This chapter provides information on the site and environs for the Palisades Plant. This information establishes a basis for evaluating the sufficiency of certain Plant systems for controlling the release, both routine and accidental, of liquids and gases to the environment.

Meteorology and hydrology of this site are extremely favorable. The Plant is designed so that there will be no uncontrolled releases of radioactive material during normal operations. Radioactive effluents, both gaseous and liquid, will be controlled to assure that discharge activities are minimal and within allowable limits. Holdup and treatment facilities for both types of effluents are provided so that any unusual amounts of these materials can be effectively processed.

The Plant is located on the eastern shore of Lake Michigan and is approximately four-and-one-half miles south of the southern city limits of South Haven, Michigan, which has a permanent population of 5,563 based on the 1990 census (Reference 1). In 1960, 1970 and 1980 the population was at 6,149, 6,471 and 5,939 respectively. There are approximately 469 acres within the site boundary, all owned by Entergy Nuclear Palisades, LLC.

The site boundary is also the exclusion area over which Entergy has control for the purpose of excluding personnel or property. The minimum exclusion area distance to an uncontrolled area is 677 meters. In March 2002, Consumers Energy Company sold its wholly owned subsidiary, the Michigan Electric Transmission Company, Inc. to an independent owner. The new company, Michigan Electric Transmission Company, LLC (METCO), assumed ownership of the transmission system to which Palisades is connected, including the lines passing over the Palisades site and certain equipment in the Palisades Substation. Entergy has ownership of all land within the site exclusion area and has granted easements to METCO for access to their transmission equipment. Entergy has the authority to exercise complete control over the Palisades Substation and associated easements located within the Exclusion Area, and to determine all activities within that area, including evacuation and exclusion of METCO personnel, contractors, visitors, guests, and other persons.

The low population zone (LPZ), as defined by 10 CFR 100, extends a distance of 4,820 meters, or 3 miles, from the Plant site. The minimum exclusion area and LPZ distances form the bases for the site evaluation in accordance with 10 CFR 100. The site area consists of rolling sand dunes which extend inland about 5,000 feet. The area adjacent to the site is primarily agricultural land and is sparsely populated.

The major structures of the Plant are built upon a dense sand stratum. The site is in a Zone I (zone of minor damage) seismological region as defined by the Uniform Building Code.

2.1 LOCATION

The Palisades site is located in Covert Township on the western side of Van Buren County, Michigan (parts of Sections 4 and 5, T2S, R17W). Figure 2-1 shows the site location and population centers of over 10,000 within a 50-mile radius of the site. The nearest population center is the Benton Harbor/St Joseph area which is greater than 15 miles away. This is more than five times the LPZ distance.

Figure 2-2 shows the site boundary and layout of the site. There is a fence around the immediate Plant area with a locked gate under the control of Plant personnel. The site boundary is posted. There are no residences within this boundary.

2.1.1 TOPOGRAPHY AND LAND USAGE

In the area near the site, sand dunes rise from the beach level which is approximately 582 feet above mean sea level (MSL) to a maximum elevation of 780 feet MSL and then drop off abruptly to 610 feet MSL approximately 5,000 feet east of the lakeshore. Figure 2-3 shows the topography near the Plant. Several topographical cross sections corresponding to the cardinal compass points are shown on Figure 2-4.

The land inland from the lake is slightly rolling. The dunes are wooded, while east from the dunes the land is partly wooded with many open fields, berry farms and orchards. The land within 50 miles of the site is used primarily for farming, with the exception of the City of Kalamazoo, Michigan, and the Cities of Elkhart, Mishawaka and South Bend, Indiana, which are heavily industrialized. During the summer, there is an influx of tourists, primarily along the lakeshore.

The information found in Table 2-1 is based on Michigan Agricultural Statistics published by the Michigan Department of Agriculture for the years 1966 and 1980. This table provides a comparison of overall state farm production with farm production for the seven-county zone in which the Palisades Plant site is located (Van Buren, Berrien, Cass, Kalamazoo, Allegan, Ottawa and Kent Counties).

The percentage of state production listed above as the 1966 value is typical of the 1964 through 1966 values with only 1% to 1-1/2% variation per year.

Several select land usages have been identified for the 0- to 10-mile radial sectors and are shown on Figure 2-5. Table 2-2 identifies these land use facilities by a "Map Code" and the map codes identify the locations shown on Figure 2-5 (Reference 2).

2.1.2 POPULATION

Figure 2-1 shows population centers of over 10,000 residents within a 50-mile radius of the Plant (Reference 30). Figure 2-6 shows population centers of over 1,000 residents within a 50-mile radius. Values shown on the figure represent the population within incorporated city or village limits. South Bend, Indiana, with a population of 105,709 based on the 1990 census, is the largest population center within the 50-mile radius and is approximately 45 miles directly south of the site.

Figure 2-7 shows the permanent residential population distribution within 0 to 10 miles of the Plant. The population figures within 5 miles were obtained by (1) counting the number of residences within each sector (Reference 2); (2) calculating the people per dwelling based on 1990 census data; and (3) multiplying the number of residences by the people per dwelling. Table 2-3 shows the people-per-dwelling computations on a township and city basis. Table 2-4 shows the permanent resident population distribution by sectors, based on 1990 data.

Tables 2-5 through 2-8 show the distribution of various transient population groups which includes motels, campsites, educational facilities and major employers (Reference 2). Table 2-9 shows the maximum probable population that may be present by combining the values from Tables 2-4, 2-5, 2-7 and 2-8.

Van Buren State Park is located immediately north-northeast of the site and has a maximum population of 2840 persons including campers and day visitors.

Covert Park is located at a distance of approximately 1-1/2 miles south-southwest. The estimated maximum summer population is 540 persons consisting of 200 walk-ins and 340 campers.

The 1990 census data show a reduced rate of growth and, when compared to the Stanford projections, indicate the end-of-plant-life population may be considerably less than originally estimated. Growth in the 9 southwestern Michigan counties was 16.3% between 1960 and 1970, 10.7% between 1970 and 1980, 9.0% between 1980 and 1990, and estimated to increase from 1990 to 2000 by 8.0%.

Growth in the 3 northern Indiana counties was estimated to be 30% between 1970 and 1980; however, the census data indicated only a 2.2% increase in population over the 10-year period. For these counties, the growth was 4.7% between 1980 and 1990 and is estimated to be 7.6% between 1990 and 2000.

Population distribution near the Plant (0- to 10-mile radius) requires consideration of several factors: (1) permanent residences, (2) summer cottages, (3) summer transients to area motels and campsites and (4) educational facilities.

Permanent resident population data were developed using a residence count from the Emergency Plan (Reference 2) and 1990 census statistics (Reference 1). These data are shown on Table 2-4 and Figure 2-7. Contributions to the population distribution from the remaining factors are described in Tables 2-5, 2-7 and 2-8. Table 2-9 summarizes the probable maximum population within 10 miles of the Plant from all categories, distributed by sector.

Figure 2-8 shows permanent population (1990 data) distribution from 10 to 50 miles from the Plant; this includes all cities and towns shown as population centers on Figure 2-6. This distribution was made by obtaining city, township and county populations and then distributing them in their proper sectors. To estimate the total population during the summer months for Figure 2-8, within a 10- to 50-mile radius of the Plant, a multiplying factor of 1.5 was used on the permanent figures. This factor is based on a comparison between sales tax returns on food for June, July and August 1965 and those for February, March and April 1965 for Van Buren, Allegan and Berrien Counties. These three counties are within 30 miles of the Plant and are adjacent to Lake Michigan.

Historical and present population data for nine Michigan counties and three Indiana counties are shown in Table 2-10. The three Indiana counties and some of the Michigan counties are only partially within a 50-mile radius of Palisades; therefore, the total population within this radius is less than the numbers shown.

Also shown in Table 2-10 are the projected populations and respective population densities through the year 2020. Current projections show one southwestern Michigan county (Kent) and one northwestern Indiana county (St. Joseph) as having a population density in excess of 500 persons per square mile. The nearest boundary of each county is approximately 40 miles from the Plant.

2.1.3 NEARBY INDUSTRIAL, TRANSPORTATION AND MILITARY FACILITIES

The Covert Generating Plant is located just East of Palisades on the East side of Interstate I-196. Other concentrations of industrial activity are located in the South Haven city area and consists primarily of light manufacturing facilities. Regional planning officials have stated that to their knowledge no major industrial developments are planned for the vicinity of the nuclear Plant.

The nearest transportation routes to the Plant are County Highway A2 and Interstate I-196 which pass about 3,600 feet and 4,200 feet, respectively, from the Plant at their closest point of approach. The highway separation distances at Palisades exceed the minimum distance criteria given in the Regulatory Guide 1.91, Revision 1, and, therefore, provide reasonable assurance that transportation accidents resulting in explosions of truck-size shipments of hazardous materials will not have an adverse effect on the safe operation of the Plant. The effect of hazardous chemical spills on Plant operations is discussed in Section 6.10, Control Room Habitability.

The nearest railroad is the Chesapeake and Ohio line about 9 miles to the east. At this distance, potential railroad accidents involving hazardous materials are not considered to be a credible risk to the safe operation of the Plant.

The nearest large pipeline to the plant is a 20-inch diameter natural gas pipeline that supplies the Covert Generating Plant. This line is 5,800 feet from the Plant and 3,350 feet from the Independent Spent Fuel Storage Installation (ISFSI). The pipeline has been analyzed and determined to not pose a significant safety hazard to the Palisades Nuclear Plant or the ISFSI.

Other pipelines near the Plant lie in a corridor about three miles southeast. These pipelines include a 30-inch diameter natural gas pipeline and a 10-inch diameter petroleum products pipeline. These pipelines are far enough removed to assure that pipeline accidents will not affect the safety of the nuclear Plant. There are no gas or oil production fields, underground storage facilities or refineries in the vicinity of the Plant.

There are no large commercial harbors along the eastern shore of Lake Michigan near the Plant. Some freight, including fuel oil, is shipped through St Joseph harbor about 17 miles to the south. Major shipping lanes in the lake are located well offshore, at least 10 miles or more from the Plant. Thus, lake shipping is not considered to be a hazard to the Plant.

The closest airport to the Plant is South Haven Regional Airport, a general aviation facility located approximately three miles northeast. Ross Field in Benton Harbor, about 15 miles south of the Plant, is also a general aviation airport with no scheduled commercial air service. Low altitude Federal Airways V193 and V55 pass about 4 miles northwest and 10 miles east of the Plant site, respectively. There are no military training routes within 30 miles of the site. Of the aviation facilities in the area, only South Haven Airport is of concern to the Plant.

South Haven Airport has one paved runway and one turf runway. The paved runway, designated 4-22 and orientated in a northeast-southwest direction was lengthened and widened in 1992 to 4,300 feet long and 75 feet wide, and has had all approaches cleared. The turf runway, 14-32, is a northwest-southeast runway and is 1,625 long and 185 feet wide. The airport is classified by the Federal Aviation Administration as a general utility airport which indicates that it can accommodate about 95% of the general aviation propeller fleet under 12,500 pounds. The main runway is equipped with high intensity runway lights. The airport has instrument approach capability consisting of a straight-in approach to Runway 22 from the Pullman VORTAC which is located 9.2 miles northeast of the field. There is no control tower at South Haven. The airport is used for general aviation activities such as business and pleasure flying and for agricultural spraying operations. There are about 22,000 operations per year at the facility. An operation is either a takeoff or a landing. A touch-and-go is considered as two operations. Several single engine and twin engine aircraft are based at South Haven Airport with gross weights from 1,250 to 5,200 pounds. Aircraft with weights up to 12,500 pounds will land at South Haven Airport at infrequent intervals.

The Plant's inherent design to withstand tornado missiles and other design loads also provides protection from the collision forces imposed by such light general aviation aircraft without adverse consequences (Chapter 5). The probability of a light aircraft striking safety-related equipment located outside a protective structure has been evaluated and found to be extremely low and within acceptable risk guidelines (Reference 26). The Individual Plant Examination of External Events (IPEEE) reevaluated the probability and consequences of an aircraft accident and reached the same conclusions. Planned or actual increases in flight operations will be followed, so that action can be taken well in advance to maintain the present high margin of safety. Refer to Section 5.5 for further discussion of Plant missile protection.

2.2 HYDROLOGY

The Palisades Plant site is surrounded on the north, east and south sides by sand dunes. The west side of the site is the Lake Michigan shoreline. As a result of this local topography, the site drainage is independent of the Brandywine Creek drainage basin which drains the hinterland. All surface water runoff drains directly to the lake and the percolating runoff also discharges to the lake (see Reference 3). There are no data available to verify the amount of surface runoff from the site; however, the flow from the Brandywine Creek drainage basin should be useful for the purpose of comparison.

Data obtained to establish base flow figures for Van Buren County streams indicate that the Brandywine Creek drainage basin is about 17 square miles (see Reference 4). The average annual rainfall for the area is 34 inches. During the period September 1962 to October 1963, the base flow measurements varied from a minimum of 0.90 cubic feet per second (ft^3/s) to a maximum of 11.4 ft^3/s. This resulted in a mean annual 7-day minimum flow of 1.6 ft^3/s or 0.094 $ft^3/s/sq$ mi (cubic feet per second per square mile). The period of stream measurements was representative of drought conditions.

The deposits of Brandywine Creek drainage basin are of low permeability which results in a nearly total runoff to Lake Michigan. This runoff probably occurs soon after precipitation. Minor groundwater storage in the old beach and reworked older sandy lake deposits observed on the surface to the east of the site area probably maintain Brandywine Creek during periods of low rainfall.

2.2.1 GROUNDWATER

Almost all the water used in Van Buren County is obtained from wells. Exceptions are the City of South Haven that obtains its municipal supply from Lake Michigan and some irrigation supplies that are obtained from streams, lakes and local ditches (see Reference 4).

The glacial drift is the only known source of fresh groundwater in the county. All the glacial deposits are capable of yielding some water to wells, but the sand and gravel outwash deposits yield the largest quantities (see Reference 4).

The area of sand dunes along Lake Michigan is not generally favorable for obtaining large supplies of groundwater. Probably most of the dune sand is above the water table and most wells must be drilled into the underlying lake deposits (see Reference 4).

1. General

   Groundwater levels were established by the 1966 Geology and Groundwater Investigation conducted by Bechtel Company for Consumers Power Company (see Reference 3). The results of the investigation are shown on Figure 2-9. It is readily apparent that subsurface drainage is generally westward toward the lake (see Profile A-A). Minor variations; ie, flow toward surface streams, may exist but are not considered significant.

   An average hydraulic gradient toward the lake of about 13 feet per mile was obtained along Profile A-A as shown on Figure 2-9. This gradient represents only the upper surface of unconfined groundwater. Water released on the surface would move toward the lake at an estimated rate of 650 feet per year (see Reference 3).

   The nearest domestic wells to the site are located one-half mile to the east and south. The data indicates that groundwater in the vicinity of the eastern wells is flowing west toward the site. Local groundwater in the area of the southern wells is also flowing west toward the lake, perpendicular to the shoreline.

   There are no major sources of groundwater withdrawal, eg, large-scale industrial or agricultural pumping, that might reverse the direction of groundwater flow and cause groundwater to flow from the Plant area toward any existing domestic wells. Without such pumping, it is difficult to envision a condition which would cause sufficient groundwater lowering at any of the domestic wells such that the direction of flow might be reversed.

2. Plant Site

   Groundwater levels in the vicinity of the site are shown on Figure 2-9. The water table generally slopes toward the lake. During the site investigations, groundwater elevations averaged 580 feet MSL beneath the building site. This elevation corresponds to the approximate mean level of Lake Michigan. As shown by water levels measured during drilling, groundwater levels rise to the east to approximately 604 feet MSL beneath the switchyard and 601 feet MSL near the eastern site boundary (see Reference 3).

   Field permeability tests performed during the 1965 exploratory drilling yielded values ranging from 30 to 1,720 feet per year in the site area, Table 2-11. In Drill Hole 5, located approximately 500 feet northwest of the containment building, the permeability values ranged from 30.4 feet per year to 143 feet per year. In Drill Hole 7, located approximately 650 feet south of the containment building, the permeability values ranged from 156 feet per year to 1,720 feet per year.

3. Groundwater Movement

   An unconfined aquifer is present in the dune area with groundwater levels controlled by the level of Lake Michigan. The rate of movement of groundwater downward into material underlying the dunes appears to be very slow. Nine samples from Drill Hole 22 in the site area were tested for sodium absorption ratio (SAR), Table 2-12. A high SAR indicates poor downward percolation of water due to sodium deposition on and between soil particles. At the Plant site, the SAR is considered to be high between elevations 596 and 566 feet MSL and low between 566 and 555 feet MSL (see Reference 3).

   Groundwater levels and permeability data from the sandy lake deposits underlying the dunes indicate a slow rate of discharge into Lake Michigan.

4. Conclusions

   a. Groundwater in the unconfined aquifer moves westerly from the Brandywine Creek basin to Lake Michigan.

   b. The hydraulic gradient is approximately 13 feet per mile and flow is essentially perpendicular to the shoreline.

   c. Water discharged on the ground surface at the Plant site will percolate downward at a slow rate and mix with groundwater moving toward Lake Michigan.

   d. Infiltration of surface water from the site to domestic wells offsite does not appear to be possible under present groundwater conditions.

2.2.2 GENERAL LAKE HYDROLOGY

1. Lake Levels

The level of Lake Michigan is cyclic and is expected to fluctuate with time due to long-term above-normal or below-normal amounts of precipitation. The highest monthly mean stage of Lake Michigan was 583.5 feet MSL in 1886. Subsequent modifications in the St Clair River and the opening of the diversion out of the basin at Chicago have tended to reduce the maximum level attainable. During the recent period of record (1900 to present), the highest recorded monthly mean stage was 583.3 feet MSL in June 2020 (see Reference 27), and the lowest monthly mean stage was 576.9 feet MSL in March and April 1964 (see Reference 5). (The previous maximum monthly mean lake level for this period was 583.2 feet MSL in October 1986.) Great Lakes levels are currently reported using International Great Lakes Datum-1985 which is converted to MSL at the Palisades site by adding 0.88 feet. The 0.88 foot correction factor is taken from the reference point at Calumet Harbor, Illinois (The correction factor for Holland, Michigan is 0.62 feet.)

Short-time variations in lake levels (seiches), caused by meteorological factors and measured in minutes rather than days, occur occasionally. The greatest level change of this type on record over a 105-year period involved a sudden rise of 6 feet at Michigan City, Indiana (8:10 AM, June 26, 1954) and a rise of 8 feet at Montrose Harbor, Chicago (9:30 AM on the same date) (see Reference 6). These seiches were reported in the "Science" article by Ewing, Press and Donn (Vol 120, Page 684). On passing into the shallow water at Michigan City, the wave was reflected and refracted to reach the Chicago shore of the lake. The US Lake Survey gauge at Holland, Michigan, which is 30 miles north of the Palisades site and has similar lake geometry to the site, indicated no surge on June 26, 1954.

As part of the Systematic Evaluation Program (SEP Topic II-3.B), the maximum probable surge elevation was reevaluated by the NRC (see Reference 28). The offshore surge value was reevaluated to produce an onshore surge height of 10.9 feet. The maximum monthly mean level was also changed from 583.5 feet MSL to 582.6 feet MSL (for the July 1974 high level), which represented the maximum monthly mean for the "modern" period of 1900 to the present (1982 for the SEP). This resulted in a "design basis" flood level for the Palisades Plant of 593.5 feet MSL.

Since a new maximum monthly mean lake level was established in 2020 for the period of 1900 to the present, a new design basis flood level is calculated to be 594.2 feet MSL. The plant is protected against flooding to a level of 594.4 feet MSL. See Section 5.4.1.2 for details. Therefore, the resultant wave surges from Lake Michigan do not present a problem at Palisades.

2. Water Movements

Conclusions from a study of lake hydrology in the Palisades Park, Michigan area by Dr J L Hough (see Reference 6) indicate that surface currents generated by wind conditions and modified by the earth's rotation and lake configuration will provide adequate mixing of Plant liquid effluents into the lake. The study included actual measurements of lake water movement in the area near the Plant site, and water mixing where the Black River enters Lake Michigan at South Haven.

A summary of the study is as follows:

Lake water is almost constantly moving past the Palisades site, with an appreciable velocity of flow, under the influence of winds. It is estimated, on the basis of wind records, that an alongshore current flows northward about 33% of the time and an alongshore current flows southward about 23% of the time. Offshore drift of surface water should occur about 38% of the time, according to frequency of offshore winds, but these would have a minimal effect close to shore, which is bordered by a high dune ridge. It is likely, therefore, that the alongshore currents would tend to persist, once set up, while offshore winds were blowing. Thus, the frequency of alongshore current flow is probably greater than the 33% and 23% based on wind directions.

Under the procedure of taking water from a depth of about 20 feet, 3,500 feet offshore, raising its temperature as it is used for service water and dilution of cooling tower blowdown, and returning the effluent to the lake near shore, the effluent water will almost always be warmer than the lake water into which it is discharged. This is because a single Lake Michigan water mass is involved during most of the year. When the effluent is warmer, it will tend to float at the surface, to drift with the surface current, and to be mixed by surface turbulence due to wave action. On rare occasions, during the spring warming period when the upper layer of lake water is less than 20 feet deep, and during the summer when strong offshore winds cause a thinning of the normally deep surface mass to less than 20 feet, the intake water coming from a colder layer may not be warmed in the Plant sufficiently to have a temperature higher than that of the surface lake water. At such times, the effluent water will tend to sink to the thermocline and it will not be subject to vigorous turbulence caused by surface wave action. It will tend to mix more slowly.

Surveys of the performance of Black River water, entering Lake Michigan at South Haven under various weather conditions, have indicated that the river water is diluted rapidly, reaching a concentration of about only 1% in the lake within a mile of the river mouth.

The discharge of the Black River was evaluated because the rate was determined to be nearly the same as the discharge rate from the Palisades Plant with once-through cooling. Since the Plant is now operated with cooling towers, the discharge to the lake has been reduced to approximately 60,000 gpm or about 1/7 the original rate. The mixing and dilution factors are considered to be as great as during the higher discharge periods and the discharge concentrations should be diluted at least 1,000 times by the time the discharge could reach the public water intake at South Haven, Michigan.

3. Conclusions

   a. The level of Lake Michigan is cyclic; however, the recorded high of 1886 is unlikely to be exceeded. High lake levels are not expected to present a problem at the Plant site.

   b. There is no recorded evidence of short-time variations in lake levels (seiches) along the eastern shore of Lake Michigan which would be expected to affect the Plant site.

   c. Surface currents generated by wind conditions and modified by the earth's rotation and lake configuration will provide adequate mixing of Plant liquid effluents into the lake.

2.3 GEOLOGY

The Palisades Plant site is located in the Eastern Lake Section of the Central Lowland Physiographic Province (see Reference 7). The land surface is mantled by glacial drift that ranges from a few feet to several hundred feet in thickness. In the immediate vicinity of the Plant, sand dunes are the prevailing surface feature. The sand dunes were formed as a result of wind and erosion. The dunes become relatively stable when covered with vegetation, however, blowouts may cause modifications. Previous modifications appear as a series of conical hills and steep ridges often separated by closed depressions. Underlying the dunes are glacial deposits of varying types which were deposited on bedrock consisting of Paleozoic Mississippian shale (see Figure 2-10).

The dunes fronting Lake Michigan rise steeply from the shoreline (approximate elevation 582 feet MSL) to elevations ranging from elevation 820 feet MSL to elevation 780 feet MSL (near the site) and maintain an average width of about 5,000 feet for approximately two miles north to five miles south of the site. Easterly from the dune area is a drainage basin of about 17 square miles. A low morainal ridge (Covert Ridge) rising to a maximum elevation of about 720 feet MSL bounds the basin on the east. This basin is drained by Brandywine Creek and its northern tributaries which combine to flow through a gap in the lakefront dune area about 3,000 feet south of the site. Glacial lake deposits and ground moraine associated with the Covert Ridge terminal moraine are found within the basin.

2.3.1 PREGLACIAL GEOLOGY

The Coldwater shale of Mississippian age lies beneath the dunes and glacial deposits at the site. These sediments represent the last phase of marine deposition in the Paleozoic Michigan Basin. During subsequent Mesozoic and Cenozoic eras, the entire Great Lakes region apparently remained above sea level.

Preglacial erosion presumably developed a stream pattern on the Paleozoic rocks favoring the softer, more easily eroded geologic formations. The locations of this original bedrock drainage pattern, modified by glacial ice grooving, are represented by the bedrock contours shown on Figure 2-10.

The bedrock, Coldwater shale, consists of compact blue, gray or occasionally red clay shale. Drill Hole 21, located in the immediate vicinity of the containment building, established bedrock at elevation 440 feet MSL (see Reference 3). A geophysical study near the site indicated top bedrock to be about 150 feet below the beach fronting Lake Michigan at an approximate elevation of 430 feet to 470 feet MSL (see Reference 8).

2.3.2 GLACIAL GEOLOGY

The Great Lakes region exhibits the four distinct glacial ages within the North American Pleistocene record. Each glacial age is represented by extensive till or boulder clay deposits. Subsequent advances reached successively less southerly, and by the early Wisconsin glacial stage (approximately 50,000 years ago) an ancestral Lake Michigan had been formed. This crescent-shaped lake covered only the most southerly end of the present Lake Michigan.

Subsequent glacial advances periodically destroyed the lake; however, the lake was permanently established during the latter stages of the Wisconsin ice age.

The morainal ridge forming the eastern boundary of the Brandywine Creek drainage basin contained several lake stages to elevation 640 feet MSL (called Lake Glenwood Stages I, II and III), which occurred during successive Wisconsin glacial advances and retreats. Well-developed shoreline features, including sand and gravel beaches, spits, bars, wave cut terraces and cliffs, have been recorded below elevation 640 feet MSL in many places in the southern portion of the Lake Michigan basin. The deposits from these lakes generally consist of low permeability silty and clayey sand beds.

There were two drilling programs conducted in the Plant area (see References 9 and 3). The preliminary program consisted of 18 holes (1 through 18) spaced on a grid pattern with distances between holes ranging from 240 feet to 360 feet. After a more precise location for the containment building had been determined, a second drilling program of 13 additional drill holes (21 through 33) was conducted. Drill hole locations in the Plant, switchyard and highway areas are shown on Figure 2-11. Logs of the 1966 drill holes are shown on Figure 2-12.

Subsurface sections of glacial and post-glacial materials encountered are shown on Figure 2-13. Four distinct layers have been identified: (1) dune sand, (2) dense to very dense gray silty sand or sandy silt, (3) stiff gray clay and (4) stiff to hard gray glacial till.

The dune sand is a uniform grain-size deposit which is generally loose above elevation 590 feet MSL. Below elevation 590 feet MSL, the dune sand is dense to very dense (see Reference 10).

Beneath the dune sand is a stratum, the upper portion of which consists of gray sand or silty sand which gets finer with depth, so that at the center of the stratum it is gray silt and in the lower part of the stratum it is a gray clay. The bottom of the stratum varies between elevation 518 feet MSL and 530 feet MSL. Below this is a dense glacial till down to bedrock which was encountered at elevation 440 feet MSL in boring No 21 (see Reference 10).

2.3.3 FAULTS

The Michigan Basin, although several hundreds of million years old, is relatively undeformed. Folds and faults have been mapped in the Paleozoic rocks of the basin, however. For example, several minor northeast plunging folds have been mapped in the site vicinity based on oil and gas drilling wells in southwest Michigan. These folds have closures in Devonian strata of 60 to 80 feet. Movement is interpreted to have occurred in post Devonian (345 million years before present, or mybp) and to have been associated with subsidence of the Michigan Basin (see Reference 11). The nearest inferred large scale faulting is the Tekonsha and Albion-Scipio Trends located about 50 and 60 miles east of the site, respectively. These postulated faults strike north northwest (see Reference 12) and affect Ordovician rocks (500 to 430 mybp). There are other structures like these within and around the Michigan Basin. All of these structures are considered to be post Devonian to pre Pleistocene (345 mybp to 1 mybp) with most activity occurring in the late Paleozoic. This conclusion is based on the observation that all Paleozoic rocks are affected by the structures, with Mississippian being the youngest; and there is no evidence that the faults cut Pleistocene sediment.

No faults have been mapped in the vicinity of the site. The major faults shown on Figure 2-14 were taken from regional geologic and tectonic maps of the US Geological Survey. It is significant that the regional faulting and general seismic activity appears related to the Paleozoic structure shown.

PSAR information for the Haven, Wisconsin site (WEPCO, 1978) contained seismic reflection data indicating the possible presence of faults beneath Lake Michigan. Careful review of these data indicated that the anomalies appearing on the seismic profiles, if indeed they were faults, did not constitute a hazard to the sites in the Lake Michigan region (see Reference 13).

2.3.4 ENGINEERING GEOLOGY

1. Exploration and Studies

   Investigations of the geological conditions at the Palisades Plant site were conducted in 1965 and 1966. Results of the investigations were published in three reports by Bechtel Corporation: Foundation Investigation for Palisades Nuclear Plant - November 1965 (see Reference 9), Geologic and Groundwater Investigation for Consumers Power Company - September 1966 (see Reference 3) and Foundation Investigation for Design of Palisades Nuclear Plant - October 1966 (see Reference 10). The second foundation investigation of 1966 was required to expand and refine the 1965 investigation to provide information for final Plant design.

The general geologic profile was disclosed by numerous borings in the areas of interest. The sand dunes which were excavated from the Plant site rose steeply from elevation 582 feet MSL at the shore of Lake Michigan to about elevation 780 feet MSL at the site of the containment vessel. The dune sand extends down to a base between elevation 560 feet to 565 feet MSL. The dune sand is uniform in grain size and is generally loose above elevation 590 feet MSL and dense to very dense below this level. Beneath the dune sand is a stratum of gray sandy silt or silty sand extending to between elevation 518 feet MSL and elevation 530 feet MSL which becomes finer with increasing depth with gray clay at the lower edge of the stratum. Below this is dense glacial till down to bedrock which was encountered at elevation 440 feet MSL.

Borings made at the switchyard location showed a similar profile as the Plant site with the exception that the fine sand is loose down to elevation 580 feet MSL.

A geophysical investigation completed by Weston Geophysical Engineers, Inc, in 1966 (see Reference 8), revealed that the site and vicinity (below the upper dune material) is underlain by materials of three distinct compressional (P wave) seismic velocities. The uppermost zone (average P wave velocity of 5,400 feet per second) extends from about elevation 590 feet MSL down to elevation 545 feet MSL. This material is interpreted as the compact glacial lake deposits. The intermediate zone is generally found below elevation 545 feet MSL and extends downward to an average elevation of 430 feet MSL. This zone has an average P wave velocity of 6,700 feet per second and is probably composed of stiff lake clays and compact glacial till. Below about elevation 430 feet MSL in the vicinity of the Plant, the material has a P wave velocity of 10,000 feet per second. This material is interpreted as the bedrock sequence of Mississippian Coldwater shale (see Figure 2-15).

The velocities obtained for the stiff lake deposits and till substantiate the driving resistances encountered during the 1965 and 1966 exploration programs. The geophysical investigation results are consistent with the decisions regarding foundation design and the anticipated seismic ground acceleration as discussed in Section 2.4, Seismicity.

2. Foundation Conditions

The loose dune sand in the site area above elevation 589 feet MSL was excavated to provide adequate foundation for all heavy structures. The reactor building foundation mat base was located at elevation 575 feet MSL and the post-tensioning tunnel was located at elevation 568 feet MSL. At these elevations, the fine sand had been consolidated to a relative density of 95% or greater by the weight of the dune sand and provides a high-bearing capacity for foundation support.

The turbine building foundation base is at elevation 568 feet MSL and is on a similar soil structure as the reactor building foundation.

The auxiliary building is carried on a foundation mat, part of which is founded in natural ground and part on compacted fill. The natural ground has a relative density of greater than 90% and the backfill was compacted to greater than 95% maximum density as determined by the Modified Proctor Method (ASTM D1557). All basement walls of the turbine and auxiliary buildings are designed to resist the loads from the compacted backfill.

Placement of fill in the switchyard area was carried out in approximately 12-inch-thick horizontal layers. Each layer was moisture conditioned and compacted to 95% density as determined by the Modified Proctor Method.

2.3.5 CONCLUSIONS

1. No geologic conditions have been found which negatively influence the construction of a nuclear power plant at the site.

2. No known active faults have been recorded in the vicinity of the site.

3. Materials occurring below the dune sand at the site provide excellent foundation materials.

2.4 SEISMICITY

The geology and the history of seismic activity of an area provide data on the surface accelerations which have occurred at a particular site. The historical data on frequencies of occurrence are useful aids of judgment in evaluating the seismic design factors which may be applicable for a particular area.

The effects of earthquake shocks and the local intensity of shocks transmitted from distant foci are known to be dominantly influenced by the geologic conditions of the specific area.

2.4.1 SITE GEOLOGY

Figure 2-10 shows a geologic map and generalized geologic section of the Palisades Plant area. This area is underlain by dune sand and approximately 150-500 feet of glacial deposits consisting of compacted dense till, terminal and ground moraines, and lake deposits. The drilling programs conducted in 1965 and 1966 revealed that the Plant site was underlain by a thick deposit of compact glacial till and lake deposits overlain by loose sand dunes. The glacial till is composed of compact silty gravelly sand and the lake deposits are of compact silty sand. The base of this surface sand dune deposit appears to vary from about 575 to 600 feet in elevation in the vicinity of the site with very dense fine sand at its base (see References 3 and 9).

Drilling to bedrock was done during the 1966 site exploration. Bedrock was encountered at elevation 440 feet. The bedrock contours shown on Figure 2-10 were taken from Figures 24 and 25 of the report "Water Resources of Van Buren County, Michigan," US Geological Survey, 1964 (see Reference 4) and from a geophysical investigation conducted by Weston Geophysical Engineers, Inc (see Reference 8). The elevation of bedrock at the site appears to be about 450 feet, or about 150 feet below ground surface, providing good agreement with the drilling study.

The seismic velocity (compressional or P wave velocities) of bedrock in the site area, as determined during the geophysical investigation, is 10,000 feet per second. The glacial deposits over bedrock were determined to have average velocities of 5,400 feet per second for the lake deposits and 6,700 feet per second for the glacial till (see Figure 2-15).

Groundwater levels in the Plant area were observed during the 1965 and 1966 investigation programs to vary from about elevation 590 feet to 580 feet (see Figures 2-9 and 2-12). This latter elevation corresponds to the water surface elevation of Lake Michigan.

Foundations for primary Plant structures utilize the compact glacial deposits and very dense, fine sand, the upper surface of which ranges from about elevation 575 feet to 590 feet as shown by the 1966 drilling program and confirmed by the seismic survey.

2.4.2 SEISMIC HISTORY

A study of available seismic data indicates that the Palisades Plant area should be considered slightly active seismically as shown on Figure 2-14. This is confirmed by its location in earthquake Zone I of the UBC 1964 Edition. Figure 2-14 is a map of the area within a radius of about 200 miles around the Palisades Plant showing earthquake epicenters, date of occurrence and intensity at the epicenter. These include all earthquakes which have been reported since 1804. Only one epicenter has been reported within 50 miles of the site since 1804.

Following are descriptions of the historic earthquakes which have occurred within 100 miles from the site:

August 20, 1804 (2:10 PM) - Fort Dearborn (present site of Chicago) was reported shaken by this earthquake. It was also felt at Fort Wayne, Indiana, located about 200 miles away, and at other points about the south end of Lake Michigan. The estimated felt area was 30,000 square miles.

February 4, 1883 (5:00 AM) - This earthquake was felt in northern Indiana and southern Michigan. At Kalamazoo, Michigan, windows were cracked and buildings were shaken. It was also felt at St Louis, Missouri and Bloomington, Illinois, and the estimated felt area for this earthquake was 8,000 square miles.

August 9, 1947 (8:47 PM) - This earthquake was strongly felt throughout southern-central Michigan. Chimneys were damaged and plaster cracked at Athens, Coldwater, Colon, Matteson Lake, Sherwood and Union City. It was also felt in parts of Indiana, Ohio, Illinois and Wisconsin, and the estimated felt area was 50,000 square miles.

A review of seismic data relating to the Palisades Plant provides the basis for Table 2-13, which is a summarization of earthquake intensity versus distance to reported epicenters.

Table 2-13 is not intended as a prediction of seismic activity at the site or epicentral location, but, rather as a summary of the available information, data and records which were useful as a basis of judgment in the selection of appropriate design factors.

2.4.3 DISCUSSION

Figure 2-16 shows a seismic regionalization map of the United States based on the map prepared by C F Richter (see Reference 14). This map is his evaluation of probable maximum intensity which may be expected in any given area in the United States. The Palisades Plant area is located in Zone VIII on this map in which the maximum probable seismic intensity is rated VIII on the Modified Mercalli (MM) scale. However, a detailed evaluation of historic epicenters, the regional geology and a study of actual foundation conditions at the site indicate that a Zone VIII assignment is too conservative for the Palisades Plant. Correlations made in the course of the recent investigations suggest a concentration of the major epicenters (Maximum Intensity VIII) about 200 miles southeast from the site focused on the ancient regional structures termed the Cincinnati and Findlay Arches (see Figure 2-14). These structural features are considered the foci of the historic earthquakes experienced along the arch lineation.

As pointed out by Richter (see Reference 14), the occurrence of a major earthquake (Intensity IX) along the western end of the St Lawrence rift would result in the assignment of Intensity VIII to areas of thick deposits of soft unconsolidated foundation materials. However, foundation conditions such as reported above at the Palisades site warrant a reduction in probable maximum intensity to between VI and VII (MM).

The lower intensity earthquakes (Intensity V to VI) recorded within 100 miles of the site have no known correlation with tectonic or structural features. These earthquakes probably can be considered as related to the marginal seismicity surrounding the Canadian shield or attributed to the lesser-known phenomenon termed "post-glacial rebound."

The compacted glacial material underlying the sand dunes would not be expected to significantly amplify seismic tremors transferred to it from the underlying bedrock. In fact, the tendency for amplification of seismic accelerations can be relatively discounted due to the relationship between the shallow depth of overburden (material over bedrock) at the site and the length of seismic waves.

Thus, the licensee considers that the site area is beyond the significant influence of the major seismic activity associated with the arch zone (because of distance and foundation conditions) but within the area where minor earthquakes resulting from Canadian shield marginal seismicity or "post-glacial rebound" are generally geographically distributed.

Based on the above, a maximum intensity at the site of between VI and VII (MM) is anticipated. This intensity corresponds to a surface acceleration value of 0.05 g.

2.4.4 CONCLUSIONS

1. Anticipated maximum earthquake intensity at the Palisades Plant site is between VI and VII (MM).

2. Recommended surface acceleration value was 0.05 g; however, 0.1 g was used for the Plant design earthquake (OBE) and 0.2 g as the hypothetical earthquake (SSE).

2.5 METEOROLOGY

2.5.1 GENERAL CLIMATOLOGY OF PALISADES PLANT AREA

In terms of the Koppen System of climatic classification, the lower peninsular area of Michigan has a "humid continental climate with cool summers." The continental characteristics include great departures from seasonal temperature means and a summer maximum in rainfall, but these features are somewhat modified due to the proximity of the Great Lakes, so that the magnitude and persistence of the larger temperature anomalies are reduced and the annual rainfall maximum is shifted toward fall, when the lake water is relatively warm.

The surface winds blowing across the area are basically westerly, with considerable variability in summer and the transition seasons. Southwesterly winds which result in a lake trajectory of about 75 to 100 miles are especially common in summer. The mean wind speed is at a maximum of approximately 20 miles per hour in December-January, falling to 10 to 15 miles per hour the rest of the year.

Snow cover is important because of high reflection of energy from the snow surface and protection of the underlying soil. Lying only 350 miles from the boundary of the subarctic climatic zone to the north, the Palisades Plant area averages 80 days per year of snow cover. The average long period temperature and precipitation values abstracted for Michigan (Reference 15) are as follows:

Annual mean monthly temperature range: 20°F (February) to 70°F (July).

Monthly precipitation: 1.5 inches (February) to 3.5 inches (September), with a yearly total of 29 inches. The annual average precipitation for Van Buren County is reported as 34 inches (Reference 6).

With a high frequency of surface winds coming from Lake Michigan, the annual temperature of the lake regime is of interest. According to Church (see References 16 and 17), the following periods are distinguishable as gross features of the lake:

Spring Warming Period, Phase 1: A slow warming to about 4°C occurs, this temperature being attained throughout the lake water. The ending of this phase is between May 10 and June 10.

Spring Warming Period, Phase 2: After the formation of a protective thermocline near the surface, a rapid warming to about 20°C takes place. This phase ends in mid-July.

Summer Stationary Period: A fairly constant temperature is maintained, there being a heat balance at the surface. This continues until late September.

Fall Cooling Period: As autumn cooling begins and wind stirring increases, the thermocline is destroyed and the lake becomes vertically isothermal. This period ends in November.

Winter Cooling Period: Further cooling continues until March, when the cycle begins to repeat itself. Ice forms in winter near the lakeshores to build inward toward the center of the lake.

The Palisades Plant area lies in maritime-polar (Pacific) and continental-polar air much of the time. However, it is frequently overrun by continental-arctic air and is reached by maritime-tropical air in all seasons. This means that there are numerous frontal passages which average two or three per week when both cold and occluded fronts are considered. Because of these frontal passages and the lake influences, there is considerable cloudiness and the overall atmospheric dispersion characteristics of the area are quite favorable.

1. Temperature Extremes

   As is common in this latitude, the annual temperature range in the Palisades Plant area is large. On the basis of a study of US Weather Bureau (USWB) records for stations reasonably close to the area, the extreme 10-year minimum temperature would be about -25°F. Because of the proximity of the cool lake, the extreme 10-year maximum temperature would be a moderate 95°F. The onsite extreme maximum and minimum air temperatures recorded at the lower thermistor of the shoreline station during the period from December 1977 through November 1978 are 88.3°F and -2.9°F, respectively.

2. Wind Loading

   The absolute maximum wind speed for Nonclass 1 design purposes is a speculative figure, generally associated with violent summer thunderstorms. Standard design practice requires that structures be built to withstand winds of 100 mi/h, which is a reasonable long-term design maximum.

3. Ice and Snow Loading

   Heavy ice storms associated with freezing rain or sleet occur in the area approximately once every two years. Standard design practice provides for an external loading of 40 lb/ft^2 for snow and/or ice.

4. Tornado Loading

Records (Reference 18) of tornado occurrences in the 14-county area of southwestern Michigan, including the counties of Ottawa, Allegan, Van Buren, Berrien, Cass, Barry, Kalamazoo, St Joseph, Eaton, Calhoun, Branch, Ingham, Jackson and Hillsdale, were analyzed for the period 1897 through 1965. A total of 58 tornado sightings was reported. Of this total, 18 were sighted in the shoreline counties of Ottawa, Allegan, Van Buren and Berrien. Only three tornadoes were reported within ten miles of Lake Michigan; none were sighted within a mile of the shore. These data indicate that, although tornadoes are relatively common in Michigan, they rarely occur near Lake Michigan. Two papers (References 19 and 20) reported results of studies which clearly show that the cool, stable air overlying the lake tends to diminish convective activity over the lake and also inland for a considerable distance. The available evidence, then, indicates that the severest forms of convective activity; eg, tornadoes and hailstorms, would be extremely rare occurrences at a shoreline site on Lake Michigan. Design specifications for tornado loading were external wind forces resulting from a tornado funnel having a peripheral tangential velocity of 300 mi/h whose center is traveling at 60 mi/h.

2.5.2 METEOROLOGICAL PROGRAM HISTORY

2.5.2.1 <u>Preoperational Program (Reference 21)</u>

The preoperational meteorological program consisted of two stations located within the Palisades Plant site boundary. Each station consisted of a selfstanding tower with thermistors mounted at the 10- and 55-foot levels for temperature measurement. Also mounted at the 55-foot level on each tower was a Gill-type propeller vane for wind speed and direction measurements. All parameters were recorded on strip chart recorders located in the construction office building, with signals transmitted via underground cables. The inland station was located approximately 2,400 feet east and 1,350 feet north of the containment building at the eastern foot of shore-line sand dunes with a ground level elevation of approximately 610 feet MSL. The shoreline station was located 150 feet east and 40 feet south of the containment building, part way up the western slope of a dune with the 55-foot tower level at the same elevation as the top of the containment building, or about 200 feet above the lake. Figure 2-17 is a map showing location of the meteorological towers at the Palisades site. Information obtained during the preoperational program was submitted to the NRC in the 1980 FSAR as Appendix D.

2.5.2.2 Interim Program (Reference 21)

The preoperational sites were abandoned after Plant construction was completed because they were not considered representative or adequate. They were replaced with a 55-foot pole located on a sand dune approximately 700 feet east of the containment building. The instrumentation included aspirated temperature probes (mounted at 10 feet and 55 feet), wind direction and wind speed sensors (mounted at 55 feet). The wind direction signal was further conditioned to provide an indication of the horizontal wind direction variation (sigma). The temperature sensors were electronically "bucked" to provide an output signal proportional to the temperature difference between the two sensors. The nonlinearities of the temperature sensors are electronically compensated. The wind speed, wind direction, wind sigma, ambient air temperature and temperature difference data were recorded in digital form on a cassette tape recorder at the base of the tower. In addition, a Bendix weather vane mounted adjacent to the above sensors on the 55-foot pole was used with wind speed and wind direction analog recorders located in the reactor control room. The results of the interim program (1973-74 data) were utilized in the applicants' 10 CFR 50, Appendix I submittal dated June 4, 1976 (Reference 22). An additional study conducted by EG&G, Environmental Consultants (see Reference 21) in 1975, recommended further meteorological program improvements in order to fully comply with Regulatory Guide 1.23.

2.5.2.3 Present Program

As a result of the EG&G study and subsequent negotiations with the NRC, the interim program was modified. A new meteorological tower was installed in the fall of 1977 with monitoring capabilities at the 10-meter and 60-meter levels. Monitoring levels are with respect to the base of the tower which is at elevation 716.74 feet MSL. The monitoring elevations are at approximately 750 feet MSL and 906 feet MSL. The tower is located 336 feet north and 4,118 feet east of the containment building. Meteorological data from the tower system are collected on digital recording devices and transmitted to the Plant. The data are averaged and edited by a processor located in the tower shelter. The standard deviations of wind direction at 10 meters and 60 meters ($\sigma\theta$) are calculated.

Entergy Nuclear Operations, Inc, is operating, maintaining and calibrating the meteorological equipment at the Palisades site. The following parameters are monitored at the Palisades site:

1. Wind direction and speed at heights of: primary sensor (a) 10.1 meters, secondary sensor (b) 10.4 meters, upper sensor 57.8 meters

2. Temperature at 10.1 meters

3. Differential temperature span of 47.7 meters

Nominal heights of 10 meters and 60 meters are used in subsequent references to instrument heights.

2.5.3 DISCUSSION OF EXISTING 1977/1978 DATA

The following is a summary and analysis of the 1977/1978 meteorological data from the Palisades Plant submitted to the NRC, April 6, 1979. Reference 25 represents one full year of data collected at greater than 90% recovery. It should be observed that the 10-meter wind frequency distribution for the current tower bears notable resemblance to the distribution presented in the 10CFR50 Appendix I Analysis of May 1976 (Reference 22).

2.5.3.1 Wind Frequency Distributions

The seasonal and annual wind frequency distributions measured at each height are graphically presented in Figures 2-18 through 2-27. For the year, December 1977 through November 1978, the predominant wind direction at 10 meters is south and at 60 meters is southwest. Secondary peaks occur in the south-southeast and north-northwest at 10 meters, and in the south and south-southwest at 60 meters. The winter (December 1977 through February 1978) and spring (March through May 1978) quarters generally exhibit predominantly north and northwesterly winds, while the summer (June through August 1978) and fall (September through November 1978) quarters generally exhibit predominantly south and southwesterly winds. The annual highest mean speeds were recorded in the west-northwest, northwest and west sectors at 10 meters and in the southwest, northwest, west and west-northwest sectors at 60 meters. As expected, the recorded mean speeds are greater for the 60-meter level than for the 10-meter level.

2.5.3.2 Stability Wind Roses

The joint stability-wind frequency distributions appear in Reference 25, Pages A-11 through A-100. These tables summarize the wind frequency distributions during each of the Pasquill stability classes.

Table 2-14 presents a summary of the stability-wind frequency distributions, showing the distribution of each stability class by wind direction sector at the 60-meter level and the distribution of all stability classes within each direction sector. Each table entry contains two numbers. The upper number is the relative percent occurrence within one stability class for each direction sector. These are comparable vertically in the table. The lower number is the relative percent occurrence of observations from all stability classes for each stability class wind sector. These data are comparable horizontally within the table. The "All Classes" column is the wind rose when valid stability measurements existed.

The annual stability class distribution for all winds (independent of direction sector) at the Palisades 60-meter height is climatologically representative of the region; the maximum occurs in the neutral (D) stability class and the secondary maximum occurs in the slightly stable (E) class. The two most unstable (A and B) classes occur with predominantly northwest and north-northwest winds, and the most stable (G) class occurs with predominantly south and south-southwest winds. As expected, the wind sectors for all classes approximately follow the wind rose distribution with peaks in the south and southwest.

2.5.3.3 Persistence

A wind persistence analysis for each of the four seasonal quarters for 22.5 degrees and 45.0 degrees wind variations is presented in Reference 25, Pages A-101 through A-132. Generally, the durations of persistence were longer in the winter season and shorter in the summer season. The longest quarterly durations of persistence observed at each height are as follows:

1. Winter Quarter (December 1977 through February 1978):

   a. At 10 m: 62 hours for a 22.5° sector centered on 310° and 73 hours for a 45.0° sector centered on 305°

   b. At 60 m: 59 hours for a 22.5° sector centered on 320° and 70 hours for a 45.0° sector centered on 315°

2. Spring Quarter (March through May 1978):

   a. At 10 m: 35 hours for a 22.5° sector centered on 340° and 47 hours for a 45.0° sector centered on 80°

   b. At 60 m: 43 hours for a 22.5° sector centered on 80° and 60 hours for a 45.0° sector centered on 70°

3. Summer Quarter (June through August 1978):

   a. At 10 m: 23 hours for a 22.5° sector centered on 345° and 29 hours for a 45.0° sector centered on 155°

   b. At 60 m: 22 hours for 22.5° sectors centered on 110° and 350°, and 39 hours for a 45.0° sector centered on 205°

4. Fall Quarter (September through November 1978):

   a. At 10 m: 26 hours for a 22.5° sector centered on 295° and 43 hours for a 45.0° sector centered on 100°

   b. At 60 m: 25 hours for 22.5° sectors centered on 185° and 235°, and 68 hours for a 45.0° sector centered on 225°

As expected with a wider sector, the maximum persistence is greater. The wider sector persistences also show fewer cases of short-duration persistence.

2.5.3.4 Hourly Data

All hourly data collected during the year at Palisades appear in Reference 25, Pages A-133 through A-330. Occasionally, analog data were substituted for missing digital data.

2.5.3.5 Data Recovery

The percent data recovery for each parameter at the Palisades site by seasonal quarter for the December 1977 through November 1978 period is presented in Table 2-15. Better than 90% data recovery for the year was achieved for all parameters. The redundant system for data recording, consisting of both digital and analog recorders, is primarily responsible for the high overall data recovery rates.

Also included as invalid data are the data outages due to routine system calibrations. The 4-month calibrations occurred in March, July and November. Various calibration checks occurred between the routine system calibrations to ensure that the data are correct. The third 4-month calibration was extended due to installation of surge arrestors on the bridge terminals and in the wind translators.

2.5.4 DIFFUSION CLIMATOLOGY

The nature of the surface over which the air flows is the prime factor in determining the atmospheric diffusion characteristics of airborne material released at the Plant site, inasmuch as these diffusion characteristics are governed by surface-generated turbulence.

2.5.4.1 Turbulence and Diffusion Regimes

Atmospheric diffusion processes are governed by turbulence generated in either of two ways: (1) by mechanical action as the airflow is made irregular as the air moves over a rough surface and (2) by thermal buoyancy forces which either stimulate or inhibit vertical turbulence and mixing.

The critical vertical temperature gradient, or vertical temperature lapse rate, is 10°C per km or 5-1/2°F per 1,000 feet. This critical lapse rate is known as the dry adiabatic lapse rate. When the temperature decreases or lapses with height at a rate greater than 10°C km^{-1}, the air is unstable and active vertical churning known as thermal turbulence occurs. Under such conditions, plume looping is observed. If the lapse rate is less than 10°C km^{-1}, the air is stable and vertical mixing is inhibited. When an inversion occurs in which the temperature increases with height, the air is very stable and mixing is very slight. A fanning plume with pronounced horizontal dispersion but minimal vertical dispersion occurs with an inversion.

With brisk winds blowing over rough terrain, mechanical turbulence develops. The vertical mixing thus induced tends to maintain the lapse rate at a value close to 10°C km^{-1}, in which the air is neither stable nor unstable but neutral. Mechanical turbulence of this type leads to plume coning, which is characterized by nearly equal horizontal and vertical dispersion.

Both types of turbulence and various plume formations are readily observed in the shoreline area of Lake Michigan. As the wind blows across the shoreline, pronounced changes in mechanical turbulence and in thermal turbulence often occur. Thermal effects are greatest in the late spring and early summer when the temperature differences between water and land are greatest.

2.5.4.2 Shoreline Influences

Based solely upon considerations of mechanical turbulence, winds coming off the water are generally expected to be less turbulent than winds coming off the land, given the same meteorological conditions. This is especially the case in the late spring and early summer months when the surface lake temperature is lower than the average air temperature. This difference in air-water temperature gives rise to an inversion condition over the water and, consequently, a reduction in the turbulence. Onshore winds reaching the Plant site during the months of May, June and July generally would have very low turbulence. As they move inland, winds gain somewhat in turbulence in the lower layers due to the surface roughness of the trees and the thermal heating of the land. The most likely postulated release would be from a low elevation and its diffusion would be enhanced by mechanical and thermal turbulence characteristics of the shore with dunes being present between the containment building and the site boundary. On the other hand, winds blowing offshore generally arrive at the Plant site with marked turbulence, but this turbulence is damped out over the lake at some distance from the site.

Dispersion observations on the shores of Lake Michigan indicate that there are phenomena operating at shorelines which greatly enhance atmospheric dispersion. The scale of these phenomena is larger than the scale of the mechanical turbulence generally induced by airflow over a forest canopy or over open fields and orchards. Evidence from dispersion studies performed at the Big Rock Point and Enrico Fermi Nuclear Plants, which are shoreline sites, indicates that these dispersion phenomena are induced by intermediate-scale thermal eddies and marked spatial variations of diffusion regime. A paper by Walke (Reference 23) discusses these phenomena in detail and estimates their effect on diffusion coefficients for use at shoreline sites.

2.5.5 SHORT-TERM DISPERSION PARAMETERS

2.5.5.1 X/Q Determination for TID Analyses

To evaluate the short-term dispersion potential of the atmosphere in the Palisades Plant area, short-term calculations were made of effluent concentrations normalized by source strength (X/Q) of the power plant release. These normalized dispersion values were calculated using meteorological data collected onsite at the 60-meter tower over the period December 1, 1977 to November 30, 1978. The physical release characteristics used in the calculations are given in Table 2-16. Tables 2-17

and 2-18 contain listings of the calculated normalized dispersion values for the exclusion area boundary and low population zone.
The short-term calculations are based on the NRC Regulatory Guide 1.145 ground level modeling technique. The following assumptions were used:

1. Radioactive decay was not used.

2. Terrain influence was not considered.

3. Open terrain recirculation factors were not used.

4. Plume depletion by wet and dry deposition was not used.

5. Building wake adjustment was used.

6. Pasquill-Gifford (Reference 24) diffusion parameters were used.

The NRC Computer Code "PAVAN" was used to make the calculations. A detailed description of the model is given in NUREG/CR-2858 "PAVAN: An Atmospheric Dispersion Program for Evaluating Design Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations." Short term X/Q data from 1983 through 1997 combined with the 77-78 data has been statistically analyzed and conservative X/Q values were calculated (Reference 29). These short term X/Qs are listed in the table below. Radiological consequence analyses based on the technical information document TID-14844 (Reference 31) source term (TID) and that use these X/Q values remain valid.

X/Q's For Offsite Radiological Dose Consequence Analyses

Interval [hr]	SB X/Q [sec/m^3]	LPZ X/Q [sec/m^3]
0 - 2	1.78E-04	2.88E-05
0 - 8	N/A	1.19E-05
8 - 24	N/A	7.68E-06
24 - 96	N/A	2.95E-06
96 - 720	N/A	7.47E-07

SB = Site Boundary, also know as Exclusion Area Boundary (EAB). Offsite doses are calculated only for the first 2 hours after an accident.

LPZ = Low Population Zone

2.5.5.2 X/Q Determination for AST Analyses

The short-term accident X/Q values for the low population zone (LPZ), exclusion area boundary (EAB), and control room were revised as part of the dose reanalysis project for implementing alternative source term (AST). The revised X/Q values are based on guidance provided in Regulatory Guide 1.145, NUREG/CR-2858, NUREG/CR-6331, and Regulatory Guide 1.194. Conservative values of atmospheric diffusion were calculated for appropriate time periods using meteorological data collected onsite during the time period from 1999 through 2003.

2.5.5.2.1 Offsite X/Q Determination

The methodology used for this calculation is consistent with Regulatory Guide 1.145 as implemented by the PAVAN computer code (Reference 33). Using joint frequency distributions of wind direction and wind speed by atmospheric stability, the PAVAN computer code provides relative air concentration (X/Q) values as functions of direction for various time periods at the site boundary (EAB) and Low Population Zone (LPZ). Three procedures for calculation of X/Qs are utilized for the EAB and LPZ; a direction-dependent approach, a direction-independent approach, and an overall site X/Q approach. The X/Q calculations are based on the theory that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all distances for which X/Q values are calculated. The theory and implementing equations employed by the PAVAN computer code are documented in Reference 33.

The EAB distance in each of the 16 downwind directions from the site was set at 677 meters, which is the minimum distance to the exclusion area irrespective of direction. The use of the same distance for each downwind direction is conservative, since no credit is taken for the different distances to the EAB in the various primary directions. The LPZ boundary distance was set at 4820 m. No offshore downwind sectors were excluded from the calculation.

All of the releases were considered ground level releases.

PAVAN computer runs for the EAB and LPZ distances were performed using the data discussed previously. Tables 2-21 and 2-22 contain listings of the normalized dispersion values for the EAB and LPZ. Per Section 4 of Reference 32, the maximum X/Q for each distance was determined and compared to the 5% overall site value for the boundary under consideration. The maximum X/Qs that resulted from this comparison are provided in the table below.

Offsite Boundary χ/Q Factors for AST Analysis Events

Time Period	EAB χ/Q (sec/m^3)	LPZ χ/Q (sec/m^3)
0-2 hours	5.39E-04	6.66E-05
0-8 hours	3.31E-04	3.03E-05
8-24 hours	2.59E-04	2.04E-05
24-96 days	1.53E-04	8.67E-06
96-720 days	7.14E-05	2.54E-06

2.5.5.2.2 Control Room X/Q Determination

The ARCON96 computer code is used by the USNRC staff to review licensee submittals relating to control room habitability (Reference 35). Therefore, the ARCON96 computer code was used to determine the relative dispersion values for the combinations of control room air intakes and inleakage locations. The ARCON96 computer code uses hourly meteorological data for estimating dispersion in the vicinity of buildings to calculate relative concentrations at control room intake and inleakage locations that would be exceeded no more than five percent of the time. These concentrations are calculated for averaging periods ranging from one hour to 30 days in duration. The theory and implementing equations employed by the ARCON96 computer code are documented in Reference 35.

A number of various release-receptor combinations were considered for the control room X/Qs. These different cases were considered to determine the limiting release-receptor combinations for the various events. The specific combinations used for each event are provided in the corresponding Chapter 14 sections.

The resulting X/Qs are listed in Table 14.24-2.

2.5.6 LONG-TERM DISPERSION PARAMETERS

To evaluate the long-term dispersion potential of the atmosphere in the Palisades Plant area, annual average calculations were made of effluent concentrations normalized by source strength (X/Q) of the power plant release. These normalized dispersion values were calculated using meteorological data collected onsite at the 60-meter tower over a five year period. The physical release characteristics used in the calculations are given in Table 2-16. Table 2-19 contains a listing of the calculated normalized dispersion values at the site boundary for 1988-1992.

The long-term calculations are based on the NRC Regulatory Guide 1.111 ground level modeling technique. The following assumptions were used:

1. Radioactive decay was not used.
2. Terrain influence was not considered.
3. Open terrain recirculation factors were not used.
4. Plume depletion by wet and dry deposition was not used.
5. Building wake adjustment was used.

The NRC Computer Code "XOQDOQ" was used to make the calculations. A detailed description of the model is given in NUREG-0324, "XOQDOQ Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations."

2.6 ENVIRONMENTAL SURVEILLANCE

A preoperational environmental survey was established for the Palisades Nuclear Power Plant to determine the naturally existing radioisotopes in the surrounding environment. The preoperational survey determined the use of the local environment and sampled those substances most consumed by the public to establish a valid basis for future comparison of preoperational levels to operational levels. By this comparison, the dose to man from operation of the facility can be determined.

The operational environmental survey is essentially an extension of the preoperational survey. In addition, sampling stations which are located outside of the influence of Plant operation and several local stations in the area of maximum influence are included to determine whether any changes in local environmental activity are due to operation of the facility and to assure that effluent releases are as low as reasonably achievable. The results of the operational environmental survey are submitted in annual reports to the NRC in accordance with the Palisades Offsite Dose Calculation Manual.

Foods are sampled and analyzed for their radioactive content in order to determine their contribution to man's dose by ingestion. Food sampling is conducted on items in the food chain closest to man in order to accurately determine the dose contribution and to account for possible reconcentration of radioisotopes in the food chain.

Air and water are sampled and analyzed for radioactive content to determine their contribution to man's dose by direct intake and their indirect contribution to man's dose via the food chain.

The external gamma dose to man was originally estimated by placing both film and thermoluminescent dosimeters (TLDs) in the environment. At the present time, TLDs are used exclusively in the operational environmental survey.

The total dose to man is then the sum of the following factors:

1. Internal

    a. Ingestion - food and water

    b. Inhalation - air

2. External

2.6.1 SAMPLE SENSITIVITY

Determining the dose to man requires analyses to be performed with sensitivities far below that which would result in a maximum allowable dose. Related to air, water and food, this implies that detection levels must be a small fraction of any maximum concentration allowed in such a sample. However, there is a level of radioactivity in air, water and food below which it is not practical to perform any specific isotopic analysis. Consequently, the sensitivities outlined in Table 2-20 are a compromise between the preceding two requirements.

Specific isotopic analyses will thus be performed only when a gross β count exceeds the following levels.

Air - When a gross β count reveals activity levels in excess of 1 pCi/meter^3, analyses for specific isotopes as listed will be performed, except that an I-131 analysis will be performed on all air samples.

Water - When a gross β count reveals activity in excess of 10 pCi/liter, the specific analyses listed will be performed. A tritium analysis will be performed on all Lake Michigan water samples regardless of gross β count.

Organic - When a gross β count reveals activity in excess of 30 pCi/g, all other listed analyses will be performed.

Milk - Listed analyses will be performed on all samples regardless of gross β count.

2.6.2 SAMPLE TYPE AND FREQUENCY

The specific types of samples to be collected along with the collection frequency are listed in the Offsite Dose Calculation Manual.

2.6.3 SAMPLING STATIONS

The reference area method of environmental surveillance is employed for the operational environmental survey program. Sampling requirements are described in the Offsite Dose Calculation Manual (ODCM).

As described in the ODCM, an inner ring of TLD stations found near the perimeter of the Plant, an outer ring of TLD stations further from the Plant, and remote control TLD stations are used to monitor direct radiation. The inner and outer ring TLD results (under the influence of the Plant) are compared to the control station results (not under the influence of the Plant). Simultaneous increases or random fluctuations in levels of radioactivity in both near site and control stations can be construed not to be of Plant origin. On the other hand, a consistent increase in levels of radioactivity in only the near site stations may be construed to be caused by releases of Plant origin.

The inner and outer rings are placed at a distance from the Plant where the maximum dose to man is expected. This was determined from a compromise of meteorological considerations and availability of fruit and milk producers in the area. The control stations are placed at a minimum of 25 miles and a maximum of 55 miles from the site. The control station locations were chosen from meteorological considerations so that the ground concentration at these stations will be less than 1% of the maximum ground concentrations expected at the local stations.

Dose to man can then be estimated when statistically significant differences occur between the results of sample analysis of the inner and outer rings as compared to the control stations. Dose estimation is performed for ingestion, inhalation and external gamma dose based on radionuclide transport, diffusion and dosimetry models described in Regulatory Guides 1.109 and 1.111.

2.6.4 SAMPLE TYPES

Sampling requirements for the Palisades environmental survey are provided in the ODCM. The sampling locations and samples represent a good cross section of the crops produced in the area. Samples of edible Lake Michigan fish are obtained near the Plant discharge.

The sampling locations and crops produced have been part of the radiological surveillance program. In the future, based on changes in ownership or crop production, it may be necessary to change locations, but the intent of the sampling program will remain the same.

2.6.5 SUMMARY OF PREOPERATIONAL RESULTS

The results of the analyses performed were compared to values from Radiological Health Data and Reports (RHD) where available.

Gross beta activity in surface air samples had values ranging from a maximum of 0.22 pCi/m^3 in July 1968 at Kalamazoo to a minimum of 0.01 observed at several sites in October and November. The average values ranged from 0.13 to 0.03 for the sites near the facility and from 0.10 to 0.03 at the Kalamazoo reference site showing no significant differences. The general trend observed showed high values in July decreasing to minimum in the period October through December and followed by a rise to February and March values, which were approximately 70% of the July values. Increases in the atmospheric burden of nuclear debris were reported in December 1968. This trend and the absolute values seen are typical of surface air results obtained from similar programs during the same period.

Comparison with values reported by the Radiation Alert Network (RAN) shows that the average seen is approximately a factor of 15 below the RAN values of 1-2 pCi/m^3. It should be noted that because of changes in the RAN method of analysis in July 1967 and in the method of reporting to the nearest whole digit instituted in June 1968, comparison with RAN data is difficult. The trends observed in the data from the program at Palisades would be completely masked in the RAN data.

Lake water values from samples taken at the site showed detectable activity in October and November 1968 and in February 1969. An Sr-90 value at the detection limit of 1.0 pCi/L was obtained in February. The method of analysis for tritium was changed in February to provide greater sensitivity and resulted in the positive values being reported. All of these values are typical for this type of sample.

Gross beta values for well water were below the detectable limit of 5 pCi/L for all samples, except the July 1968 sample from a sample station at the Covert township park. This value of 21 pCi/L is probably due to contamination from surface water or other foreign material since one would not expect large, sudden changes in well water activity.

Specific nuclide analysis and gamma spectrometry have shown significant quantities of Cs-137 and Sr-90 in fish. The Cs-137 values range between 0.07 and 0.37 pCi/g and appear relatively constant. The Sr-90 values range from less than 0.01 to 0.04 pCi/g and also appear relatively constant. There do not seem to be differences between types of fish. These values indicate that a significant quantity of fallout has been taken up by the fish. These gamma and gross beta values for fish are comparable to values from other locations throughout the Great Lakes.

Gross beta measurements on crops from the area are typical of results generally seen for this type of sample. The gamma scans showed only the presence of naturally occurring K-40.

Gamma scans on milk samples showed no detectable I-131, Cs-137, Ba-140 or La-140. Specific nuclide analysis gave Sr-90 values ranging from 3.6 to 16.0 pCi/L and Cs-137 values from 9.2 to 39.2 pCi/L. The higher values were obtained on samples from March 1969 and are probably related to cows being returned to pasture and ingesting, through grazing, the winter fallout accumulation. This is also the typical seasonal pattern for these nuclides. The values obtained were comparable to available values reported in Radiological Health Data and Reports for Grand Rapids and Lansing, Michigan. It should be noted that the values for Lansing and Grand Rapids differ by a factor of 2-3, the Lansing values being consistently lower.

Gamma dose rates were measured during the preoperational period using film and thermoluminescent dosimeters (TLDs). Due to problems with early TLD design, the film results during 1968 and 1969 provided the most consistent data and indicated monthly doses in the range of 5 to 10 mrad per month. Refinement in TLD design has provided values consistent with film results, and TLD now is used to the exclusion of film due to ease of handling and lack of fading. There are 17 environmental TLDs located on the site property and 7 located offsite at offsite air sampler locations. In addition to these 24 TLDs, an additional 18 accident TLD packets are placed at 1-2 miles and 4-5 miles from the Plant in each of the 9 overland sectors.

In addition to the film and TLD comparison program at the nine inner rings and three background stations, several film dosimeters and TLDs were placed at the site boundary beginning in early 1969 and have continued during the operational program.

2.6.6 ADJUSTMENTS TO THE ENVIRONMENTAL SURVEY

The environmental survey will remain flexible so that future adjustments can be made as a result of the knowledge gained from past sample collection and analysis. Finding a critical food chain pathway or vector may justify the elimination of a given sample or samples and the addition of others.

In addition to the above, significant changes in the usage of land and water surrounding the facility will be reflected in the program. A new population center, introduction of a new commercial crop or a change in the use of water are all examples of such changes.