

2.3 Meteorology

The fourth nuclear power plant, Lungmen NPS site, and its neighboring climatic conditions can be explained by the actual weather data measured by the weather station in the plant and the weather data collected by the weather stations in neighboring Taipei, Keelung, and Ilan.

The Lungmen NPS site is located in northern Taiwan at a latitude of 25°03' N north of the Tropic of Cancer, in a subtropical zone. Its annual average temperature is 22°C; weather is hot in summer, warm in spring and fall, and not very cold in winter because it is warmed by the ocean currents and Kuroshio.

Taiwan is located in the east Asian monsoon area and is subject to monsoons. Its northeast monsoon period lasts for 7 months: from October to the mid-May of the following year and its southwest monsoon period lasts for 4 months: from the end of May to the end of September. The northeast monsoon period is prevailed by northern and north-northeast winds, strong winds and rainy days. The southwest monsoon period is prevailed by south winds, weaker winds, sunny and hot weather, and occasional thunderstorms and typhoons (when a typhoon invades the area, damaging gusty winds and rains usually result).

The Lungmen NPS site is located in the seaside area of the northeastern part of Taiwan and is 40km east of Taipei and 20 km southeast of Keelung. The Pacific Ocean is on the eastern side of the plant, and some consecutive small hills and high hills occupy the western side of the Lungmen NPS site; its southern boundary is the Shung Chi and its northeastern boundary is the Shih-Ting Chi – the overall Lungmen NPS site area is about 480 hectares. The terrain of the Lungmen NPS site area is flat and 12 m above sea level. The neighboring northern, northeastern and eastern areas of the Lungmen NPS site area are also geologically flat. However, there are some small hills of 300 m in height in the southern part of the Lungmen NPS site area and some higher hills of 600 m in height in the western and northwestern areas. All the hills in the west-southwestern, southern and south-southwestern directions of the area are over 1000 m in height. Moreover, some hills in the southwest reach as high as 2300 m. The general terrain of the Lungmen NPS site area and its neighboring areas is “higher on the western side and lower on the eastern side.” For the cross-sectional view of the Lungmen NPS site area terrain and its neighboring areas (within an 80 km radius from the Lungmen NPS site), see Figure 2.3-1.

The terrain of the Lungmen NPS site area, its neighboring northern and eastern areas is flat, so the northeastern monsoons can reach these areas directly. Moreover, the strong outer circulation of the summer typhoons can have a longer impact on these areas by their direct entrance to these areas from the north and east, these typhoons would affect the Lungmen NPS site area longer and more seriously. In addition, there are a lot of higher hills in the southwest and south-southwest directions of the Lungmen NPS site area, and these hills have a topographic lifting effect on the northeast monsoons; as a result, there is a lot of rainfall for the Lungmen NPS site area in winters. On the other hand, these hills have a blocking effect on the southwest monsoon. This in turn reduces the rainfall for the Lungmen NPS site area and cuts wind strength in summer.

The air quality of the Lungmen NPS site and its neighboring areas has been measured by the Environmental Engineering Research Center of the National Taiwan University and Yi Din Company in 1990 and 1991. For detailed results, see Section 2.3.4.

2.3.1 Regional Meteorology

Northern Taiwan includes Taipei, Keelung, and Ilan. These three cities are close to the plant area (Yenliao).

2.3.1.1 Data Source

From the climatic data measured by weather stations (Central Weather Bureau) in Taipei, Keelung, and Ilan, we can carry out climatic analyses and evaluation of northern Taiwan. Measured data includes all the weather conditions in these areas for the past 50 years, so data can justifiably represent the weather conditions of these areas. For the locations and latitudes of these weather stations as well as periods of record, see Table 2.3-1.

2.3.1.2 General Climate

In the Koppen climate classification, the climate of northern Taiwan is classified as a humid subtropical climate. The characteristics of this climate include: average temperature of the coldest month is in the range of 18 to -3°C , the average temperature of the hottest month is over 22°C , the rainfall is distributed evenly all year round and the average rainfall for the driest month is over 70mm. To analyze northern Taiwan climate, we will discuss the temperature, wind, rainfall and humidity conditions for Taipei, Keelung, and Ilan.

2.3.1.2.1 Air Temperatures

For the average temperatures and extreme temperatures measured by the weather stations in the northern Taiwan, see Table 2.3-2.

(1) Taipei Area:

Geographically, the Taipei area is a basin. Surrounded by hills, the temperatures of Taipei are relatively unaffected by the sea. The annual average air temperature of the area is 21.8°C ; the annual average maximum air temperature has hit 26.3°C and the minimum is 18.8°C . The hottest month of the year is July with the monthly average air temperature of 28.6°C . The coldest month of the year is January, and with monthly average air temperature of 15.2°C . The annual air temperature range is 13.4°C . The absolute maximum air temperature on record was 38.6°C , which occurred on July 31, 1921; the absolute minimum air temperature on record was minus -0.2°C , which occurred on February 13, 1901.

(2) Keelung Area:

The Keelung area is close to the sea and its temperatures are affected by the sea more. The annual average air temperature of the area is 21.9°C; the annual average maximum temperature has hit 24.9°C and the minimum is 19.8°C. The hottest month of the year is August with the monthly average air temperature of 28.2°C. The coldest month of the year is January with the monthly average air temperature of 15.5°C. The annual air temperature range is 12.7°C. The absolute maximum air temperature on record is 37.9°C, which occurred on August 10, 1926; the absolute minimum air temperature on record is -3.9°C, which occurred on Jan. 28, 1963.

(3) Ilan Area:

The annual average air temperature of the area is 22.0°C; the annual average maximum air temperature is 25.7°C, and the minimum is 18.8°C. The hottest month of the year is July with the monthly air temperature of 28.0°C. The coldest month of the year is January, with the average air temperature of 15.7°C. The annual air temperature range is 12.3°C. The absolute maximum air temperature on record is 37.9°C, which occurred on August 19, 1951; the absolute minimum temperature on record is -3.2°C, which occurred on Jan. 27, 1962.

2.3.1.2.2 Winds

In winter, northern Taiwan is very much affected by the stronger northeast monsoon; in summer, the region is affected by the weaker southwest monsoon. For the prevailing wind directions and average/extreme wind speeds measured by the various weather stations, see Table 2.3-3.

(1) Taipei Area:

During the period (from October to May of the following year) of northeast monsoon, these winds are blocked by the Ta Tun Mt. and Chi Shin Mt., so they enter the area via the Keelung River valley. Therefore, the dominant winds in winter for the Taipei area are the east winds. The average wind speed is 3.4 m/s. During the period (from June to August) of southwest monsoon, the wind direction is south-southeast and the average wind speed is 2.5 m/s. September is the transition period of the southwest and northeast monsoon. The instantaneous maximum wind speed on record is 48.8 m/s, which occurred in a typhoon invasion during August. There are only 15 days in a year that the average wind speed reaches 10.0 m/s. or more (the 6th grade wind) and these days are spread out evenly in each month.

(2) Keelung Area:

During the period (from October to May of next year) of northeast monsoon, the average speed of these winds is 3.6 m/s. During the period (from June to August) of southwest monsoon, the wind is from the southwest direction and the average wind speed is 2.8 m/s. The instantaneous maximum wind speed on record is 66.6m/s, which occurred during a September. There are only

36.8 days in a year that the average daily wind speed reaches 10.0 m/s or more (the 6th grade wind) and 67% of these days are concentrated in fall and winter.

(3) Ilan Area:

The winds in this area are quite unique: for fall and winter (October to February of the following year), the wind is from the southwest direction; for spring and summer (from March to September), the wind directions are from the northeast and east directions. Wind conditions are like this because there is the high Central Mt. in the southwest region of the Ilan area (southwest monsoons are blocked out and those summer winds are relatively weak), and there are sea breezes in the day time. In winter, the northeast monsoons are bounced back by the Central Mt. and converted into the southwest winds blowing to the Ilan area near ground layer.

Because the winds are blocked out by the unique terrain in the area, the wind speeds in this area are rather slow. The annual average wind speed plummets to 1.6 m/s and the monthly average wind speed is below 1.8m/s. The strongest winds occur in July, August and September. The instantaneous maximum wind speed on record is 65.3m/s, which occurred during an August.

There are only 7.3 days in a year when the average wind speed reaches 10.0m/s or more (the 6th grade wind), and 49% of these days are in July, August, and September.

2.3.1.2.3 Precipitation

There is plenty of rainfall in northern Taiwan. Rainfall is brought to this region mainly by the northeast monsoon rains, typhoon rains and “Mei-Yu.” For the average and extreme rainfalls measured by the weather stations in the region, see Table 2.3-4. For the rainy days, rainy hours and thunderstorms days measured by these stations, see Table 2.3-5.

(1) Taipei Area:

Because the northeast monsoons are blocked by hills, the rainfall in this area is less than those of Keelung and Ilan; the annual average rainfall is 2118.8mm. The rainfall of the wettest month (June) is 297mm; the rainfall of the driest month (November) is 73.2mm. Seasonally variation shows the heaviest monthly rainfall is in summer (819.1mm); and lightest monthly rainfall in winter (303.9mm).

The maximum 24-hour and 1-hour duration rainfall recorded were 358.9mm (July), and 110.0 mm (April), respectively.

The annual average rainy days are 180.3 days. The monthly rainy days is in the range of 13 to 17 days. The annual average rainy hours are 1247 hours. The rains in the period from November to March belong to the northeast monsoon rains, so they last for a longer duration and the monthly rainy hours are longer also, with the monthly average rainy hours are over 110 hours. The rains

in the period from July to August belong to the thunderstorm and typhoon rains, so they last for a shorter duration and the monthly rainy hours are below 81 hours.

The annual average thunderstorm days are 35.5 days. 81% of them are in the period from May to September. In winter, the monthly average thunderstorm days are less than 1 day.

(2) Keelung Area:

The area faces the direction of the northeast monsoon, so its rainfall is quite ample. The annual average rainfall of the area is 3330.1mm. The monthly average rainfall of the wettest month (December) is 344.6mm; while the driest month (July) is 139.7mm. In seasonal variation, there is the heaviest rainfall in winter with the seasonal average rainfall of 1009.2mm; and the lightest rainfall in summer with 606.2mm.

The maximum 24-hour and 1-hour duration rainfalls recorded were 351.3mm and 107mm, respectively, which all occurred in September.

The annual average rainy days are 211.6 days. From November to March of the following year, the monthly rainy day is over 20 days. From June to September, the monthly rainy day is less than 16 days. The annual average rainy hours are 2028.2 hours. From November to March of the following year, the monthly rainy hours are over 200 hours. From June to September, the monthly rainy hours are below 100 hours.

The annual average thunderstorm days are 20.6 days. 78% of them are in the period from May to September. In winter, the monthly average thunderstorm days are less than 1 day.

(3) Ilan Area:

The annual average rainfall of the area is 2784.4mm. The monthly average rainfall of the wettest month (September) is 438.3mm; the monthly average rainfall of the driest month (April) is 116.4mm. In seasonal variation, there is the heaviest rainfall in fall (with the seasonal average rainfall of 1188.4mm); there is the lightest rainfall in spring (with 480.8mm).

The maximum rainfall in a 24-hour and 1-hour duration are 460.5mm and 112.0mm, respectively, all occurred in September.

The annual average rainy days are 213.2 days. For the seasonal average rainy days, there are 40.2 days for summer and from 55 to 66 days for the other three seasons. The most rainy days are in November – 21.9 days; there are the least rainy days in July – 10.1 days. The annual average rainy hours are 1584.1 hours. From October to March of the following year, the monthly rainy hours are over 150 hours. From April, July, August, and September, the monthly rainy hours are below 100 hours. The most rainy hours are in November – 199.3 hours; the least rainy hours are in July – 44.9 hours.

The annual average thunderstorm days are 38 days. 81% of them are in the period from May to September. In winter, the monthly average thunderstorm days are less than 1 day.

2.3.1.2.4 Humidity

The humidity in northern Taiwan is relatively high. This is because the rainfall is ample all year round, there are many rainy days, and the climate of the area is affected by the sea. For the average and extreme relative humidities measured by the weather stations in the region, see Table 2.3-6.

(1) Taipei Area:

The annual average relative humidity of the Taipei area is 81%. The monthly average relative humidities for July, August and September are below 80%; for all the other months, the monthly average relative humidities are above 80%. Concerning the seasonal average humidities, the average relative humidities for spring and winter are the same – 83%; 80% for the fall, and 79% for summer. The highest monthly average relative humidity of 80% occurred in February and March –and the lowest 78% occurred in July and August. The minimum relative humidity ever recorded was 15%, which occurred in April.

(2) Keelung Area:

The annual average relative humidity of the Keelung area is 82%. Except for July, for all the rest of the months, the monthly average relative humidities are above 80%. The highest monthly average relative humidity occurs in March – 85%; the lowest one occurs in July – 79%. Concerning the seasonal average relative humidities, the values for the spring, winter, summer and fall are 84%, 83%, 81% and 80%, respectively. The minimum relative humidity ever recorded was 23%, which occurred in January.

(3) Ilan Area:

The annual average relative humidity of the Ilan area is 85%. The monthly average relative humidities for all the months are above 83%. The highest monthly average relative humidities of 87% occurred in June and November, the lowest ones of 83% occurred in January and July. Concerning the seasonal average relative humidities, the values for the spring and fall are the same – 86%; the values for the winter and summer are 84% and 85%, respectively. The minimum relative humidity ever recorded was 23%, which occurred in February.

2.3.1.3 Severe Weather

For northern Taiwan, the prevalent severe weathers are typhoons and heavy rains caused by fronts. There have been only two tornadoes ever recorded in Hsinchu. The two main severe weathers are discussed in detail below.

2.3.1.3.1 Typhoons

A typhoon is a kind of violent storm and the most damaging one among natural disasters. Geographically, Taiwan is located in the typhoon paths of the western Pacific Ocean and South China Sea regions; there is some typhoon invasion on the island every year. With the Central Mt. lying in the middle of Taiwan, the geographical terrain of Taiwan is relatively complicated; so, the impact of a typhoon to the land is very much determined by its path. Another impact factor is season; the seasonal differences will cause typhoons with the same path to have quite different impacts.

According to the records of Central Weather Bureau, for the past 44 years (from 1947 to 1990), there have been 125 typhoons on the island; the annual typhoon frequency has been 2.8 typhoons. Among these typhoons, 54 of them with 43.2% were classified as the severe typhoons (which means the maximum wind speed close to the center reached 51m/s.). 41 of them with 32.8% were classified as the typhoons (which means the maximum wind speed close to the center is in the range of 32.7 to 50.9m/s.). 30 of them with 24% were classified as tropical storm (which means that the maximum wind speed close to the center was in the range of 17.2 to 32.6m/s.); (see Table 2.3-7). According to the monthly typhoon distribution (see Table 2.3-7), the highest monthly typhoon frequency occurs in August (with 35 typhoons); the second highest in September (with 31 typhoons). In addition, 72.2% of all these typhoon invasions took place in July, August, and September; so these three months have a high typhoon invasion probability (see Figure 2.3-2). If grouped by 10-day periods, the monthly distribution can be obtained on Figure 2.3-2. The earliest invasion occurred in the last 10 days of April (from April 21 to April 30), and the latest invasion occurred in the last 10 days of November (from November 21 to November 30). There was no invasion for the duration from May 1 to May 10 on record. The higher invasion frequencies occurred in the periods from July 21 to July 31 and from August 21 to August 31.

Because there were no long-term measurements for typhoons recorded for the Lungmen NPS site area, in this section the measured typhoon records obtained by the three weather stations of the Central Weather Bureau in Keelung, Ilan, and Taipei were used to evaluate the likely typhoon impact on the Lungmen NPS site and its neighboring areas.

(1) The Impact on the Lungmen NPS Site Area (Yenliao) of Typhoons with Different Paths.

To understand the impact on the greater Lungmen NPS site region (including Keelung, Ilan and Taipei) from typhoons with different paths, these paths are classified into seven categories (see Figure 2.3-3) with the past 125 typhoon invasions data recorded by the Central Weather Bureau stations from 1947 to 1990. These seven categories are as follows:

- The first kind: passing through the sea by northern Taiwan
- The second kind: landing on northeastern Taiwan (in the north of Hualien)
- The third kind: landing on eastern Taiwan (Hualien or Hsin Kong)
- The fourth kind: landing on southeastern Taiwan (in the south of Hsin Kong)
- The fifth kind: passing through the Bashi Channel or Luzon Island
- The sixth kind: going northward in the sea close to eastern Taiwan

The seventh kind: going northward along the Taiwan Straits or landing on southern Taiwan

From the path classification shown on Figure 2.3-3, for a typhoon that lands on the Lungmen NPS site area or its neighboring areas belongs to the second kind; there were 19 such typhoons on record. Analysis of the wind direction and speed data collected by the three weather stations of the Central Weather Bureau in Keelung, Ilan, and Taipei from 1947 to 1990, shows the strongest winds had direct linkage to the typhoons. We put the top 10 instantaneous maximum wind speeds ever measured by these three stations in Tables 2.3-8 to 2.3-10. Among these top 10 maximum wind speeds, about 50% of them were caused by the typhoons of the second kind of path; 7 of these 10 were recorded in the Taipei weather station; therefore, this kind of typhoon most affects the Lungmen NPS site area and its neighboring areas. The instantaneous maximum wind speeds ever measured by these three stations are: Keelung Station – 67.0m/s, (N); Ilan Station – 66.0m/s, (E); Taipei Station – 49.1m/s, (E). For the Keelung and Taipei Stations, there were eight to nine strong winds caused by severe typhoons; for the Ilan Station, there were four strong winds caused by typhoons (see Tables 2.3-8 to 2.3-10). These three tables show that half of these strong winds occurred in September; this was obviously closely related to the presence of the northeast monsoon and the terrain factor. Therefore, strong winds are characteristic of fall typhoons. For example, a typhoon of the 5th kind of path can have a serious impact on the Lungmen NPS site area and its neighboring areas only after September (see Table 2.3-9). In Table 2.3-9, we can see that none of the top 10 strongest winds recorded by the Ilan Station were caused by a typhoon of the first kind (passing through the sea off northern Taiwan). For the typhoons of this kind, the center were rather close to Ilan; the impact of them to Ilan was not as serious as the impact to Taipei and Keelung because Ilan lies at the lee side of the mountain.

(2) Adjacent Site Area Frequency Analysis of Strong Winds Caused by Typhoons

Table 2.3-11 shows the records of the strong winds greater than 7 grades (wind speed ≥ 15 m/s) caused by typhoons in the Yenliao vicinity (including Keelung, Ilan, and Taipei) during 1947 to 1990. They have been classified statistically according to the typhoon path.

The table shows that the strong winds that happened most frequently were caused by the third typhoon path (landing at Hualien and Hsinking) and the fifth typhoon path (across Bashi Channel or Lusong Island).

Table 2.3-12 shows the three classifications of strong winds defined by wind speed at Keelung, Ilan, and Taipei Stations. There were 95 occurrences of strong winds with 75% for greater than 7 grades in Taipei., Keelung was 74.6% to be the second. Of all greater than 12 grades wind force were 16.7%, 7.1%, and 11.9% observed at Keelung, Ilan and Taipei Stations, respectively. For over 16 grades of wind force occurred, there were 6 times at Keelung, only once at Ilan.

Figure 2.3-4 shows that the wind rose of the wind force greater than 7 grades observed from Keelung, Ilan, and Taipei Stations during 1947 to 1990. These wind forces have been classified into three classifications (grade 7-11, 12-15, and greater than 16 grades) according to 16

different wind directions. These 3 classifications equate to the force of tropical storm, typhoon, and severe typhoon.

In Keelung the wind force greater than 12 grades were mostly prevailed with the north and southeast wind, greater than 7 grades were mostly with the southeast and south-southeast winds even the wind force greater than 12 grades were with south to southwest. In Ilan the wind force greater than 7 grades were with the northeast and southeast mostly, and even some occurrences were greater than 12 grades with the northwest to the north, northeast, east and south-southeast. In Taipei, the wind force greater than 7 grades were primarily with the east and east-southeast winds. Also wind force greater than 12 grades occurred with the northeast, southeast, and north-northwest but they never exceeded 16 grades.

(3) Conclusions:

- (a) The most serious damage caused by typhoons which ravaged the adjacent site area was the second typhoon path (landing at the northeastern Taiwan or beyond the north side of Hualien). Over one-half of the top 10 strong winds (1947–1990) were caused by the second typhoon path at Keelung, Ilan, and Taipei. The majority happened in September.
- (b) The extreme wind speeds induced by typhoons at Keelung, Ilan, and Taipei occurred while the typhoon center was approaching the sea coast near the area, not passing through the area.
- (c) The wind data from typhoons greater than 7 grades at Ilan Station are less than the data at Keelung and Taipei. The wind data of Ilan is less representative than the data of the two other stations. This might be concerned with the differences of the height from the anemometer and topographic effects.
- (d) The 1st typhoon path passed through the sea near the northern coast of Taiwan, through the typhoon centers were not far from Ilan, at Ilan would become lighter due to the location at the lee side of the mountain.

2.3.1.3.2 Tornadoes

In Taiwan there were 49 tornadoes during 1961 to 1989. However, there were no records of tornadoes occurring beyond the north side of Hsin-Chu (see Figure 2.3-5).

2.3.1.3.3 Heavy Precipitation Caused by Fronts

According to the definition defined by the Central Weather Bureau: the precipitation over 15 mm/h and 130 mm/day continuously in one place, which could cause serious damage is called heavy precipitation. In Taiwan the heavy precipitation normally caused by typhoons, fronts, tropical low pressure, southwest wind flows, and northeast monsoons mostly caused by the typhoons and the fronts.

According to the climatological data of the Taipei, Keelung, and Ilan Stations of the Central Weather Bureau, northern Taiwan (Taipai, Keelung, and Ilan, had 128 days of heavy precipitation in the latest 31 years (from 1958 to 1988). On the average, there were 4 days of heavy precipitation each year. There were 58 days with 45% of heavy precipitation caused by typhoons, while 49 days with 38% were caused by fronts, the rest, 21 days of precipitation, were caused by tropical low pressure, northeast monsoons, and southwest wind flows.

(1) Frequency of Occurrence

There were 49 days of heavy precipitation caused by fronts in northern Taiwan for the latest 31 years, on the average, there were 1.6 days of fronts that caused heavy precipitation in each year. The most days of fronts that caused heavy precipitation were 6 days which occurred in 1974 and 5 days in 1970.

The heavy precipitation caused by fronts were 33 days (67%) and 8 days (16.3%) that occurred from September to October and from May to June, respectively. The rest of the days were in January, April, and November, but there were none in February, March, July, August, and December.

(2) Difference of Location

Fronts cause heavy precipitation in northern Taiwan is because of the geography. There are differences between Keelung, Ilan, and Taipei geography; therefore, heavy precipitation may not occur at these three locations on the same day under the same weather conditions. Ilan is at the northeast corner of Taiwan. When a front goes south and meets the typhoon at Bashi Channel or around the Philippines, it usually causes heavy precipitation due to the corn effect, so heavy precipitation days in Ilan are more than any other area in northern Taiwan.

(3) Intensity of Burst Rains

To analyze burst rains, they can be classified by daily rainfall as the following 5 grade: 131 to 150mm, 151 to 200mm, 201 to 250mm, 251 to 300mm and over 300mm. For burst rain days caused by fronts, the largest number, 17 days with 40% of the total, was of the 151 to 200mm grades. The second largest number, 12 days with 23% ,was of the 131 to 150mm grade. The terrain of Keelung and Ilan has the effect of lifting air flow; this will increase instability of the air. All the burst rains of this grade occurred in September. The prevailed winds are southwest or southeast for northern Taiwan in September. During this month, the air is warm and humid with ample water vapor and is unstable in the upper layer. When the cold front goes south, and the cold and dry air meets the warm and humid air in northern Taiwan, severe burst rains will be generated resulting from strong convection.

2.3.2 Local Meteorology

2.3.2.1 Normal and Extreme Value of Meteorological Parameters

The onsite meteorological monitoring program has been performed at the Lungmen NPS site since July 1980. Two towers, each 40 m and 52 m in height, respectively, have been installed on site since then for various meteorological measurements. Their location and general sketches are shown on Figures 2.3-6 and 2.3-7. Up to now, a total of 16 years of records was used for statistical analysis.

Besides the onsite meteorological data collection, Keelung weather station of the Central Weather Bureau, located approximately 20 km northwest of the Lungmen NPS site, and its 93-year climatological statistics from 1903 to 1995 have been considered valuable and provided for comparison with onsite meteorological data.

2.3.2.1.1 Winds

For the low tower, winds are measured at elevation 21 m from July 1980 to December 1996. The winds at elevation 63 m of the low tower and the winds at elevation 63 m and elevation 93 m of the high tower are measured from September 1982 to December 1996. All wind data are processed and analyzed separately. Their monthly wind roses are depicted on Figures 2.3-8 to 2.3-9, while the annual wind roses are shown on Figures 2.3-12 to 2.3-15. The monthly and annual frequency distribution of wind direction and wind speed are presented in Tables 2.3-13 to 2.3-16.

In general, the wind flow regime in the site area is governed by the strong and persistent northeast monsoon in winter season, and the more intermittent southwest monsoon and sometimes typhoons during summer time. From the monthly wind data, it could indicate such a seasonal variation at the site area. Winter months generally show higher wind speeds than that of the summer months. On an annual basis, the prevailing wind directions at elevation 21 m of the low tower are from northwest to northeast with a frequency 52.7% of the time. The prevailing winds of the upper levels, i.e., at elevation 63 m of the low tower and at elevation 63 m and elevation 93 m of the high tower are uniformly in the sector between north and northeast directions with a frequency 31.8%, 34.4%, and 33.3% of the time, respectively.

Table 2.3-17 shows the wind speed summaries at the Lungmen NPS site. According to the historical statistics, the average wind speeds at elevation 21 m and elevation 63 m of the low tower, and at elevation 63 m and elevation 93 m of the high tower are 2.9 m/s, 4.0 m/s, 3.5 m/s, and 4.7 m/s, respectively. The 15-minute average maximum wind for the above mentioned wind measurements were 28.4 m/s (E), 44.0 m/s (E), 44.0 m/s (E), 41.0 m/s (NNE), and 49.2 m/s (NNE), respectively, which all occurred on July 31, 1996. As to the instantaneous maximum wind speeds ever recorded, they were 48.5 m/s (NW, October 10, 1994), 57.8 m/s (NE, August 8, 1994), 59.0 m/s (N, July 31, 1996), and 59.6 m/s (NNE, August 8, 1994), respectively.

Table 2.3-18 indicates the wind speed summaries at Keelung Station. The annual average wind speed was 3.2 m/s, while the 10-minute average maximum and instantaneous maximum wind ever recorded were 43.0 m/s (SE, August 30, 1959) and 67.0 m/s (N, September 22, 1971), respectively.

Hourly wind data collected on both the low and high towers were also taken to study the persistence of wind direction. The results are presented in Tables 2.3-19 to 2.3-22. The longest persistent calm at the low tower elevation 21 m and elevation 63 m levels were 14 hours and 9 hours; and at the high tower elevation 63 m and elevation 93 m levels, they were 11 hours and 16 hours. The longest persistent wind directions at the low tower elevation 21 m and elevation 63 m levels were 94 hours, and 56 hours from the southwest wind which occurred in July; while at the high tower elevation 63 m, it was 59 hours from the northeast wind in July, and 56 hours at elevation 93 m from the north wind in March and from the north-northeast wind in October.

2.3.2.1.2 Air Temperature

Table 2.3-23 presents monthly and annual air temperature summaries at the Lungmen NPS site. The annual average temperature was 21.9°C, with the lowest monthly average at 15.6°C in January, and the highest monthly average at 28.1°C in July. The maximum and minimum temperatures were 37.2°C on August 21, 1981 and 3.4°C on March 2, 1986, respectively. The monthly average diurnal temperature range was from 4.8°C to 7.7°C, with its maximum diurnal temperature range at 15.8°C on April 2, 1983.

The monthly and annual air temperature summaries at Keelung are listed in Table 2.3-24. According to the historical data, the annual average temperature is 22.0°C. The warmest month, July, has an average temperature of 28.5°C, and the coldest months, January and February, have an average temperature of 15.5°C. The absolute maximum temperature experienced was 38.0°C on July 21, 1995, while the absolute minimum temperature was 3.9°C on February 3, 1986. The maximum diurnal temperature range was 18.2°C on April 5, 1941.

The statistics show that the air temperature characteristics both at the Lungmen NPS site and Keelung, are quite similar, which indicate the representatives of the Lungmen NPS site data for the general region.

2.3.2.1.3 Relative Humidity

Table 2.3-25 lists the monthly and annual data of relative humidity for the Lungmen NPS site and Keelung. In general, relative humidity is high throughout the year at both stations. The annual average relative humidities observed at the Lungmen NPS site and Keelung were 84% and 81%, respectively, while the minimum relative humidities at both stations all occurred in January, with the Lungmen NPS site at 31% and Keelung with the lowest value at 23%. The monthly average diurnal range was from 19% to 26% at the Lungmen NPS site, with the extreme value of 67% occurring on May 31, 1991.

2.3.2.1.4 Dew Point Temperature

Besides the relative humidity, the dew point temperature also shows the amount of water vapor contents in the atmosphere. Table 2.3-26 shows the monthly and annual dew point temperatures from March 1994 to February 1997 at the Lungmen NPS site. The annual average dew point temperature was 18.3°C. Monthly average dew point temperatures ranged from 11.8°C in February to 23.9°C in July. The maximum dew point temperature was 29.5°C on July 29, 1996, while the minimum value was -2.2°C on

February 6, 1995. The maximum average diurnal range was 6.4°C in March, and the minimum average value was 4.9°C in July, with the extreme value of 17.2°C on November 23, 1995.

2.3.2.1.5 Precipitation

Table 2.3-27 indicates the monthly and annual precipitation summaries at the Lungmen NPS site (1966-1971 and 1980-1996). The annual average precipitation was 3123.9 mm, with the monthly average rainfall ranging from 119.8 mm in July to 358.4 mm in February. The maximum precipitation for specified time intervals is also shown in the table. For example, the maximum 10-minute, 1-hour, and 24-hour durations of rainfall were 26.5 mm in December, 79.0 mm in October, and 305.0 mm in August, respectively. On average, there are 191.3 rainy days and 1596.5 rainy hours annually. Their extremes usually occur in winter months.

Long-term, monthly, annual precipitation summaries for Keelung (1903-1995) are presented in Table 2.3-28. The annual average precipitation was 3330.9 mm, with the heaviest and lightest monthly average rainfalls of 339.2 mm in February and 134.4 mm in July. The maximum 10-minute, 1-hour, and 1-day durations of rainfall were 40.0 mm, 107.0 mm, and 351.3 mm, respectively. Annually, the average rainy days and hours were 210.3 days and 2076.5 hours, respectively.

The tendencies of rainfall distribution for each month at both the Lungmen NPS site and Keelung are generally similar. The rainfall amounts in summer and fall are comparatively less than that of the winter season. And the precipitation associated with typhoons in the summer and fall is generally heavy and brief, while it is less intense and lasts for a longer period of time during the winter season.

Tables 2.3-29 to 2.3-32 present the joint frequency distribution of wind direction and precipitation occurrence for the four different tower levels at the Lungmen NPS site. The relevant monthly precipitation wind roses with precipitation rate classes are shown on Figures 2.3-16 to 2.3-19, while the annual precipitation wind roses are presented on Figures 2.3-20 to 2.3-23. During the winter time, the precipitation occurs largely when the winds prevail in the quadrant from north-northeast directions, and during the summer months, the winds prevail in the quadrant from southeast to south directions. On an annual basis, precipitation occurs most often with winds between north-northwest and the northeast directions.

2.3.2.1.6 Fog

Fog forms when the air temperature and dew-point temperature are nearly identical or equal. By definition, fog reduces visibility to less than 1 km. Table 2.3-33 presents the average fog days at the Lungmen NPS site and Keelung. Annually, there were about 8.1 days at Lungmen NPS site and 26 days at Keelung. The most prevalent months at both locations were in the spring.

2.3.2.1.7 Atmospheric Stability

Temperature difference data collected between the elevation 21 m and elevation 63 m of the low tower and between elevation 63 m and elevation 93 m of the high tower were used to assess atmospheric stability by

the method of vertical temperature gradient. Tables 2.3-34 and 2.3-35 present the monthly and annual summaries of atmospheric stability from 1987 to 1996.

On an annual basis, the distribution of atmospheric stability classes of the two towers were quite similar. The most frequent stability class was slightly stable (E), 40.46% and 45.11% of the time at the low tower and the high tower, respectively. The stability class of neutral (D) at the low tower and the high tower were 28.55% and 23.82% of the time, respectively. The monthly atmospheric stability data indicate seasonal variations. Winter months showed the relatively high frequency of occurrence of the slightly stable (E) and neutral (D) classes, while summer months showed a significant increase in frequency of the extremely unstable (A) class at both towers.

Monthly and annual joint frequency distributions in percent of wind speed and wind direction by atmospheric stability classes for the same period-of-record are shown in Tables 2.3-36 to 2.3-61 for the low tower; and in Tables 2.3-62 to 2.3-87 for the high tower.

At the low tower elevation 21 m level, the joint frequency of occurrence of calm wind by stability classes were 0.04%, 0.02%, and 0.01% associated with the unstable classes group (A, B, C); 0.18% of occurrence with the neutral stability class (D); and 1.19%, 0.67% of occurrence with the stable classes group (E, F, G), respectively. At the low tower elevation 63 m level, the occurrence of calm winds were 0.05%, 0.01% class, and 0.02% with the unstable classes group (A, B, C); 0.27% with neutral stability (D); and 1.94%, 1.25%, and 0.30% with the stable classes group (E, F, G).

As for the winds at the high tower elevation 63 m and elevation 93 m levels, the combination of stability class A with calm winds occurred at 0.07% and 0.04% of the time; class B with calm 0.02% and 0.01%; class C with calm 0.03% and 0.01%; class D with calm 0.34% and 0.17%; class E with calm 0.99% and 0.59%; class F with calm 0.28% and 0.22%; class G with calm 0.03% and 0.06%, respectively.

Monthly, joint frequency distributions of wind speed and wind direction by each atmospheric stability class also showed seasonal variations. There was a good distribution of slightly stable (E) and neutral (D) classes over all the wind directions at all measured levels of the two meteorological towers.

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

The effect of the plant and its facilities on the local meteorology will be fairly minor. Modification of local terrain as a consequence of the construction of the plant and its facilities to the site will redistribute the natural terrain features and add roughness elements. In all wind directions, the only notable effect will be the addition of mechanical turbulence to the air that enhances diffusion.

Due to the change of surface materials, absorption of solar radiation will increase. Thus, it will result in a slightly higher temperature during night time at the plant vicinity, but will have no effect beyond the site boundaries.

Operational cooling will be accomplished entirely through the closed heat exchange with the Pacific Ocean. Modest increase in localized surface temperature of the water offshore will not add significantly to

the air temperature or water vapor contents of the local meteorology. A little added heat will increase the instability of the air and enhance mixing and diffusion.

2.3.2.3 Topographical Description

The Lungmen NPS site, fronting the Pacific Ocean, is located on the northeast coast of Taiwan, about 20 km southeast of the city of Keelung, and 40 km east of Taipei, a metropolitan city. The terrain of the plant is flat along the north to the east-southeast directions. Ridges and hills are generally distributed in the areas of south, west, and north-northwest directions. Figures 2.3-24 and 2.3-25 are the topographic maps showing the areas within a radius of 8 km and 80 km of the site respectively. Figure 2.3-26 shows topographic profiles in each of the 16 compass directions radiating from the site. These cross sections give graphic pictures of the terrain characteristics of the Lungmen NPS site.

The topographical characteristics will have an effect on the northeast and southwest monsoons. Because the northeast quadrant of the plant is wide and open, the northeast monsoon will govern the climate without obstruction from October to April every year. Storms and waves could easily attack the site once the typhoons pass through the east of Taiwan and its vicinity in the summer and fall seasons. The mountain ridges and hills on the southwest quadrant of the site may act as obstacles to prevent the southwesterly winds from blowing over the site. Thus, less rainfall and weaker winds will occur in summer.

2.3.3 Onsite Meteorological Measurements Program

The onsite meteorological measurements program was designed to meet the requirements of USNRC Regulatory Guide 1.23. Meteorological observation stations were set up at the plant site from August 1966 to July 1971 to monitor air temperatures, relative humidity, precipitation, amounts of heat generated, wind speeds and directions, and other climatic factors. In addition, the stations were set up again in July 1980 and observation towers were added to record wind directions and wind speeds in high and low layers and to observe degrees of stability. Joint frequency tables by stability class, generated from the measured meteorological data, will be provided in FSAR.

2.3.3.1 Preoperational Program

Meteorological observations including atmospheric pressure, air temperature, relative humidity, rainfall and cloudiness have been in progress on the site since August 1966. At present, the related data reduction and compilation are as follows:

- (1) General meteorological elements such as temperature, dew point, insolation, etc. are observed for obtaining the necessary average value or time distribution.
- (2) The basic reduced data are compiled into monthly and annual joint frequency distribution of wind speed and direction by atmospheric stability class.
- (3) The distribution of calm conditions at the site are based on hourly spot readings and the analog trace.

- (4) Using fluctuation of wind direction and temperature gradient, the stability classification is ascertained.

After data collection, additional meteorological data are investigated which include inversion condition, atmospheric stability and air flow (i.e., local wind pattern, sea breeze) calm condition, etc. Table 2.3-88 shows an outline of meteorological instruments used at the Lungmen NPS site.

2.3.3.2 Operational Program

After conclusion of the preoperational program, only the necessary meteorological monitoring instruments will remain as the primary operational meteorological monitoring system, with remote data readout and recording systems in the plant main control room (MCR). Other meteorological stations may be removed, relocated or added as necessary. Additional meteorological measurements, if necessary, will meet the requirements of USNRC Regulatory Guide 1.23.

2.3.4 Short-Term (Accident) Diffusion Estimates

2.3.4.1 Objective

Estimation of atmospheric diffusion (c/Q) at the exclusion area boundary (EAB) and the low population zone (LPZ) can be obtained from the site data and the measured meteorological data.

2.3.4.2 Conservative and Realistic Dilution Factors

The atmospheric relative concentration (c/Q) values were calculated according to USNRC Regulatory Guide 1.145. Two classes of releases were considered in the calculation: (1) ground release through vents or building penetrations and (2) stack release.

For ground releases including all release points or areas that are effectively lower than two and one-half times the height of adjacent solid structures, two sets of meteorological conditions are treated differently, as follows:

- (1) During neutral (D) or stable (E, F, or G) atmospheric stability conditions when the windspeed at the 10 meter level is less than 6 meters per second, horizontal plume meander may be considered. c/Q values may be determined through selective use of the following set of equations for ground-level relative concentration at the plume centerline:

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

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

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

where

- c/Q = relative concentration, in s/m^3 ,
- π = 3.14159,
- \bar{U}_{10} = windspeed at 10 meters above plant grade, in m/s
- σ_y = lateral plume spread, in m,
- σ_z = vertical plume spread, in m,
- Σ_y = lateral plume spread with meander and building wake effects, in m,
- A = the smallest vertical-plane cross-sectional area of the reactor building, in m^2 .

c/Q values should be calculated from Equations 2.3-1, 2.3-2, and 2.3-3. The values from Equations 2.3-1 and 2.3-2 should be compared and the higher value selected. This value should be compared with the value from Equation 2.3-3, and the lower value of these two should then be selected as the appropriate c/Q value.

- (2) During all other meteorological conditions, plume meander should not be considered. The appropriate χ/Q value for these conditions is the higher value calculated from Equation 2.3-1 or 2.3-2.

For stack releases including all release points at levels that are two and one-half times the height of adjacent solid structures or higher and for nonfumigation conditions, the equation for ground-level relative concentration at the plume centerline for stack releases is:

$$\chi / Q = \frac{1}{\pi \bar{U}_h \sigma_y \sigma_z} \exp\left[\frac{-h_e^2}{2\sigma_z^2}\right] \quad (2.3-4)$$

Where

- \bar{U}_h = windspeed representing condition at the releases height, in m/s,
- h_e = effective stack height, in m: $h_e = h_s - h_t$,
- h_s = the initial height of the plume (usually the stack height) above

plant grade, in m, and

h_t = the maximum terrain height above plant grade between the releases point and the point for which the calculation is made, in m. If h_t is greater than h_s , then $h_e = 0$.

For fumigation conditions, a “fumigation χ/Q ” should be calculated for each sector as follows. The equation for ground-level relative concentration at the plume centerline for stack releases during fumigation conditions is:

$$\chi / Q = \frac{1}{(2\pi)^{1/2} \bar{U}_{h_e} \sigma_y h_e}, h_e > 0 \quad (2.3-5)$$

where χ/Q

\bar{U}_h = windspeed representative of the fumigation layer of depth h_e , in m/s, and

σ_y = the lateral plume spread, in m; a moderately stable (F) atmospheric stability condition is usually assumed.

The procedures described above are used to calculate the two-hour χ/Q values for the EAB and the LPZ.

An annual average (8760-hour) χ/Q should be calculated for each sector at the outer LPZ boundary distance for that sector, using the method described in Regulatory Guide 1.111.

The χ/Q values for EAB or LPZ evaluations are the maximum sector χ/Q or the 5% overall site

χ/Q , whichever is higher. The procedure of calculating these χ/Q values is described below.

Using the χ/Q values calculated for each hour of data, a cumulative probability distribution of χ/Q values is constructed for each of the 16 sectors. A plot of χ/Q versus probability of being exceeded is made for each sector, and a smooth curve is drawn to form an upper bound of the computed points. For each of the 16 curves, the χ/Q value that is exceeded 0.5 percent of the total number of hours in the data set is selected. These are the sector χ/Q values. The highest of the 16 sector values is defined as the maximum sector χ/Q value.

For the outer LPZ boundary, sector χ/Q values are determined for various time period throughout the course of the postulated accident. For a given sector, the average χ/Q values for the various time periods are approximated by a logarithmic interpolation between the 2-hour sector χ/Q and the annual average (8760-hour) χ/Q for the same sector. The highest for the 16 sector values is defined as the maximum χ/Q value for each time period.

The 5% overall site χ/Q values are determined by constructing the overall cumulative probability distribution for all directions combined. The 2-hour χ/Q value that is exceeded 5% of the time is then selected from the plot of χ/Q versus probability of being exceeded. In addition, for the outer LPZ boundary the maximum of the 16 annual average χ/Q values is used along with the 5% 2-hour χ/Q value to determine χ/Q values for the intermediate time periods by logarithmic interpolation.

The computer code PAVAN (Reference 2.3-5) is used to calculate the short-term accident atmospheric dispersion factors. For the analysis, Unit 1 was found to be limiting due to its proximity to the plant southern boundary and therefore χ/Q values for Unit 1 were used for both units to provide a conservative licensing basis. The calculated χ/Q values are listed as follows:

	χ/Q (s/m ³)	
	Elevated Release	Ground Release
2h	1.19E-4	3.95E-4
8h	4.62E-5	3.06E-4
1d	2.88E-5	2.69E-4
4d	1.04E-5	2.04E-4
30d	2.38E-6	1.37E-4
Annual Average	3.94E-7	8.44E-5

For the ground release, accidents, the limiting χ/Q was found in the ENE sector which represents the minimum distance to the site (or exclusion area) boundary. The χ/Q 's for the distances from the Turbine Building truck doors were found to be limiting and used for both the Turbine Building releases and the Spent Fuel Cask releases from the Reactor Building truck doors. Reference 2.3-6 was used to evaluate the short term (2 hours) ground level diffusion coefficient with building wake.

The plant stack, which receives inputs from the Standby Gas Treatment and Containment Overpressure Systems, is a seismically qualified stack reaching a height of 116 meters. The height of the stack allows for buoyancy of the stack plumes and qualifies the stack as an elevated release point in accordance with RG 1.145. Using PAVAN code, maximum χ/Q values were found in the WNW sector on the ridge rising to the west of the plant site. This χ/Q was used for all releases from the plant stack.

2.3.4.3 Main Control Room Dilution Factors

The limiting doses to the operator in the Main Control Room (MCR) under the accident conditions listed above will result from releases from the Turbine Building truck doors. This release point is approximately the same distance from the MCR intakes as the doors are from the site boundary. Therefore, for the PSAR, a χ/Q equivalent to the ground releases offsite χ/Q was used for the control building. The χ/Q calculated from the plant stack to the control room intakes was on the order of 10^{-20} s/m³ compared to the site boundary χ/Q of 3.95×10^{-4} . To provide a conservative calculation, the elevated release site boundary χ/Q 's were used for the MCR calculations.

2.3.5 Long-Term (Routine) Diffusion Estimates

2.3.5.1 Objective

Conservative and realistic estimates of annual average atmospheric diffusion are calculated based on the site data and the measured meteorological data.

2.3.5.2 Long-Term Dilution Factors

Annual average χ/Q s were calculated according to USNRC Regulatory Guide 1.111 using the following equation:

$$\chi/Q = \frac{2.032}{x} \sum \frac{f}{\sigma_z \bar{U}} \exp \left\{ -\frac{1}{2} \left(\frac{h_s + \Delta h - h_g}{\sigma_z} \right)^2 \right\} \quad (2.3-6)$$

where

- χ/Q = annual average ground level concentration normalized by effluent emission rate
- f = the joint probability of stability, windspeed and wind direction
- x = downwind distance from releases, meters
- \bar{U} = mean horizontal windspeed, m/s
- h_s = stack height, meters
- Δh = plume rise, meters
- h_g = height of ground at downwind distance x , meters

The "worst case" annual χ/Q values at the EAB/LPZ is 8.44×10^{-5} in the ENE sector for the ground release and 3.94×10^{-7} in the WNW sector for the stack release. These values were used in the graphical interpolation scheme for intermediate short-term χ/Q values described in Subsection 2.3.4.

2.3.6 References

- 2.3-1 *Summary Report of Meteorological Data in Taiwan*, Central Weather Bureau, Volume V, 1981-1990.
- 2.3-2 *Climatological Data Annual Report*, Central Weather Bureau, 1991, 1992, 1993, 1994, and 1995.

- 2.3-3 *Annual Report of Meteorological Data for Lungmen Site*, Power Resources Survey Team, Taiwan Power Company.
- 2.3-4 *Monthly Report of Meteorological Data for Lungmen Site*, Power Resources Survey Team, Taiwan Power Company.
- 2.3-5 T. J. Bander, *PAVAN: An Atmospheric Dispersion Program for Evaluating Design Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations*, NUREG/CR-2858, November 1982.
- 2.3-6 J. V. Ramsdell, *Atmospheric Diffusion for Control Room Habitability Assessments*, May 1988 (NUREG/CR-5055).