Table of Contents

List of Tables

List of Figures

2.0 Site Characteristics

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.0.

THIS PAGE LEFT BLANK INTENTIONALLY.

2.1 Geography and Demography

2.1.1 Site Location and Description

2.1.1.1 Specification Of Location

Oconee Nuclear Station is located in eastern Oconee County, South Carolina, approximately 8 miles northeast of Seneca, South Carolina at latitude 34°-47'-38.2"N and longitude 82°-53'-55.4"W. Duke Power Company's Lake Keowee occupies the area immediately north and west of the site. The Corps of Engineer's Hartwell Reservoir is south of the site. Duke's Lake Jocassee lies approximately 11 miles to the north. Figure 2-1 shows the site location with respect to neighboring states and counties within 50 miles. Figure 2-2 shows the relationship of the site with Lakes Keowee and Hartwell and the topography within 5 miles. Figure 2-3 shows the general geographical and topographical features within 50 miles of the site.

2.1.1.2 Site Area Map

Figure 2-4 shows the site layout, property lines, and other structures within the site area. There are no industrial, commercial, institutional, recreational or residential structures within the site boundary.

Located within 1 mile of the station center are the World of Energy (Visitor Center) and boat docks, the Keowee Hydroelectric Station, the 183 Annex, the South-Lake Services office complex and appurtenances, the Mosquito Control Facility and boat dock, and the Employee Recreational Facilities (including Employee Softball Field Restroom Building, Employee Recreational Site Restroom Building, Picnic Shelter, and boat dock). All of these facilities are Duke properties. Old Pickens Church and Cemetery, an historic property which is not in use, occupies a small property to the east of the station.

The exclusion area is defined as a 1 mile radius from the station center.

2.1.1.3 Boundaries for Establishing Effluent Release Limits

The boundary for establishing gaseous effluent release limit is the exclusion area. The exclusion area is defined as a 1 mile radius from the station center. For the purposes of satisfying 10 CFR Part 20, the "Restricted Area," for gaseous release purposes only, is the same as the exclusion area as defined above. The boundary for liquid effluent is a 154 ft. wide by 216 ft. long area at the Keowee Dam extending from the face of the powerhouse to the crest of the tailrace. This area lies within the l mile radius for establishing gaseous effluent limits. The exclusion area boundary and the site boundary fences for the liquid effluents are shown in Figure 2-5.

Access to the owner-controlled area is normally controlled by automatic gates equipped with magnetic card readers. The OCA is periodically patrolled by security personnel.

2.1.2 Exclusion Area Authority and Control

2.1.2.1 Authority

All the property within the l mile radius exclusion area is owned in fee, including mineral rights, by Duke except for the small rural church plot belonging to Old Pickens Church, rights-of-way for existing highways and approximately 9.8 acres of U. S. Government property involved with Hartwell Reservoir.

The Hartwell property is either a portion of the Hartwell Reservoir or subject to flooding and not suitable for other uses. Duke has obtained from the owners of the church plot and from the United States the right to restrict activities on these properties and to evacuate them of all persons at any time without prior notice if, in its opinion, such evacuation is necessary or desirable in the interest of public health and safety.

The property which is within the exclusion area and which is not owned by Duke is shown on Figure 2-4.

2.1.2.2 Control of Activities Unrelated to Plant Operation

Unrelated activities are limited to the highways through the Exclusion Area, Duke's Visitor Center, Cresent Resources, the Mosquito Control Facility and boat dock, recreation on the lakes, and the Old Pickens Church and Cemetery which are historical landmarks and will not be used for regular services. The only commercial enterprises within the Exclusion Area will be Duke's Keowee Hydroelectric Station, Crescent Resources and the Oconee Nuclear Station.

2.1.2.3 Arrangements for Traffic Control

Arrangements have been made with the South Carolina State Highway Department to control and limit traffic on public highways in the Exclusion Area should it become necessary in the interest of public health and safety.

2.1.3 Population Distribution

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

The 1970 population distribution is based on the 1970 census. The 2010 population projection is a linear extrapolation of the 1910-1960 long term trend adjusted upward to anticipate lake proximity developments extending out as much as 20 miles from the site, particularly in the NW and NNW sectors.

Figure 2-6 shows the location and population of population centers within 100 miles of Oconee. The largest city, Knoxville, Tennessee, located 97 miles northwest of the site, had a 1970 population of 174,587. The nearest population center is Anderson, South Carolina, located approximately 21 miles to the south southeast of the plant, with a 1970 population of 27,556.

2.1.3.1 Population Within 10 Miles

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

Table 2-1 gives the 1970 population distribution within 10 miles of Oconee. The projected population for 2010 are shown on Table 2-2. The current population distribution is shown in Section J of the Oconee Nuclear Site Emergency Plan.

2.1.3.2 Population Between 10 and 50 Miles

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

Table 2-3 and Table 2-4 show the 1970 and projected 2010 population distribution. Figure 2-6 shows population centers within 100 miles of the site.

2.1.3.3 Transient Population

When the Lake Keowee's 300 mile shoreline is fully developed the estimated transient population will be 36,000. This estimate is based on development of lakeside lots, public access areas, and expanded commercial activities to take advantage of expanded recreational opportunities. There will not be any cottages within the Exclusion Area.

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

The estimated transient population within the low population boundary is 2000 for 1970 and 19000 for 2010.

The visitors center, located on Duke Property just north of the plant and within the Exclusion Area, was host to 510,000 people during its first 25 months of operation.

There are no industries within 5 miles of the site therefore no industrial transients.

2.1.3.4 Low Population Zone

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

The actual permanent population within the low population boundary (6 miles from site) is 3620 for 1970 and estimated to be 8900 for 2010.

2.1.3.5 Population Center

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

The nearest population center is Anderson, South Carolina, located approximately 21 miles to the south southeast of the plant (Figure 2-6).

2.1.3.6 Population Density

"HISTORICAL INFORMATION NOT REQUIRED TO BE REVISED"

Table 2-5 and Table 2-6 tabulate the population density to 50 miles for 1970 and projected density for 2010.

2.1.3.7 Updated Population Information

The above sections contain population data for 1970 and population data projections for 2010. Actual population data is subject to constant change. The Oconee Nuclear Station Site Emergency Plan is the licensing document which contains the most recent population statistics based on 10 year census information.

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.1.

THIS PAGE LEFT BLANK INTENTIONALLY.

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1 Location and Routes

Figure 2-3 shows the transportation routes within 5 miles of Oconee. There are no oil or gas pipelines within 5 miles of the site, except that natural gas distribution pipelines are located approximately 3.5 miles from the site in the direction of Six Mile, 2.5 miles from the site in the direction of Seneca, and 2.6 miles from the site in the direction of Walhalla.

2.2.2 Descriptions

2.2.2.1 Description of Facilities

There are no industrial or military facilities or activities within 5 miles of Oconee.

2.2.2.2 Description of Products and Materials

The highways passing through the 1 mile radius exclusion area are State and local roads with infrequent trucking of hazardous chemicals and explosives since the general area is nonindustrial.

Chlorine and hydrazine are stored and used on site as described in Section 2.2.3.1.3.

2.2.2.3 Pipelines

There are no pipelines within 5 miles of Oconee, except for natural gas distribution pipelines located approximately 3.5 miles from the site in the direction of Six Mile, 2.5 miles from the site in the direction of Seneca, and 2.6 miles from the site in the direction of Walhalla. The lines, which run parallel to highways 183 and 130, are considered high pressure with an operating pressure of approximately 400 psi.

2.2.3 Evaluation of Potential Accidents

2.2.3.1 Determination of Design Basis Events

2.2.3.1.1 Explosions

An incident involving fire, chemicals or explosives at the closest point along the highway would be more than 1000 feet from the Reactor and Auxiliary Buildings. We believe that fire or chemical reactions at this distance would not affect plant operation. The blast pressure (Reference 1) from a truck loaded with 40,000 pounds (Reference 2) of TNT at this distance would be less than the design tornado loading on the structures.

2.2.3.1.2 Deleted per 1990 Update

2.2.3.1.3 Toxic Chemicals

If a highway incident should result in the release of toxic gases, the gases under most circumstances would either move in a direction away from the plant or be sufficiently dispersed by the time they reach the plant that they would not interfere with the safe operation of the plant. But if adverse environmental conditions should make it necessary, the plant could safely be operated or shut down from the control room. The control room is an enclosed area which can be isolated from the outside environment. Portable breathing equipment is also provided to allow access to areas outside the control room.

Only small quantities of chlorine are stored on-site since chlorine is not used for condenser cleaning at Oconee. No individual container on the site contains more than 150 pounds of chlorine. The chlorine is used for disinfection of raw water, with one 150-pound container typically being in use, and the maximum total number of containers on hand at any time is four. It is unlikely that leaks from these small chlorine containers could result in dangerous concentrations in the control room, but the control room can be isolated from the outside environment if necessary and portable breathing equipment, suitable for protection against chlorine, is also provided.

Hydrazine in concentrations up to 54.4% can be stored on-site in various size containers. The amount of hydrazine on-site at any time should be ≤10 (340 gallon containers) of 54.4% hydrazine which equals 15,885 lbs. of hydrazine. If a concentration <54.4% is stored on-site, then the total amount of hydrazine allowed on-site should be based on lbs. of hydrazine and not the number of containers. The total amount of hydrazine for any percent concentration should be ≤15,885 lbs. of hydrazine. Hydrazine is used to maintain feedwater chemistry during power operation and Steam Generator wet layup chemistry during outages. Hydrazine is also used as needed to reduce reactor coolant dissolved oxygen concentrations during unit startups. It is unlikely that leaks from hydrazine containers stored on-site could result in dangerous concentrations in the control room. In addition, the control room can be isolated from the outside environment and portable breathing equipment is also available.

2.2.3.1.4 Fires

Liquid material spills would follow the pattern of roadside drainage toward Lake Keowee and Keowee River. On the event flammable material should reach the cooling water intake structure and burn, the cooling water pumps and related equipment would likely not be affected, but the operation of these pumps is not required for plant safety, and the most serious consequence would be a plant shutdown due to lack of condenser cooling water.

2.2.3.2 Effects of Design Basis Events

No design basis events have been identified in Section 2.2.3.1.

2.2.4 References

1. Effects of Impact and Explosion, AD 221 586, National Defense Research Committee, Vol. 1, 1946.
2. Interstate Commerce Commission and Department of Transportation Regulations of Maximum Truck Limit.

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.2.

2.3 Meteorology

Meteorology is evaluated for use in structural design and in consideration of environmental safeguards for gaseous releases. The following paragraphs summarize the atmospheric characteristics pertinent to these design bases.

"HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED"

2.3.1 Regional Climatology

2.3.1.1 General Climate

In addition to synoptic features that are modified in the crossing and descent of the Appalachian Mountains, the mountains cause channeling of surface winds. As a result, the prevailing wind direction is bimodal, with maximum frequencies in the sectors north-northeast to east-northeast and southwest to west.

2.3.1.2 Regional Meteorological Conditions for Design and Operating Bases

In general, the threat of tropical storms in the fall months of the year (and sometimes in other months) is present almost every year. Table 2-7 indicates the frequency of occurrences of conditions which produce some effect on the weather at the nuclear plant site. In the 95 years of record shown, 164 storms of tropical origin affected the area in some manner. There were only 11 years in the 95 in which no storms affecting the area occurred. There were six years where more than twice the average number of storms occurred.

Despite the fact that so many storms have influenced the area, no hurricane conditions which would include damaging winds of major proportions have ever been reported, so far as is known. Normally, by the time a tropical cyclone has passed onto the continent to the nuclear site area, winds have always been reduced below hurricane strength. However, major problems have been encountered with rainfall amounts generally four to five inches within a 24-hour period and occasionally up to nine to ten inches. Stations within a 50-mile radius of the nuclear site have reported up to double the latter amount but normally over more than a single 24-hour period (References 1, 2 3, and 4).

Tornado events are rather rare and cover extremely small areas. In order to provide for more than a superficial estimate, it was decided to ascertain the frequency of tornadoes for Oconee County in South Carolina as well as those which occurred in the peripheral counties in Georgia, South Carolina, and North Carolina. Accordingly, records were examined for the following counties:

In Georgia: Rabun, Habersham, Stephens, Franklin, and Hart

In South Carolina: Oconee, Pickens, and Anderson

In North Carolina: Macon, Jackson, Transylvania, and Henderson

(References 5, 6, 7, 8, 9, and 10 were consulted.)

The records revealed that five tornadoes have occurred in Oconee County and 17 the peripheral counties in the 50-year period from 1916 through 1965. These storms, however, were only those which had tracks long enough to plot. In order to gain a more realistic figure, the overall statistics showed that each of these figures should be multiplied by 2.5 yielding 55 tornadoes in the 12-county area in the 50-year period. This is considered a reasonable estimate of those tornadoes which reached the ground. Funnel clouds not reaching the ground have also been observed but are not included in the above statistics. Tornadoes reach their maximum frequency during the spring months of the year and normally are more likely in April and May at the site.

The values above indicate only 13 tornadoes in Oconee County in the 50-year period and the relative incidence of tornadoes proximal to the site area is small.

Table 2-8 indicates the mean number of thunderstorm days which are encountered in the plant site vicinity. A thunderstorm day is defined as a day in which thunder is heard at any time in the 24-hour period. Past experience indicates that increasing the thunderstorm day statistic by 10 to 15 percent will provide a reasonable estimate of the frequency of actual thunderstorms in the area.

The site is located in a region characterized by a generally high frequency of low wind speeds and calm conditions. These characteristics lead to a relatively high forecast of high-pollution-potential days as shown in Figure 2-7. The duration and frequency of calm and near-calm conditions for three nearly locations are tabulated by season in Table 2-9.

2.3.2 Local Meteorology

"HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED"

2.3.2.1 Normal and Extreme Values Of Meteorological Parameters

Table 2-10 illustrates the overall wind direction and speed statistics for a five-year period (1959-1963) at Greenville, South Carolina. In general, the NE sector and the WSW sector (22.5 degree sectors) dominate the flow over the site area. The NNE, NE, and ENE sectors account for 30.7 percent of all winds while the SW, WSW, and W sectors account for 25.2 percent. These sectors combined then account for 55.9 percent of all winds at the Greenville, South Carolina airport station. This dominance is important as it continues to appear in all wind statistics in varying degrees as the study progresses. Apparently, the main reason for this dominance is the nearby Appalachian Mountain range which causes surface winds to channel toward these directions whenever the opportunity affords itself. The wind rose is schematically shown in Figure 2-8.

Winds of three knots or less occurred 17.4 percent of the time at Greenville. Winds greater than ten knots appear to favor the prevailing directions. (One knot = 0.515 meters per second.)

Table 2-11 illustrates the diurnal variation of wind speeds at various hours of the day. Lighter winds dominate the nighttime hours while the strongest winds tended to occur in the afternoon. The statistics illustrate the typical diurnal pattern of wind speeds.

Table 2-12 shows the frequency of calms and near-calm (winds equal to or less than one knot) conditions at three locations. Calm conditions occur on the average some 332 hours per year or about 4.0 percent of the time. Of these calms, 93.4 percent last less than six hours. Wind speeds equal to or less than one knot occur 4.21 percent of the time and of these conditions 93.5 percent last less than six hours. (The prolonged calm condition shown on Table 2-12 in the 36 - 41 hour winter block was investigated. The observation was made at Charlotte, North Carolina immediately after the anemometer had been moved from a building top level to the ground. Thus one can ignore this as a statistic applicable to the discussion.)

Reference 14 indicates that winds can be expected to reach a highest speed in excess of 50 miles per hour in any month of the year as an estimate of maximum winds to be encountered. Fourteen years of record for Greenville, South Carolina Municipal Airport indicate that 50 miles per hour has been exceeded at least once for every month of the year except September where it was 47. Two months of the year showed values of 70 and 79 miles per hour, the former in January 1948, and the latter in October 1946. Clemson, South Carolina records (Reference 15B) indicate that the highest one-minute wind speed was 73 miles per hour in June of 1948.

Table 2-13 and Table 2-14 illustrate the percentage distribution of annual winds at Athens, Georgia as observed at 0630 Eastern Standard Time. These statistics are derived from an analysis of the Adiabatic Chart records of the Athens, Georgia Rawinsonde data. The period of record is December 1, 1959 through November 30, 1961. The data have been analyzed and documented in Reference 16. The wind roses are schematically shown in Figure 2-9 and Figure 2-10.

The winds observed over Athens, Georgia are probably more representative than those from any other Rawinsonde station near the site. Note that the height above ground in each table is variable. This is because the winds are normally transmitted at standard pressure levels in the atmosphere rather than at fixed heights.

Table 2-13 indicates that the wind sectors which dominate the flow at around 1000 feet above terrain are the NE, ENE, and E sectors (24.54 percent) and the W, WNW, and NW sectors (33.43 percent). These sectors combined account for about 58 percent of all winds. Compared to the surface winds, there has been a shift of dominance from the northeast sector to the northwest - more westerly flow. Calms occurred only 12 times.

Table 2-14 portrays wind conditions 2300-2800 feet above the ground. At this level, wind sector dominance has shifted to westerly flow. In fact, the WSW, W, and WNW sectors account for 33.6 percent of all winds, whereas the SW, WSW, W, WNW, and NW sectors account for 49.8 percent of all winds. Calms occurred less than eight times in the total period of record.

The combination of the surface and upper winds indicates that in the layer between the ground and about 3000 feet, there is likely to be considerable wind shear. As a matter of interest, the change in wind direction with height was examined in a previous study (Reference 16) as a function of the lapse rate in the lower 50 meters of the atmosphere. The results for the two-year period of record are shown in Table 2-15. Note that the directional shear for stable conditions is from 50 to 100 percent greater than for unstable conditions. This favors slightly greater diffusive properties at the site than is calculated with a single wind direction prevailing throughout the diffusion period during a stable condition, particularly if any significant depth of atmosphere is taken into account.

Figure 2-11 represents cumulative probability of wind directional persistence at Greenville, South Carolina, for winds observed annually. Curve A represents the duration of persistence for a single sector wind direction, i.e., from the northeast, or from the southwest. Note that about 70 percent of all wind directions persist for only one hour. About 94 percent persist for three hours or less, etc.

Curve B indicates the persistence of a single wind direction plus or minus one additional direction on either side of the prime direction, i.e., northeast plus north-northeast and east-northeast (67.5 degrees). Curve B shows that 93 percent of all winds persist five hours or less under these conditions. Curve C indicates the persistence of a single wind direction plus and minus two additional directions on either side of the prime direction (112.5 degrees). About 90 percent of all wind directions persist for ten hours or less.

The above wind persistence statistics are derived for all wind directions, including calms. Directional persistence statistics are also calculated. However, the statistics for a single wind sector essentially show similar results to Curve A. Table 2-16 reveals persistence values by direction. Two values are shown for each of the two seasons, the average value P, and the root-mean-square value RMSP. The merit of the RMSP values is that these are reasonable approximations of the 65 to 70 percent frequency of occurrence level. In other words, 65 to 70 percent of all persistence values were less than the RMSP figures.

The remaining two columns in each case are those specific events when the wind condition persisted 24 hours or more. (1-41 means one case of 41 hours duration.)

Table 2-16 deals with wind directions for a single 67.5 degree sector (or single sector plus and minus one sector). Table 2-17 deals with single wind directions for a single 112.5 degree sector (or single sector plus and minus two sectors).

Table 2-16 reveals that the most persistent winds come from the prevailing directions as might be expected. Table 2-17 shows a more confused pattern in general, but again shows prevailing wind dominance.

The nearest station of long-term surface temperature is that of Clemson, South Carolina where some 68 years of record are available. The means and extremes shown in Table 2-18 for minimum temperatures are all on the cooler side than records available from the Greenville WBAS, South Carolina weather station and are regarded as more representative of the nuclear site area. The References for these records are listed as 15A through 15F.

Clemson, South Carolina records are also used to gain estimates of rainfall statistics. Some 71 years of record are available as shown in Table 2-19. Again References 15A through 15F are used as source material. Considerable fluctuation in precipitation from month to month and from year to year is experienced from the normals shown in Table 2-19. From a brief examination of Reference 14, it can be postulated that the normal annual precipitation for the site area is actually about ten percent higher than at Clemson. It is interesting to note that the maximum rainfall occurrences in short periods of time have all been associated with proximal tropical storms or their aftermath. However, severe thunderstorms can produce similar amounts of rainfall in the same periods of time.

By dividing the wind directional frequency for heavy precipitation intensity by the total precipitation wind directional frequency for each direction, directions which are more likely to produce heavy precipitation can be determined. Those directions which produce frequencies greater than the average are north through west and southeast plus south-southeast. These are directions which dominate the showery weather regimes at the site, particularly the thundershowers.

Precipitation occurs only 9.8 percent of all hours of the year.

Statistics related to wind directions and speeds while precipitation is falling are shown in Table 2-20 (Reference 17). The most frequent wind sectors are NNE, NE, and ENE which account for 52 percent of all precipitation winds. The table is set up in terms of precipitation intensities. Precipitation rates determine these intensities and are normally classed as light, moderate and heavy. Approximately 90 percent of all precipitation at Greenville, South Carolina during this five-year (1959-1963) period was light, seven percent was moderate, and about three percent was heavy. The precipitation wind rose is schematically shown in Figure 2-12.

Comparison with all of the surface wind data in Table 2-10 shows that with winds from the southwest through west to north (the mountain exposure side), precipitation occurs about five percent of the time, while all other directions experience twice this percentage.

In 1961, Pasquill (Reference 18) suggested that a relationship might be established which would be useful for estimating the frequency of various wind-temperature lapse rate conditions for a given area. The inputs were:

Time of Day

Cloud Cover

Surface Wind Speed

The wind speed that was used was that observed at ten meters above the ground. Essentially his classification system identified six categories of stability regimes. These have come to be known as Pasquill categories. These are:

Pasquill Categories	*Stability Class*
A	*Extremely Unstable*
B	*Unstable*
C	*Slightly Unstable*
D	*Neutral*
E	*Stable*
F	*Extremely Stable*

Although Pasquill suggested the initial classification scheme, it remained merely a scheme until Turner (Reference 19) quantified it into a reasonably rigorous method. The technique is amenable for use with standard United States Weather Bureau hourly weather observations which are readily available at the National Climatic Center at Asheville, North Carolina, for certain specific United States Weather Bureau weather stations - namely those which observe the weather 24 hours per day throughout the year.

The closest station to the site which maintains such records is Greenville, South Carolina. Data was procured for the Greenville WBAS, South Carolina location (References 20 and 21) and the classification of the hourly weather records into Pasquill categories was accomplished for the two-year period of records selected for analysis.

The Pasquill categories selected follow:

Pasquill Category	*Stability*
A-B	*Unstable*
C	*Slightly Unstable*
D	*Neutral*
E	*Stable*
F	*Extremely Stable*

The period of record was December l, 1959 through November 30, 1961. The results of these classifications are shown in Table 2-21 and Table 2-22. A wind direction rose for Pasquill E and F conditions is shown on Figure 2-13.

Table 2-21 shows the percentage frequency of occurrence of the Pasquill categories and their associated mean wind speeds by direction. All values in the percentage columns are in terms of percent of total observations. Column 1 deals with the Pasquill C category, Column 2 with the Pasquill D category, Column 3 with the Pasquill E and F categories, while Column 4 deals with the Pasquill F category alone. All winds are in knots. Total percentages by categories are also shown.

Table 2-22 completes the Pasquill classification effort. Column 5 deals with Pasquill A-B, unstable categories or "Lapse" conditions. Column 6 deals with a category which normally falls under Pasquill A-B but does not if a stack is used to vent at the site. Column 6 indicates the percentage frequency of fumigation from a stack release. Fumigation is typical of the early portion of the day between sunrise and roughly ten AM.

Column 7 of Table 2-22 shows the results of combining all wind data. Note particularly the dominance of northeasterly and west-southwesterly flow in the sample data. Column 8 shows the results of a much larger sample of data taken for the entire five-year period, 1959-1963, (Reference 12).

The frequency of wind directions for the limited sample shown in Column 7 is correlated with the much larger sample shown in Column 8. The correlation coefficient is +0.987, showing that the limited sample indeed possesses a very high agreement with the much larger sample.

Work completed over a period of years has produced a useful relationship which was applied to the nuclear site area in mountain-plain relationships. It is found (Reference 22) that with terrain differences of greater than about 200 feet, the minimum or early morning temperature observed on hilltops is fairly representative of the free air temperature at the same altitude above proximal valley locations. Thus, it is possible to obtain estimates of the frequency of temperature inversions by comparing hilltop minimum temperatures with valley floor minimum temperatures. Subsequent tower measurements in the same valley location indicate that this postulation, indeed, possesses considerable merit in assessing the strength and frequency of the low-level temperature inversions. Examination of climatic records (Reference 23) for South Carolina indicates that some estimate of temperature inversion frequency might be possible through a comparison of daily minimum temperatures from Paris Mountain Fire Tower, located seven miles north of Greenville, South Carolina, at an altitude of 2047 feet and Clemson, South Carolina, at an altitude of 850 feet.

Limited data permitted the analysis of some 602 days representing the four seasons of the year for the two-year period of December 1, 1959 through November 30, 1961. It is possible to examine the daily minimum temperature difference (Paris Mountain Fire Tower minus Clemson) for these days and compare these differences with Pasquill Stability classes as observed from hourly weather observations at Greenville, South Carolina, on the same days at hours near dawn. Table 2-23 shows the results. The table essentially shows that, in general, the Pasquill classes do match the proper average temperature differences.

Combined Pasquill E and F conditions logged for the entire two-year period from Greenville, South Carolina, for the dawn hour revealed the following frequency of inversions by season:

Frequency of Pasquill E and F Conditions (Inversions)

	Winter	***Spring***	***Summer***	***Fall***
Two years of Dawn-Hour Records at Greenville, South Carolina	*43.96%*	*56.52%*	*65.58%*	*60.56%*
602 Days of Paris Mountain-Clemson Records	*49.14%*	*54.30%*	*67.41%*	*53.10%*

As a result of the above, it appears that the estimates shown by the Pasquill Stability classes are reasonable estimates for inversion data at and near the proposed nuclear site.

STAR Processing of Greenville-Spartanburg Airport is shown for the period January, 1975 - December, 1975 in Table 2-24. The five-year period of January, 1968 - December, 1972 is shown in Table 2-25. The STAR program gives annual joint frequency distributions of wind speed and wind direction by atmospheric stability. These tables will be used to judge the representativeness of a year of onsite data with regard to long-term conditions (e.g., five-year period) as described in Section 2.3.3.

2.3.2.2 Potential Influence Of the Plant and its Facilities on Local Meteorology

Several modifications to the local climatology occur as site development progresses. The initial clearing and leveling of land at the specific site location produces an increase in drainage potential of light winds within the site boundary.

The addition of the large bodies of water has three effects on meteorology. First, it lessens ground frictional effects and tends to increase the wind speeds, most noticeably under light wind conditions.

Second, the large bodies of water increase the humidity by about ten percent in the area and tend to decrease the frequency of Pasquill F and to increase the frequency of Pasquill E conditions. Third, the creation of a major lake area in the vicinity of the nuclear plant serves to increase the precipitation approximately an additional five to ten percent.

The heat load on the lake, due to the operation of the nuclear plant, results in additional local fogging during some days of the year, although the area beyond the lake that is affected is not expected to be large. The increase of temperature of the lake results in the evaporation of about 32 million gallons of additional water per day from the reservoir into the atmosphere.

The incremental offset in the diffusion climatology due to heated water discharge should be in the direction of improvement, but is not of a magnitude to warrant special emphasis. The effect of warmer surface waters in the vicinity of the discharge increases the speed change of air flow from land to water and decreases the change of wind range for such trajectories (Reference 24). In regard to further modification of low-level stability, additional enhancement is tempered, to some extent, from effects of the relatively large deep reservoir. A conservative assessment would assume some improvement, but minimal impact on the total climate.

Figure 2-2 shows a detailed topography, as modified by the plant, to 5 mi. Figure 2-3 shows the general topography within a 50 mi. radius of the plant.

Figure 2-14 through Figure 2-23 show plots of the maximum elevation versus distance from the center of the plant in each of the sixteen 22.5 degree compass point sectors radiating from the plant to a distance of ten miles.

2.3.3 Onsite Meteorological Measurements Programs

"HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED"

2.3.3.1 Early Meteorological Studies (1966-1975)

Onsite meteorological measurements used in diffusion analyses were conducted for various time periods and measurement locations. These time periods include October 19, 1966 through January 23, 1967, June 19, 1967 through May 31, 1968, March 15, 1970 through March 14, 1972, and January, 1975 through December, 1975. Data for the period June 19, 1968 through June 19, 1969 is discussed in relation to the valley drainage model in Section 2.3.4.2.

The evaluations of two comprehensive meteorological surveys conducted on-site confirm that the meteorological characteristics of the site are favorable for the Oconee Nuclear Station.

The first survey, started in mid-October 1966 and extended until late October 1967, was a study of near-ground diffusion climatology. Wind data were continuously recorded, on a 14 meter pole located near mid-site (see Figure 2-24). Temperature gradients were determined by thermographs located in standard United States Weather Bureau Cotton Region Instrument Shelters stationed on the site at varying terrain elevations. A standard recording precipitation gage with wind shield was installed near the base of the 14 meter pole. The results of this study established the frequency of wind conditions with varying lapse rates near ground. The results are shown below:

1. *Frequency of temperature inversions of total hourly observations was 24 percent.*
2. *Direction of predominating inversion wind was north (Figure 2-25).*
3. *Inversion wind speed average was 1.40 meters per second.*
4. *The minimum average standard deviation of inversion winds in any sector for the one year averages 6.6 degrees.*

Wind roses presenting near-ground data, Figure 2-25, Figure 2-26, and Figure 2-27 compared to Greenville-Spartanburg, South Carolina Airport data (Figure 2-8 and Figure 2-13), reflect wind reorientation by nearby mountain ranges and some channeling by the river valley.

The second survey was started in June of 1967, using the permanent station equipment at the time, to establish meteorological parameters related to elevated (vent) releases. Reference to Figure 2-24 illustrates the arrangement of meteorological instrumentation required to initiate this study. Investigations of winds and atmospheric stability were made at vent effluent levels by wind and temperature gradient measuring systems mounted on the 46 meter tower. In addition to tower meteorological instrumentation, a standard weather instrument shelter containing a thermograph and a mercury-in-glass dry bulb thermometer, for comparison was set up near the tower base. A standard recording precipitation gage with wind shield was also installed nearby.

A brief summary of data through the first year (June 19, 1967 through May 31, 1968) shows the following:

1. *The average wind speed recorded by the anemometer at elevation 1028 ft (232 ft above plant yard level) was 6.5 miles per hour or about 3 meters per second for all conditions, and about 2 meters per second during inversions.*
2. *The dominant all-wind direction was northerly which accounts for 10.98 percent of all observations (Figure 2-28 and Figure 2-29).*
3. *The average standard deviation associated with winds less than 1 meter per second was about 22 degrees. As expected, the standard deviations decreased generally as wind speeds increased.*
4. *A frequency of inversions of approximately 40 percent was found for the one year of tower data compared to 24 percent for near-ground observations. Although the two periods of observations are not chronologically identical, one would expect the inversion duration time to be less near-ground due to more rapid inversion "burn-off"; however, it is also noteworthy that the frequency of inversions for the Greenville-Spartanburg Airport for Pasquill-Turner computations also increased for the year during tower observations compared to near-ground observation period.*
5. *The maximum amount of rain was from the northeast where during the year 7.09 inches of rain fell in an aggregate of 71 hours (Figure 2-30).*

2.3.3.2 Continuous Meteorological Data Collection

Meteorological data has been taken continuously onsite since June 23, 1967. Meteorological measurements include wind direction and speed, horizontal wind direction fluctuation, temperature, and vertical temperature gradient. The current relative position of instruments with respect to station yard is noted in Figure 2-5. Relative elevations of both surface levels and instrument levels are depicted in Figure 2-24.

"HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED"

The location of the 46m wind measuring sensors on the microwave tower (Figure 2-5), was appropriate for estimating wind direction and speed for vent releases. Inasmuch as low level flow direction could not be adequately represented by a 10m sensor due to 20m trees near the tower base, all low level input was derived from sensors atop the tower. Wind speed was adjusted by a power law relationship in accordance with the evaluation in Reference 25. The location of the 46m meteorological system was taken as reasonably representative of topography in the vicinity of the plant with respect to wind direction and vertical temperature gradient. The surface immediately below the tower was characterized as a grassy area.

The effect on vertical temperature gradient from the positioning at 1.5m (June 23, 1967 to February 24, 1977) was to introduce some uncertainty where partially elevated releases were concerned. Consequently, the lower level was moved to 10m on February 24, 1977. The following is offered as the limits in uncertainty in delta temperature measured at 1.5m. A bias toward very unstable lapse rates during the day is seen by the occurrence of intense lapse conditions in the existing data. It was suspect, however, after observing daytime stability Class A rates at other Duke Power lake sites, in that the total number of Class A conditions would not change appreciably with the lower sensor at 10 meters. The effect of the 20 meter trees on unstable lapse rates should not have been significant. These trees were not sufficiently dense to constitute a canopy, and the effect could be disregarded during well mixed conditions. The bias towards more stable profiles at night did not readily appear in the strength of inversions typical at the site. This condition was not unexpected since the 20m trees would provide radiative exchange, to some extent, tending to sustain relatively warmer temperatures near the ground. Assuming the effect of the trees was to shift the temperature profile below 20 meters toward a less stable rate, the measured gradient with the 1.5m sensor could be slightly less stable or slightly more stable than a gradient measured with a 10m sensor. No pronounced bias toward anomalously stable conditions is expected in the pre-February 24, 1977 data.

Table 2-26 depicts joint frequencies of wind direction and speed by stability class for the period March 15, 1970 through March 14, 1972. Stability is defined in terms of vertical temperature gradient and indexed as follows, for the period:

Stability Class	***Vertical Temperature Gradient Range (°c) between 46m and 1.5m***
ONS	*46m - 1.5m dT* ***(°c)***
A	$dT \leq -0.85$
B *C*	$-0.85 < dT \leq -0.67$
D	$-0.67 < dT \leq -0.22$
E	$-0.22 < dT \leq +0.67$
F	$+0.67 < dT \leq +1.78$
G	$dT > +1.78$

Table 2-27 is a display of the joint frequency of wind direction and speed by atmospheric stability type for both low-level and high-level wind summaries for the period, January, 1975 through December, 1975. Comparison of Table 2-27 with Greenville-Spartanburg Airport data (Table 2-24 and Table 2-25) forms the basis for judging the representativeness of data for this time period with regard to long-term conditions (e.g., five year period). Consideration of wind speed by stability type for the two periods shows a lower wind speed in general for the period January, 1975 through December, 1975; the occurrence of calms and winds less than 4 knots are up about four percentage points from 23 percent for the period January, 1968 through December, 1972. A slight shift in stability is noted for the period January, 1975 through December, 1975; intermediately stable and unstable Classes E, F, and C, respectively, decreased while strongly stable and unstable Classes G, A, and B increased. Minor changes in wind direction frequencies are also noted for the period January, 1975 through December, 1975; prevailing wind sectors north, northeast, south, southwest, and south-southwest increased their frequency, at the expense of the other sectors. On balance, the period is taken as reasonably representative of long-term conditions in the vicinity of the site.

When the lower temperature sensor was moved from the 1.5 m level to the 10m level on the microwave tower the ranges in vertical temperature gradient, used to determine stability class changed to the following(22 Feb 1977 -22 April 1988):

Stability Class	***Vertical Temperature Gradient Range (°c) between 46m -10m***
ONS	*46m - 1.5m dT* ***(°c)***
A	$dT \leq -0.68$
B *C*	$-0.68 < dT \leq -0.54$
D	$-0.54 < dT \leq -0.18$
E	$-018 < dT \leq +0.54$
F	$+0.54 < dT \leq +1.44$
G	$dT > +1.44$

Since April 17, 1984, operational measurements have consisted of near real-time digital outputs in addition to the previous analog system. An entirely new set of instrumentation was installed at this time, including the measurement of dew point at the 10 m level. A supplemental low-level wind system at 10 m level was installed January 30, 1981, (see Figure 2-5 and Figure 2-24). The type of rain gauge was changed to a tipping bucket rain gauge, and was relocated near the supplemental wind system, as well.

1988-Present

The primary meteorological tower was relocated to approximately 1750 ft. northwest of its original location at the microwave tower on April 23, 1988. Relocating the meterological tower became necessary due to the erection of the new Administration Building near the microwave tower. The building's close proximity to the tower would have significantly influenced air flow near the tower. The relative position of the new tower is shown in Figure 2-4 and Figure 2-5 and the instrumentation elevations relative to the plant are given in Figure 2-24.

The new 60 meter high meteorological tower began operation on April 23, 1988, with wind speed and direction measured at the 10m and 60m levels and delta temperature measured between these intervals. The dew point temperature system was not reinstalled, since no regulatory requirements for this parameter at Oconee Nuclear Station. Instrument specifications are the same as those given in the 1984-1988 listing, with the exception of discontinued dewpoint measurements. Both upper and lower wind direction sensors for the northwest tower were upgraded from potentiometric sensors to resolver sensors. This improved performance and reliability. The wind direction sensor for the supplemental tower at Keowee River was upgraded June 22, 1990. The wind speed range was set at 0-60 mph until September 11, 1996, when it was increased to a range of 0-90 mph.

Because of the change in distance between temperature sensors (50m) for measuring ΔT, the stability classifications are defined by new delta temperature ranges as given below:

Stability Class	***Delta Temperature Range (°C) Between 60m - 10m***
A	$dT \leq - 0.95$
B	$-0.95 < dT \leq -0.85$

Stability Class	*Delta Temperature Range (°C) Between 60m - 10m*
C	*-0.85 < dT ≤ -0.75*
D	*-0.75 < dT ≤ -0.25*
E	*-0.25 < dT ≤ +0.75*
F	*+0.75 < dT ≤ +0.2.00*
G	*dT> +2.0*

Instrumentation signals are processed digitally, transmitted via buried cable to the plant, and then processed back to analog for use by the chart recorders and the plant OAC at the time 1-minute average data collection began which is available on the OAC's in the Control Room.

Near real-time digital outputs of meteorological measurements are summarized for end-to-end 15 minute periods for use in a near real-time puff-advection model to calculate offsite dose during potential radiological emergencies. The Operator Aid Computer (OAC) system computes the 15 minute quantities from a sampling interval of 60 seconds. It calculates 15 minute average values for high and low level wind direction and speed; 15 minute averages are also calculated for delta temperature and ambient temperature. Total water equivalence is computed for precipitation. All 15 minute values are stored with a 24 hour recall. Permanent archiving of data from the digital system is made by combining the 15 minute quantities into one hour values.

Periodic equipment calibration and maintenance checks are performed in the field for all parameters, as specified by station procedure. Semiannual calibration checks are performed as per associated station procedures, listed below.

Instrument specifications for operational measurements are:

1. *Wind Direction*
   a. *Manufacturer MetOne*
   b. *Time-averaged digital accuracy ± 3 degrees of azimuth*
   c. *Time-averaged analog accuracy ± 6 degrees of azimuth*
   d. *Starting threshold 0.3m/sec at 10 degrees initial deflection*
   e. *Damping ratio 0.4 at 10 degrees initial deflection*
   f. *Distance constant 1.1m*
2. *Wind Speed*
   a. *Manufacturer MetOne*
   b. *Time-averaged digital accuracy ± 0.27 m/sec for speeds < 27 m/sec*
   c. *Time-averaged analog accuracy ± 0.40 m/sec for speeds < 27 m/sec*
   d. *Starting threshold 0.45 m/sec*
   e. *Distance constant 1.5m*
3. *Temperature*
   a. *Manufacturer MetOne*
   b. *Time-averaged digital accuracy ± 0.3 degrees C*

  c. *Time-averaged analog accuracy ± 0.5 degrees C*

4. *Delta Temperature*
   a. *Manufacturer MetOne*
   b. *Time-averaged digital accuracy ± 0.10 degrees C*
   c. *Time-averaged analog accuracy ± 0.15 degrees C*
5. *Precipitation*
   a. *Manufacturer MetOne*
   b. *Digital accuracy ± 6% of total accumulation at 15 cm/hr*
   c. *Analog accuracy ± 9% of total accumulation at 15 cm/hr*
   d. *Resolution 0.25mm*

2.3.4 Short-Term Diffusion Estimates

2.3.4.1 Objectives

Conservative and realistic estimates of atmospheric dilution factors at the site boundary or exclusion area boundary and at the outer boundary of the low population zone are provided in this subsection for various time periods to 30 days. Various periods of onsite and offsite data are used in the different studies conducted and are noted in the text where appropriate.

"HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED"

2.3.4.2 Calculations

Reference 26 indicates that the equation used for calculating the two-hour site boundary relative concentration is:

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

In this equation σ_y and σ_z are the standard deviations of the cloud concentration in the horizontal and vertical directions, respectively. These values are normally determined from on-site observations. In lieu thereof, it is permissible to use graphical values as shown in Reference 27. The σ_y σ_z values are those which are appropriate for the one mile (1610 meters) exclusion radius of the site.

Normal assumptions to be used with this equation are:

1. *Moderate temperature inversion - Pasquill F Conditions prevail.*
2. *Unidirectional wind for two consecutive hours.*
3. *Average wind speed ($\bar{u}$) is one meter per second.*
4. *Building shape factor (c) is between 0.5 and 2.0.*
5. *Building cross-section (A) is in square meters.*

Each of the entry values to the equation is discussed below.

Pasquill F conditions occur frequently at the site. Their overall frequency has been documented at 24 percent in an earlier section of this report. It is estimated that this frequency will diminish to about 12 percent when all lakes in the vicinity of the nuclear plant are full. The frequency of Pasquill F conditions *is expected to diminish, while Pasquill E conditions will increase from a current eight percent to about 14 percent of all observations. Thus, there is about a 50-50 chance, once the site is completed, that an inversion condition will be either Pasquill F or E.*

The assumption of the unidirectional wind for two hours was examined. Neglecting calms, in a sample of 547 hours of Pasquill F conditions, only 68 cases were found where winds persisted from the same direction for two hours. Thus, it appears that this assumption is conservative.

The average wind speed ($\bar{u}$) observed under Pasquill F conditions (neglecting calms) was found to be 1.9 meters per second for the Greenville area. It is recommended that this wind speed be used for on-site wind speed estimates.

The building shape factor (c) was assumed to be equal to 1.0.

The cross-sectional areas of the buildings are shown in Figure 2-31. The minimum total building cross-section is 5180 square meters, while the front view area is 6792 square meters. The minimum building complex cross-section will be oriented in such a manner as to take advantage of increased flow due to site air drainage patterns, although no credit is taken for this in the analysis.

The values for entry into the equation are:

$\bar{u}$ = *1.9 mps*

σ_y = *60 m*

σ_z = *20 m*

$\frac{X}{Q}$ = 5.9×10^{-5}

c = *1.0*

A = $5180\ m^2$

An investigation was conducted to determine the most pessimistic theoretical 24-hour period at the site.

Thirty months of data from Greenville, South Carolina were scanned and those days where the average wind speeds for the entire day were approximately two meters per second or less were studied in detail. Thirty-seven cases were documented. Each hour of each day was classified according to the Pasquill method and a composite was derived which shows the poorest diffusion condition observed for each hour of the day during the 37 cases examined. The composite conditions are shown in Table 2-28.

Examination of Table 2-28 indicates that the poorest composite diffusion day would be to start at 1700 hours and maintain a Pasquill F condition for 16 consecutive hours, then one hour of Pasquill E, and finally seven hours of Pasquill D. This could be referred to as the most pessimistic theoretical 24-hour day for diffusion. (Meteorologically, this type of day would be difficult to achieve since cloud cover would be required to arrive immediately after dawn. Normally, if low cloud cover forms, it indicates that moisture sufficient to raise the probability of fog to very high values must have existed. In which case, fog would have been expected earlier, and some relaxation of the F and E criteria for the early morning hours would be realized).

This condition (as shown in Table 2-28) was not observed. It merely serves to document what might be termed a poorest possible diffusion day. This day is recommended for use in diffusion calculations.

Dispersion factors (X/Q, seconds m^{-3}) as shown in Table 2-29 are to be used for accident (10CFR100) and routine operational (10CFR20) analyses. The 1973 SER (Reference 30) for addition of Units 2 and 3 superceded the values originally agreed to for Unit 1 in 1970. Dispersion factors for elevated releases *were based on analysis of on-site meteorological data. The factors given for ground releases were negotiated through discussions with the AEC/DRL staff during the early summer of 1970. These discussions were related to the additional meteorological studies in support of the 0 to 2 hour Valley Drainage Model presented later in this subsection. During the negotiations, Duke has agreed to reduce the Reactor building design leakage rate from 0.5 percent by volume in 24 hours to 0.25 percent by volume and increase the atmospheric dispersion factors for ground releases. It was agreed to depart from the dispersion factors for ground releases as submitted previously and supported by the Near Ground Study and the Valley Drainage Model. The accepted ground release dispersion factor at the exclusion area boundary (one mile) for Oconee Units 1, 2, and 3 was originally* 1.16×10^{-4} *for the 0-2 hour analysis. This value was then increased to 2.20 E-4 by the 1973 SER..*

Table 2-30 indicates appropriate dispersion factors to be used during various release conditions. (e.g. averaging times and releases modes.)

Estimates of atmospheric dispersion of radioactive effluents employed a Gaussian straight-line trajectory model for evaluation at routine releases. The data of 1975 used in Section 2.3.3 was applied as a data base for these estimates. Joint recovery of wind speed, direction, and stability data was 86 percent for the period.

The calculational grid contains 504 receptors. Seventy-two receptors are located at five degree intervals on each of seven radii from the Exclusion Area Boundary to a distance of five miles from the nearest reactor vent.

The model calculated hourly relative concentration (X/Q) values at each receptor for each hour of the period. These values were accumulated, then averaged to obtain the field of annual average X/Q values.

Releases from the 60 meter vent stacks were considered partially elevated and partially ground level releases. The fraction of the plume material which remains elevated depends on the ratio of exit velocity to wind speed at release height. This fraction was calculated from equations 7 and 8 of Regulatory Guide 1.111.

Plume height for elevated releases was calculated from equation 4 of Regulatory Guide 1.111. Stack downwash is determined from equation 5 of the same reference. Plume rise is computed from the exit velocity (20 m sec^{-1}*), stack diameter (1.8 m) and annual mean wind speed at vent height (3 m* sec^{-1}*) according to Reference 28. The effect of terrain on effective plume height is included according to Reference 29. If all heights are referenced to plant grade,* h_e *is the effective plume height without terrain correction, and* h_t *is the height of the terrain feature: then the corrected plume height is* $h_e - h_t/2$*. An exception noted is that plume height is constrained to remain between* h_e *and* $h_e/2$*. The* h_t *values represent the highest terrain in the vicinity of the receptor within the 22.5° sector.*

The equation employed for each hourly X/Q calculation for the ground release portion is

$$(X/Q)_g = \frac{F_g}{u_1(\pi\sigma_y\sigma_z + cA)} \exp\left[\frac{-y_1^2}{2(\sigma_y^2 + cA/\pi)}\right]$$

The equation employed for the elevated portion is

$$(X/Q)_e = \frac{F_e}{u_2\pi\sigma_y\sigma_z}\left[\exp\left(\frac{-y_2^2}{2\sigma_y^2}\right) + \exp\left(\frac{-H^2}{2\sigma_z^2}\right)\right]$$

F_g *and* F_e *are the fractions of the plume which are ground level and elevated respectively.*

u_1*and* u_2 *are the low level and high level average wind speeds respectively (m/sec.). A minimum value of .447 m/sec is assumed.*

cA is the mixing zone for the aerodynamically entrained effluent. It is one half the cross-sectional area of the adjacent containment structure normal to the wind, that is 1150 m^2.

Y_1 *and* Y_2 *are the lateral distances of the receptor from the wind direction vectors* u_1 *and* u_2 *respectively.*

H is the plume height considering all corrections as discussed above (m).

σ_y *and &sigma*$_z$ *are the crosswind and vertical plume standard deviations (m) which are functions of atmospheric stability and distance downwind. Stability categories were determined by vertical temperature gradient according to Regulatory Guide 1.23. Standard deviation values were consistent with Reference 19.*

The factor $(\pi\sigma_y\sigma_z + cA)$ *is a measure of plume spread. This factor was restricted to be no greater than* $(3\pi\sigma_y\sigma_z)$ *as recommended in Regulatory Guide 1.111.*

The $(X/Q)_g$ *values were modified to account for plume depletion by dry deposition. The method employed was as recommended in Regulatory Guide 1.111.*

The X/Q value at each receptor for each hour is the sum of the elevated contribution and the ground level contribution. Successive hourly values were calculated to crosswind distances of ± 20 degrees from observed wind directions. Points in the computational grid beyond ± 20 degrees for any one hour were assumed at zero relative concentration for that hour.

Regulatory Guide 1.111 suggests the use of a correction factor to adjust the computed X/Q values. The Oconee station is located in a river valley which does induce some channelling and valley drainage wind; therefore, the river valley correction factors of the above reference are applicable. Although the derivation of these factors is not presented in the Guide, they are a result of a limited comparison of a Gaussian straight-line X/Q projection and variable trajectory model X/Q projecton for a hypothetical valley site where all winds are parallel to the valley axis. Also, recirculation of effluent with a time scale of about 24 hours is the most probable cause of the different X/Q values. A significant percentage of winds not along the valley axis at Oconee and the relatively short duration of higher activity effluent releases would result in lower correction factors or no correction at the Oconee station. Since there was no evidence to confirm or quantify the above hypotheses, the indicated correction factors for river valley sites were applied. The resulting X/Q values are conservative estimates.

The diffusion model used for this study differed from the recommendations of Regulatory Guide 1.111. The principal differences from the Guide were as follows:

1. *X/Q values are calculated at 5° intervals instead of averaged over 22.5° sectors;*
2. *X/Q values are accumulated from a chronological record of meteorological data instead of employing the joint frequency distribution developed from the meteorological data; and*
3. *For the purpose of achieving realistic X/Q estimates, a less conservative terrain correction is employed.*

Because the onsite winds were recorded to the nearest 5° direction, the model effectively assumes that the plume centerline impacts some radial line of receptors at each hour. This assumption is slightly more conservative than the sector average approach. The use of a time series of meteorological data would be no different from the use of a well formulated frequency distribution of the same data. Finally, the terrain correction prohibits impaction of the plume centerline onto terrain features, but does simulate the approach of the plume toward hills as they are forced over or around the obstruction.

Values for dry deposition (m^{-2}) *were calculated according to Regulatory Guide 1.111. These D/Q values account for the terrain correction factors considered above. Also they consider the fractional breakdown of elevated and ground level plume contributions to D/Q in the same manner as the X/Q values above.*

Wind direction, speed, and stability frequencies for these calculations were obtained from a joint frequency distribution of hourly onsite meteorology for the period of record (1975).

All X/Q and D/Q values at specific receptors were interpolated from isopleth fields generated using the above mentioned receptor grid.

Values of X/Q, adjusted for dry deposition, are shown for selected receptors in Table 2-31. Relative deposition values, depicted in Table 2-32, are computed for the same set of receptors. X/Q values, which do not allow for removal processes, are presented in Table 2-33.

For the 0 to 2 hour accident relative concentration, X/Q, a value of 7.41 x 10^{-5} *was submitted based on the valley drainage concept. Additional meteorological studies were performed subsequent to this submittal which gave evidence that the valley drainage model is conservative. These studies show a X/Q value of 6.12 x* 10^{-5} *as being descriptive of the 0 to 2 hour accident relative concentration; therefore, the relative concentration value of 7.41 x* 10^{-5} *will not be changed. The following is a description of additional meteorological studies supporting this conclusion.*

The site dispersion characteristics were investigated with five instruments (Figure 2-32) indicating and recording wind direction and speed, two of which were elevated. During these studies, vertical temperature gradients were measured at two locations. Fifteen SF_6 *(Sulfur Hexafluoride) gas-tracer experiments were conducted under poor diffusion conditions, during periods with a temperature inversion, without fog or precipitation. Sampling points are shown in (Figure 2-33) with the* SF_6 *test release point shown in (Figure 2-33).*

The 0 to 2 hour accident relative concentration was recalculated using the equation $X/Q = (\bar{u}\pi\sigma_y\sigma_z)^{-1}$. *Wind speed was obtained from the microwave tower instrument. Standard deviations of the lateral concentration distribution (Sigma Y) were computed from Pasquill assignments for standard deviations of the horizontal wind azimuth (Sigma Theta). Standard deviation of the horizontal wind was derived from wind range on the microwave tower instrument. Standard deviations of the vertical concentration distribution (Sigma Z) were determined by vertical temperature gradients for the following class intervals.*

Pasquill Categories	***Vertical Temp. Gradient Class Intervals***
F	*> 2.0F in 150 feet*
E	*2.0 to 0.1F in 150 ft.*
D	*0.0 to - 1.4F in 150 ft.*
C	*- 1.5 to - 2.9F in 150 ft.*
B	*- 3.0 to - 4.5F in 150 ft.*
A	*< -4.5F in 150 ft.*

Pasquill assignments for Sigma Z were again made for categories A, B, and C; however, for D, E, and F gas-tracer test values, were substituted. Test Sigma Y values, although larger than Pasquill values, were not used because analysis for given stabilities and wind speeds showed horizontal dispersion too directionally dependent. It is noteworthy that Sigma Y was computed and used without a building effect term. Gas-tracer test results implied that Pasquill Sigma Z values for D, E, and F were too low. A reasonable representation for standard deviation of the vertical concentration distribution was sought for these class intervals, and based on test results, redefined as follows:

Pasquill Stability	*Sigma Z*
D	*50m*
E	*50m*
F	*40m*

A relative concentration calculation was made for each pair of valid consecutive observations from the microwave tower wind and temperature data. Relative concentration was computed as the average of the two one hour concentrations, if in successive hours, there was an overlap in plume widths defined as 4.30 Sigma Y. Relative concentration was computed from the highest one hour concentration averaged with ten percent of the lowest one hour concentration, if successive hours showed no overlap as above, but did give an overlap of wind range sectors. Finally, relative concentration was computed from the highest one hour concentration averaged with 0, if successive hours showed no overlap of wind range sectors. A relative concentration frequency distribution was determined for the period June 1, 1968 to May 31, 1969 (Table 2-34). A hand calculation check on the relative concentration program ascertained its validity.

Wind speed for each hour was read as the average speed in the preceding 30 minute period. Wind speeds less than or equal to 0.9 miles per hour were read as 1.0 miles per hour. Wind range read for each hour also covered the preceding 30 minute period. Vertical temperature differentials read for each hour covered a period of 30 minutes before and after the hour. Further, vertical temperature differentials for each hour were read: (a) as highest value if all readings positive, (b) as highest value if both positive and negative readings occurred the same hour, (c) as 0 if both 0 and negative readings occurred the same hour, and (d) as the lowest value if all readings were negative during the same hour.

Data from the five wind instruments were evaluated simultaneously and classified into five flow patterns. Comparisons were made of flow patterns during gas-tracer test (January 15, 1970 to March 11, 1970) with those during temperature inversions from available data of an earlier period (October 13, 1969 to November 23, 1969). The most frequent test flow pattern was also the most frequent configuration during the earlier period. All five patterns occurred in both periods.

Sample calculation at 1 mile (1609 meters):

$$X/Q = (\bar{u}\pi\sigma_y\sigma_z)^{-1}$$

Input Parameters:

$\bar{u}$ = 2.5 meters per second

wind range = 15°

vertical temperature differential = 3°F in 150 feet

σ_θ = 15/6 = 2.5°

σ_y = 57 meters

σ_z = 40 meters

X/Q = 1/(3.1416)(2.5)(57)(40)

X/Q = 5.58×10^{-5} *seconds per meter*^{3}

The procedures for the study analysis are summarized below:

1. *Note each pass through a detection area and approximate time of the pass. Place data points marking positions where* SF_6 *is detected in a sequential space order (not time).*
2. *From map of area, determine the average distance from the source to the detection stations.*
3. *Convert the source strength, Q, to micrograms per second from the release rate data.*
4. *Convert the detector scale readings to micrograms per cubic meter.*
5. *Estimate the average wind speed from surface instrumentation, and when applicable, microwave tower winds.*
6. *Utilize computer program to fit a Gaussian curve to the spatially ordered data points.*
7. *Find the first and second moment arms of the distribution of concentration. From the first moment arm, note the center line position; from the second moment arm, note the variance of the horizontal dispersion of the concentration.*
8. *Take positive square root of the variance to get a standard deviation in the horizontal, Sigma Y.*
9. *Obtain center line concentration by X =* $A\sigma_y - 1\ (2\pi)^{-1/2}$ *where A is the area under the distribution curve.*
10. *Calculate the standard deviation in the vertical, Sigma Z, by* $\sigma_z = Q(\pi\bar{u}\sigma_y X)^{-1}$ *which is applicable for a ground release.*
11. *Determine the stability category by the temperature differential on the microwave tower.*
12. *Using graphs of Sigma Y and Sigma Z as functions of stability and distance from a source, locate test values.*
13. *Following the curvature of the Pasquill curves for the stability found in Number 11 above, read Sigma Y and Sigma Z values for one (1) mile from the graph.*
14. *Compute the center line values X/Q at one (1) mile by X/Q =* $[\pi\bar{u}\sigma_y(1\ \text{mi.})\sigma_z(1\ \text{mi.})]^{-1}$.

Results of the gas-tracer experiment are shown in Table 2-35.

A 1.4 wind speed correction factor for the period June 1968 to September 1969 may be warranted, based on a calibration check made October 1, 1969, and comparative wind speed data at Greenville-Spartanburg and Oconee. A relative concentration frequency distribution was determined with a 1.4 wind speed correction factor for the period June 1, 1968 to May 31, 1969, (Table 2-36). No wind speed correction was factored into the 0 to 2 hour accident relative concentration value of 6.12 x 10^{-5}.

Table 2-37 displays comparative wind speed data for Greenville-Spartanburg and Oconee from June, 1968 to January, 1970. Comparisons were made at 13:00 EST for wind speeds equal to or greater than 9.2 mph (i.e. eight knots) at Greenville-Spartanburg.

Supplemental data is presented and includes an all occurrence annual joint frequency distribution, a Pasquill F annual joint frequency distribution, a Pasquill E annual joint frequency distribution, a Pasquill A, B, C, and D annual joint frequency distribution, a relative concentration frequency distribution based on single hour calculations, and SF_6 *sample locations. This material is presented in Table 2-38, Table 2-39 and Figure 2-37.*

To assess the effects of topography on short-term diffusion estimates, terrain profiles were plotted for the 16 principal points of the compass within the 0.5 mile radius. Maximum and minimum elevations were *recorded for each of the eight principal lines drawn to gain an estimate of potential drainage wind flow. The results are shown below:*

Orientation	*Maximum Height Upstream*	*Minimum Height Downstream*	*Difference*
From N to S	*870 feet*	*740 feet*	*130 feet*
From NNW to SSE	*880*	*710*	*170*
From NW to SE	*827*	*690*	*137*
From WNW to ESE	*872*	*680*	*192*
From W to E	*910*	*670*	*240*
From WSW to ENE	*817*	*700*	*117*
From SW to NE	*917*	*750*	*167*
From SSW to NNE	*862*	*760*	*102*

All of the eight lines pass through the central site area, i.e., from one-half mile north through the site center to one-half mile south. In general, the results show that the drainage of wind would be toward the east within the site exclusion radius.

Within the 3.0 mile radius - USGS topographic maps permit estimates of the overall drainage possibilities out to a three-mile radius. Figure 2-38 shows the results of a gross assessment of the terrain. The terrain at elevations equal to or less than 800 feet is shaded to more readily portray the potential drainage wind area. It is important to note that this approximate plot assumes that all proposed lakes are full in the final configuration as proposed for this area. Note that, although drainage to the east and east-south-east is shown for the central site area, the terrain modifies the drainage flow direction to that following the Keowee River.

2.3.5 Long-Term Diffusion Estimates

2.3.5.1 Objectives

The adequacy of onsite meteorological data in terms of long-term diffusion estimates is presented in this subsection. The discussion of long-term diffusion factors is presented in Section 2.3.4 for continuity purposes.

“HISTORICAL INFORMATION IN ITALICS BELOW NOT REQUIRED TO BE REVISED”

2.3.5.2 Calculations

Examination of the joint frequency of wind direction and speed by atmospheric stability class reveals a preponderance of air flow movement down the Keowee River valley axis at Oconee. This is taken as symptomatic of the occurrence of gravity induced flows during stable atmospheric conditions when winds are observed in this direction. In the absence of a straight walled river valley in the vicinity of Oconee, interactions of gravity flows on a smaller scale with the more general gravity flow down the Keowee River valley are postulated for flows near the surface. An indication of near surface flow during these conditions cannot be ascertained by a simple measurement of wind direction at the surface.

Considering the above, tower data at Oconee has been analyzed and can be shown representative of long-term diffusion conditions at the site. For the X/Q and D/Q models employed, meteorological and effluent exit conditions as given above result in only about 2 percent of total radioactivity released at *ground level. Some portion of this 2 percent would occur during synoptic flows, and thus would be adequately represented by tower data. Consequently, annual doses can be represented by X/Q and D/Q estimates with wind direction inputs from tower data.*

For other than gravity flow conditions, air flow trajectories can be assumed to be adequately represented by straight line flow on all time and distance scales to a distance of five miles. For the relatively undulating terrain surrounding Oconee, the measurement of wind speed and delta temperature from the meteorological tower is viewed as characteristic of prevailing conditions at the site.

2.3.6 References

1. *Tropical Cyclones of the "North Atlantic Ocean,* United States Department of Commerce, Weather Bureau, Technical Paper No. 55, 1965."
2. Cry, C.W., "North Atlantic Tropical Cyclones, 1964," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau, Vol. 15, No. 13, 1964.
3. Cry, C.W., and DeAugelis, R.M., "North Atlantic Tropical Cyclones, 1965," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau, Vol. 16, No. 13, 1965.
4. Purvis, J.C., *South Carolina Hurricanes,* South Carolina Civil Defense Agency, 1964.
5. *Tornado Occurrence in the United States,* United States Department of Commerce, Weather Bureau, Technical Paper No. 20, 1960.
6. Wolford, L.V., "General Summary of Tornadoes, 1961," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau Vol. 12, No. 13, 1961.
7. Wolford, L.V., "General Summary of Tornadoes, 1962," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau, Vol. 13, No. 13, 1962.
8. Dye, L.W., "General Summary of Tornadoes, 1963," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau, Vol. 14, No. 13, 1963.
9. Dye, L.W., and Grabill, E.K., "General Summary of Tornadoes, 1964," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau, Vol. 15, No. 13, 1964.
10. Guttman, N.B., "General Summary of Tornadoes, 1965," *Climatological Data, National Summary,* United States Department of Commerce, Weather Bureau Vol. 16, No. 13, 1965.
11. *Mean Number of Thunderstorm Days in the United States,* United States Department of Commerce, Weather Bureau, Technical Paper No. 19, September, 1952.
12. *Percentage Frequency of Wind and Temperature Data for Greenville, South Carolina, WBAS 1/59 - 9/62; Greenville-Spartanburg, South Carolina, WBAS 10/62 - 12/63,* Job No. 6361, United States Department of Commerce, Weather Bureau, National Climatic Center, June 2, 1965.
13. *Duration and Frequency (In Hours) of Calm and Near-Calm Winds - Average of Three Locations, Charlotte WBAS and Winston-Salem WBAS, North Carolina; and Greenville WBAS, South Carolina, 1/59-12/63,* Job No. 6361, United States Department of Commerce, Weather Bureau, National Climatic Center, May 20, 1965.
14. *Climate of the States, South Carolina,* Climatography of the United States, No. 60-31, United States Department of Commerce, Weather Bureau, December, 1959.
15. Department of Agronomy and Soils, South Carolina Agricultural Experiment Station, Clemson Agricultural College.
    a. Series 17, "Daily Temperature and Rainfall Record for Clemson, South Carolina, 1929-1958."

   b. Agronomy and Soils Research Series 38, December 1963, "Temperature, Rainfall, Evaporation and Wind Record for Clemson, South Carolina, 1959-1962."
   c. Series 17, September 1959, "Daily Temperature and Rainfall Record for Clemson, 1929-1958."
   d. Series 44, January 1964, "Clemson College Local Climatological Data, 1963."
   e. Agricultural Weather Research Series No. 4, January 1965, "Clemson University Local Climatological Data, 1964."
   f. Agricultural Weather Research Series No. 7, January 1966, "Clemson University and South Carolina Agricultural Experiment Stations, Climatological Data, 1965."

16. Courtney, F.E., Jr., Analysis of Wind-Lapse Rate Combinations at Athens, Georgia, and Charleston, South Carolina for period December 1, 1959 through November 30, 1961, Lockheed-Georgia Company, Unpublished Study, 1964.

17. *Precipitation Wind Rose for Greenville, South Carolina, January, 1959 through December, 1963,* Job No. 7329, United States Department of Commerce, Weather Bureau, National Climatic Center, August 31, 1966.

18. Pasquill, F., "The Estimation of the Dispersion of Windborne Material," *Meteorology Magazine 90,* pp. 33-49 (1961).

19. Turner, D. Bruce, *Workbook of Atmospheric Dispersion Estimates,* United States Division of Technical Information, 1968.

20. *Local Climatological Data for Greenville, South Carolina, Municipal Airport, December l, 1959 through November 30, 1961,* United States Department of Commerce, Weather Bureau, 1961.

21. *Local Climatological Data - Supplement, for Greenville, South Carolina, Municipal Airport, December 1, 1959 through November 30, 1961,* United States Department of Commerce, Weather Bureau, 1961.

22. Courtney, F.E., and Allen, R.G., *Mesometeorological Parameters Affecting Low-Level Temperature Inversions at the Georgia Nuclear Laboratory,* Paper Presented Before American Meteorological Society Meeting, New York, New York, January, 1959.

23. *Climatological Data - South Carolina, December, 1959 through November, 1961,* United States Department of Commerce, Weather Bureau, 1961.

24. Slade, D.H., "Atmospheric Dispersion Over Chesapeake Bay," *Monthly Weather Review,* Vol. 90, No. 6, pp. 217-224 (1962).

25. *Safety Evaluation by the Directorate of Licensing, United States Atomic Energy Commission, in the Matter of Duke Power Company, Oconee Nuclear Station Units 2 and 3,* Dockets Nos. 50-270/287, July 6, 1973.

26. Di Nunno, J.J., et al, *Calculation of Distance Factors for Power and Test Reactor Sites,* AEC, TID-14844, March 23, 1962.

27. Culkowski, W.M., *Deposition and Washout Computations Based on the Generalized Gaussian Plume Model,* United States Weather Bureau, ORD-599, September 30, 1963.

28. Sagendorf, J.F., A Program for Evaluating Atmospheric Dispersion Considering Spatial and Temporal Meteorological Variations, NOAA Technical Memo *ERL-ARL-44,* 1974.

29. Egan, B.A., "Turbulent Diffusion in Complex Terrain," *Lectures on Air Pollution and Environmental Impact Analysis,* American Meteorological Society, 1975.

30. Oconee Nuclear Station Units 2 and 3 Safety Evaluation Report, "Safety Evaluation by the Directorate of Licensing, U.S. Atomic Energy Commission, In the matter of Duke Power Company

Oconee Nuclear Station Unit 2 and 3 Docket Nos. 50-270/287, "Preface and Section 11.0 and Table 11-2, dated 7/16/1973.

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.3.

2.4 Hydrologic Engineering

2.4.1 Hydrologic Description

2.4.1.1 Site and Facilities

The location and description of Oconee presented in Chapter 1 and Chapter 2 include reference to figures showing the general arrangement, layout and relevant elevations of the station. Yard grade is 796 ft. mean sea level (msl). The mezzanine floor elevation in the Turbine, Auxiliary, and Service Buildings is 796.5 it. (msl). Exterior accesses to these buildings are at elevation 796.5 ft. (msl).

All of the man-made dikes and dams forming the Keowee Reservoir rise to an elevation of 815 ft. msl including the intake channel dike. The crest of the submerged weir in the intake canal is at elevation 770 ft. msl.

Changes to the natural drainage of the original site are shown on Figure 2-4.

2.4.1.2 Hydrosphere

The main hydrologic features influencing the plant are the Jocassee and Keowee Reservoirs. Lake Jocassee was created in 1973 with the construction of the Jocassee Dam on the Keowee River. The lake provides pump storage capacity to the reversible turbine-generators of the Jocassee Hydroelectric Station, located approximately 11 miles north of the plant. At full pond, elevation 1110 ft. msl, Lake Jocassee has a surface area of 7565 Ac, a shoreline of approximately 75 mi, a volume of 1,160,298 Ac-ft., and a total drainage area of about 148 sq mi.

Lake Keowee was created in 1971 with the construction of the Keowee Dam on the Keowee River and the Little River Dam on the Little River. Its primary purpose is to provide cooling water for the plant and water to turn the turbines of the Keowee Hydroelectric Station. At full pond, elevation 800 ft. msl, Lake Keowee has a surface area of 18,372 Ac, a shoreline of approximately 300 mi, a volume of 955,586 Ac-ft., and a total drainage area of about 439 sq mi. The Jocassee and Keowee Reservoirs and the hydroelectric stations located at these reservoirs are owned and operated by Duke.

The area presently provides for a few raw water users. The City of Greenville and the Town of Seneca take their raw water supplies from Lake Keowee. The Town of Anderson, the Town of Clemson, the Town of Pendleton, Clemson University, and several industrial plants take their raw water supplies from Hartwell Reservoir.

Greenville's raw water intake is located approximately 2 miles north of the plant on Lake Keowee. Seneca's raw water intake is located approximately 7 miles south of the plant on the Little River Arm of Lake Keowee. Anderson raw water intake is located approximately 40 river miles downstream of the Keowee tailrace and also supplies Pendleton, Clemson and Clemson University.

The existing raw water intakes for Greenville, Seneca, and Anderson are shown and located relative to the site on Figure 2-39.

2.4.2 Floods

2.4.2.1 Flood History

Since Oconee is located near the ridgeline between the Keowee and Little River valleys, or more than 100 ft. above the maximum known flood in either valley, the records of past floods are not directly applicable to siting considerations.

2.4.2.2 Flood Design Consideration

In accordance with sound engineering practice, records of past floods as well as meteorological records and statistical procedures have been applied in studies of floods through the Keowee and Jocassee Reservoirs as a basis for spillway and freeboard design.

The spillway capacities for Lake Keowee and Jocassee were selected in accordance with the empirical expression for design discharge:

$$Q = C\sqrt{DA}$$

Where Q = peak discharge in cfs

D A = drainage area in square miles

C = 5000, a runoff constant judged to be characteristic of the drainage area

The following tabulation gives pertinent data on this design flood flow:

Lake Keowee(1)	**Lake Jocassee**	
439	148	Drainage area at damsite, sq mi
25,200 (Newry Gage D A 455 sq mi)	21,000 (Jocassee Gage D A 148 sq mi)	Maximum recorded flow at nearby USGS gages, cfs
8-13-40	10-4-64	Data of maximum flow
1939-1961	1950-1965	Period of record
105,000	61,000	Spillway design discharge, cfs
800	1,110	Full pond elevation
815	1,125	Crest of dam elevation
0	0	Surcharge on full pond for design discharge
4	2	Number of spillway gates
38 ft. x 35 ft.	40 ft. x 32 ft.	Size of spillway gates
		Discharge capacity, cfs
107,200	45,700	Spillway
–	16,500 (2 units of 4)	Dependable flood flow through units
107,200	62,200	Total discharge capacity, cfs

Note:

1. Little River and Keowee River Arms

The above discharge capacities assume no surcharge above normal full pond level. Statistical analyses have shown design reservoir inflows for both Lake Keowee and Lake Jocassee equal to respective design discharge capacities outlined above to have recurrence intervals less frequent than once in 10,000 years.

The maximum wave height and wave run-up have been calculated for Lake Keowee and Lake Jocassee by the Sverdrup-Munk formulae. The results of these calculations are as follows:

Wave Height	Wave Run-Up	Maximum Fetch	Lake
3.70 ft.	7.85 ft.	8 miles	Keowee (Keowee River Arm)
3.02 ft.	6.42 ft.	4 miles	Jocassee
3.02 ft.	6.42 ft.	4 miles	Keowee (Little River Arm)

The wave height and wave run-up figures are vertical measurements above full pond elevations as tabulated above.

Studies were also made to evaluate effects on reservoirs and spillways of maximum hypothetical precipitation occurring over the entire respective drainage areas. This rainfall was estimated to be 26.6 inches within a 48 hour period. Unit hydrographs were prepared based on a distribution in time of the storms of October 4-6, 1964, for Jocassee and August 13-15, 1940, for Keowee. Results are summarized as follows:

Keowee	Jocassee	
147,800	70,500	Maximum spillway discharge, cfs
808.0	1114.6	Maximum reservoir elevation
7.0 ft.	10.4 ft.	Freeboard below top of dam

While spillway capacities at Keowee and Jocassee have been designed to pass the design flood with no surcharge on full pond, the dams and other hydraulic structures have been designed with adequate freeboard and structural safety factors to safely accommodate the effects of maximum hypothetical precipitation. Because of the time-lag characteristics of the runoff hydrograph after a storm, it is not considered credible that the maximum reservoir elevation due to maximum hypothetical precipitation would occur simultaneously with winds causing maximum wave heights and run-ups.

Two Reinforced Concrete Trenches extend through the Intake Dike with a minimum elevation of 810+0 with all removable covers removed. These Trenches are protected from wave action by the CCW Intake Structure and the Causeway at the west end of the Intake Structure. Therefore, only the maximum reservoir elevation of 808+0 is applicable with regard to flooding through the reinforced concrete trenches.

The maximum Keowee tailwater level during hydro operation has been calculated to be elevation 672.0 ft. (msl), which is 124 ft. below the nuclear station yard elevation 796.0 ft. (msl).

The maximum discharge calculated, due to hydro operating, is expected to be 19,800 cfs. The minimum discharge calculated with no units operating, is expected to be 30 cfs.

In summary, the above results of flood studies show that Lakes Keowee and Jocassee are designed with adequate margins to contain and control floods which pose no risk to the nuclear site.

2.4.3 Probable Maximum Flood on Streams and Rivers

2.4.3.1 Probable Maximum Precipitation

See Section 2.4.2.2.

2.4.3.2 Deleted per 1990 Update

2.4.3.3 Runoff and Stream Course Models

See Section 2.4.2.2.

2.4.3.4 Probable Maximum Flood Flow

See Section 2.4.2.2.

2.4.3.5 Deleted per 1990 Update

2.4.3.6 Coincident Wind Wave Activity

See Section 2.4.2.2.

2.4.4 Potential Dam Failures, Seismically Induced

Duke has designed the Keowee Dam, Little River Dam, Jocassee Dam, Intake Canal Dike, and the Intake Canal Submerged Weir based on sound Civil Engineering methods and criteria. These designs have been reviewed by a board of consultants and reviewed and approved by the Federal Power Commission in accordance with the license issued by that agency. The Keowee Dam, Little River Dam, Jocassee Dam, Intake Canal Dike, and the Intake Canal Submerged Weir have also been designed to have an adequate factor of safety under the same conditions of seismic loading as used for design of Oconee.

The construction, maintenance, and inspection of the dams are consistent with their functions as major hydro projects. The safety of such structures is the major objective of Duke's designers and builders, with or without the presence of the nuclear station.

2.4.5 Deleted per 1990 Update

2.4.6 Deleted per 1990 Update

2.4.7 Deleted per 1990 Update

2.4.8 Deleted per 1990 Update

2.4.9 Deleted per 1990 Update

2.4.10 Flooding Protection Requirements

See Section 3.4.

2.4.11 Low Water Considerations

2.4.11.1 Deleted per 1990 Update

2.4.11.2 Deleted per 1990 Update

2.4.11.3 Deleted per 1990 Update

2.4.11.4 Deleted per 1990 Update

2.4.11.5 Deleted per 1990 Update

2.4.11.6 Heat Sink Dependability Requirements

Oconee has four sources of water for shutdown and cooldown. These sources are: (1) water from Lake Keowee via the intake canal using the circulating water pumps; (2) gravity flow through the circulating water system; (3) water trapped between the submerged weir in the intake canal and the intake structure in the event of a loss of Lake Keowee and; (4) 8,776,948 gallons of water trapped in the plants Circulating Water System (below elevation 791 ft.) with appropriate valving, pumping and recirculation as a backup in the event of the loss of all external water supplies.

2.4.12 Deleted per 1990 Update

2.4.13 Groundwater

2.4.13.1 Description and Onsite Use

2.4.13.1.1 Regional Groundwater Conditions

The Oconee site lies within the drainage area of the Little and Keowee Rivers which flow southerly into the Seneca River and subsequently discharge into the main drainage course of the Savannah River. The average annual rainfall at the site area is approximately 53 inches.

The deposits of the Little and Keowee drainage basin are generally of low permeability which result in nearly total runoff to the two rivers and their numerous tributary creeks. Runoff occurs soon after precipitation, particularly during the spring and summer months when the soil percolation rates are exceeded by the short term but higher yielding rainfall periods. The area is characterized by youthful narrow streams and creeks which discharge into the mature Little and Keowee Rivers.

Throughout the area, groundwater occurs at shallow depths within the saprolite (residual soil which is a weathering product of the underlying parent rock) soil mantle overlying the metamorphic and igneous rock complex (Reference 1). Refer to Section 2.5. This saprolite soil, which ranges in thickness from a few feet to over 100 feet, is the aquifer for most of the groundwater supply. Wells are shallow and few exceed a total depth of 100 feet. Depths to water commonly range from 5 to 40 feet below the land surface. Seasonal fluctuation is wholly dependent of the rainfall and the magnitude of change may vary considerably from well to well due to the limited areas of available recharge. Average fluctuation is about 3 to 5 feet. Both surface water and groundwater in this area are of low mineral content and generally of good quality for all uses.

To determine the general groundwater environment surrounding the proposed site, groundwater levels were established in numerous domestic wells and exploratory drill holes within a four-mile radius.

Additional data was obtained from interviews with local residents regarding specific wells and discussions with State and Federal personnel. The results of the groundwater level survey are shown on Figure 2-40. The results demonstrate that local subsurface drainage generally travels down the topographic slopes within the more permeable saprolite soil zones toward the nearby surface creek or stream. Gross drainage is southward to the Little and Keowee Rivers which act as a base for the gradient.

Because the topography and thickness of the residual soil, overlying bedrock control the hydraulic gradient throughout the area, and further, the relief is highly variable within short distances, it is not possible to assign a meaningful average gradient for the 15 square mile area surveyed. In all small areas studied within the four-mile radius, the groundwater hydraulic gradient is steep and conforms to the topographic slope. Water released on the surface will percolate downward and move toward the main drainage channels at an estimated rate of 150 to 250 feet per year.

The gradient throughout the area represents the upper surface of unconfined groundwater and therefore is subject to atmospheric conditions. Confined groundwater occurs only locally as evidenced by the existence of isolated springs and a few exploratory drill holes which encountered artesian conditions. These examples do not reflect general conditions covering large areas but merely represent isolated local strata within the saprolite soil which contain water under a semi-perched condition and/or permeable strata overlain by impermeable clay lenses which have been breached by erosion at its exit and recharged short distances upslope by vertical percolation.

The site area is on a moderately sloping, northwest trending topographic ridge which forms a drainage divide between the Little and Keowee Rivers located approximately 0.5 mile to the west and east, respectively. Groundwater levels at the site, measured during the 1966 drilling program and subsequently in four piezometer holes drilled for pre-construction monitoring purposes, ranged from elevation 792 ft. (msl) to 696 ft. (msl). The slope of this apparently free water surface is predominantly southeasterly toward the Keowee River and its tributary drainage channels. An average hydraulic gradient to the southeast of approximately 8.0 percent was plotted along a line of measured wells. This closely conforms to the existing topography as expected. Refer to Figure 2-41 for measured water levels and typical water table profile.

Field permeability tests conducted during the 1966 exploratory program within the saprolite soil yielded values ranging from 100 to 250 feet per year. Refer to Section 2.4.13.2.2. The permeability tests were performed in holes of varying depths to determine if the zoned typed weathering of the saprolite soil affects vertical permeability. Based on the test results, inspection of nearby road cuts, and a study of the exploratory drill logs, it is tentatively concluded that the surficial saprolite possesses lower permeability values than that found in the deeper strata. This correlates with the general profile of the saprolite in that the later stages of weathering produce a soil having a higher clay content than the more coarse-grained silty sand sediments below. This natural process of weathering results in the formation of a partial barrier to downward movement of surface water.

2.4.13.1.2 Groundwater Quality

The surface water and groundwater of the area is generally of good quality (Reference 2). Of the wells surveyed, none were noted where water treatment is being conducted. Temperature of well water measured ranged from a low of 46 to a high of 59 degrees. The majority of readings were from 50 to 53 degrees Fahrenheit.

Water contains different kinds and amounts of mineral constituents. Temperature, pressure and length of time water is in contact with various rock types and soils determine the type and amount of mineral constituents present. Because ground waters are in intimate contact with the host rocks for longer periods of time, they have a more uniform and concentrated mineral content than surface waters. The mineral content of natural surface waters in the Piedmont Province is low due to the relative insolubility of the granitic, gneissic, and schistose host rocks and the reduced contact time caused by rapid runoff in the mountainous areas.

Tabulated below are the surface water constituents reported in parts per million from the Keowee River near Jocassee, South Carolina. The water sample was taken and analyzed by the U.S. Geological Survey, Water Resources Division in June 1965.

Silica (SiO_2)	7.8	Carbonate (CO_3)	0.0
Iron (Fe)	0.01	Bicarbonate (HCO_3)	7.0
Calcium (Ca)	1.0	Sulfate (SO_4)	1.0
Magnesium (Mg)	0.1	Chloride (Cl)	0.6
Sodium (Na)	1.2	Fluoride (F)	0.1
Potassium (K)	0.4	Nitrate (NO_3)	0.1
Dissolved Solids	15.0	Phosphate (PO_4)	0.0
Hardness as $CaCO_3$	3.0		
pH	6.6		
Specific Conductance	13.0		

Present and future environmental monitoring will be completed per Selected Licensee Commitments, the Oconee NPDES Permit Groundwater Monitoring Plan, and the Oconee Landfill Permit requirements. Based on industry experience, a radiological ground water monitoring program was established for Oconee. Refer to Section 11.8

Soil surveys conducted by the U.S. Department of Agriculture in cooperation with the South Carolina Agricultural Experiment Station assign pH values of between 5.0 and 6.0 for the Hayesville and Cecil soil series which are present at the site area (Reference 3). Surface water samples taken from the Keowee River within one mile of the site have a pH of 6.5 to 7.0. Groundwater at the site has a pH ranging between 5.5 and 6.0.

The cation exchange potential can be evaluated by knowing the SAR (Sodium Absorption Ratio), saturation extract values, and the pH of the soil. Two samples of saprolite soil were obtained from drill holes used in determining field permeability values and tested for Sodium Absorption Ratio (SAR). The results are tabulated as follows:

Sample No.	**pH**	**Saturation Extract Values Milligram-equivalent per 100 grains of soil**				**SAR**
		Cond. (mhos)	Calcium	Magnesium	Sodium	
1	5.8	5	0.015	0.000	0.0108	0.122
2	5.7	7	0.010	0.000	0.0166	0.235

Considering the amount of soil that is available is so great, it is evident that many times the amount of strontium and/or cesium contained in the waste could be absorbed. Further, the distribution coefficient for ion exchange of radionuclides with the sediments is dependent on the pH of the water in the formation

(Reference 4). The distribution coefficient is a ratio of the reaction of these radionuclides that are absorbed on the soil and the fraction remaining in solution. It is expected that the soils surrounding Oconee have a ratio in the range of 80 to 150, and consequently a substantially lower average velocity for any radionuclide to that of natural water will result.

The estimated maximum rate of movement of water through the soils is about 0.75 feet per day. Using this rate in relation with the above distribution coefficient, bulk density and porosity of the soil, and ratio of the weight of soil to volume of groundwater it indicates the radionuclide velocity will be about .0015 that of groundwater. Using a safety factor of five for variance in flow and competition for exchangeable sodium ions, it would require more than 1000 years for strontium or cesium ions to migrate a distance of one-half mile. In summary, the movement would be so extremely slow that the saprolite soil is an effective natural barrier to the migration of radionuclides.

2.4.13.2 Sources

2.4.13.2.1 Groundwater Users

The completed field survey of approximately 30 wells determined that groundwater usage is almost entirely from the permeable zones within the saprolite with only minor amounts obtained from the underlying fractured bedrock. Yields from these shallow wells are low, generally less than 5 gpm, and are used to supply domestic water for homes and irrigation of lawns, gardens, and limited amounts for livestock. With only a few exceptions, the wells are hand dug, equipped with bucket lift and/or jet pump, and 40 to 60 feet deep. At present, there is no industrial demand for groundwater within the area.

2.4.13.2.2 Program of Investigation

Permeability tests were performed in borings to determine permeabilities of the soil underlying the site. The tests were run according to the Bureau of Reclamations Field Permeability Tests, Designation E-19. Figure 2-42 shows the arrangement of the field test equipment along with a brief description of the procedure used in determining the soil permeability test results. Test results are from 5 borings as presented in Table 2-93. The formulae used in the calculations of the k values are shown in Figure 2-43.

2.4.13.2.3 Groundwater Conditions Due to Keowee Reservoir

As previously discussed, the groundwater levels at the site range from elevation 792 ft. (msl) to below elevation 696 ft. (msl). The Keowee Reservoir will operate with a maximum pool elevation of 800 ft. (msl). This will result in raising the surface water elevation to that datum on the northern and western portions of land adjoining Oconee. It will also raise the existing groundwater table for those local areas bordering the reservoir where presently the ground water surface is below elevation 800.0 ft (msl). The reservoir will materially contribute in establishing a potentially larger recharge area and where it affects the groundwater will result in a more stable hydraulic gradient with less seasonal fluctuation than presently exists.

Preliminary studies indicate that Keowee Reservoir will create the following groundwater conditions at Oconee.

1. Groundwater should continue to migrate downslope through the saprolite soil on a slightly steeper gradient in a southeasterly direction toward the Keowee River base datum.
2. There are two topographic divides which will separate the nuclear station from the nearby reservoir: (1) a one-half mile wide north-south stretch of terrain west of the site, and (2) a narrow 500 foot wide ridge north of the site. Recent groundwater measurements in drill hole K-12, located atop the northern ridge, show water table conditions exist at about elevation 810 ft. (msl).

3. It is unknown if the saprolite soil existing beneath those topographic ridges provide a hydraulic connection between the nuclear plant and the reservoir. However, it is probable that there will be avenues of slow seepage whereby percolating water may locally raise the groundwater surface at the plant to an elevation approaching elevation 800 ft. (msl). A drainage system will be provided to control all seepage encountered.
4. There should be no reversal of groundwater movement at the site, and all water will percolate downward and away from the plant area.
5. The construction of Keowee Dam and Reservoir will not create adverse groundwater conditions at the plant site.
6. Infiltration of domestic wells, located beyond the proposed one-mile exclusion radius, by surface water from the site should not be possible under the existing or future groundwater conditions imposed by Keowee Reservoir.

2.4.13.3 Deleted per 1990 Update

2.4.13.4 Deleted per 1990 Update

2.4.13.5 Design Bases for Subsurface Hydrostatic Loading

See Section 2.4.13.2.3.

2.4.14 References

1. *Geologic Notes*, Division of Geology, State Devel opment Board, Vol. 7, No. 5, September-October 1963.
2. *Chemical Character of Surface Waters of South Carolina* , South Carolina State Development Board, (Bulletin No. 16C) 1962.
3. *Soil Survey - Oconee County, South Carolina*, United States Department of Agriculture, Series 1958, No. 25, February 1963.
4. *Storage of Radioactive Wastes in Basement Rock Beneath the Savannah River Plant*, DP-844 Waste Disposal and Processing (TID-4500, 28th Ed.), March 1964.

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.4.

THIS PAGE LEFT BLANK INTENTIONALLY.

2.5 Geology, Seismology, and Geotechnical Engineering

2.5.1 Basic Geologic and Seismic Information

Geologic and seismic investigative studies for Oconee Nuclear Station include the following:

1. a review of the available geological and seismological literature pertaining to the region;
2. a geological reconnaissance of the site, performed primarily for the purpose of evaluating the possibility of active faulting in the area;
3. geophysical explorations and laboratory tests to provide parameters for evaluating the response of foundation materials to earthquake ground motion;
4. an evaluation of the seismic history to aid in the selection of the design earthquake that the station might experience; and
5. The development and recommendation of aseismic design parameters for the proposed structures.

The geologic field work at the site started concurrently with the drilling. The site reconnaissance is a continuation of the geologic field work done for the Keowee Dam. Local outcrops, though scarce, are examined and the rock types, joint and foliation orientation noted.

The 21 borings completed at the Oconee Nuclear Site, supplemented by information from the nearby Keowee Hydro Site borings, have been sufficient for a determination of the geologic structure and petrography.

The structures are founded on normal Piedmont granite gneisses. The construction characteristics of the residual soils overlying the rock are known and present no problems in design or construction. The rock underlying the site, below surface weathering, is hard and structurally sound and contains no defects which would influence the design of heavy structures.

The southeastern Piedmont rocks are highly stable seismologically, and the Oconee Nuclear Site should be one of the nation's most inactive areas with respect to earthquake activity.

2.5.1.1 Regional Geology

The regional structure is typical of the southern Piedmont and Blue Ridge. The region was subjected to compression in the northwest-southeast direction which produced a complex assortment of more or less parallel folds whose axes lie in a northeast-southwest direction. The Blue Ridge uplift was the climax of the folding, and it was accompanied by major faulting, along a line stretching northeast through Atlanta and Gainesville, Georgia and across South Carolina, 11 miles northwest of the site. This has been termed the Brevard Fault.

The age of these uplifts has not been agreed on by geologists. The consensus of geologic opinion seems to require a period of severe deformation followed by at least one additional period of less severity. Probably all occurred during the Paleozoic Era, but it has been suggested that the last major uplift was as late as the Triassic (180 million years ago) when the Coastal Plain to the east was downwarped. A number of investigators have maintained that the major deformative movements occurred at least 225 million years ago. However, all the resulting stresses have not yet been fully dissipated.

There is no evidence of any displacement along these faults during either historic times or during the Geologic Recent Era as indicated in displacements in the residual soils that blanket the region. While the well known Brevard Fault passes 11 miles northwest of the site, there is no indication of a major fault in the immediate vicinity of the site. Furthermore, the major faults of the region are ancient and dormant, except for minor adjustments at considerable depth. Therefore, there is no indication of any structural hazard to foundations.

The site is underlain by crystalline rocks which are a part of the southeastern Piedmont physiographic province. This northeastward - trending belt of ancient metamorphic rocks extends northward from Alabama east of the Appalachians, and in South Carolina crosses the State from the Fall Line on the east to the Blue Ridge and Appalachian Mountains on the west. These rocks are generally recognized as being divided into four northeast-southwest trending belts in the Carolinas. From southeast to northwest they are the Carolina slate belt, Charlotte belt, Kings Mountain belt, and Inner Piedmont belt. The Oconee Nuclear Site is in the western, or Inner Piedmont Belt.

The Piedmont metamorphic rocks of the site were formed under many different combinations of pressure and temperature, and represent a complex succession of geologic events. The formerly accepted concept that the Piedmont consists only of the deep, worn-down roots of ancient mountains now seems untenable. The older theory that the rocks were exclusively of igneous origin is being replaced by the proposition that they represent highly metamorphosed sediments which have been folded, faulted, and injected to result in one of the most complex geologic environments in the world. It can be said with certainty, however, that these rocks represent some of the oldest on the continent. The new techniques of dating by radioactive decay have placed the age of the metamorphic episodes that produced these rocks as occurring from 1,100 my (million years) to 260 my ago. The successive northeastward trending bands of rocks vary greatly in lithology from granitic types to highly basic classifications, with gneisses and schists being the predominant classifications petrographically. In summary, the regional geology of the Oconee Nuclear Site can be accepted as typical of the southeastern Piedmont - narrow belts of metamorphic rocks trending northeast, with the foliation dipping generally to the southeast. The regional geologic map is shown in Figure 2-44.

2.5.1.2 Site Geology

2.5.1.2.1 Geologic History, Physiography, and Lithography

The rock present at this site is metamorphic. It is believed to be Precambrian in age; thus, it was formed over 600 million years ago. The complete history of this region is quite complex and has not been fully unravelled. However, it is the consensus of the geologic opinion that the formation consisted of thick strata of sedimentary rocks which were later downwarped and altered by heat and pressure. This first rock formed is termed the country rock.

More than one episode of regional metamorphism transformed the rock into metasediments with accompanying injection and mobilization by plastic flow.

Since the formation of the country rock, most of the mass has been altered or replaced by injection of granite gneiss, biotite hornblende gneiss, and one or possibly more pegmatite dikes.

It is not definite which is the younger: the granite gneiss injection or the biotite hornblende gneiss injection. The limited evidence points to the granite gneiss as the younger of the two.

The pegmatite dikes are the youngest rock known at this site. One such dike is exposed in the road cut on the east side of the state highway passing through the site. It clearly shows the pegmatite cutting through the older rocks, and thus, demonstrates that it is the youngest.

Regional metamorphism, folding, and some minor faulting occurred concurrently much of this early time.

This site is located within the Inner Piedmont Belt, at this locality the westernmost component of the Piedmont Physiographic Province. The topography of the area is undulating to rolling; the surface elevations ranging from about 700 feet to 900 feet. The region is moderately well dissected with rounded hilltops, representing a mature regional development. The area is well drained by several intermittent streams flowing away from the center of the site in a radial pattern. The general station area is shown on the maps in Figure 2-45, Figure 2-46, Figure 2-2, and Figure 2-4.

The local geology of the Oconee Nuclear Site is typical of the southeastern Inner Piedmont Belt. The foundation rock is biotite and hornblende gneiss, striking generally northeast, with the foliation dipping southeast. The rock is overlain by residual soils, which vary from silty clays at the surface, where the rock decomposition has completed its cycle, to partially weathered rock, and finally to sound rock.

The strike of the foliation planes or bands of mineral segregation is north 6 degrees to 15 degrees east with an average dip of 22 degrees to 28 degrees to the southeast. However, due to the local folding or warping at this site, minor variations in the strike and dip of the foliation will occur within the site.

It is almost inevitable that when minor compression folding of this nature occurs, some minor shear displacements will result. We noted only one such displacement. In boring NA-20, at depth of about 79.6 feet below the ground surface, a shear displacement of about one-half inch was recorded. This should not be considered uncommon where hard rock or possibly slightly plastic rock has been folded. While the rock is being folded, minute cracks in the rock develop. The acting compressive forces then cause slight shifts or displacements in the rock resulting in a more relaxed state. The shear displacement noted in boring NA-20, was completely healed or recemented. There is no evidence noted of any recent displacements.

There have been periods of erosion and perhaps even continuous erosion since the close of the Paleozoic Era. The rock now encountered at this site represents the deeper portions of the original metamorphic complex.

The rock encountered at this site is of three main types; light to medium gray granite gneiss, light gray to black biotite hornblende gneiss and white quartz pegmatite with local concentrations of mica, both muscovite and biotite varieties.

The dominate rock type at this site is the light to medium gray granite gneiss. This rock type is generally moderately hard and hard below the initial soft layers encountered in the rock surface. Joints in this rock are brown iron stained in the upper softer layers, but in the deeper harder rock, the joints are not stained. This helps illustrate that the jointing at this site does not control the weathering or decomposition of the rock.

The second most abundant rock type is the biotite hornblende gneiss. The rock is generally weathered or softer to a greater depth than the granite gneiss. This is probably due to the higher percentage of biotite mica. Biotite mica is a potassium magnesium-iron aluminum silicate. The iron content of the biotite mica causes the rate of decomposition to accelerate. However, generally at the deeper portions of the borings, the biotite hornblende gneiss hardness increases to moderately hard or harder. Only a few thin soft layers were noted in this rock in the deeper portion of the borings.

A few layers of hard quartz pegmatite with local concentrations of mica were recorded. The thickness of the pegmatite layers are generally less than three feet. These pegmatite layers are dikes. A dike is a sheetlike body of igneous rock that fills a fissure in the older rock which it encountered while in a molten condition. There is an exposure of mica-quartz pegmatite dike on the east side of the state road cut passing through this project. This dike exposure is about 3.5 feet wide, but due to the lack of knowledge of orientation of the dike, the exact width cannot be computed. The quartz pegmatite encountered in the borings probably represent other smaller dikes of the same material. These dikes are of hard, sound and durable material and should cause no concern to construction or foundation requirements.

2.5.1.2.2 Rock Weathering

Where heavily banded with dark biotite and hornblende the rock is weaker than in its lighter colored portions, since the highly foliated biotite will split along the foliations, and is also more subject to weathering and consequent rock decay. The borings indicate that even after apparently sound rock has been reached local bands or zones of biotite - usually less than a foot thick - may be soft and weathered to considerable depths.

Rock weathering at the Oconee Nuclear Site is about normal for Piedmont biotite gneisses. While highly variable, the normal range of depth before sound rock is reached is 30 to 50 feet. Although the weathering is deep, the resulting residual materials - clays, silts, and weathered rock - are structurally strong, and are used for the foundations of moderately loaded structures.

2.5.1.2.3 Jointing

The rock at this site is moderately jointed. All of the visible rock outcrops were studied in attempting to determine the correct orientation of the joint patterns. Some moderately good rock outcrops were found and several joint pattern orientations measured. While studying and logging the rock cores, all of the joint dips were recorded. The dips of the joint patterns recorded in the rock cores were associated with the dips measured in the rock outcrops.

The rock has apparently not been subjected to stresses causing high concentrations of joints. The core borings indicate that jointing is widely spaced, and has not influenced the weathering pattern. Joints are about equally divided between strike and dip joints, with occasional oblique joints.

Four joint patterns were found, two of which appear to be most significant. The two most significant joint patterns are: strike north 55 degrees east with a dip of 61 degrees northwest, and strike north 28 degrees west with a dip of 85 degrees southwest. The other two joint patterns are: strike north 9 degrees west with a dip of 67 degrees southwest and strike northsouth with a dip of 74 degrees west. The strike and dip of the joints are shown on Figure 2-47.

2.5.1.2.4 Ground Water

Subsurface water is typical of Piedmont area. The top of the zone of saturation, or water table, follows the topography, but is deeper in the uplands and more shallow in valley bottoms. It migrates through the pores of the weathered rock, where the feldspars have disintegrated and left intersticial spaces between the quartz grains. Additional water is contained in the deeper fractures and joints below the sound rock line. The water table is not stationary, but fluctuates continually as a reflection seasonal precipitation. Additional information on ground water is included in Section 2.4.13.

2.5.2 Vibratory Ground Motion

2.5.2.1 Seismicity

Two different methods of evaluating earthquakes are in general used. These are the Modified Mercalli (MM) Intensity (damage) Scale and the Richter Magnitude Scale. The magnitude of, and the intensities resulting from, an earthquake are only indirectly related. The Richter Magnitude is an approximate measure of the total amount of energy released by an earthquake. The Modified Mercalli Intensity, however, is an estimate of the amount of damage caused at a particular site by an earthquake. The intensity of an earthquake at a particular site is only a general indicator of the amount of ground motion since it is a damage criteria and, therefore, dependent on structural considerations as well as ground motion amplitude. The actual amplitude of ground motion at a particular site is dependent upon the following factors:

1. the total amount of energy released by earthquake;
2. the distance of the site from the focus of the earthquake; and
3. the thickness and dynamic properties of the materials above the basement rock complex.

A considerable number of earthquakes have been felt in the region. However, most of these shocks resulted in a little or no damage. A plot of the more significant shocks, occurring prior to 1961 and those having a recorded intensity of Modified Mercalli V or larger, is shown on Figure 2-48, Earthquake Epicenters.

Accurate locations for earthquake epicenters have only been available since the installation of modern seismographs in the region. Previous to these installations, epicentral locations, based upon known damage and reports of people who felt the earthquake, could be in considerable error. Even with instrumental locations, epicenters could be in error by 20 miles or so. It is estimated that major shocks in the region would probably have been recorded for at least 200 years. However, smaller earthquakes before about 1850 were probably either unrecorded or were unreliably located.

Several large earthquakes outside the area shown on Figure 2-48 have been felt in the region. North of the region, the closest major shocks had epicenters in the St. Lawrence Rift valley or on the folded and faulted coast of Massachusetts. The catastrophic earthquakes of 1811 and 1812 near New Madrid, Missouri, approximately 480 miles from the site, are the closest known large earthquakes to the west. These shocks were probably related to the Ozark Dome. With the exception of the earthquakes at Charleston, South Carolina, no major shocks have occurred south or east of the site within the continental United States. These distant large earthquakes are unrelated to any of the known faulting within the crystalline-metamorphic or overthrust zones in which the site is located.

The largest earthquakes close to the site occurred near Charleston in August, 1886, some 200 miles from the site. Two shocks occurring closely in time, had an intensity estimated to be about Modified Mercalli IX at the epicenter and were perceptible over an area of greater than two million square miles. However, damage was confined to a relatively small area. Aftershocks of the main earthquake had intensities ranging up to Modified Mercalli VII. These shocks may be associated with a downfaulted Triassic basin under the coastal plain.

There have been two moderate earthquakes in the immediate vicinity of the plant since construction began.

In 1971, an earthquake occurred near Seneca, South Carolina. The descriptions of this event which occurred at 07:42 (EST) on July 13, 1971 have been examined from various sources. A MM intensity VI was assigned to the event by USGS based primarily on the report of a cracked chimney near Newry, about 10 km south of the present epicentral area. A detailed examination of the buildings and chimneys by Sowers and Fogle (1978) convinced them that the chimney in question had been broken and in a state of disrepair before the shock. They assigned an intensity IV (MM) to the shaking at Newry.

The July 13, 1971 event at 07:42 AM EDT was preceded by a felt shock at about 4:15 AM EDT and followed by at least one felt aftershock at 7:45 AM (Sowers and Fogle, 1978).

On August 25, 1979 (9:31 PM EDST, Aug. 26) a magnitude 3.7 earthquake occurred in the vicinity of Lake Jocassee, South Carolina. This MM intensity VI event was felt in an area of about 15,000 sq. km and was recorded locally on the three station Lake Jocassee seismographic network, and regionally on seismic stations in South Carolina, North Carolina, Georgia, Tennessee, and Virginia. During the period (August 26, 1979 - September 15, 1979) 26 aftershocks were recorded and they ranged in magnitude from -.60 to 2.0.

A list of earthquakes in the region, based on data available at the time of this update, is provided in Table 2-94.

2.5.2.2 Geologic Structures and Tectonic Activity

The region (defined as North Carolina and South Carolina, and parts of Georgia, Alabama, Tennessee, and Virginia) is comprised of three large northeast-southwest trending tectonic zones: The coastal plain, the crystalline-metamorphic zone and the overthrust zone. These zones are shown on Figure 2-49 Regional Tectonics.

The site is located nearly in the center of the crystalline-metamorphic zone, which consists of six generally recognized metamorphic belts. From southeast to northwest these are: The Carolina slate belt, Charlotte belt, Kings Mountain belt, Inner Piedmont belt, Brevard belt, and Blue Ridge belt. The site location is within the Inner Piedmont belt. The rocks in the belts consist of metamorphosed sediments and volcanics that have been folded, faulted, and intruded with igneous rocks. These belts are delineated by differing degrees of metamorphism. Generally, the degree of metamorphism becomes progressively less from the northwest to the southeast.

The oldest metamorphic rocks are located in the Blue Ridge belt. The more easterly belts of younger rocks have undergone progressively less metamorphism.

To the north and west are found a series of fault systems. Since these faults are both numerous and extensive, they can be grouped together and referred to as the overthrust zone, as shown on Figure 2-49. These faults no doubt resulted from the formation of the Appalachians.

The great system of thrust faults in the overthrust zone and most of the known faulting within the crystalline-metamorphic zone apparently occurred during the last period of metamorphism (260 million years ago).

During the Triassic Period (180 to 225 million years ago), sediments were deposited over parts of the exposed metamorphic belts. These deposits and the older metamorphics were intruded by a system of northwest-trending diabase dikes and were faulted by northeast-trending normal faults in the late Triassic Time (200 million years ago). Some of the older faults within the crystalline-metamorphic zone may have been active at this time.

From the late Triassic time until the present, the coastal plain has accumulated a sedimentary cover over its crystalline-metamorphic bedrock. These sediments overlap the bedrock and thicken toward the southeast, effectively masking any ancient faulting in the basement.

It is considered possible that igneous activity has occurred in the region after the Triassic because volcanic bentonitic clays of Eocene (approximately 50 million years ago) and possible Miocene age (12 million years ago) have been mapped in the sediments of the coastal plain in South Carolina. The source of this volcanic activity is presently unknown.

Faulting: The names, distances and directions from the proposed site, and the probable age of the known faulting in the region are as follows:

Name	Distance-Direction From Site	Probable Age Millions of Years
Brevard Fault	11 Miles NW	260
Dahlonega Fault	40 Miles W	260
Whitestone Fault	47 Miles NW	260
Towaliga Fault	90 Miles S	260
Cartersville Fault	104 Miles W	260
Gold Hill Fault	115 Miles E	260
Goat Rock Fault	140 Miles SW	260
Triassic, Deep River Basin, N.C. and S.C.	140 Miles E	200

Name	Distance-Direction From Site	Probable Age Millions of Years
Triassic, Danville Basin, N.C.	145 Miles NE	200
Crisp and Dooly Counties, Ga.	190 Miles SW	12 to 70
Probable Triassic Basin Charleston, S.C.	200 Miles SE	200

The locations of these faults with respect to the site are shown on Figure 2-49.

The first seven faults are all associated with the last metamorphic period. The Brevard, Whitestone, Dahlonega, and Cartersville faults apparently form an interrelated system. This system separates the eastern metamorphic belts from the Blue Ridge metamorphic belt and the overthrust zone on the west.

The Towaliga, Goat Rock, and Gold Hill Faults, and the Kings Mountain belt apparently form another interrelated alignment within the eastern metamorphic belts. The Kings Mountain belt is not considered a fault. Its association and alignment in relation to the three known faults mentioned and the location of earthquake epicenters within the area bounded by these features, lead to the conclusion that these features form an interrelated alignment.

There is no surface indication that any of these three faults have been active since the Triassic Period (200 million years).

Two fault locations in the region have been thoroughly investigated by borings. These are the Cartersville fault near the Allatoona Dam, and the Oconee-Conasauga fault in Georgia. These faults were found to be completely healed and not to have moved in many millions of years.

The Triassic basins of the Carolinas and further north may be due to the release of the compressional forces which formed the Appalachians. These basins are down-faulted grabens which are filled with Triassic sediments. Two earthquakes in the vicinity of McBee, South Carolina, may be related to an extension of a Triassic basin which has been inferred in the Chesterfield-Durham area.

Some faulting within the tertiary sediments in Dooly, Crisp, and Clay Counties, Georgia, has been mapped. The true areal extent of this faulting is unknown. This faulting apparently ranges from Cretaceous to possibly Miocene in age (70 to 12 million years).

The earthquake activity near Charleston, South Carolina, may indicate an active fault in that region. However, no evidence of surface faulting has been found.

2.5.2.3 Correlation of Earthquake Activity with Geologic Structures or Tectonic Provinces

The region surrounding the site can be divided into three major areas on the basis of the regional tectonics and the seismic history. These major seismic areas are:

1. the overthrust zone and Blue Ridge metamorphic belt;
2. the crystalline-metamorphic zone, exclusive of the Blue Ridge belt; and
3. the coastal plain.

The greatest number of recorded shocks have occurred within the overthrust zone and the Blue Ridge metamorphic belt northwest of the Brevard, Whitestone, Dahlonega, and Cartersville fault system. The epicenters in this area are generally widely scattered.

There have been a small number of earthquakes within the crystalline-metamorphic zone, exclusive of the Blue Ridge metamorphic belt. These earthquakes, extending from central Georgia to North Carolina, may be associated with the Towaliga, Goat Rock, Gold Hill, Kings Mountain alignment.

The coastal plain has experienced few earthquakes outside of the Charleston area. Four shocks, at Wilmington, North Carolina and Savannah, Georgia, have occurred but are unrelated to any known faulting, although the Wilmington shocks were adjacent to the Cape Fear Arch.

The only earthquake which does not closely fit this system of seismic areas is the 1924 shock in Pickens County, South Carolina (MM V Intensity). However, it is likely that this earthquake is associated with the overthrust-Blue Ridge seismic area.

2.5.2.4 Maximum Earthquake Potential

The assignment of probable future earthquake activity can only be based upon the previous record and the known geology of the area. Although the seismic history of the region is fairly short, a reasonable picture of the seismicity of the area becomes apparent from a study of the epicenter locations and the regional tectonics.

There are three significant zones of seismic activity in the general vicinity of the site; the Brevard and related faults zone, the overthrust zone, and the Towaliga, Goat Rock, Gold Hill, Kings Mountain alignment.

An evaluation of the earthquake activity and the regional geology can result in the selection of a series of maximum-sized shocks which are likely to occur in these various areas. Conservatively, we can assume that the previous maximum-sized shock on a particular fault zone can occur during the economic life of the proposed power station at perhaps the nearest approach of the particular fault system to the proposed site.

Zone	Location	(MM) Intensity at Epicenter	Estimated Magnitude (Richter)
Brevard Fault Zone	11 Miles NW	VI	Less than 4½ to 5
Overthrust	75 Miles NW	VIII	Less than 5½ to 6
Towaliga, Goat Rock Gold Hill, Kings Mountain Alignment	30 Miles SE	VII-VIII	Less than 5½ to 6

2.5.2.5 Seismic Wave Transmission Characteristics of the Site

Static and dynamic engineering properties of the soil and rock materials that underlie the site are discussed in Section 2.5.4. Design response spectra that include considerations of the thickness and distribution of these materials are discussed in Section 2.5.2.8.

2.5.2.6 Maximum Hypothetical Earthquake (MHE)

The MHE acceleration value is 0.10 g for Class 1 structures founded on bedrock and 0.15 g for structures founded on overburden. The design response spectra are covered in Section 2.5.2.8.

2.5.2.7 Design Base Earthquake

It is considered likely that the shocks listed in Section 2.5.2.4 could occur no closer than the indicated distances from the site during the life of the planned facilities. Since the magnitudes of these shocks are fairly small, the distance from the epicenter becomes extremely important. Ground accelerations would diminish rapidly with the distance from the epicenter. Although larger earthquakes occur within other fault zones, the highest ground accelerations at the site would be experienced from an earthquake along the Brevard fault zone. The assumption of a shock of less than Richter Magnitude five occurring along the Brevard fault zone at its closest location to the site (11 miles), would give ground motions on the order of five percent of gravity at the site. Vertical ground accelerations, as contrasted to the horizontal accelerations, would be only slightly less than five percent of the gravity in the competent rock at the site.

The DBE acceleration value is 0.05 g for both vertical and horizontal ground acceleration. The design response spectra are covered in Section 2.5.2.8.

2.5.2.8 Design Response Spectra

The Recommended Ground Motion for the 0.05 g, 0.10 g, and 0.15 g earthquakes are presented on Figure 2-50, Figure 2-52, and Figure 2-54.

The Recommended Ground Motion shows the expected maximum ground acceleration, velocity and displacement versus frequency at the site for the DBE and MHE. These plots are the expected ground motions of a particle within the rock at foundation level, and does not indicate the motions to be expected within a structure.

The Recommended Response Spectra curves for the 0.05 g, 0.10 g, and 0.15 g earthquakes are presented on Figure 2-51, Figure 2-53, and Figure 2-55. The upper curve on the Recommended Response Spectra shows the expected maximum acceleration, velocity and displacement versus frequency that would be experienced by a simple inverted pendulum which has no damping if the pendulum was excited by the ground motions specified in the Recommended Ground Motion Spectrum. The other curves on the graph are plotted to show the effects of damping.

2.5.3 Surface Faulting

This information is discussed in Section 2.5.1 and Section 2.5.2.

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 Geologic Features

This information is discussed in Section 2.5.1.

2.5.4.2 Properties of Subsurface Materials

The materials underlying the site can be characterized by four zones. These four zones are shown on the subsurface profiles in Figure 2-56 through Figure 2-64 and are described in the following sections.

Zone 1 (Red Sandy Silty Clay or Clayey Silty Sand)

This residual soil derived from the in-place weathering of the parent rock, is the zone at the surface. This soil has been severely desiccated and partially cemented by oxidation of the iron it contains. This soil is strong, incompressible, and should not swell appreciably when saturated.

Zone 2 (Micaceous Silty Sand)

The second zone, like the first is derived from the in-place weathering of the parent rock. This zone consists of micaceous silty sand; decomposed rock that retains the relic structure of the original rock, often termed “saprolite”. As is indicated by the standard penetration resistance, it is firm near the ground surface in the switchyard area (where it is thickest) but becomes denser with increasing depth. At this plant site, much of this zone has penetration resistances of 30 blows per foot or more and could be described either as a dense soil or a very soft rock. In general, this stratum is elastic and somewhat compressible because it has lost most of the intercrystalline bonds of the rock due to weathering, while much of the mica has not weathered sufficiently to lose its resiliency. The compressibility decreases and the rigidity increases with increasing density as reflected in the penetration resistances. In spite of this elastic nature, it is strong when confined and exhibits limited cohesion (both inter-particle bonding and capillary tension) as well as internal friction.

Zone 3 (Alternate Seams of the Soft Decomposed Rock and Hard Partially Decomposed Rock)

The third zone is the transition between soil and rock. This zone of alternate hard and soft weathered rock is exceedingly variable in its properties depending on the relative thicknesses of the contrasting seams. It is stronger than the saprolite zone above in shear across the seams but no stronger than the weakest seam parallel to them. The elasticity and compressibility are in proportion to the thickness of the soft seams because by comparison, the harder seams do not appreciably deflect under stress.

Zone 4 (Relatively Sound Rock)

The relatively sound rock below is both strong and rigid. The strength and elastic properties of small intact portions of the rock range from those of good concrete to several times those of concrete. The properties of the mass, however, are partially controlled by the joints and fissures. Therefore, the modulus of elasticity, the strength and the deflection of the mass are all somewhat lower than might be deduced from small scale laboratory tests of individual samples.

2.5.4.3 Exploration

A grid pattern of borings was established to provide the maximum amount of information for determining the foundation and soil conditions and permit flexibility in final plant layout, alignment, and elevation.

The general station area is shown on the included Location and Topographic Map, Figure 2-46 and the site and boring layout is shown on the Boring Plan, Figure 2-65.

The drilling, sampling, and rock coring were performed in accordance with methods specified by the American Society for Testing and Materials:

> "Penetration Testing and Split Barrel Sampling of Soils" - D-1586-64T
>
> "Diamond Core Drilling for Site Investigation" - D-2311-62T
>
> "Thin Walled Tube Sampling of Soils" - D-1587-63T

NX and BX size rock cores were drilled at this site. The respective diameters of the rock cores are 2-1/8 and 1-5/8 inches. Boring logs are given in Figure 2-66 through Figure 2-115.

A limited amount of auger drilling, not required by the plant foundation exploration outline, was done in the vicinity of boring NA-9 in conjunction with seismic field testing. Also, auger boring was done for a piezometer installation to be used during percolation inflow tests made for groundwater analysis and evaluation.

Various laboratory tests were run on cores from Borings NA-4 and NA-9.

Compressional wave velocity and specific gravity measurements were performed on four cores. The results of these measurements are shown in Table 2-95.

Measurements were run on eight cores from the two borings to determine Young's modulus, Poisson's ratio, and ultimate crushing strength. The results of these measurements are shown in Table 2-96.

2.5.4.4 Geophysical Surveys

An uphole velocity survey was Performed on Boring NA-9. A Dynametric Interval Timer, Model 117-A, capable of measuring times of 0.0001 seconds, was used. Explosives in the boring of up to one-half pound of dynamite were used to create the shock wave.

The calculated velocities from this survey are somewhat anomalous because of the weathered and fractured character of the rock.

Two seismic refraction lines were shot across the site. A Mandrel Industries Interval Timer, ER-75, 12-trace refraction seismograph was used to record the lines. Explosives were used to provide the shock waves.

The location of the uphole boring and the seismic lines are shown on Figure 2-117.

Two cross sections through the site along the seismic refraction lines is shown on Figure 2-118. The interpretations on these cross sections are based upon the uphole velocity survey, the seismic refraction lines and velocity measurements on core samples. This interpretation of the velocities is considered generally reliable. These velocities are general averages and small areas within the site may not fit the cross section because the character and the depth and degree of weathering of the rock at the site varies greatly in short distances. The water table elevation may also vary somewhat from that shown on the cross sections.

The pattern of microtremor motion was recorded at the site. The instrument used is capable of a maximum gain of 150,000. However, this site is extremely quiet and no appreciable amplitudes were recorded. (For example, a truck passing along the road less than 75 feet from the geophone produced double amplitudes of only 2.5×10^{-6} inches of ground motion.)

Because of the extremely low amplitudes of both the microtremor and the refraction energies, it was decided to perform an attenuation curve of the ground motion produced by explosives. Both the microtremor equipment and a Sprengnether Blast Recorder were used to measure the ground motion at 50, 100, 200, and 400 feet from 40-pound charges. This attenuation curve was compared with attenuation curves from sites with known characteristics to gain a better idea of the probable ground motion characteristics of the site. The results of this data indicated a marked attenuation of ground motion with distance.

2.5.4.5 Deleted per 1990 Update

2.5.4.6 Groundwater Conditions

This information is discussed in Section 2.4.13.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

Under dynamic load the elastic materials may deform significantly. Experience with vibratory loading at a number of high-pressure pumping stations has demonstrated sufficient elastic response which can develop to be troublesome. The site is in a region of definite but infrequent seismic activity of moderate intensity. Under such dynamic loadings, foundations supported upon any appreciable thickness of the resilient micaceous materials could respond unfavorably, developing some magnification of the amplitude compared to the more rigid rock below.

Detailed studies of the elastic qualities of the soil-rock mass supporting the critical structures could probably develop a configuration for the structure-foundation system that would not provide amplification for the seismic frequencies anticipated. Such an analysis, however, is dependent on (1) an accurate evaluation of the rock-soil-structure elastic response and (2) an accurate knowledge of seismic frequency spectra. Available theories on soil-structure response are approximate at best and must be corrected from empirical observations made during earthquakes. Realistic frequency spectra must properly be determined from observations of ground motion during seismic activity of the same intensity as anticipated. Unfortunately, there was no instrumental observation of any of the earthquakes of the region sufficiently close to the site that either reliable frequency spectra or structural response of the soil can be evaluated. Microtremors, while of academic interest, are not of sufficient magnitude to make a reliable evaluation of earthquake response of the magnitude of those observed. In fact, there is some evidence that microseisms may arise from different mechanisms, particularly superficial, near surface strains and adjustments.

2.5.4.8 Deleted per 1990 Update

2.5.4.9 Earthquake Design Basis

The earthquake design basis is discussed in Section 2.5.2.

2.5.4.10 Static Stability

Although the individual critical station units may not tolerate substantial settlement, they are functionally inter-connected only by piping. This can absorb some differential movements if it is anticipated in the design.

Because of the relatively small thickness of the surface clayey soils and the irregular topography, the upper zone does not have an appreciable influence on the design of foundations for the major structures. This stratum does furnish excellent support for the smaller structures where there is no cut or only shallow fill.

Under static load alone, a major design consideration for heavy structures is the elastic deflection and consolidation of the micaceous soils of the saprolite zone and the micaceous, more weathered layers of the zone of alternate hard and soft seams. Experience, confirmed by laboratory tests, has shown that these materials can support power station loadings without appreciable settlement when the densities are sufficient, that is the penetration resistances consistently exceed 30 blows per foot.

2.5.5 Deleted per 1990 Update

2.5.6 Embankments and Dams

2.5.6.1 Deleted per 1990 Update

2.5.6.2 Exploration

A thorough investigation has been made of the Keowee-Little River dam foundations (including the dam at the east end of the Oconee intake canal) by the Law Engineering Testing Company under the direction of Professor George F. Sowers.

A total of 74 soil and rock borings have been made to investigate the foundations of the Keowee and Little River dams and that of the dike at the east end of the Oconee intake canal. One hundred forty-six additional borings have been made to investigate foundations of nearby Keowee and Oconee structures and waterways.

At Keowee, 23 undisturbed samples were taken for laboratory testing to determine shear strength of the foundations.

At Little River, 19 undisturbed samples were taken for laboratory testing to determine shear strengths of the foundation.

2.5.6.3 Foundation and Abutment Treatment

At Keowee dam, based on test results, the extent of removal of material is specified such that shear strength of remaining material would equal or exceed shear strength of dam embankment. All alluvial material is removed. Since monitoring of any seepage in vicinity of the river itself would be extremely difficult due to backwater of Hartwell reservoir, a shallow grout curtain (10 ft-15 ft) is installed between and below the elevation 685 contours. The foundation report specifically notes that grouting is not required "to improve stability, reduce consolidation, or increase impermeability." The permeability of the intact reservoir soils varied between 1 x 10^{-3} and 1 x 10^{-4} feet per second as determined by laboratory tests.

Due to proximity of Keowee powerhouse (and its excavation) to left embankment, a core trench to rock is installed to provide a positive cutoff. A shallow grout curtain is placed below the bottom of core trench.

At Little River dam, as at Keowee, all material weaker in shear than the embankment materials and alluvium is excavated. A shallow (10 ft-15 ft) grout curtain is placed between and below elevation 675 contours. The permeability of the intact reservoir soils varied between 1 x 10^{-4} and 1 x 10^{-6} feet per second as determined by laboratory tests.

At Keowee and Little River dams and at Oconee intake canal dike, a three layer graded filter is placed under the downstream third of the dams and dike to intercept safely any seepage through the embankment and foundation. The dam abutments and upstream reservoir areas have natural blankets of residual, impervious material, and it is expected that these will prevent excessive seepage through the foundation.

2.5.6.4 Deleted per 1990 Update

2.5.6.5 Slope Stability

2.5.6.5.1 Static Analyses

Static analyses are performed for both Keowee and Little River dams, and these studies are checked by re-analyzing the most critical circles of failure independently. The conditions studied, both upstream and downstream, included "steady state seepage", "sudden drawdown", and "construction" before the reservoir was filled, utilizing the appropriate shear strength data for each condition.

2.5.6.5.2 Seismic Analyses

The static analyses extend to include the effect of acceleration and the resulting "inertia forces" on stability. The method utilized is that proposed by N. Newmark (1965) in the Rankine Lecture at the Institution of Civil Engineers (London).

In this analysis a steady acceleration is assumed to be applied to the centroid of the potentially sliding segment of soil in the direction which produces the greatest increase in overturning moment.

The results show that the embankments will have safety factors of 1.0 or more when the steady state acceleration is introduced. Of course, as Dr. Newmark points out, this dynamic approach is not rigorous because earthquakes loadings are transient, not steady, but the results should be on the safe side.

For earthquake loadings, the minimum permissible safety factor considered prudent by such organizations as the Corps of Engineers is 1.0 when combined with steady state seepage.

2.5.6.5.3 Shear Parameters

The shear parameters utilized in Section 2.5.6.5.1 and Section 2.5.6.5.2 are the consolidated-undrained or R values which impose a rapid change in stress upon a soil that has consolidated under sustained load.

The load change is applied so rapidly that no change in water content could occur even though the soils are saturated. The rate of loading, however, could not be termed “dynamic”. In dynamic loading of such clayey soils, viscous forces would be mobilized, and therefore, the strength would be somewhat greater.

Only one loading cycle is employed. In loose cohesionless soils or sensitive clays repeated loading can cause a change in structure and progressive loss in strength. Previous experience with the undisturbed soils of the region, as well as the compacted soils, shows that the soils do not suffer progressive breakdown with repeated load. Therefore, the static shear parameters should be safe and the steady state acceleration, N, for seismic loading will be substantially the same as for static.

2.5.6.6 Seepage Control

Investigation and corrective action are discussed in Section 2.5.6.2 and Section 2.5.6.3 respectively. Permeability is discussed in Section 2.4.

2.5.7 References

General Geology

1. Overstreet and Bell 1965, *The Crystalline Rocks of South Carolina*, United States Geological Survey Bulletin 1183 and Miscellaneous Geologic Investigations, Map I-413.
2. Cazeau, J., “Geology and Structure of the Pendleton - LaFrance Area, Northwestern South Carolina”, Division of Geology, State Development Board, Columbia, South Carolina, *Geologic Notes*, Vol. 7, Nos. 3 and 4, 1963.
3. Cazeau, C. J., and Brown, C. Q., “Guide to the Geology of Pickens and Oconee Counties, South Carolina”, Division of Geology, State Development Board, Columbia, South Carolina, *Geologic Notes*, Vol. 7, No. 5, 1963.
4. Crickmay, G. W. 1952, *Geology of the Crystalline Rocks of Georgia*, Georgia Geological Survey Bulletin No. 58.
5. Elkins, T. A., “Test of a Quantitative Mountain Building Theory by Appalachian Structural Dimensions”, *Geophysics* VII, No. 1, 45-60, 1941.
6. King, P. B. 1951, *The Tectonics of Middle North America*, Princeton University Press.
7. *Geologic Map of North Carolina*, with explanatory text 1958, State of North Carolina, Department of Conservation and Development.
8. *Geologic Map of Georgia* 1939, Georgia Division of Mines, Mining and Geology.
9. *Geologic Map of East Tennessee*, with explanatory text 1953, Tennessee Division of Geology Bulletin 58.
10. *Tectonic Map of the United States* 1962 by the United States Geological Survey and the American Association of Petroleum Geologists.
11. Reed and Bryant 1964, “Evidence for Strike Slip Faulting Along the Brevard zone in North Carolina”, *Geological Society of America Bulletin*, Volume 75, No. 12.
12. Reed, J. C. Jr. and others, 1961, *The Brevard Fault in North and South Carolina*, United States Geological Survey Professional Paper 424.C.
13. Straley, H. W. Personal Communication-Structural Geology, 1966.
14. White, W. A. 1950, “Blue Ridge Front - A Fault Scarp,” *Geological Society of America Bulletin*, Volume 61, No. 12.

Areal Geology

1. Conn, William V., *Engineering Geology of the Keowee-Toxaway Project for Duke Power Company*, December 16, 1965.
2. Conn, William V., *Engineering Geology of Oconee Nuclear Station for Duke Power Company*, October 26 1966.
3. Law Engineering Testing Company Reports on Preliminary Foundation Studies for Oconee Nuclear Station, October 26, 1966.
4. Brown, C. Q. and Cazeau, C. J. 1963, "Guide to the Geology of Pickens and Oconee Counties", *Geologic Notes South Carolina Division of Geology*, Volume 7, No. 5.
5. Cazeau, C. J. *Geology and Mineral Resources of Oconee County, South Carolina*, to be published as Bulletin 34, South Carolina Division of Geology.
6. *Geologic Map of Six Mile Quadrangle* to be published by South Carolina Division of Geology, MS Map Series.
7. *Geologic Map of Clemson Quadrangle* by Brown, C. Q. and Cazeau, C. J. South Carolina Division of Geology, MS-9.
8. Cazeau, C. J. 1963, "Geology and Structure of the Pendleton - LaFrance area, Northwestern South Carolina", *South Carolina Division of Geology Geologic Notes*, Volume 7, No. 3 and 4.

Seismology

1. *Earthquake History of the United States* - Part I 1965, United States Department of Commerce, Coast and Geodetic Survey, Washington, D.C.
2. *United States Earthquakes* - (Serial Publications, 1928 through 1963) United States Department of Commerce, Coast and Geodetic Survey, Washington, D. C.
3. *Preliminary Determination of Epicenters* - (Card Series 1964 through 1966) United States Department of Commerce, Coast and Geodetic Survey, Washington, D. C.
4. Richter, Charles F. 1958, *Elementary Seismology*, W. H. Freeman and Company, San Francisco.
5. Dutton, C. E. 1889, "The Charleston Earthquake of August 31, 1886", *Ninth Annual Report of the United States Geological Survey*, Washington, D. C.
6. MacCarthy, Gerald R. 1957, "An Annotated List of North Carolina Earthquakes", *Journal of the Elisha Mitchell Scientific Society*, Volume 73, No. 1, pages 84-100.
7. MacCarthy, Gerald R. 1963, "Three Forgotten Earthquakes", *Bulletin of the Seismological Society of America*, Volume 53, No. 3, pages 687-692.
8. MacCarthy, Gerald R. 1961, "North Carolina Earthquakes, 1958 and 1959 with Additions and Corrections to Previous Lists", *Journal of the Elisha Mitchell Scientific Society*, Volume 77, No. 1, pages 62-64.
9. MacCarthy, Gerald R. 1956, "A Marked Alignment of Earthquake Elicenters in Western North Carolina and Its Tectonic Implications", *Journal of the Elisha Mitchell Scientific Society*, Volume 72, No. 2, pages 274-276.
10. MacCarthy, Gerald R. and Washkam, John D. 1964, "The Virginia-North Carolina Blue Ridge Earthquake of October 28, 1963", *Journal of the Elisha Mitchell Scientific Society*, Volume 80, pages 82-84.

11. MacCarthy, Gerald R. and Sinka, Evelyn Z. 1958, “North Carolina Earthquakes: 1957”, *Journal of the Elisha Mitchell Scientific Society*, Volume 74, No. 2, pages 117-121.
12. Berkey, C. P., “A Geological Study of the Massena - Cornwall Earthquake of September 5, 1944, and its Bearing on the Proposed St. Lawrence River Project”.
13. Fischer, J. A., “Earthquake Engineering”, *Dames & Moore Engineering Bulletin No. 23*.
14. Heck, H. N., “Earthquake Problems of the Atlantic Coastal Plain”, *Bulletin of the Seismological Society of America*, Vol. 30, No. 2, p. 109-114 April, 1940.
15. Hedges, C. S. “Earthquake Activity and Intensity within the Southeastern United States”, private publication, law Engineering Testing Company, 1965.
16. Housner, G. W., “Characteristics of Strong Motion Earthquakes”, *Bulletin of the Seismological Society of America*, Vol. 37, p. 18-31, 1947.
17. Housner, G. W., “Geotechnical Problems of Destructive Earthquakes”, *Geotechnique*, Vol. 4, p. 153-154, 1954.
18. Leet, L. Don and Leet, Florence, “*Earthquake - Discoveries in Seismology*,” *Laurel Science Original* - Dell Publishing Company, 1946.
19. Neuman, Fred Robert, “The Southern Appalachian Earthquake of October 20, 1924”, *Bulletin of the Seismological Society of America*, Vol. 14, No. 4, p. 223-229, December, 1924.
20. Taber, Stephen, “The South Carolina Earthquake of January 1, 1913”, *Bulletin of the Seismological Society of America*, Vol. 3, No. 1, p. 6-13, March 1913.
21. Taber, Stephen, “The Earthquake in the Southern Appalachians, February 21, 1916”, *Bulletin of the Seismological Society of America*, Vol. 06, No. 4, p. 218-226, December 1916.
22. White, W. A., “The Blue Ridge - A Fault Scarp”, *Bulletin*, *GSA* 61, 1309-1346, 1950.
23. Newmark, N., “Effects of Earthquake on Dams and Embankments”, *Geotechnique*, Volume 25, No. 2, June 1965, p. 139-160.

THIS IS THE LAST PAGE OF THE TEXT SECTION 2.5.