

2.7.3 Severe Weather

2.7.3.1 Thunderstorms, Hail and Lightning

2.7.3.1.1 Thunderstorms

Thunderstorms are common in the region and normally occur 42 to 55 days per year (Reference 2.7.3-1; Reference 2.7.3-2; Reference 2.7.3-3; Reference 2.7.3-4). (This region includes data from National Weather Service [NWSs] Stations in Chattanooga, the Bristol/Johnson City/Kingsport area, Knoxville and Nashville; data was not available from the Oak Ridge NWS Station.) Thunderstorms occur most frequently during the summer with a range of 31 to 36 days during May through August. This is characteristic of a diurnal afternoon thunderstorm pattern due to solar heating.

2.7.3.1.2 Hail

In Roane County, severe hail (3/4 inches [in.] in diameter or larger) was reported 32 days during the period from 1950 through January 31, 2015 (Reference 2.7.3-5). During the same period, severe hail was reported in adjacent Loudon and Knox counties 44 and 84 days, respectively (Reference 2.7.3-6; Reference 2.7.3-7). This corresponds to about 0.49, 1.29, and 0.68 days per year with severe hail for Roane, Knox, and Loudon counties, respectively.

2.7.3.1.3 Lightning

The Clinch River Nuclear (CRN) Site averages 13 cloud-to-ground lightning flashes per square mile (sq mi) annually (Reference 2.7.3-8). The power block area is expected to be 28 acres (ac) or 0.0438 sq mi. Based on the region's estimated annual number of cloud-to-ground lightning flashes per sq mi, the estimated frequency of potential lightning strikes to an area the size of the power block area is 0.57 per year, or approximately one lightning strike every other year.

2.7.3.2 Extreme Winds

Windstorms are relatively infrequent at the CRN Site, but may occur several times a year, and are usually associated with thunderstorms. Moderate and occasionally strong winds sometimes accompany migrating cyclones and air mass fronts.

Strong winds are usually associated with lines of thunderstorms along or ahead of cold fronts and are more probable in the late winter and spring than any other time of the year. Brief, strong gusts of wind due to downdraft and outflow from individual thunderstorms can occur, but are generally limited to the large, intense thunderstorms that develop in the spring and summer. The National Climatic Data Center [NCDC] Storm Events Database provides long-term data for thunderstorm winds. From 1950 through January 31, 2015 (65.083 yr), 214 thunderstorm wind events were reported for Roane County (Reference 2.7.3-9). Therefore just over three (3.29) thunderstorm wind events per year occur on average.

Estimated extreme winds for the CRN Site region are based on climatological data from the Oak Ridge NWS Station and Knoxville NWS Station, along with hourly observations from the CRN Site. The reported and estimated maximum wind measurements (fastest mile and fastest 3-second gust) for the NWS stations are shown in Table 2.7.3-1. The maximum estimated wind speed is a fastest mile of 73 miles per hour (mph; which corresponds to a 3-second gust of 87 mph). Hourly average wind speed observations at the 10-meter (m) level are available from the CRN Site for April 2011 through July 2014. The maximum observed hourly wind speed was 15.1 mph at the CRN Site which correspond to a 3-second gust of 23 mph.

The basic design wind speed for the CRN Site is 90 mph (50-year [yr] return period, 3-second gust wind speed at 33 ft above ground level) based on the American Society of Civil Engineers (ASCE) design loads for buildings and structures. This converts to a 100-yr return period 3-second gust wind speed of 96.3 mph (ASCE).

The 100-yr recurrence interval fastest mile of wind in the CRN Site area is approximately 90 mph (Reference 2.7.3-10).

Hurricane winds are mainly a concern for coastal locations as shown by the wind speed contours presented in NRC Regulatory Guide (RG) 1.221, *Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants*, and NUREG/CR-7005, *Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants*. The wind speed contours in RG 1.221 and NUREG/CR-7005 place the CRN Site in the 130-mph design basis wind speed range. This design basis wind speed is a 3-second gust with an annual exceedance probability of 10^{-7} . A discussion of hurricane and tropical storm frequencies is provided in Subsection 2.7.3.5.

2.7.3.3 Tornadoes

2.7.3.3.1 Tornado Strike Probability

The probability of a tornado occurring at the CRN Site is low based on records from the NWS Morristown Tornado Database and the NCDC Storm Events Database. During the 64-yr period from 1950 through 2013, five tornadoes were reported within 10 mi of the CRN Site. Data for these five tornadoes are summarized in Table 2.7.3-2. Only one of these (tornado occurring on February 21, 1993) had a magnitude greater than the Fugita Tornado Damage Scale F0 or Enhanced Fugita Scale EF0. (F0 and EF0 are the lowest levels of the Fugita and Enhanced Fugita scales.)

NRC NUREG/CR-4461, *Tornado Climatology of the Contiguous United States*, provides the number of tornado events within 2 degree boxes for the Contiguous United States for the period from January 1950 through August 2003. During this period, 226 tornado events occurred for the 2 degree box that includes the CRN Site.

Using the principle of geometric probability described by H.C.S. Thom, the probability of a tornado striking any point within a 1° latitude by 1° longitude square (3887 sq mi) is calculated for the CRN Site. The annual probability of a tornado striking any point in the area around the CRN Site is 1.43E-04 and the recurrence interval is 6993 yr.

2.7.3.3.2 Design Basis Tornado (DBT) Parameters

The CRN Site is located in Region II for DBT considerations (NRC RG 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*). The design-basis characteristics applicable to structures, systems, and components important to safety at the proposed CRN Site include the following parameters (NRC RG 1.76, Table 1):

- Maximum Wind Speed = 230 mph
- Translational Speed = 46 mph
- Maximum Rotational Speed = 184 mph
- Radius of Maximum Rotational Speed = 150 feet (ft)
- Pressure Drop = 1.2 pounds per square inch (psi)
- Rate of Pressure Drop = 0.5 psi/second

2.7.3.4 Winter Storms

Winter storms producing snowfall or glaze ice in excess of 1 in. are infrequent for Eastern Tennessee (Reference 2.7.3-1; Reference 2.7.3-2; Reference 2.7.3-3; Reference 2.7.3-4; Reference 2.7.3-11; Reference 2.7.3-12). The NCDC Storm Events Database reports 18 winter storms for Roane County from 1950 through January 31, 2015 (Reference 2.7.3-13).

2.7.3.4.1 Snow

Snowfall records for stations around the CRN Site (Table 2.7.3-3) show a maximum 24-hr snowfall of 20.0 in. (March 1993) at the Chattanooga NWS Station. At the Oak Ridge NWS Station, the maximum 24-hr reported snowfall is 12 in. in March 1960. Maximum monthly snowfall is 23.3 in. at the Knoxville NWS Station reported in February 1960.

The normal number of days per year with snowfall greater than one inch, for the stations around the CRN Site, is a maximum of 2.2 days per year (Table 2.7.3-3).

2.7.3.4.2 Ice Storms

Estimations of regional glaze probabilities have been made by Tattelman and Gringorten. For Region V, which contains Tennessee, storms with ice ≥ 2.5 centimeters (cm) occurred 5 times in 50 yr and storms with ice ≥ 5.0 cm occurred 2 times in 50 yr. (Reference 2.7.3-12)

For ice storms with wind gusts ≥ 20 meters per second (m/s), the estimated ice thickness is < 2.5 cm for 25- and 50-yr return periods, and 3.6 cm for a 100-yr return period (Reference 2.7.3-12).

For glaze ice, the point probabilities are 0.20 for ice thickness ≥ 1.25 cm and 0.36 for ice thickness ≥ 0.63 cm (Reference 2.7.3-12). These probabilities correspond to, recurrence intervals of once in five years and once in three years, respectively.

2.7.3.5 Tropical Cyclones

Due to the significant inland distance from both the Atlantic Ocean and the Gulf of Mexico (more than 300 mi), tropical storm impacts are rare at the CRN Site, and are mostly from tropical storm remnants (Reference 2.7.3-14).

The NCDC Storm Events Database shows no hurricanes impacting Roane County from 1950 through January 31, 2015, and only one tropical storm is recorded for Roane County over this same period (Reference 2.7.3-15; Reference 2.7.3-16). The tropical storm is reported on September 16, 2004 and is from the remnant of Hurricane Ivan (Reference 2.7.3-17).

2.7.3.6 Droughts

Precipitation is well spread throughout the year and droughts are generally uncommon (Reference 2.7.3-11). The NCDC Storm Events Database reports that during the period of 1950 through January 31, 2015, drought conditions in Roane and surrounding counties occurred in late summer of 1998, throughout much of 2007 and 2008, and in mid-summer 2012. (Reference 2.7.3-18)

2.7.3.7 Heavy Fog

Episodes of heavy fog (visibility less than or equal to 0.25 mi) are reported to occur at the Oak Ridge NWS Station on average 51.9 days per year and 29.7 days per year at the Knoxville NWS Station. At the Oak Ridge NWS Station, the months with the maximum mean number of days with heavy fog are September and October (7.5 days for each month) and the minimum is 1.4 days in February. (Reference 2.7.3-2; Reference 2.7.3-11)

2.7.3.8 References

Reference 2.7.3-1. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Chattanooga, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-2. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Knoxville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-3. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Nashville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-4. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Bristol/Jhnsn Cty/Kingsprt, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-5. National Oceanic and Atmospheric Administration, NCDL Storm Events Database - Roane County, TN Hail Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-6. National Oceanic and Atmospheric Administration, NCDL Storm Events Database - Knox County, TN Hail Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-7. National Oceanic and Atmospheric Administration, NCDL Storm Events Database - Loudon County, TN Hail Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-8. Changnon, S. A., "Thunderstorms Across the Nation, Figure 29," 2001.

Reference 2.7.3-9. National Oceanic and Atmospheric Administration, NCDL Storm Events Database - Roane County, TN Thunderstorm Wind Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-10. Thom, H. C. S., "New Distributions of Extreme Winds in the United States, Figure 5," Journal of the Structural Division, Proceedings of the American Society of Civil Engineers 94(No. ST 7): 1787-1801, July, 1968.

Reference 2.7.3-11. National Oceanic and Atmospheric Administration, 2013 Local Climatological Data Annual Summary with Comparative Data - Oak Ridge, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-12. Tattelman, Paul and Gringorten, Irving I., "Estimated Glaze Ice and Wind Loads at the Earth's Surface for the Contiguous United States," AFCRL-TR-73-0646, Air Force Cambridge Research Laboratories, October 16, 1973.

Reference 2.7.3-13. National Oceanic and Atmospheric Administration, NCDL Storm Events Database - Roane County, TN Winter Storm Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-14. Chattanooga/Hamilton County Air Pollution Control Bureau, "Ambient Air Monitoring Plan 2012," Chattanooga/Hamilton County Air Pollution Control Bureau, Knox

County Health Department, Memphis/Shelby County Health Department, Metropolitan Health Department, and Tennessee Department of Environment and Conservation, June 15, 2012.

Reference 2.7.3-15. National Oceanic and Atmospheric Administration, NCDC Storm Events Database - Roane County, TN Tropical Storm Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-16. National Oceanic and Atmospheric Administration, NCDC Storm Events Database - Roane County, TN Hurricane Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-17. Franklin, James L., Pasch, Richard J., Avila, Lixion A., Beven II, John L., Lawrence, Miles B., Stewart, Stacy R., and Blake, Eric S., Monthly Weather Review, Atlantic Hurricane Season of 2004, Website: http://www.aoml.noaa.gov/hrd/hurdat/mwr_pdf/2004.pdf, March, 2006.

Reference 2.7.3-18. National Oceanic and Atmospheric Administration, NCDC Storm Events Database - Roane County, TN Drought Events: 1950-2015, Website: <http://www.ncdc.noaa.gov/stormevents/>, 2015.

Reference 2.7.3-19. National Oceanic and Atmospheric Administration, 1998 Local Climatological Data Annual Summary with Comparative Data - Oak Ridge, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-20. National Oceanic and Atmospheric Administration, 1974 Local Climatological Data Annual Summary with Comparative Data - Knoxville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

Reference 2.7.3-21. National Oceanic and Atmospheric Administration, 1995 Local Climatological Data Annual Summary with Comparative Data - Knoxville, Tennessee, Website: <http://www.ncdc.noaa.gov/IPS/lcd/lcd.html>, 2015.

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Table 2.7.3-1
Maximum Wind Speeds at Oak Ridge and Knoxville

Station	Time Period	Observed Maximum (mph)		Estimated Maximum (mph)	
		Fastest Mile	3-Second Gust	Fastest Mile	3-Second Gust
Oak Ridge NWS	1985-1998 ¹	NR	51 (Nov 1995)	40	51
	2000-2013 ²	NR	53 (Feb 2009)	42	53
Knoxville NWS	1942-1974 ³	73 (Jul 1961)	NR	73	87
	1985-1995 ⁴	NR	86 (Aug 1995)	72	86
	1996-2013 ⁵	NR	76 (Apr 1996)	63	76

¹ (Reference 2.7.3-19)

² (Reference 2.7.3-11)

³ (Reference 2.7.3-20)

⁴ (Reference 2.7.3-21)

⁵ (Reference 2.7.3-2)

Notes:

Conversions are based on TIA-222-G

NR = not recorded

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Table 2.7.3-2
Tornadoes reported within 10 Miles of CRN Site (1950-2013)

Date	County(s)	Magnitude (WS range)	Length (miles)	Width (yards)	Closest Distance to CRN Site
10/1/1977	Roane	F0 (40-72 mph)	0.2	100	7 miles
2/21/1993	Roane Loudon	F3 (158-206 mph)	30	100	5 miles
5/18/1995	Morgan	F0 (40-72 mph)	0.5	23	8 miles
4/27/2011	Knox	EF0 (65-85 mph)	1	50	10 miles
6/22/2011	Roane	EF0 (65-85 mph)	0.6	20	8 miles

Sources:

NWS Morristown Tornado Database (<http://innovation.srh.noaa.gov/tors/index.php?cw=mrn>).

NCDC Storm Events Database (<http://www.ncdc.noaa.gov/stormevents>).

Table 2.7.3-3
Extreme Snowfall for NWS Stations Around CRN

Station	Period of Record (years)	Max 24-hour Snowfall (in.)	Max Monthly Snowfall (in.)
Oak Ridge NWS	52	12.0 (Mar 1960)	21.0 (Mar 1960)
Knoxville NWS	69	18.2 (Nov 1952)	23.3 (Feb 1960)
Chattanooga NWS	76	20.0 (Mar 1993)	20.0 (Mar 1993)
Nashville NWS	66	10.2 (Dec 1963)	18.9 (Feb 1979)

Sources:

(Reference 2.7.3-1; Reference 2.7.3-2; Reference 2.7.3-3; Reference 2.7.3-11)