2.0 SITE CHARACTERISTICS

The principal purpose of this chapter of the SHINE Medical Technologies, LLC (SHINE, the applicant) operating license application safety evaluation report (SER) is to describe why the site selected is suitable for constructing and operating the SHINE facility.

This chapter of the SER describes the technical review and evaluation of the U.S. Nuclear Regulatory Commission (NRC, the Commission) staff of the final design of the SHINE irradiation facility (IF) and radioisotope production facility (RPF) site characteristics as presented in Chapter 2, "Site Characteristics," of the SHINE Final Safety Analysis Report (FSAR), as supplemented by the applicant's responses to NRC requests for additional information (RAIs).

SER Chapter 2, "Site Characteristics," provides an evaluation of the SHINE site selection as presented in SHINE FSAR Sections 2.1, "Geography and Demography"; 2.2, "Nearby Industrial, Transportation, and Military Facilities"; 2.3, "Meteorology"; 2.4, "Hydrology"; and 2.5, "Geology, Seismology, and Geotechnical Engineering."

2.1 Areas of Review

SHINE FSAR Sections 2.1 through 2.5 provide the bases for the site selection and describe the applicable site characteristics, including geography, demography, meteorology, hydrology, geology, seismology, and interaction with nearby installations and facilities.

The NRC staff reviewed SHINE FSAR Sections 2.1 through 2.5 against applicable regulatory requirements, using appropriate regulatory guidance and acceptance criteria, to assess the sufficiency of the site selection for the SHINE facility. The staff's review evaluated the geography and demography of the site; nearby industrial, transportation, and military facilities; site meteorology; site hydrology; and site geology, seismology, and geotechnical engineering to ensure that issuance of the operating license will not be inimical to public health and safety. The staff's review evaluated structures, systems, and components (SSCs) designed to ensure safe operation, performance, and shutdown when subjected to extreme weather, floods, seismic events, missiles (including aircraft impacts), chemical and radiological releases, and loss of offsite power.

2.2 Summary of Application

As stated above, the SHINE facility would consist of the IF (itself consisting of eight irradiation units) and the RPF. Both the IF and the RPF would be collocated within a single building on the site.

The SHINE site is on previously undeveloped property in the City of Janesville, Rock County, Wisconsin. The SHINE site is on the south side of the City of Janesville corporate boundaries, and the densely populated parts of the city are more than 1 mile (mi) (1.6 kilometers (km)) to the north.

The SHINE site boundaries encompass approximately 91 acres (36.8 hectares) of land. All safety-related SSCs of the SHINE facility are located within a square area located near the center of the property, referred to as the safety-related area. The center point of the safety-related area has the following coordinates: 42° 37' 26.8" north latitude and 89° 1' 29.7" west longitude. The SHINE site boundary corresponds to the property line around the perimeter of the site. The facility operating license would define the owner-controlled area as being delineated by the site boundary.

The distance and direction from the center point of the safety-related area to major nearby features are as follows:

- U.S. Highway 51: < 0.1 mi (0.2 km) west
- Southern Wisconsin Regional Airport: 0.4 mi (0.6 km) west
- Union Pacific Railroad: 1.6 mi (2.7 km) northeast
- Rock River: 1.9 mi (3.1 km) west
- Interstate (I-)90/39: 2.1 mi (3.4 km) east

The finished site grade elevation is approximately 825 feet (ft) (251.46 meters (m)) per the North American Vertical Datum of 1988 (NAVD 88). The SHINE site and adjacent ground within a radius of approximately 1 mi (1.6 km) is generally flat. The tallest building on the SHINE site would be the main production facility, which at its highest point would be approximately 57 ft (17.4 m) above the site grade level. There would be a free-standing 67 ft (20.4 m) high exhaust stack adjacent to the main production facility. The distance from a release point to the site boundary in each of the 16 compass directions, calculated from a circle (radius of 70 m) that envelopes the main production facility, is provided in FSAR Table 2.1-2.

The applicant estimated the resident population distribution surrounding the SHINE site within five distance bands. These bands are represented as concentric circles at 0 to 1 km (0 to 0.6 mi), 1 to 2 km (0.6 to 1.2 mi), 2 to 4 km (1.2 to 2.5 mi), 4 to 6 km (2.6 to 3.7 mi), and 6 to 8 km (3.7 to 5.0 mi) from the center point of safety-related area. The applicant described the population growth rates used in FSAR Section 2.1.2. The resident population distribution within 8 km (5.0 mi) of the SHINE site is presented in FSAR Table 2.1-4 for the years 2019, 2024, and 2051. The area within 8 km (5 mi) of the SHINE site supports a 2019 population estimated to be about 53,000 people. SHINE estimated the 2051 population surrounding the SHINE site at about 73,000 people.

The nearest permanent residence is located approximately 0.80 km (0.50 mi) northwest of the center point of the safety-related area. There are permanent residences in two other directions that are only slightly farther away; a house located approximately 0.86 km (0.54 mi) north-northwest of the center point and a house located approximately 0.94 km (0.59 mi) to the south-southwest.

In addition to the permanent residents around the SHINE site, there are people who enter this area temporarily for activities such as employment, education, recreation, medical care, and lodging. This data is presented in FSAR Tables 2.1-5 through 2.1-9. To accurately represent the transient population, the weighted average population is estimated for each directional sector and distance, based on the length of time people are expected stay at the respective facility. SHINE estimated a 2019 total weighted transient population of about 8,600 people (FSAR Table 2.1-10).

In SHINE FSAR Section 2.2, "Nearby Industrial, Transportation, and Military Facilities," the applicant identified potential hazards from facilities and transportation routes within the 8 km (5 mi) vicinity of the SHINE site and airports within 16.1 km (10 mi) of the SHINE site. The applicant provided detailed descriptions of these facilities and transportation routes for further consideration of hazards evaluation. There are seven industrial facilities, one major highway, four major roads, two natural gas pipelines, one waterway, three railroads, five airports, four heliports, and eleven airways. There are no major military facilities located within 8 km (5 mi) of the SHINE site, although military aircraft do sometimes utilize the Southern Wisconsin Regional Airport (SWRA).

The descriptions of the industrial and transportation facilities are presented in FSAR Section 2.2.1.1. The information and evaluations with respect to air traffic pertaining to airports and airways is presented in FSAR Section 2.2.2. The city of Janesville and the city of Beloit Comprehensive Plans do not provide details of any projected or future planned industrial growth.

SHINE FSAR Section 2.2.2, “Air Traffic,” discusses air traffic located within 10 mi (16 km) of the SHINE facility (distance from the center of the SHINE facility to the nearest edge of the airway). SHINE also described its analysis of aircraft hazards associated with these airways, including approach and holding patterns near its facility.

SHINE FSAR Section 2.2.3, “Analysis of Potential Accidents at Facilities,” describes the analysis of postulated accidents and possible effects that could occur at the SHINE facility, including explosions, flammable vapor clouds, toxic chemicals, and fires. The applicant evaluated potential accidents based on the information compiled for the identified facilities in FSAR Section 2.2.1, using the guidance provided in NUREG-1537, Part 2, pursuant to 10 CFR Part 50. The applicant also used applicable guidance in Regulatory Guide (RG) 1.78, Revision 1, “Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release” (ADAMS Accession No. ML013100014), and RG 1.91, Revision 1, “Evaluation of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants” (ADAMS Accession No. ML003740286). The applicant performed an analysis of these accidents to determine whether any of them should be considered as design-basis events (DBEs). The DBEs are defined as those accidents that have a probability of occurrence on the order of magnitude of 10^{-6} per year or greater with potential consequences serious enough to affect the safety of the facility to the extent that the guidelines specified in 10 CFR Part 100 could be exceeded. The following accident categories are considered in selecting DBEs: explosions; flammable vapor clouds (delayed ignition); toxic chemicals; aircraft crashes; and fires. Aircraft crash evaluations are addressed in SER Section 2.2.2.

SHINE FSAR Section 2.3 describes the general and local climate, including historical averages and extremes of climatic conditions and regional meteorological phenomena. The SHINE site is located in a region with the Köeppen classification, which is a humid continental climate with warm summers, snowy winters, and humid conditions. The climate features a large annual temperature range and frequent short duration temperature changes. Although there are no pronounced dry seasons, most of the annual precipitation falls during the summer. During the autumn, winter, and spring, strong synoptic scale surface cyclones and anticyclones frequently move across the site region. During the summer, synoptic scale cyclones are usually weaker and pass north of the site region. Most air masses that affect the site region are generally of polar origin; however, air masses occasionally originate from arctic regions or the Gulf of Mexico. Air masses originating from the Gulf of Mexico generally do not reach the site region during winter months. There are occasional episodes of extreme heat or high humidity in the summer. The windiest months generally occur during the spring and autumn. The annual average number of days with thunderstorms varies from approximately 45 days at the southwest corner of the state of Wisconsin, to approximately 35 days at the northeast corner of the state. Hail is most frequent in the southwestern and west central portions of the state, and is most common during summer months, peaking in late July. Tornadoes are relatively infrequent. Winter storms that affect the region generally follow one of three tracks: Alberta, Panhandle, or Gulf Coast. During an average winter, the ground is covered with snow about 60 percent of the time. In addition, the applicant also discussed the potential meteorological effects to the SHINE facility and discussed the dispersion analysis of airborne releases, in both restricted and unrestricted areas, from routine releases during normal operations and from postulated releases resulting from accidents.

In SHINE FSAR Section 2.3.1, the applicant provided a description of the general climate of the region and meteorological conditions relevant to the design and operation of the facility, including:

- Identification of the region with climate representative of the site
- Regional data sources
- Identification and selection for analysis of weather monitoring stations located within the site climate region
- Extreme wind
- Tornadoes and waterspouts
- Water equivalent precipitation extremes
- Hail, snowstorms, and ice storms
- Thunderstorms and lightning
- Snowpack and probable maximum precipitation (PMP)
- Design dry bulb and wet bulb temperatures
- Extreme dry bulb temperatures
- Restrictive dispersion conditions
- Air quality
- Climate change

In SHINE FSAR Section 2.3.2, the applicant provided a description of local topography, local meteorological data sources, regional and local wind patterns, atmospheric stability, and the development of joint frequency distributions (JFD) for input to dispersion models.

SHINE FSAR Section 2.4.1, “Hydrological Description,” identifies the SHINE site surface water, groundwater aquifers, types of on-site groundwater use, sources of recharge, present known withdrawals and likely future withdrawals, flow rates, travel time, gradients, and other properties that affect movement of accidental contaminants in groundwater, groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and man-made changes that have the potential to cause long-term changes in the local groundwater regime.

In SHINE FSAR Section 2.4.2, “Floods,” the applicant indicated that flooding near the SHINE site is very unlikely to be caused by local intense precipitation or by the Rock River or the unnamed tributary stream overflowing their banks. The applicant described its analysis of the potential flooding from other natural events, including surges, seiches, tsunami, dam failures, flooding caused by landslides, and effects of ice formation on water bodies. The applicant noted that the Rock River and the unnamed tributary stream are subject to flooding throughout the year. The largest potential for flooding occurs during the spring as a result of precipitation and snow melt. Peak flows occur during the winter and are primarily caused by ice jams.

SHINE FSAR Section 2.5.1, “Regional Geology,” describes the regional geology within about 322 km (200 mi) of the SHINE site, including regional physiography and geomorphology; tectonic provinces and structures within the basement rocks; bedrock geology including stratigraphy, lithology, and structure; magnetic and gravity geophysical anomalies; and surficial geology and glacial history. SHINE FSAR Section 2.5.2, “Site Geology,” describes the geologic setting, stratigraphy, and structure within about 8 km (5 mi) of the SHINE site. SHINE FSAR Section 2.5.3, “Seismicity,” describes the history of recorded and felt earthquakes in southern Wisconsin and northern Illinois. SHINE FSAR Section 2.5.4, “Maximum Earthquake Potential,” describes the historical maximum expected moment magnitude from past earthquakes, and frequency of occurrence. SHINE FSAR Section 2.5.5, “Vibratory Ground Motion,” presents an evaluation of the earthquake ground shaking expected at the SHINE site. Because most of the regional geological structures are not considered to be seismically capable, the analysis of earthquake ground shaking at the SHINE site is based on interpolation of the national seismic hazard model. The development of an earthquake ground motion design response spectrum follows the procedures set out in the structural codes and standards applicable to Wisconsin. SHINE FSAR Section 2.5.6, “Surface Faulting,” describes the surface faults and folds located in the surrounding region. SHINE FSAR Section 2.5.7, “Liquefaction Potential,” describes the soil liquefaction potential within the SHINE site.

2.3 Regulatory Requirements and Guidance and Acceptance Criteria

The NRC staff reviewed SHINE FSAR Chapter 2 against the applicable regulatory requirements, using appropriate regulatory guidance and acceptance criteria, to assess the sufficiency of the bases and the information provided by SHINE for the selection of the SHINE site for the issuance of an operating.

2.3.1 Applicable Regulatory Requirements

The applicable regulatory requirements for the evaluation of the SHINE site characteristics are as follows:

> 10 CFR 50.34, “Contents of applications; technical information,” paragraph (b), “Final safety analysis report,” subparagraph (1), which states:
>
> > All current information, such as the results of environmental and meteorological monitoring programs, which has been developed since issuance of the construction permit, relating to site evaluation factors identified in [10 CFR] part 100….

The NRC staff notes that the requirements of 10 CFR Part 100 are specific to nuclear power and testing reactors and, therefore, not applicable to the SHINE facility. However, the staff evaluated SHINE’s site-specific conditions using site criteria similar to 10 CFR Part 100, by using the guidance in NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content,” issued February

1996, and NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria," issued February 1996.

2.3.2 Applicable Regulatory Guidance and Acceptance Criteria

In determining the regulatory guidance and acceptance criteria to apply, the NRC staff used its judgment, as the available guidance and acceptance criteria were typically developed for nuclear reactors. Given the similarities between the SHINE facility and non-power research reactors, the staff determined to use the following regulatory guidance and acceptance criteria:

NUREG-1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content," issued February 1996.

NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria," issued February 1996.

"Final Interim Staff Guidance Augmenting NUREG-1537, Part 1, 'Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Format and Content,' for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors," dated October 17, 2012.

"Final Interim Staff Guidance Augmenting NUREG-1537, Part 2, 'Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria,' for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors," dated October 17, 2012.

As stated in the interim staff guidance (ISG) augmenting NUREG-1537, the NRC staff determined that certain guidance originally developed for heterogeneous non-power research and test reactors is applicable to aqueous homogenous facilities and production facilities. SHINE used this guidance to inform the design of its facility and to prepare its FSAR. The staff's use of reactor-based guidance in its evaluation of the SHINE FSAR is consistent with the ISG augmenting NUREG-1537.

As appropriate, the NRC staff used additional guidance (e.g., NRC regulatory guides, Institute of Electrical and Electronics Engineers (IEEE) standards, American National Standards Institute/American Nuclear Society (ANSI/ANS) standards, etc.) in the review of the SHINE FSAR. The additional guidance was used based on the technical judgment of the reviewer, as well as references in NUREG-1537, Parts 1 and 2; the ISG augmenting NUREG-1537, Parts 1 and 2; and the SHINE FSAR. Additional guidance documents used to evaluate the SHINE FSAR are provided as references in Appendix B, "References," of this SER.

2.4 Review Procedures, Technical Evaluation, and Evaluation Findings

SHINE FSAR Chapter 2 discusses the SHINE site characteristics including the geographical, geological, seismological, hydrological, and meteorological characteristics of the site, the vicinity to present and projected population distributions and industrial facilities, land use, and site activities and controls. The NRC staff's review of the SHINE site considers the site characteristics; design and performance of SSCs; radiation protection and waste management programs; and accident analyses.

The NRC staff performed a review of the technical information presented in SHINE FSAR Chapter 2, as supplemented, to assess the sufficiency of the SHINE site characteristics for the issuance of an operating license. The sufficiency of the final design and performance of the SHINE site characteristics is determined by ensuring that the design and performance meet applicable regulatory requirements, guidance, and acceptance criteria, as discussed in Section 2.3, “Regulatory Requirements and Guidance and Acceptance Criteria,” of this SER. The findings of the staff review are described in Section 2.5, “Review Findings,” of this SER

2.4.1 Geography and Demography

The NRC staff evaluated the sufficiency of the SHINE site characteristics regarding geography and demography, as presented in SHINE FSAR Section 2.1, using the guidance and acceptance criteria from Section 2.1, “Geography and Demography,” of NUREG-1537, Parts 1 and 2, and Chapter 2, “Site Characteristics,” of the ISG augmenting NUREG-1537, Parts 1 and 2.

2.4.1.1 Site Location and Description

The description in SHINE FSAR Chapter 2 of the SHINE medical isotope production facility located in the city of Janesville, Rock County, Wisconsin is used to assess the acceptability of the site. The NRC staff’s review covers the following specific areas: (1) specification of the SHINE site location with respect to latitude and longitude, political subdivisions, and prominent natural and manmade features of the area and (2) maps of the SHINE site area showing the boundaries and zones applicable to project area and owner controlled area and the distance and direction from the center point of the safety-related area to major nearby features such as highways, railways, and waterways in close proximity to the SHINE site. The purpose of the review is to ascertain the accuracy of the applicant’s description of the SHINE site for use in independent evaluations of the site boundary, owner controlled area, the surrounding population, and potential man-made hazards due to nearby facilities.

The applicant addressed the SHINE site location and description in FSAR Section 2.1.1, “Site Location and Description,” in which the applicant provided site-specific information related to the SHINE site location and description, including political subdivisions, natural and manmade features, population, highways, railways, waterways, and other significant features of the area.

The NRC staff reviewed the information and site maps presented by the applicant in the FSAR. The staff also performed an independent review of information available in the public domain. Based on its review of the information in the FSAR, and independent confirmatory review of prominent, natural, and manmade features of the area as found in publicly available documentation, the staff finds the information provided by the applicant with regard to the SHINE site location and description adequate and acceptable.

Based on its review, the NRC staff determined that the level of detail provided on site location and description satisfies the applicable acceptance criteria of NUREG-1537, Part 2, Section 2.1, allowing the staff to make the following relevant findings:

(1) The information is sufficiently detailed to provide an accurate description of the geography surrounding the facility.

(2) There is reasonable assurance that no geographic features render the site unsuitable for operation of the facility.

Therefore, the NRC staff concludes that the SHINE facility's geography, as described in SHINE FSAR Section 2.1, is sufficient and meets the applicable regulatory requirements and guidance for the issuance of an operating license.

2.4.1.2 Population Distribution

The NRC staff reviewed the data on the population distribution and future population projections in the SHINE site environs as presented in SHINE FSAR Section 2.1.2. The staff's review of the applicant's estimates of the present and projected populations surrounding the SHINE site, including transients, found them to be reasonable and acceptable. The staff estimated population growth rates for Rock County and the cities of Janesville and Beloit, based on US Census data for 2000 and 2010. The staff also independently reviewed the county and city population projections data that is available in the public domain and found the growth rates to be comparable to those estimated by the applicant.

Based on its review, the NRC staff determined that the level of detail provided on population distribution satisfies the applicable acceptance criteria of NUREG-1537, Part 2, Section 2.1, allowing the staff to make the following relevant findings:

(1) The demographic information is sufficient to allow accurate assessments of the potential radiological impact on the public resulting from the siting and operation of the facility.

(2) There is reasonable assurance that no demographic features render the site unsuitable for operation of the facility.

Therefore, the NRC staff concludes that the SHINE facility's demography, as described in SHINE FSAR Section 2.1, is sufficient and meets the applicable regulatory requirements and guidance for the issuance of an operating license.

2.4.2 Nearby Industrial, Transportation, and Military Facilities

The NRC staff evaluated the sufficiency of the SHINE site characteristics regarding nearby industrial, transportation, and military facilities, as presented in SHINE FSAR Section 2.2, using the guidance and acceptance criteria from Section 2.2, "Nearby Industrial, Transportation, and Military Facilities," of NUREG-1537, Parts 1 and 2, and Chapter 2, "Site Characteristics," of the ISG augmenting NUREG-1537, Parts 1 and 2.

2.4.2.1 Locations and Routes

The identification of potential hazards in the site vicinity covering the description of present and future industrial, transportation, and military installations refers to potential external hazards or hazardous materials that are present or may reasonably be expected to be present during the projected lifetime of the SHINE facility. The purpose of the NRC staff's review of this section is to determine the adequacy of information in meeting regulatory requirements and to ensure that all facilities and activities within 8 km (5 mi) are considered in the evaluation of potential hazards. The staff's review covers the following specific areas: (1) the locations of, and separation distances to, transportation facilities and routes, including airports and airways, roadways, railways, pipelines, and navigable bodies of water and (2) the presence of military and industrial facilities, such as fixed manufacturing, processing, and storage facilities.

The NRC staff reviewed the SHINE FSAR information in evaluating potential hazards due to industrial, transportation, and military installations in the SHINE site area.

In the FSAR Section 2.2.1, the applicant identified the potential hazard facilities within 8 km (5 mi) of the SHINE site for further analysis based on the U.S. Environmental Protection Agency's Envirofacts Database.

Descriptions of the industrial and transportation facilities other than airports and airways identified within 8 km (5 mi) of the SHINE site are presented in FSAR Section 2.2.1.1.

SHINE FSAR Table 2.2-1 provides a concise description of each facility, including its primary function and major products. The hazardous chemicals potentially transported on highways within 8 km (5 mi) of the SHINE site are presented in SHINE FSAR Table 2.2-5. These highways are U.S. Highway 51 (closest approach of 0.22 mi) and I-90/39 (closest approach of 2.1 mi).

There are three railroad lines within 8 km (5 mi) of the SHINE site: Union Pacific line (closest approach of 2.3 km (1.4 mi) east of the site); Canadian Pacific located on west bank of Rock River (closest approach of 3.2 km (2.0 mi) west of the site); and Wisconsin & Southern Railroad Company on the west bank of Rock River (closest approach of 4.3 km (3.7 mi) north of the site). A single railroad tank car has a maximum capacity of 30,000 gallons.

Natural gas distribution pipelines located within 8 km (5 mi) of the SHINE site are presented in FSAR Table 2.2-2. Alliant Energy operates two main natural gas pipelines—one located at approximately 4.2 km (2.6 mi) east of the site at its closest approach and the other located at approximately 4.5 km (2.5 mi) south of the site at its nearest approach. A gas feeder line at 0.3 mi (0.48 km) is located just west of U.S. Highway 51. ANR Natural gas operates a natural gas distribution pipeline approximately 5.8 km (3.6 mi) northeast of the site at its closest approach.

The airports within 16 km (10 mi) of the SHINE site are listed in FSAR Table 2.2-3. There are four airports or heliports within 8 km (5 mi) and six airports or heliports within between 8 and 16 km (5 and 10 mi), of which one has not been in operation since 1991. There are 10 low altitude airways and one jetway located within 16 km (10 mi) of the SHINE site and they are identified in FSAR Table 2.2-4. Considerable industrial growth is not projected in the area based on city comprehensive plans.

As discussed above, the applicant presented the detailed information to establish the identification of facilities that may have a potential for hazards in the SHINE site vicinity. The NRC staff reviewed the information presented by the applicant and determined that the applicant, using the applicable guidance, provided reasonable and appropriate information with respect to the identification of potential hazards in the SHINE site vicinity. The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities that have the potential for adversely affecting SHINE facility safety-related SSCs are identified. Based on its review of the information in the FSAR, as well as information obtained independently from the public domain, the staff concludes that the potentially hazardous activities on site and in the vicinity of the SHINE facility have been identified and are reasonable and acceptable.

2.4.2.2 Air Traffic

There are four airports or heliports within 5 mi (8 km) and six airports or heliports within between 5 mi (8 km) and 10 mi (16 km) of the SHINE site. The majority of the airports/heliports have only sporadic activity. FSAR Table 2.2.3 lists the airports within 10 mi (16 km); FSAR Figure 2.2-2 identifies the airports within 10 mi (16 km). There are no military airports or training routes located within 10 mi (16 km) of the SHINE site.

Airways

There are 10 low altitude airways and one jetway located within 10 mi (16 km) of the SHINE site, which are identified in FSAR Table 2.2-4. Since no screening criterion is provided in NUREG-1537, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: [Light-Water Reactor] Edition," Section 3.5.1.6, Revision 4, "Aircraft Hazards" (ADAMS Accession No. ML100331298), guidance is used for the evaluation of aircraft hazards. Three low altitude airways and one jetway located within 10 mi (16 km) of the SHINE site were identified as having an edge of the airway within two statue miles of the SHINE site and the hazards associated with these airways were evaluated in FSAR Section 2.2.2.5.1. Three airports have holding patterns near the SHINE site; however, the distance from the edge of each holding pattern to the site is greater than the 2 mi screening criterion in NUREG-0800, Section 3.5.1.6 and, therefore, this hazard screens out.

Evaluation of the Aircraft Hazards

The non-airport crash impact frequency evaluation from airways is determined by using a four-factor formula outlined in U.S. Department of Energy (DOE) Standard (STD) 3014-96, "Accident Analysis for Aircraft Crash into Hazardous Facilities." The Southern Wisconsin Regional Airport (SWRA) and three heliports are within 5 mi (8 km) of the SHINE site. A probabilistic hazard analysis was performed by the applicant for the SWRA. The three heliports have sporadic activity and their evaluation is considered by the applicant as bounded by the evaluation performed for the SWRA. Therefore, only the SWRA is evaluated for the potential aircraft hazard by the applicant.

The potential impact probabilities for small non-military aircraft, large non-military aircraft, and military aircraft from airports are provided in FSAR Table 2.2-9. Also included are the effects from increased traffic due to future potential air shows. The risk of an aircraft accident is considered acceptable if the frequency of occurrence is less than 1E-6 per year. The calculated crash probability for small non-military aircraft (3.92 E-4 per year) does not meet the acceptance criterion of 1E-6 per year. Therefore, the safety-related SSCs of the SHINE facility credited to prevent a release in excess of regulatory limits are designed to withstand the impact of a small non-military aircraft, as discussed and addressed in FSAR Section 3.4.2. The NRC staff evaluation of the safety-related SSCs is discussed in Chapter 3, "Design of Structures, Systems, and Components," of this SER. The combined probability (3.09E-7 per year) of all other aircraft crashes meet the acceptance criterion of 1E-6 per year.

2.4.2.3 Analysis of Potential Accidents at Facilities

The NRC staff's evaluation of potential accidents considers the applicant's probability analyses of potential accidents involving hazardous materials or activities on the SHINE site and in the vicinity of the SHINE site to confirm that appropriate data and analytical models were used. The review covers the following specific areas: (1) hazards associated with nearby industrial activities, such as manufacturing, processing, or storage facilities; and (2) hazards associated with nearby transportation routes (i.e., highways, railways, navigable waters, and pipelines). Each hazard review area includes consideration of the following principal types of hazards:

- Overpressure resulting from explosions or detonations involving materials such as munitions, industrial explosives, or explosive vapor clouds resulting from the atmospheric release of gases (such as propane, hydrogen and natural gas, or any other gas) with a potential for ignition and explosion;
- Missile effects attributable to mechanical impacts, such as aircraft impacts, explosion debris, and impacts from waterborne items such as barges;
- Toxic vapors or gases and their potential for incapacitating control room operators; and
- Thermal effects attributable to fires.

The NRC staff reviewed the information presented by the applicant in FSAR Section 2.2.3, pertaining to potential accidents, and reviewed the applicant's responses to RAIs, as discussed below. The staff's review confirmed that the applicant addressed the required information in the FSAR relating to the evaluation of potential accidents.

The NRC staff reviewed FSAR Section 2.2.1, containing information related to industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards that include accident categories, such as explosions, flammable vapor clouds (delayed ignition), toxic chemicals, and fires, addressed in FSAR Section 2.2.3.

Explosions

The applicant considered hazards involving potential explosions resulting in blast overpressure as a result of detonation of explosives, munitions, chemicals, liquid fuels, and gaseous fuels that are processed, stored, used, or transported near the SHINE site. The allowable and actual distances of potential hazardous explosive chemicals transported or stored are determined based on using 1 pound per square inch (psi) overpressure as a criterion for adversely affecting facility operation or preventing safe shutdown of the facility. In accordance with RG 1.91, peak positive incident overpressures below 1 psi are considered to cause no significant damage.

The chemicals stored at nearby facilities and chemicals transported by roadways and railways near the SHINE site are presented in FSAR Table 2.2-15 along with the respective chemical quantity and distance from the SHINE site. These chemicals are evaluated by the applicant and the results are summarized in FSAR Table 2.2-16. The applicant's analysis included 1,258,091 lb diesel fuel storage, 440,000 lb ethylene oxide by rail transport, 133,946 lb gasoline storage, 79,968 lb jet fuel storage, 50,000 lb each of diesel fuel, ethylene oxide, gasoline, and propane by truck transport, and 3,300 lb hydrogen by truck transport. The applicant determined either that the minimum safe distance to reach 1 psi overpressure due to potential explosion from each chemical source is less than the actual distance from the source to the center of the SHINE site or that the quantity of each chemical source is less than the quantity of chemical required to produce 1 psi at a chemical source distance from the center of the SHINE site. Based on this analysis, the applicant concluded that potential explosions would not adversely affect the operation of the SHINE facility.

The NRC staff's confirmatory calculations confirmed the applicant's results with the exception of three chemicals: ethylene oxide, propane, and hydrogen. For an ethylene oxide tanker truck carrying 50,000 lb travelling on U.S. Highway 51 at a distance of 0.22 mi from the SHINE facility, the staff finds that, although its analysis finds that the minimum safe (standoff) distance for this truck transport exceeds the actual distance of 0.22 mi, the applicant's evaluation is acceptable because it is bounded by a potential explosion of a storage tank of 440,000 lb at a distance of 2 mi from the facility. For propane and hydrogen, the applicant analyzed only an unconfined explosion scenario with a yield factor of 0.03. However, there is vapor in the tank that could explode as a confined vapor with a 100% yield factor. The staff's analysis found that this scenario results in a minimum safe distance that exceeds the actual road-way distance of 0.22 mi for both propane and hydrogen. In response, by letter dated January 29, 2021 (ADAMS Accession No. ML21029A103), the applicant clarified its methodology and justified the rationale applied in its analysis. The staff finds the applicant's response reasonable and acceptable.

Flammable Vapor Clouds (Delayed Ignition)

Flammable gases in the liquid or gaseous state can form an unconfined vapor cloud that could drift toward the SHINE facility before ignition occurs, and then could burn or explode when the vapor concentration is within flammable range. For those chemicals with an identified flammability range, an air dispersion model based on the methods and equations in RG 1.78 and NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release" (ADAMS Accession No. ML063480551),was used to determine the distance that the vapor cloud could travel before the concentration is less than the Lower Explosive Level (LEL). Chemicals listed in FSAR Table 2.2-15 were evaluated by the applicant to ascertain which hazardous chemical materials had the potential to form a flammable vapor cloud or vapor cloud explosion. For those chemicals with an identified flammability range, the Areal Locations of Hazardous Atmospheres (ALOHA) air dispersion model was used to determine the distances where the vapor cloud may exist between the Upper Explosive Level (UEL) and the LEL, thus, presenting the possibility for potential explosion and thermal radiation effects. The chemicals were also evaluated for potential vapor cloud explosion. The ALOHA model was used to model the worst-case accidental vapor cloud explosion, including the standoff distances and overpressure effects at the nearest SHINE safety-related area. The standoff distance was measured as the distance from the spill site to the location where the pressure wave is at 1 psi overpressure consistent with guidance in RG 1.91 that defines the standoff distance. The analyzed effects of flammable vapor clouds and vapor cloud explosions from internal and external sources are summarized in FSAR Table 2.2-17. The applicant determined that the distances to LEL for both ethylene oxide and propane transported by truck on U.S. Highway 51 exceeded the distance from U.S. Highway 51 to the SHINE facility (0.22 mi (0.35 km)). Therefore, the applicant performed probabilistic analyses to determine the number of shipments required to equal the acceptable probability of 1×10^{-6} per year. The applicant determined that the required number of annual ethylene oxide and propane shipments would be 99 and 404, respectively. Based on information collected from end users of these chemicals, the applicant concluded that the actual number of annual shipments of these chemicals on U.S. Highway 51 are much less than the determined maximum number of shipments associated with the probability of 1×10^{-6} and, therefore, the potential adverse impact on the operation of the SHINE facility is low.

The NRC staff's independent confirmatory calculations also identified the same two chemicals, ethylene oxide and propane, as having a distance to LEL in excess of the actual distance from U.S. Highway 51 to the SHINE site. The staff reviewed the applicant's probabilistic approach in back calculating the number of shipments of each chemical required to meet the acceptance criterion of 1×10^{-6} per year to demonstrate that the actual number of shipments, based on information and transportation data, are far less than the determined maximum acceptable number of shipments. Based on its review of the applicant's information as well as the staff's independent assessment, the staff determined that the information provided in the FSAR is reasonable and acceptable and satisfies the appropriate guidance.

Toxic Chemicals

The applicant considered the hazards due to potential accidents involving the release of toxic or asphyxiating chemicals from nearby facilities, transportation, and onsite sources that may have a potential for impact on the SHINE site. These hazards include chemicals stored, used, or transported near the SHINE site. The list of toxic chemicals within 8 km (5 mi) that were evaluated by the applicant is presented in FSAR Table 2.2-19. Chemicals transported by truck were modeled as a release of 50,000 lb of the chemical, except for chlorine and sodium bisulfite. Chlorine is shipped in 150-lb cylinders, one-ton containers, cargo tankers 15–22 tons, and up to 90-ton rail cars. The maximum amount of chlorine at one site is 900 lb. The potential release of chlorine transported on U.S. Highway 51 is from the failure of one 150-lb cylinder. Chlorine releases on I-90/39 were considered for standard size shipment containers (one ton or 2,000 lb) and 22-ton (44,000 lb) cargo tankers. Sodium bisulfite was modeled as a 15,000 lb release (maximum inventory size) for truck transport on U.S. Highway 51. Of the applicant's analysis of chemicals listed in FSAR Table 2.2-19, only four chemicals—ammonia (50,000 lb) from U.S. Highway 51, chlorine (44,000 lb) from I-90/39, propylene oxide (50,000 lb) from I-90/39, and sodium bisulfite (15,000 lb) from U.S. Highway 51—were found to exceed the respective chemical's Immediately Dangerous to Life and Health (IDLH) concentrations at the SHINE site. As such, these four chemicals were identified by the applicant to be a potential hazard to the control room habitability. These four chemicals were further evaluated using probabilistic analysis to demonstrate that their release probability meets the acceptable criterion of 1×10^{-6} per year or lower. Based on the review of the applicant's probability calculations, the NRC staff considers the estimated release probabilities of these four chemicals reasonable and acceptable.

The NRC staff's independent confirmatory analysis of the toxic chemicals listed in FSAR Table 2.2-19, identified five more toxic chemicals that have the potential to be hazardous to control room habitability, which are: ethylene oxide from U.S. Highway 51, gasoline from U.S. Highway 51, vinylidene chloride from rail (1.6 mi), sodium hypochlorite from I-90/39, and carbon monoxide from a stationary source. The concentration of each of these chemicals exceeds respective IDLH concentrations of chemicals in the control room. Therefore, the staff requested via an RAI that the applicant justify and demonstrate why these five chemicals were excluded from further consideration. By letter dated January 29, 2021, the applicant addressed these chemicals with a clarified methodology and approach to justify the rationale applied in the analysis. The staff finds the applicant's response reasonable and acceptable.

In FSAR Section 2.2.3.1.3.4, the applicant addressed on-site toxic chemicals by stating that they are evaluated in FSAR Section 13b.3 (Table 13b.3-2). The applicant also stated that worker exposures are representative of exposures to control room personnel. Based on its review of the analyses and results, the NRC staff determined that the evaluation methodology used is different than what is used in FSAR Section 2.2.3.1.3. Using methodology consistent with what is used in FSAR Section 2.2.3.1.3 (i.e., wind speed 1 m/s and F stability; using IDLH concentration limiting value), the staff determined the chemicals ammonia, nitric acid, and sodium hydroxide to be a potential hazard to control room habitability as each of their concentrations exceed their respective chemical IDLH concentrations. By letter dated January

29, 2021, the applicant revised FSAR Section 2.2.3.1.3.4. Bulk chemical storage is provided in the storage building, as described in FSAR Section 9b.7.10. The location of the storage building relative to the main production facility is identified in FSAR Figure 1.3-3. The distance from the north side of the storage building to the ventilation air intake for the main production facility is approximately 233 ft (71 m). Chemicals that are stored in bulk in the storage building are identified in FSAR Table 2.2-20. The applicant's analysis determined the limiting quantity of a solution spill that could result in exceeding the toxicity limits in the control room. The limiting quantity of each chemical determined to pose a potential hazard to control room habitability is provided in FSAR Table 2.2-20. The applicant stated that the maximum container size used for the storage of each of these chemicals in the storage building is lower than the determined limiting quantities. Therefore, the applicant concluded that these onsite stored chemicals do not pose a threat to control room habitability.

<u>Fires</u>

Fires in adjacent industrial plants, storage facilities, oil and gas pipelines, and from transportation accidents were evaluated by the applicant as events that could lead to high heat fluxes. Three types of fires were analyzed for high heat flux: boiling liquid expansion vapor explosion (BLEVE) fireballs, pool fires, and jet fires. A BLEVE fireball occurs when a tank containing a flammable liquified gas bursts resulting in a flash fire. The energy released causes the flammable gas to ignite causing a large fireball. A BLEVE fireball has a high heat flux, but a short duration. Pool fires occur when a chemical that is liquid at standard conditions spills and catches fire. A jet fire occurs when a pipeline ruptures or a pressurized tank has a hole causing the continuous release of flammable gas.

The applicant considered the tank rupture of a truck containing 50,000 lb (22,679 kg) of liquified propane as the limiting BLEVE fireball at a distance of 0.22 mi (0.35 km) from the facility. The estimated heat flux is 10.8 kW/m^2 with a fireball duration of 11 sec. This would cause a temperature rise on a concrete wall surface of 32.4^0 F. This is not a significant rise compared to the requirements for short and long-term maximum concrete temperature.

The applicant considered the limiting pool fire from a gasoline truck containing 50,000 lb (22,679 kg) on U.S. Highway 51 at a distance of 0.22 mi (0.35 km) from the facility. The estimated maximum heat flux is 2.92 kW/m^2 lasting for about 53 sec. This would cause a temperature rise on a concrete wall surface of 43.2^0 F. This is not a significant rise compared to the requirements for short and long-term maximum concrete temperature.

The applicant evaluated the limiting off-site jet fire from the feeder pipeline at 0.28 mi (0.45 km) from the SHINE facility. The applicant used the ALOHA computer program and estimated the maximum heat flux to be 0.011 kW/m^2, which is negligible compared to a typical solar heat flux of 1 kW/m^2. This is well below a heat flux of 5 kW/m^2, which could cause 2nd degree burns in 60 seconds and could cause deterioration of plastic casing of electrical cables. As the determined heat flux is negligibly small, it is not considered a threat to the facility.

The applicant evaluated the limiting on-site jet fire from the 3-in. pipeline that feeds the SHINE facility. The applicant used the ALOHA computer program and estimated the maximum heat flux to be 0.0565 kW/m^2, which is negligible compared to a typical solar heat flux of 1 kW/m^2, and, therefore, not considered a threat to the facility.

Based on its review of the applicant's information and its independent confirmatory analysis, the NRC staff determined that the applicant's evaluation is reasonable and that the applicant's conclusion of no adverse impact is acceptable.

The NRC staff reviewed the information provided and, for the reasons discussed above, concludes that the applicant provided adequate and reasonable information that established site characteristics and design parameters acceptable to meet the applicable regulatory requirements and guidance for the issuance of an operating license.

2.4.3 Meteorology

The NRC staff evaluated the sufficiency of the applicant's description of site meteorology, as presented in SHINE FSAR Section 2.3, using the guidance and acceptance criteria from Section 2.3, "Meteorology," of NUREG-1537, Part 2.

2.4.3.1 General and Local Climate

SHINE FSAR Section 2.3.1,"General and Local Climate," provides a description of the general climate of the region and the meteorological conditions relevant to the design and operation of the SHINE facility.

The NRC staff reviewed FSAR Section 2.3.1 to ensure that the application represents the complete scope of information relating to general and local climatology. The staff's review confirmed that the application addresses the required information relating to the preceding subject matter.

In Section 2.3.1, the applicant provided information regarding regional climatic conditions and the occurrence of meteorological phenomena (including both averages and extremes) that could potentially affect the operating bases of SSCs for the SHINE site.

2.4.3.1.1 Regional Climate

The applicant stated that the SHINE site is located in south-central Wisconsin, which has a humid continental climate with warm summers, snowy winters, and humid conditions. The applicant stated that the climate features a large annual temperature range, frequent short duration temperature changes and, although there are no pronounced dry seasons, most of the annual precipitation falls during the summer. During the autumn, winter, and spring, strong synoptic scale surface cyclones and anticyclones frequently move across the site region. During the summer, synoptic scale cyclones are usually weaker and pass north of the site region. The applicant stated that most air masses that affect the site region are generally of polar origin; however, air masses occasionally originate from arctic regions or the Gulf of Mexico. The applicant noted that there are occasional episodes of extreme heat or high humidity in the summer and that the windiest months generally occur during the spring and autumn. The annual average number of days with thunderstorms varies from approximately 45 at the southwest corner of the state of Wisconsin, to approximately 35 at the northeast corner of the state. The applicant stated that hail is most frequent in the southwestern and west central portions of the state, and is most common during summer months, peaking in late July. The applicant noted that tornadoes are relatively infrequent and that during an average winter, the ground is covered with 1 inch (in.) (2.54 centimeters (cm)) or more of snow about 60 percent of the time.

The applicant provided additional details about the climate region as it relates to the following:

- Regional land use
- The landforms of Wisconsin
- Lake breeze phenomena
- Effects of the local radiation balance and winds
- Mean monthly temperatures
- Monthly mean liquid-equivalent precipitation
- Climatic statistics
- Monthly mean relative humidity
- Mean monthly water equivalent precipitation and snowfall
- Mean numbers of days per month and per year of rain or drizzle, freezing rain or drizzle, snow, and hail or sleet

Identification of the Region with Climate Representative of the Site

The applicant stated that the SHINE site is located in central Rock County, Wisconsin, which is at the south-central edge of the state. It is located near the boundary of two Wisconsin physiographic provinces, the Western Uplands and the Eastern Ridges and Lowlands. It is located in National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Network (COOP) Climate Division 8 South Central. The applicant summarized the site location as follows:

- Located in south-central Wisconsin, on rural prairie silt-loam soil.
- Located within till plains glacial deposits on the Central Lowland Province of the Interior Plains Division of the United States. It is on the border between the state of Wisconsin Eastern Ridge/Lowland and Western Upland Terrain, and most like the ridge/lowland to the east because the local topography is relatively gently rolling.
- Located outside the zone of influence of Lake Michigan lake breeze circulation systems.
- Located within the zone of influence of Lake Michigan effects on temperature and precipitation, including the following: added local warmth during winter and autumn, cooling during summer and spring, and additional local precipitation during winter, spring, and autumn.

Based on these characteristics, the applicant outlined a perimeter for the geographic region. This climate region of the site is used to identify regional weather monitoring stations and other local counties that can be used for comparisons in the analysis of local and regional climate.

Regional Data Sources

After identifying the site climate region, the applicant identified a number of published data sources that provided the meteorological parameters from weather stations in the site climate region that are used in the meteorological analysis in the application. The applicant provided a list of the data sources and described the information provided by each one.

Identification and Selection for Analysis of Weather Monitoring Stations Located within the Site Climate Region

The applicant presented maps of the site climate region with additional annotations of locations within that region of NOAA Automated Surface Observing Stations (ASOS stations) and NOAA COOP stations for which NOAA Climatography of the United States No. 20 (Clim-20) publications and digital updates have been published by the National Climatic Data Center (NCDC). The applicant presented a list of the ASOS and COOP stations that are identified. A subset of the ASOS stations presented is selected for analysis. The criteria used to select that subset of stations is noted. All COOP stations presented are analyzed. Input information for that analysis includes statistics in the NOAA Clim-20 documents and updates for each station, that summarize climatic conditions during the 30-year period 1971 through 2000 and subsequent updates through 2018.

Extreme Wind

The applicant provided the basic wind speed for the SHINE site; the basic wind speed is a statistic that is used for design and operating bases. Basic wind speeds are 50-year recurrence interval nominal design 3-second gust wind speeds (mph) at 33 ft (10.1 m) above ground for Exposure C category in Chapter 6 of American Society of Civil Engineers (ASCE) ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures." The applicant stated that it considered several sources to determine the wind speeds for the SHINE site. The basic wind speed for the SHINE site is 90 mph (40.2 m/s) based on the plot of basic wind speeds in Figure 6-1 of ASCE/SEI 7-05. Basic wind speeds reported in Air Force Combat Climatology Center Engineering Weather Data, 1999, for hourly weather stations in the site climate region are 90 mph (40.2 m/s) for Madison, Wisconsin, and 90 mph (40.2 m/s) for DuPage County Airport, West Chicago, Illinois. Based on the consistency of these three values, the applicant selected a value of 90 mph (40.2 m/s) for the SHINE site. That value applies to a recurrence interval of 50 years.

The applicant used the method in Section C6.5.5 of ASCE/SEI 7-05 to calculate wind speeds for other recurrence intervals. Based on that method, a 100-year return period value is calculated by multiplying the 50-year return-period value (90 mph (40.2 m/s)) by a factor of 1.07. This approach produces a 100-year return period 3-second gust wind speed for the SHINE site area of 96.3 mph (43.0 m/s).

Tornadoes and Waterspouts

The applicant used the NCDC Storm Events Database, 2018 and selected 30 regional counties that are at least partially included within the site climate region. The applicant used the database to extract statistics on regional tornadoes and waterspouts. These tornado and waterspout statistics, for the 68-year period from May 1950 through November 2018, are presented in FSAR Table 2.3-7. As presented in FSAR Table 2.3-7, total tornadoes and waterspouts reported in the 30-county area during the 68-year period are 794 and 3, respectively. The SHINE site is in Rock County. The strongest tornado in that county and for the seven counties adjacent to Rock County was an F4 storm.

International Atomic Energy Agency (IAEA) IAEA-TECHDOC-403, "Siting of Research Reactors," requires design tornado information to be based on the maximum historical intensity within a radius of about 100 km (62 mi) of the site. The applicant stated that for the SHINE site, a 100 km (62 mi) radius partially extends outside of the representative site climate region included within the 30-county region described above. An F5 intensity tornado was recorded on June 8, 1984, in Iowa County, Wisconsin, at the town of Barneveld, which is located approximately 50 mi (80 km) west northwest of the SHINE site (NCDC Storm Data, 1984).

Water Equivalent Precipitation Extremes

The applicant stated that the daily total water equivalent precipitation is measured at the local NOAA COOP monitoring station at Beloit, Wisconsin, and several regional COOP stations within the SHINE site climate region. FSAR Table 2.3-10 presents maximum recorded 24-hour and monthly water equivalent precipitation values for the local COOP station at Beloit, and the COOP stations located within the SHINE site climate region.

The applicant stated that the regional historic maximum recorded 24-hour liquid-equivalent precipitation from the local Beloit station or for regional stations is 9.62 in. (24.43 cm). The regional historic maximum monthly liquid-equivalent precipitation from records for either the local Beloit station or for regional stations is 18.27 in. (46.41 cm) at Portage, Wisconsin, in June 2008. The regional recorded maximum 24-hour snowfall is 21.0 in. (53.34 cm) at Dalton, Wisconsin and the regional recorded maximum monthly snowfall is 50.4 in. (128.0 cm) at Watertown, Wisconsin in January 1979.

Hail, Snowstorms, and Ice Storms

The applicant listed the mean hail or sleet frequencies during winter, spring, summer, autumn, and annual periods for Rockford and Madison in FSAR Table 2.3-11. Mean hail frequencies are less than one day per season at both stations. Hail events that are either severe or large are reported to have occurred in Rock County, Wisconsin, on 11 occasions during the period of 1961–1990, or with a frequency of approximately 0.37 occurrences per year (NCDC Climate Atlas of the United States, 2002). The Storm Events Database through December 31, 2018, lists the largest hailstones that Rock County has experienced as follows: diameter of 3.00 in. (7.62 cm) on one occasion during June 1975.

The applicant stated that the daily total snowfall amounts are measured at the local NOAA COOP monitoring station at Beloit, Wisconsin, as well as at several regional COOP stations within the SHINE site climate region. FSAR Table 2.3-10 lists that the maximum recorded 24-hour snowfall for either the local Beloit station or for regional stations is 21.0 in. (53.34 cm) at Dalton, Wisconsin. The overall historic maximum monthly snowfall from records for either the local Beloit station or for regional stations is 50.4 in. (128.0 cm) at Watertown, Wisconsin.

In FSAR Table 2.3-4, the applicant listed the mean number of days with freezing rain or drizzle at 2 days per year at both Madison, Wisconsin, and Rockford, Illinois. The applicant provided in FSAR Table 2.3-12 a summary of 14 ice storms that affected Rock County, Wisconsin, during the period of 1995–2011.

The applicant stated that: A 50-year return-interval atmospheric ice load due to freezing rain is estimated to be 0.75 in. (1.91 cm) for the SHINE site (ASCE/SEI 7-05); the estimated concurrent three-second wind gust is 40 mph (17.9 m/s); a 500-year return-interval atmospheric ice load due to freezing rain is estimated to be 1.5 in. (3.81 cm) for the SHINE site (ASCE/SEI 7-05); and the estimated concurrent three-second wind gust is 40 mph (17.9 m/s).

Thunderstorms and Lightning

The applicant listed the mean seasonal thunderstorm frequencies for Madison, Wisconsin, and Rockford, Illinois, in FSAR Table 2.3-13 from data in NCDC 2018 Local Climatological Data, Annual Summary with Comparative Data Rockford, Illinois and NCDC 2018 Local Climatological Data Annual Summary with Comparative Data Madison, Wisconsin.

The applicant calculated the mean frequency of lightning strikes to earth via a method from the Electric Power Research Institute (EPRI), per the U.S. Department of Agriculture Rural Utilities Service, "Rural Utilities Service Summary of Items of Engineering Interest," 1998. Based on the average number of thunderstorm days per year at Rockford during the 63-year period of 1955–2018 (43.1 days, which is slightly higher than the value of 39.5 days for Madison), the applicant stated that the frequency of lightning strikes to earth per square mile per year is 13.4 (5.2 strikes per square km per year) for the SHINE site and surrounding area. For comparison, the applicant looked at the National Lightning Safety Institute Vaisala 10-Year Flash Density Map, 2014, which indicates 6 to 12 flashes per square mile per year (2.3 to 4.6 flashes per square kilometer per year) for the SHINE site region. Therefore, the applicant considered the EPRI value to be a reasonable indicator.

<u>Snowpack and Probable Maximum Precipitation (PMP)</u>

The applicant determined the snow load by using ASCE/SEI 7-05. Figure 7-1 of that standard provides site estimates of the 50-year ground snow load. Based on the location of the SHINE site, the 50-year ground snow load is 30 pounds per square foot (lb/ft^2). As outlined in ASCE/SEI 7-05, Section C7.3.3, a factor of 1.22 is used to account for the 100-year recurrence interval. The resulting 100-year ground snow load as 36.6 lb/ft^2 (178.7 kilograms per square meter (kg/m^2)).

The applicant determined the weight of the 48-hour PMP for the SHINE site vicinity using U.S. Department of Commerce Hydrometeorological Report No. 51, "Probable Maximum Precipitation Estimates," 1978. It was derived by multiplying the 48-hour PMP (in inches) from Figure 21 of the report by the weight of one inch of water (one inch of water covering one square foot weighs 5.2 lb (2.4 kg)). The estimated 48-hour PMP for the SHINE site from Figure 21 is 34 in. (86.4 cm). The resulting estimated weight of the 48-hour PMP for the SHINE site is 176.8 lb/ft^2 (863.2 kg/m^2).

<u>Design Dry Bulb and Wet Bulb Temperatures</u>

The applicant outlined the statistics used to define the design basis dry bulb temperatures (DBTs) and wet bulb temperatures (WBTs) for the SHINE site and its climate area.

Most of the statistics listed are readily available from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), "ASHRAE Handbook – Fundamentals," 2017, which includes values for the following stations in the SHINE site climate region: Fond du Lac, Wisconsin; Madison, Wisconsin; Rockford, Illinois; and DuPage County Airport, Illinois. The resulting statistics are listed in FSAR Table 2.3-14.

The applicant stated that statistics for the maximum and minimum DBT with an annual exceedance probability of 5 percent were not available from ASHRAE, 2017. In lieu of values from other sources, values were extracted from published DBT and wet-bulb depression joint-frequency tables in NCDC International Station Meteorological Climate Summary, 1996. Joint-frequency tables are available only for Madison, Wisconsin, and Rockford, Illinois. The extracted statistics for Madison and Rockford are listed in FSAR Table 2.3-14.

The applicant outlined the techniques used to calculate the estimated 100-year return maximum and minimum DBT; mean coincident wet bulb temperature (MCWB) coincident with the 100-year return maximum DBT; historic maximum WBT; and estimated 100-year annual maximum return WBT. The resulting values are listed in FSAR Table 2.3-15.

Extreme Dry Bulb Temperatures

The applicant performed an additional review of regional extreme DBTs using NOAA COOP climate monitoring stations in the SHINE site climate region. The locations of these stations are shown in FSAR Figure 2.3-17. The COOP climate monitoring stations do not measure WBT and do not record hourly DBTs. These stations only record maximum and minimum daily DBTs and daily precipitation totals. Therefore, it is not possible to identify WBTs coincident with the extreme DBTs recorded at those stations. FSAR Table 2.3-16 presents extreme DBTs recorded at the climate monitoring stations and also includes the extreme DBTs recorded at the two first-order stations in the site climate region (i.e., Madison, Wisconsin, and Rockford, Illinois).

The applicant stated that the overall extreme DBTs for the SHINE climate region are a maximum of 109°F (42.8ºC) recorded on July 14, 1936, at Marengo in Boone County, Illinois, and a minimum of -45°F (-42.8ºC) recorded on January 30, 1951, at Baraboo in Sauk County, Wisconsin. Since Marengo is a COOP station, the WBT coincident with the extreme DBT at Marengo (109°F (42.8ºC)) is not available.

The applicant outlined the methodology used to estimate a WBT coincident with the overall extreme DBT and listed the estimated MCWB coincident with the overall extreme DBT of 109°F (42.8ºC) at Marengo as 79°F (26.1ºC).

Restrictive Dispersion Conditions

The applicant stated that major air pollution episodes are typically a result of persistent surface high pressure weather systems that cause light and variable surface winds and stagnant meteorological conditions for four or more consecutive days. The applicant reviewed NOAA estimates of the stagnation frequency, which indicate that, on average, the site location experiences less than 10 days with stagnation per year. When stagnation occurs, stagnation lasts, on average, less than two days.

Air Quality

The applicant stated that the SHINE site is located in Rock County, Wisconsin, which is part of the Rockford-Janesville-Beloit Interstate Air Quality Control Region and that this air quality control region combines agricultural activities with the Beloit-Janesville, Wisconsin, and Rockford, Illinois, urban-industrial areas. The applicant noted that the Wisconsin portion of the air quality control region, Rock County, is mostly flat to gently rolling farmland and that industry in the region consists of manufacturing, foundry operations, and electrical power plants. The applicant stated that Rock County is currently in attainment for criteria pollutants (ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead). The applicant also discussed whether the surrounding counties are in attainment or non-attainment with regards to local air quality standards.

The applicant stated that the SHINE site is not located within 100 km (62 mi.) of a Class I area, which are national parks and wilderness areas that are potentially sensitive to visibility impairment. Thus, a Class I visibility impact analysis is not necessary.

Climate Change

The applicant stated that, generally, projections of climatic changes have been done at global scales and that predictions of changes at a single station or at a relatively small area, such as the SHINE site climate region, are not reliable. The applicant stated that facility design is most reliably based on a standard approach of projecting conditions via scientifically defensible statistical methods, using historic statistics as input.

The applicant stated that it is nevertheless valid to examine historic records for indications of long-term trends for informational purposes. The applicant examined trends of the following parameters for the climate region within which the SHINE site is located:

a. Values, for six separate 30-year division normal periods, of mean annual dry bulb temperature and mean annual precipitation. Variations of these parameters are identified in the top half of FSAR Table 2.3-18.

b. During six separate single-decade periods of record, extremes at Madison, Wisconsin, of hourly dry bulb temperature, one-day liquid-equivalent precipitation, one-day snowfall, and strongest tornadoes. Variations of those historic meteorological parameters are identified in the bottom half of FSAR Table 2.3-18.

The NRC staff reviewed the description of the general climate of the region and meteorological conditions relevant to the design and operation of the SHINE facility presented in FSAR Section 2.3.1. The staff reviewed the data resources and analytical approaches used by the applicant to prepare the information. The NRC staff used the guidance and acceptance criteria described in Section 2.3, "Meteorology," of NUREG-1537, Part 2. Based on its review, the staff concludes that the site characteristics associated with meteorology and general and local climatology are acceptable and reasonably representative of the proposed SHINE site region.

2.4.3.2 Site Meteorology

SHINE FSAR Section 2.3.2, "Site Meteorology," provides data and descriptions necessary to determine the atmospheric dispersion conditions in the vicinity of the SHINE site. This includes local and regional airflow, meteorological measurements used for dispersion estimates, and local topography.

2.4.3.2.1 Topography

The applicant described the topography immediately around the SHINE site as being flat farmland. Within a 10-mile radius of the site, elevations range from approximately 72 ft (21.9 m) below the site elevation of 825 ft (251 m) NAVD88, to 206 ft (62.8 m) above the site elevation. Most of the land surrounding the SHINE site is used for agriculture, mostly corn and soybean farming.

2.4.3.2.2 Local Data Sources

According to the applicant, local meteorological data was gathered from the SWRA in Janesville, Wisconsin. Data from the SWRA for the purposes of the application were recorded during the period from January 1, 2005, to December 31, 2010. Since there is no onsite meteorological monitoring system at the SHINE site, the applicant used the SWRA data as a substitute. In a letter dated March 16, 2021 (ADAMS Accession No. ML21075A012), the applicant stated that the SWRA observation station is located directly across U.S. Highway 51 from the SHINE site. This is a distance of 0.25 mi (0.4 km) and is the closest source of meteorological data to the site and is shown in FSAR Figure 2.2-1, “Facilities and Transportation within 8 km (5 mi.) of the Site.” The applicant also stated that the SHINE site and the SWRA meteorological station are located at approximately the same grade elevation in a relatively open, flat, and rural location and, therefore, the air dispersion conditions as sampled by the meteorological instruments at the SWRA are expected to be representative of dispersion conditions at the SHINE site. Based on the meteorological data provided to the NRC staff and the description of the SWRA meteorological tower, the staff finds the use of this data acceptable.

2.4.3.2.3 Plans to Access Local Meteorological Data during License Period

The applicant provided a description of the process to access local meteorological data in the event of an accidental radiological release at the SHINE facility. The SHINE facility does not employ an onsite meteorological measurement system and relies on the local weather station at the SWRA, which is located adjacent to the SHINE site. Although there are no acceptance criteria specific to this approach, the NRC staff finds that the applicant has described a process that will result in the ability to get local, reliable, and accurate meteorological data in the event of an accidental radiological release and, therefore, that the approach is acceptable.

2.4.3.2.4 Comparison of Local and Regional Wind Roses

SHINE FSAR Figure 2.3-36, “Annual Wind Rose Southern Wisconsin Regional Airport (Janesville, WI) and Regional Stations,” provides a depiction of the wind direction and speeds for the SWRA in Janesville, Wisconsin, along with six other regional stations. The Janesville, Wisconsin, wind rose shows a similar wind pattern to the regional sites, with the predominant wind directions coming from the south and west.

2.4.3.2.5 Atmospheric Stability

The applicant used the PAVAN atmospheric dispersion computer model from NUREG/CR-2858, “PAVAN: An Atmospheric-Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations” (ADAMS Accession No. ML12045A149), to estimate χ/Q values as discussed in SHINE FSAR Chapter 13. The PAVAN model implements the methodology outlined in RG 1.145, Revision 1, “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants” (ADAMS Accession No. ML003740205).

The PAVAN code estimates the short-term atmospheric dispersion factors, χ/Q values, for various time-average periods ranging from 2 hours to 30 days. The meteorological input to PAVAN consists of a JFD of hourly values of wind speed and wind direction by atmospheric stability class. The χ/Q values calculated using PAVAN are based on the theoretical assumption that material released to the atmosphere would be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all distances for which χ/Q values are calculated.

For each of the 16 downwind direction sectors (e.g., N, NNE, NE, ENE), PAVAN calculates χ/Q values for each combination of wind speed and atmospheric stability at the appropriate downwind distance. The χ/Q values calculated for each sector are then ordered from greatest to smallest and an associated cumulative frequency distribution is derived based on the frequency distribution of wind speed and stabilities for each sector. The smallest χ/Q value in a distribution would have a corresponding cumulative frequency equal to the wind direction frequency for that particular sector. For each sector, PAVAN determines an upper envelope curve based on the derived data (plotted as χ/Q versus the probability of being exceeded) such that no plotted point is above the curve. From this upper envelope, the χ/Q value that is equaled or exceeded 0.5 percent of the total time is obtained. The maximum 0.5 percent χ/Q value from the 16 sectors becomes the 0-to-2-hour "maximum sector χ/Q value".

Using the same approach, PAVAN also combines all χ/Q values independent of wind direction into a cumulative frequency distribution for the entire site. An upper envelope curve is determined, and the program selects the χ/Q value that is equaled or exceeded 5.0 percent of the total time. This is known as the 0-to-2-hour "5 percent overall site χ/Q value."
The larger of the two χ/Q values, either the 0.5 percent maximum sector value or the 5 percent overall site value, is selected to represent the χ/Q value for the 0-to-2-hour time interval (note that this resulting χ/Q value is based on 1-hour averaged data but is conservatively assumed to apply for 2 hours).

To determine χ/Q values for longer time periods during an accident scenario (i.e., 0 to 8 hours, 8 to 24 hours, 1 to 4 days, and 4 to 30 days), PAVAN performs a logarithmic interpolation between the 0-to-2-hour χ/Q values and the annual average χ/Q values for each of the 16 sectors and the overall site. For each time period, the highest χ/Q value from among the 16 sectors and the overall site is identified and becomes the short-term site characteristic χ/Q value for that time period.

The meteorological input to PAVAN used by the applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from January 1, 2005, through December 31, 2010, as described in FSAR section 2.3.2.5. The wind data was obtained from the NOAA meteorological observation station at SWRA in Janesville, Wisconsin, located about 0.25 miles from the SHINE site.

The NRC staff independently developed an annual wind rose from the hourly meteorological database provided by the applicant. The wind roses developed by the staff and the wind roses provided by the applicant in FSAR Figures 2.3.2-3 through 2.3.2-54, show high frequencies of winds from the south through the west and northwest (clockwise). As stated above, this is generally consistent with the wind patterns recorded in the SHINE site region.

The wind roses presented in FSAR Figures 2.3-19 through 2.3-36, depict the wind patterns and wind speeds for all 16 wind direction sectors. FSAR Figure 2.3-19, "Annual Wind Rose Southern Wisconsin Regional Airport (2005-2010)," shows that the wind was calm during 16.61 percent of all hours recorded. The NRC staff compared the number of calms in the wind rose to the JFDs included in FSAR Tables 2.3-24 through 2.3-29 and determined that the JFDs contained about 1% more calms than shown in FSAR Figure 2.3-19. The staff considers this difference to be negligible and that it will not have an impact on the atmospheric dispersion modeling results. The staff determined that the wind rose in the application followed the guidance provided in

Table 3 of RG 1.23, Revision 1, “Meteorological Monitoring Programs for Nuclear Power Plants” (ADAMS Accession No. ML070350028), and defined any wind speed below the 0.5 m/s (1.1 mph) threshold as “calm.” The JFD tables referenced in FSAR Section 2.3.2.5 provide a summary of the wind speed distribution by stability class. The staff noted and accounted for the different units of measure between the wind roses and the JFD tables in the application.

Based on the above discussion related to the SWRA meteorological data, the NRC staff considers the 2005–2010 meteorological database suitable for input to the PAVAN model.

Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145 as a function of atmospheric stability for its PAVAN model runs. The NRC staff evaluated the applicability of the PAVAN diffusion parameters and concluded that no unique topographic features (such as rough terrain, restricted flow conditions, or coastal or desert areas) preclude the use of the PAVAN model for the SHINE site at the site boundary.

The applicant modeled one ground-level release and did not take credit for building wake effects. Ignoring building wake effects for a ground-level release decreases the amount of atmospheric turbulence assumed to be in the vicinity of the release point, resulting in higher (more conservative) χ/Q values. A ground-level release is, therefore, acceptable to the NRC staff. Distances to the site boundary for each of the 16 direction sectors is provided in FSAR Table 2.1-1. The staff reviewed the meteorological input, as well as the diffusion parameters, and finds the applicant’s use of diffusion parameter assumptions, as outlined in RG 1.145, acceptable.

The applicant included the short-term atmospheric dispersion estimates for the site boundary, resulting from its PAVAN modeling run, in response to RAIs. The NRC staff finds these χ/Q values acceptable for use in the SHINE FSAR because they are a conservative estimate of the atmospheric dispersion at the SHINE site.

The NRC staff finds, based on its review of the application and supplemental information provided through the RAI response, that the applicant’s analyses of meteorological hazards and atmospheric dispersion are sufficient and acceptable as they followed the applicable local, state, and federal guidelines. The staff concludes that the SHINE site is not located where catastrophic meteorological events are likely, that the applicant considered credible meteorological events in developing the design basis parameters for the facility, and that the applicant provided adequate site characteristics needed to evaluate an uncontrolled release of radioactive materials.

2.4.4 Hydrology

The NRC staff evaluated the sufficiency of the applicant’s description of site characteristics regarding hydrology, as presented in SHINE FSAR Section 2.4, “Hydrology,” using the guidance and acceptance criteria from Section 2.4, “Hydrology,” of NUREG-1537, Part 2.

2.4.4.1 Hydrological Description

In SHINE FSAR Section 2.4.1, the applicant described the SHINE site surface water bodies related to establishing the design basis flood hazards as well as groundwater properties that would affect the movement of accidental radionuclide contaminations in groundwater.

The applicant stated that the Rock River, which is the main water body near the SHINE site, is located approximately 2 miles west of the site and flows generally north to south from Janesville (located to the north), around the site. The Rock River has a contributing drainage area of approximately 3,340 square miles near the SHINE site. Water surface elevations along the Rock River channel during normal flow conditions are approximately 750 ft at NAVD 88 near the site.

The applicant stated that an unnamed creek (tributary) is located approximately 1 mile southeast of the SHINE site. This tributary stream flows south and then west to where it meets the Rock River approximately 2 miles southwest of the site. The tributary has a drainage area of approximately 18.4 square miles.

The applicant discussed in the SHINE Construction Permit (CP) application (ADAMS Accession Nos. ML13088A192, ML15259A272, and ML15258A431), 2019) that the central and southeastern portions of Rock County are characterized as a flat glacial outwash plain. The majority of the county's rivers and stream valley surfaces are filled with thick deposits of alluvial sand and gravel. The alluvial sediments and upland plains are the result of glacial activities. Surface soils include silt loam, which are underlain by glacial till or stratified sand and gravel outwash units. These soils then serve as the source of sediments to nearby rivers and streams.

The applicant stated that the SHINE site was originally an agricultural field with a center-pivot irrigation system. The fields were cultivated with corn and soybeans. Generalized surface topography of the area slopes gently to the southwest. Based on the 2012 field measurements by the applicant, the ground surface across the proposed site area slopes gently from the southeast to the northwest.

The NRC staff determined that the hydrologic descriptions in FSAR Section 2.4 are adequate to understand the local hydrology and drainage patterns for the proposed site. This understanding supports the relevant evaluation findings in Section 2.4 of NUREG-1537, Part 2.

2.4.4.2 Effect of Local Intense Precipitation

SHINE FSAR section 2.4.2.3 discusses the effects of the local intense precipitation (LIP) flooding on the safety-related SSCs of the SHINE facility. The applicant revised FSAR Section 2.4 from the CP application to address the changes associated with the facility layout, grading plan, roof drain of the Main Production Facility, onsite and peripheral drains, LIP scenario and the corresponding LIP flood analysis. The application uses a 100-year precipitation event. The NRC staff focused its review on these revised areas of the LIP flood analysis.

<u>Site Grade and Facility Layout</u>

The applicant stated that the finished site grade elevation is approximately 825 ft NAVD 88, with the highest point of grade set at 827 ft NAVD 88. According to the applicant, the top of the finished foundation (floor) elevation of the Main Production Facility is at least 4 in. above site grade, which will prevent the LIP flood water from entering the buildings. As described in the application, the Main Production Facility (building), which is the largest among the facility buildings, has a length (north to south) and a width of 212 ft and 158 ft, respectively. There are many other small storage buildings, pads, and tanks that are located on the east and south side of the Main Production Facility. Proposed drainage features include the onsite drainage system, peripheral drainage channels and ditches, and infiltration ponds.

The NRC staff reviewed each of these components as they are related to the LIP flood analysis. The staff found that the applicant's description of these components is adequate to understand their impact on the LIP analysis.

Design LIP Scenario

The applicant estimated onsite runoff for the 100-year rainfall event. FSAR Table 2.4-7 summarizes the applicant's 100-year point rainfall value and intensities for different durations (up to 6 hours). The applicant's 100-year, 5-minute rainfall estimate is 8 inches per hour or 0.67 inches in total. These rainfall estimates are based on the Madison, Wisconsin, intensity-duration-frequency curve from the Wisconsin Department of Transportation, "Facilities Development Manual," 1979 (WDOT, 1979). The applicant also used the 100-year, 24-hour rainfall value of 6 inches using the data provided by the Rock County Storm Water Management Ordinance, 2004. This 24-hour rainfall was used in estimating offsite runoff used to design the peripheral drainage channel and evaluating the capacity of the existing channel.

The NRC staff compared the applicant-provided rainfall values to those provided by the NOAA Atlas 14, 2020. The staff obtained, from the NOAA website, a 100-year, 5-minute rainfall at the SHINE site of 0.9 inches, with 90 percent confidence intervals ranging from 0.7 inches to 1.18 inches. The staff also estimated the 100-year, 24-hour rainfall depth of 6.59 inches, with 90 percent confidence intervals ranging from 5.05 inches to 8.37 inches. As a result, the staff determined that the applicant-provided design LIP rainfall values are within the range of the site-specific Atlas 14 values. Therefore, the staff concludes that the applicant's LIP rainfall values are acceptable for use in the LIP flood analysis.

Flooding from Onsite Drainage Area

As described in SHINE FSAR Section 2.4.2.3, the drainage system is designed to carry runoff from rooftops and adjacent areas, ultimately reaching the peripheral ditches. The SHINE facility is surrounded by berms with interior ditches along the berms. FSAR Figure 1.3-2 shows that the roof of the Main Production Facility has two continuous downslopes from the mild east-side slope to the steep west side slope. Therefore, the roof runoff flows only to the west of the building.

The application states that stormwater from the onsite boundary is directed to the stormwater management system (marked by green lines in FSAR Figure 2.4-11). The entire onsite basin is divided into six drainage subbasins (FSAR Figure 2.4-12). The onsite drain system is designed so that the runoff generated from each subbasin is collected to a lower point and diverted to a trench drain through inlet. There are six inlets located on the east, south, and west sides of the Main Production Facility.

As described in the application, the trench flow is eventually drained into two infiltration cells (ponds) on the southwest corner of the site boundary. The main purpose of these infiltration cells is to control total suspended solids in water. Infiltration cell #1 collects onsite drain water which in turn flows via a spillway to infiltration cell #2. The spillway has a top elevation of 810 ft NAVD 88. The applicant stated that the infiltration cells will not pose a site flooding concern because the spillway was designed to have the peak water surface elevation of 810 ft NAVD 88 plus overflow margin.

The applicant stated that the peak LIP runoff in each subbasin was calculated using the Rational Dekalb method. This method estimates the peak flow rate as a function of runoff coefficient, rainfall intensity, and subbasin area. The applicant described that the onsite ground is graded in such a way that any runoff exceeding the inlet capacity would flow offsite or to another inlet. The applicant used a 100-year, 5-minute frequency rainfall event. The NRC staff confirmed that the onsite runoff estimates are acceptable as they followed the guidelines provided by the State of Wisconsin (WDOT, 1979).

With the estimated peak runoff rate, the applicant estimated the total runoff volume using a temporal runoff distribution method provided by the State of Wisconsin guidelines (WDOT, 1979). The applicant then calculated the maximum flood level at each inlet point using the stage-volume curve for the low area (so called pond/pit) at the inlet point. The applicant stated that, during a design basis LIP event, the onsite storm water drainage system is conservatively assumed to not be functional so that all runoff would be stored in the pond/pit of each subbasin.

The applicant determined, based on the above runoff analysis, that the maximum depth in all low points from impounded water would be below the ground floor elevations of the Main Production Facility and waste staging and shipping buildings, with margin. The NRC staff determined that the applicant's onsite flood level estimates are acceptable as they followed the applicable state guidelines (WDOT, 1979).

<u>Flooding from Offsite Drainage Area</u>

In its application and March 16, 2021, RAI response, the applicant stated that the SHINE site is protected from offsite flooding approaching from the north and northeast by proposed and existing drainage channels (see FSAR Figure 2.4-11). The applicant proposed a peripheral channel system that will be located on the north and east sides of the site. This proposed channel is intended to direct offsite runoff away from the SHINE facility. Offsite runoff generated from the 92-acre basin that flows from the north towards the site is intended to be captured by the peripheral channel which directs flow to an uncontrolled subbasin on the west side of the site.

The applicant designed the peripheral channel to carry offsite flooding caused by a 100-year rainfall event. The upstream bank elevation of the channel is 827 ft NAVD 88. The channel is approximately 1100 ft long with a 0.8% slope. The applicant also stated that the portion of the offsite runoff that flows from the northeast towards the site is captured by an existing channel southeast of the site that eventually flows to the unnamed tributary approximately one mile south of the site. The unnamed tributary flows from east to west to meet the Rock River approximately two miles south of the site.

The application stated that offsite runoff (in depth) for channel drainage was calculated using the Soil Conservation Service (SCS) methodology provided by the Natural Resources Conservation Service (NRCS), "National Engineering Manual," 1986. The key input parameters to the SCS methodology are 24-hour rainfall depth and potential maximum retention depth, which is estimated as a function of the SCS Curve Number. The applicant estimated peak discharge in cubic feet per second (cfs) as a function of the runoff (in depth), subbasin area, unit peak discharge, and pond adjustment factor. The applicant used the Hydrologic Engineering Center's River Analysis System (HEC-RAS), a hydraulic modeling system, to route flows in each channel (peripheral or existing one).

The applicant stated that the estimated peak runoff flow rate for the peripheral channel basin is 42 cfs. The estimated water surface elevation at the upstream end of the channel reaches a maximum height of 826.3 ft NAVD 88, which is below the channel bank height of 827 ft NAVD 88. The NRC staff determined that the channel has enough capacity to carry offsite runoff as there is approximately 0.7 ft margin for the channel flow to reach the top of the embankment of the channel.

The applicant evaluated runoff from the entire 91-acre basin conservatively, which was in turn used to estimate the maximum water depth in the existing channel from offsite drainage. The applicant reported the peak runoff flow rate of 197 cfs. The runoff is estimated to reach a water surface elevation of 826 ft NAVD 88 at the upstream end of the existing channel. The flood level is below its bank elevation of 827 ft NAVD 88. The NRC staff concludes that the applicant's estimation of the offsite runoff and flood levels at existing channels are acceptable as they followed the guidelines provided by the NRCS, 1986 and U. S. Army Corps of Engineers, "HEC-RAS River Analysis System: User Manual, 2016.

2.4.4.3 Other Flood Causing Mechanisms

In addition to the LIP flooding discussed in FSAR Section 2.4.2.3, FSAR Sections 2.4.3 through 2.4.9 discuss other flood causing mechanisms, including river or stream flooding, surge and seiche, wave runup, landslide, sediment erosion and deposition, cooling water canal and reservoir flooding, channel diversion, tsunami, dam failure, ice, and their plausible combined events. These FSAR sections are identical to those of the CP application. Also, FSAR Section 2.4.10, which describes groundwater conditions, was not changed from the CP application. There are no additional requirements related to these sections for the issuance of an operating license. Therefore, the NRC staff determined that the conclusions made in NUREG-2187, "Safety Evaluation Report Related to SHINE Medical Technologies, Inc. Construction Permit Application for a Medical Radioisotope Production Facility" (ADAMS Accession No. ML16229A140), for these eight sections are still sufficient and acceptable without further review.

2.4.4.4 Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters

SHINE FSAR Section 2.4.11, "Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters," discusses the hydrogeologic characteristics of the site related to potential accidental releases of radionuclide effluents. The specific topics covered by this section include alternate conceptual models, pathways, and travel times that affect radionuclide transports in groundwater. The staff reviewed these topics because they have been revised since the CP application.

SHINE FSAR Table 2.4-12 presents a summary of parameters used for advective travel times in the saturated zone. The applicant updated the travel times of five radionuclide pathways, including the new pathway to the nearest pre-1988 well "Receptor" (namely RO3286). The applicant also updated Table 2.4-12 by updating advective groundwater travel times of each pathway for expected (30 percent porosity) and conservative (10 percent porosity) scenarios. The NRC staff reviewed the applicant's calculations, which used local monitoring information, and found the applicant's estimation of the travel times to be acceptable.

In addition, the applicant stated that liquid effluent is not routinely discharged from the Radiologically Controlled Area (RCA) within the Main Production Facility. The applicant mentioned that liquid radioactive wastes generated at the SHINE facility are generally solidified and shipped to a disposal facility, and that radioactive liquid discharges from the SHINE facility to the sanitary sewer are infrequent and made in accordance with 10 CFR 20.2003 and 10 CFR 20.2007. There are no piped liquid effluent pathways from the RCA to the sanitary sewer. Sampling is used to determine suitability for release. Ramps at the entrances to the RCA limit the release of unplanned water discharges in the RCA, such as from a cooling water system rupture or firefighting hose discharge. Therefore, the applicant concluded that there are no accidental radioactive liquid discharges from the RCA. The NRC staff determined that these statements meet the acceptance criteria in Section 2.4 of NUREG-1537, Part 2, for determining if the proposed SHINE facility is designed to mitigate or prevent an uncontrolled release of radioactive materials in the event of a predicted hydrologic occurrence.

The NRC staff finds, based on the review of the application and supplemental information provided through the RAI response, that the applicant's analyses of hydrologic hazards are sufficient and acceptable as they followed the applicable local, state, and federal. The staff concludes that the SHINE site is not located where catastrophic hydrologic events are credible, that the applicant considered credible hydrologic events in developing the design basis flood parameters for the facility, and that the applicant provided adequate site characteristics needed to evaluate an uncontrolled release of radioactive materials in the event of a credible hydrologic occurrence.

2.4.5 Geology, Seismology, and Geotechnical Engineering

The NRC staff evaluated the sufficiency of the geology, seismology, and geotechnical engineering characteristics of the SHINE site, as presented in SHINE FSAR Section 2.5, using the guidance and acceptance criteria from Section 2.5, "Geology, Seismology, and Geotechnical Engineering," of NUREG-1537, Part 2.

Consistent with the review procedures in Section 2.5 of NUREG-1537, Part 2, the NRC staff confirmed that the information presented in the SHINE FSAR was obtained from sources of adequate credibility and is consistent with other available data, such as data from the U.S. Geological Survey (USGS) or in the FSAR of a nearby nuclear power plant. The staff also evaluated whether there is reasonable assurance that the seismic characteristics of the site are considered in the design bases of SSCs discussed in FSAR Chapter 3, "Design of Structures, Systems, and Components." In addition, the staff performed a confirmatory Probabilistic Seismic Hazard Analysis (PSHA), described below, using NRC accepted models and methods.

Section 2.5 of NUREG-1537, Part 1 states, in part, that "the applicant should detail the seismic and geologic characteristics of the site and the region surrounding the site. The degree of detail and extent of the considerations should be commensurate with the potential consequences of seismological disturbance, both to the … facility and to the public from radioactive releases."

In SHINE FSAR Section 2.5, the applicant provided descriptions on the regional geologic features, the site-specific geologic features, the historical seismic information, the maximum earthquake potential, how vibratory ground motion was addressed, the surface faults in the region, and the liquefaction potential.

The regulations in 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," define a capable fault as a fault with "[m]ovement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years." Using this definition of capable fault, SHINE FSAR Section 2.5.1.4, "Structural Geology," provides a discussion of 17 major faults and folds in Wisconsin and the six surrounding states, and based on lack of evidence for Pleistocene or post-Pleistocene displacement, concludes that only the faults responsible for creating the liquefaction features associated with the Wabash Valley seismic zone are considered capable faults under the regulations in 10 CFR Part 100, Appendix A. The NRC staff reviewed the information provided by the applicant, as well as information contained in the USGS Quaternary Fault database and in NUREG-2115, “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities,” (ADAMS Accession No. ML12048A776). The staff’s review of this information confirmed that there are no capable quaternary faults located within approximately 200 mi (320 km) of the SHINE site, except for Wabash Valley liquefaction features, which are included in the USGS seismic hazard analysis.

The applicant used the 2008 USGS National Seismic Hazard Mapping Project (NSHMP) results for determining the seismic hazard at the SHINE site and establishing the Safe Shutdown Earthquake discussed in FSAR Section 3.4.1. The 2008 NSHMP results have been superseded by the 2014 USGS NSHMP results. The NRC staff compared the 2014 results to those from 2008 at peak ground acceleration (PGA) for four recurrence intervals (Table 2.5-1). This comparison shows that the 2014 results are generally lower than those from 2008, which provides additional assurance that the 2008 results form a reasonable basis for determining the Safe Shutdown Earthquake (SSE) ground motion at the SHINE site.

Table **2.4.5 -1**: Comparison of 2008 and 2014 USGS NSHMP results for PGA.

PGA Spectral Acceleration (g)		
Return Period (yrs.)	**2008**	**2014**
475	0.0173	0.0176
2475	0.0509	0.0448
4975	0.0799	0.0691
9950	0.1254	0.1085

In addition to reviewing the application and USGS results, the NRC staff performed a confirmatory PSHA that incorporates at-site information about the subsurface geology to develop uniform hazard spectra at the surface for Seismic Design Classification 3 and 4 (SDC-3 and SDC-4) facilities as defined in ANSI/ANS 2.26-2014, “American National Standard Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design,” and computed following guidance in ASCE/SEI 43-05, “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities.” The staff used the seismic source model described in NUREG-2115, the ground motion model described in “EPRI (2004, 2006) Ground-Motion Model Review Project,” 2013, and the site-specific dynamic properties described by the applicant in a letter dated August 3, 2012 (ADAMS Accession No. ML13311A770). The staff’s results, presented in Figure 2.4.5-1, show that for an SDC-4 facility, the SSE envelopes the site-specific hazard at all frequencies greater than 0.6 Hz with significant margin. Greater margin is demonstrated for an SDC-3 facility.

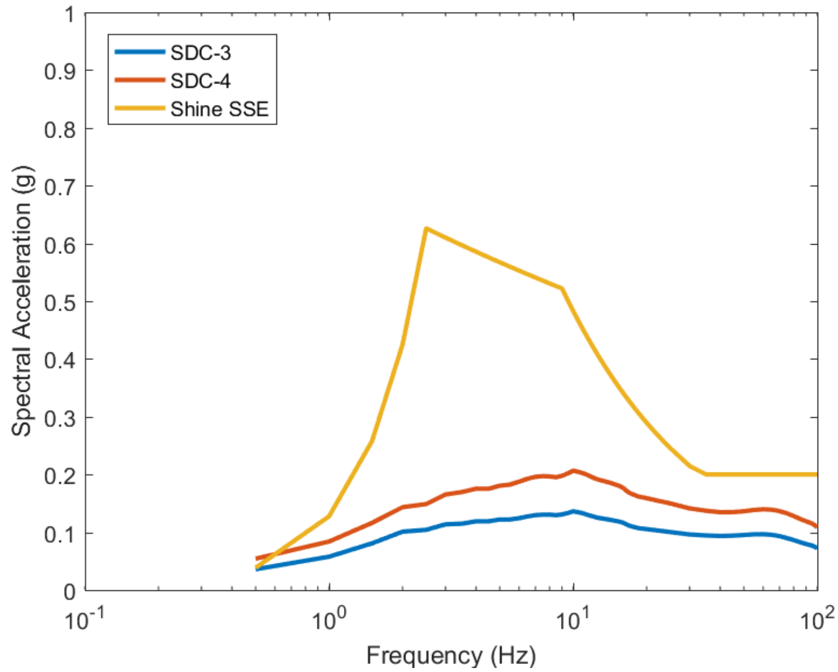

Figure 2.4.5 - 1: Comparison of SSE (yellow) with uniform hazard spectra for SDC–3 and SDC–4 facilities using site-specific subsurface information.

Section 2.5.7, “Liquefaction Potential,” of NUREG-1537, Part 1 states that, in part, the applicant should discuss soil structure. SHINE FSAR Section 2.5.7.1, “Site Soil Conditions,” states that geotechnical engineering characteristics of the SHINE site were evaluated by field investigations of standard penetrometer test (SPT) blow counts (N-values) measured in 14 boreholes, and laboratory tests including soil grain sizes, soil moisture contents, soluble-sulfate in soil, liquid limits, and plastic limits. The NRC staff reviewed the geotechnical information provided by the applicant in its FSAR, especially in Section 2.5.7.1, “Site Soil Conditions,” Section 2.5.7.2, “Groundwater Level,” Section 2.5.7.3, “Liquefaction Assessment,” Section 3.4.2.6.3.1, “Soil Parameters,” and Section 3.4.2.6.4.7 “Soil Pressure,” and related calculations and specifications provided by the applicant and the Preliminary Geotechnical Engineering Report (Golder Associates Inc., 2012) to determine whether the geotechnical engineering features underlying and in the area surrounding the SHINE site are sufficient to provide stable support.

In FSAR Section 2.5.7.3, “Liquefaction Assessment,” the applicant stated that there was no potential for liquefaction to occur within the soils underlying the site based on the results of both the qualitative and quantitative liquefaction analysis. The NRC staff reviewed Section 8.4, “Liquefaction Potential and Other Seismically Induced Ground Failures,” and Appendix F, “Results of Liquefaction Analysis,” of the Preliminary Geotechnical Engineering Report, which provided detailed analyses of both qualitative and deterministic liquefaction to support the applicant’s conclusion in FSAR Section 2.5.7.3. The staff confirmed that the measured groundwater level elevations range from 58 to 65 ft (17.7 to 19.8 m) below the ground surface and that the relative density of the sandy soils in the upper 100 feet is generally compact to dense. The staff also reviewed the procedure and calculation of liquefaction assessment. The staff verified that the empirical procedure based on the SPT blow counts is in accordance with Regulatory Guide 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,” 2003, and that its calculated results of factor of safety against liquefaction range from 2 to 30, and in most cases exceed 3, which is higher than the 1.4

specified in RG 1.198 for soil elements that would suffer relatively minor cyclic pore pressure generation. Based on a review of the subsurface condition and the liquefaction analysis, the staff concludes that no soils underlying the SHINE site are considered to be potentially liquefiable.

In FSAR Section 3.4.2.6.4.7, "Soil Pressure," the applicant stated that static earth pressure consists of at-rest, active, and passive soil pressure loads, which are applied as required to ensure the stability of the building. The NRC staff noted that the coefficients of lateral earth pressure for at-rest, active, and passive soil pressure loads on sub-grade walls of the SHINE facility were estimated in Section 7.2.3, "Below Grade Walls," of the Preliminary Geotechnical Engineering Report. The staff performed a confirmatory calculation that confirmed the coefficients of lateral earth pressure. The staff's review of this information confirmed that proper consideration of static, active, and passive lateral soil pressure loads towards the subgrade wall has been given to the structural analysis and design of the SHINE facility.

The NRC staff noted that FSAR Section 3.4.2.6.3.1, "Soil Parameters," provided some soil parameters that were used in soil-structure interaction (SSI) analysis, such as the minimum average shear wave velocity, minimum unit weight, and Poisson's ratio. The staff also noted that backfill materials will be used underneath and surrounding safety-related SSCs after excavation. As the properties of backfill materials are important input parameters in structural stability analysis, especially SSI analysis, the staff reviewed Section 7.3, "Excavations," of the Preliminary Geotechnical Engineering Report. The staff noted that the Preliminary Geotechnical Engineering Report stated that backfill should be placed in maximum 8-inch-thick loose lifts and compacted to a minimum of 95 percent of the maximum Modified Proctor Dry Density value, which is in line with the requirements of general engineering practice in the industry. Based on its review of the Preliminary Geotechnical Engineering Report, the staff concludes that the soil parameters used in the SSI analysis are reliable and reasonable.

The applicant also provided other parameters in FSAR Section 3.4.2.6.3.1, "Soil Parameters," such as net allowable static bearing pressures at foundation levels. In response to RAI 3.4-6, by letter dated December 15, 2020 (ADAMS Package Accession No. ML21011A264), the applicant provided detailed information on determination of allowable soil bearing capacity at foundation elevations and allowable total and differential settlements for the specific designed structures, and a comparison of maximum structural foundation responses and soil/foundation capacities. The applicant stated that the allowable soil bearing pressure for the building foundation is at least 6,000 pounds per square foot (287 kPa). The applicant concluded that the allowable soil bearing pressure is higher than the foundation contact pressures. The applicant provided a brief settlement evaluation that is based on the structural analysis results with soil subgrade reaction springs supporting the foundation. The applicant concluded that differential and total settlements are not beyond maximum allowable values.

To support the review of the applicant's geotechnical evaluation, the NRC staff conducted a regulatory audit (ADAMS Accession No. ML21089A334) to seek a detailed geotechnical evaluation to confirm that the allowable soil bearing pressure is higher than the foundation contact pressures, and that differential and total settlements of foundations will not exceed maximum allowable values. During the audit, the staff reviewed the documents that included the evaluation of ultimate bearing capacity and allowable soil bearing capacity, as well as a calculation package for the structural design of the SHINE facility, including a detailed total settlement analysis and the predicted subgrade modulus of the site soils for the structural analysis. The staff's review of the analyses and calculations confirmed that the soil property parameters used for the analysis are adequate and conservative. For the applicant's bearing capacity evaluation, the staff noted that the calculation method based on Terzahgi's theory is widely accepted and used by the industry, and that the assumption of foundation sizes used in the calculation is conservative with respect to the bearing capacity. Regarding the applicant's settlement calculation, the staff noted that the total settlement was evaluated by three different recognized methods, including elastic analysis, Burland & Burbidge approximation, and Meyerhoff Settlement estimate.

The NRC staff also conducted a regulatory audit teleconference on March 16, 2021 with the applicant to better understand how the analyses and calculations support the information provided by the applicant in its response to RAI 3.4-6. As a result of this audit, the applicant revised its FSAR and supplemented its response to RAI 3.4-6 in the letter dated April 16, 2021 (ADAMS Accession No. ML21106A136). The staff reviewed the information in revised FSAR Section 3.4.2.6.3.1, "Soil Parameters," and noted that the applicant clarified the net allowable static bearing pressure, provided information on the maximum foundation contact pressure predicted through structural response analysis under design load conditions, and verified that the maximum pressure can be enveloped by the allowable soil bearing capacity. The staff also reviewed the updated response to RAI 3.4-6 and noted that the applicant included the information in the response that the facility structure is designed to accommodate the potential differential and total settlements of the foundation of the facility structure and, consequently, that there are no allowable settlement limits. Based on its review of the information provided to the staff during the audit, the discussion at the audit teleconference, and the review of the revised application materials, the staff concludes that the applicant's evaluation of soil bearing capacity and settlement is adequate. The staff further concludes that the calculated bearing capacities based on conservatively assumed parameters still provide enough safety margin against the bearing demands, thereby ensuring the stability of the foundations and subsurface materials.

Based on its review, the NRC staff determined that the level of detail and analyses provided in SHINE FSAR Section 2.5 demonstrate an adequate design basis and satisfy the applicable acceptance criteria of NUREG-1537, Part 2, Section 2.5, allowing the staff to find the following:

1) The information on the geologic features, the potential seismic activity, and the geotechnical engineering properties including soil parameters, specifications, and foundation and subsurface material stability evaluations at the site has been provided in sufficient detail and in a form to be integrated acceptably into the design bases for SSCs and operating characteristics of the facility.

2) The information in the FSAR indicates that damaging seismic activity at the site during its projected lifetime is very unlikely. Furthermore, if seismic activity were to occur, any radiological consequences are bounded or analyzed in FSAR Chapter 13.

3) The FSAR shows that there is no significant likelihood that the public would be subject to undue radiological risk following seismic activity; therefore, the potential for earthquakes does not make the site unsuitable for the facility.

Therefore, the NRC staff concludes that the SHINE site's geology, seismology, and geotechnical characteristics, as described in SHINE FSAR Section 2.5, as supplemented by the applicant's responses to RAIs, is sufficient and meets the applicable regulatory requirements and guidance for the issuance of an operating license.

2.5 Review Findings

The NRC staff reviewed the descriptions and discussions of the SHINE site characteristics, as described in Chapter 2 of the SHINE FSAR, as supplemented, against the applicable regulatory requirements and using appropriate regulatory guidance and acceptance criteria. Based on its review of the information in the FSAR and independent confirmatory review, the staff determined that:

- The information provided by the applicant with regard to the SHINE site location and description is adequate and acceptable.
- The applicant's estimates of the present and projected populations surrounding the SHINE site, including transients, are reasonable and acceptable.
- The potentially hazardous activities on the site and in the vicinity of the facility have been identified and are reasonable and acceptable.
- The site characteristics associated with meteorology and general and local climatology are acceptable and reasonably representative of the site region.
- The site is not located where catastrophic meteorological events are likely, the applicant considered credible meteorological events in developing the design basis parameters for the facility, and the applicant provided adequate site characteristics needed to evaluate an uncontrolled release of radioactive materials.
- The site is not located where catastrophic hydrologic events are credible, the applicant considered credible hydrologic events in developing the design basis flood parameters for the facility, and the applicant provided adequate site characteristics needed to evaluate an uncontrolled release of radioactive materials in the event of a credible hydrologic occurrence
- No soils underlying the site are potentially liquefiable, and consideration of static, active, and passive lateral soil pressure loads towards the subgrade wall has been given to the structural analysis and design of the facility.

Based on the above determinations, the NRC staff finds that the SHINE site characteristics are sufficient and meet the applicable regulatory requirements and guidance and acceptance criteria for the issuance of an operating license.