turbine Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

	Downwind Distance (KM)				
Sector	11.2	12.0	12.8	13.6	14.4
NNE	1.94E-10	1.72E-10	1.54E-10	1.38E-10	1.25E-10
NE	1.66E-10	1.47E-10	1.32E-10	1.19E-10	1.07E-10
ENE	1.73E-10	1.54E-10	1.38E-10	1.24E-10	1.12E-10
E	1.31E-10	1.17E-10	1.04E-10	9.39E-11	8.51E-11
ESE	1.17E-10	1.04E-10	9.29E-11	8.36E-11	7.57E-11
SE	1.15E-10	1.02E-10	9.11E-11	8.20E-11	7.43E-11
SSE	7.90E-11	7.01E-11	6.27E-11	5.64E-11	5.11E-11
S	7.32E-11	6.50E-11	5.81E-11	5.23E-11	4.74E-11
SSW	6.23E-11	5.53E-11	4.95E-11	4.45E-11	4.04E-11
SW	8.55E-11	7.59E-11	6.79E-11	6.11E-11	5.54E-11
WSW	1.06E-10	9.38E-11	8.39E-11	7.56E-11	6.85E-11
W	7.97E-11	7.08E-11	6.34E-11	5.71E-11	5.18E-11
WNW	1.05E-10	9.31E-11	8.33E-11	7.50E-11	6.80E-11
NW	1.24E-10	1.10E-10	9.85E-11	8.87E-11	8.04E-11
NNW	1.14E-10	1.01E-10	9.02E-11	8.12E-11	7.36E-11
N	1.30E-10	1.15E-10	1.03E-10	9.29E-11	8.42E-11

Source: Turbine Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

	Downwind Distance (KM)				
Sector	15.2	16.0	24.0	32.0	40.0
NNE	1.14E-10	1.04E-10	5.16E-11	3.12E-11	2.12E-11
NE	9.79E-11	8.96E-11	4.42E-11	2.67E-11	1.81E-11
ENE	1.02E-10	9.35E-11	4.61E-11	2.79E-11	1.89E-11
E	7.75E-11	7.09E-11	3.50E-11	2.12E-11	1.44E-11
ESE	6.90E-11	6.31E-11	3.12E-11	1.89E-11	1.28E-11
SE	6.77E-11	6.20E-11	3.07E-11	1.86E-11	1.26E-11
SSE	4.65E-11	4.26E-11	2.10E-11	1.27E-11	8.64E-12
S	4.32E-11	3.95E-11	1.95E-11	1.18E-11	8.03E-12
SSW	3.68E-11	3.36E-11	1.66E-11	1.01E-11	6.84E-12
SW	5.04E-11	4.61E-11	2.28E-11	1.38E-11	9.37E-12
WSW	6.24E-11	5.71E-11	2.83E-11	1.72E-11	1.17E-11
W	4.72E-11	4.32E-11	2.15E-11	1.31E-11	8.89E-12
WNW	6.19E-11	5.67E-11	2.81E-11	1.70E-11	1.15E-11
NW	7.33E-11	6.71E-11	3.33E-11	2.03E-11	1.38E-11
NNW	6.70E-11	6.13E-11	3.04E-11	1.84E-11	1.25E-11
N	7.67E-11	7.02E-11	3.48E-11	2.11E-11	1.43E-11

Source: Turbine Building

TABLE 2A-9 ANNUAL AVERAGE D/Q VALUES FOR THE TURBINE BUILDING

Sector	Downwind Distance (KM) 48.0	56.0	64.0	72.0	80.0
NNE	1.54E-11	1.17E-11	9.22E-12	7.47E-12	6.19E-12
NE	1.32E-11	1.01E-11	7.93E-12	6.44E-12	5.36E-12
ENE	1.38E-11	1.05E-11	8.29E-12	6.74E-12	5.61E-12
E	1.05E-11	8.03E-12	6.35E-12	5.17E-12	4.31E-12
ESE	9.38E-12	7.17E-12	5.68E-12	4.64E-12	3.89E-12
SE	9.24E-12	7.06E-12	5.58E-12	4.55E-12	3.80E-12
SSE	6.33E-12	4.85E-12	3.84E-12	3.14E-12	2.64E-12
S	5.88E-12	4.49E-12	3.56E-12	2.90E-12	2.43E-12
SSW	5.00E-12	3.81E-12	3.01E-12	2.45E-12	2.04E-12
SW	6.83E-12	5.19E-12	4.09E-12	3.32E-12	2.75E-12
WSW	8.53E-12	6.49E-12	5.12E-12	4.15E-12	3.45E-12
W	6.50E-12	4.95E-12	3.91E-12	3.17E-12	2.63E-12
WNW	8.40E-12	6.39E-12	5.03E-12	4.08E-12	3.38E-12
NW	1.01E-11	7.67E-12	6.05E-12	4.92E-12	4.08E-12
NNW	9.13E-12	6.95E-12	5.48E-12	4.45E-12	3.70E-12
N	1.05E-11	7.99E-12	6.30E-12	5.11E-12	4.25E-12

Source: Turbine Building

APPENDIX 2B

Rock Foundation Treatment
Residual Heat Removal Complex
Fermi 2 Nuclear Power Plant
for
Detroit Edison Company

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REPORT

ROCK FOUNDATION TREATMENT

RESIDUAL HEAT REMOVAL COMPLEX

FERMI II NUCLEAR POWER PLANT

FOR

THE DETROIT EDISON COMPANY

INTRODUCTION

This report describes the rock foundation treatment program for the Residual Heat Removal Complex at the Fermi II Nuclear Power Plant located near Monroe, Michigan. The primary purpose of the rock foundation treatment program was to explore for solution cavities or features and if found grout them in order to minimize the potential for ground motion amplification in the event of an earthquake.

The foundation treatment consisted of two separate operations: rock surface preparation and clean-up (Part A) and rock grouting (Part B). Detailed descriptions of both operations are presented herein.*

* Note: all references listed separately at end of report.

PART A

FOUNDATION ROCK SURFACE PREPARATION AND CLEAN-UP

Foundation Rock Surface Preparation and Clean-up

General

Upon the completion of the RHR complex excavation and prior to the placement of a concrete leveling mat for the grouting program, preparation and clean-up of the foundation rock surface was performed as recommended (Reference 1). All loose debris, loosely-chinked rock fragments, mud films and most clay was removed by high pressure jetting and by mechanical and hand equipment. The supervision and inspection of this program was carried out by Dames & Moore between February 19, 1974 and April 1, 1974.

Scope

The scope of our services during this phase of the foundation rock treatment was as follows:

1 - To supervise and inspect the clean-up of the foundation rock surface prior to placement of the concrete leveling mat;

2 - To prepare a geologic map of the rock surface features;

3 - To assist the AEC representative during his inspection of a cleaned portion of the foundation rock surface;

4 - To work closely on a daily basis with personnel of Ralph M. Parsons Company, the general contractor in order to coordinate the clean-up and leveling mat placement and to report progress to representatives of the Detroit Edison Company.

General Surface Geology

Lithology - The foundation rock surface consists of light brownish-gray, very fine-grained dolomite, a few areas of which are roughly textured and covered by black, paper-thin shale.

Much of the foundation rock surface is irregular, generally containing 2- to 4-foot diameter and 1/2- to 1- foot high mounds of medium to thin-bedded dolomite. These mounds or dome-like features are characterized by: (1) a wavy onionskin structure; (2) healed, massive brecciation due to primary sedimentary processes; and (3) vugs which vary from 1 inch to 1 foot in maximum dimension and contain celestite crystals. The northwest corner of the foundation is an exception to the general rock surface because there, the rock is evenly bedded and contains no mounds of brecciated dolomite.

The mounds are of sedimentary origin and were probably formed by the accumulation of layers of algae and lime mud in the original environment of deposition. In several places along the rock walls of the foundation, vertical zones of massive sedimentary breccia occur which are several feet wide and taper to a flattened top at bedding planes. These flattened tops are the result of truncation by primary erosional processes. One of these zones near column line intersection A8 is flanked and overlain by unbrecciated, layered, dolomite dipping downward from both sides. Below the brecciated zone the general dip of the strata appears to be uninterrupted, thus indicating a non-tectonic origin. The zone is well-cemented and exhibits no more fracturing than is

evident throughout other parts of the excavation. Because of the similarity of the mounds observed both on the foundation floor and on the walls they are considered the same type of feature and sedimentary in origin.

Gray clay seams ranging from 1/8 inch to 2 inches in thickness fill some joints and some bedding plane fractures. This clay appears to be of the same physical character as that of the overlying glacial till. The fillings, therefore, are probably derived from the till. Areas of sedimentary breccia and clay fillings are shown on Plate A1, and detailed descriptions of the subsurface dolomite to a depth of 20 feet below the excavation surface are given on Plates B6 through B13.

Structure - Bedding plane attitudes vary from point to point in the foundation and in general seem to reflect the presence of the above mentioned breccia mounds. Despite local variations there is an apparent structural dip of a few degrees in a northerly direction. This compares favorably with the regional dip of a few degrees northwest towards the center of the Michigan Basin.

Fractures - The majority of the fractures in the foundation rock are tight, although some are filled with soft gray clay as described above. No displacements, tectonic breccias, or slickensided surfaces, other than slickensides associated with stylolites, were noted.

Most of the fractures are naturally occurring joints and can be grouped into three aprpproximately orthogonal sets. The dominant or major joint set trends from N21°-38°W and dips from

60^{o}-80^{o} to the southwest. Generally these joints vary in length from 5 to 30 feet but some are as much as 65 feet long. Spacing between joints is from 2 to 10 feet.

A bend of approximately 15^{o} to the west of the major joint set occurs along a southwest-northeast zone from column line intersection A7 to the area of intersection E11. Since (1) many joints of the major set are continuous across this zone; and (2) no displacements or slickensides were noted along joints either parallel or transverse to the bend, therefore the bend only reflects a local variation in the orientation of the major joint set.

A minor set of joints trends from N54^{o}-72^{o}E and dips from 30^{o}-60^{o} to the northwest. Generally, these joints vary in length from 2 to 10 feet but some are as much as 30 feet long. Spacing between these joints is from 1 to 5 feet. In general, joints of the minor set are more irregular than those of the major set and certain ones terminate against major joints.

Bedding plane joints, which undulate but are essentially horizontal, are spaced from 6 inches to 2 feet apart. As seen in the rock walls of the sides of the foundation and in the sumps, these joints are generally tight but occassionally exhibit some minor openings which are often clay-filled as described above.

Also present are numerous relatively short, irregular fractures. Many of these, especially those radiating from the diamond-cored shot holes, can be attributed to the blasting program.

Procedures

A recommended procedure for rock surface preparation is described in Reference 1.

Following the initial program of blasting and mucking for the RHR Complex excavation, the rock surface was cleared of clay, rock fragments, and loosely-chinked rock by rubber-tired backhoes. At this point a veneer of gravel-to cobble-sized rock and clay remained. A high-pressure water hose, attached to a backhoe and moved laterally was then used for washing. This was subsequently followed by picks, shovels, brooms, hand-held water hoses and air-jet equipment for dental cleaning. Later, a three-man team working with a high-pressure water hose having a flattened nozzle was found to be very effective for the total removal of remaining surface debris. A ten-foot diameter area of thinly layered dolomite in the northwest section of the foundation was found to have open bedding plane fractures. A backhoe-mounted pneumatic hammer and picks were used to remove this section of rock which extended to a depth of 6 inches.

Following completion of the cleaning operation in a given area the rock surface was inspected and all features mapped. All open or closed fractures, joints, clay seams, and other structures or rock types were noted. These mapped features are shown on Plate A1, Foundation Rock Surface Features.

The foundation rock walls were inspected but not mapped. Photographs of the walls were taken instead by the Detroit Edison Company, and these are available for examination.

Conclusions

Based on our technical supervision and inspection of the rock surface preparation and clean-up, it is our opinion that the work has been carried out in accordance with project plans and specifications. During an AEC inspection of a cleaned portion of the excavation, it was determined that the clean-up had been done satisfactorily and that no detrimental structural features existed on the foundation surface. The surface was also free of any loose rock, mud films or clay which might prevent an effective bond with the concrete leveling mat, which was subsequently placed over the rock surface.

PART B

FOUNDATION ROCK GROUTING

Foundation Rock Grouting

General

Specifications and criteria for the foundation grouting program were prepared by Sargent & Lundy Engineers for the Residual Heat Removal Complex (Reference 3). Any modifications to the grouting procedure were effected by the Detroit Edison Company after consultation with representatives of Sargent and Lundy. Data on water pressure tests, drilling, grout takes, sand-cement-water ratios and grout pressures were recorded on a daily basis by the Lee Turzillo Contracting Company and regularly distributed to representatives of the Ralph M. Parson Company. The complete grouting program was observed by Dames & Moore between March 20, 1974, and May 1, 1974. Where pertinent, recommendations on the program were made by Dames & Moore to representatives of The Detroit Edison Company.

Purpose

The primary purpose of the rock foundation grouting program was to minimize the potential for ground motion amplification in the event of an earthquake through consolidation by grouting of any solution features in the foundation.

Scope

The scope of our services during this phase of the rock foundation treatment was as follows:

1 - To supervise the location and logging of eight exploratory test holes which were core drilled

prior to grouting operations;

2 - To observe the water pressure testing of the eight preliminary test holes;

3 - To observe grouting operations performed by the Lee Turzillo Contracting Company which included drilling, washing and grouting primary, secondary, tertiary and quaternary sets of holes;

4 - To supervise the location and logging of eight exploratory test holes which were core drilled following the grouting operations;

5 - To observe water pressure testing and grouting of the eight final test holes;

6 - To discuss on a daily basis progress of the foundation treatment program with representatives of the Ralph M. Parsons Company and The Detroit Edison Company.

Procedures

In order to evaluate conditions which might be encountered during the grouting operations, eight exploratory holes were core drilled, logged and water pressure tested prior to the commencement of grouting. The pressure testing was performed by setting an air inflatable packer 5 feet from the bottom of a hole, pressure testing that interval, and then moving the packer up the hole 5 feet at a time. The test intervals, therefore,

ranged from 5 feet to 20 feet for the four tests in each exploratory hole. This method was the standard procedure used for all pressure testing in the exploratory holes although the original specifications called for the testing of discrete 5-foot intervals. When more than 80 percent of the grouting program had been completed, eight additional exploratory core holes were begun in order to compare final rock conditions with conditions before grouting. These final eight test holes were logged and pressure tested in the manner of the preliminary holes and the last of these holes were drilled following the end of the grouting operations. Flow rates from the water pressure tests performed on the 16 exploratory holes are presented in Table B2. The positions of all the exploratory holes are shown on Plates B1 through B5.

The sequence of grouting operations consisted of drilling, washing and grouting each grout hole. The elevation of the bases of the grout holes was selected (Reference 3) for the RHR Complex at 530 feet. A concrete leveling mat or slab at elevation 550 feet was placed over the excavated, cleaned rock surface. The leveling mat varied in thickness from approximately 6 inches to 2 feet due to the irregularity of the excavated rock surface. Grouting of primary and secondary holes was performed in two zones, hereafter referred to as first and second zones, extending to depths of 6 and 20 feet, respectively. Tertiary holes as well as the few quarternary holes were grouted in single stages to elevations 530 feet and 540 feet respectively. Primary holes were spaced 30 feet on centers and final closure was achieved by

subsequently grouting necessary intermediate holes (secondary, tertiary, and some quarternary holes). The locations of all holes are presented in Plates B-1 through B-5, Foundation Treatment. The volume of grout injected into each hole during each sequence of grouting is shown on those plates. The grout takes shown on plates B-1 and B-2 would only be for primary holes, the grout takes shown on plates B-3 and B-4 would only show those for secondary holes and plate B-5 only shows grout takes corresponding to tertiary and quarternary holes. A detailed description of the grouting procedure is presented below.

Prior to grouting, 2 1/2 foot long, 4-inch diameter casings were drilled and cemented into the concrete leveling mat and rock to a depth of 2 feet leaving approximately 6 inches of stick-up. This step tended to reduce surface leakage around the pipes during subsequent grouting. Primary grout holes of the first zone were drilled on approximately 30-foot centers, 6 feet into concrete and rock, to elevation 544. Crawler mounted percussion drills were used to drill the 3-inch diameter grout holes. All holes were washed thoroughly with air and water prior to grouting. Grouting of each hole in the first zone (Plate B1) was done as a single stage with a 1.6:1 water/cement plus fly ash ratio under pressure from 5 to 12 psi. A few primary holes were grouted with a water/cement plus fly ash ratio of 1.2:1. In areas of high take, grout frequently flowed from the nearby holes, in which case the initial hole was temporarily sealed and the flowing holes injected to refusal.

Second zone grouting (Plate B2) was begun by extending the primary holes to a depth of 20 feet to elevation 530 feet. All holes were grouted to their full depth as a single stage with the mechanical packer set at the top of the hole and pressure held between 20 and 50 psi. A mix of 2:1 water/cement plus fly ash was generally used, although in the north and south sump areas the ratio was thickened to 1.2:1 or 1:1 water/cement plus fly ash.

Each secondary hole was located at the geometric center of four primary holes. Grouting of the secondary holes in the first zone (Plate B3) was done in the same manner as were the primary holes. Initially the mix was 3:1 water/cement plus fly ash, but when holes began taking grout the ratio was thickened to 1.8:1 and in a few cases to 1.2:1. Grouting of the second zone (Plate B4) was continued by extending the first zone secondary holes to a depth of 20 feet to elevation 530 feet. Grout mixes for the second zone, secondary holes were 1.2:1 water/cement plus fly ash, except in one case when a 1:1 ration was used.

Tertiary grout holes are at the center of the 15-foot square formed by two primary and two secondary holes. These holes were drilled 20 feet deep to an elevation of 530 feet and grouted as a single zone (Plate B5) rather than using the two-zone procedure as was done with the primary and secondary holes. The reason for this was the general very low take in grouting the second zone - secondary holes. A ratio of 1.2:1 water/cement plus fly ash was generally used. In the only area where grout takes were significant, five quarternary holes, each located in the center of the diamond formed by a primary, secondary, and two

tertiary holes, were drilled and grouted to a depth of 10 feet. A 20-foot deep core hole completed this quarternary array and was grouted at the same time.

All grout holes were grouted to refusal. In holes in which grout interconnections occurred, packers were set and maintained until back pressure reduced to zero. Some grout leaks occurred in the north and south sumps, especially during the first zone primary grouting, and where significant these were dry packed by hand with cement. Subsequent first zone grouting indicated these areas were sealed.

As noted above in grouting the first and second zones, injection gage pressures ranged from 5 to 12 psi and from 20 to 50 psi, respectively. These pressures were changes made to the original specifications and were felt necessary by the contractor in order to properly move the grout and to counter any artesian pressures, which were indicated in some cases by slight water flows from a number of the open holes. The ground water surface in the general area of the plant is approximately 575 feet and is, therefore, 25 feet above the RHR foundation rock surface or 45 feet above the bases of the grout holes. Local artesian conditions may have existed despite the dewatering program. In a few instances pressure build-ups may have been indicated by water flows from previously grouted holes. These holes were each re-grouted. To determine if heaving of the concrete leveling mat was occurring due to grout being forced between the concrete leveling mat and the rock, elevations on the concrete surface were checked by transit from time to time. No changes in elevations

were observed. It was also noted in all eight final core-drilled exploratory holes that the concrete mat was tightly-bonded to the rock surface.

Table B1 summarizes the volume of grout injected into the foundation for the RHR Complex. There is a general decrease in unit take, both from first to second zone grouting and from primary to secondary to tertiary holes within these zones. The unit take of the secondary holes in the first zone is 94 percent of the take of the primary holes in that zone, and by comparison the secondary holes of the second zone showed a unit take which was 18 percent of that of the primary holes in that zone. The unit take and the tertiary holes is consistent with a decrease in grout take and seems to confirm the single zone grouting which was used at this point.

Visual inspection of the leveling mat following completion of the grouting program confirmed that virtually all water flow had been eliminated, including all artesian flow from each of three preliminary borings which predated the RHR excavation in the vicinity of holes S43, P6, and P48.

Conclusions

Exploration drilling both prior to and after grouting along with careful observation of the drilling of the grout holes and amount of grout take prove there are no continuous open solution features in the foundation of the RHR Complex.

References:

(1) Dames & Moore letter, "Recommended Procedure for Foundation Preparation, Residual Heat Removel (RHR) Complex, Enrico Fermi Atomic Power Plant - Unit 2", dated February 11, 1974.

(2) Dames & Moore "Report, Results of Rock Foundation Treatment, Fermi II Nuclear Power Plant, for The Detroit Edison Company", dated January 12, 1971.

(3) Sargent & Lundy "Specification 3071-135, Pressure Rock Grouting for Residual Heat Removal Complex, Enrico Fermi Atomic Power Plant - Unit 2, The Detroit Edison Company", dated September 21, 1973.

Table B1

SUMMARY OF GROUTING

Holes Drilled	Number of Holes	Holes With Take	% Holes With Take	Volume of Grout (cubic ft)	Unit Take (Total Holes-Cubic Feet of Grout per ft. of hole)
		First Zone Grouting (Holes drilled 6 feet deep to elevation 544 feet)			
Primary	78*	40	51%	707.4	1.51
Secondary	78*	45	58%	663.2	1.42
		Second Zone Grouting (Holes drilled 20 feet deep to elevation 530 feet - except for north and south sumps)			
Primary	90	58	64%	636.7	.51
Secondary	90	22	24%	115.8	.09
		Single Zone Grouting (Holes drilled 20 feet deep to elevation 530 feet)			
Tertiary	171	29	17%	189.3	.06
		(Holes drilled 10 feet deep to elevation 540 feet - except for Q1--20 feet deep)			
Quaternary	6	4	67%	29.3	.49
		Exploratory Test Holes (Holes drilled 20 feet deep to elevation 530 feet)			
Pre-grouting	8	7	88%	93.4	.58
Post-grouting	8	7	88%	42.7	.27

* Does not include area of sumps.

TABLE B2

WATER PRESSURE TESTING
(Flow Rates in Gallons/Minute)

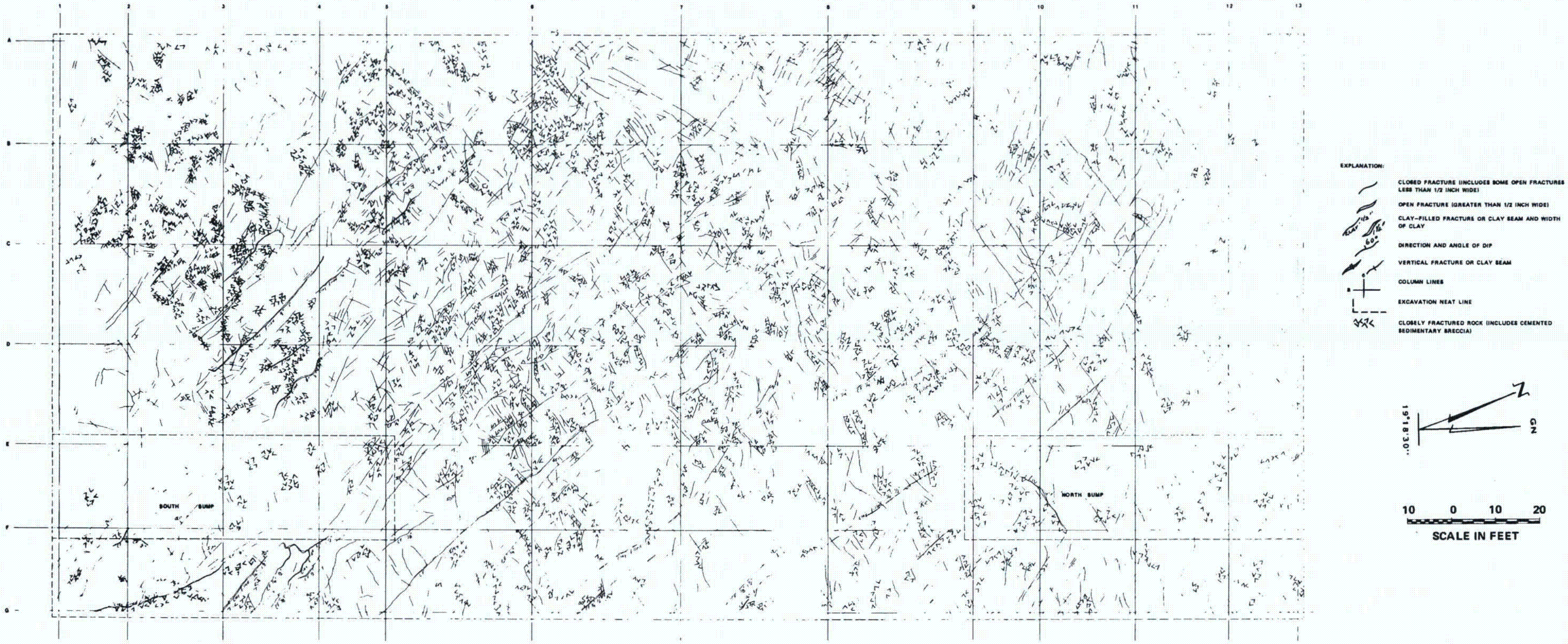
Test Hole Number	Intervals Tested (Elevations in Feet) (1) 530-535	(2) 530-540	(3) 530-545	(4) 530-550
		Pre-Grouting Exploratory Holes		
S44	.02	.41	.90 [5]	1.30 [3]
S21	.09	.92	.79	1.94
P15	.02	.17	.54	1.97
S75	.03	.00	1.22*	1.78*
P19	.00	.04	.22	.23
P37	.02	.08	1.01	2.08 [3]
S83	.22	.22	.62	.90 [5]
P77	.00	.03	.69	1.54 [2]
		Post-Grouting Exploratory Holes		
Q1	.00	.05	1.00**	.10
Q2	--	--	--	.70**
Q3	.10	.70	.50	.10
Q4	.20	.70	.70	.00 [5]
Q5	.00	.40	.60	.00 [4]
Q6	.00	.00	.00	--
Q7	.00	.81	.01	.78
Q8	.00	1.36	.83	.24

Note:

1. Each interval tested at constant pressure of 10 psi for 10 minutes unless otherwise noted by asterisk for a different pressure or number in upper right hand corner of block for different time.

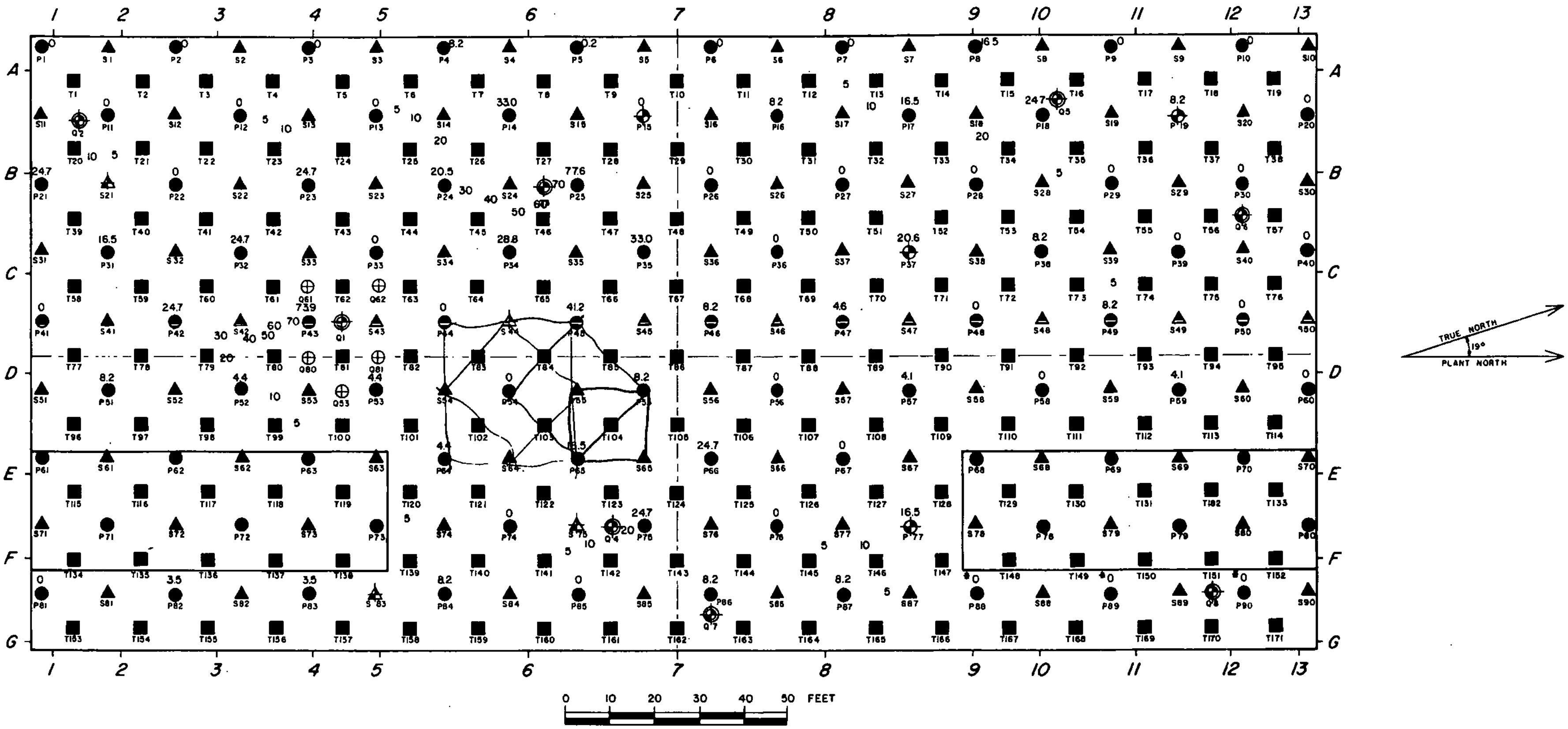
2. See Plates B1 - B5 for hole locations.

* 5 psi
** 0 psi



FOUNDATION ROCK SURFACE FEATURES
RESIDUAL HEAT REMOVAL COMPLEX

PLATE A–1



EXPLANATION

- PRIMARY GROUT HOLES
- SECONDARY GROUT HOLES
- TERTIARY GROUT HOLES
- QUATERNARY GROUT HOLES

8.2 GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.6:1 (WATER: CEMENT PLUS FLY ASH)

*8.2 MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)

0 NO GROUT TAKEN BY ROCK

PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)

POST-GROUTING EXPLORATORY HOLES

2 A BUILDING COLUMN LINES

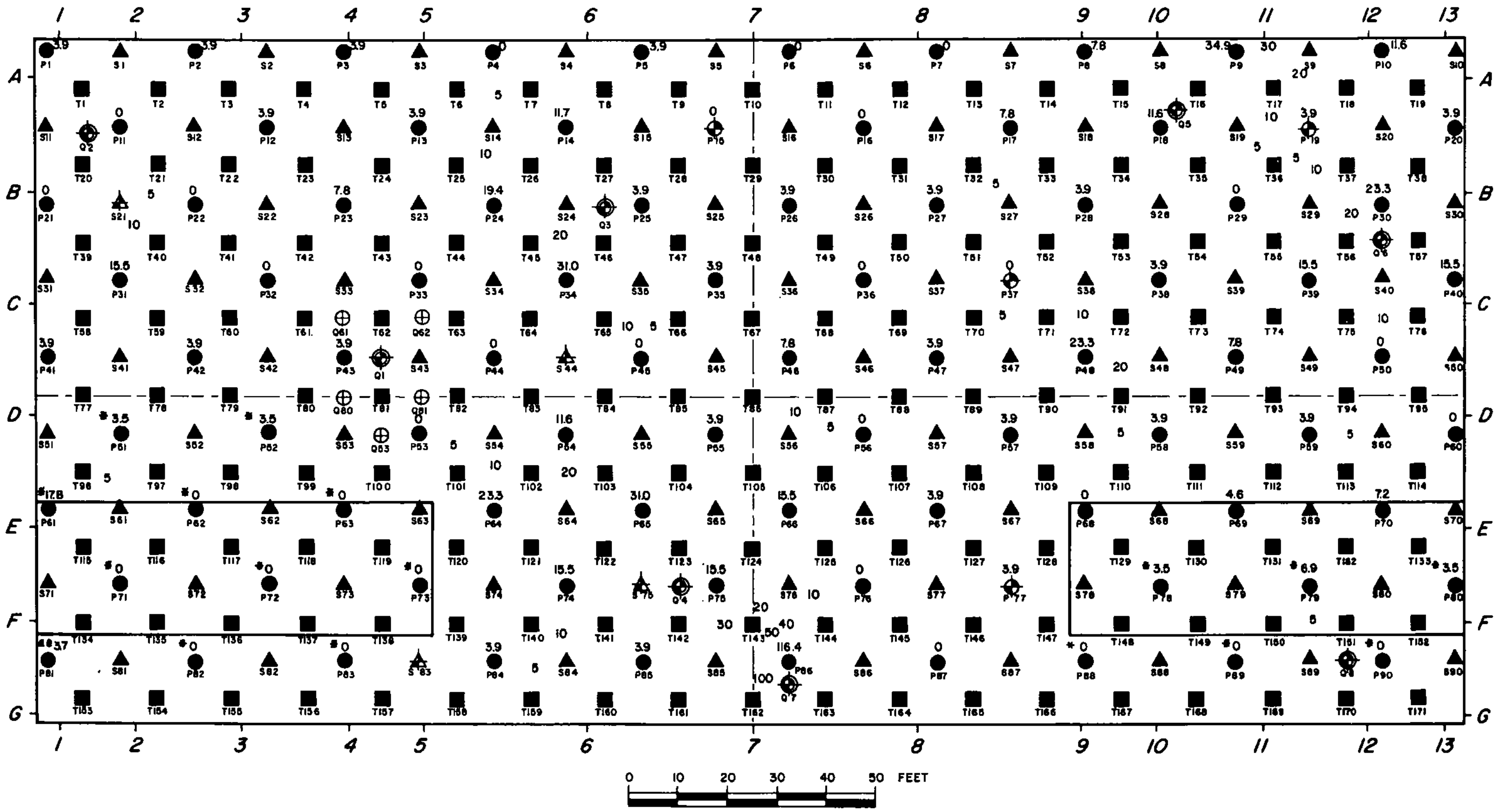
APPROXIMATE BUILDING AND EXCAVATION LINES

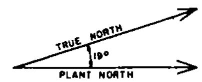
BUILDING CENTER LINE

REFERENCE: MODIFIED FROM LEE TURZILLO CONTRACTING CO.
DRAWING NUMBER 2410-1
FEBRUARY 19, 1974

PRIMARY HOLES – FIRST ZONE GROUTING (0–6 FEET)

PLATE B–1





EXPLANATION

- PRIMARY GROUT HOLES
- SECONDARY GROUT HOLES
- TERTIARY GROUT HOLES
- QUATERNARY GROUT HOLES

3.9 GROUT VOLUME IN CUBIC FEET-MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 2:1 (WATER: CEMENT PLUS FLY ASH)

*3.9 MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)

**3.9 MIX WITH 1:1 (CEMENT:FLY ASH) AND 1:1 (WATER:CEMENT PLUS FLY ASH)

0 NO GROUT TAKEN BY ROCK

OR PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION).

POST-GROUTING EXPLORATORY HOLES

2 A BUILDING COLUMN LINES

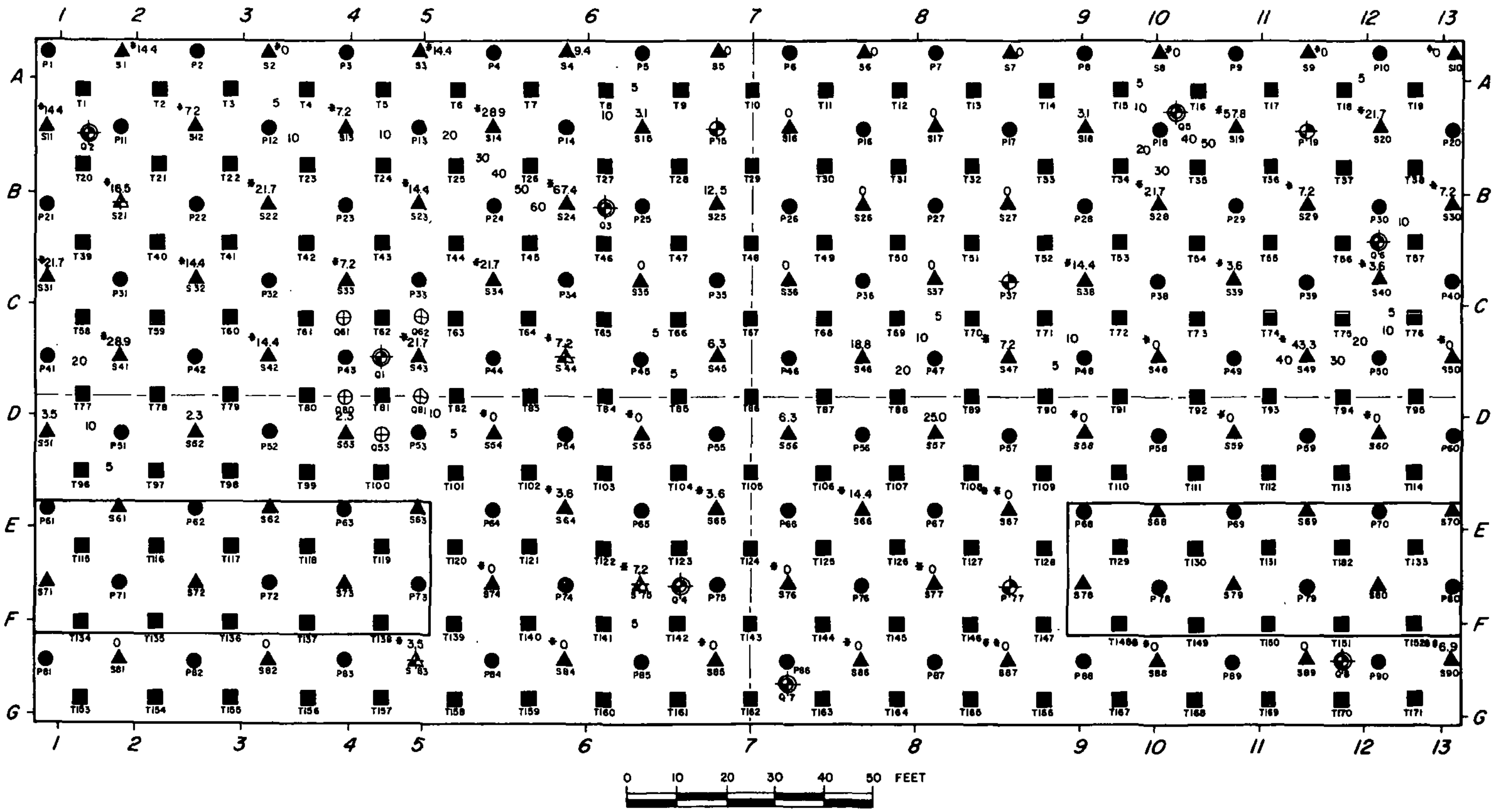
APPROXIMATE BUILDING AND EXCAVATION LINES

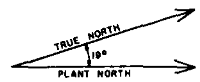
BUILDING CENTER LINE

REFERENCE: MODIFIED FROM LEE TURZILLO CONTRACTING CO. DRAWING NUMBER 2410-1 FEBRUARY 19, 1974

PRIMARY HOLES – SECOND ZONE GROUTING (6–20 FEET)

PLATE B–2





EXPLANATION

- ● PRIMARY GROUT HOLES
- ▲ SECONDARY GROUT HOLES
- ■ TERTIARY GROUT HOLES
- ⊕ QUATERNARY GROUT HOLES

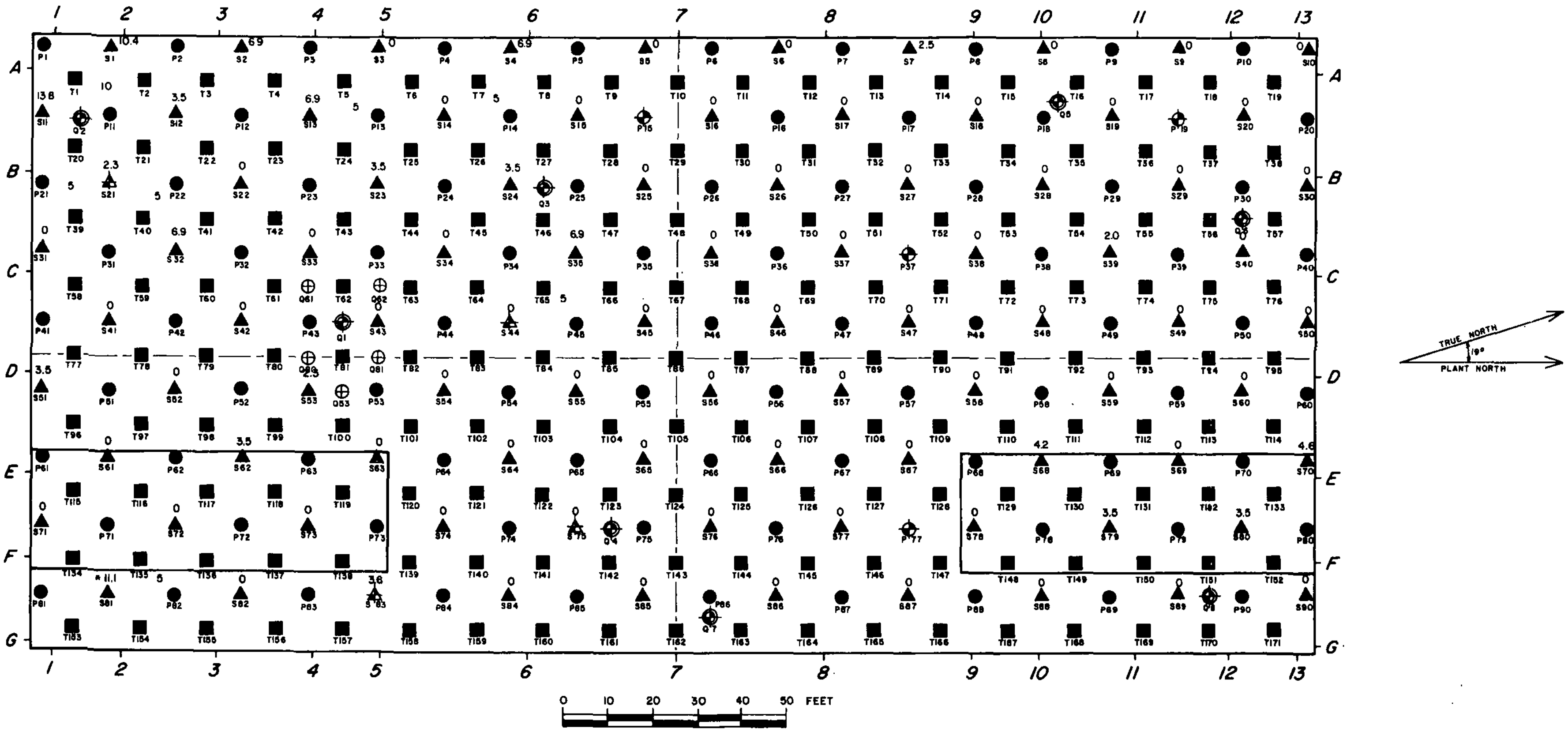
- 7.2 ▲ GROUT VOLUME IN CUBIC FEET-MIX WITH 2:1 (CEMENT:FLY ASH) AND 3:1 (WATER: CEMENT PLUS FLY ASH)
- *7.2 ▲ MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 1.8:1 (WATER:CEMENT PLUS FLY ASH)
- **7.2 ▲ MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER:CEMENT PLUS FLY ASH)
- 0 ▲ NO GROUT TAKEN BY ROCK

- PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)
- POST-GROUTING EXPLORATORY HOLES
- 2, A BUILDING COLUMN LINES
- APPROXIMATE BUILDING AND EXCAVATION LINES
- BUILDING CENTER LINE

REFERENCE: MODIFIED FROM LEE TURZILLO CONTRACTING CO. DRAWING NUMBER 2410-1 FEBRUARY 19, 1974

SECONDARY HOLES – FIRST ZONE GROUTING (0–6 FEET)

PLATE B–3



EXPLANATION

- ● PRIMARY GROUT HOLES
- ▲ SECONDARY GROUT HOLES
- ■ TERTIARY GROUT HOLES
- ⊕ QUATERNARY GROUT HOLES

3.5 ▲ GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER: CEMENT PLUS FLY ASH)

*3.5 ▲ MIX WITH 1:1 (CEMENT:FLY ASH) AND 1:1 (WATER:CEMENT PLUS FLY ASH)

0 ▲ NO GROUT TAKEN BY ROCK

PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT HOLE POSITION)

POST-GROUTING EXPLORATORY HOLES

2 A BUILDING COLUMN LINES

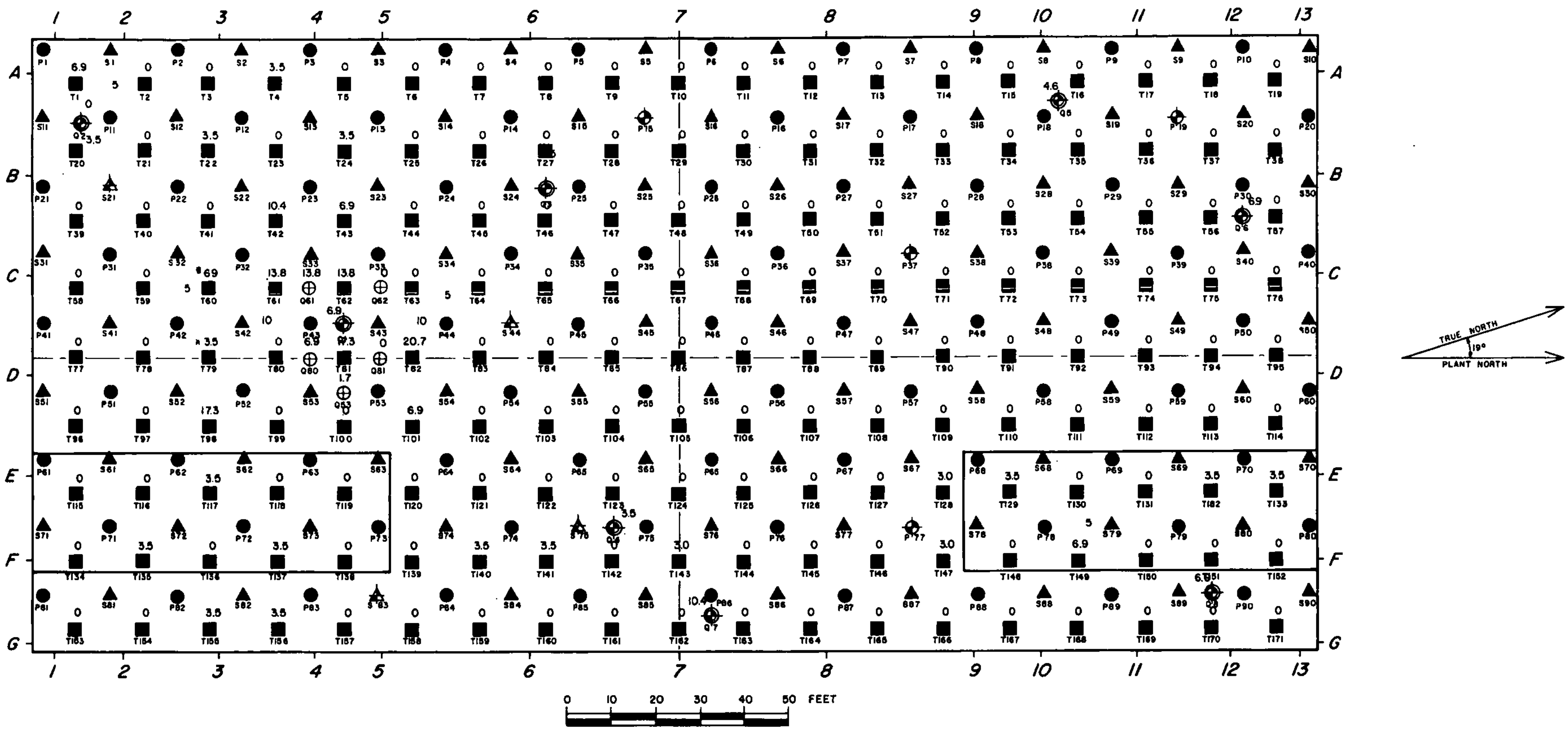
APPROXIMATE BUILDING AND EXCAVATION LINES

BUILDING CENTER LINE

REFERENCE: MODIFIED FROM LEE TURZILLO CONTRACTING CO. DRAWING NUMBER 2410-1 FEBRUARY 19, 1974

SECONDARY HOLES –
SECOND ZONE GROUTING (6–20 FEET)

PLATE B–4



EXPLANATION

- ● PRIMARY GROUT HOLES
- ▲ SECONDARY GROUT HOLES
- ■ TERTIARY GROUT HOLES
- ⊕ QUATERNARY GROUT HOLES

6.9 ■ OR 6.9 ⊕ OR 6.9 ⊕ GROUT VOLUME IN CUBIC FEET-MIX WITH 1:1 (CEMENT:FLY ASH) AND 1.2:1 (WATER: CEMENT PLUS FLY ASH)

*6.9 ■ MIX WITH 1.5:1 (CEMENT:FLY ASH) AND 1.5:1 (WATER:CEMENT PLUS FLY ASH)

0 ■ NO GROUT TAKEN BY ROCK

PRE-GROUTING EXPLORATORY HOLES (SYMBOLS CORRESPOND TO EITHER A PRIMARY OR SECONDARY GROUT-HOLE POSITION)

POST-GROUTING EXPLORATORY HOLES

2, A BUILDING COLUMN LINES

APPROXIMATE BUILDING AND EXCAVATION LINES

BUILDING CENTER LINE

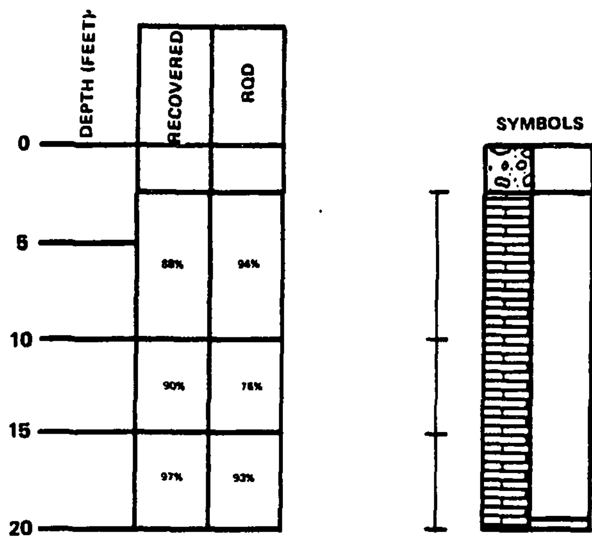
REFERENCE: MODIFIED FROM LEE TURZILLO CONTRACTING CO. DRAWING NUMBER 2410-1 FEBRUARY 19, 1974

TERTIARY AND QUATERNARY HOLES – SINGLE ZONE GROUTING (0–20 FEET)

PLATE B–5

BORING P-15

SURFACE ELEVATION 550.0



DESCRIPTIONS

CONCRETE

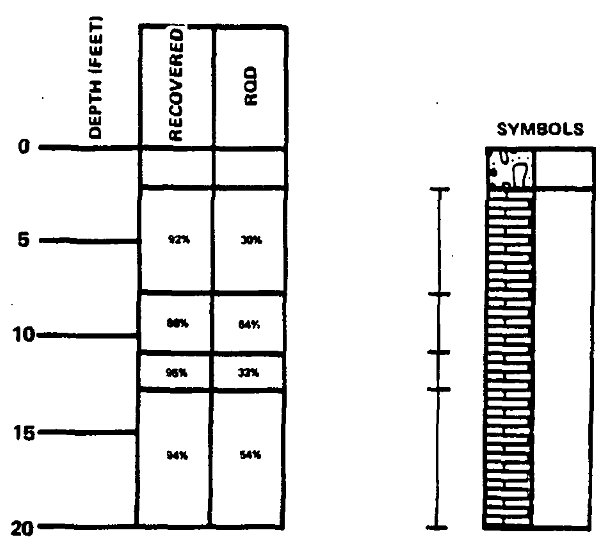
<u>DOLOMITE</u> LIGHT GRAY TO GRAY. FINE-GRAINED FREQUENT GRAY LAMINATIONS. SOME MOTTLING. HORIZONTAL SHALE PARTINGS 4 INCHES TO 1 FOOT APART
OCCASIONAL VERTICAL CLOSED FRACTURES
IRREGULAR 70° FRACTURE AT 4.8 FEET
GRADES MOTTLED. FOSSILIFEROUS WITH PINPOINT POROSITY
GRADES WITH PINPOINT TO 3/4 - INCH VUGS AND 5 POROSITY
60° 1/16 - INCH SHALE-LINED FRACTURE
HORIZONTAL. WAVY. 1/8 - INCH SHALE PARTINGS 2 TO 6 INCHES APART FROM 8.0 TO 10.0 FEET
60° TO 70° FRACTURE AT 10.5 FEET
PINPOINT TO 3/4 - INCH VUGS WITH 5% TO 10% POROSITY FROM 10.5 TO 12.5 FEET
30° FRACTURE
IRREGULAR 60° FRACTURE
VUGGY WITH 5% POROSITY FROM 15.8 TO 16.2 FEET
SUBHORIZONTAL FRACTURES AT 16.0 AND 16.4 FEET
CONGLOMERATIC FROM 16.6 TO 18.5 FEET
IRREGULAR 60° FRACTURE AT 18.0 FEET
HAIRLINE 60° FRACTURE AT 19.2 FEET

<u>OOLITIC DOLOMITE</u> LIGHT GRAY MEDIUM-GRAINED

BORING COMPLETED AT 20.0 FEET ON 3-20-74

BORING P-19

SURFACE ELEVATION 550.0



DESCRIPTIONS

CONCRETE

<u>DOLOMITE</u> LIGHT BROWNISH-GRAY TO GRAY FINE-GRAINED OCCASIONAL DARK GRAY LAMINATIONS AND STYLOLITES
2 NEAR-VERTICAL. CLOSED FRACTURES
30° FRACTURE
GRADES WITH SOME MOTTLING TO 10.0 FEET
1/8-INCH HORIZONTAL SHALE PARTINGS AT 3.5 FEET
FREQUENT 45° TO VERTICAL. CLOSED FRACTURES FROM 3.5 TO 8.0 FEET
PINPOINT TO 1/4-INCH VOIDS IN FOSSILIFEROUS ZONE WITH 5% POROSITY FROM 8.3 TO 8.7 FEET
HORIZONTAL SHALE PARTING
GRADES FOSSILIFEROUS AND VUGGY WITH PINPOINT TO 1/2-INCH VOIDS WITH 5% TO 10% POROSITY
FREQUENT CLOSED IRREGULAR 40° TO NEAR-VERTICAL FRACTURE
GRADES WITH WAVY GRAY LAMINATIONS
1/16-INCH SHALE PARTING AT 15.7 FEET

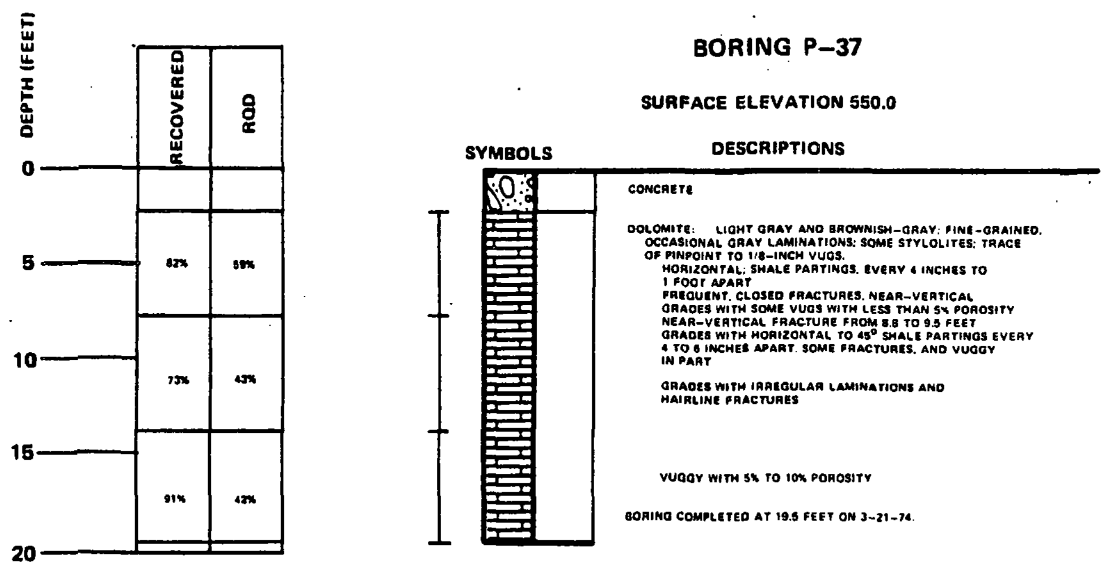
60° TO VERTICAL FRACTURES WITH SOME CRYSTAL FILLINGS FROM 18.5 TO 20.0 FEET

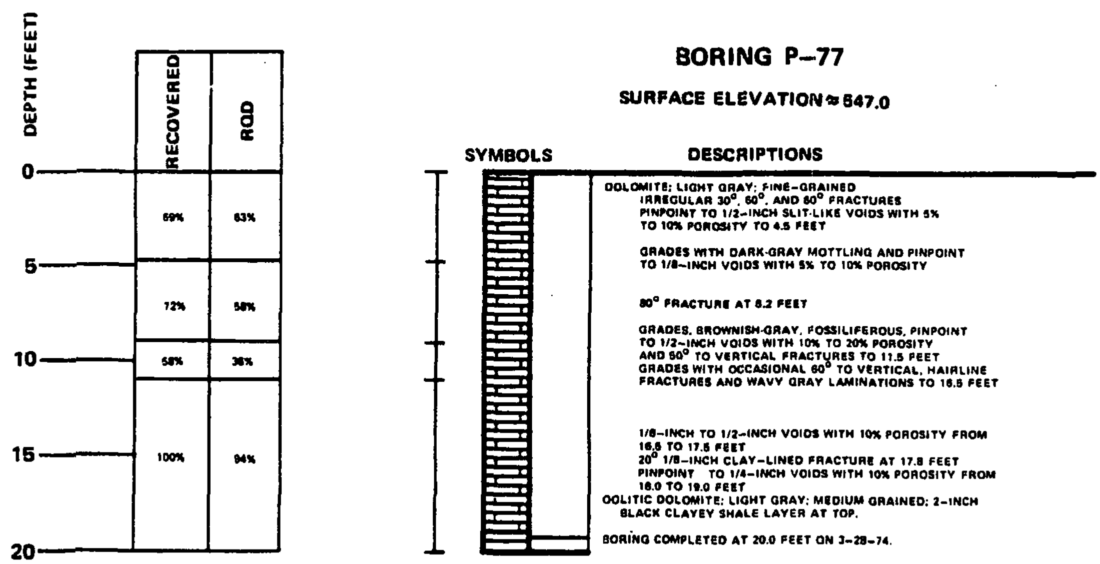
BORING COMPLETED AT 20.0 FEET ON 3-22-74

REFERENCE:
DAMES & MOORE REPORT
RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, ENRICO FERMI ATOMIC POWER PLANT UNIT 2, JUNE 1974

LOG OF BORINGS

PLATE B-6





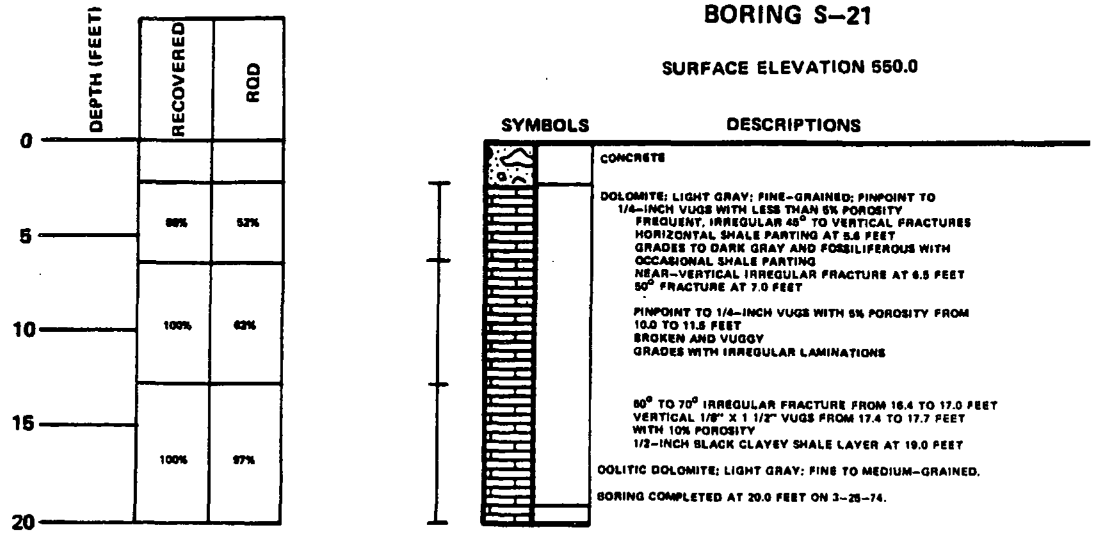
REFERENCE:
DAMES & MOORE REPORT,
RESULTS OF ROCK FOUNDATION TREATMENT,
RESIDUAL HEAT REMOVAL COMPLEX,
ENRICO FERMI ATOMIC POWER PLANT UNIT 2,
JUNE 1974

LOG OF BORINGS

PLATE B-7

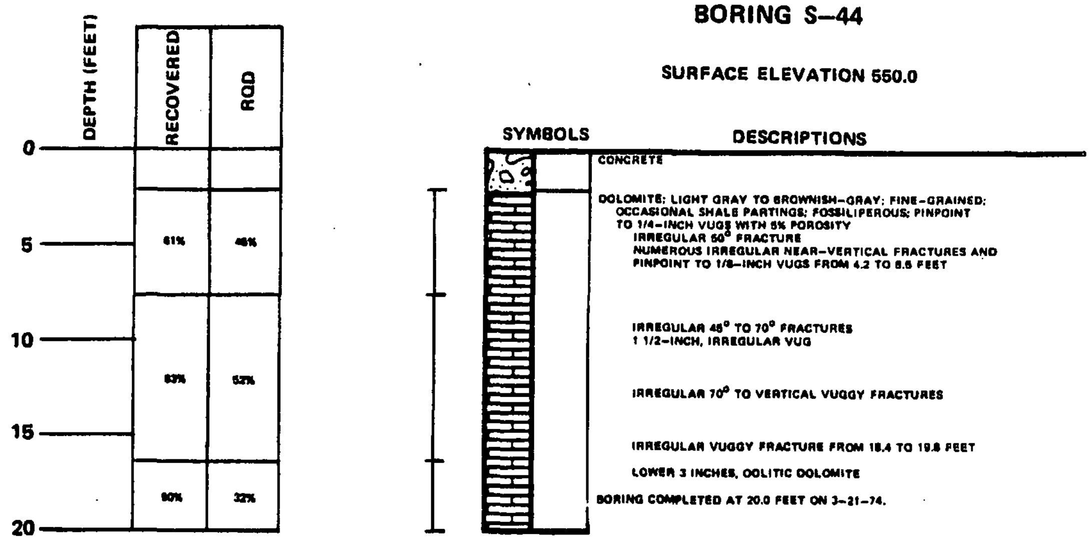
BORING S–21

SURFACE ELEVATION 550.0



BORING S–44

SURFACE ELEVATION 550.0



REFERENCE:
DAMES & MOORE REPORT,
RESULTS OF ROCK FOUNDATION TREATMENT
RESIDUAL HEAT REMOVAL COMPLEX,
ENRICO FERMI ATOMIC POWER PLANT UNIT 2,
JUNE 1974

LOG OF BORINGS

PLATE B–8

BORING S–75

SURFACE ELEVATION 550.0

DEPTH (FEET): 0, 5, 10, 15, 20

RECOVERED	RQD
100%	75%
55%	0
100%	56%
89%	62%

SYMBOLS / DESCRIPTIONS

CONCRETE

DOLOMITE: LIGHT BROWNISH–GRAY: FINE–GRAINED: OCCASIONAL HORIZONTAL LAMINATIONS AND SOME DARK GRAY MOTTLING: SOME FOSSILS.
SUBHORIZONTAL 1/16–INCH BLACK SHALE PARTING
GRADES WITH PINPOINT TO 1/4–INCH VOIDS, 5% TO 10% POROSITY, TO 11.0 FEET

VERTICAL HAIRLINE FRACTURE
GRADES TO GRAYISH–BROWN WITH 1/16–INCH BLACK SHALE PARTINGS APPROXIMATELY EVERY 6 INCHES
1/2–INCH OPEN 70° FRACTURE AT 11.0 FEET
GRADES WITH PINPOINT TO 1–INCH SLIT-LIKE VOIDS WITH 5% TO 15% POROSITY TO 14.0 FEET
60° FRACTURE WITH SLICKENSIDED BLACK SHALE COATING
30° IRREGULAR FRACTURE
GRADES WITH WAVY LAMINATIONS AND SOME PINPOINT TO 1/4–INCH VOIDS WITH LESS THAN 5% POROSITY:
TRACE OF 50° TO 70° HAIRLINE FRACTURES

BORING COMPLETED AT 20.0 FEET ON 3–27–74

BORING S–83

SURFACE ELEVATION 550.0

DEPTH (FEET): 0, 5, 10, 15, 20

RECOVERED	RQD
50%	0
36%	50%
64%	62%
100%	50%
56%	47%
100%	88%

SYMBOLS / DESCRIPTIONS

CONCRETE

DOLOMITE: LIGHT–GRAY; FINE–GRAINED; OCCASIONAL CLOSED HAIRLINE 60° FRACTURES.
PINPOINT TO 1/4–INCH VOIDS WITH 10% POROSITY FROM 3.0 TO 4.5 FEET

GRADES LIGHT BROWNISH–GRAY, SOME FOSSILS, OCCASIONAL 40° TO 60° CLOSED FRACTURES, HORIZONTAL 1/16–INCH BLACK SHALE PARTINGS FROM 4–INCH TO 6–INCH APART; SOME PINPOINT TO 1/4– INCH VOIDS WITH LESS THAN 5% POROSITY

GRADES TO LIGHT GRAY
OCCASIONAL 1 1/2–INCH SLIT-LIKE VOIDS WITH 15% POROSITY FROM 15.0 TO 15.5 FEET
TRACE OF 30° TO VERTICAL CLOSED FRACTURES FROM 18.0 TO 20.0 FEET

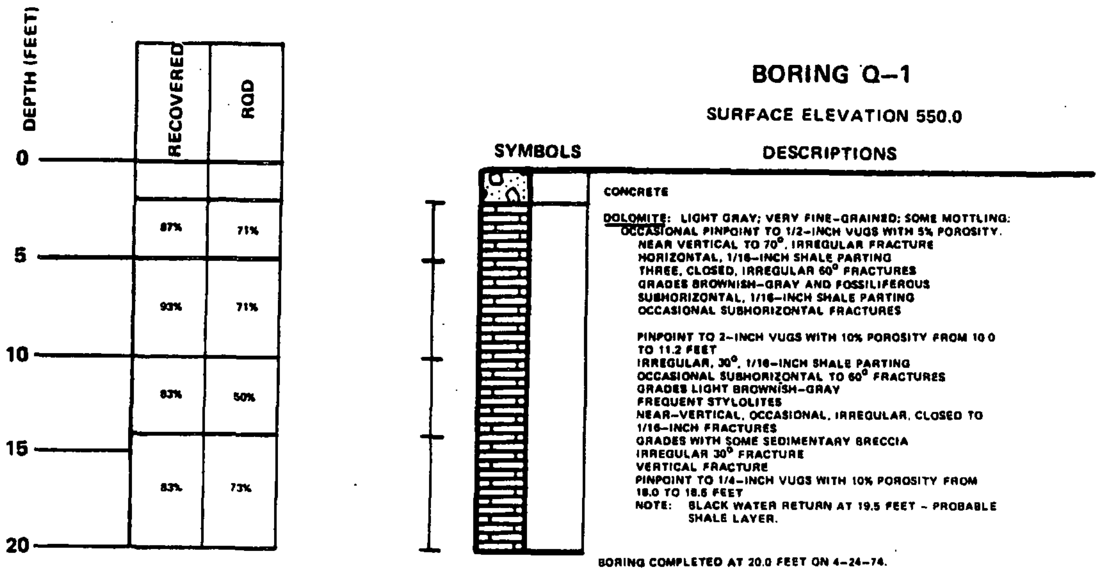
PINPOINT TO 1/4–INCH VOIDS WITH 5% TO 10% POROSITY FROM 18.0 TO 20.0 FEET

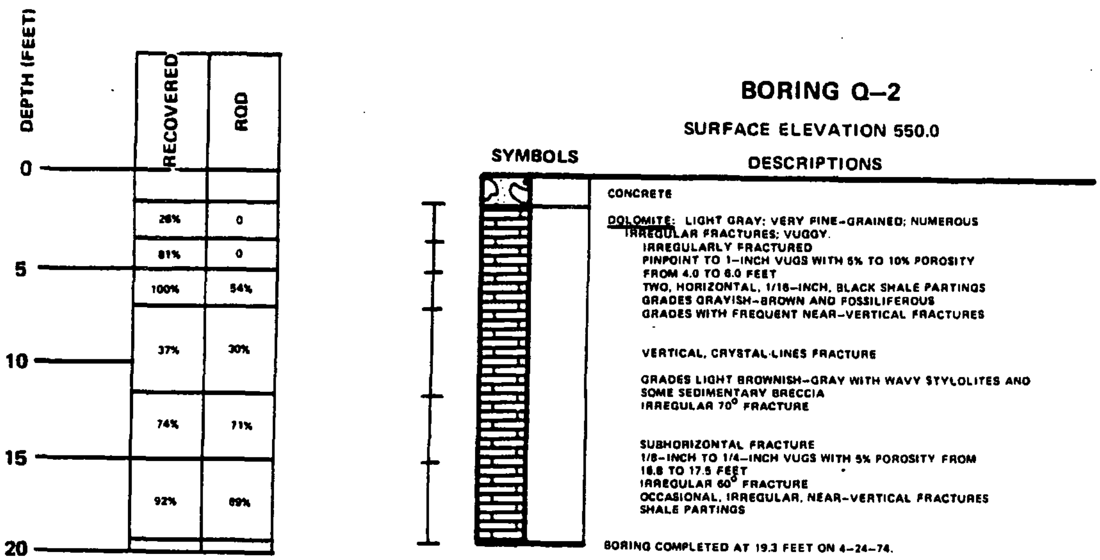
BORING COMPLETED AT 20.0 FEET ON 3–28–74.

REFERENCE:
DAMES & MOORE REPORT
RESULTS OF ROCK FOUNDATION TREATMENT
RESIDUAL HEAT REMOVAL COMPLEX,
ENRICO FERMI ATOMIC POWER PLANT UNIT 2,
JUNE 1974

LOG OF BORINGS

PLATE B–9





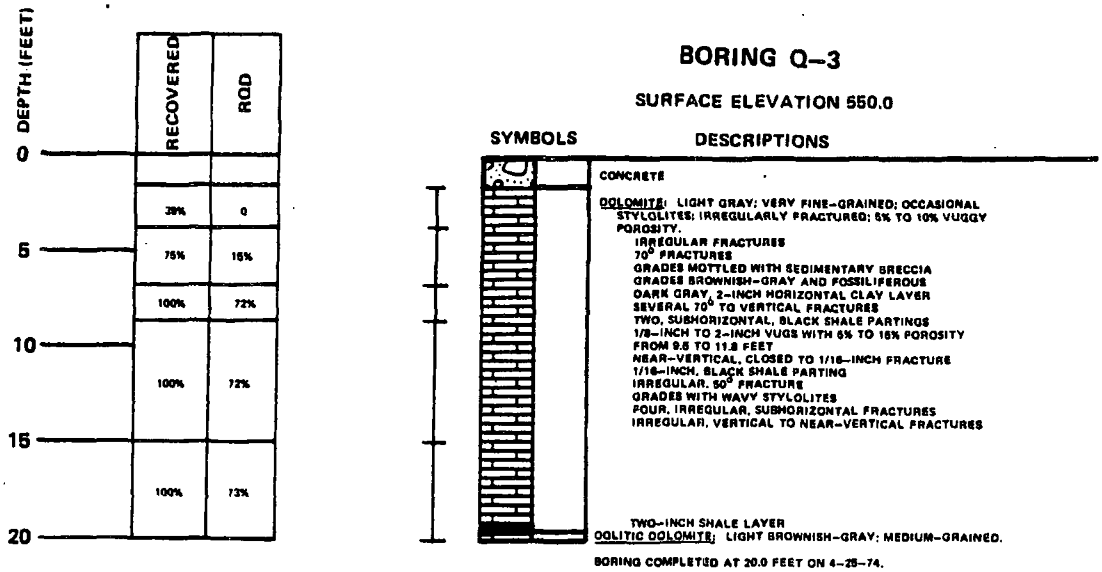
REFERENCE,
DAMES & MOORE REPORT,
RESULTS OF ROCK FOUNDATION TREATMENT
RESIDUAL HEAT REMOVAL COMPLEX,
ENRICO FERMI ATOMIC POWER PLANT UNIT 2,
JUNE 1974

LOG OF BORINGS

PLATE B-10

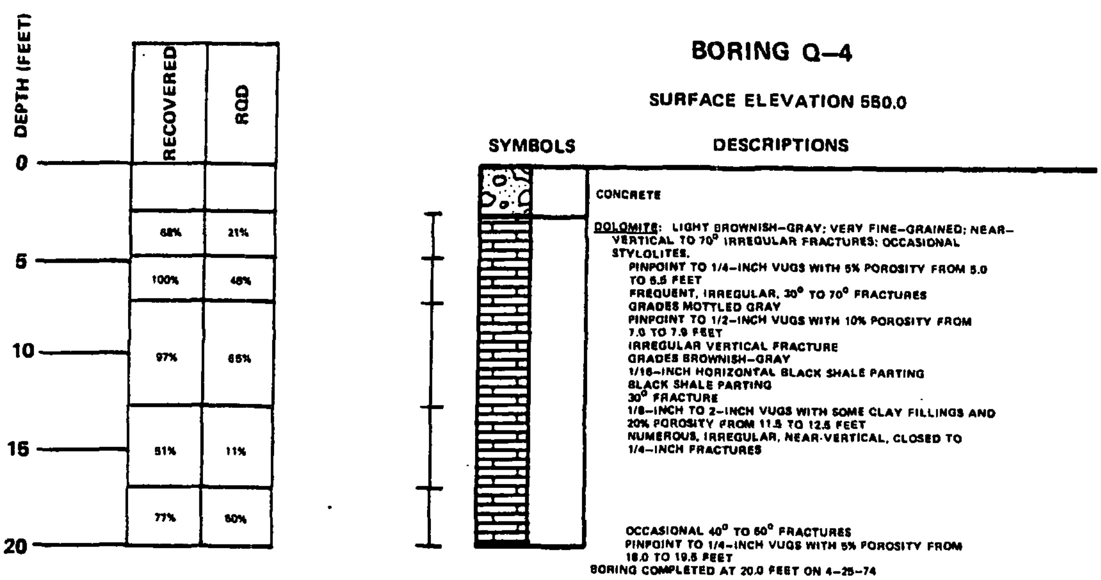
BORING Q–3

SURFACE ELEVATION 550.0



BORING Q–4

SURFACE ELEVATION 550.0



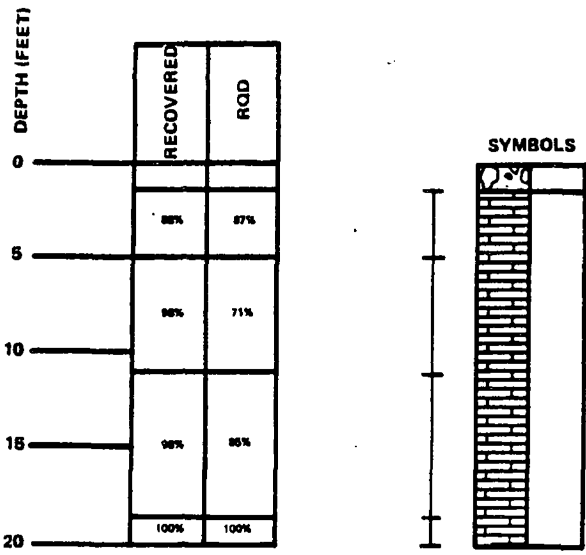
REFERENCE:
DAMES & MOORE REPORT
RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX UNIT 2, JUNE 1974

LOG OF BORINGS

PLATE B–11

BORING Q-5

SURFACE ELEVATION 550.0



DESCRIPTIONS

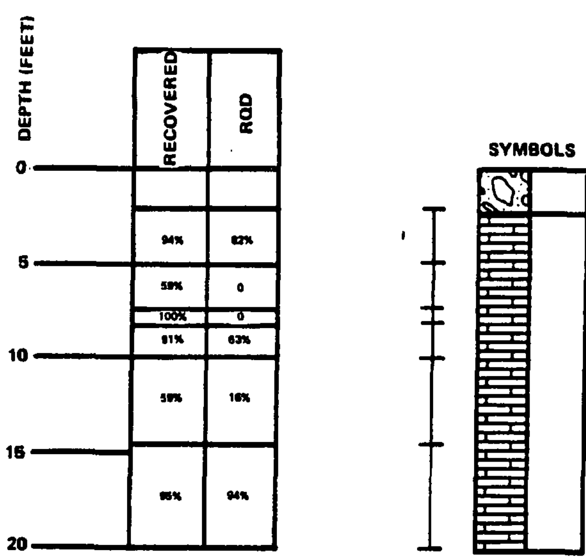
CONCRETE
DOLOMITE: LIGHT GRAY; VERY FINE-GRAINED; HORIZONTAL BLACK STYLOLITES EVERY 2 INCHES TO 6 INCHES APART.
TWO 1/16-INCH, HORIZONTAL, BLACK SHALE PARTINGS

SUBHORIZONTAL FRACTURE
SHALE PARTING
TWO, 80° FRACTURES
PINPOINT TO 1/2-INCH VUGS WITH 5% TO 15% POROSITY FROM 7.3 TO 9.3 FEET
GRADES WITH SOME GRAY MOTTLING AND SEDIMENTARY BRECCIA
GRADES BROWNISH-GRAY WITH NEAR-VERTICAL FRACTURES WITH BLACK SHALE LININGS
1/4 -INCH VUGS WITH 10% POROSITY FROM 10.5 TO 12.0 FEET
PINPOINT TO 1/2-INCH VUGS WITH 5% POROSITY FROM 12.0 TO 14.3 FEET
IRREGULAR, 1/16-INCH, 30° BLACK SHALE PARTING
OCCASIONAL, WAVY GRAY LAMINATIONS AND HAIRLINE FRACTURES
SUBHORIZONTAL FRACTURE

BORING COMPLETED AT 20.0 FEET ON 4-25-74.

BORING Q-6

SURFACE ELEVATION 550.0



DESCRIPTIONS

CONCRETE

DOLOMITE: LIGHT BROWNISH-GRAY; VERY FINE-GRAINED; OCCASIONAL DARK GRAY LAMINATIONS AND STYLOLITES.
80° FRACTURE
SEVERAL, NEAR-VERTICAL FRACTURES

80° FRACTURE
SUBHORIZONTAL, 1/16-INCH, BLACK SHALE PARTING
GRADES WITH DARK GRAY MOTTLING
20° FRACTURE
SUBHORIZONTAL PARTING
GRADES DARK GRAYISH-BROWN WITH SOME VUGS
BLACK SHALE PARTINGS EVERY 4 TO 6 INCHES APART
NOTE: 10.0 FEET - SOME WATER FLOW, APPROXIMATELY 2 GALLONS/MINUTE.
60° FRACTURE
NEAR-VERTICAL, IRREGULAR, 1/16-INCH, CRYSTAL-LINED FRACTURE
GRADES WITH IRREGULAR GRAY LAMINATIONS AND STYLOLITES

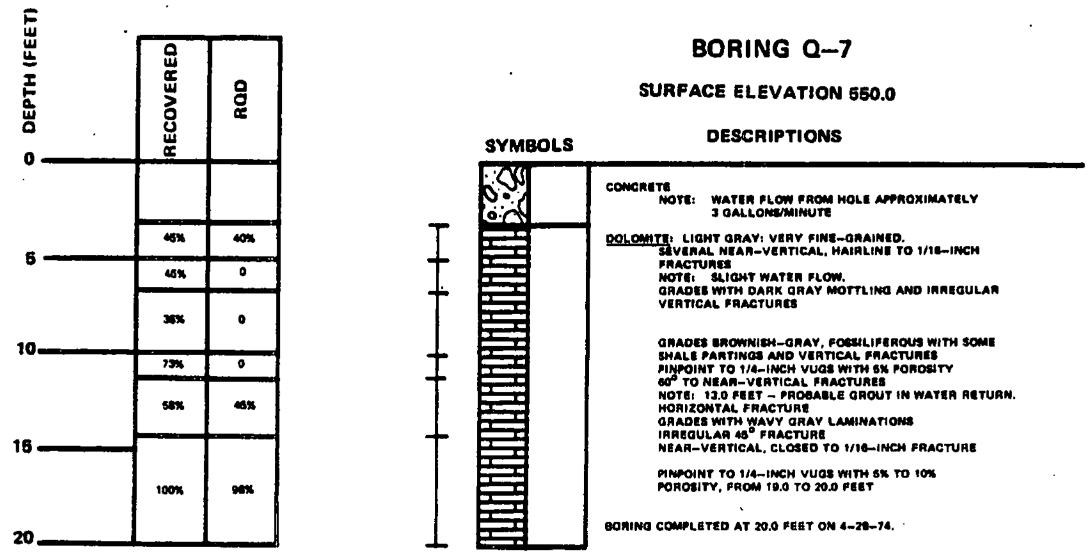
PINPOINT TO 1/4-INCH VUGS WITH 5% POROSITY

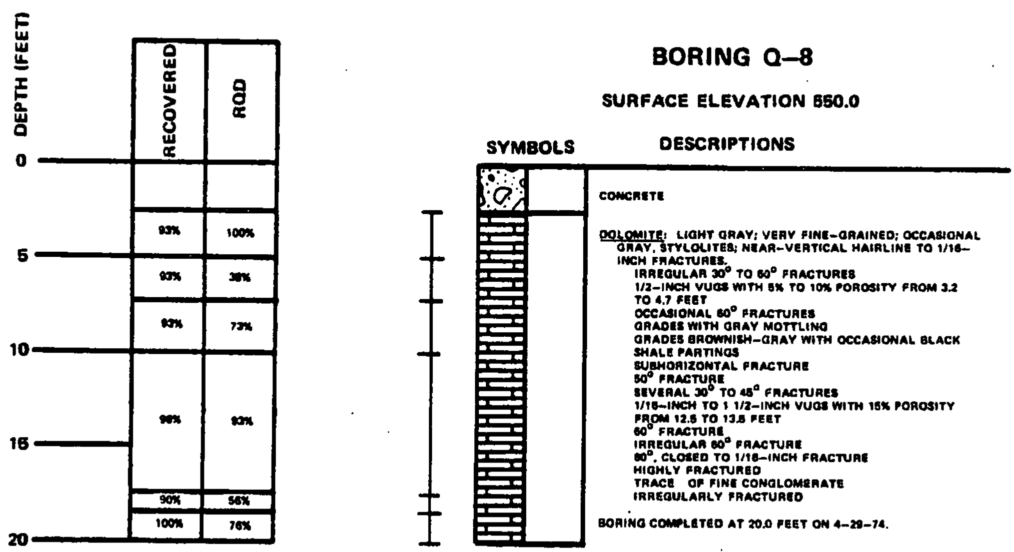
BORING COMPLETED AT 20.0 FEET ON 4-26-74.

REFERENCE:
DAMES & MOORE REPORT
RESULTS OF ROCK FOUNDATION TREATMENT, RESIDUAL HEAT REMOVAL COMPLEX, UNIT 2, JUNE 1974

LOG OF BORINGS

PLATE B-12





REFERENCE:
DAMES & MOORE REPORT
RESULTS OF ROCK FOUNDATION TREATMENT
RESIDUAL HEAT REMOVAL COMPLEX, UNIT 2
JUNE 1974

LOG OF BORINGS

APPENDIX 2C

THE DETROIT EDISON COMPANY
SPECIFICATION

FILL MATERIALS, PLACEMENT AND COMPACTION

Enrico Fermi Atomic Power Plant
6400 Dixie Highway
Stony Creek, Monroe County,
Michigan.

THE DETROIT EDISON COMPANY
SPECIFICATION

SPECIFICATION 3071-37
PREPARED BY
ENGINEERING DESIGN &
SERVICES DEPARTMENT

Issued: 11-27-70

FILL MATERIALS, PLACEMENT AND COMPACTION

Enrico Fermi Atomic Power Plant
6400 Dixie Highway
Stony Creek, Monroe County,
Michigan.

PART 1 : GENERAL

1-01 GENERAL CONDITIONS

a. All work under this contract shall be governed by "The General Conditions of the Contract", Edison Specification 3071, this specification and the applicable drawings and bills of material.

b. The Contractor, including his suppliers and sub-contractors, shall conform to Edison Specification 3071-8B, "Field Contractor Quality Assurance Requirements for Construction, Installation and Erection of Quality Levels 1 and 2 Structures and Equipment. Quality Levels 1 and 2 will apply to this work as defined on the drawings and bills of material.

c. The term, Engineer, used herein shall mean the Architectural-Civil Design Division of Edison's Engineering Design and Services Department or its authorized representative.

1-02 SCOPE

a. Furnish all labor, supervision, and equipment necessary to perform the filling, compaction, and grading as described herein and as shown on the drawings.

b. Fill materials shall be from sources designated and approved by the Engineer.

PART 2 : PRODUCT

2-01 GENERAL

a. All fill materials shall be maintained free of foreign matter such as vegetation, organic matter, rubbish, metal scrap, and ice.

2-02 QUARRY RUN ROCK FILL

a. Material shall be shattered rock obtained by blasting or ripping in rock cuts. Shattered rock shall be reasonably well graded with a maximum size not to exceed ½ cubic yard.

b. No specific moisture content at time of placing is required.

c. Shattered rock shall be deposited on the fill and pushed over the end of the fill by means of bulldozers or other equipment into approximately horizontal layers not exceeding 3 feet in thickness. The final surface of the Quarry Run Rock Fill shall be so choked with small rock fragments and fines that there will be no infiltration of any soil which may subsequently be placed on this surface. Where insufficient rock fines are available to properly choke the surface, sand or fine gravel and sand shall be used.

2-03 CRUSHER RUN ROCK FILL - 6 INCH AND UNDER

a. Material shall be that obtained by crushing Quarry Run Rock (see 2-02 a) and shall be graded as follows:

Sieve Size - U.S. Standard	Percent Passing.
6 inch	95
3 inch	30- 75

Loss by washing 0-10 percent.

2-03 CRUSHER RUN ROCK FILL - 6 INCH AND UNDER Cont'd

b. No specific moisture content at time of placing is required.

c. TYPE A: Material shall be spread in approximately horizontal layers not exceeding 15 inches in thickness and compacted by 2 passes of a vibratory type compactor.

TYPE B: Material shall be spread in approximately horizontal layers not exceeding 15 inches in thickness and compacted by one pass of the treads of a crawler type tractor weighing 40,000 pounds or more.

2-04 CRUSHER RUN ROCK FILL - 1½ INCH AND UNDER

a. Material shall be that obtained by crushing Quarry Run Rock (see 2-02 a) and shall be graded as follows:

Sieve Size - U.S. Standard	Percent Passing.
2 inch	100
1½ inch	95-100
½ inch	25-50
No. 10	6-18
No. 200	3-10

b. The moisture content at time of placing shall be not greater than 12 percent.

c. TYPE A: Material shall be spread in approximately horizontal layers not exceeding 12 inches in thickness and compacted by a minimum of six passes of a vibratory type compactor to not less than 95 percent of the maximum unit weight.

TYPE B: Material shall be spread in approximately horizontal layers not exceeding 12 inches in thickness and compacted by one pass of the treads of a crawler type tractor weighing 40,000 pounds or more.

2-05 SELECT GRANULAR FILL

a. Material shall be graded as follows:

Sieve Size - U.S. Standard.	Percent Passing.
2½ inch	100
1 inch	60-100
No. 100	0-30

Loss by washing 0-7 percent.

b. The moisture content at time of placing shall not vary more than ± 2% of optimum.

c. Material shall be spread in approximately horizontal layers not exceeding 15 inches in thickness and compacted to not less than 95 percent of the maximum unit weight.

2-06 MISCELLANEOUS GRANULAR FILL

a. Material shall be graded as follows:

Sieve Size - U.S. Standard	Percent Passing.
3 inch	100

Loss by washing 0-15 percent.

b. The moisture content at time of placing shall not vary more than ± 1% of optimum.

c. Material shall be spread in approximately horizontal layers not exceeding 15 inches in thickness and compacted to not less than 95 percent of the maximum unit weight.

2-07 QUARRY SCREENINGS FILL

a. Material shall be screenings obtained from the crusher operation at the France Stone Quarry, Monroe, Michigan and shall be graded as follows:

Sieve Size - U.S. Standard	Percent Passing.
No. 4.	90-100
No. 10.	50-65
No. 40.	25-40
No. 200	20 maximum.

2-07 QUARRY SCREENINGS FILL Cont'd

b. The moisture content at time of placing shall not vary more than ± 2% of optimum.

c. TYPE A: Material shall be spread in approximately horizontal layers not exceeding 9 inches in thickness and compacted to not less than 100 percent of the maximum unit weight.

TYPE B: Material shall be spread in approximately horizontal layers not exceeding 9 inches in thickness and compacted to not less than 95 percent of the maximum unit weight.

2-08 SELECT CLAY FILL

a. Material shall be the sandy silty clay (till) obtained from site excavation below approximate elevation 565.

b. The moisture content at time of placing shall be no greater than optimum nor less than 2% below optimum.

c. TYPE A: Material shall be spread in approximately horizontal layers not exceeding 9 inches in thickness and compacted to not less than 100 percent of the maximum unit weight.

TYPE B: Material shall be spread in approximately horizontal layers not exceeding 9 inches in thickness and compacted to not less than 95 percent of the maximum unit weight.

2-09 MISCELLANEOUS CLAY FILL

a. Material shall be clay from on or off-site sources not meeting Select Clay Fill description.

b. The moisture content at time of placing shall not vary more than ± 2% of optimum.

c. Material shall be spread in approximately horizontal layers not exceeding 9 inches in thickness and compacted to not less than 95 percent of the maximum unit weight.

PART 3 : EXECUTION

3-01 FOUNDATION REQUIREMENTS

a. The foundation material on which the fill is to be placed shall be as specified on the drawings and its suitability shall be approved by the Engineer prior to placing fill.

b. The surface of the sandy silty clay till (below approximate elevation 565 in the main building area) on which fill is to be placed shall be graded as required to provide for drainage and eliminate ponding.

3-02 LAYER THICKNESS

a. Thickness of layers in excess of that specified will be permitted only after satisfactory demonstration by the Contractor that the required density can be obtained. Whenever the required density is not obtained after such permission is granted, the thickness of the layers shall be reduced upon instructions of the Engineer.

b. The thickness of the first layer of materials other than clay to be constructed on poorly drained soil may be increased to a maximum of 24 inches upon approval by the Engineer.

3-03 COMPACTION

a. One pass of the treads of a crawler type tractor is defined as the required number of successive tractor trips which, by means of sufficient overlap, will insure complete coverage of an entire layer by the tractor treads.

b. One pass of a vibratory compactor is defined as the required number of successive tractor trips which, by means of sufficient overlap, will insure complete coverage of an entire layer by the compacting device.

c. A vibratory compactor is defined as one of the following:

Plate type vibratory compactor, tractor mounted, as manufactured by International Vibrator or Jackson Vibrators, Inc.

Drum type vibratory compactor, tractor drawn, such as Hyster C200B, Vibro-Plus CH33, or equal as approved by the Engineer.

3-03 COMPACTION Cont'd

d. In areas inaccessable to large equipment, obtain required compaction with mechanical vibrators for granular fill, and with mechanical rammers for cohesive fill.

3-04 COLD WEATHER RESTRICTIONS

a. Frozen material shall not be placed in the fill. All ice and snow shall be removed from the surface of the foundation material before fill is placed thereon. In addition where the fill is to support a structure, all ground containing frost within limits of 1 on 1 slopes spreading outward in all directions from the bottom of structure footings shall be removed. In other areas ground containing more than 4 inches of frost shall be removed. Ground containing less than 4 inches of frost and not used for fill which will support structure footings need not be removed.

b. The placing of materials described in sections 2-07, 2-08 and 2-09 shall be limited to the period between May 1 and November 1 unless otherwise approved by the Engineer.

3-05 DRAINAGE

a. The surface of the fill shall be maintained with sufficient slope to provide for runoff of surface water from every point.

b. The working surface of fill described in Sections 2-07, 2-08 and 2-09 shall regularly be sealed with a smooth-wheel static roller at the close of each working day and shall be sealed during the day when practicable prior to rainfall.

c. Filling shall be conducted so that no obstruction to drainage from other sections of the fill area is created at any time. Sumps, if any, will be continuously maintained in effective operating condition.

d. The Contractor shall protect compacted fill and foundation material in excavated areas from becoming rutted or distorted. All rutting or distortion caused by the Contractor's operation shall be corrected by the Contractor at his expense before any succeeding layers are placed.

3-06 FILL AGAINST STRUCTURES

a. Fill shall not be placed against any portion of a structure until the required surface finishing and waterproofing of such portions have been completed. Waterproofing materials shall be protected as required to prevent damage which might occur from fill operations.

b. Fill which will cause a horizontal loading on an unshored portion of a structure shall not be placed until the concrete has attained at least 70 percent of its design strength.

c. Fill around isolated structures such as piers shall be placed on opposite sides at the same time to equalize horizontal loadings.

3-07 MAXIMUM UNIT WEIGHT

a. Maximum unit weight when used as a measure of compaction or density of cohesive soils having a loss by washing greater than 10 percent, shall be understood to mean the maximum weight per cubic foot as determined using the One-Point T-99 Test or the AASHO T-99 Test as described in the MDSH Density Control Handbook, August, 1969.

b. The One-Point Michigan Cone Test or the Michigan Cone Test as described in the MDSH Density Control Handbook, August, 1969, modified as follows, will be used for determining the maximum unit weight for granular materials having a loss by washing of 10 percent or less:

For granular soils having a unit weight of 120 pounds per cubic foot or less, the unit weight will be determined at any moisture content between 6 percent and a point short of saturation.

For granular soils having a unit weight over 120 pounds per cubic foot, the unit weight will be determined at the moisture content, between 6 percent and a point short of saturation, which will give the maximum weight.

c. In-place density of materials shall be obtained using a volumeter which measures the volume of a hole by means of a rubber balloon and water under air pressure.

PART 4 : SPECIFICATIONS AND STANDARDS

4-01 EDISON SPECIFICATIONS

a. 3071, The General Conditions of the Contract.

b. 3071-8B, Field Contractor Quality Assurance Requirements for Construction, Installation and Erection of Quality Levels 1 and 2 Structures and Equipment.

4-02 MICHIGAN DEPARTMENT OF STATE HIGHWAYS

a. MDSH Density Control Handbook, August, 1969.

APPENDIX 2D

Records of Laboratory Test Results on Rock Core Samples

ST. LOUIS SAN FRANCISCO LONDON, ENG. LOS ANGELES PITTSBURGH

ROBERT W. HUNT COMPANY ENGINEERS
CHICAGO 7, ILLINOIS

December 27, 1968

File No. 1187-2
Order B-13686

Report 3584
Page 1

Tests On Stone Cores

Job: No. 7605-002-16

Dames and Moore
309 West Jackson Boulevard
Chicago, Illinois 60606

Attention: Mr. D. G. Staggs

Gentlemen:

We report test results on four (4) stone cores obtained by our representative at your office on December 17, 1968 marked as shown in the following tabulations:

The sample cores were prepared for test by us.

Test core size: Diameter 2.00 inches Length 4.00 inches

Sample Core Designation			Compressive Strength		Modulus of Elasticity At 50% of Maximum Load, Lbs. Per Square Inch	Weight Per Cubic Foot Lbs.
Boring Number	Depth Feet	Classification	Maximum Load Lbs.	Per Square Inch Lbs.		
20	27	Dolomite	49,200	15,661	13,346,000	154.02
32A	52	Oolite	30,400	9,677	4,359,000	145.29
28	106	Argillaceous Dolomite	28,400	9,040	2,601,000	162.12
4	58	Dolomite	24,500	7,799	- - -	137.80

Specific Gravity:

Sample Core Designation				
Boring No.	20	32A	28	4
Depth, Ft.	27	52	106	58
Classification	Dolomite	Oolite	Argillaceous Dolomite	Dolomite
Specific Gravity:-	2.47	2.33	2.60	2.21

Respectfully submitted,
ROBERT W. HUNT COMPANY

G. E. Matoush
G.E. Matoush, Manager
Cement and Concrete Department

GEM:rek-4

ROBERT W. HUNT COMPANY, ENGINEERS
Chicago 7, Illinois

March 31, 1972

File No. 1187-2 Report 853
Order 13-C-6283 Page 1

Unconfined Compression Tests

Purchase Order No. PA 205

Job Number: 7605-020

Dames and Moore
1550 Northwest Highway
Park Ridg, Illinois 60068

Gentlemen:

We report results on unconfined compression test performed on Rock Core samples picked up by our representative on March 28, 1972 at your office.

Boring Identification		Compressive Strength Lbs. Per Square Inch
RHR-8	36.3'-37.0'	7536
RHR-3	29.2'-29.8'	8188
RHR-5	40.5'-41.6'	8333
RHR-7	33.9'-34.6'	7388
RHR-6	29.2'-29.8'	10,362
RHR-4	30.9'-31.5'	9928
RHR-2	39.1'-39.6'	9130

Respectfully submitted,
ROBERT W. HUNT COMPANY

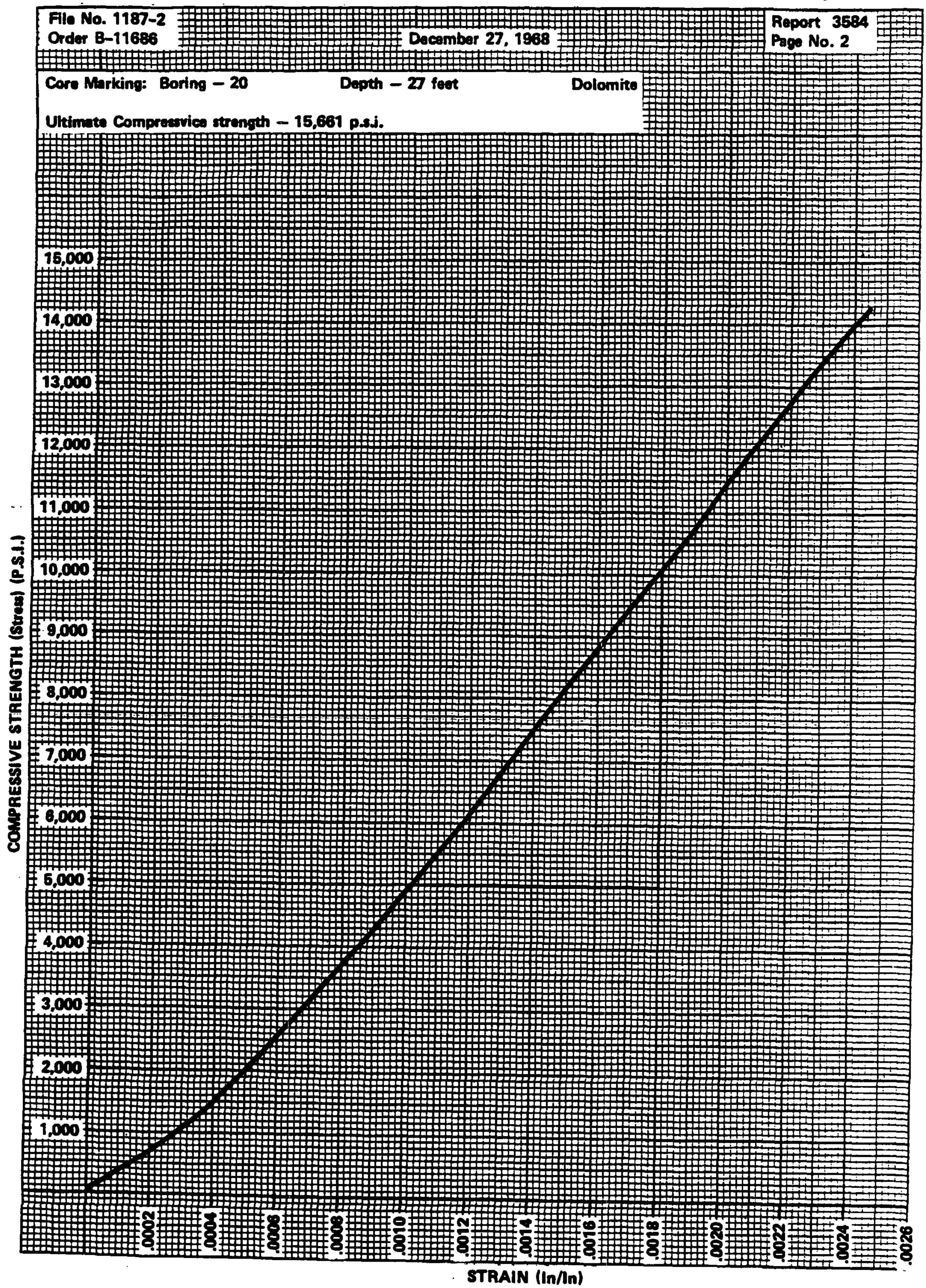
G.E. Matoush, Manager
Cement and Concrete Department

GEM:rek- 4

(exact copy - not original)

ROBERT W. HUNT COMPANY, Engineers

DAMES AND MOORE Job: 7605-002-16



ROBERT W. HUNT COMPANY, Engineers DAMES AND MOORE JOB: 7605-002-16

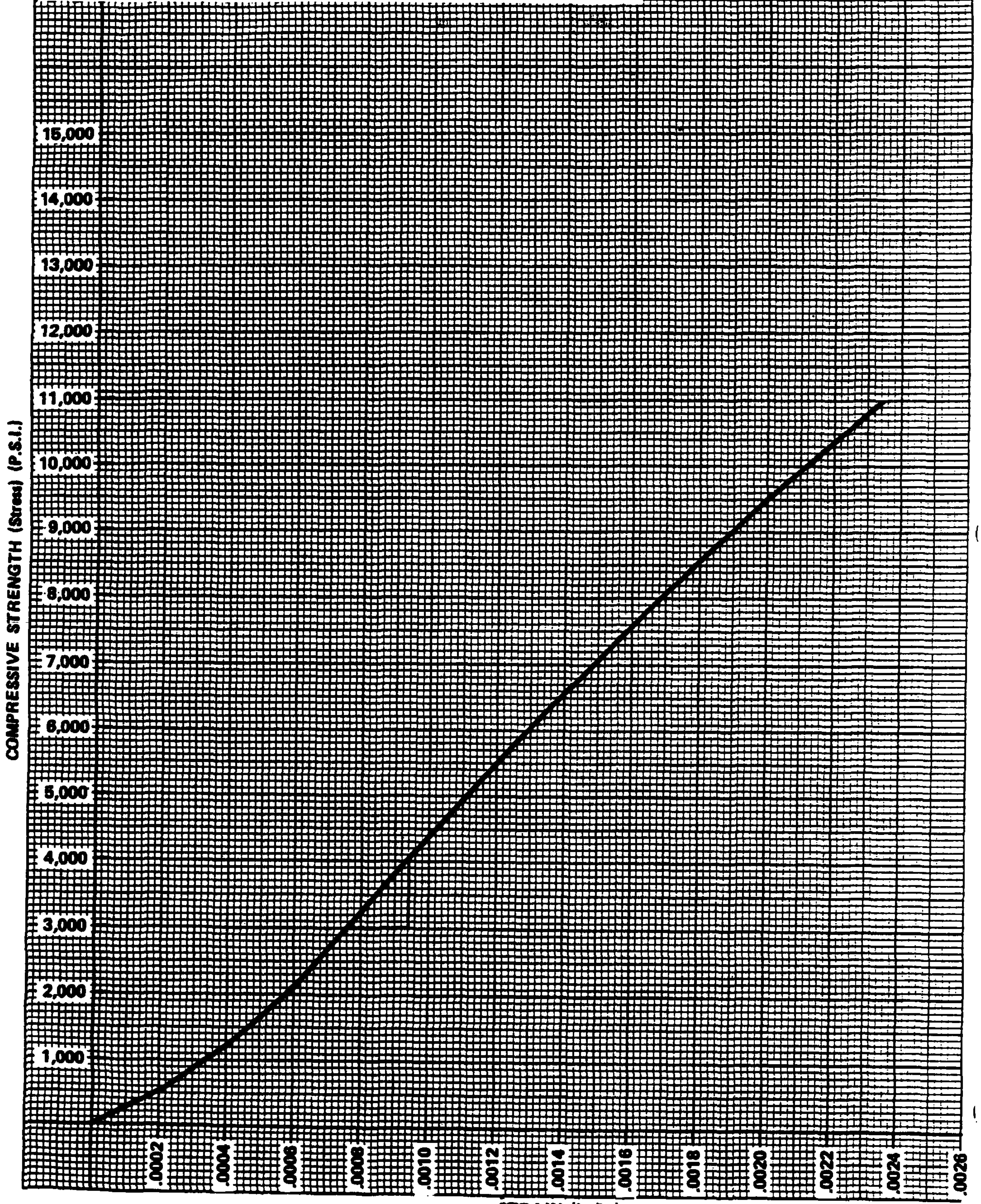
File No. 1187-2
Order No. B-13686

December 27, 1968

Report 3684
Page No. 3

Core Marked: Boring – 32A Depth – 52 feet Oolite

Ultimate Compressive-Strength-9,677 p.s.i.



ROBERT W. HUNT COMPANY, Engineers

DAMES AND MOORE Job: 7605-002-16

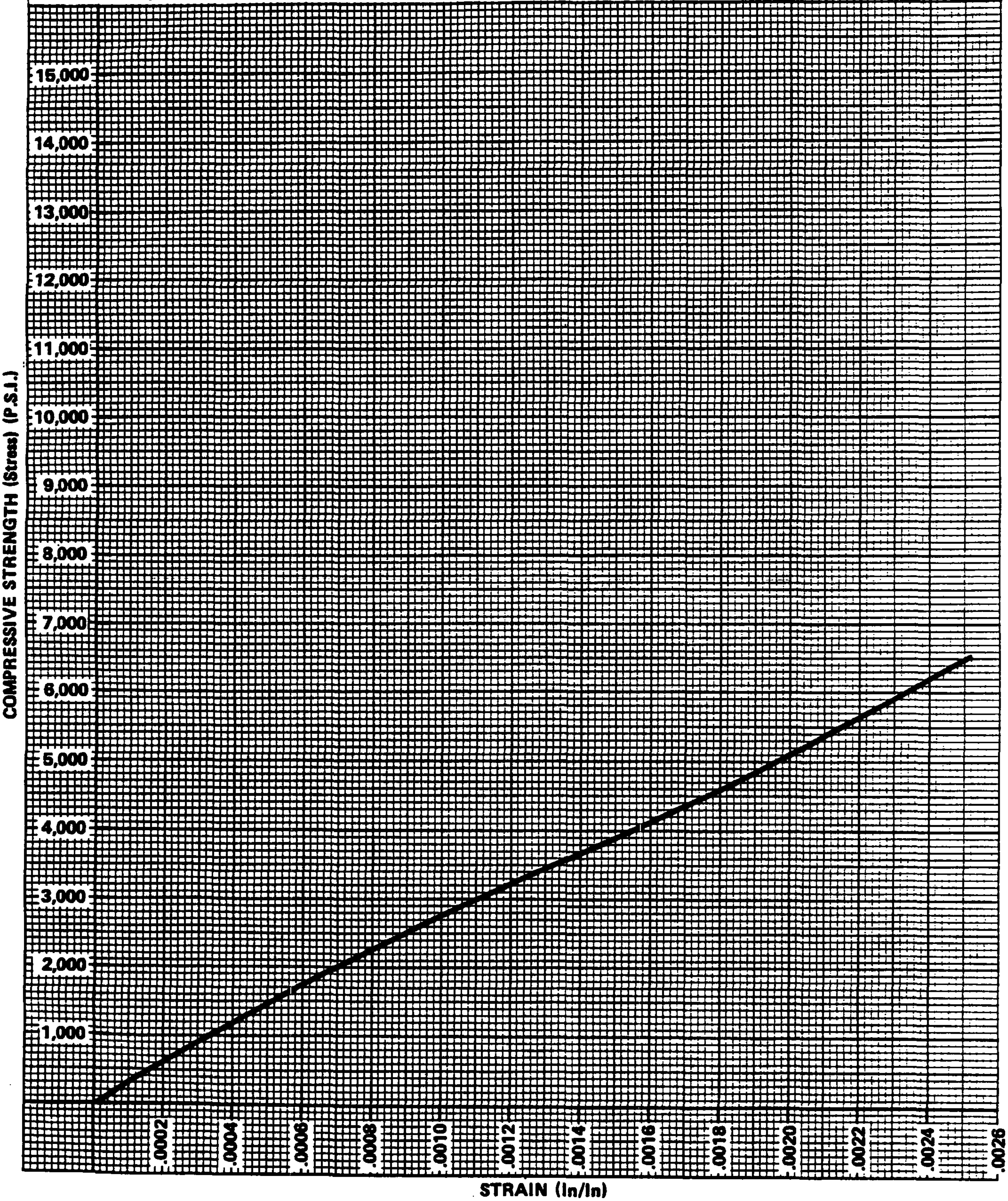
File No. 1187-2
Order No. B-13686

December 27, 1968

Report 3584
Page No. 4

Core Marked: Boring – 28 Depth – 106 feet Argillaceous Dolomite

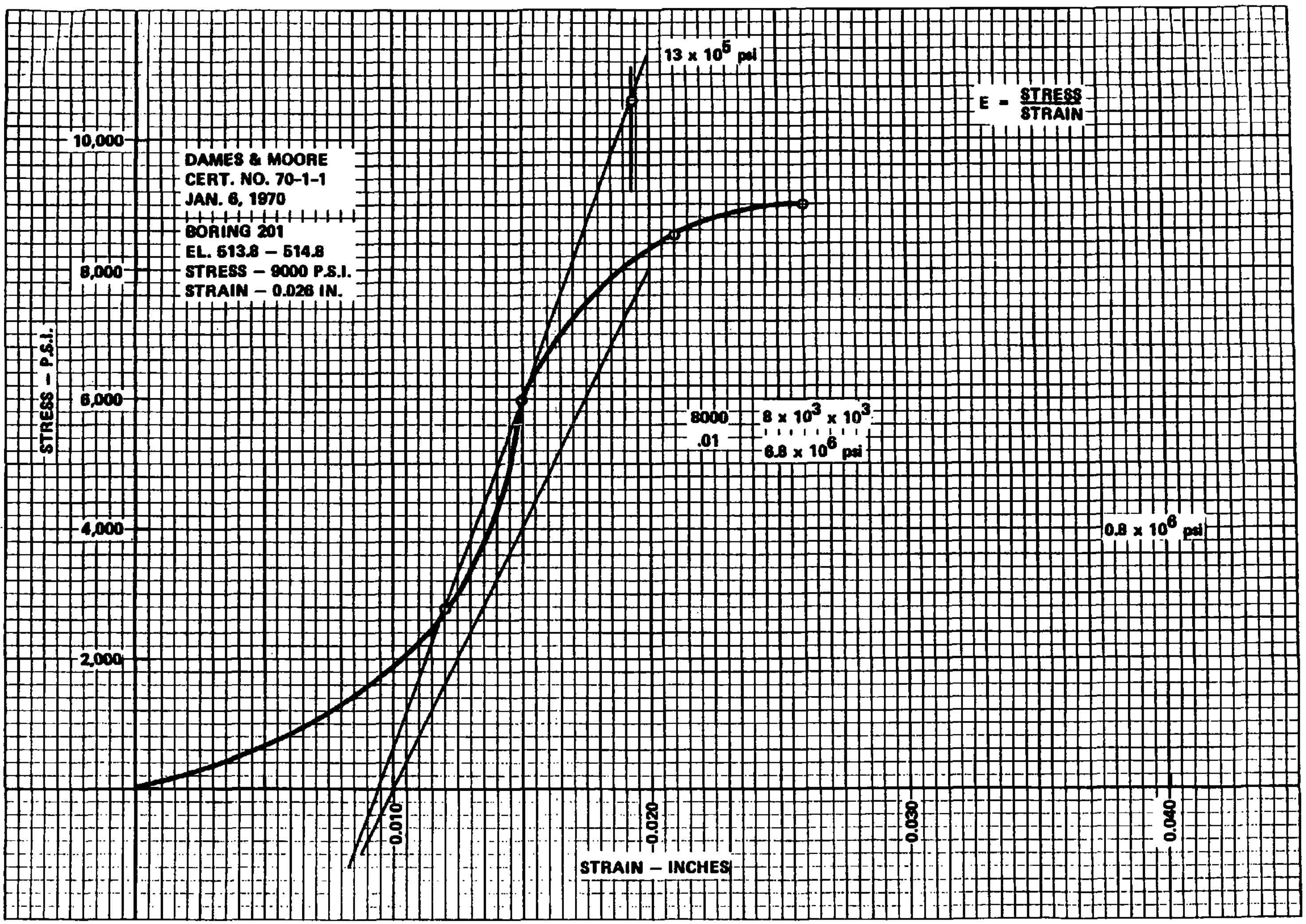
Ultimate-Compressive-Strength – 9,040 P.S.I.

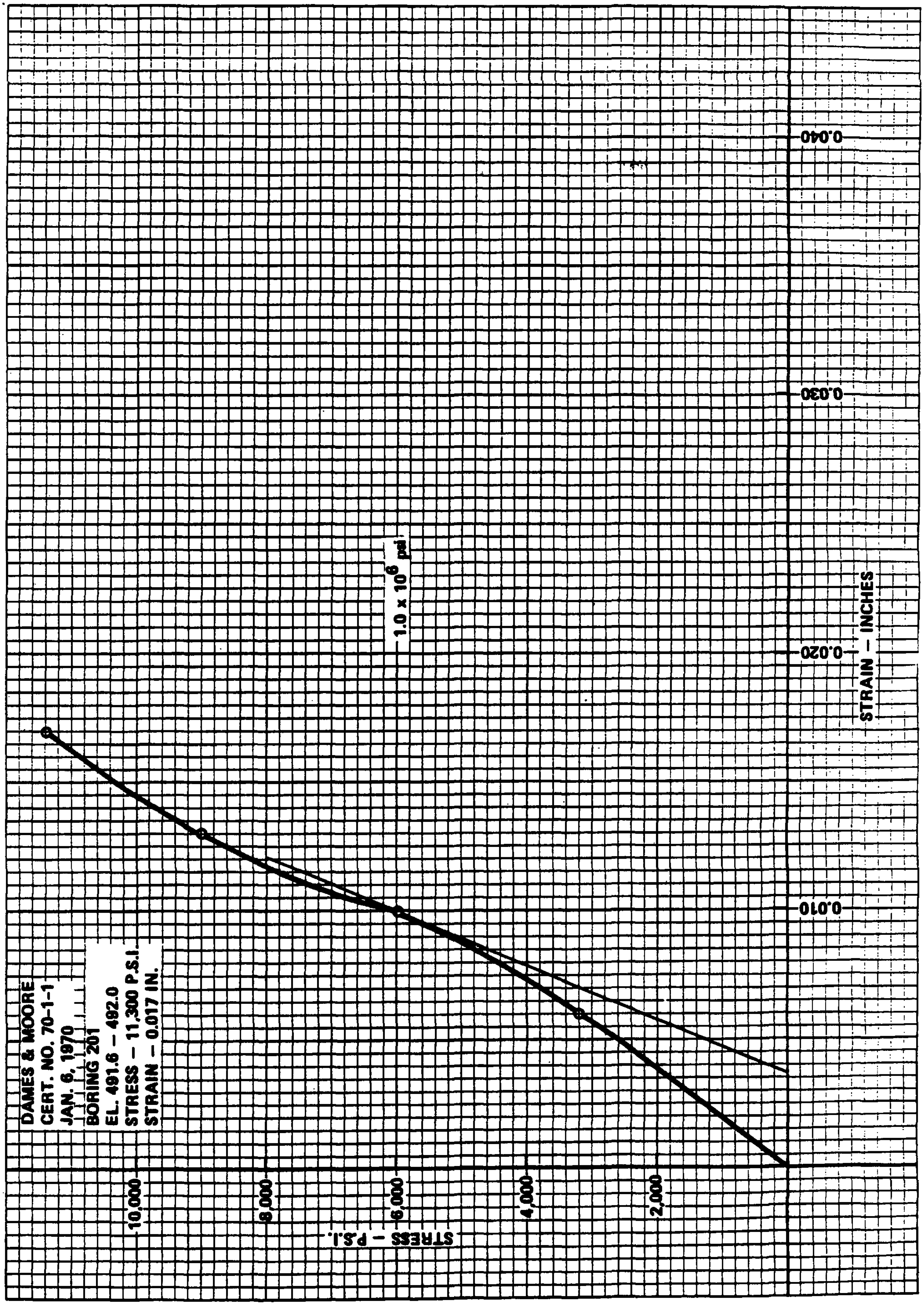


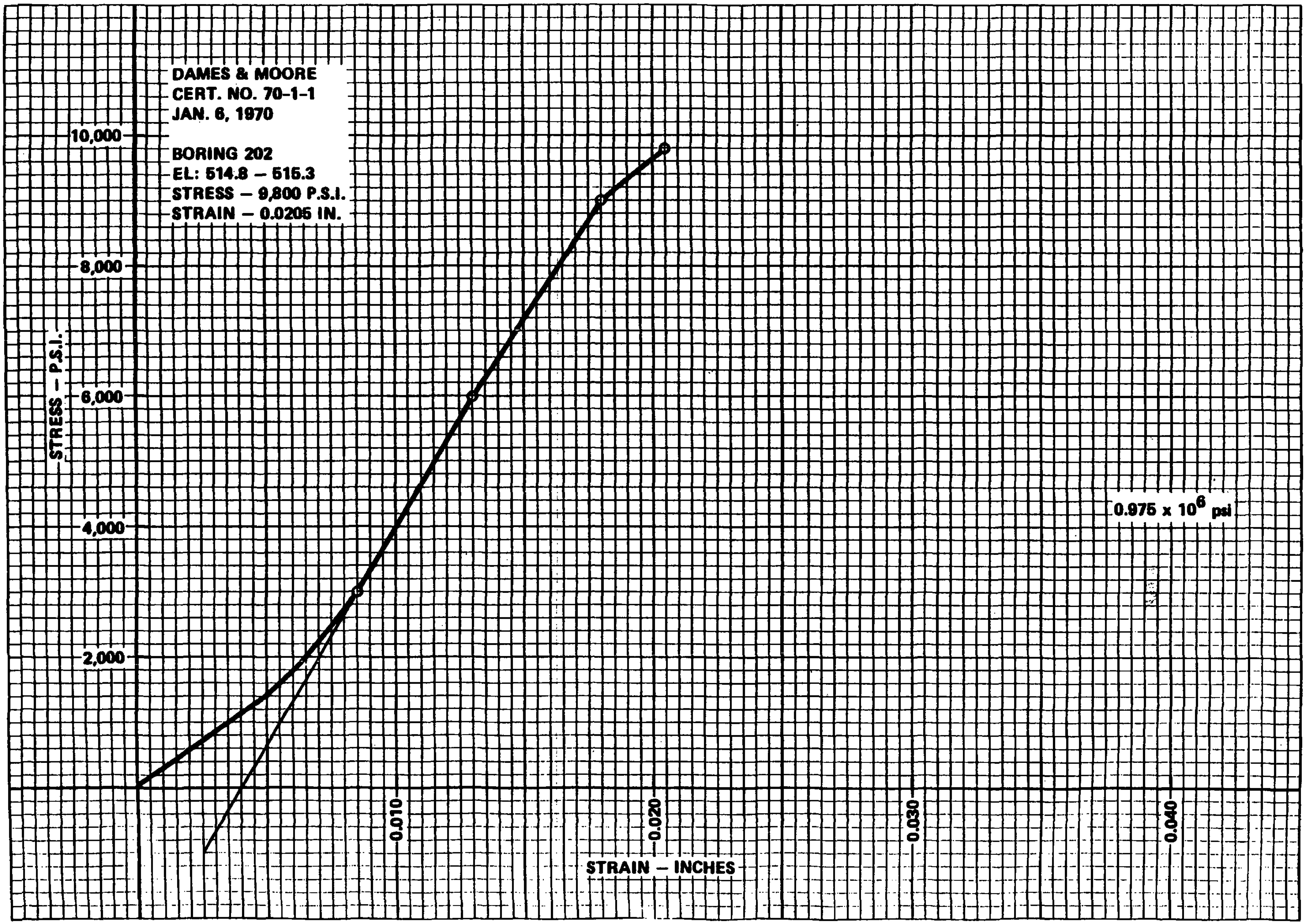
Dames & Moore
1414 Dexter Ave. No.
Seattle, 98109

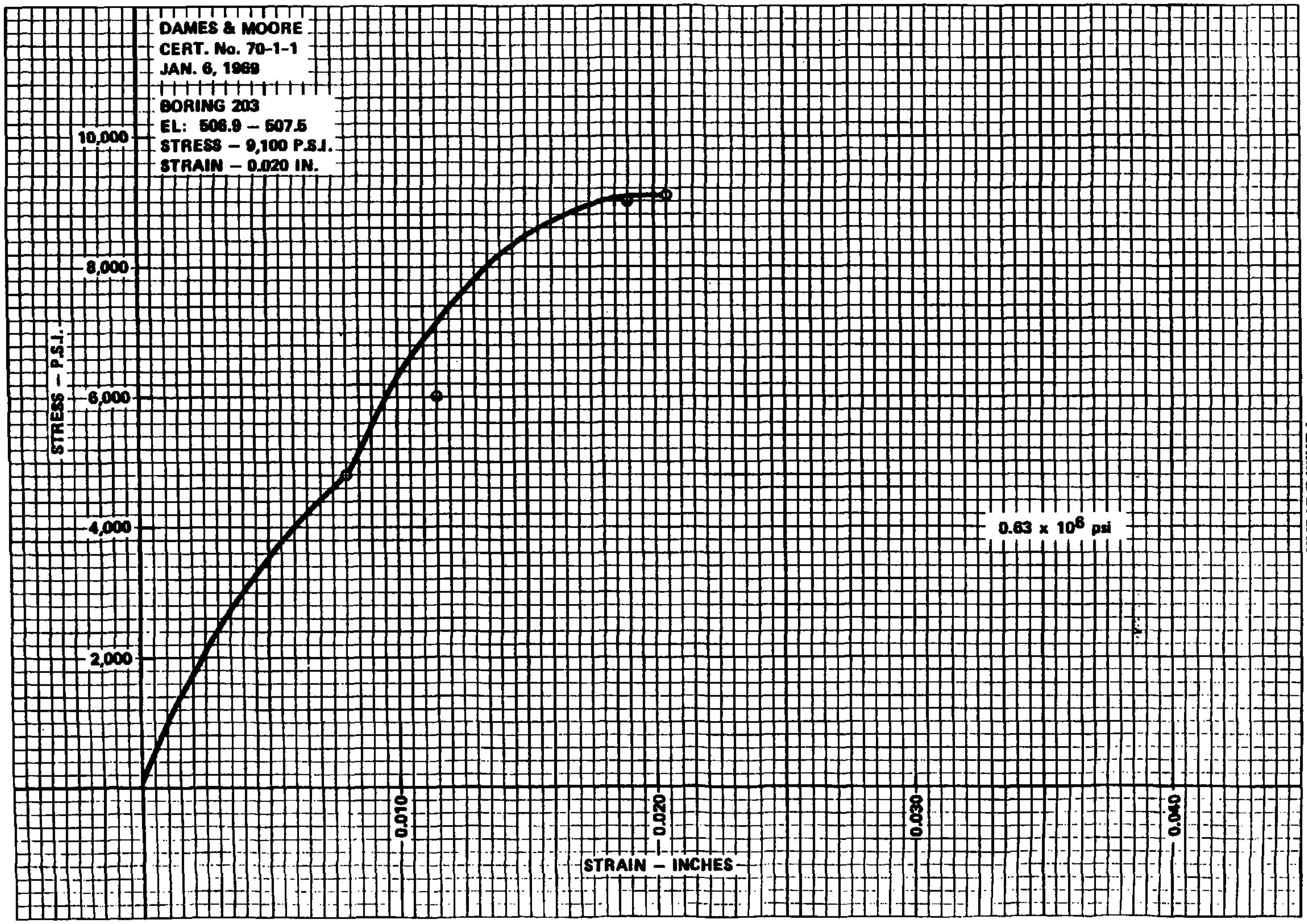
CERT. NO. 701-1
January 6, 1970

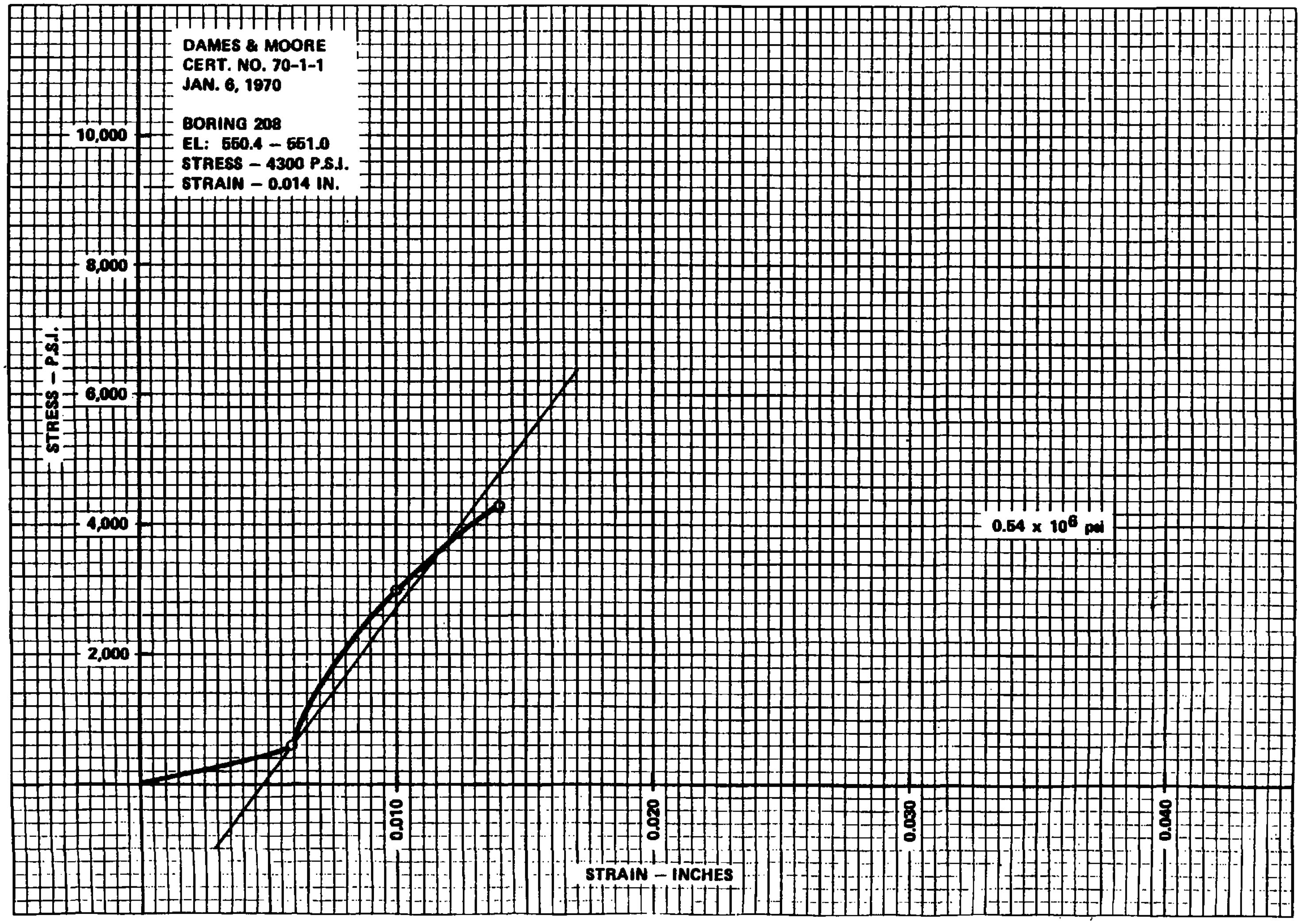
Boring No.	Sample Elev.	Diameter	Height	Area Sq./In.	Weight	Unit Wt. Lb. ft.^{3}	Gross Load	P.S.I.	PSF
201	514.8/ -513.9	2.050	4.269	3.301	1.231	151.0	29,700	9,000	1.29×10^6
201	492.0/ -491.6	2.050	4.324	3.301	1.400	169.5	37,400	11,300	1.62×10^6
202	515.3/ -514.8	2.040	4.282	3.269	1.185	146.3	32,000	9,800	1.41×10^6
203	507.5/ -506.9	2.051	4.265	3.304	1.257	154.2	30,000	9,100	1.31×10^6
211	532.9/ -531.8	2.050	4.315	3.301	1.205	146.2	19,400	5,900	0.85×10^6
213	543.8/ -543.1	2.050	4.312	3.301	1.230	149.3	18,700	5,700	0.82×10^6
208	551.0/ -550.4	2.050	4.343	3.301	1.203	145.0	14,200	4,300	0.62×10^6
210	546.5/ -545.5	1.862	4.256	2.723	1.028	153.3	22,700	6,900	0.99×10^6
211	549.2/ -548.7	2.050	4.272	3.301	1.392	170.6	62,200	18,800	2.70×10^6

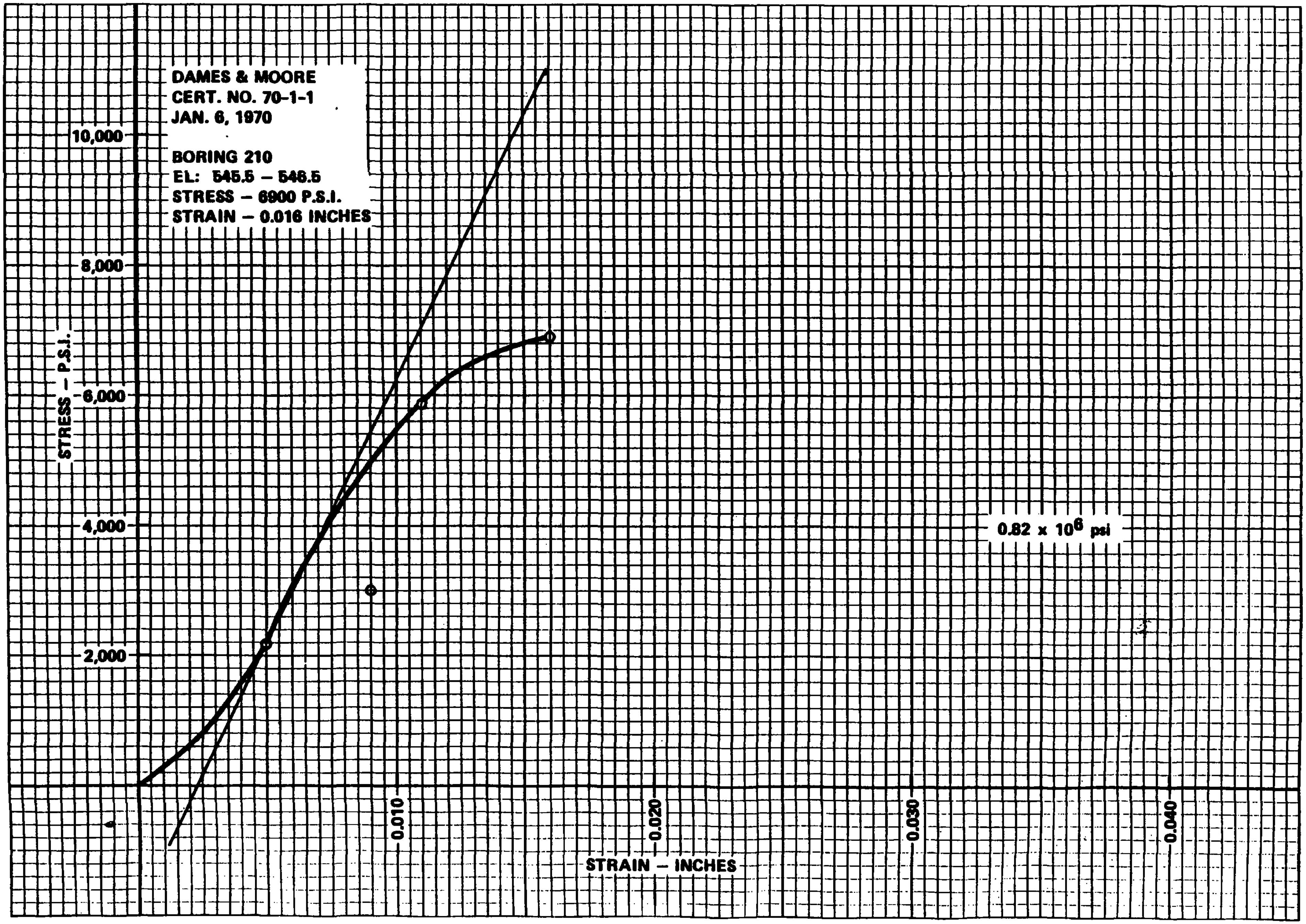

13 x 10^5 psi
E = STRESS / STRAIN
10,000
DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 201
EL. 513.8 – 514.8
STRESS – 9000 P.S.I.
STRAIN – 0.026 IN.
8,000
STRESS – P.S.I.
6,000
8000 / .01
8 x 10^3 x 10^3
6.8 x 10^6 psi
4,000
0.8 x 10^6 psi
2,000
0.010
0.020
0.030
0.040
STRAIN – INCHES

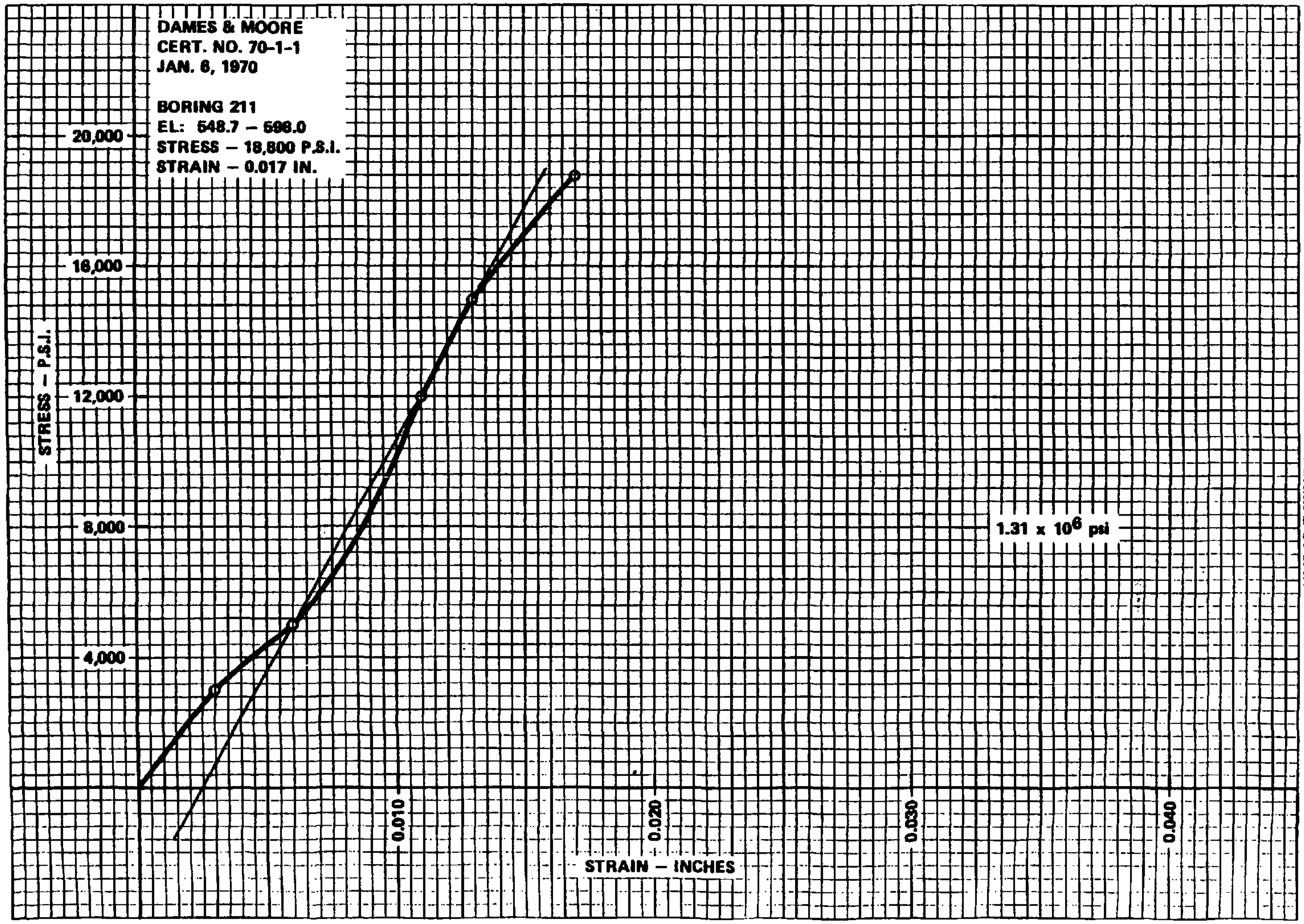

0.040
0.030
0.020
0.010
STRAIN – INCHES
1.0 x 10^6 psi
DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 201
EL. 491.6 – 492.0
STRESS – 11,300 P.S.I.
STRAIN – 0.017 IN.
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.

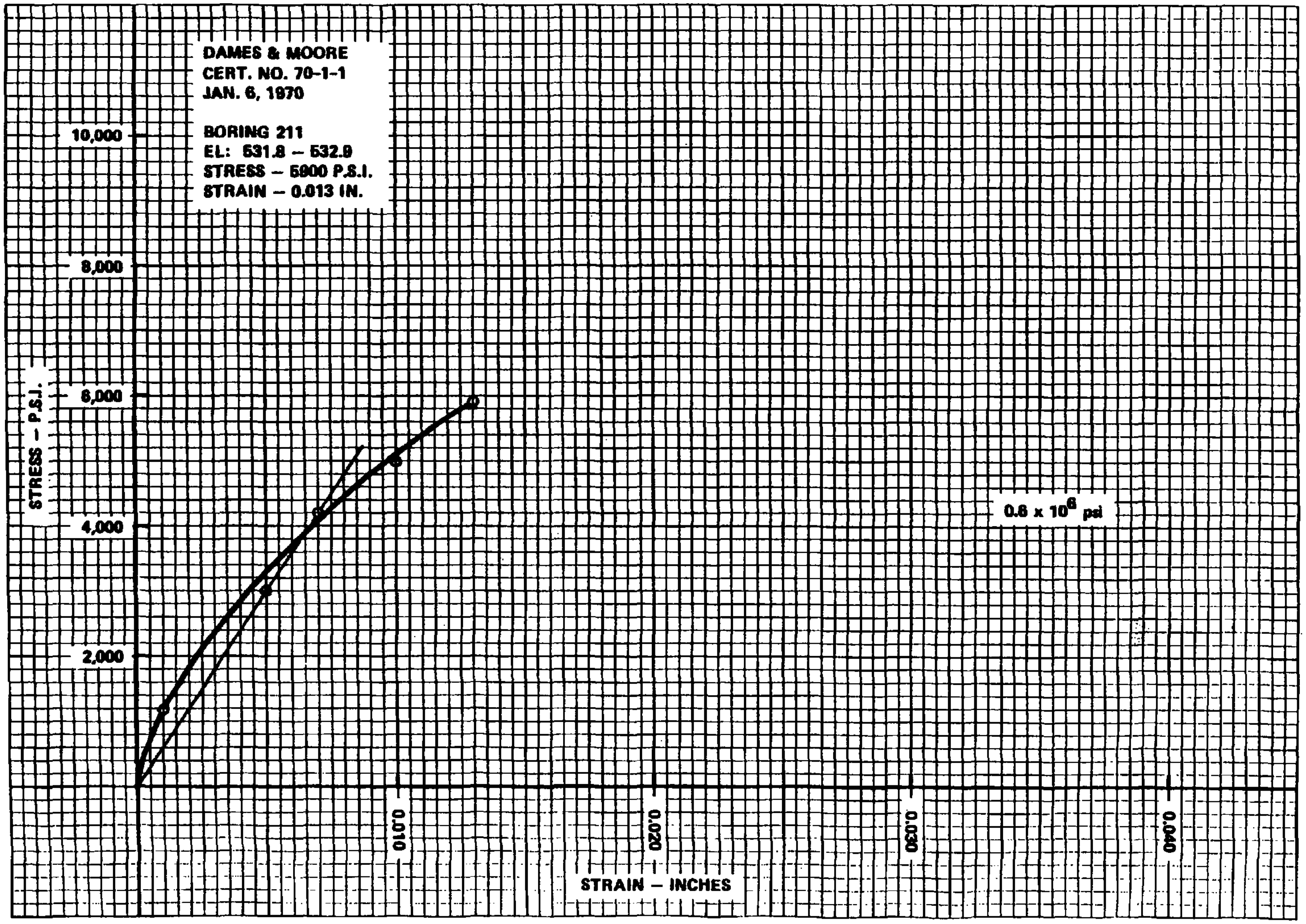

DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 202
EL: 514.8 – 515.3
STRESS – 9,800 P.S.I.
STRAIN – 0.0205 IN.
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.
0.010
0.020
0.030
0.040
STRAIN – INCHES
0.975 x 10^6 psi

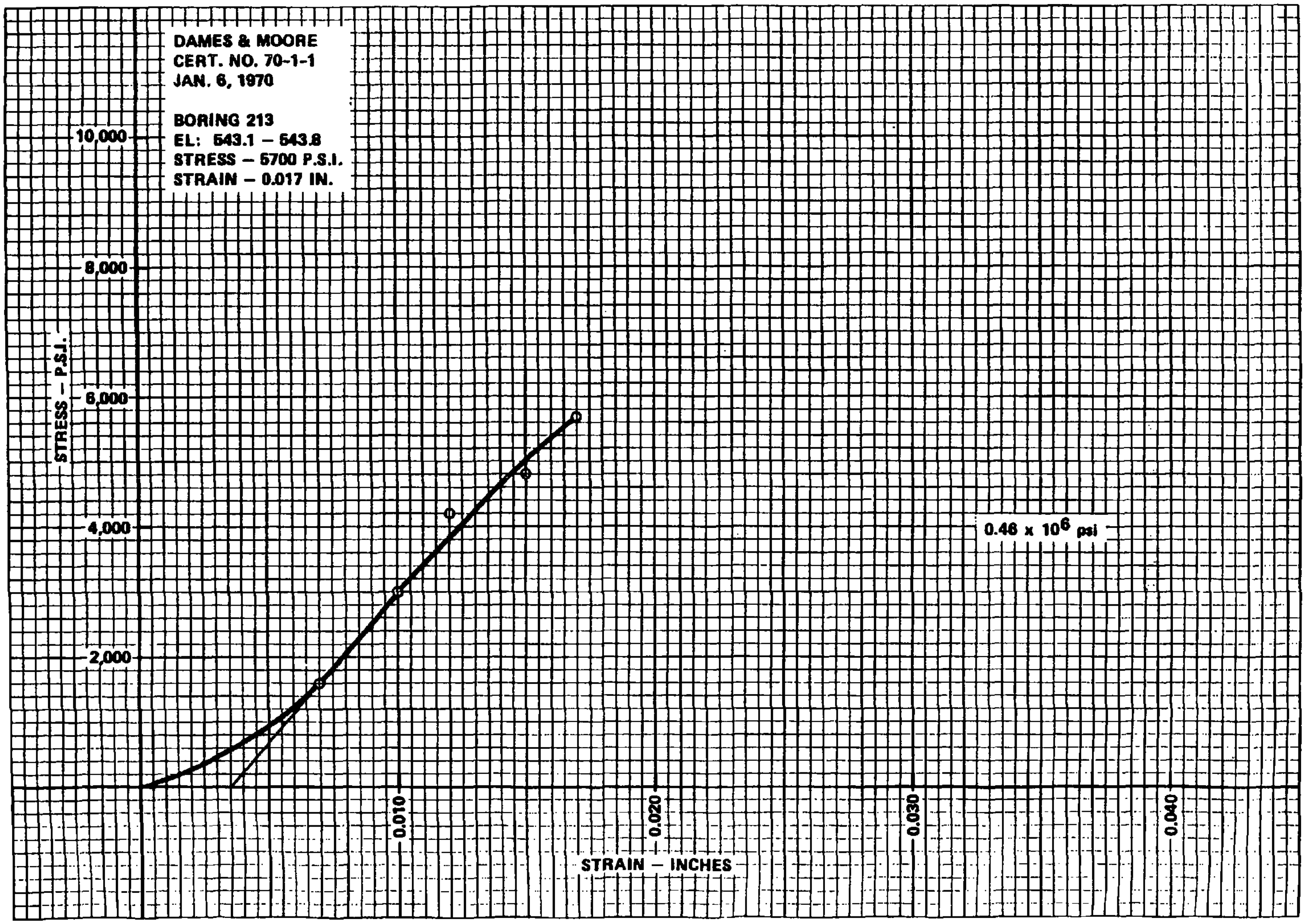

DAMES & MOORE
CERT. No. 70-1-1
JAN. 6, 1969
BORING 203
EL: 506.9 – 507.5
STRESS – 9,100 P.S.I.
STRAIN – 0.020 IN.
STRESS – P.S.I.
10,000
8,000
6,000
4,000
2,000
0.63 x 10^6 psi
0.010
0.020
0.030
0.040
STRAIN – INCHES


DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 208
EL: 550.4 – 551.0
STRESS – 4300 P.S.I.
STRAIN – 0.014 IN.
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.
0.010
0.020
0.030
0.040
STRAIN – INCHES
0.54 x 10^6 psi


DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 210
EL: 545.5 – 546.5
STRESS – 6900 P.S.I.
STRAIN – 0.016 INCHES
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.
0.82 x 10^6 psi
0.010
0.020
0.030
0.040
STRAIN – INCHES


DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 211
EL: 548.7 – 596.0
STRESS – 18,800 P.S.I.
STRAIN – 0.017 IN.
STRESS – P.S.I.
20,000
16,000
12,000
8,000
4,000
0.010
0.020
0.030
0.040
STRAIN – INCHES
1.31 x 10⁶ psi


DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 211
EL: 531.8 – 532.9
STRESS – 5900 P.S.I.
STRAIN – 0.013 IN.
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.
0.8 x 10^6 psi
0.010
0.020
0.030
0.040
STRAIN – INCHES


DAMES & MOORE
CERT. NO. 70-1-1
JAN. 6, 1970
BORING 213
EL: 543.1 – 543.8
STRESS – 5700 P.S.I.
STRAIN – 0.017 IN.
10,000
8,000
6,000
4,000
2,000
STRESS – P.S.I.
0.010
0.020
0.030
0.040
STRAIN – INCHES
0.46 x 10^6 psi