2.0 SITE CHARACTERISTICS

This chapter of the Fermi 3 Combined Operating License (COL) Final Safety Analysis Report (FSAR) addresses the geological, seismological, hydrological, and meteorological characteristics of the site and vicinity, in conjunction with present and projected population distribution and land use, and site activities and controls.

2.0.1 Introduction

The site characteristics are reviewed by the U.S. Nuclear Regulatory Commission (NRC) staff to determine whether the applicant has accurately described the site characteristics and site parameters together with site-related design parameters and design characteristics in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, certifications, and approvals for nuclear power plants." The review is focused on the site characteristics and site-related design characteristics needed to enable the NRC staff to reach a conclusion on all safety matters related to siting of Fermi 3. Because this combined license application (COLA) references the Economic Simplified Boiling-Water Reactor (ESBWR) Design Control Document (DCD), Revision 10, this section focuses on the applicant's demonstration that the characteristics of the site fall within the site parameters specified in the design certification (DC) rule or, if outside the site parameters, that the design satisfies the requirements imposed by the specific site characteristics and conforms to the design commitments and acceptance criteria described in the ESBWR DCD.

2.0.2 Summary of Application

Section 2.0 of the Fermi 3 COL FSAR, Revision 7, incorporates by reference Section 2.0 of the ESBWR DCD, Revision 10. In addition, the applicant provides the following:

COL Items

- EF3 COL 2.0-1-A DCD Site Parameter Values

  Table 2.0-201 of the Fermi 3 COL FSAR identifies each DCD site parameter value and the corresponding Fermi 3 site characteristic values, and evaluates, as applicable, whether the Fermi 3 site characteristic values fall within the DCD values.

- EF3 COL 2.0-2-A through
  EF3 COL 2.0-30-A Site Characteristics

  Information in Sections 2.1 through 2.5 of the Fermi 3 COL FSAR identifies site characteristics and addresses NRC guidance in NUREG-0800.

Supplemental Information

- EF3 SUP 2.0-1 Site Specific Input Values

  Appendix 2A provides site specific input values used in the analysis of on-site atmospheric dispersion factors (χ/Q values).

2.0.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is in NUREG–1966, "Final Safety Evaluation Report Related to the Certification of the Economic Simplified Boiling Water Reactor." In addition, the acceptance criteria associated with the relevant requirements of the Commission regulations for the site characteristics, and the associated acceptance criteria, are given in Section 2.0 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)," the Standard Review Plan (SRP).

The applicable regulatory requirements for site characteristics are as follows:

- 10 CFR 52.79(a)(1)(i) - (vi) provides the site-related contents of the application.

- 10 CFR 52.79(d)(1), as it relates to information sufficient to demonstrate that the characteristics of the site fall within the site parameters specified in the DC.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to the siting factors and criteria for determining an acceptable site.

- The acceptance criteria associated with specific site characteristics/parameters and site-related design characteristics/parameters are addressed in the related Chapter 2 or other referenced sections of NUREG-0800.

2.0.4 Technical Evaluation

As documented in NUREG–1966, the NRC staff reviewed and approved Section 2.0 of the certified ESBWR DCD. The staff reviewed Section 2.0 of the Fermi 3 COL FSAR, Revision 7, and checked the referenced ESBWR DCD to ensure that the combination of the information in the Fermi 3 COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information contained in the application and the information incorporated by reference address the relevant information related to this section.

The staff reviewed the information in the Fermi 3 COL FSAR as follows:

COL Items

- EF3 COL 2.0-1-A

  DCD site parameter values for the ESBWR standard plant are identified in DCD Tier 2, Table 2.0-1 and DCD Tier 1, Table 5.1-1.

- EF3 COL 2.0-2-A through EF3 COL 2.0-30-A

  Information on Fermi 3 site characteristics is provided in Section 2.1 through Section 2.5. This information addresses NRC guidance in NUREG-0800 as identified in Table 2.0-2R. In the "COL Information" column, the COL item from

[1] See "*Finality of Referenced NRC Approvals*" in SER Section 1.2.2 for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

the DCD is replaced with information responding to the COL item and identifying the FSAR section which addresses the SRP section invoked by the COL item.

The NRC staff reviewed the COL information in Fermi 3 COL FSAR Section 2.0, "Site Characteristics", describing the characteristics and site-related design parameters for the Fermi site. The appropriateness of the site characteristic values presented by the applicant for the Fermi 3 site is reviewed by the staff in Section 2.1 through 2.5 of this SER. The applicant compared its site specific characteristics to the DCD site parameters from DCD Tier 2, Table 2.0-1 and DCD Tier 1, Table 5.1-1 in Fermi 3 COL FSAR Table 2.0-2R and Table 2.0-201.

In Fermi 3 FSAR, Revision 2, Table 2.0-201, the applicant listed Fermi 3 long term dispersion estimate site characteristic values that do not fall within the corresponding ESBWR DCD site parameter values. The staff issued RAI 02-1 and requested the applicant justify why this is not listed as a departure in Part 7 of the Fermi 3 COLA. In a letter dated September 2, 2010 (Agency wide Documents Access and Management System (ADAMS) Accession No. ML102570700) the applicant provided the response discussed below.

The applicant stated that the Fermi 3 long term atmospheric dispersion estimates are not referenced as a departure from the ESBWR DCD for the following reasons:

- The departure definition of Regulatory Guide (RG) 1.206 is not applicable to the Fermi 3 long term atmospheric dispersion estimates presented in FSAR Chapter 2 because the site specific atmospheric dispersion estimates do not constitute a deviation from DCD design information. The χ/Q and D/Q estimates presented in the DCD are not utilized as bounding analysis to determine or demonstrate site suitability, as each COL applicant is responsible to perform site specific analysis.

- The departure definitions of current DC rules are not applicable to ESBWR DCD long term atmospheric dispersion estimates. Although the GEH ESBWR DC rule had not yet been finalized, a previous DC rule has stated that a departure from a method of evaluation described in the plant-specific DCD used in establishing the design bases or in the safety analyses means (1) changing any of the elements of the method described in the plant-specific DCD unless the results of the analysis are conservative or essentially the same, or (2) changing from one method described in the plant-specific DCD to another method unless that method has been approved by the NRC for the intended application. The applicant contends that the Fermi 3 COLA has not changed the method of evaluation described in the DCD; instead, it presents the required site specific atmospheric dispersion estimates and associated dose analysis utilizing methods specified in the DCD.

- The 10 CFR 52.79(d)(1) and NUREG-0800 discussions of DC site parameters that must be met by COL applicants are not applicable to ESBWR DCD long term atmospheric dispersion estimates. According to NUREG-0800, site parameters used in bounding evaluations of the certified design define the requirements for the design that must be met by a site. The ESBWR DCD χ/Q and D/Q estimates are not utilized in any bounding evaluations of the certified design, as each COL applicant is required to present a site specific evaluation.

- Footnote 12 of the ESBWR DCD, Tier 2, Table 2.0-1 requires the Fermi 3 analysis of site parameters associated with long term atmospheric dispersion estimates to be extended to the dose analysis of Chapter 12. In other words, the Fermi 3 COLA demonstrates that the estimated atmospheric dispersion site characteristics fall within the site parameters specified in the DCD by presenting a site specific dose analysis as required in Chapter 12 of the Fermi 3 FSAR.

The staff evaluated the applicant's response to Request for Additional Information (RAI) 02-1 (ADAMS Accession No. ML102570700) and finds the response to be acceptable because the ESBWR DCD long term χ/Q and D/Q estimates are not utilized in any bounding evaluations of the certified design as each COL applicant is required to present a site specific evaluation.

The NRC staff reviewed the applicant's comparison of site specific characteristics against the ESBWR DCD site parameters and finds the comparison to be acceptable. The staff review confirms that the DCD values enveloped site specific values, except for the long term atmospheric dispersion estimates discussed above.

Supplemental Information

- EF3 SUP 2.0-1 Site Specific Input Values

  Appendix 2A provides site specific input values used in ARCON96 analysis of on-site χ/Q values.

The site specific input to the ARCON96 analysis which is provided in Appendix 2A is reviewed in SER Subsection 2.3.4 of this SER.

The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

2.0.5 Post Combined License Activities

There are no post-COL activities related to this section.

2.0.6 Conclusion

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. The NRC staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference are resolved.

In addition, the staff compared the additional COL information in the application, and the applicant's response to RAI 02-1 (ADAMS Accession No. ML102570700) to the relevant NRC regulations, the guidance in Section 2.0 of NUREG–0800, and other NRC RGs. The staff's safety evaluation (SE) of Fermi 3 COL FSAR, Section 2.0 is provided in Section 2.0 of this SER, and concluded that Fermi 3 COL FSAR Section 2.0 is acceptable and meets NRC regulatory requirements in 10 CFR 52.79(a)(1)(i) - (vi), 10 CFR 52.79(d)(1), 10 CFR Part 100 and Section 2.0 of NUREG-0800.

2.1 Geography and Demography

Section 2.1 of the Fermi 3 FSAR, Revision 7, discusses the site characteristics that could affect the safe design and siting of the plant and includes information about the site boundaries and location of the site with respect to prominent natural and man-made features.

The descriptions of the site area and reactor location are used to assess the acceptability of the reactor site. The review covers the following specific areas: (1) specification of reactor location with respect to latitude and longitude, political subdivisions; and prominent natural and manmade features of the area, (2) site area map to determine the distance from the reactor to the boundary lines of the exclusion area, including consideration of the location, distance, and orientation of plant structures with respect to highways, railroads, and waterways that traverse or lie adjacent to the exclusion area, and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable Subparts to 10 CFR Part 52. The purpose of the review is to ascertain the accuracy of the applicant's description for use in independent evaluations of the exclusion area authority and control, the surrounding population, and nearby manmade hazards.

2.1.1 Introduction

Section 2.1, "Geography and Demography" of the Fermi 3 COL FSAR addresses site-specific information related to the site location and description, exclusion area authority and control, and population distribution.

2.1.2 Summary of Application

Section 2.1 of the Fermi 3 COL FSAR describes the geography and demography of the Fermi 3 site. In addition, the applicant provides the following:

COL Items

- EF3 COL 2.0-2-A Site Location and Description

  The proposed location for Fermi 3 is on the same site as Fermi 2. The Fermi 3 FSAR specifies the latitude, longitude and coordinates for the Fermi 3 site.

- EF3 COL 2.0-3-A Exclusion Area Authority and Control

  The Fermi 3 Exclusion Area Boundary (EAB) is designated as the area encompassed by an 892.45 m (2928 ft) radius circle around the reactor center.

- EF3 COL 2.0-4-A Population Distribution

  The permanent population data presented in this section are primarily derived from the 2000 U.S. Census.

2.1.3 Regulatory Basis

The acceptance criteria associated with the relevant requirements of the Commission regulations for the site characteristics are given in Section 2.0 of NUREG-0800.

The applicable regulatory requirements for site characteristics are as follows:

10 CFR Parts 50 and 52, as they relate to the inclusion in the SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design 10 CFR 52.79(a)(1).

10 CFR Part 100, as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3); (2) addressing and evaluating factors that are used in determining the acceptability of the site as identified in 10 CFR100.20(a) and 10 CFR100.20(b); (3) determining an exclusion area such that certain dose limits would not be exceeded in the event of a postulated fission product release as identified in 10 CFR 52.79(a)(1) as it relates to site evaluation factors identified in 10 CFR Part 100; and (4) requiring that the site location and the engineered features included as safeguards against the hazardous consequences of an accident, should one occur, should ensure a low risk of public exposure.

10 CFR 100.20(a) and 10 CFR 100.20(b) as they relate to population densities.

The related acceptance criteria are:

Specification of Location: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 52.79(a)(1) if it describes highways, railroads, and waterways that traverse the exclusion area in sufficient detail to allow the reviewer to determine that the applicant has met the requirements in 10 CFR 100.3.

2.1.4 Technical Evaluation

As documented in NUREG–1966, the NRC staff reviewed and approved Section 2.1 of the certified ESBWR DCD. The staff reviewed Section 2.1 of the Fermi 3 COL FSAR, Revision 7, and checked the referenced ESBWR DCD to ensure that the combination of the information in the Fermi 3 COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[2]

The staff's review confirmed that the information contained in the application address the relevant information related to this section.

The staff reviewed the information in the Fermi 3 COL FSAR as follows:

<u>COL Items</u>

- EF3 COL 2.0-2-A Site Location and Description

[2] See "*Finality of Referenced NRC Approvals"* in SER Section 1.2.2 for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

The proposed reactor is designated as Fermi 3. It is located on the same site as Fermi 2. The location of each reactor at the Fermi site is specified by latitude, longitude and Universal Transverse Mercator (UTM) coordinates.

- EF3 COL 2.0-3-A Exclusion Area Authority and Control

  As shown in Figure 2.1-204, the Fermi 3 Exclusion Area Boundary (EAB) is designated as the area encompassed by an 892.45 m (2928 ft) radius circle around the reactor center. The Fermi 2 and Fermi 3 exclusion areas overlap a significant amount of the same area and are entirely within the 509.9 hectares (1260 acres) owned by Detroit Edison with the exception of a few small areas in Lake Erie to the east. Detroit Edison owns a 16.2 hectare (40 acre) parcel of submerged land in Lake Erie expressly for protection and maintenance of the intake channel. Detroit Edison has fee simple absolute ownership of all the land within the Fermi site property boundary, and therefore the applicant has the authority to determine all activities, including exclusion and removal of personnel and property from the EAB, as specified by 10 CFR 100.21(a). All points of personnel and vehicle access to the site are strictly controlled utilizing methods such as searches, escorts for visitors, and ensuring individuals are evacuated in the event of an emergency.

- EF3 COL 2.0-4-A Population Distribution

  The permanent population data presented in this section are primarily derived from the 2000 U.S. Census information contained in LandView® 6. This software is a flexible tool capable of identifying economic and demographic information in a selected geographic area. Sources for population data and projections, as well as information on seasonal variations (transient) population in the area around the Fermi site are identified and referenced in this section, as appropriate. The population data and general descriptions of human activity and seasonal variations are provided to comply with RG 1.206. In general, the Fermi 3 Environmental Report was the basis for the information included in this section. This information was updated with data obtained by research, as cited.

The NRC staff reviewed the resolution to the site-specific items related to the site location and description included under Section 2.1 of the Fermi 3 COL and independently estimated and verified the site latitude and longitude coordinates, and the UTM coordinate system coordinates provided by the applicant in the Fermi 3 COLA.

Using maps readily available in most libraries and the internet, the NRC verified the political subdivisions and prominent manmade features of the area provided by the applicant.

The NRC staff verified that the site area map, Figure 2.1-1 provided by the applicant, showed the distance from the reactor to the boundary lines of the Fermi 3 exclusion area. The NRC staff verified that no public roads, commercial railroads, or commercial waterways cross or lie adjacent to the exclusion area. The exclusion area does extend into Lake Erie to the east of Fermi 3. Lake Erie is too shallow for commercial shipping in this area. The nearest commercial shipping channel is 4.5 miles east of Fermi 3.

The site area map submitted by the applicant is adequate and meets the requirements of 10 CFR 52.79(a)(1) if it describes the site location, including the exclusion area and the location of the plant within the area, in sufficient detail to enable the reviewer to evaluate the applicant's analysis of a postulated fission product release, thereby allowing the reviewer to determine (in SRP Sections 2.1.2 and 2.1.3 and Chapter 15) that the applicant has met the requirements of 10 CFR Part 100.

On the basis of the NRC staff's review of the information addressed in the Fermi 3 COL, and also the NRC staff's confirmatory review of pertinent information generally available in literature and on the internet, the information provided by the applicant with regard to the site location and description is considered adequate and acceptable.

The NRC staff reviewed the resolution to the Fermi 3 COLA related to the exclusion area authority and control including size of the area, and activities that may be permitted within the designated exclusion area included under Section 2.1 of the COL using the review procedures described in Section 2.1.2 of NUREG-0800.

The applicant provided the information concerning the following:

- Complete legal authority to regulate access and activity within the exclusion area boundary (EAB).

- Identification of any facilities within the EAB that have activities unrelated to plant operation being controlled and considered for emergency planning (EP).

The NRC staff verified the applicant's ownership of all property within the EAB, including mineral rights, absolute ownership of all lands within the exclusion area, including mineral rights, is considered to carry with it the required authority to determine all activities on this land and is acceptable to meet the requirements of 10 CFR Part 100. The NRC staff verified the applicant's description of the exclusion area as well as the authority under which all activities within the exclusion area can be controlled. The NRC staff also verified, for consistency, that the EAB is the same as that being considered for the radiological consequences in Chapters 15 and 13.3 of the FSAR by the applicant. The staff concludes that the applicant has acquired authority to control all activities within the designated exclusion area.

The property is clearly posted and includes actions to be taken in the event of emergency conditions at the plant. The Fermi 3 EAB is greater than 0.5 mile from the potential release points.

The NRC staff reviewed the resolution to the COL specific items related to the population distribution around the site environs included under Section 2.1.3 of the Fermi 3 COL.

The staff reviewed the data on the population in the site environs, as presented in the applicant's FSAR, to determine whether the exclusion area, Low Population Zone (LPZ), and population center distance for the proposed site comply with the requirements of 10 CFR Part 100. The staff also evaluated whether, consistent with Regulatory Position C.4 of RG 4.7, the applicant should consider alternative sites with lower population densities.

The staff also reviewed whether appropriate protective measures could be taken on behalf of the enclosed populace within the emergency planning zone, which encompasses the LPZ, in the event of a serious accident.

The staff compared and verified the applicant's population data estimates against U.S. Census Bureau Internet data. The staff reviewed the projected population data provided by the applicant, including the weighted transient population for 2013, 2018, 2020, 2030, 2040, 2050, and 2060. Based on the comparison of the applicant's data to Census Bureau data, the staff finds that the applicant's estimate of the population, including transients, is reasonable.

The staff verified that the distances to the nearest population centers are well in excess of the minimum population center distance of 4 miles (1 1/3 times the distance from center point to the outer boundary of the LPZ). The Fermi 3 LPZ is defined as a circle with a 3 mile radius from the Unit 3 site center point. The nearest population center, as defined by 10 CFR 100.3, is Monroe, Michigan. The distance to Monroe's urban boundary, as defined by US Census files, is 5.5 miles from the Unit 3 center point. This distance is approximately 1 mile greater than the calculated minimum distance of 4 miles to population center as required by 10 CFR Part 100, and satisfies the acceptance criteria of NUREG-0800 and the guidance provided in RG 4.7. Therefore, the NRC staff concludes that the proposed site meets the population center distance requirement set forth in 10 CFR Part 100, Subpart B.

The NRC staff evaluated the site population density against the criterion in Regulatory Position C.4 of RG 4.7, Revision 2, regarding whether it is necessary to consider alternative sites with lower population densities. The NRC staff's evaluation confirmed the applicant's conclusion that the population densities at the time of initial site approval (assumed 2013), and 5 years thereafter, would not exceed the criteria of 500 persons per square mile averaged over any radial distance out to 20 miles (cumulative population within a distance of up to 20 miles divided by the area of the same radius circle), and thus is acceptable.

The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Therefore, the NRC staff concludes that the applicant's Fermi 3 site density estimates conform with Regulatory Position C.4 of RG 4.7, Revision 2, as well as the requirements in 10 CFR Part 100, Subpart B, and 10 CFR 50.34(a)(1)(ii)(D)(1).

2.1.5 Post Combined License Activities

There are no post COL activities related to this section.

2.1.6 Conclusion

The NRC staff reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference has been resolved.

In addition, the staff compared the additional COL information in the application to the relevant NRC regulations; guidance in Section 2.1 of NUREG–0800, and to the regulatory requirements in 10 CFR 52.79(a)(1), 10 CFR 100.3 and 10 CFR 100.20(b).

As set forth above, the applicant has presented and substantiated information to establish the site location and description. The staff has reviewed the information provided and, for the reasons given above, concludes that it is sufficient for the staff to evaluate compliance with the siting evaluation factors in 10 CFR Part 100.3, as well as with the radiological consequence evaluation factors in 10 CFR 52.79(a)(1).

The staff further concludes that the applicant provided sufficient details about the site location and site description to allow the staff to evaluate, as documented in Sections 2.1.2, 2.1.3, and 13.3 and Chapters 11 and 15 of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Parts 50, 52, and 100.

As set forth above, the applicant has provided and substantiated information concerning its legal authority and control of all activities within the designated exclusion area.

The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant's exclusion area is acceptable to meet the requirements of 10 CFR 52.79(a)(1), 10 CFR Part 100, and 10 CFR 100.3 with respect to determining the acceptability of the site. This conclusion is based on the applicant having appropriately described the plant exclusion area, the authority under which all activities within the exclusion area can be controlled, and the methods by which access and occupancy of the exclusion area can be controlled during normal operation and in the event of an emergency situation. In addition, the applicant has the required authority to control activities within the designated exclusion area, including the exclusion and removal of persons and property, and has established acceptable methods for control of the designated exclusion area. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Parts 50, 52, and 100.

As set forth above, the applicant has provided an acceptable description of current and projected population densities in and around the site. The staff has reviewed the information provided and, for the reasons given above, concludes that the population data provided is acceptable to meet the requirements of 10 CFR 52.79(a)(1), 10 CFR 100.20(a), 10 CFR 100.20(b), 10 CFR Part 100, and 10 CFR 100.3. This conclusion is based on the applicant having provided an acceptable description and safety assessment of the site, which contains present and projected population densities that are within the guidelines of Regulatory Position C.4 of RG 4.7, and properly specified the low-population zone and population center distance. In addition, the staff has reviewed and confirmed, by comparison with independently obtained population data, the applicant's estimates of the present and projected populations surrounding the site, including transients. The applicant also has calculated the radiological consequences of design-basis accidents at the outer boundary of the low-population zone (SRP Chapter 15) and has provided reasonable assurance that appropriate protective measures can be taken within the low-population zone to protect the population in the event of a radiological emergency. This addresses COL Section 2.1 specific items. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Parts 50, 52, and 100.

2.2 Nearby Industrial, Transportation, and Military Facilities

Section 2.2, "Nearby Industrial, Transportation, and Military Facilities" of the Fermi 3 COL FSAR provides information on the site characteristics that could affect the safe design and siting of the plant. The information consists of three subsections: Subsection 2.2.1 provides information on locations and routes; Subsection 2.2.2 describes nearby industrial transportation facilities (airports, airways, roadways, railways, etc.) and military facilities; and Subsection 2.2.3 evaluates potential hazards.

2.2.1 Locations and Routes

The locations of and separation distances from transportation facilities and routes, including airports and airways, roadways, railways, and navigable bodies of water are addressed as information item EF3 COL 2.0-5-A in Fermi 3 FSAR Sections 2.2.1 and 2.2.2. The staff's review of this information is below in Section 2.2.2 of this Safety Evaluation Report (SER).

2.2.2 Descriptions

2.2.2.1 *Introduction*

The description of locations and routes 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 proposed plant. The purpose is to evaluate the sufficiency of information concerning the presence and magnitude of potential external hazards so that the reviews and evaluations described in standard review plan Sections 2.2.3, 3.5.1.5, and 3.5.1.6 can be performed. The 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; (2) the presence of military and industrial facilities such as fixed manufacturing, processing, and storage facilities; and (3) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.2.2.2 *Summary of Application*

Subsection 2.2.2 of the FSAR addresses the need for locations and route descriptions and descriptions of nearby industrial and military facilities. The applicant addressed the information as follows:

COL Items

- EF3 COL 2.0-5-A Locations and Routes

  EF3 COL 2.0-5-A resolves DCD COL Item 2.0-5-A by providing information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards. The site-specific information needed to address DCD COL Item 2.0-5-A in the Fermi 3 FSAR is addressed by EF3 COL 2.0-5-A in Fermi 3 FSAR Sections 2.2.1 and 2.2.2 in accordance with RG 1.206 and relevant sections of 10 CFR Parts 52 and 100.

Locations and Routes

The significant manufacturing plants, storage facilities, quarrying operations, and transportation routes within 8 km (5 mi) of Fermi 3 are presented in Fermi 3 COL FSAR, Figure 2.2-201. There are no chemical plants, refineries, mining operations, drilling operations, active oil or gas wells, military bases, or missile sites within the vicinity of Fermi 3. The Fermi 2 reactor is located approximately 0.42 km (0.26 mi) northeast of the Fermi 3 centerline.

The western basin of Lake Erie is adjacent to the eastern property boundary of the Fermi site. The Port of Monroe is the closest waterway shipping facility at the mouth of River Raisin approximately 11.2 km (7 mi) southwest. The West Outer Channel and the East Outer Channel connect in Lake Erie approximately 11.2 km (7 mi) northeast of the plant as shown in Fermi 3 FSAR Figure 2.2-201. The West Outer Channel provides the closest shipping approach in Lake Erie at over 8 km (5 mi) away from Fermi 3.

The nearest major highways are Interstate 75 and Interstate 275. These two highways intersect at 6.6 km (4.1 mi) northwest of Fermi 3. State Route 24 runs parallel to Interstate 75 approximately 9.3 km (5.8 mi) northwest of Fermi 3. Interstate 75 has heavy commercial traffic since it is a major access route to industries in the Detroit area.

Two railroad companies transport freight in the vicinity of Fermi 3 as shown in FSAR Figure 2.2-201. Canadian National Railway operates the closest rail line within 5.6 km (3.5 mi) of Fermi 3, and also provides service to the single spur track onto the site. Norfolk Southern Railway has two parallel rail lines at distances of 5.6 km (3.5 mi) and 6.1 km (3.8 mi) from Fermi 3 and operates the nearest railroad yard in Monroe over 9.6 km (6 mi) away.
Nearby airports and air routes are shown in FSAR Figure 2.2-202.

Industrial Facilities

Industrial facilities which use, store, or transport significant quantities of hazardous materials in the vicinity of 8 km (5 mi) of Fermi 3 are presented in FSAR Table 2.2-201, including primary function, major products, and number of persons employed. No hazardous materials are manufactured within 8 km (5 mi) of Fermi 3.

Hazardous materials identified, including toxic chemicals, flammable materials, explosive substances, and shipment information reported by nearby industrial facilities, are summarized in FSAR Table 2.2-202.

There are two extractive industries within 8 km (5 mi) of Fermi 3. However, explosive materials are not stored overnight. For both Stone Co. of Michigan's Newport Quarry and Rockwood Quarry LLC, a blasting company truck delivers the required quantity of ammonium nitrate fuel oil only on the days that blasting occurs. The chemicals are mixed with explosive components immediately prior to use for blasting, and unused explosives are removed from the quarries by the end of the day.

Onsite chemical storage for Fermi 3 and Fermi 2 is shown in FSAR Table 2.2-203.

Pipelines

There are no pipelines carrying potential hazardous materials (e.g., propane, chlorine, toxic chemicals) within 8 km (5 mi) of the site. Even though there are local, residential and commercial natural gas distribution pipelines and service lines near the site, there is no large diameter natural gas or oil transmission pipelines in the vicinity of Fermi 3.

Waterways

The station water intake structure at Fermi 3 is located inside the water intake bay (groin area) and does not extend out into Lake Erie. Additional protection for the intake structure is provided by the designation of all waters and adjacent shoreline of Fermi 2 as a security zone as set forth by 33 CFR 165.915. Entry into this zone is prohibited unless authorized by the U.S. Coast Guard. The station intake structure is located over 8 km (5 mi) from the West Outer Channel as shown in FSAR Figure 2.2-201.

The depths of the shipping channels that extend from the Port of Monroe and from the Detroit River range between 6.4 m (21 ft) to 8.8 m (29 ft). The types of ships using Lake Erie in these channels include self-propelled vessels and integrated tug/barge units ranging in length from 116.7 m to 209 m (383 ft to 1014 ft).

Small amounts of fuel are stored and used near the boat docks at Swan Boat Club and Swan Yacht Basin on Swan Creek about 2.4 km (1.5 mi) north of Fermi 3 and at the Brest Bay Marina approximately 4.8 km (3 mi) southwest. The closest maritime facility is the Port of Monroe located approximately 11.3 km (7 mi) southwest of Fermi 3, where the principal imports and exports are asphalt, asphalt flux, coal, equipment, petroleum coke, and armor stone. On Lake Erie in general, and likely to be shipped on the West Outer Channel about 8 km (5 mi) east of the site, are Great Lakes fleet vessels such as dry-bulk carriers, cement carriers, and tankers which transport cargo primarily consisting of iron ore, coal, limestone, cement, salt, sand and gravel, grain, potash, liquid bulk, and general cargo.

Highways

Nearby industries reported receiving shipments of hazardous material primarily by truck. Trucks deliver freight along Interstates 75 and 275 which pass approximately 6.4 km (4 mi) northwest of the plant. Petroleum products are delivered to the site from Dixie Highway via Fermi Drive in transport trucks.

Railroads

Canadian National Railway operates the closest rail line within 5.6 km (3.5 mi) of Fermi 3, and also provides service to the single spur track onto the site. The rail spur is used infrequently and primarily for the transportation of non-hazardous heavy items and large equipment. Norfolk Southern Railway has 2 parallel rail lines at distances of about 5.6 km (3.5 mi) and 6.1 km (3.8 mi) from the plant running in a northeast to southwest direction, basically paralleling Interstate 75.

Airports

Nearby airports, runway descriptions, types of aircraft, number of operations per year, and accident statistics are provided in FSAR Table 2.2-204. The Fermi helipad is located approximately 1.2 km (0.75 mi) southwest of the Fermi 3 reactor and is available for emergency MediVac air ambulance service.

Mills Field (MI53), a private turf runway, is the only operational airport within 8 km (5 mi) of Fermi 3. The National Transportation Safety Board aviation accident database lists no reported accidents/incidents in the last 40 years at Mills Field. Detroit Metropolitan Wayne County Airport located 30.6 km (19 mi) to the northwest is the only airport in the region which has annual flight operations greater than the 1000 D^2 criteria (where D= Statute miles from the site) per RG 1.206. As shown in FSAR Figure 2.2-202, the closest edges of V 383 and V 10 176-188 airways fall within the proximity criteria provided in RG 1.206 and NUREG-0800. Federal airway V 383 passes 8 km (5 statute miles) west of Fermi 3 oriented in a north-south direction. Federal airway V 10-176-188 passes 8 km (5 statute miles) north of Fermi oriented in an east-west direction.

Outside the vicinity, Airway V 133 is located approximately 10.46 km (6.5 mi) to the northeast, Airway V 426 runs about 11.26 km (7 mi) to the southwest, Airway 26 is located approximately 12.1 km (7.5 mi) to the northeast, and Airway V 467 passes over 14.5 km (9 mi) to the west at its closest point.

Projections of Industrial Growth

Very limited long-term growth of industrial facilities is expected in the vicinity, which is predominantly rural, agricultural and residential. According to the Monroe County Industrial Development Corporation, future plans call mainly for prime agricultural uses and open space in the areas surrounding the Fermi site. Most of the anticipated industrial growth for facilities using hazardous materials will take place outside the 8 km (5 mi) vicinity near the Port of Monroe about 11.3 km (7 mi) to the southwest near Interstate 275/Telegraph Road intersection area, or in the city of Monroe. Overall, the region is continuing to experience a decline in manufacturing and industrial processes that are the most likely candidates to use hazardous materials.

2.2.2.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the nearby industrial, transportation, and military facilities, and the associated acceptance criteria are given in Section 2.2.1-2.2-2 of NUREG-0800.

The applicable regulatory requirements for identifying locations and routes are:

- 10 CFR 100.20(b), which requires that the nature and proximity of human-related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) be evaluated to establish site parameters used to determine whether the plant's design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

- 10 CFR 52.79(a)(1)(iv), as it relates to the factors to be considered in the evaluation of sites that require the location and description of industrial, military, or transportation facilities and routes.

- 10 CFR 52.79(a)(1)(vi), as it relates to compliance with 10 CFR Part 100.

The related acceptance criteria are:

- Data in the FSAR adequately describe the locations of and distances from the plant of nearby industrial, military, and transportation facilities; and the data are in agreement with data obtained from other sources, when available.

- Descriptions of the nature and extent of activities conducted at the site and in its vicinity, including the products and materials likely to be processed, stored, used, or transported; and that they are adequate to permit identification of the possible hazards cited in Subsection III of Section 2.2.1-2.2.2 of NUREG-0800.

- Sufficient statistical data with respect to hazardous materials that establish a basis for evaluating the potential hazards to the plant or plants considered at the site.

2.2.2.4 *Technical Evaluation*

The staff reviewed the information in the Fermi 3 COL FSAR as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-5-A Locations and Routes

  The significant manufacturing plants, storage facilities, quarrying operations, and transportation routes within 8 km (5 mi) of Fermi 3 are presented in Figure 2.2-201. There are no chemical plants, refineries, mining operations, drilling operations, active oil or gas wells, military bases, or missile sites within the vicinity of Fermi 3. The Fermi 2 reactor is located approximately 0.42 km (0.26 mi) northeast of the Fermi 3 centerline. The Davis-Besse Nuclear Power Station is located about 42 km (26 mi) south-southeast of the Fermi site. The nearest military facilities are Camp Perry Military Reservation near Port Clinton, Ohio, approximately 48 km (30 mi) southeast and Selfridge Michigan Air National Guard Base about 80 km (50 mi) northeast of Fermi 3.

The NRC staff reviewed Section 2.2 of the Fermi 3 COL FSAR to ensure that the required information is presented in the COL. The staff's review confirms that the information contained in the application addresses the relevant information related to identification of potential hazards in the vicinity of the site.

The NRC staff reviewed EF3 COL 2.0-5-A as a resolution to DCD COL Item 2.0-5-A related to identification of potential hazards in the vicinity of the site, including nearby industrial, transportation, and military facilities addressed in summary of application in Subsection 2.2.2.2.

As set forth above, the applicant presented and substantiated information that identified potential hazards in the site vicinity. The staff reviewed the information in the FSAR and, for the reasons given above, concludes that the applicant had provided information that identified potential hazards in accordance with the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance evaluation.

2.2.2.5 *Post Combined License Activities*

There are no post-COL activities related to this section.

2.2.2.6 *Conclusion*

The NRC staff reviewed the information provided by the applicant in the Fermi 3 COLA Part 2 FSAR. The staff's review confirms that the applicant addressed the relevant information, and there is no outstanding information expected to be addressed in the COL FSAR related to this subsection.

As set forth above, the applicant presented and substantiated information that identified potential hazards in the site vicinity. The staff reviewed the information in the FSAR and, for the reasons given above, concludes that the applicant has provided information that identified potential hazards in accordance with the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance evaluation. The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities have been evaluated to identify those activities that have the potential for adversely affecting plant safety-related structures. Based on information in the FSAR, as well as information that the staff independently obtained, the staff concludes that all potentially hazardous activities on the site and in the vicinity of the plant have been identified. The hazards associated with these activities have been reviewed and are discussed in Sections 2.2.3, 3.5.1.5, and 3.5.1.6 of this SER. In conclusion, the applicant has provided sufficient information to satisfy 10 CFR Part 50, 10 CFR 52.79(a)(1)(iv), 10 CFR 52.79(a)(1)(vi),10 CFR 100.20, and 10 CFR 100.21.

2.2.3 Evaluation of Potential Accidents

2.2.3.1 *Introduction*

The evaluation of potential accidents considers the applicant's probability analyses of potential accidents involving hazardous materials or activities on the site and in the vicinity of the proposed site to confirm that appropriate data and analytical models have been used. This review covers the following specific areas: (1) hazards associated with nearby industrial activities such as manufacturing, processing, or storage facilities; (2) hazards associated with nearby military activities such as military bases, training areas, or aircraft flights; and (3) hazards associated with nearby transportation routes (aircraft routes, highways, railways, navigable waters, and pipelines). Each hazard review area includes consideration of the following principal types of hazards: (1) toxic vapors or gases and their potential for incapacitating nuclear plant control room operators; (2) 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 and natural gas or any other gas) with a potential for ignition and explosion; (3) missile effects attributable to mechanical impacts such as aircraft impacts, explosion debris, and impacts from waterborne items such as barges; and (4) thermal effects attributable to fires.

2.2.3.2 *Summary of Application*

This section of the COL FSAR addresses the need to evaluate potential accidents. The applicant addressed the information as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-6-A Evaluation of Potential Accidents

  EF3 COL 2.0-6-A resolves DCD COL Item 2.0-6-A by addressing the provision for evaluating potential accidents. The site-specific information needed to address DCD COL Item 2.0-6-A in Fermi 3 FSAR is incorporated in Fermi 3 COLA Part 2 FSAR Section 2.2.3.

2.2.3.3 *Regulatory Basis*

The applicable regulatory requirements for identifying and evaluating potential accidents are: 10 CFR 52.79(a)(1)(iv) as it relates to the factors to be considered in the evaluation of sites, which require the location and description of industrial, military, or transportation facilities and routes.

- 10 CFR 52.79(a)(1)(vi) as it relates to compliance with 10 CFR Part 100.

The acceptance criteria presented in the Fermi 3 COLA Part 2 FSAR are based on meeting the relevant requirements of 10 CFR Parts 52 and 100.

The related acceptance criteria are:

- Event Probability: The identification of design-basis events resulting from the presence of hazardous materials or activities in the vicinity of the plant or plants of specified type is acceptable if all postulated types of accidents are included for which the expected rate of occurrence of potential exposures resulting in radiological dose in excess of the 10 CFR 50.34(a)(1) limits, as it relates to the requirements of 10 CFR Part 100, is estimated to exceed the NRC staff objective of an order of magnitude of 10^{-7} per year.

- Design-Basis Events: The effects of design-basis events have been adequately considered, in accordance with 10 CFR 100.20(b), if analyses of the effects of those accidents on the safety-related features of the plant or plants of specified type have been performed and measures have been taken (e.g., hardening, fire protection) to mitigate the consequences of such events.

2.2.3.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.2.3 of the Fermi 3 COL FSAR and performed independent checks of the information presented. The staff's review confirms that the information contained in the application addresses the relevant information related to the evaluation of potential accidents. Where the information or analyses lack sufficient details, the staff requested additional information from the applicant.

The staff reviewed the information in the Fermi 3 COL FSAR as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-6-A Evaluation of Potential Accidents

The staff's technical evaluation of this application is based on reviewing the information pertaining to COL Item EF3 COL 2.0-6-A, related to the evaluation of potential accidents to be covered under resolving the DCD COL Item 2.0-6-A.

Explosions

The applicant addressed potential explosions from the transportation of explosive materials from Interstates 75 and 275 at a minimum distance of 4 mi, the nearest railway at a minimum distance of 5.6 km (3.5 mi), and the nearest waterway (West Outer Channel) at a minimum distance of 8 km (5 mi) from the Fermi site. According to RG 1.91, Revision 1, "Evaluations of Explosions Postulated to Occur on Transportation Routes Nnear Nuclear Power Plants," the separation distance between the interstate highways, railway and waterway and the Fermi site are within the respective safe distance criteria, and therefore, explosion events from these transportation routes are not considered design basis events.

The applicant listed propane in Fermi 3 FSAR Table 2.2-202, but did not evaluate for the potential as an explosion hazard. The staff requested the applicant for additional information in RAI 2.2.3-1 on the basis for not evaluating this potentially explosive material.

In letter dated September 30, 2009 (ADAMS Accession No. ML092750405), the applicant responded to RAI 2.2.3-1 and provided the following information:

The propane explosion scenario was analyzed using the methodology of RG 1.91. RG 1.91 provides guidance for evaluations of explosions postulated to occur on transportation routes near nuclear power plants. As described in Section B, fifth paragraph, of RG 1.91, a TNT mass equivalence is used to determine the safe separation distance.

For determining the safe stand-off distance for the off-site propane storage, the reasonable upper bound of 240 percent is used.

The applicant included in the response a table, "Determination of Safe Stand-Off Distances For Off-Site Propane Storage Locations", which lists the quantities, TNT equivalents and safe stand-off distances for the Meijer Distribution facility (4 miles distance), the TWB Company (4.5 miles distance) and the Rockwood Landfill (4.5 miles distance). The applicant stated the propane quantities stored at the three facilities are located much farther away than the calculated minimum safe stand-off distance determined using the guidance in RG 1.91. Based on the staff's review of the applicant provided information, and confirmatory calculations, the staff considers the information adequate and acceptable, therefore RAI 2.2.3-1 is closed.

The applicant evaluated hydrogen and oxygen from the nearest storage tank farm for potential explosions resulting in blast overpressure using 1 psi overpressure as a criterion for adversely affecting plant operations or preventing the safe shutdown of the plant. The applicant determined the safe separation distance of 229 ft between the hydrogen and oxygen storage area and the nearest safety-related structures. The applicant did not provide sufficient details for determining this safe separation distance. Therefore, the staff requested the applicant for additional information (RAI 2.2.3-2).

In letter dated September 30, 2009 (ADAMS Accession No. ML092750405), the applicant responded to RAI 2.2.3-2 and provided the following information:

> In Fermi FSAR Section 2.2.3.1.1, the safe separation distance between the hydrogen and oxygen storage area and nearest safety-related structure is calculated using methods based on EPRI Document No. NP-5283-SR-A, "Guidelines for Permanent BWR Hydrogen Water Chemistry Installations - 1987 Revision". Appendix B of the guidelines in EPRI Document No. NP-5283-SR-A provides an evaluation report recommending separation distances based on stored quantities and building design factors.
>
> The method in EPRI Document No. NP-5283-SR-A is based on a reinforced concrete wall at least 18 inches thick; a tensile steel factor between 0.12 ksi and 0.3 ksi, and the minimum static lateral load capacities for the tornado region the plant is located in per RG 1.76.
>
> The ESBWR DCD shows that the outer walls for the ESBWR safety-related structures are at least 18 inches thick. The analysis assumes a tensile steel factor of 0.12 ksi (lower end of range in EPRI Document No. NP-5283-SR-A). The lower value for the tensile steel factor results in a larger safe separation distance. RG 1.76, "Design -Basis Tornado and Tornado Missiles for Nuclear Power Plants," Revision 1, Figure 1, indicates that the Fermi site is located within Tornado Intensity Region I. NUREG/CR-2642, "Capacity of Nuclear Power Plant Structures to Resist Blast Loadings," dated September 1983, Section 6, states:

"A conservative static capacity can be based upon the required design pressure drop for the tornado zone in which the plant is sited."

For Tornado Region I, the design pressure drop is 3.0 psi. Therefore, a static capacity of 3.0 psi is used in the analysis.

Based on these input values, the minimum safe separation distance for the hydrogen and oxygen storage area is 229 m (750.ft) from the nearest safety-related structure.

The staff reviewed the applicant provided information and the reference material. Based on independent determination, staff considers the applicant response reasonable, adequate and acceptable as it satisfies the NRC provided guidance, therefore, RAI 2.2.3-2 is closed.

It is shown in Fermi 3 FSAR Table 2.2-202, that the nearest storage location of flammable liquids, diesel fuel and gasoline, is 3.4 mi away from the site. The applicant stated that the potential formation and detonation of a flammable vapor is not a design basis event due to the size and distance of the tanks.

The staff noted that Fermi 3 FSAR Table 2.2-203 lists two 8,000 gallon underground gasoline storage tanks adjacent to the southeast corner of building 24. The staff requested additional information from the applicant (RAI 2.2.3-3) to address potential explosion hazard of tanker truck for onsite delivery of gasoline to these tanks.

In letter dated September 30, 2009 (ADAMS Accession No. ML092750405), the applicant responded to RAI 2.2.3-3 and provided the following information:

The Fermi 3 FSAR Table 2.2-203 indicates that there are two 8,000 gallon gasoline underground storage tanks. In further review there is only one 8,000 gallon underground gasoline storage tank, with two dispensing islands (gas pumps). The underground storage tank is currently located adjacent to the holding pond, one dispensing island is located adjacent to the south of the underground storage tank, and the second dispensing island is located adjacent to southeast corner of Fermi 2 Building No. 24. Fermi 3 FSAR Table 2.2-203 will be revised to reflect the single tank and its location.

Fermi 3 FSAR Section 2.2.2.5 Description of Highways states:

"Petroleum products are delivered to the site from Dixie Highway via Fermi Drive in transport trucks."

The current location of the gasoline storage tank will be moved when Fermi 3 is constructed because the current location creates interference with Fermi 3 construction activities. The gasoline storage tank and tanker truck access will be relocated to a safe distance from Fermi 3. The safe separation distance for the gasoline storage tank and tanker truck access is determined using the methodology of RG 1.91 for explosions postulated to occur on transportation routes near nuclear power plants. RG 1.91 uses a TNT mass to determine the safe separation distance.

The minimum safe separation distance is determined by assuming a 10,000 gallon gasoline tanker truck delivering to underground storage tank. The underground gasoline storage tank will be located such that the tank and the gasoline tanker truck access are a minimum of 721.4 m (2367 ft) from the nearest Fermi 3 safety related structure.

The NRC staff considers the applicant's response reasonable and the conclusion acceptable because it meets the requirements in 10 CFR 52.79(a)(1)(i) - (vi), 10 CFR 52.79(d)(1), and 10 CFR Part 100 and the guidance in Section 2.0 of NUREG-0800, therefore RAI 2.2.3-3 is closed.

Aircraft Hazards

The applicant addressed the potential risks due to aircraft hazards associated with airports and airways. The safety evaluation of these impact analyses are performed as a part of the NRC staff's review in SER Section 3.5.1.6 based on the guidance provided in RG 1.206 and NUREG-0800.

Toxic Chemicals

The applicant identified the onsite storage of chemicals for Unit 3 and Unit 2 in Fermi 3 FSAR Table 2.2-203 and the toxic chemicals considered for the potential impact for the control room habitability are identified in Fermi 3 FSAR Table 2.2-205. However, there is no detailed information on the methodology for screening out chemicals or the analyses demonstrating that determined concentrations of chemicals are lower than their respective limiting concentrations. The staff requested the applicant for additional information (RAI 02.02.03-4) to provide its toxic chemicals analyses. The applicant also identified toxic chemicals from offsite stationary sources in Fermi 3 FSAR Table 2.2-202. The applicant stated that the chemicals were evaluated and screened out using criteria in RG 1.78. But no details were provided. Therefore, the staff requested the applicant for additional information (RAI 02.02.03-5) to provide the rationale and methodology used for the toxic chemical analyses. The applicant provided the response for these RAIs with adequate information. The NRC staff reviewed the applicant's response dated September 30, 2009 (ADAMS Accession No. ML092750405), and concluded that the information is reasonable and acceptable because the applicant provided the details and results of analyses except for on-site storage of propane. The applicant stated in the response that the current onsite location of propane will be relocated prior to the operation of Fermi 3. The NRC staff has developed License Condition 2.2.3-1 that will require the applicant to use tanks with a maximum capacity of 1000 gallons for the on-site storage of propane and ensure that no more than 1000 gallons of propane will be stored in any single location, and no storage location will be located closer than the minimum safe distance of 854 meters (2800 ft) from any Fermi 3 safety-related structure and the Main Control Room (MCR). In addition, the applicant proposed revision to Fermi 3 FSAR Sections 2.2.3.1.4.1 and 2.2.3.1.4.2. In the Fermi 3 FSAR Section 2.2.3.1.4.3, the applicant stated that the transportation of toxic chemicals in the vicinity is not a concern for the Fermi 3 control room habitability analysis. There is no discussion to support this statement. Therefore, the staff requested the applicant for additional information (RAI 02.02.03-6) to provide the rationale and methodology applied for making this statement. The applicant provided the response with adequate information. The NRC staff reviewed the applicant's responses dated September 30, 2009 (ADAMS Accession No. ML092750405), for RAIs 02.02.03-4, 02.02.03-5 and 02.02.03-6 and concludes that the information is reasonable and acceptable.

The staff evaluated the information pertaining to toxic chemicals from onsite and offsite stationary and mobile sources identified by the applicant in Fermi 3 FSAR Section 2.2.1-2.2.2 and addressed in Section 2.2.3, for the applicant's analysis of control room habitability in Section 6.4.

The staff reviewed the applicant's inventory of chemicals from the above sources, and screening out of toxic chemicals that do not pose a threat to control room habitability. Based on evaluation of the information presented in above sections of the application, confirmatory analyses, and review of the responses to the RAIs dated September 30, 2009 (ADAMS Accession No. ML092750405), the staff accepts the applicant's identified toxic chemicals, liquid nitrogen and carbon dioxide, for the control room habitability analysis. The staff concludes that these two applicant listed chemicals should be further evaluated in Section 6.4 for control room habitability.

Potential fires due to accidents from the transportation routes do not jeopardize the safe operation of Fermi 3 due to the separation distance of potential fires from Fermi 3. A detailed description of the fire protection system is addressed in FSAR Section 9.5.1. The NRC staff considers the applicant's response reasonable and the conclusion acceptable because it meets the requirements in 10 CFR 52.79(a)(1)(i) - (vi), 10 CFR 52.79(d)(1), 10 CFR Part 100 and Section 2.0 of NUREG-0800.

Collision with Unit 3 Intake Structure

The Fermi 3 intake structure is adjacent to the Fermi 2 intake structure, located on the Lake Erie shoreline within the intake bay. This bay is protected by two rock groins that extend into the lake. The water in the vicinity of the intake structure is very shallow, and therefore, a large ship would not easily reach the intake structure. In addition, the Fermi 3 intake structure is not a safety-related structure, and therefore, any such collision, although unlikely, would not affect the safe operation or shutdown of Fermi 3. Based on the review of the information, the staff considers the applicant's conclusion acceptable.

Liquid Spills near the Intake Structure

No liquid hazardous materials are stored at, delivered to or transported through the intake bay, and an accidental liquid spill in the intake bay is considered very unlikely. No shipping lanes pass within 5 mi of Fermi 3; therefore waterway traffic unrelated to the plant is not likely to cause a spill near the intake bay. The staff considers that the liquid spills would not affect the safe operation of Fermi 3.

2.2.3.5 *Post Combined License Activities*

The staff identified the following license condition for the safe storage of an onsite propane tank:

License Condition 2.2.3-1: The applicant shall use tanks with a maximum capacity of 1000 gallons for the on-site storage of propane. No more than 1000 gallons of propane will be stored in any single location, and no storage location will be located closer than the minimum safe distance of 854 meters (2800 ft) from any Fermi 3 safety-related structure and the MCR.

2.2.3.6 *Conclusion*

As set forth above, the applicant has identified potential accidents related to the presence of hazardous materials or activities in the site vicinity that could affect a nuclear power plant or plants of the specified type that might be constructed on the proposed site, has appropriately determined those that should be considered as design-basis events, and has demonstrated that the plant is adequately protected and can be operated with an acceptable degree of safety with regard to the design-basis accidents. The staff has reviewed the information provided in Fermi 3 FSAR and, for the reasons given above, concludes that the applicant has established that the construction and operation of a nuclear Unit 3 of the specified type on the proposed site location is acceptable to meet the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi) for compliance with respect to determining the acceptability of the site. This addresses EF3 COL Information Item 2.0.6-A. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1)(iv), 10 CFR 52.79(a)(1)(vi), 10 CFR 100.20, and 10 CFR 100.21.

2.3 <u>Meteorology and Air Quality</u>

To ensure that a nuclear power plant or plants can be designed, constructed, and operated on an applicant's proposed site in compliance with the Commission's regulations, the NRC staff evaluates regional and local climatological information, including climate extremes and severe weather occurrences that may affect the design and siting of a nuclear plant. The staff also reviews the applicant's onsite meteorological monitoring program and information on the atmospheric dispersion characteristics of a nuclear power plant site to determine whether the radioactive effluents from postulated accidental releases, as well as routine operational releases, are within Commission guidelines.

The staff has prepared Subsections 2.3.1 through 2.3.5 of this SER in accordance with the review procedures described in NUREG-0800, using information presented in Sections 2.0 and 2.3 of the Fermi 3 COL FSAR, Revision 7, which references ESBWR DCD, Revision 10, responses to staff RAIs, and applicable sections of NUREG-0800.

2.3.1 General Regional Climate

2.3.1.1 Introduction

Subsection 2.3.1, "General Regional Climate," of the Fermi Unit 3 COLA addresses observed averages and measured and probabilistic extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant, including information describing the general climate of the region, seasonal and annual frequencies of severe weather phenomena, and other meteorological conditions to be used for design- and operating-basis considerations.

2.3.1.2 Summary of Application

Section 2.3 of the Fermi 3 COL FSAR, Revision 7, addresses characteristics of the regional climate considered by the applicant to be reasonably representative of conditions that may be expected to occur at the Fermi Unit 3 site. In addition, in FSAR Section 2.3.1, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-7-A Regional Climatology

  The meteorological data presented were published by the National Oceanic and Atmospheric Administration (NOAA), and included in industry standards and RGs.

2.3.1.3 Regulatory Basis

The relevant requirements of the Commission regulations for the regional climatology, and the acceptance criteria are given in Section 2.3.1 of NUREG-0800.

The acceptance criteria for identifying regional climatological characteristics are based on meeting the relevant requirements of 10 CFR Parts 52 and 100. The staff considered the following regulatory requirements in reviewing the applicant's discussion of the regional climatology:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c)(2) and 10 CFR 100.21(d), with respect to the consideration given to the regional meteorological characteristics of the site.

NUREG-0800, Section 2.3.1, specifies that an application meets the above requirements, if the application satisfies the following criteria:

- The description of the general climate of the region should be based on standard climatic summaries compiled by the National Oceanic and Atmospheric Administration (NOAA). Consideration of the relationships between regional synoptic-scale atmospheric processes and local (site) meteorological conditions should be based on appropriate meteorological data.

- Data on severe weather phenomena should be based on standard meteorological records from nearby representative National Weather Service (NWS), military, or other stations recognized as standard installations that have long periods of data on record. The applicability of these data to represent site conditions during the expected period of reactor operation should be substantiated.

- The tornado parameters should be based on RG 1.76; alternatively, an applicant may specify any tornado parameters that are appropriately justified, provided that a technical evaluation of site-specific data is conducted.

- The extreme (straight-line) 100-year return period 3-second gust wind speed site characteristics should be based on appropriate standards, with suitable corrections for local conditions.

- Ultimate Heat Sink (UHS) meteorological data, as stated in RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants,” should be based on long-period regional records which represent site conditions.

- The 100-year ground-level snowpack or snowfall, whichever is greater, should be based on data recorded at nearby representative climatic stations or obtained from appropriate standards with suitable corrections for local conditions. The 48-hour probable maximum winter precipitation (PMWP) should be determined in accordance with reports published by NOAA’s Hydrometeorological Design Studies Center.

- Ambient temperature and humidity statistics should be derived from data recorded at nearby representative climatic stations or obtained from appropriate standards with suitable corrections for local conditions.

- High air pollution potential information should be based on U.S. Environmental Protection Agency (EPA) studies.

- All other meteorological and air quality conditions identified by the applicant as design and operating bases should be documented and substantiated.

Generally, the information should be presented and substantiated in accordance with acceptable practice and data as promulgated by the NOAA, industry standards, and RGs.

Subsequent to the publication of SRP Section 2.3.1, the staff issued interim staff guidance document DC/COL-ISG-7, “Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures,” (74 FR 31470) (ADAMS Accession No. ML091490565) to clarify the staff’s position on identifying winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of seismic Category I structures.

To the extent that the data are applicable to the acceptance criteria outlined above, the applicant has applied the following NRC-endorsed meteorological information selection methodologies and techniques:

- RG 1.23, “Meteorological Monitoring Programs for Nuclear Power Plants,” which provides criteria for an acceptable onsite meteorological measurements program, which can be used to monitor regional meteorology site characteristics.

- RG 1.76, which provides criteria for selecting the design-basis tornado parameters.

- RG 1.206, “Combined License Applications for Nuclear Power Plants,” which describes the type of regional meteorological data that should be presented in FSAR Section 2.3.1.

- RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,” which provides criteria for selecting the design basis hurricane parameters.

When independently assessing the acceptability of the information presented by the applicant in FSAR Chapter 2.3.1, the NRC staff applied the same methodologies and techniques cited above.

2.3.1.4 Technical Evaluation

The NRC staff reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information regarding regional climate. The staff followed the procedures in Section 2.3.1 of NUREG–0800 as part of this review.

The staff reviewed the information in the Fermi 3 COL FSAR as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-7-A Regional Climatology

  This COL information item requires that the COL applicant supply site-specific information in accordance with SRP Section 2.3.1; that is, the COL applicant should describe averages and extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant.

In response to this COL information item, the applicant describes (1) data sources used to characterize the regional climatological conditions pertinent to the proposed site, (2) the general climate of the region with respect to types of air masses, synoptic features (high- and low-pressure systems), general airflow patterns (wind direction and speed), temperature and atmospheric moisture, and precipitation (rain, snow, and ice), (3) the frequencies of severe weather phenomena that have affected the proposed site, including thunderstorms and lightning, extreme wind, tornadoes and waterspouts, hail, drought, dust (sand) storms, freezing rain, and winter precipitation (snow and ice), (4) design-basis dry- and wet-bulb temperatures for the proposed site, and (5) regional air quality and the potentiality for restrictive air dispersion conditions and high air pollution at the proposed site.

The NRC staff reviewed the applicant's resolution to EF3 COL 2.0-7-A related to averages and extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant and finds the information to be acceptable and to meet the regulatory requirements.

General Climate

In Subsection 2.3.1.1 of the FSAR, the applicant characterizes the regional climatology of the proposed Fermi Unit 3 site using data from the National Climatic Data Center (NCDC), including the first-order NWS stations at Detroit Metropolitan Airport; Toledo, Ohio; and Flint, Michigan, as well as four NWS Cooperative Observation Program (COOP) stations located within 80 km (50 mi) of the Fermi site (Monroe, Michigan; Windsor, Ontario; Ann Arbor, Michigan; and Adrian, Michigan). The regional climatic observation stations used by the applicant are included in the list presented in FSAR Table 2.3-201.

The applicant addresses relevant information related to regional climatology. The applicant states that the meteorological data obtained for the climatology were collected and processed by the NOAA Midwestern Regional Climate Center and the NCDC. The applicant states that the meteorological stations it chose have long-term data (30 years or greater) that are representative of the short- and long-term climate characteristics of the region surrounding the Fermi site.

The applicant describes the general climate of the Fermi site and the surrounding region as humid continental, characterized by warm and humid summers and severe winters. Lake Erie adjacent to the Fermi site has a large influence on temperature, wind, and precipitation patterns at the site and surrounding region. The thermal capacity of the lake moderates the daily temperature extremes from those found farther inland. Lake and land breezes are common during the late spring through late fall. During late December, ice typically forms on the lake, decreasing the lake's influence on the climate in the coastal areas; the ice cover usually thaws by the middle of March, prolonging cooler temperatures into early spring. Annually, the region experiences approximately six days below –17.8 degrees C (0 degrees F) and twelve days above 32.2 degrees C (90 degrees F).

The applicant states that monthly values of precipitation vary slightly throughout the year in the region surrounding the Fermi site. The meteorological conditions in the Fermi region are also affected by the mean storm track, which brings a high frequency of storm systems and cloudiness to the region. During the late spring and summer, the storm track migrates north of the region, and the Fermi region experiences increased sunshine and warmer temperatures. Monthly rainfall is highest in summer due to frequent thunderstorms that occur about six days per month, higher than other months throughout the year. During the winter, the storm track is situated near the Fermi region, and storm systems come from the southwest, west, and northwest, which could bring wintery precipitation, including rain, freezing rain, sleet, and snow, into the region. Heavy snowfalls are possible throughout the winter and can cause significant accumulations.

The staff verified that the applicant's description of the general climate of the region in FSAR Subsection 2.3.1.1 is consistent with the NCDC narrative, "2006 Local Climatological Data, Annual Summary with Comparative Data for Detroit, Michigan (KDTW)."

Normal, Mean, and Extreme Climatological Conditions

In Subsection 2.3.1.2 of the FSAR, the applicant states that the monthly prevailing winds at the nearest first-order NWS station, Detroit Metropolitan Airport, are generally from the southwest, except during spring when the prevailing wind is from the northwest. Annual prevailing wind directions at two other first-order NWS stations (Toledo, Ohio, and Flint, Michigan) are also from the southwest, but there are differences in monthly prevailing winds among the three stations in late winter and spring months which can be attributable to the relative position of the storm track and general weakening of the jet stream. The annual mean wind speed at the Detroit Metropolitan Airport is 15.9 km/hr (9.9 mph), with the highest speeds occurring during the winter and spring months and the lowest during summer months. Wind speed patterns at two other first-order NWS stations are almost the same, but wind speeds are generally lower than those at Detroit because of the relative position of the storm track near the Fermi region.

The applicant states that stations that are closer to Lake Erie, such as Monroe, Michigan and Windsor, Ontario, have slightly higher daily minimum and lower daily maximum temperatures than other stations located farther inland due to the heat content of the Lake. One exception is that daily minimum temperature at Detroit Metropolitan Airport is slightly higher than Monroe or Windsor due to the heat island effect caused by the Detroit metropolitan area.

During the summer months of June through August, the daily mean maximum and minimum temperatures average 27.2 degrees C (81 degrees F) and 15.5 degrees C (60 degrees F), respectively. The highest daily maximum temperature recorded at Detroit Metropolitan Airport was 40 degrees C (104 degrees F) in June 1988; a higher temperature, 40.5 degrees C

(105 degrees F), was recorded in July 1934 at nearby Detroit City Airport. The highest temperature around the Fermi site was 42.2 degrees C (108 degrees F), recorded at the Adrian 2 NNE COOP station in July 1934.

Mean daily maximum and minimum temperatures at the Detroit Metropolitan Airport during the winter months of December through February are 1.1 degrees C (34 degrees F) and –6.7 degrees C (20 degrees F), respectively. The lowest daily minimum temperature recorded at Detroit Metropolitan Airport was –29.4 degrees C (–21 degrees F) in January 1984. The lowest temperature recorded around the Fermi site was –32.2 degrees C (–26 degrees F) at the Adrian 2 NNE COOP station in January 1892. During the winter, arctic air masses pass over Lake Michigan, which provides heat and moisture to the air masses. The region experiences increasing cloudiness and moderation of extreme arctic temperatures due to the lake effect caused by the Great Lakes.

The applicant states that mean annual relative humidity values at the three first-order NWS stations range from about 71 to 73 percent, with the highest relative humidity occurring around early morning (7 a.m.) and the lowest relative humidity occurring around early and mid-afternoon. The highest nighttime relative humidity occurs during late summer and early fall, while the highest daytime relative humidity occurs during late fall and winter.

The applicant states that the mean annual wet-bulb temperature at Detroit Metropolitan Airport is 7.2 degrees C (45.0 degrees F), with the highest monthly average of 18.8 degrees C (65.9 degrees F) in July and the lowest monthly average of –4.6 degrees C (23.7 degrees F) in January. Because they are closer to Lake Erie, Detroit and Toledo have somewhat higher mean annual wet-bulb temperatures than Flint.

The applicant states that the mean annual dew-point temperature at Detroit Metropolitan Airport is 4.6 degrees C (40.3 degrees F), with the highest dew-point temperatures in July and the lowest dew-point temperatures in January when the mean monthly temperature is the lowest. Dew point temperatures at Detroit Metropolitan Airport are higher than those at Flint but lower than those at Toledo, Ohio. It appears that atmospheric moisture content could be directly correlated to the latitude of the station and, to lesser extent, its distance to Lake Erie.

The applicant states that annual precipitation, which ranges from 80.3 cm (31.6 in.) in Flint, Michigan, to 91.9 cm (36.2 in.) in Winsor, Ontario, is uniformly distributed across the region and fairly consistent throughout the year. Annual precipitation at the Detroit Metropolitan Airport averaged about 83.5 cm (32.89 in.), with the highest monthly average of 9.0 cm (3.55 in.) occurring in June and the lowest monthly average of 4.8 cm (1.88 in.) occurring in February. The highest 24-hour and monthly precipitation values occurred at the Flint station, with a maximum 24-hour precipitation of 15.3 cm (6.04 in.) in September 1950, and a maximum monthly precipitation of 28.0 cm (11.04 in.) in August 1975. Although the frequency of weather systems decreases in summer, the highest precipitation is recorded during the summer months due to the intensity of precipitation associated with thunderstorms. The annual snowfall amount at the Detroit Metropolitan Airport is about 111.8 cm (44.0 in.), falling mostly during winter months. The highest snowfall amount in a 24-hour period was 62.2 cm (24.5 in.) near what is now the Detroit City Airport in April 1886, while the highest monthly snowfall 148.6 cm (58.5 in.) at the Ann Arbor COOP station in February 1923.

The staff compared the applicant's statements about the normal, mean, and extreme climatological conditions in the region surrounding the Fermi site in FSAR Section 2.3.1.2, and verified those statements, based on the NCDC narrative, "2006 Local Climatological Data, Annual Summary with Comparative Data," for three first-order meteorological stations (Detroit and Flint, Michigan, and Toledo, Ohio), "Climatology of the United States No. 20 1971-2000" and "DS 3200-Surface Summary of the Day for Monroe, Ann Arbor (University of Michigan), and Adrian (2 NNE)-1880-2007," and Environment Canada publication "Canadian Climate Normals 1971-2000" for a COOP station in Windsor, Ontario.

The NRC staff issued RAI 02.03.01-1 requesting the applicant to be more specific when using the term "storm" because "storm" could be interpreted as a thunderstorm, tropical depression, tropical storm, or hurricane. The applicant's response to RAI 02.03.01-1, dated February 8, 2010 (ADAMS Accession No. ML093570220), states that "storm" will be replaced with "surface low pressure systems." The applicant has incorporated this into the Fermi 3 FSAR, Revision 2, and thus RAI 02.03.01-1 is considered resolved.

Regional Meteorological Conditions for Design and Operating Bases

a. Severe Weather Phenomena

i. Thunderstorms and Lightning

Subsection 2.3.1.3.1.1 of the FSAR provides a discussion of severe weather phenomena, thunderstorms and lighting.

The following discussion on thunderstorms and lightning is intended to provide a general climatic understanding of the severe weather phenomena in the site region. However, the discussion does not generate site characteristics for use as design or operating bases.

The applicant states that, on average, thunderstorms occur 33 days of the year at the Detroit Metropolitan Airport. About 54 percent of these thunderstorm days occur between June and August, reaching a maximum of 6.3 days in July. Thunderstorm days are least frequent during the late fall and winter, reaching a minimum of 0.2 days in January. The applicant calculated the average number of lightning strikes as 10 per square mile per year or nearly four strikes per square kilometer per year for the Fermi region. Further, the applicant estimates that 1.13 lightning strikes per year occur near the planned location of the Fermi Unit 3 reactor (within 305 m [1000 ft]).

The staff confirmed that the statistics provided by the applicant for thunderstorms are correct based on the NCDC narrative, "2006 Local Climatological Data, Annual Summary with Comparative Data for Detroit, Michigan (KDTW)." The staff finds the applicant's estimate of the frequency of lightning strikes acceptable because "Vaisala's National Lightning Detection Network (NLDN) Cloud-to-Ground Lightning Incidence in the Continental U.S. (1997-2007)" (http://www.lightningsafety.noaa.gov/stats/08_Vaisala_NLDN_Poster.pdf, accessed July 8, 2010) shows that the annual average flash density around the Fermi site is 3 to 4 flashes per square kilometer.

ii. Extreme Winds and High Wind Events

FSAR Subsection 2.3.1.3.1.2 states that the Fermi 3 site characteristic value for the 3-second gust 50-year return period wind speed is 144.8 km/hr (90 mph). The applicant derived this site characteristic value from engineering weather data statistics published by NCDC for the Detroit City Airport. The applicant applied a multiplier of 1.07 to convert the 50-year return period wind speed value to its 100-year return period wind speed site characteristic value of 155 km/hr

(96.3 mph). The applicant obtained the 1.07 conversion factor from the American Society of Civil Engineers (ASCE) Standard ASCE/SEI 7-05.

The staff reviewed the basic wind speed map in ASCE/SEI 7-05 (which is a plot of 50-year return period 3-second gust wind speeds) for the portion of the United States that includes the Fermi Unit 3 site and obtained the same 144.8 km/hr (90 mph) 3-second gust wind speed value. Because the applicant's extreme wind site characteristic values are consistent with ASCE/SEI 7-05, the staff finds the applicant's extreme wind site characteristic values to be acceptable.

The applicant states in Revision 1 of FSAR Subsection 2.3.1.3.1.2 that 770 high wind events (50 knots [92.6 km/hr or 57.5 mph] or greater) were reported in the 5-county area surrounding the Fermi Unit 3 site (Lenawee, Monroe, Washtenaw, and Wayne counties in Michigan; Lucas county in Ohio) between January 1, 1955, and December 31, 2007, based on the NCDC online storm database. The highest wind speed was 83 knots (153.7 km/hr or 95.5 mph) in Monroe County on May 21, 2004. The highest wind speeds for the surrounding counties were 90 knots (166.7 km/hr or 103.6 mph), occurring in Wayne and Lucas Counties on July 22, 1960, and July 4, 1969, respectively. For comparison, a maximum 2-minute wind speed of 98.2 km/hr (61 mph) and a corresponding 125.5 km/hr (78 mph) 5-second wind gust were recorded at the Detroit Metropolitan Airport in May of 2004.

The applicant states that local and regional records of maximum wind speeds occurring from thunderstorms and other high wind events present values higher than the 100-year site characteristic extreme wind speed of 155.0 km/hr (96.3 mph) for seismic Category I, II, and radwaste building (RWB) structures. However, these reported maximum wind speed values are below the ESBWR seismic Category I and II structures extreme wind site parameter value of 242 km/hr (150 mph) for a 3-second gust wind speed, and therefore do not represent a threat to these structures.

The NRC staff issued RAI 02.03.01-2 requesting that the applicant (1) revise its incorrect counting of the number of high wind events and (2) address the possibility of underestimating high wind events, considering that the first year reported in the NCDC online storm database is later than 1955.

The staff counted 816 high wind (50 knots [92.6 km/hr or 57.5 mph] or greater) event reports for the 5-county area in the NCDC online storm database, not 770 as reported in Revision 1 to FSAR Section 2.3.1.3.1.2. The number of high wind events may be under-reported in the FSAR or it may be that only 770 unique high wind events occurred, as some of the events counted by the staff may have occurred concurrently in several of the five counties. In response to RAI 02.03.01-2, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant found a counting error and revised the number of high wind events to 816 in Revision 2 of the Fermi 3 COL FSAR.

The FSAR states that the NCDC online storm database does not cover the entire 1955–2007 period, but in Revision 1 to Section 2.3.1.3.1.2, "Extreme Winds and High Wind Events," the FSAR does not estimate the increase in the number of high wind events that would result from a complete record. The number of high wind events is probably underestimated by virtue of the reporting periods of some of the stations used having begun much later than 1955. Therefore, the number of reported high wind events during the 53-year period considered may be underestimated. In response to RAI 02.03.01-2, the applicant analyzed the storm database on a decade-by-decade basis and concluded that annual-average high wind events in five counties do not show a significant deviation over the first four decades, as compared with the two most recent decades. Lower high wind events reported during the first four decades might be attributable to the sparseness and precision of instrumentation. The applicant has incorporated the results of its analysis into Revision 2 of the FSAR, and thus RAI 02.03.01-2 is considered resolved.

Revision 1 of FSAR Table 2.0-201, Sheet 1 of 28, stated under the evaluation for extreme wind exposure category that "the Fermi 3 site characteristic is Exposure Category C as this value cannot be exceeded." The NRC staff requested that the applicant explain this statement in RAI 02.03.01-3. In its response to RAI 02.03.01-3, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant identified the Fermi region as being classified as Exposure Category C in accordance with ASCE/SEI 7-05 and agreed that the statement "as the value cannot be exceeded" is incorrect. The applicant removed this statement from Revision 2 of the FSAR. Thus, RAI 02.03.01-3 is considered resolved.

Because the applicant's extreme wind site characteristic values are consistent with ASCE/SEI 7-05, the staff finds the applicant's extreme wind site characteristic values to be acceptable.

iii. Tornadoes and Waterspouts

Subsection 2.3.1.3.1.3 of the FSAR discusses tornadoes and waterspouts. The applicant's report of the number of waterspouts and tornadoes in Revision 1 of FSAR Subsections 2.3.1.3.1.2 and 2.3.1.3.1.3 was based on the NCDC online storm database. Revision 1 to the FSAR stated that eight waterspouts were reported to have occurred off the shoreline of Lucas and Monroe Counties between 1993 and 2007, while 92 tornadoes were reported to have occurred in the 5-county area during the 53-year period January 1, 1955, through December 31, 2007. However, the staff counted 110 tornado reports in the NCDC online storm database for the same 53 year period. The NCDC online database indicated that several tornadoes and a waterspout have occurred in the vicinity of the Fermi site.

The staff issued RAI 02.03.01-4 to clarify the following two issues. First, some of the tornadoes counted by the staff may have spanned multiple counties, so the number of unique tornadoes in the 5-county area may have been 92, as reported by the applicant. If so, the FSAR should state that there were 92 unique tornadoes and that some of the 110 tornadoes counted by the staff spanned multiple counties. However, if the 110 tornadoes counted by the staff are unique, the statistics on tornadoes per year and strike probabilities presented in the FSAR should be revised. Second, the first year of tornado reports for each of the five counties began later than 1955. The applicant should therefore assess whether the number of tornado events that occurred during the 53-year reporting period (January 1, 1955, through December 31, 2007) could be underestimated.

In response to RAI 02.03.01-4, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated it combined tornado occurrences if the tornado reports indicated that the tornado tracked in a traceable direction between different counties or within the same county during a narrow time period and occurred within 45 minutes of one another. Therefore, the applicant concluded that the 92 tornadoes reported in Revision 1 to FSAR Section 2.3.1.3.1.2 is a valid count of tornadoes within the 5-county area between January 1, 1950, and December 31, 2007. The applicant also stated it analyzed the storm data on a decade-by-decade basis and concluded that the annual-average high wind events in five counties do not show a significant deviation over the first four decades. The staff reviewed the response to

RAI 02.03.01-4 and determined that the question is closed but that two issues remained unresolved. To address these issues, the staff issued follow-up question RAI 02.03.01-15.

The staff issued RAI 02.03.01-15 to clarify the following two issues. First, contrary to the information provided in response to RAI 02.03.01-4, in which the applicant stated 92 tornadoes are a valid count in the 5-county area between January 1, 1950, and December 31, 2007, Revision 2 to FSAR Section 2.3.1.3.1.2 states that 92 tornadoes were reported between January 1, 1955, and December 31, 2007. The staff requested the applicant to clarify this apparent discrepancy in the reporting period and revise the FSAR accordingly. Second, two tornadoes occurring in different counties at almost the same time cannot necessarily be counted as one tornado. The staff requested the applicant provide a list of the tornadoes occurring within the 5-county area indicating which tornado reports were considered unique and which tornado reports were combined.

In response to RAI 02.03.01-15, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant stated that the tornado reporting period begins in January 1, 1950, and revised the reporting period accordingly in Revision 4 of the FSAR. The applicant also performed an updated tornado evaluation for the 5-county area and the 2-degree latitude/longitude box around the Fermi 3 site, where the applicant combined tornadoes with matching coordinates or tornadoes within 8 km (5 mi) of one another over a time period of 30 minutes or less. The applicant concluded that 110 tornadoes out of 117 reported tornado occurrences in the 5-county area for the period between January 1, 1950, and December 31, 2007 were unique. The applicant's updated analysis resulted in an increase in the overall number of separate tornadoes, tornado area, and strike probability. The applicant revised Revision 4 of the FSAR accordingly. The staff reviewed the applicant's response and finds the revised tornado analysis to be reasonable. Therefore, RAI 02.03.01-15 is considered to be resolved.

The staff conducted an independent analysis to determine whether any tornadoes are unique, based on begin/end times, direction of tornado path, length/width, and relative locations (plotted on the map). Although some tornadoes are uncertain as to a determination of uniqueness, the staff arrived at a conclusion that was similar to the applicant's analysis.

Around 2:33 a.m. on June 6, 2010, a tornado hit the Fermi site and Unit 2 sustained damage due to this severe storm. The tornado touched down in Detroit Beach, Michigan, traveled about 10.5 km (6.5 mi) northeast, and entered Lake Erie at Estral Beach six minutes later. Based on the extent of damage, NOAA classified the tornado as an EF1 on the enhanced Fujita scale (i.e., 3-second gusts between 38.4 m/s [86 mph] and 49.2 m/s [110 mph]). Fermi Unit 2, which was along the tornado's path, automatically shut down when offsite power was lost. Although the reactor building (RB) was undamaged, the storm tore a 6-m (20-ft) by 9-m (30-ft) hole in the roof of the building housing the steam turbines, blew off siding from the auxiliary building, and damaged the cooling fins at the twin NDCTs. The Fermi Unit 2 reactor was safely shut down and kept in standby for more than a week as repairs to associated facilities were made.

The applicant calculated the probability of a tornado striking a point structure on the Fermi site by evaluating the frequency of occurrence of tornadoes in the counties that are either fully or partially inside a 2-degree latitude by 2-degree longitude box centered on the Fermi site. The applicant determined a strike probability of 3.87×10^{-4} per year or a recurrence interval of once every 2584 years. The staff performed a similar, independent analysis and derived a tornado strike probability of 4.94×10^{-4} per year or a recurrence interval of 2032 years. The difference between the applicant's and staff's tornado strike probabilities and recurrence intervals may be due, in part, to the fact that the staff identified a slightly different set of counties that were within the 2-degree box.

NUREG/CR–4461 Revision 2, “Tornado Climatology of the Contiguous United States,” provides the basis for the design-basis tornado wind speed in Revision 1 to RG 1.76. Appendix A to NUREG/CR-4461 contains estimates of strike probabilities by 2-degree latitude and longitude boxes. The Fermi site is located about N 42.0 degree latitude and W 83.3 degree longitude, near the center of the 2-degree box bounded by 41-degree and 43-degree North latitude and 82-degree and 84-degree West longitude. The expected strike probability per year in this 2-degree box for a structure with a characteristic dimension of 61 m (200 ft) is 5.37×10^{-4}, which corresponds to a mean recurrence interval of approximately once every 1860 years. The staff accepts the applicant’s tornado strike probability as it is reasonably close to the staff’s estimates.

The applicant chose the tornado site characteristics based on Revision 1 to RG 1.76. RG 1.76 provides design-basis tornado characteristics for three tornado intensity regions throughout the United States, each with a 10^{-7} per year probability of occurrence. The proposed Fermi Unit 3 site is located in tornado-intensity Region I where the most severe tornadoes frequently occur and corresponds to the most severe design-basis tornado characteristics. The applicant has chosen to use the design-basis tornado characteristics from Region I and, correspondingly, proposes the following tornado site characteristics:

- A maximum wind speed of 230 mi/h (103 m/s)
- A translational speed of 46 mi/h (21 m/s)
- A maximum rotational speed of 184 mi/h (82 m/s)
- The radius of a maximum rotational speed of 150 ft (45.7 m)
- A pressure drop of 1.2 pounds per square inch (psi) (83 mb)
- A rate of pressure drop of 0.5 psi per second (37 mb/s)

Because the applicant’s design-basis tornado site characteristics are based on RG 1.76, the staff concludes that the applicant has chosen acceptable tornado site characteristics.

Revision 1 of RG 1.76 reduced the design-basis tornado criteria as compared to previous guidance documents. Therefore, it was no longer clear that the design-basis tornado winds and missiles in Revision 1 of RG 1.76 would bound design-basis hurricane wind and missiles in all areas of the United States. As a result, the NRC issued RG 1.221 in October 2011. RG 1.221 provides the design-basis hurricane wind speeds that correspond to an exceedance frequency of 10^{-7} per year, which is similar to the exceedance frequency for the design-basis tornado wind speeds. The staff issued RAI 02.03.01-20 asking the applicant to include new site characteristics in the FSAR called “hurricane wind speed” and “hurricane missile spectra” or provide a justification as to why the FSAR should not be updated to include these new site characteristics.

In response to RAI 02.03.01-20, dated April 3, 2012 (ADAMS Accession No. ML12095A283), the applicant stated that the Fermi 3 site is located well inland from the hurricane wind speed profiles shown in RG 1.221. Therefore, the applicant concluded that the current Fermi 3 tornado site characteristic values remain valid and are inclusive of all winds associated with an annual exceedance frequency of 10^{-7}. The staff found that the applicant’s assessment is acceptable because the Fermi 3 site is located well inland from areas impacted by hurricanes. The staff has confirmed that the applicant incorporated this information into the Fermi 3 FSAR.

iv. Hail

Subsection 2.3.2.3.1.4 of the FSAR provides a discussion on hail and is intended to provide a general climatic understanding of the severe weather phenomena in the site region. However, the discussion does not generate site characteristics for use as design or operating bases.

The online NWS Glossary defines hail as showery precipitation in the form of irregular pellets or balls of ice more than 5 millimeters (mm) in diameter, falling from a cumulonimbus or thunderstorm cloud. Hail generally occurs during the spring and can be a major weather hazard, causing significant damage to crops and property.

The applicant used the NCDC online storm database to find that in the 5-county area surrounding the Fermi site 571 severe hail events were reported over the 53-year period of January 1, 1955, through December 31, 2007, producing an average of 10.8 occurrences of severe hail per year. Eighty-seven of these hail events involved large hail (defined as diameter equal to or greater than 4.4 cm [1.75 in.]). The largest hail diameter reported was 10.2 cm (4.00 in.) in Wayne County on November 13, 1955, and in Monroe County on March 27, 1991. During the 53-year period, there were no reports of hail during the winter months of December and January.

In Revision 1 of FSAR Subsection 2.3.1.3.1.4, “Hail,” the staff finds the reporting of hail events to be generally consistent with the NCDC online storm database, although the staff counted 576 hail events using the same online database. Some of the hail events probably spanned multiple counties, so the number of hail events may actually have been fewer. However, hail reports may have begun later than 1955 in four of the counties. Therefore, the number of hail events during the period considered may be underestimated. If the number of hail events reported in the NCDC online storm database reflect unique events, hail events per year for the 5-county area is likely greater than stated by the FSAR, although the number of events per year in Monroe County itself is very small. If the hail events in the NCDC online storm database are not unique, but span multiple counties, this should be stated by the FSAR as a justification for the smaller number of hail event reports. Consequently, the staff issued RAI 02.03.01-5 asking the applicant to clarify its reporting of hail events.

In response to RAI 02.03.01-5, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated it recounted the same number of hail events. In addition, the applicant demonstrated that, in comparison with hail events reporting during the 1960–1969 and 1970–1979 periods, the limited number of hail events reported between 1955 and 1959 is representative of the 1955–1959 period. The staff finds the applicant’s analysis acceptable, and thus RAI 02.03.01-5 is considered resolved.

v. Drought

Subsection 2.3.1.3.1.5 of the FSAR is a discussion on drought that is intended to provide a general climatic understanding of the severe weather phenomena in the site region. However, the discussion does not generate site characteristics for use as design or operating bases.

The applicant states that periodic extreme drought can occur from time to time in the vicinity of the Fermi site. Based on hourly precipitation data at the Detroit Metropolitan Airport during 1961–2007, the longest period with no measurable precipitation occurred for 644 hours (26.8 days) from June 17 through July 13, 1963. According to an analysis performed by the NCDC, 10 extreme droughts (Palmer Drought Index ≤ –4) have occurred in Michigan between 1900 and February 2008.

The staff examined the same databases (Solar and Meteorological Surface Observational Network (SAMSON) data for 1961–1990, Hourly U.S. Weather Observations (HUSWO) data for 1991–1995, and Integrated Surface Hourly Data (ISHD) for 1996–2007) and has verified the longest drought stretch in the summer of 1963 and the number of drought periods reported by the applicant in FSAR Subsection 2.3.1.3.1.5.

b. Probable Maximum Annual Frequency of Occurrence and Duration of Dust (Sand) Storms

Subsection 2.3.1.3.2 of the FSAR is a discussion on dust and sand storms that is intended to provide a general climatic understanding of the severe weather phenomena in the site region. However, the discussion does not generate site characteristics for use as design or operating bases.

The applicant states that prolonged dry periods are infrequent and the occurrence of dust, blowing dust, blowing sand, and dust storms are rare in the vicinity of the Fermi site. Dust storms are most likely when dry conditions and high winds occur in the southern plains States and/or the upper Midwest, with synoptic systems carrying the dust northeastward. FSAR Table 2.3-207 presents the annual number of hours that dust was reported for each year during the period 1961–1995 at the Detroit Metropolitan Airport using the SAMSON and HUSWO databases. Dust was reported for very few years, and the majority of dust events lasted four hours or less, with a maximum of seven hours. The applicant determined the probable maximum annual frequency of occurrence as 0.09 percent of hours annually (8 hours), corresponding with the year that contained the highest number of hours of reported dust. The applicant also determined the probable maximum duration of dust events as seven hours, based on the longest duration during the same period.

The staff has verified the applicant’s statements in FSAR Subsection 2.3.1.3.2 concerning dust (sand) storm occurrence in the region surrounding the Fermi site using the same database and found one dust event in July 4, 1974, that was missing. RAI 02.03.01-6 was issued asking the applicant to confirm the missing 1974 dust event. In its response (ML093570220, dated February 8, 2010) to RAI 02.03.01-6, the applicant again reviewed the database and found the one missing event and revised the text in Revision 2 of the FSAR accordingly. Thus RAI 02.03.01-6 is considered resolved.

c. Probable Maximum Annual Frequency of Occurrence, Duration, and Historical Amounts of Freezing Rain

Subsection 2.3.1.3.3 of the FSAR is a discussion on freezing rain that is intended to provide a general climatic understanding of the severe weather phenomena in the site region. However, the discussion does not generate site characteristics for use as design or operating bases.

The applicant reported that freezing rain and ice pellet events have occurred from November through April, but mostly from December through March for the Fermi region for the 1976–1990 period. In addition, freezing rain occurred about four to five days per year around the Fermi site, while ice pellets occurred about four days per year. A total of 24 ice events were reported in the 5-county area surrounding the Fermi site during the period 1993–2007. The frequency of freezing rain events during this 15-year period was calculated at 1.6 events per year by the applicant. The applicant stated that a severe winter storm lasting nearly 24 hours during January 1967 produced ice accumulations of up to 7.6 cm (3 in) across northwest Ohio and parts of southern Michigan. The staff has verified these values using the NCDC storm database and storm data reports.

In Revision 1 to FSAR Subsection 2.3.1.3.3, “Probable Maximum Annual Frequency of Occurrence and Duration of Freezing Rain,” the applicant uses the terms “freezing rain” and “ice pellets” interchangeably to refer to ice events. However, these two phenomena are different. Freezing rain is rain that falls in liquid form and freezing upon impact to form a coating of glaze upon the ground and exposed objects, whereas ice pellets are a type of precipitation consisting of pellets of ice. It is sometimes confusing within the FSAR as to whether the two types of ice events are being spoken of separately, as a group, or interchangeably. The NCDC ice storm reports include freezing rain only. The FSAR also refers to a “sub-freezing air mass near the surface,” which more accurately should be called a “sub-freezing air layer.” The staff issued RAI 02.03.01-7 requesting that the applicant clarify these issues.

In response to RAI 02.03.01-7, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant revised the text in FSAR Revision 2 as suggested by the staff to indicate that ice events mean freezing rain events. Thus RAI 02.03.01-7 is considered resolved.

d. Roof Loads of Winter Precipitation Events on Fermi Structures

Subsection 2.3.1.3.4 of the FSAR is a discussion on roof loads of winter precipitation events.

DC/COL-ISG-7, “Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures,” (ADAMS Accession No. ML091490565) states that normal and extreme winter precipitation events should be identified in SRP Section 2.3.1 as a COL site characteristic for use in SRP Section 3.8.4 to determine the normal and extreme winter precipitation loads on the roofs of seismic Category I structures.

ISG-7 states that the normal winter precipitation roof load should be a function of the normal winter precipitation event. The extreme winter precipitation roof loads should be based on the weight of the antecedent snowpack resulting from the normal winter precipitation event plus the larger resultant weight from either (1) the extreme frozen winter precipitation event or (2) the extreme liquid winter precipitation event. The extreme frozen winter precipitation event is assumed to accumulate on the roof on top of the antecedent normal winter precipitation event, whereas the extreme liquid winter precipitation event may or may not accumulate on the roof, depending on the geometry of the roof and the type of drainage provided.

Appropriate methodologies for determining the normal and extreme winter precipitation events are discussed in ISG-7. For example, ISG-7 states that the extreme liquid winter precipitation event should be determined in accordance with the Hydrometeorological Reports (HMRs) published by NOAA’s Hydrometeorological Design Studies Center.

The staff issued RAI 02.03.01-9 requesting the applicant evaluate the winter precipitation roof loadings in FSAR Revision 1, Section 2.3.1.3.4 using the criteria presented in ISG-7 or justify an alternative methodology. The staff also stated in the RAI that FSAR Revision 1, Subsection 2.3.1.3.4, assumes that scuppers and drains on the roof of the ESBWER are designed to limit water accumulation to no more than 10.2 cm (4 in.) of water. This assumption conflicts with the ESBWR DCD, Tier 2, Table 3G.1-2 which assumes water accumulation on the roof could reach 0.61 meter (2.0 feet), which is the height of the parapets, during the extreme winter precipitation event when the roof scuppers and drains are assumed to be clogged.

The applicant's response to RAI 02.03.01-9, dated February 8, 2010 (ADAMS Accession No. ML093570220), presented an evaluation of the winter precipitation roof loads based on ISG-7. The staff reviewed the response to RAI 02.03.01-9 and has determined that, for the reasons cited below, the question is closed but there were two issues that remained unresolved. To address these issues, the staff issued follow-up questions RAI 02.03.01-16 and RAI 02.03.01-18.

i. Maximum Ground-Level Weight of the Normal Winter Precipitation Event

Guidance from ISG-7 defines the normal winter precipitation event as the highest ground-level weight (lb_f/ft^2) among (1) the 100-year return period snowpack, (2) the historical maximum snowpack, (3) the 100-year return period two-day snowfall event, or (4) the historical maximum two-day snowfall event in the site region. In its evaluation of the ground-level weight of the normal winter precipitation event, the applicant developed the following:

- Weight of the 100-year return period snowpack: 1403 Pa (29.3 lb_f/ft^2)

  The applicant stated in its response ADAMS Accession No. (ML093570220) to RAI 02.03.01-9 that ASCE/SEI 7-05 identifies the Fermi Unit 3 site as being located in a ground snow load zone of 1149 Pa (24 lb_f/ft^2) based on a 50-year return period and used a conversion factor of 1.22 (derived from Table C7-3 of ASCE/SEI 7-05) to convert to a 100-year return period ground snow load of 1403 Pa (29.3 lb_f/ft^2). The staff reviewed the ground snow load map (Figure 7-1) in ASCE/SEI 7-05 and concludes that the applicant appropriately assigned the Fermi Unit 3 site as being located in a 100-year return period ground snow load zone of 1403 Pa (29.3 lb_f/ft). The applicant included this information in Revision 2 to FSAR Section 2.3.1.3.4.

- Weight of the historical maximum snowpack: 1551 Pa (32.4 lb_f/ft^2)

  The applicant stated in its response to RAI 02.03.01-9 that the maximum snow depth measurement obtained for stations surrounding the Fermi site was 60.96 cm (24 in.) occurring at the Detroit Metropolitan Airport in January 1999. The applicant used Equation 1 from ISG-7 to convert this maximum snow depth to a maximum snowpack event weight of 1005 Pa (21 lb_f/ft^2).

  The staff issued RAI 02.03.01-16 asking the applicant to reevaluate the historical maximum snowpack event, as the staff found a higher snowpack record than that used by the applicant. The staff found an extreme daily snow cover value of 83.82 cm (33.0 in.) for the Willis 5 SSW COOP station (located approximately 32 km [20 mi] northwest of the Fermi 3 site in Washtenaw County) using the NCDC Snow Climatology database. Using Equation 1 from ISG-7, the staff converted the 83.82 cm (33.0-in.) snow cover to a snowpack weight of 1551 Pa (32.4 lb_f/ft^2).

  In response to RAI 02.03.01-16, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant confirmed the historical maximum snowpack weight for the Fermi vicinity is 1551 Pa (32.4 lb_f/ft^2), based on 83.82 cm (33 in.) snow cover that was recorded at the Willis 5 SSW COOP station. The applicant revised the weight of the historical maximum snowpack from 21 lb_f/ft^2 (1005 Pa) to 1551 Pa (32.4 lb_f/ft^2) in Revision 4 of FSAR Subsection 2.3.1.3.4.1. Therefore, RAI 02.03.01-16 is considered to be resolved.

- Weight of the 100-year return period two-day snowfall event: 685 Pa (14.3 lb_f/ft^2)

  The applicant stated in its response to RAI 02.03.01-9 (ADAMS Accession No. ML093570220) that maximum 100-year return period snowfall for the Fermi region is 46.48 cm (18.3 in.) based on data from the NCDC Snow Climatology database. The applicant used the assumptions presented in Equation 2 from ISG-7 to convert this maximum snowfall to a snow load weight of 685 Pa (14.3 lb_f/ft^2). Therefore, the staff finds the applicant's weight of the 100-year return period two-day snowfall event to be acceptable. The applicant included this information in Revision 2 to FSAR Subsection 2.3.1.3.4.

- Weight of the historical maximum two-day snowfall event: 915 Pa (19.1 lb_f/ft^2)

  Revision 1 to FSAR Subsection 2.3.1.3.4.2 stated that the highest 24-hour snowfall was 62.2 cm (24.5 in.) during April of 1886 in the vicinity of what is now the Detroit City Airport whereas the highest 2- and 3-day snowfalls occurred at the Flint recording station where 57.7 cm (22.7 in.) was reported for both snowfalls. The reported maximum 2- and 3-day snowfalls at Flint were inconsistent with (i.e., lower than) the maximum 24-hour snowfall at the Detroit City Airport. The staff issued RAI 02.03.01-8 to clarify this apparent discrepancy in snowfall statistics.

  In response to RAI 02.03.01-8, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that the maximum 2- and 3-day snowfall data were obtained from the NCDC snow climatology database and that this database has a shorter period-of-record than the database used to obtain the maximum 24-hour snowfall data. Therefore, the applicant stated that it is appropriate that the maximum 24-hour snowfall value of 62.2 cm (24.5 in.) also be used to represent the maximum 2- and 3-day snowfall values for the Fermi site. The staff finds this assessment acceptable because it results in a higher maximum 2-day snowfall than that indicated by the NCDC snow climatology database which is referenced in ISG-7. The applicant revised the text in Revision 2 to FSAR Subsections 2.3.1.3.4.1 and 2.3.2.1.3 accordingly, and thus RAI 02.03.01-8 is considered resolved.

The applicant used the assumptions presented in Equation 2 from ISG-7 to convert the 62.2 cm (24.5 in.) snowfall to a snow load weight of 915 Pa (19.1 lb_f/ft^2). Therefore, the staff finds the applicant's weight of the historical maximum two-day snowfall event to be acceptable. The applicant included this information in Revision 2 to FSAR Subsection 2.3.1.3.4.

As part of its response (ML102570700) to RAI 02.03.01-16, the applicant identified the weight of the historical maximum snowpack (1551 Pa [32.4 lb_f/ft^2]) as providing the maximum ground-level weight for the normal winter precipitation event. This estimate is bounded by the corresponding ESBWR standard plant site parameter value of 2394 Pa (50 lb_f/ft^2). The staff finds the applicant's ground-level weight for the normal winter precipitation event to be acceptable because it is based on guidance provided in ISG-7.

ii. Maximum Ground-Level Weight of the Extreme Winter Precipitation Event

ISG-7 states that the extreme frozen winter precipitation event should be the higher ground-level weight (lb_f/ft^2) between (1) the 100-year return period two-day snowfall event (i.e., 685 Pa [14.3 lb_f/ft^2]) and (2) the historical maximum two-day snowfall event in the site region (i.e., 915 Pa [19.1 lb_f/ft^2]). Therefore, the extreme frozen winter precipitation event results in a ground-level weight of 915 Pa (19.1 lb_f/ft^2).

ISG-7 states that the extreme liquid winter precipitation event is defined as the theoretically greatest depth of precipitation (in inches of water) for a 48-hour period that is physically possible over a 25.9-square-kilometer (10-square-mile) area at a particular geographical location during those months with the historically highest snowpacks. The applicant estimated that the extreme liquid winter precipitation event is 49 cm (19.3 in.) in accordance with HMR-53 (NUREG/CR-1486). This is equivalent to a weight of 4805 Pa (100.4 lb_f/ft^2). The staff independently used HMR-53 to calculate a slight lower value for the extreme liquid precipitation event. Therefore, the staff finds the applicant's extreme liquid winter precipitation event of 49 cm (19.3 in.) to be acceptable.

iii. Maximum Roof Load

Guidance from ISG-7 defines the extreme winter precipitation roof load as the weight of the antecedent snowpack resulting from the normal winter precipitation event (i.e., 1551 Pa [32.4 lb_f/ft^2]) plus the larger resultant weight from either (1) the extreme frozen winter precipitation event or (2) the extreme liquid winter precipitation event.

Revision 2 to FSAR Subsection 2.3.1.3.4 calculated the maximum roof load for the Fermi site for the following three scenarios:

- the extreme liquid winter precipitation event (e.g., the 48-hour PMWP) on top of the 100-year return ice accretion
- historical maximum snowfall on top of the 100-year return period snowpack
- the extreme liquid winter precipitation event on top of the 100-year return period snowpack with a 5 lb_f/ft^2 rain-on-snow surcharge

Because the applicant calculated a revised historical maximum snowpack weight of 1551 Pa (32.4 lb_f/ft^2) in its response to RAI 02.03.01-16 which is higher than the 100-year return period snowpack weight of 1403 Pa (29.3 lb_f/ft^2), the applicant revised the last two scenarios listed above and provided maximum roof load calculations for the following three scenarios as part of its response to RAI 02.03.01-16:

- the extreme liquid winter precipitation event (e.g., the 48-hour PMWP) on top of the 100-year return ice accretion
- historical maximum snowfall on top of the historical maximum snowpack
- the extreme liquid winter precipitation event on top of the historical maximum snowpack with a 5 lb_f/ft^2 rain-on-snow surcharge

The applicant found the last scenario listed above resulted in the most severe roof load, 7407 Pa (154.7 lb_f/ft^2), and stated this roof load was bounded by the ESBWR maximum roof load resulting from the normal and extreme winter precipitation events (7828 Pa [163.5 lb_f/ft^2]).

The FSAR derived the 7828 Pa [163.5 lb_f/ft^2] ESBWR maximum roof load value by summing the roof load resulting from the normal winter precipitation event (1843 Pa [38.5 lb_f/ft^2]) and the extreme winter precipitation event (5985 Pa [125 lb_f/ft^2]) maximum roof snow load values that are listed in ESBWR DCD, Tier 2, Table 3G.1-2. This summation conflicts with the GEH response to RAI 2.3-4 S05 dated May 11, 2009 (ADAMS Accession No. ML091320434) which states that the 5985 Pa (125 lb_f/ft^2) extreme live load for roofs includes the contribution of 1843 Pa (38.5 lb_f/ft^2) from the normal winter precipitation event. Similarly, footnote 5 to ESBWR DCD, Tier 2, Table 2.0.1, states the corresponding maximum ground snow load for the extreme winter precipitation event (7757 Pa [162.5 lb_f/ft^2]) includes the contribution from the normal winter precipitation event (2394 Pa [50 lb_f/ft^2]). The staff issued RAI 02.03.01-18 asking the applicant to address this apparent contradiction in defining the ESBWR extreme winter precipitation event roof load.

In its response to RAI 02.03.01-18, dated January 10, 2011 (ADAMS Accession No. ML110110550), the applicant agreed that the methodology it used to derive the maximum roof load in Revision 2 to FSAR Section 2.3.1.3.4 as modified as part of its response to RAI 02.03.01-16 is not consistent with the ESBWR DCD. Instead, the applicant stated the extreme frozen winter precipitation event is considered to be the higher ground-level weight between the 100-year return period snowfall event (685 Pa [14.3 lb_f/ft^2]) and the historical maximum snowfall event (915 Pa [19.1 lb_f/ft^2]). Adding this value (915 Pa [19.1 lb_f/ft^2]) to the maximum ground snow load for the winter precipitation event (1551 Pa [32.4 lb_f/ft^2]) results in a total maximum ground snow load for both the normal and extreme frozen winter precipitation events of 2466 Pa (51.5 lb_f/ft^2). This ground snow load value is bounded by the ESBWR maximum ground snow load for extreme winter precipitation event site parameter value of 7757 Pa (162 lb_f/ft^2).

The applicant also notes in its response to RAI 02.03.01-18, dated January 10, 2011 (ADAMS Accession No. ML110110550), that the parapets on the roof of the ESBWR could allow water to accumulate up to 60.96 cm (24 in.) during an extreme winter precipitation event when the roof scuppers and drains are assumed to be clogged. The ESBWR extreme live load roof design of 5985 Pa (125 lb_f/ft^2) is based on 60.96 cm (24 in.) of standing water on the roof. Therefore, the staff notes that the Fermi 3 extreme liquid winter precipitation event of 49 cm (19.3 in.) of water does not challenge the integrity of the ESBWR extreme live load roof design.

The staff finds the applicant's response to RAI 02.03.01-18 acceptable because the applicant derived its extreme winter precipitation event roof load following the description of the ESBWR roof design as described in the DCD. The applicant incorporated the information provided in response to RAI 02.03.01-18 into Revision 4 of the FSAR. Therefore, RAI 02.03.01-18 is considered to be resolved.

e. Design Basis Ambient Temperature and Humidity Statistics

In Subsection 2.3.1.3.5 of the FSAR, the applicant presented ambient temperature and humidity statistics for the Detroit Metropolitan Airport in Table 2.3-210 of the FSAR Revision 1 (dated March 2009). The Detroit Metropolitan Airport is the closest first-order NWS climatic observation station to the Fermi Unit 3 site (located approximately 17 mi [27 km] to the north-northwest) which has a long-term history of recording hourly temperature and humidity data. The staff expects that the temperature and humidity data recorded at the Detroit Metropolitan Airport should be generally representative of Fermi 3 site conditions. In order to confirm this hypothesis, the staff generated 2001-2007 Detroit Metropolitan Airport dry-bulb (DB) statistics from the NCDC ISHD database and compared them with similar statistics generated from the applicant's 2001-2007 onsite meteorological database. Table 2.3-1 provides the results of this comparison.

Table 2.3-1 Comparison of Detroit Metropolitan Airport and Fermi 3 Site Dry- Bulb Statistics for 2001–2007

Dry-Bulb Statistic	2001–2007	
	Detroit Metropolitan Airport	**Fermi 3 Site**
Maximum	37.2 °C	34.6 °C
1 Percent Exceedance	31.0 °C	29.4 °C
Median	10.0 °C	10.5 °C
99 Percent Exceedance	-12.2 °C	-12.6 °C
Minimum	-20.6 °C	-19.9 °C
Unit in the table is in degrees Celsius (C). To convert to degrees Fahrenheit (F), use the formula: F = 1.8 C + 32.		

This comparison shows that the maximum and the 1 percent exceedance Detroit Metropolitan Airport DB statistics tend to be higher (more conservative) than the Fermi 3 site statistics, probably due to the Fermi 3 site location being closer to Lake Erie and the lake's moderating effects on temperature during the summer (more detail is provided in SER Subsection 2.3.2 of this SER). The 99 percent exceedance and minimum Detroit Metropolitan Airport DB statistics are generally representative of (e.g., within 1 degree C) of the Fermi 3 data.

The staff also compiled and compared, in Table 2.3-2, the Detroit Metropolitan Airport dew point statistics with the onsite dew point data provided by the applicant.

Table 2.3-2 Comparison of Detroit Metropolitan Airport and Fermi 3 Site Dew-Point Statistics for 2001–2007

Dew Point Statistic	2001–2007	
	Detroit Metropolitan Airport	Fermi 3 Site
Maximum	26.0 °C	23.7 °C
1 Percent Exceedance	22.2 °C	20.2 °C
Median	5.0 °C	3.2 °C
Unit in the table is in degrees Celsius (C). To convert to degrees Fahrenheit (F), use the formula: F = 1.8 C + 32.		

This comparison shows that the Detroit Metropolitan Airport dew point statistics tend to be higher (more conservative) than the Fermi 3 site statistics. This may be due, in part, to the differences in instrumentation between the Detroit Metropolitan Airport station and the Fermi 3 station.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) climatic design data are available for the Detroit Metropolitan Airport. Based on 1972–2001 period of record in the 2005 ASHRAE Handbook, the applicant identified the maximum 2.0 and 1.0 percent annual DB cooling exceedance temperatures with the corresponding mean coincident wet-bulb (MCWB) temperatures, the maximum 2.0 and 1.0 percent annual non-coincident WB cooling exceedance temperatures, and the minimum 99.0 and 99.6 percent annual DB heating exceedance temperatures. The staff compared the applicant's 2.0 and 1.0 percent exceedance DB and coincident and non-coincident WB temperatures and 99-and 99.6 percent exceedance DB temperature with the Detroit Metropolitan Airport data statistics published by ASHRAE. The staff has confirmed that the statistics provided by the applicant are correct.

In addition, the applicant calculated zero percent exceedance (i.e., historic) values of maximum DB temperature with the corresponding MCWB temperature, maximum non-coincident WB temperature, and minimum DB temperature for the 1961 to 2007 period of Detroit Metropolitan Airport data. The applicant also estimated values of the 100-year maximum and minimum DB temperatures and 100-year maximum non-coincident WB temperature based on the same 1961–2007 database.

10 CFR 52.79(a)(iii) states, in part, that the COL FSAR shall include the meteorological characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated. In order to be compliant with 10 CFR 52.79(a)(1)(iii), the ambient design temperature site characteristics should be based on the more extreme of either historic or 100-year return period values. Temperatures based on a 100-year return period are considered to provide a sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated as required by regulation.

The zero percent exceedance ambient design temperature Fermi Unit 3 site characteristic values presented in Revision 1 to FSAR Table 2.0-201 (Sheet 6 of 28) are based on historic extreme values. The NRC staff issued RAI 02.03.01-10 requesting that the applicant justify why these site characteristic values are not based on the more extreme of either the historic or

100-year return values. Note that FSAR Section 2.3.1.3.5 already states that the more extreme 100-year temperature values are considered representative of the Fermi site for design purposes. The staff further requested a revision of FSAR Revision 1, Table 2.0-201 (Sheet 6 of 28) to identify the Fermi Unit 3 maximum and minimum zero percent exceedance ambient design temperature site characteristic values as the more extreme of either the historic recorded values or the 100-year return values.

In the response to RAI 02.03.01-10, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant estimated a 100-year return period MCWB temperature by using the 2009 ASHRAE's Weather Data Viewer Version 4.0 (WDView 4.0) to extrapolate a MCWB temperature value from a joint frequency matrix of 1982-2006 Detroit Metropolitan Airport DB and WB values. The NRC staff also compiled and compared maximum DB with MCWB, maximum non-coincident WB, and minimum DB temperatures as shown in the Table 2.3-3 below.

Table 2.3-3 Maximum DB with MCWB, Maximum Non-coincident WB, and Minimum DB Temperatures[a]

Parameter		DCD Zero percent Exceedance Values	Fermi 3 Values					
			DTE		LCD	NRC		
			Historic	100-yr	Historic	Historic	100-yr	
Max	DB	47.2	40.0[b]	40.1[c]	40.0[b]	39.4[d]	40.8[e]	40.3[f]
	MCWB	26.7	24.8[c]	23.3[f]	-[g]	23.3[d]	23.8[e]	23.2[f]
	WB	31.1	29.4[c]	30.0[c]	-	29.4[d]	30.1[d]	-
Min	DB	–40.0	–29.4[b]	–34.9[c]	–29.4[b]	–28.9[d]	–33.8[e]	–33.2[f]

(a) Unit in the table is in degrees Celsius. To convert to degrees Fahrenheit, use the formula: F = 1.8 C + 32.
(b) Based on the 1959–2006 data (source: 2007 LCD).
(c) Based on the 1961–2007 data (source: SAMSON/HUSWO/ISHD).
(d) Based on the 1961–2009 data (source: SAMSON/HUSWO/ISHD).
(e) Based on the 1972–2001 data (source: 2005 ASHRAE Handbook).
(f) Based on the 1982–2006 data (source: 2009 ASHRAE Handbook).
(g) Not available.

DB=dry bulb; DCD= design certification document; ISHD= Integrated Surface Hourly Data; HUSWO= Hourly U.S. Weather Observations; LCD= Local Climatological Data; MCWB= mean coincident wet bulb; WB= wet bulb

- Maximum Dry Bulb Temperature: The applicant determined the Fermi 3 site characteristic value of 40.1 degrees C (104.2 degrees F) based on a 100-year value derived from a review of the 1961–2007 Detroit Metropolitan Airport annual maximum DB temperature values using a Gumbel distribution. The staff performed an independent evaluation of the 100-year site characteristic value using Equation 1 from Chapter 14 of the *2009 ASHRAE Handbook – Fundamentals*. Using the Detroit Metropolitan Airport 1972–2001 mean and standard deviation of annual extreme maximum DB temperature data provided in the *2005 ASHRAE Handbook*, the staff derived a value of 40.8 degrees C (105.4 degrees F); using the 1982–2006 mean and standard deviation data provided in the *2009 ASHRAE Handbook*, a value of 40.3 degrees C (104.5 degrees F) was derived. The staff calculated maximum DB temperature values that were slightly higher than the applicant's values; however, given that the corresponding ESBWR site parameter value, 47.2 degrees C (117 degrees F), is significantly higher than either the applicant's or staff's maximum DB temperature values, the applicant's site characteristic value is considered acceptable.

- Mean Coincident Wet Bulb Temperature: The applicant determined the Fermi 3 site characteristic value of 23.3 degrees C (73.9 degrees F) based on its review of Detroit Metropolitan Airport 1982–2006 MCWB temperature values (from the 2009 ASHRAE database, WDView 4.0) extrapolated to a DB temperature value of 40.1 degrees C (104.2 degrees F). Using the 2005 ASHRAE database WDView 3.0, the staff extrapolated a MCWB temperature of 23.8 degrees C (74.8 degrees F) for a DB temperature of 40.8 degrees C (105.4 degrees F). Using the 2009 ASHRAE database WDView 4.0, the staff extrapolated a MCWB temperature of 23.2 degrees C (73.8 degrees F) for a DB temperature of 40.3 degrees C (104.5 degrees F). Although the staff calculated slightly higher values, the applicant's site characteristic value of 23.3 degrees C (73.9 degrees F) is considered acceptable, given that the corresponding ESBWR site parameter value of 26.7 degrees C (80 degrees F) is significantly higher than either the applicant's or staff's MCWB temperature values.

- Maximum Wet Bulb Temperature: The applicant determined the Fermi 3 site characteristic value of 30.0 degrees C (86.0 degrees F) based on a 100-year value derived from a review of Detroit Metropolitan Airport 1961–2007 mean and standard deviation of annual maximum WB temperatures using a Gumbel distribution. Using the 1961–2009 mean and standard deviation of annual maximum WB temperatures with a Gumbel distribution, the staff derived a maximum WB temperature of 30.1 degrees C (86.2 degrees F). Because the staff's value is only slightly higher than the applicant's site characteristic value, the applicant's value is considered acceptable.

- Minimum Dry Bulb: The applicant determined the Fermi 3 site characteristic value of –34.9 degrees C (–30.8 degrees F) based on a 100-yr value derived from a review of the Detroit Metropolitan Airport 1961–2007 mean and standard deviation of annual minimal DB temperatures using a Gumbel distribution. Using the 1972–2001 mean and standard deviation of annual extreme minimum DB temperatures provided in the 2005 ASHRAE Handbook, the staff derived a value of –33.8 degrees C (–28.8 degrees F); using the 1982–2006 mean and standard deviation data provided in the 2009 ASHRAE Handbook, a value of –33.2 degrees C (–27.8 degrees F) was derived. On this basis, the staff concludes that the applicant's site characteristic value of –34.9 degrees C (-30.8 degrees F) is conservative.

The applicant revised the zero percent exceedance ambient design temperature site characteristic values presented in FSAR Table 2.0-1 to be the more extreme of either the historic or 100-year return values. For this reason, RAI 02.03.01-10 is considered resolved.

GEH added three new site parameters related to ESBWR control room habitability area (CRHA) transient room temperature analysis in Revision 8 to DCD Tier 2, Table 2.0-1. The applicant submitted proposed changes to the Fermi 3 COL FSAR in response to ESBWR DCD Revision 8 in a letter dated November 9, 2010. These three new site parameters, along with the corresponding Fermi 3 site characteristic values developed by the applicant, are as follows:

- Maximum average dry bulb temperature for zero-percent exceedance maximum temperature day

This ESBWR site parameter value, 39.7 degrees C (103.5 degrees F), is used to evaluate maximum temperature conditions for the CRHA transient room temperature analysis. The corresponding site characteristic value is defined as the average of the zero percent exceedance maximum dry bulb temperature and the dry bulb temperature resulting from a daily temperature range, where the daily temperature range is defined as the dry bulb temperature difference between the zero percent exceedance maximum dry bulb temperature and the dry bulb temperature that corresponds to the higher of the two lows occurring within 24 hours before and after that maximum.

The applicant reported that the historic maximum dry bulb temperature value reported for the Detroit Metropolitan Airport during the period 1961-2007 was 40.0 degrees C (104.0 degrees F) which occurred on June 25, 1988. The applicant stated that the higher of the two lows occurring within 24 hours before and after the historic maximum dry bulb temperature was 18.9 degrees C (66.0 degrees F). Because the 100-year return maximum dry bulb temperature (40.05 degrees C [104.1 degrees F]) is higher than the historic maximum dry bulb temperature, the applicant used the higher 100-year value in calculating a Fermi 3 maximum average dry bulb temperature for zero-percent exceedance maximum temperature day site characteristic value of 29.48 degrees C (85.1 degrees F). The resulting Fermi 3 site characteristic value is bounded by the corresponding ESBWR site parameter value.

- <u>Minimum average dry bulb temperature for zero-percent exceedance minimum temperature day</u>

This ESBWR site parameter value, −32.5 degrees C (−26.5 degrees F), is used to evaluate minimum temperature conditions for the CRHA transient room temperature analysis. The corresponding site characteristic value is defined as the average of the zero percent exceedance minimum dry bulb temperature and the dry bulb temperature resulting from a daily temperature range, where the daily temperature range is defined as the dry bulb temperature difference between the zero percent exceedance minimum dry bulb temperature and the dry bulb temperature that corresponds to the lower of the two highs occurring within 24 hours before and after that minimum.

The applicant reported that the historic minimum dry bulb temperature value reported for the Detroit Metropolitan Airport during the period 1961-2007 was −29.44 degrees C (−21.0 degrees F) which occurred on January 21, 1984. The applicant stated that the lower of the two highs occurring within 24 hours before and after the historic maximum dry bulb temperature was −17.8 degrees C (−0.04 degrees F). Because the 100-year return minimum dry bulb temperature (−34.89 degrees C [−30.8 degrees F]) is lower than the historic minimum dry bulb temperature, the applicant used the lower 100-year value in calculating a Fermi 3 minimum average dry bulb temperature for zero-percent exceedance minimum temperature day site characteristic value of −26.35 degrees C (−15.4 degrees F). The resulting Fermi 3 site characteristic value is bounded by the corresponding ESBWR site parameter value.

- <u>Maximum high humidity average web bulb globe temperature index for zero-percent exceedance maximum wet bulb temperature day</u>

This ESBWR site parameter value, 30.3 degrees C (86.6 degrees F), is used to evaluate high humidity conditions for the CRHA transient room temperature analysis. It is defined as the average of the wet bulb globe temperature (WBGT) index values for the zero-percent exceedance maximum wet bulb temperature and the highest of the six low wet bulb temperatures that occurs in each of the three 24-hour periods before and after the zero-percent exceedance wet bulb temperature. The WBGT index value is defined as the dry bulb temperature multiplied by 0.3 plus the wet bulb temperature multiplied by 0.7.

The applicant reported that the historic maximum wet bulb temperature value reported for the Detroit Metropolitan Airport during the period 1961-2007 was 29.44 degrees C (85.0 degrees F) which occurred on July 14, 1995. The coincident dry bulb temperature was 36.7 degrees C (98.1 degrees F). Because the 100-year return maximum wet bulb temperature (30.0 degrees C [86.0 degrees F]) is higher than the historic maximum wet bulb temperature, the applicant used the higher 100-year value in calculating a WBGT index of 32.01 degrees C (89.62 degrees F).

The applicant stated that the highest of the six low wet bulb temperatures that occurred in each of the 24-hour periods before and after the historic maximum wet bulb temperature was 24.1 degrees C (75.4 degrees F). The coincident dry bulb temperature was 28.9 degrees C (84.0 degrees F), resulting in a WBGT index of 25.54 degrees C (77.97 degrees F).

The average of the WBGT index values for the zero-percent exceedance maximum wet bulb temperature and the highest of the six low wet bulb temperatures that occurs in each of the three 24-hour periods before and after the zero-percent exceedance wet bulb temperature is 28.78 degrees C (83.80 degrees F). This value represents the site characteristic value for the Fermi 3 maximum high humidity average web bulb globe temperature index for zero-percent exceedance maximum wet bulb temperature day. The resulting Fermi 3 site characteristic value is bounded by the corresponding ESBWR site parameter value.

The staff reviewed meteorological data from the Detroit Metropolitan Airport for the period 1961-2009 and identified the same dates and times as the applicant regarding the occurrence of the historic maximum and minimum dry bulb temperatures and the historic maximum wet bulb temperature. The staff also found that its historic temperature values were the same or bounded by the applicant’s values. The staff also concluded that the applicant used the correct methodology in developing the three CRHA transient room temperature analysis site parameter values by following the definitions presented in ESBWR DCD, Tier 2, Appendix 3H, Section 3H.3.2.1. Therefore, the staff finds the applicant’s three CRHA transient room temperature analysis site parameter values to be acceptable.

The staff issued RAI 02.03.01-19 requesting that the applicant address the following in its proposed revision to the FSAR that develops the CRHA transient room temperature analysis site characteristic values: (1) change the use of the term “Fermi site parameters” to “Fermi site characteristics” in order to be consistent with the terms defined in 10 CFR 52.1(a), and (2) more precisely describe the methodology used in determining the CRHA site characteristic values in accordance with Revision 8 to ESBWR DCD, Tier 2, Appendix 3H, Section 3H.3.2.1.

In its response to RAI 02.03.01-19, dated January 10, 2011 (ADAMS Accession No. ML110110550), the applicant agreed to revise the FSAR to change the term “Fermi site parameters” to “Fermi site characteristics” when referring to the site-specific CRHA transient room temperature analysis values. The applicant also agreed to update the FSAR to more precisely describe the methodology used in determining the CRHA transient room temperature analysis site characteristic values in accordance to the definitions in the ESBWR DCD. The staff reviewed the applicant response to RAI 02.03.01-19 and finds the response acceptable because the applicant agreed to revise the FSAR to address the staff's concerns.

The applicant incorporated the three CRHA transient room temperature analysis site characteristic values into Revision 4 of the Fermi 3 FSAR, including the changes indentified in the applicant's response to RAI 02.03.01-19. Therefore, RAI 02.03.01-19 is considered to be resolved.

f. Ultimate Heat Sink

Subsection 2.3.1.3.7 of the FSAR discusses the ultimate heat sink (UHS) function for the ESBWR design that is provided by safety systems integral and interior to the reactor plant. DCD Tier 2, Subsection 3.1.4.15, states that the ESBWR UHS is the isolation condenser/passive containment cooling system (IC/PCCS) pool. In the event of a design-basis accident, heat is transferred to the IC/PCCS pool(s) through the isolation condenser system and the PCCS. The water in the IC/PCCS pool(s) is allowed to boil, and the resulting steam is vented to the environment.

Because the UHS for the Fermi Unit 3 ESBWR design does not require an external source of safety-related cooling water and there are no cooling towers, basins, or cooling water intake/discharge structures external to the reactor plant, specialized meteorological data for evaluating the UHS are not required.

g. Regional Air Quality

i. Background Air Quality

In Revision 1 of FSAR Subsection 2.3.1.3.8, the applicant states that air quality at the Fermi site is heavily influenced by the Detroit and Toledo Metropolitan areas and surrounding emission sources. The Michigan Department of Environmental Quality (MDEQ) evaluates the air quality in the Detroit metropolitan area with a network of monitors mostly located in Wayne County, north of the Fermi site. The MDEQ routinely monitors the EPA criteria pollutants of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter equal to or smaller than 2.5 micrometers in diameter ($PM_{2.5}$), particulate matter equal to or smaller than 10 micrometers in diameter (PM_{10}), and ozone (O_3). The applicant identified that Monroe County is designated a nonattainment area for EPA's annual $PM_{2.5}$ standard (i.e., the three-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors exceeded 15.0 $\mu g/m^3$) and 8-hour O_3 standard (i.e., the three-year average of the fourth-highest daily maximum 8-hour average O_3 concentrations measured at each monitor within an area over each year exceeded 0.075 ppm). Maximum concentrations for the annual average of $PM_{2.5}$ and 8-hour O_3 pollutants were obtained from monitors in Monroe and Wayne Counties. The applicant reports that the highest annual $PM_{2.5}$ concentration reported between 1999 and 2006 is 20.1 $\mu g/m^3$, occurring at the Dearborn monitor located west of downtown Detroit. During the same period, the highest 8-hour O_3 concentration recorded was 0.104 ppm, measured at the East Seven Mile monitor located in northeastern Wayne County.

The NRC staff verified the statements and values determined by the applicant using the EPA's *Green Book* and *Air Data* database, and MDEQ' *2006 Annual Air Quality Report*.

In Revision 1 of FSAR Subsection 2.3.1.3.8.1, “Background Air Quality,” the applicant stated that Monroe County is a member of the Air Quality Control Region (AQCR) that included the counties of the Detroit metropolitan area. However, per 40 CFR 81.43, Monroe County is in Metropolitan Toledo Interstate Air Quality Control Region (AQCR 124), and the nonattainment status for $PM_{2.5}$ and O_3 is reported as a part of the Detroit-Ann Arbor designated area as in 40 CFR 81.243. The NRC staff issued RAI 02.03.01-11 asking the applicant to clarify the jurisdiction for air quality control management at the Fermi Unit 3 site.

The applicant’s response to RAI 02.03.01-11, dated February 8, 2010 (ADAMS Accession No. ML093570220), revised Revision 2 of FSAR to state that Monroe County is a member of the Metropolitan Interstate Toledo AQCR and is also included in the Detroit-Ann Arbor air quality designation area. The applicant also updated the FSAR to indicate that the Detroit-Ann Arbor air quality designation area is reclassified as a maintenance area for 8-hour O_3 standard on June 29, 2009. The NRC staff has confirmed this information, and thus RAI 02.03.01-11 is considered resolved.

In Revision 1 of FSAR Subsection 2.3.1.3.8.1, “Background Air Quality,” the FSAR states that only annual-average $PM_{2.5}$ concentrations exceeded the ambient air quality standards. However, 24-hour average $PM_{2.5}$ concentrations at monitoring stations around the Fermi site frequently exceeded the respective 35 $\mu g/m^3$ standard as well. The NRC staff issued RAI 02.03.01-12 asking the applicant to discuss exceedances of 24-hour $PM_{2.5}$ concentrations around Fermi site and to revise the $PM_{2.5}$ units used in this section from mg/m^3 to $\mu g/m^3$.

In its response to RAI 02.03.01-12, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant agreed to revise the FSAR to include the latest $PM_{2.5}$ nonattainment area designations for Monroe County and nearby monitor concentrations for 24-hour $PM_{2.5}$. The applicant also corrected the units associated with the $PM_{2.5}$ standard. Consequently, RAI 02.03.01-12 is considered resolved.

Section C.I.2.3.1.2 of RG 1.206 and Section III.3.e of SRP Section 2.3.2 state that regional air quality conditions that should be considered in the evaluation of the design and operation of the facility should be identified. Revision 1 of FSAR Section 2.3.1.3.7.1 states that Monroe County is a member of an Air Quality Control Region (AQCR) that has been classified as nonattainment for $PM_{2.5}$ and O_3 national ambient air quality standards (NAAQS). NAAQS are promulgated to protect public health and welfare. The NRC staff issued RAI 02.03.01-13 requesting the applicant to discuss the impact on plant design and operation due to the Fermi site being located in a $PM_{2.5}$ and O_3 nonattainment area.

The applicant response to RAI 02.03.01-13, dated February 8, 2010 (ADAMS Accession No. ML093570220), states that the Detroit-Ann Arbor designation area including Monroe County is redesignated as a maintenance area for the 8-hour O_3 standard, and thus is currently a nonattainment area for $PM_{2.5}$ only. The applicant states that the construction and operation of Fermi Unit 3 would meet the MDEQ regulations and programs and that only few infrequently operated sources of criteria pollutants exist at a new nuclear unit. The applicant concluded that the operation of Fermi Unit 3 will have neither a negative impact on the current air quality nor impede the State’s plans for attaining the NAAQS, and thus will not adversely impact public health and welfare via air quality. In addition, the applicant mentioned the need for a conformity analysis for construction and operation at the Fermi Unit 3 site because the project is subject to a Federal action (i.e., NRC's approval for construction and operation) and the area is classified as a maintenance and nonattainment area for 8-hour O_3 and $PM_{2.5}$ standards, respectively.

The NRC staff reviewed the applicant's response to RAI 02.03.01-13 and accepts portions of the applicant's statement. The NRC staff has concluded that the conformity analysis will be addressed separately from this SER. However, the NRC staff found the response to RAI 02.03.01-13 incomplete. The NRC staff closed RAI 02.03.01-13 and issued a follow-up question, RAI 02.03.01-17, to address the unresolved issues.

The staff issued RAI 02.03.01-17 asking the applicant to address the impact on plant design and operation due to the Fermi site being located in a $PM_{2.5}$ nonattainment area. For example, the applicant should discuss whether the increased particulate loading associated with a $PM_{2.5}$ nonattainment area would adversely impact dust loading on HVAC filter systems.

The applicant's response to RAI 02.03.01-17, dated September 2, 2010 (ADAMS Accession No. ML102570700), states that Monroe County is below the NAAQS for $PM_{2.5}$ based on recent (2006-2008) monitoring data. The applicant further states that, per a letter from MDEQ to U.S. EPA, dated March 4, 2009, only one monitor in Southeast Michigan, in Wayne County, shows nonattainment of the standard. All other monitors in Southeast Michigan, including the eight other monitors in Wayne County, are meeting the 24-hour $PM_{2.5}$ standard. The applicant further states that, given that the entire state of Michigan will be in attainment with the $PM_{2.5}$ NAAQS prior to construction and operation of Fermi 3, there is no impact on plant design and operation. The staff has confirmed that there are two exceedances among the monitors in the current nonattainment area of Southeast Michigan, including Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne Counties, based on 2006-2008 monitoring data (U.S. EPA's *AirData* database, available at http://www.epa.gov/air/data/, accessed October 29, 2010). One exceedance occurred in Dearborn, Wayne County, which is located about 25 miles north of the Fermi site. The other exceedance occurred in Port Huron, St. Clair County, which is located about 82 miles north-northeast of the Fermi site. The 2000-2008 monitoring data show a general decreasing trend of 24-hour and annual $PM_{2.5}$ concentrations in Monroe County, except for peaks in 2002 and 2005. The staff also notes that in July 2011, the MDEQ submitted a request asking the EPA to redesignate southeast Michigan as being in attainment with the $PM_{2.5}$ NAAQS. This request would be based, in part, on air quality monitoring data collected in the 2007-2010 period showing all seven counties in southeast Michigan in attainment for the $PM_{2.5}$ NAAQS.

Considering all of these findings, the staff accepts the applicant's conclusion that $PM_{2.5}$ concentrations in Monroe County would be likely to comply with NAAQS during construction and operation of Femi 3 and are not likely to adversely impact dust loading on HVAC filter systems. Therefore, RAI 02.03.01-17 is considered resolved.

ii. Air Stagnation

In Revision 1 to FSAR Subsection 2.3.1.3.8.3 "Air Stagnation," the applicant estimates that high-pressure stagnation conditions, usually accompanied by light and variable wind conditions, can be expected at the proposed Fermi Unit 3 site. These conditions would occur about 10 days per year or in about two cases per year, with a mean duration of about three to four days for each case. This estimation is based on findings by Wang and Angell (NOAA/Air Resources Laboratory ATLAS No. 1, "Air Stagnation Climatology for the United States (1948-1998)," April 1999). Stagnation conditions primarily occur from May through October, with the highest incidences recorded between July and September. This 3-month period also coincides with the lowest monthly mean wind speeds during the year, as reported by the LCD summary for Detroit Metropolitan Airport.

The staff has confirmed that the information presented by the applicant regarding restrictive dispersion conditions is correct. Section 2.3.1 of this SER discusses the proposed Fermi Unit 3 site air quality conditions for design and operating considerations. Sections 2.3.4 and 2.3.5 of this SER discuss atmospheric dispersion site characteristics used to evaluate short-term, post-accident airborne releases and long-term routine airborne releases, respectively.

Potential Changes in Climate

As specified in NUREG–0800, the applicability of data used to discuss severe weather phenomena that may impact the proposed COL site during the expected period of reactor operation should be substantiated. Long-term environmental changes and changes to the region resulting from human or natural causes may affect the applicability of the historical data to describe the site's climate characteristics. The staff believes current climate trends should be analyzed for potential ongoing environmental changes.

The applicant did not address potential impacts associated with climate changes in Revision 1 of the FSAR. SRP Section 2.3.1 states that the applicability of the data on severe weather phenomena that is used to represent site conditions during the expected period of reactor operation should be substantiated. SRP Section 2.3.1 further states that current literature on possible changes in the weather in the site region should also be reviewed to be confident that the methods used to predict weather extremes are reasonable. RAI 02.03.01-14 was issued requesting that the applicant evaluate the trends in severe weather phenomena and extremes in the proposed site vicinity and discuss whether such trends may be indicative of climate change.

The applicant's response to RAI 02.03.01-14, dated February 8, 2010 (ADAMS Accession No. ML093570220), states the applicant analyzed normal temperature and rainfall trends during a 70-year period for successive 30-year intervals by decade for the climate division in which the Fermi site is located. The applicant states that normal (i.e., 30-year average) temperatures have not changed between the beginning period of 1931–1960 and the latest period of 1971–2000, but the normal rainfall has trended upward from 78.0 cm (30.72 in.) per year for the 1931–1960 period to 83.5 cm (32.86 in.) per year for the 1971–2000 period. The applicant also showed that a change in annual-average temperature between the 1920–1940 period and 1980–2000 period for the Detroit Metropolitan Airport has no trend, but annual-average temperature for the 2000–2009 period increased about 0.5 degrees C (0.9 degrees F) compared to the 1980–2000 period. The annual-average precipitation generally shows upward trends: from 77.2 cm (30.4 in.) for the 1920–1940 period to 86.1 cm (33.9 in.) for the 1980–2000 period and 86.6 cm (34.1 in.) for the 2000–2009 period.

The U.S. Global Change Research Program (GCRP) released a report to the President and Members of Congress in June 2009 titled, *Global Climate Change Impacts in the United States*. This report was produced by an advisory committee chartered under the Federal Advisory Committee Act. The report summarizes the science of climate change and the impacts of climate change on the United States.

The GCRP report found that the average annual temperature of the Midwest (which includes the State of Michigan where the Fermi Unit 3 site is located) did not change significantly during the past century as a whole, but the annual average temperature has risen about 1–2 degrees F since 1961. Climate models predict continued warming across the Midwest and an increase in the rate of warming throughout the end of the 21st century. Under a low heat-trapping gas emission scenario, average temperatures around the Fermi site are projected to rise by about 5–6 degrees F by the 2080s, while a higher emissions scenario yields about a 9 degrees F increase in average warming.

The GCRP report also states that there is a 15 to 20 percent increase in observed annual average precipitation from 1958 to 2008 in the region in the proposed location of Fermi 3. Future changes in total precipitation are more difficult to project than changes in temperature. Model projections of future precipitation generally indicate that northern areas of the United States will become wetter due to more northward incursions of storm tracks, with about a 15 to 20 percent increase in winter and spring, a 5 to 10 percent decrease in summer, and a zero to 5 percent increase in fall around the Fermi site.

The applicant stated that there are no discernable trends in extreme weather events, considering that extreme temperatures and precipitation events around the Fermi site occurred more than 30 years ago and increasing trends of severe weather events are primarily due to a simple increase in communication techniques in more recent years. The applicant concluded that the data for extreme weather events presented in the FSAR remain bounded by the design values, as this type of return period goes beyond the design life of the proposed new unit.

The GCRP reports that the distribution by intensity of the strongest 10 percent of hail and wind reports has changed little, and there is no evidence of an observed increase in the severity of such events. Climate models project future increases in the frequency of environmental conditions favorable to severe thunderstorms. But the inability to adequately model the small-scale conditions involved in thunderstorm development remains a limiting factor in projecting the future character of severe thunderstorms and other small-scale weather phenomena.

The staff has verified that, except for a couple of incorrect temperatures, the data and related discussion presented in the response to RAI 02.03.01-14 are reasonable and thus RAI 02.03.01-14 is considered resolved.

The NRC staff acknowledges that long-term climatic change resulting from human or natural causes may introduce changes into the most severe natural phenomena reported for the site. However, no conclusive evidence or consensus of opinion is available on the rapidity or nature of such changes. There is uncertainty in projecting future conditions because the assumptions regarding the future level of emissions of heat-trapping gases depends on projections of population, economic activity, and choice of energy technologies. The GCRP report states that climate will be continually changing toward more extreme weather events. However, there is considerable margin between many of the ESBWR climatic site parameters and the corresponding Fermi 3 site characteristic values as shown in FSAR Table 2.0-201. If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported at the site, the COL holders have a continuing obligation to ensure that their plants stay within the licensing basis.

The NRC staff has reviewed the application and finds that the applicant has presented and substantiated information to establish the regional meteorological characteristics.

2.3.1.5 *Post Combined License Activities*

There are no post-COL activities associated with this section.

2.3.1.6 *Conclusion*

The NRC staff has reviewed the application and checked the referenced DCD. The NRC staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

The NRC staff reviewed the application and finds that the applicant has presented and substantiated information to establish the regional meteorological characteristics. The staff's review confirms that the applicant has established the meteorological characteristics at the site and in the surrounding area acceptable to meet the requirements of 10 CFR 100.20(c)(2) and 100.21(d) with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the most severe natural phenomena historically reported for the site and surrounding area in establishing its site characteristics. Specifically, the staff accepts the methodologies used to analyze these natural phenomena and to determine the severity of the weather phenomena reflected in these site characteristics. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the applicant has considered these historical phenomena with margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified site characteristics meet the requirements of 10 CFR 52.79(a)(1)(iii) with respect to identifying the most severe of the natural phenomena historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 2.3.1 of NUREG–0800, and the applicable NRC regulatory guides. The staff's review confirms that the applicant has adequately addressed the COL license information item in accordance with Section 2.3.1 of NUREG–0800.

2.3.2 Local Meteorology

Measurements from the Fermi onsite meteorological tower, located approximately one-quarter mile from the Fermi 3 RB, will be used in this section to characterize the local meteorology conditions at the Fermi site.

2.3.2.1 *Introduction*

Subsection 2.3.2, "Local Meteorology," of the Fermi 3 COL FSAR, Revision 7, addresses the local (site) meteorological characteristics, the assessment of the potential influence of the proposed plant and its facilities on local meteorological conditions and the impact of these modifications on plant design and operations, and provides a topographical description of the site and its environs.

2.3.2.2 *Summary of Application*

Subsection 2.3.2 of the Fermi 3 COL FSAR, Revision 7, discusses the local meteorology at the Fermi 3 site. In addition, in FSAR Section 2.3.2, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-8-A Local Meteorology

  The onsite meteorological tower (the details of which are contained in Subsection 2.3.3) collects wind speed, wind direction, and ambient temperature at the 10-m (33-ft) and 60-m (197-ft) levels, dew-point temperature at 10-m (33-ft) level, and vertical air temperature difference (ΔT) between the 60-m (197-ft) and 10-m (33-ft) levels. In addition, precipitation is collected at ground level near the base of the tower.

2.3.2.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the local meteorology, and the associated acceptance criteria, are in Section 2.3.2 of NUREG–0800. The acceptance criteria for identifying regional climatology are based on meeting the relevant requirements of 10 CFR Parts 52 and 100. The staff considered the following regulatory requirements in reviewing the applicant's discussion of site location and description:

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

- 10 CFR 100.20(c)(2), and 100.21(d) with respect to the consideration that has been given to the local meteorological and air quality characteristics of the site and other physical characteristics of the site that can influence the local meteorology.

NUREG-0800, Section 2.3.2, specifies that an application meets the above requirements, if the application satisfies the following criteria:

- local summaries of meteorological data based on onsite measurements are provided in accordance with RG 1.23 and NWS station summaries or other standard installation summaries from appropriate nearby locations (e.g., within 80 km [50 miles]) are presented as specified RG 1.206, Section 2.3.2.1

- a complete topographical description of the site and environs out to a distance of 80 km (50 mi) from the plant, as described in RG 1.206, Section 2.3.2.2, is provided

- a discussion and evaluation of the influence of the plant and its facilities on the local meteorological and air quality conditions are provided and the applicant identifies potential changes in the normal and extreme values resulting from plant construction and operation

- a description of local site airflow that includes wind roses and annual joint frequency distributions (JFDs) of wind speed and wind direction by atmospheric stability for all measurement levels is provided using the criteria provided in RG 1.23

When independently assessing the acceptability of the information presented by the applicant in FSAR Section 2.3.2, the NRC staff applied the same methodologies and techniques cited above.

2.3.2.4 *Technical Evaluation*

The NRC staff reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information regarding local meteorology. The staff followed the procedures in Section 2.3.2 of NUREG–0800 as part of this review.

<u>COL Item</u>

- EF3 COL 2.0-8-A Local Meteorology

This COL information item requires that the COL applicant supply site-specific information in accordance with SRP Section 2.3.2; that is, the COL applicant should provide summaries of the local (site) meteorological characteristics, an assessment of the potential influence of the proposed plant and its facilities on local meteorological conditions, the impact of these modifications on plant design and operation, and a topographical description of the site and its environs.

In response to this COL information item, the applicant provides the following:

- Summaries of the local (site) meteorology in terms of temperature, atmospheric moisture, precipitation, fog and smog, wind direction and wind speeds, wind persistence, mixing heights, and atmospheric stability and inversions.

- An assessment of the construction and operation impacts of the plant and its facilities on the local meteorological parameters listed above. These impacts include the effects of plant structures, terrain modification, and heat and moisture sources due to plant operation.

- A topographical description of the site and its environs, as modified by the plant structures.

The NRC staff reviewed the applicant's resolution to EF3 COL 2.0-8-A related to supplying site-specific information in accordance with SRP Section 2.3.2. The staff's review of the applicant's summaries of the local (site) meteorological characteristics, an assessment of the potential influence of the proposed plant and its facilities on local meteorological conditions, the impact of these modifications on plant design and operation, and a topographical description of the site and its environs is described below.

Normal, Mean, and Extreme Values

In Subsection 2.3.2.1 of the FSAR, the applicant uses measurements made at the Fermi onsite meteorological tower, located approximately one-quarter mile from the Fermi 3 RB, to characterize the local meteorology conditions at the Fermi site. The onsite meteorological tower collects wind speed, wind direction, and ambient temperature at the 10-m (33-ft) and 60 m (197-ft) levels, dew-point temperature at 10-m (33-ft) level, and vertical air temperature difference (ΔT) between the 60-m (197-ft) and 10-m (33-ft) levels. In addition, precipitation is collected at ground level near the base of the tower. The vertical temperature difference (ΔT) between the 60-meter (197-foot) and 10-meter (33-foot) levels is used to compute atmospheric stability in accordance with the guidance provided in RG 1.23. Hourly data from a recent 5-year period (2003 through 2007) were used by the applicant in the analysis of the local meteorology of the Fermi site. The data recovery rate for all the meteorological parameters during this period exceeded 94 percent. Wet-bulb temperature, relative humidity, and the occurrence of fog and visibility are not collected at the Fermi onsite meteorological station; subsequently, the applicant presents data from the nearby Detroit Metropolitan Airport to supplement Fermi site data. The applicant also presents data from the next two closest first-order NWS stations, Toledo, Ohio, and Flint, Michigan. The applicant also obtained extreme values of temperature, rainfall, and snowfall for four NWS COOP stations located within 80 km (50 mi) of the Fermi site (Monroe, Michigan; Windsor, Ontario; Ann Arbor, Michigan; and Adrian, Michigan), since those parameters are also representative from a regional perspective.

a. Temperature

In Subsection 2.3.2.1.1 of the FSAR, the applicant presents monthly and annual temperature data for 10-meter (33-foot) and 60-meter (197-foot) levels at the Fermi site and for the 10-meter (33-foot) level at the Detroit Metropolitan Airport for the 5-year period 2003–2007 in FSAR Section 2.3.2.1.1. While mean annual temperatures at the 10-meter (33-foot) level at the Fermi site and the Detroit Metropolitan Airport are comparable, the mean monthly values are somewhat different. Due to its proximity to Lake Erie, the Fermi site experiences moderating effects of the water's high heat content by onshore and offshore breezes throughout the year except for winter. During winter months, Lake Erie is generally covered with ice, which inhibits the moderating effects of Lake Erie, and thus temperatures between the two sites are nearly identical. During the spring, ice over the lake melts but the water temperature is still cold, which results in cooler temperatures at the Fermi site than those at the Detroit Metropolitan Airport, which is farther inland. As the lake water warms up during the late spring, the lake exerts moderating effects on temperature, and the temperature contrast along the coast creates onshore and offshore breezes. As a result, temperatures at the Fermi site are a little cooler than those at the Detroit Metropolitan Airport. During the fall season, lake water remains warm, and thus temperatures at the Fermi site are warmer than at the Detroit Metropolitan Airport. Due to the moderating effects of lake water, the Fermi site experiences lower maximum and higher minimum temperatures than the Detroit Metropolitan Airport. The applicant states that, in consequence, annual mean temperatures of the Detroit Metropolitan Airport are representative of the Fermi site from a longer climatological standpoint.

The staff evaluated the applicant's statements in FSAR Subsection 2.3.2.1.1 regarding mean, maximum, and minimum temperatures using the 2003–2007 meteorological data from the Fermi site and from the Detroit Metropolitan Airport.

The applicant originally submitted its 2001-2007 onsite meteorological database in response to environmental RAI AQ2.7-3, dated October 30, 2009 (ADAMS Accession No. ML093090165).

The applicant subsequently reviewed its onsite database to confirm the validity of the data as described in the supplemental response to RAI 02.03.04-3, dated March 30, 2010 (ADAMS Accession No. ML100960472), and provided a revised 2001-2007 onsite database in a supplemental response to environmental RAI AQ2.7-3, dated March 30, 2010 (ADAMS Accession No. ML093090165). The staff performed a precursory review of the revised database and determined that the database still contained errors. The staff subsequently issued RAI 02.03.02-7 asking the applicant to review the revised 2001-2007 onsite meteorological database for mislabeled hours and for DB and dew-point temperature data that were out of range and drastically different from the surrounding data and revise the database accordingly.

In response to RAI 02.03.02-7, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant states that it conducted a comprehensive review of the onsite meteorological database to identify instances where the hourly DB and dew-point temperature data may be out of range. The applicant flagged for further analysis those hours with a temperature change of ±3 degrees C from the previous hour. The applicant reviewed the validity of the flagged data by considering frontal passages, precipitation events, sea/land breezes, or instrument malfunctions, and also by comparisons with hourly observations at the Detroit Metropolitan Airport. The applicant subsequently identified 25 hours in the 2001-2007 database that contained questionable DB or dew-point temperature values as compared with their surrounding hourly values. The 25 hours amount to about 0.04 percent of the over 60,000 observations contained in the 2001-2007 onsite meteorological database. The applicant further states that no additional hours were found where wind speed, wind direction, or stability class data were considered questionable. The applicant stated that these problematic data have no or minor impact on the SACTI cooling tower plume modeling analysis and the JFD tables of wind speed, wind direction, and atmospheric stability presented in the FSAR. In addition, the applicant revised the monthly and annual onsite dew-point temperature summary presented in FSAR Table 2.3-212. The applicant provided a revised 2001-2007 onsite database in its response to RAI 02.03.02-7 which corrected the mislabeled hours and the questionable DB and dew-point temperature data.

The staff examined the applicant's revised onsite database for mislabeled hours and large hour-to-hour changes in parameter values by performing time-series plotting and found no discontinuities in time labels or out-of-range data. The staff also compiled its own monthly and annual dew-point temperature statistics, which it compared with the revised summary table (FSAR Table 2.3-212) presented by the applicant. The staff found the two sets of dew-point temperature data statistics to be consistent (within 0.056 degree C [0.1 degree F]). Accordingly, the RAI 02.03.02-7 is considered resolved.

The staff issued RAI 02.03.02-8 asking the applicant to confirm the extreme monthly DB temperature values presented in Revision 2 to FSAR Table 2.3-211 for the Detroit Metropolitan Airport. The applicant derived the values presented in FSAR Table 2.3-211 using the NCDC's ISHD. The staff also compiled extreme monthly DB temperature values from the ISHD and found discrepancies between the applicant's values and the staff's values.

In response to RAI 02.03.02-8, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant confirmed that it also found data discrepancies that occurred through the use of different versions of the ISHD database; i.e., a full ISHD format used by the staff versus an abridged ISHD format used by the applicant. The applicant reported the apparent data discrepancies to the NCDC. The NCDC acknowledged that its application that is used to generate the abridged ISHD format contained an error and began working to resolve the issue. The applicant reanalyzed the DB temperature data using the full ISHD format and revised the Detroit Metropolitan Airport extreme monthly DB temperature values reported in FSAR Table 2.3-211 accordingly. The applicant incorporated the revised Table 2.3-211 into Revision 3 of the FSAR. Therefore, RAI 02.03.02-8 is considered resolved.

The staff compiled its own monthly DB temperature statistics from the onsite and Detroit Metropolitan Airport data and compared its statistics with the revised DB statistics in the applicant's proposed revision to FSAR Table 2.3-211. In general, the discrepancies between the two are within an acceptable range, but a couple of monthly values are different by more than one degree F: For example, the staff compiled a mean January temperature for the Detroit Metropolitan Airport of –3.3 degree C (26.1 degree F) as compared to the applicant's value of –2.6 degree C (27.4 degree F); similarly, the staff compiled a 60-meter onsite minimum September temperature of 5.5 degree C (41.9 degree F) as compared to the applicant's value of 2.9 degree C (37.3 degrees F). These few temperature discrepancies do not affect the staff's determination that the applicant has adequately described the temperature conditions at the Fermi 3 site.

b. Atmospheric Moisture

In FSAR Subsection 2.3.2.1.2, the applicant compares long-term atmospheric moisture parameters (relative humidity, wet-bulb temperature, and dew-point temperature) among the three first-order NWS stations in the region surrounding the Fermi site. In FSAR Section 2.3.2.1.2, the applicant states that the atmospheric moisture content for stations in the Fermi region is directly related to the latitude of the station and, to a smaller extent, the distance from the Lake Erie shoreline. The applicant indicates that the atmospheric moisture conditions at the Detroit Metropolitan Airport are representative of those at the Fermi site and the atmospheric moisture content at the Fermi site is influenced by Lake Erie and the other Great Lakes.

During the five-year period 2003–2007, the applicant found that the Fermi site meteorological data shows the mean annual dew point temperature for the Fermi site to be 3.1 degree C (37.6 degree F), with the mean monthly dew point temperature highest during July and August (14.5 degree C [58.1 degree F]) and lowest in February (–9.1 degree C [15.7 degree F]). The highest dew point temperature measured was 23.7 degree C (74.7 degree F) while the lowest dew-point temperature measured was –29.9 degree C (–21.8 degree F). Mean monthly diurnal variations in dew point vary the least during summer and early fall when mean dew point temperatures are highest.

The NRC staff has evaluated and confirmed the applicant's statements about monthly and annual, dew point temperature data summaries at the Fermi site in FSAR Subsection 2.3.2.1.2 using 2003–2007 hourly meteorological data from the Fermi station. The staff therefore concludes that the applicant has adequately described the atmospheric moisture conditions at the Fermi 3 site.

c. Precipitation

In FSAR Subsection 2.3.2.1.3, the applicant states that the Fermi onsite meteorological station precipitation sensor malfunctioned several times during the 2003–2007 period, so the applicant used precipitation records for the Detroit Metropolitan Airport to describe the precipitation characteristics of the Fermi site. The applicant characterized the Fermi region as having consistent precipitation amounts during the year and routine wintertime snowfall. The applicant concluded that, when comparing precipitation data from NWS first-order and COOP stations in the Fermi region, precipitation values are reasonably uniform over the region, and therefore are representative of precipitation that would be observed at the Fermi site.

The applicant found that the highest 24-hour precipitation amount measured at the seven stations used to characterize the Fermi Unit 3 site climate was 15.3 cm (6.04 inches) during September 1950 at Flint. The highest monthly precipitation, 28.0 cm (11.04 inches), was also observed at Flint during August 1975. Based on the most recent five years of data from the Detroit Metropolitan Airport (2003–2007), the applicant found precipitation was recorded about 16 percent of the time. January experiences the most frequent hourly precipitation while September has the lowest. The applicant also found that majority of hourly precipitation is of light intensity (less than 0.25 cm [0.1 inches]), and hourly rainfall events greater than 1.27 cm (0.50 inches) occur most frequently with winds from the southwest and south-southwest.

The staff evaluated and confirmed the applicant's statements in FSAR Subsection 2.3.2.1.3 by reviewing NCDC's Local Climatological Data Summary for the three first-order NWS stations (Detroit, Flint, and Toledo) and Climatography for four COOP stations (Adrian 2 NNE, Ann Arbor, Monroe, and Windsor) in the Fermi region and the NCDC's TD-3240 hourly precipitation data at Detroit Metropolitan Airport for the period 2003–2007.

d. Fog and Smog

In FSAR Subsection 2.3.2.1.4, the applicant uses 1961–1995 hourly surface observation data from the Detroit Metropolitan Airport to describe fog and smog conditions at the Fermi site. The applicant stated that the Detroit Metropolitan Airport is the nearest NWS station that monitors visibility and fog. Detroit Metropolitan Airport also has similar elevation and relative proximity to Lake Erie as does the Fermi site, implying that fog conditions would be similar for the two locations. The applicant stated that fog[2] occurred 12.7 percent of the time (1112 hours per year) at Detroit Metropolitan Airport. Fog is most frequent in November and December (14.8 and 17.4 percent, respectively) and least frequent in June and July (9.0 and 9.3 percent, respectively). Heavy fog, defined as a horizontal visibility of 0.4 km (0.25 mi) or less, was found by the applicant to occur about 0.7 percent of the time (60.2 hours per year), most frequently (8 to 11 hours per month) during December through March and least frequently (1 to 2 hours per month) during April through July. The applicant found that smog, defined as a combination of fog and smoke, occurred most frequently during summer and early fall (June through September), and is characterized by warmer air above the surface and lighter winds. This corresponds with the months of weak atmospheric dispersion conditions.

[2] The applicant states that fog is reported by the NWS when horizontal visibility is less than or equal to 9.7 km (6 mi) and the difference between the temperature and dew point is five degrees F or less. However, per SAMSON and HUSWO data format, fog is recorded when visibility is less than 11.3 km (7 mi).

The staff has evaluated and confirmed the applicant's statements in FSAR Subsection 2.3.2.1.4 using 1961–1995 hourly surface observation data for the Detroit Metropolitan Airport (NCDC's SAMSON database for 1961–1990 and HUSWO database for 1991–1995 on CD-ROMs).

e. Wind Direction and Wind Speeds

In Subsection 2.3.2.1.5 of the FSAR, the applicant compares the wind direction and wind speed characteristics of the Fermi site and the Detroit Metropolitan Airport in FSAR Subsection 2.3.2.1.5. The applicant states that the mean annual wind speeds for the 10-meter (33-foot) and 60-meter (197-foot) levels at the Fermi site were 10.6 km/hr (6.57 mph) and 20.5 km/hr (12.74 mph), respectively. The mean annual wind speed at the Detroit Metropolitan Airport is reported as 14.1 km/hr (8.75 mph) at the 10-meter (33-foot) level. The applicant attributes the differences in wind speeds at 10-meter (33-foot) level between the Detroit Metropolitan Airport and the Fermi site to land use characteristics (e.g., Detroit Metropolitan Airport has a flat and suburban location versus the Fermi meteorological tower which is located near a grove of trees that may be reducing the measured wind speed at the 10-meter [33-foot] elevation). Due to frictional effects of the earth's surface, wind speeds at the 60-meter (197-foot) level at the Fermi site are considerably higher than those at the 10-meter (197-foot) level at the Fermi site and the Detroit Metropolitan Airport.

The applicant states that wind directions at the Detroit Metropolitan Airport and at the Fermi site are predominantly from the southwesterly directions and wind directions with a northwesterly component are the second most comment direction. Monthly wind roses for Detroit Metropolitan Airport show definite wind direction patterns by season, depending on the location of the Bermuda High and mean storm track. There is a greater frequency of easterly and southeasterly winds at the Fermi site when compared to the Detroit Metropolitan Airport at the 10-meter (33-foot) level, which the applicant attributes to onshore lake breezes which occur more frequently at the Fermi site.

The staff independently plotted annual and monthly wind roses using 2003–2007 meteorological data from the Fermi site and the Detroit Metropolitan Airport. The staff has confirmed that the applicant's statements in FSAR Subsection 2.3.2.1.5 are correct.

The NRC staff issued RAI 02.03.02-1 requesting the applicant to review and explain the reason for the differences in ratios between 10-meter (33-foot) and 60-meter (197-foot) onsite wind speeds, compared with other meteorological towers. Staff experience indicates 60-meter (197-foot) wind speeds are typically 1.2–1.6 times higher than the 10-meter (33-foot) wind speed during the day and twice as high or higher at night. The Fermi site wind roses appear to show a difference of a factor of about 2 for all hours combined, whereas the staff would expect a factor closer to 1.5 to 1.7. In response to RAI 02.03.02-1, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that the differences between 10-meter (33-foot) and 60-meter (197-foot) wind speeds were possibly due to the presence of the polar jet, the occurrence of offshore winds, and deciduous tree growth to the west of the onsite meteorological tower. The impacts of the apparent increasing frequency of low wind speed observations due to the flow blockage resulting from the trees to the west of the Fermi meteorological tower is discussed further in the applicant's response to RAI 02.03.03-1 in SER Section 2.3.3. RAI 02.03.02-1 is therefore considered resolved.

The NRC staff issued RAI 02.03.02-2 requesting the applicant to address whether the contents of FSAR Figure 2.3-204 changed from a precipitation rose in FSAR Revision 0 to a wind rose in FSAR Revision 1. In response to RAI 02.03.02-2, dated February 8, 2010 (ADAMS Accession

No. ML093570220), the applicant stated that the FSAR Figure 2.3-204 precipitation rose graphic in Revision 0 was correct and revised Figure 2.3-203 in FSAR Revision 2 to once again be a precipitation rose. Thus RAI 02.03.02-2 is considered resolved.

The NRC staff issued RAI 02.03.02-3 requesting the applicant to describe the methodology it used to generate the Detroit Metropolitan Airport wind and precipitation roses presented in FSAR Figures 2.3-204 through 2.3-229. The applicant used wind direction data from the ISHD database to develop these figures and the wind direction data in the ISHD database are reported to the nearest 10 degrees. However, the precipitation and wind rose wind directions plotted from the ISHD database by the applicant are binned into sixteen 22.5 degree sectors, which means the reported wind direction data are typically more concentrated in the four cardinal directions (N, E, S, and W) if wind direction randomization is not applied. In response to RAI 02.03.02-3, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that it randomized the wind directions in order to prevent directional bias for the four cardinal wind directions. Because the applicant used randomized wind direction data to generate the Detroit Metropolitan Airport wind and precipitation roses, RAI 02.03.02-3 is considered resolved.

f. Wind Persistence

In FSAR Subsection 2.3.2.1.6, the applicant presented wind direction persistence summaries based on measurements at the Fermi site for the five-year preoperational period 2003 through 2007. The summaries account for consecutive hours of wind direction at 10-meter (33-foot) and 60-meter (197-foot) levels from the 22½-degree (single) and 67½-degree (three adjoining) wind sectors. The applicant reports in FSAR Section 2.3.2.1.6 that the longest persistence periods for a single sector were 31 hours (in the north and southwest sectors) at the 10-meter level and 36 hours at the 60-meter level (in west-southwest sector). The longest persistence periods for three adjoining sectors occurred 158 hours (west-southwest) at both 10-meter (33-foot) and 60-meter (197-foot) levels.

The staff issued RAI 02.03.02-9 asking that the applicant provide the methodology used to generate the wind direction persistence summaries for the 67½-degree wind sectors. The NRC staff performed an independent analysis of these statistics and found similar distributions of persistence for the 22½-degree wind sectors. However, the staff could not reproduce the applicant’s values for the 67½-degree wind sectors.

In response to RAI 02.03.02-9, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant provided detailed step-by-step procedures and a schematic diagram describing its methodology for generating the 67½-degree wind sector persistence summaries. The staff processed the onsite meteorological data using the applicant’s methodology and compared its results to the applicant’s results. There are some discrepancies between the staff’s and the applicant’s wind persistence summaries, especially for the 67½-degree wind sectors, but the staff does not consider these discrepancies to be significant. Consequently, the staff finds the applicant's wind direction persistence summaries to be acceptable and thus considers RAI 02.03.02-9 to be resolved.

g. Mean Monthly Mixing Heights

In FSAR Subsection 2.3.2.1.7, the applicant noted that from a climatological standpoint, the lowest morning mixing heights occur in the summer and fall and the highest mixing heights occur in the winter. Conversely, afternoon mixing heights reach a seasonal minimum in the winter and a seasonal maximum during the summer, which is expected because of more intense summer heating. The applicant presented on a monthly and annual basis mean morning and afternoon mixing height data calculated by NCDC during 2003–2007 for White Lake, Michigan, which is located about 84 km (52 mi) north-northwest of the Fermi site. The NCDC calculated daily morning and afternoon mixing height data based on vertical temperature and wind information at White Lake along with surface data from the Detroit Metropolitan Airport.

The NRC staff has confirmed that the applicant's annual and monthly morning and afternoon mixing height statistics for White Lake, Michigan, are correct by processing the NCDC 2003–2007 twice-daily mixing height data.

h. Inversions

An air stagnation event is associated with persistent light or calm winds and the presence of an inversion, which is defined as an increase in temperature with height. In FSAR Subsection 2.3.2.1.8, the applicant describes the annual and monthly frequency and persistence of temperature inversions for the 2003–2007 time period, based on the temperature difference (ΔT) between the 10-meter (33-foot) and 60-meter (197-foot) levels at the Fermi onsite meteorological tower being greater than zero. An inversion was present for 13,098 of the 42,800 hours analyzed during the five-year period, which was equivalent to about 30.6 percent of the total hours. About 48.5 percent of the inversions lasted six hour or less, while about 1.3 percent of the inversions lasted longer than 24 hours, with the longest one lasting 76 hours. Inversions are more common during March through October and are most prominent during the summer months of June through August. The applicant states that this concurs with the findings by Wang and Angell (NOAA/Air Resources Laboratory ATLAS No. 1, "Air Stagnation Climatology for the United States (1948-1998)," April 1999) that air stagnation days are highest during July through September.

A comparison of an estimate made by the NRC staff from the hourly ΔT data submitted by the applicant with the summary table presented by the applicant showed reasonable agreement.

i. Atmospheric Stability

In FSAR Subsection 2.3.2.1.9, the applicant discusses atmospheric stability, which is a critical parameter for estimating dispersion characteristics. The dispersion of effluents is greatest for extremely unstable atmospheric conditions (i.e., Pasquill Stability Class A) and decreases progressively through extremely stable conditions (i.e., Pasquill Stability Class G). The applicant based its stability classification on temperature change with height (i.e., vertical temperature difference or ΔT) between the 60-meter and 10-meter height, as measured by the Fermi onsite meteorological monitoring program during the five-year preoperational period 2003–2007 in accordance with the guidance provided in RG 1.23.

The applicant provided seasonal and annual frequencies of atmospheric stability classes. According to the applicant, there is a predominance of neutral stability (Pasquill Stability Class D) and slightly stable (Pasquill Stability Class E) conditions about 56 percent of the time at the proposed Fermi 3 site, which range from approximately 45 percent of the time during the summer to approximately 68 percent of the time during the winter. Extremely unstable conditions (Pasquill Stability Class A) occur most frequently during the summer and least frequently during the winter. Conditions that are extremely and moderately stable (Pasquill

Stability Classes G and F, respectively) occur most frequently during the summer and fall months.

The frequency of occurrence for each stability class is one of the inputs to the dispersion models used in FSAR Sections 2.3.4 and 2.3.5. The applicant included these data in the form of a JFD of wind speed and direction data as a function of the stability class. A comparison of a JFD developed by the staff from the hourly data submitted by the applicant with the JFD developed by the applicant showed reasonable agreement.

Based on the NRC staff's past experience with stability data at various sites, a predominance of neutral (Pasquill Stability Class D) and slightly stable (Pasquill Stability Class E) conditions at the proposed Fermi site is considered generally consistent with expected meteorological conditions. A more detailed review of the applicant's hourly ΔT data is provided by the staff in Section 2.3.3 of this SER.

Regional Topography

The proposed Fermi Unit 3 site is located in the northeastern part of Monroe County, Michigan, along the western shoreline of Lake Erie. In FSAR Section 2.3.2.2, the applicant presents maps of topographical features within a 5-mile (8-km) and a 50-mile (80-km) radius of the site. The applicant also presents terrain elevation profiles along each of the 16 standard 22½-degree compass radials to distances of 5 miles (8 km) and 50 miles (80 km). Based on these profiles, the applicant characterizes the proposed Fermi Unit 3 site terrain as flat plains that gently slope to higher elevations to the west and northwest of the site (towards the Irish Hills) and to lower elevations to the northeast clockwise to the southwest of the site (towards Lake Erie).

Based on topography data from the U.S. Geological Survey (USGS) and on a site visit, the staff accepts this terrain characterization. The NRC staff concludes that the applicant has provided the necessary topographic information.

Influence of Fermi 3 and Its Facilities on Local Meteorology

In FSAR Subsection 2.3.2.2, the applicant states that potential impacts from construction activities for Fermi Unit 3 on the local climate are expected to be minor. Fermi Unit 3 will be located in the southwest portion of the Fermi site, which is already cleared of trees and may require a low level of grading, leading to minimal change in the overall topography. In addition, construction of new roads for the new facility and addition of new structures would have little to no effect on the local meteorology of the site. The staff accepts that these construction activities are too small in scale to impact the local meteorological characteristics of the site.

The NDCT for Fermi 3 will be built in the approximate location of the current onsite meteorological tower. Thus, a new meteorological tower will be erected in the southeast corner of the Fermi site (approximately 1268 meters [4160 feet]) from the existing meteorological tower) prior to the construction of Fermi 3. In FSAR Subsection 2.3.2.2, the applicant discusses the possible influence of Fermi 3 and its facilities on the proposed location of the new meteorological tower. The staff's review of this discussion is in Section 2.3.3 of this SER.

The applicant states that emissions of particulate matter and cooling tower plumes associated with large electricity generation could have effects on the local climate. Potential air emission sources of particulate matter include two standby diesel generators, an auxiliary boiler, a diesel fire pump, and increased traffic. Given their small size and infrequent operation, the applicant states that these emission sources will have a minimal impact on the local climate as well as the local and regional air quality. The staff finds the applicant's assessment to be acceptable.

The applicant states that plumes emitted from cooling towers can also influence local climate. Fermi Unit 3 will use the NDCT as a primary means of heat dissipation and two multi-cell mechanical draft cooling towers (MDCTs) as an auxiliary cooling method. The applicant stated that the potential meteorological effects due to the operation of these cooling towers may include enhanced ground-level fogging and icing, plume shadowing, as well as increased salt deposition.

The applicant states that the operation of the two multi-cell MDCTs is expected to be minimal because they will be used to dissipate heat from the plant service water system primarily during plant cool down and shutdown. For this reason, the applicant considers the environmental impact associated with the operation of the two multi-cell MDCTs to be bounded by the impacts associated with the NDCT and therefore only evaluated the potential plume impacts associated with the operation of the NDCT.

The applicant modeled the NDCT plume impacts with EPRI's Seasonal/Annual Cooling Tower Impact (SACTI) prediction code. The applicant states that this model is endorsed by the staff's Environmental Standard Review Plan (NUREG-1555). The applicant executed the SACTI model using five years (2003 through 2007) of meteorological data provided as input to the code in the NCDC card deck 144 (CD-144) format. Wind direction, wind speed, dew-point temperature, and DB temperature data were taken from the onsite meteorological tower. When the CD-144 format is used as the meteorological input to SACTI, the model determines stability class based on measured wind speed, ceiling height, cloud cover, solar elevation angle, and time of day. Because the onsite meteorological tower does not record ceiling height or cloud cover data, these data were obtained from the Detroit Metropolitan Airport. Mean monthly mixing height data from White Lake, Michigan were also used as input to the SACTI cooling tower model analysis.

The NRC staff issued RAI 02.03.02-4 requesting the applicant to justify why meteorological data were provided as input to the code in the CD-144 format instead of the optional NRC format. If the meteorological data were to be provided as input in the NRC format mode, the SACTI code would determine stability class using the NRC RG 1.23 ΔT methodology instead of the ceiling height/cloud cover method mentioned above. In response to RAI 02.03.02-4, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant justified its use of the CD-144 format by stating that no format example or references to any formatting guides are provided in the SACTI user's manual and the NRC format expected by SACTI code is not the official meteorological format published by the NRC in Appendix A of RG 1.23. The applicant further stated that the SACTI model is not extremely robust when it comes to the execution of its code. For example, only two of the five years of onsite data in the NRC format (2005 and 2006) executed successfully and the model did not provide error messages as to why the other three years of onsite data in NRC format would not execute. The applicant compared the results using the five years of meteorological data in the CD-144 format with the results using the two years of meteorological data in the NRC format and concluded there were no significant changes in model-predicted results between the two data sets. The applicant stated that parameters such as maximum annual and seasonal plume length and average hours per year of shadowing showed a decrease in impacts when using the NRC-formatted dataset whereas other parameters such as maximum annual water deposition showed a slight increase. The applicant further stated that maximum annual and seasonal salt deposition showed no change between the two datasets. The NRC staff finds the applicant's assessment acceptable because the staff also ran the SACTI code using onsite meteorological data in the NRC format input to the model and obtained similar results (for example, less than one percent difference in the annual average plume lengths).

In RAI 02.03.02-4, the staff requested the applicant to justify the use of a surface roughness of 100 cm as input to the SACTI cooling tower model analysis. The applicant assumed that the area surrounding the site is an urban environment (a roughness height of 100 cm) by considering that the Fermi facility is an industrial complex. However, the farther area is agricultural land or water bodies. The area of interest is somewhere between urban and rural. In response to RAI 02.03.02-4 (ADAMS Accession No. ML093570220), the applicant stated that it found that the SACTI model shows no sensitivity in the selection of surface roughness heights between 10 cm and 100 cm (0.33 ft and 3.28 ft) for a NDCT analysis. The NRC staff ran the SACTI code with different surface roughness and also found that the SACTI code is insensitive to surface roughness length. Thus the staff accepts the applicant's conclusion because it meets the requirements of 10 CFR 52.79(a)(1)(iii),10 CFR 100.20(c)(2), and 10 CFR 100.21(d).

In the RAI 02.03.02-4, the staff also requested the applicant to justify the use of mean monthly mixing heights as inputs to the SACTI cooling tower model analysis, even though twice-daily morning and afternoon mixing height data are available and are accepted as input by the SACTI code. In response to RAI 02.03.02-4, the applicant stated that monthly average mixing height data were chosen to simplify the analysis since the NCDC twice daily mixing height data would undoubtedly contain missing height values which would require data filling and substitution. The applicant also performed a mixing height sensitivity analysis between monthly mixing heights and twice-daily mixing heights and concluded that there were no significant changes in the model-predicted results between the two data sets. In comparing the model results using the twice-daily mixing height data versus the monthly mixing height data, the applicant found a decrease in maximum annual and seasonal plume lengths and average hours per year of shadowing, no change in maximum and seasonal salt deposition, and a slight increase in maximum water deposition. The NRC staff reran the SACTI code with different mixing height inputs and also found that the SACTI code is insensitive to mixing height input option. Thus the staff accepts the applicant's assessment.

For the reasons stated above, the staff considers RAI 02.03.02-4 to be resolved.

The applicant used its SACTI model runs to conclude that the annual average plume length is 1.15 miles (1.85 km), with seasonal average plume lengths ranging from a high of 1.47 miles (2.37 km) during winter to a low of 0.24 miles (0.39 km) during the summer. The applicant stated that cooling tower plumes will influence some of the ground level meteorological variables very near the base of the cooling tower. The applicant stated that the NDCT draws air at the base of the tower by the driving force of a density differential that exists between the heated (less dense) air inside the stack and the relatively cool (more dense) ambient air outside the tower. As air rises in the tower, it begins to cool and eventually saturates, which forms a plume at the top of the tower. The air flow toward the cooling tower is localized, and thus its effects will likely be limited to the Fermi property. In addition, a hyperbolic-shaped tower such as the NDCT creates a wake effect to the downwind distance of about five times the width of the top of the tower, i.e., about 445 meters (1460 feet). The applicant stated that some of the heat and moisture from the plume is transported downward to the ground downwind of the NDCT and therefore slightly warmer temperatures and increase absolute humidity can be expected at times within a few hundred feet of the tower. The applicant also reported that the SACTI code predicts a water deposition rate for the NDCT of about 0.00001 mm per month, which corresponds to 0.0001 percent of the mean monthly rainfall of the driest month at the Detroit

Metropolitan Airport. Thus, water deposition (additional precipitation) from the NDCT is anticipated to be small at the Fermi site. Ground-level fogging occurs when the visible plume strikes the ground. Icing occurs when the visible plume strikes the ground under freezing conditions. Fogging and icing from the NDCT are very unlikely, and thus the SACTI code does not compute fogging and icing impacts for the NDCT.

The staff issued RAI 02.03.02-5 requesting the applicant to provide estimates of the likelihood of drizzle icing effects from the NDCT. The Revision 1 to FSAR Subsection 2.3.2.2.2 addressed icing as a result of fogging from the NDCT plume, but did not discuss icing resulting from drizzle produced by the NDCT plume. In response to RAI 02.03.02-5, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that drizzle and light snow have been observed downwind of the NDCT but it is rare and localized. The applicant further stated that freezing drizzle from the NDCT occurs less frequently, as the surface temperature has to be at or below freezing for freezing drizzle to occur. The SACTI code predicts that water deposition rate from the NDCT to be less than 0.0001 percent of the mean monthly rainfall of the driest month. This would result in an even smaller percent of contribution. The staff finds the applicant's analysis to be reasonable and RAI 02.03.02-5 is considered resolved.

The staff issued RAI 02.03.02-6 asking the applicant to revise FSAR Subsection 2.3.2.2 to address the effects of the NDCT moisture and salt deposition on electrical transmission lines and electrical equipment (including transformers and switchyard). In response to RAI 02.03.02 6, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that due to the high initial plume height, the SACTI modeling predicts that no salt will be deposited within 4100 meters (13,500 feet) of the NDCT. Given this large distance, no salt deposition is expected at the existing Fermi Unit 2 switchyard or the planned Fermi Unit 3 switchyard and main transformer area, all of which are located within the Fermi property. The other electrical equipment associated with the operation of Fermi Unit 3 are the transmission lines running offsite. The applicant predicted that the maximum seasonal salt deposition rate of 0.02 kilograms per square-kilometer per month (kg/km^2/month) (0.017 pounds per square mile per month [lb/mi^2/month]) will occur between 4400 and 9400 meters (14,400 and 30,800 feet) east-northeast of the NDCT. The applicant stated that this value is well below the lowest bound salt deposition density level of 300 kg/km^2 for light contamination environments suggested by the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std) C57,19.100-1995 (IEEE-Guide for Application of Power Apparatus Bushings). The applicant concluded that cumulative salt deposition buildup would not cause a contaminated environment on electrical equipment because the predicted maximum monthly deposition rate is in orders of magnitude below the light contamination level and natural precipitation would wash off salt deposition before significant salt buildup would occur.

The staff ran the SACTI code and found that maximum seasonal salt deposition occurs at a rate about four times higher than the applicant's value and at closer distance but still beyond the Fermi property boundary. The staff's estimate is still well below the lowest bound salt deposition density level of 300 kg/km^2 (255.47 lb/mi^2) for light contamination environments suggested by IEEE Std C57,19.100-1995. For this reason, the NRC staff finds that the applicant's conclusion that the operation of the NDCT is not expected to adversely impact the electrical transmission lines and other electrical equipment to be reasonable, and thus considers RAI 02.03.02-6 to be resolved.

The staff ran the SACTI code to examine the plume behaviors using the same tower-specific data, such as tower dimensions, circulating water flow rate, drift loss rate, exit air flow rate, heat rejection rate, and drift droplet diameter spectrum. Rather than using the CD-144 format from the applicant, the staff used onsite meteorological data in the NRC format input to the model and obtained similar results as described above. The staff has verified the applicant's SACTI modeling results and concludes that the applicant has demonstrated that the results presented in the FSAR are a representative and valid analysis of potential impacts associated with operation of the proposed NDCT.

2.3.2.5 *Post Combined License Activities*

There are no post-COL activities associated with this section.

2.3.2.6 *Conclusion*

The NRC staff has reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 2.3.2 of NUREG–0800, and the applicable NRC regulatory guides. The NRC staff's review finds that the applicant has presented and substantiated information describing the local meteorological, air quality, and topographic characteristics important to evaluating the adequacy of the design and siting of this plant. The staff reviewed the information provided and, for the reasons given above, concludes that the identification and consideration of the meteorological, air quality, and topographical characteristics of the site and the surrounding area are acceptable and meet the requirements of 10 CFR 100.20(c)(2) and 100.21(d), with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the site characteristics. Specifically, the staff has generally accepted the methodologies used to determine the meteorological, air quality, and topographic characteristics as documented in SERs for previous licensing actions. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the use of these methodologies results in site characteristics containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified site characteristics meet the requirement of 10 CFR 52.79(a)(1)(iii) with respect to identifying the most severe of the natural phenomena historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and time in which the historical data have been accumulated.

The staff's review confirms that the applicant has adequately addressed the COL license information item in accordance with Section 2.3.2 of NUREG–0800.

2.3.3 Meteorological Monitoring

The current Fermi onsite Meteorological Monitoring Program (MMP) has been in place since it was implemented for Fermi 2 pre-operational meteorological assessment beginning in June 1975.

2.3.3.1 *Introduction*

This FSAR Section addresses the pre-application meteorological measurements program as well as the onsite MMP to be used during site preparation and construction, pre-operation, and operation (i.e., the operational meteorological measurements program). The staff's review covers the following specific areas: meteorological instrumentation, including siting of sensors, sensor type and performance specifications, methods and equipment for recording sensor output, the quality assurance program for sensors and recorders, data acquisition and reduction procedures, and special considerations for complex terrain sites.

The staff's review also evaluated the resulting onsite meteorological database from the pre-application monitoring phase, including consideration of the period of record and amenability of the data for use in characterizing atmospheric dispersion conditions.

2.3.3.2 *Summary of Application*

Subsection 2.3.3, "Meteorological Monitoring," of the Fermi 3 COL FSAR addresses site-specific information on the onsite meteorological measurement program. In addition, in FSAR Section 2.3.3, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-9-A Onsite Meteorological Measurements Program

  The purpose of this section is to confirm that the onsite meteorological measurements program provides an adequate meteorological database for estimating atmospheric dispersion for design basis accident and routine radiological releases and for evaluating the effects of plant operation.

2.3.3.3 *Regulatory Basis*

The acceptance criteria for an onsite meteorological measurements program are based on meeting the relevant requirements of 10 CFR Parts 20, 50, 52, and 100. The staff considered the following regulatory requirements in reviewing the applicant's descriptions of its pre-application and operational onsite meteorological measurements programs:

- 10 CFR Part 20, Subpart D, "Radiation Dose Limits for Individual Members of the Public," with respect to the meteorological data used to demonstrate compliance with dose limits for individual members of the public.

- 10 CFR Part 50, Paragraphs 50.47(b)(4), 50.47(b)(8), and 50.47(b)(9), as well as Section IV.E.2 of Appendix E with respect to the onsite meteorological information available for determining the magnitude and continuously assessing the impact of the releases of radioactive materials to the environment during a radiological emergency.

- 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 19, "Control Room," with respect to the meteorological data used to evaluate the personnel exposures inside the control room during radiological and airborne hazardous material accident conditions.

- 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," with respect to meteorological data used in determining the compliance with numerical guides for design objectives and limiting conditions for operation to meet the requirement that radioactive material in effluents released to unrestricted areas be kept as low as is reasonable achievable.

- 10 CFR 52.79(a)(1)(vi), with respect to a safety assessment of the site, including consideration of major structure, system and components (SSCs) of the facility and site meteorology, to evaluate the offsite radiological consequences at the EAB and LPZ.

- 10 CFR 100.20(c)(2), with respect to the meteorological characteristics of the site that are necessary for safety analysis or that may have an impact upon plant design in determining the acceptability of a site for a nuclear power plant.

- 10 CFR 100.21(c), with respect to the meteorological data used to evaluate site atmospheric dispersion characteristics and establish dispersion parameters such that (1) radiological effluent release limits associated with normal operation can be met for any individual located off site, and (2) radiological dose consequences of postulated accidents meet prescribed dose limits at the EAB and outer boundary of the LPZ.

NUREG-0800, Section 2.3.3 specifies that an application meets the above requirements, if the application provides the following information:

- The pre-application and operational monitoring programs should be described, including (1) a site map (drawn to scale) that shows tower location and true north with respect to man-made structures, topographic features, and other features that may influence site meteorological measurements, (2) distances to nearby obstructions of flow in each downwind sector, (3) measurements made, (4) elevations of measurements, (5) exposure of instruments, (6) instrument descriptions, (7) instrument performance specifications, (8) calibration and maintenance procedures and frequencies, (9) data output and recording systems, and (10) data processing, archiving, and analysis procedures.

- Meteorological data from the pre-application monitoring program should be presented in the form of JFDs of wind speed and wind direction by atmospheric stability class in the format described in RG 1.23. An hour-by-hour listing of the hourly-averaged parameters should be provided in the format described in RG 1.23. If possible, evidence of how well these data represent long-term conditions at the site should also be presented, possibly through comparison with offsite data.

- At least two consecutive annual cycles (and preferably three or more whole years), including the most recent one-year period, should be provided with the application. These data should be used by the applicant to calculate (1) the short-term atmospheric dispersion estimates for accident releases discussed in FSAR Section 2.3.4 and (2) the long-term atmospheric dispersion estimates for routine releases discussed in FSAR Section 2.3.5.

- The applicant should identify and justify any deviations from the guidance provided in RG 1.23.

When independently assessing the acceptability of the information presented by the applicant in FSAR Section 2.3.3, the NRC Staff applied the same above-cited methodologies and techniques.

2.3.3.4 *Technical Evaluation*

The NRC staff reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information regarding meteorological monitoring. The staff followed the procedures in Section 2.3.3 of NUREG–0800 as part of this review.

The NRC staff reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information regarding the onsite pre-application and operational meteorological measurements programs. The staff followed the procedures described in Section 2.3.3 of NUREG–0800 as part of this review.

<u>*COL Item*</u>

- EF3 COL 2.0-9-A Onsite Meteorological Measurements Program

This COL information item states that the COL applicant should supply site-specific information in accordance with SRP Section 2.3.3; that is, the COL applicant should describe its onsite meteorological measurements program and provide a copy of the resulting meteorological data. In response to this COL information item, the applicant describes the following:

- A description of the pre-application and operational MMPs, including siting of sensors, sensor type and performance specifications, methods and equipment for recording sensor output, the quality assurance program for sensors and recorders, data acquisition and reduction procedures.

- The meteorological database resulting from the pre-application monitoring program, presented in the form of a JFD of wind speed and direction by atmospheric stability class and an hour-by-hour listing of the hourly-averaged parameters.

The NRC staff reviewed the applicant's resolution to EF3 COL 2.0-9-A related to supplying site-specific information in accordance with SRP Section 2.3.3. The staff's review of the applicant's description of its onsite MMP and the resulting meteorological data is described below.

Fermi 3 Pre-application Meteorological Measurement Program

Subsection 2.3.3.1 of the FSAR discusses the pre-application MMP for Fermi Unit 3 that is based on the preexisting operational meteorological monitoring program and equipment used for Fermi 2.

In Subsection 2.3.3 of the FSAR, the applicant states that the current onsite meteorological monitoring program has been in place since June 1975 and complies with proposed Revision 1 to RG 1.23, except for the proximity of trees to the meteorological tower. The staff notes that most of pre-application meteorological data was collected prior to the implementation of Revision 1 to RG 1.23. Thus, the staff reviewed the pre-application meteorological monitoring program primarily against the criteria in proposed Revision 1 to RG 1.23.

The information on the pre-application meteorological measurements program presented below is based on information presented in FSAR Subsection 2.3.3.1, applicant's responses to RAIs, and an onsite environmental site audit conducted by the staff on February 2-6, 2009.

a. Tower and Instrument Siting

In Subsection 2.3.3.1.1 of the FSAR the applicant discusses the 60-meter (197-foot) open-latticed guyed meteorological tower that serves as the primary data collection system, including redundant sensors at both the 10-meter (33-foot) and 60-meter (197-foot) levels. The width of the tower at its base exceeds 6 meters (20 feet) and decreases with height. The meteorological sensors are mounted on booms which are greater than one tower width away from the tower and are oriented normal to the prevailing wind direction. The tower is situated in a relative flat area with natural ground cover. A small climate controlled instrument shelter is located at the base of the onsite meteorological tower.

Proposed Revision 1 to RG 1.23 states that the meteorological tower site should represent as close as possible the same meteorological characteristics as the region into which any airborne material will be released. Whenever possible, the tower or mast should be sited at approximately the same elevation as finished plant grade. The height of natural or man-made obstructions to air movement should ideally be lower than the measuring level to a horizontal distance of ten times the measuring level height. Revision 1 to RG 1.23 provides clarifying guidance regarding the tower's proximity to obstructions to air movement, stating that wind sensors should be located over level, open terrain at a distance of at least ten times the height of any nearby obstruction if the height of the obstruction exceeds one-half the height of the wind measurement.

Visual inspection during a site audit conducted February 2-6, 2009, indicated that the distance from the meteorological tower to the nearest obstructions (i.e., a wooded area located west of the tower where some of the trees were higher than 10 meters (33 feet)) did not meet the distance offset criterion identified in Revision 1 to RG 1.23. The applicant stated during the audit that this was a self-identified issue which was entered into the Fermi 2 corrective action system in 2004 and was resolved as having no impact on the monitoring program based on a comparison with historic data collected during the previous 30 years. The staff requested the applicant in RAI 02.03.03-1 to identify the current average height of these trees and their closest distance to the tower. The staff also requested the applicant in RAI 02.03.03-1 to describe the 2004 corrective action evaluation that closed out this issue.

In its original response to RAI 02.03.03-1 (dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant provided a figure showing the current separation between the meteorological tower and nearby trees to the west. This figure showed that there are trees within ten times their height of the meteorological tower. The applicant also stated that it evaluated the impact of the trees by comparing the 10-meter (33-foot) and 60-meter (197-foot) wind roses from the 1974/1975 time frame with 10-meter (33-foot) and 60-meter (197-foot) wind roses from 1985, 1994, 2003, 2004, and 2005 and concluded that there was no significant difference in wind direction and speed patterns between the time periods analyzed.

Based on the information provided by the applicant in its December 23, 2009 response to a similar question (environmental RAI AQ6.4-1), the staff compared the percent of time the wind speed was less than 4.83 km/h (3 mph) between the "downwind sectors" (i.e., when the wind was from the west-southwest clockwise to west-northwest sectors and the meteorological tower was downwind of the trees) and the "upwind sectors" (i.e., when the wind was from the north-

northwest clockwise to south-southwest sectors and the meteorological tower was upwind of the trees). This comparison indicated that, at the 10-meter (33-foot) level, the percent of time the wind speed was less than three mph for the downwind sectors increased from 5.6 percent in 1985 to 19.9 percent in 1994 to 26.5 percent in 2003-2005. For the upwind sectors, the percent of time the wind speed is less than three mph at the 10-meter (33-foot) level also increased, but not in such a drastic fashion. The staff noted that there was essentially no change in the percent of time the wind speed was less than 4.83 km/h (3 mph at the 60-meter (197-foot) level for either the upwind or downwind sectors during the time periods analyzed. The staff has determined these statistics support the conclusion that the heights of nearby trees have impacted the wind flow in certain wind direction sectors. The staff provided this feedback to the applicant in an e-mail dated January 26, 2010 (ADAMS Accession No. ML100500226).

In response to the January 26, 2010 e-mail, the applicant provided a supplemental response to RAI 02.03.03-1, dated March 30, 2010 (ADAMS Accession No. ML100960474), stating it performed an additional review of the 10-meter (33-foot) and 60-meter (197-foot) wind roses ranging from 1975 through 2003. The applicant concluded that there is an apparent increase in the percent of time that the indicated wind speed was less than 4.83 km/h (3 mph at the 10-meter (33-foot) elevation for a given wind direction sector and therefore the potential exists for the wind measurements at the 10-meter (33-foot) elevation to be lower than the actual wind speed at the 10-meter (33-foot) elevation. The applicant also assessed the effect of lower measured wind speeds at the 10-meter (33-foot) level on a number of evaluations presented within the FSAR, including the short-term (accident) dispersion estimates presented in FSAR Section 2.3.4 and the long-term (routine) dispersion estimates presented in FSAR Section 2.3.5. Because the applicant acknowledged that nearby trees could be impacting the 10-meter (33-foot) wind speed measurements and assessed the effect of lower measured wind speeds at the 10-meter (33-foot) level on a number of evaluations presented in the FSAR, the staff considers RAI 02.03.03-1 to be resolved. The staff has also evaluated the effects of lower measured wind speeds on the applicable evaluations within Sections 2.3.4 and 2.3.5 of this report.

The staff finds that the tower is appropriately located such that it can measure the onshore flow conditions that could affect gaseous effluent releases from Fermi Unit 3. The effect of the nearby trees on prior measurements and the adjustments made to compensate for lower measured wind speeds due to the proximity of the trees, are described above. In all other respects, the staff finds the tower location complies with the recommendations provided in proposed Revision 1 to RG 1.23 and is therefore acceptable to the staff.

b. Instrumentation and Their Accuracies and Thresholds

In FSAR Subsection 2.3.3.1.2, the applicant states that the meteorological tower instrumentation consists of wind speed and wind direction sensors at the 10-meter (33-foot) and 60-meter (197-foot) levels, a temperature sensor at the 10-meter (33-foot) level, a vertical air temperature difference (ΔT) system between the 60-meter (197-foot) and 10-meter (33-foot) levels, and a dew-point temperature sensor at the 10-meter (33-foot) level. A heated tipping bucket precipitation gauge which is surrounded by a windscreen is located at ground level at the base of the meteorological tower. External heaters are installed on the primary wind sensors to minimize data loss during ice storms.

Based on an onsite environmental site audit conducted by the staff on February 2-6, 2009, the staff noticed that the wind speed and wind direction sensor information provided in Revision 0 to FSAR Table 2.3-289 appeared to be in error. The staff also noticed an apparent discrepancy in the dew point monitoring system description in the FSAR. The staff subsequently asked the applicant in RAI 02.03.03-2 to verify all of the instrumentation information provided in FSAR Table 2.3-289, including sensor performance specifications and system accuracies, and update FSAR Table 2.3-289 accordingly. The applicant was also requested to identify any deviations from the guidance provided in RG 1.23.

The applicant provided a response to RAI 02.03.03-2, dated February 8, 2010 (ADAMS Accession No. ML100960472), in which the applicant updated Table 2.3-289 in FSAR Revision 2 by listing the sensor manufacturer and model numbers, range, system accuracy, starting threshold, and measurement resolution. The applicant also revised Subsection 2.3.3.1.2 in FSAR Revision 2 to state that the accuracies and thresholds for each sensor are within the limits specified in the proposed Revision 1 to RG 1.23. The staff reviewed the response to RAI 02.03.03-2 and determined that the question is closed but there were issues that remained unresolved. To address these issues, the staff issued follow-up question RAI 02.03.03-8.

The staff notes that FSAR Table 1.9-202 is intended to evaluate the applicant's conformance with applicable RGs in effect six months prior to the submittal of the Fermi 3 COLA. Included in Table 1.9-202 of FSAR Revision 2 is the applicant's evaluation regarding the pre-application meteorological monitoring program conformance to Revision 1 to RG 1.23. The staff issued RAI 02.03.03-8 regarding the following information contained in FSAR Tables 1.9-202 and 2.3-289 regarding the pre-application MMP:

- Revision 2 to FSAR Table 2.3-289 lists the differential temperature (ΔT) channel as having a system accuracy of ±0.15 °C which exceeds the Revision 1 to RG 1.23 specified accuracy of ±0.1 °C. The staff requested the applicant to revise the FSAR to address the ΔT channel nonconformance with the system accuracy specified in Revision 1 to RG 1.23, including the impact this nonconformance may have on any analyses presented in FSAR Section 2.3.

  In its response to RAI 02.03.03-8, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant stated that pre-application monitoring program ΔT channel accuracy of ±0.15 °C is consistent with the guidance provided in proposed Revision 1 to RG 1.23, which was the regulatory guidance in effect during most of the pre-application monitoring program. The staff finds it acceptable that the majority of the onsite ΔT data submitted by the applicant was collected by a monitoring program that was in compliance with the regulatory guidance in effect at the time. The applicant committed to updating FSAR Subsection 2.3.3.1.2 to state that the accuracy of the ΔT channel does not comply with Revision 1 to RG 1.23 but does comply with proposed Revision 1 to RG 1.23, which was the regulatory guidance in effect during most of the pre-application monitoring program.

- Revision 2 to FSAR Subsection 2.3.3.1.1 states the sensors for the existing pre-application MMP are mounted on booms that are greater than one tower width away from the tower. Revision 1 to RG 1.23 states (1) wind sensors on the side of a tower should be mounted at a distance equal to at least twice the longest horizontal dimension of the tower and (2) temperature sensor shield inlets should at least 1½ times the tower horizontal width away from the nearest point on the tower. The staff asked the applicant to revise the FSAR to clarify whether the pre-application MMP was in conformance with the boom length criteria specified in Revision 1 to RG 1.23. If the pre-application program is not in conformance with Revision 1 to RG 1.23, the staff asked the applicant to discuss the impact the nonconformance may have on any analyses presented in FSAR Section 2.3.

In its response (ML102570700) to RAI 02.03.03-8, the applicant stated that the length of the instrument booms on the Fermi 3 pre-application meteorological tower do not meet the Revision 1 to RG 1.23 criteria of two tower widths. However, the width of the meteorological tower at the 10-meter (33-foot) elevation is nearly 6 meters (20 feet) and the staff finds that boom lengths of 12 meters (40 feet) are not practical. The large open areas between the support frames of such a wide open-lattice tower also tend to lessen the impact from turbulent flow downwind of the tower structure. For these reasons, the staff finds the instrument booms on the pre-application meteorological tower to be acceptable. The applicant committed to updating FSAR Subsection 2.3.3.1.1 to address the pre-application monitoring program boom length exception to Revision 1 to RG 1.23.

- Revision 1 to RG 1.23 specifies a digital sampling rate of at least once every 5 seconds. The staff asked the applicant to revise the FSAR to discuss the digital sampling rates for the pre-application meteorological monitoring program. If the pre-application monitoring program is not in conformance with Revision 1 to RG 1.23, the staff requested the applicant to discuss the impact the nonconformance may have on any analyses presented in FSAR Section 2.3.

  In its response to RAI 02.03.03-8 (ADAMS Accession No. ML102570700), the applicant stated that the digital recorders used for the pre-application meteorological monitoring system sample data at least once every five seconds and therefore meet the sampling criteria in Revision 1 to RG 1.23. The applicant committed to updating FSAR Subsection 2.3.3.1.2 to include the digital recorders sampling rate.

The applicant incorporated the information discussed above into Revision 4 of the FSAR.

The staff finds the applicant's response to RAI 02.03.03-8, dated January 10, 2011 (ADAMS Accession No. ML110110550), to be acceptable for the reasons cited above, except that one issue remained unresolved. To address this issue, the staff issued follow-up RAI 02.03.03-9 which is discussed later in this SER Subsection.

c. Instrumentation Calibration

In FSAR Subsection 2.3.3.1.3, the applicant describes the calibration of the sensors, electronics, and recording equipment. The applicant states the sensors, electronics, and recording equipment are calibrated on a six-month basis. More frequent onsite calibrations are performed if the past operating history of the sensor indicates it is necessary. The applicant states any necessary adjustments are made onsite and the equipment that malfunctioned is either corrected onsite or replaced with similar equipment. After any adjustments or repairs, the calibration is repeated. The records documenting the results of calibration drift and the corrective action taken are kept and filed onsite.

The staff requested the applicant in RAI 02.03.03-3 to describe the calibration practices used to ensure that the wind sensors starting thresholds meet the starting threshold criteria presented in RG 1.23. The applicant provided a response to RAI 02.03.03-3, dated February 8, 2010 (ADAMS Accession No. ML100960472) in which it describes the calibration practices used. In particular, the applicant states that a wind tunnel is used to determine the starting thresholds of the wind speed sensors and the starting thresholds of the wind direction sensors are assessed by rotating the wind direction sensor body with the shaft in the horizontal plane and observing that the vane remains stationary. Because these are standard industry practices, the staff finds the information provided in the response to RAI 02.03.03-3 acceptable and thus RAI 02.03.03-3 is considered to be resolved. The applicant incorporated this information on wind sensor starting threshold tests into Revision 2 of FSAR Subsection 2.3.3.1.3.

The staff requested the applicant in RAI 02.03.03-4 to clarify the statement made by the Fermi meteorological system engineer, during the February 2–6, 2009, Fermi environmental site audit, that the secondary ΔT channel recorded values were consistently higher than the primary ΔT channel values. The staff requested that the applicant (1) identify the ΔT channel having the more accurate measurements, (2) describe the impact of the ΔT channel offset on the atmospheric dispersion and deposition factors presented in FSAR Sections 2.3.4 and 2.3.5, and (3) describe the corrective actions to be taken to address this apparent deviation from RG 1.23 criteria.

The applicant provided a response to RAI 02.03.03-4, dated February 8, 2010 (ADAMS Accession No. ML100960472), in which it presents the conclusions of a review of the meteorological data that evaluated the differences between the primary and secondary ΔT measurements. The applicant's data review indicates that there is not a consistent variance between the primary and secondary ΔT indications. That is, the secondary ΔT does not always indicate higher than the primary ΔT. Instead, the applicant stated that its data review indicated that the instantaneous readings from the primary and secondary ΔT indications consistently follow each other over time and any difference in temperature indications is random. The applicant further states that the review of ΔT data, meteorological instrumentation, calibration and surveillance requirements and historical records, and system configuration identified no consistent data variance in primary and secondary channel measurements. The applicant also clarified the statement made by the Fermi meteorological system engineer during the site audit that the difference between the primary and secondary ΔT channel recorded values is due to sensor "wobble" that is corrected by the plant computer software.

Because the primary and secondary ΔT indications follow reliably over time and do not exhibit a consistent difference between the two channels, the staff considers this issue to be resolved and therefore considers RAI 02.03.03-4 to be closed.

d. Instrumentation Service and Maintenance

Proposed Revision 1 to RG 1.23 states that meteorological instruments should be inspected at a frequency that will ensure data recovery of at least 90 percent on an annual basis.

In FSAR Subsection 2.3.3.1.4, the applicant describes the service and maintenance of the meteorological sensors and supporting equipment. Visits are made periodically to the 60-meter (197-foot) tower to make a visual inspection of the sensors, as well as the data output and recording equipment in the instrument shelter, to see if they are damaged and need maintenance. In the event the sensors or monitoring equipment are found damaged or malfunctioning, the equipment is replaced or corrected in a timely fashion. A stock of spare parts and equipment is maintained to minimize and shorten the periods of outages. The instrumentation is checked using the same precision test equipment used for calibration. Records documenting the results of major causes of instrument sensor outages and other malfunctions of the meteorological monitoring system are kept and filed onsite.

The staff finds that instrumentation service and maintenance are in accordance with the guidance of proposed Revision 1 to RG 1.23 and follow standard industry practice.

e. Data Reduction and Transmission

In FSAR Subsection 2.3.3.1.5, the applicant describes the data reduction and transmission. The pre-application MMP is composed of two independent meteorological trains of instrumentation – a primary train and a secondary train – mounted on the meteorological tower. Sensor signals from both trains are independently conditioned inside the environmentally controlled instrument shelter located near the base of the meteorological tower and the outputs from the signal conditioning equipment are transmitted to the Fermi 2 control room via two independent transmission lines. Both trains feed the digital data acquisition equipment belonging to the Integrated Plant Computer System (IPCS) located in the Fermi 2 control room.

The staff finds that data reduction and transmission techniques are performed in accordance with proposed Revision 1 to RG 1.23 and follow standard industry practice.

f. Data Acquisition and Processing

Proposed Revision 1 to RG 1.23 states that meteorological monitoring systems should use a dual recording system consisting of one digital and one auxiliary analog system. The Fermi 3 pre-application monitoring program utilizes dual digital recorders that monitor both trains of instrumentation at the meteorological instrument building to archive raw data. An analog backup recorder is utilized as well.

In FSAR Subsection 2.3.3.1.6, the applicant describes data acquisition and processing. Dual IPCS data acquisition multiplexers accept two trains of data from the primary and secondary data acquisition equipment. These data are provided to the IPCS computers to screen data for data validity and quality, perform meteorological calculations, update the data archive, display the information on the man–machine interface, and output the data to communication devices. The IPCS system monitors error signals to determine equipment status. If an instrument input malfunctions, if data are suspect, or if an instrument input is manually removed from service, the IPCS will substitute the reading from the next level of redundancy and indicate the substitution on the IPCS computers.

The applicant states that the meteorological data are generally reviewed each day by personnel to identify possible data problems. The meteorological data are also validated to ensure that the regulatory requirement for minimum recovery rate of 90 percent (on an annual basis), as outlined in RG 1.23, is met. The data validation process includes utilizing software to review the raw data, identifying and editing questionable or invalid data, recovering data from backup sources, and adjusting the data to reflect calibration sources. After the validation process is completed, the processed data are archived and permanently stored electronically.

Meteorological data are available in five different formats: instantaneous values, 1-minute blocked averages, 15-minute rolling averages, 15-minute block averages, and 1-hour block averages. Routine data summaries are generated for each day, calendar month, and calendar year, and then archived on the IPCS computers. In addition, JFDs of wind speed and wind direction for each stability category are created from the 1-hour block averages. The applicant states that the format of the annual onsite meteorological data summaries and JFD tables conforms to the recommended format found in RG 1.23.

The staff finds that the data acquisition and processing conform to the guidelines in proposed Revision 1 to RG 1.23 and follow standard industry practice.

g. Resulting Meteorological Database

The applicant presented several years of meteorological data from the pre-application MMP to support its Fermi 3 COLA:

- Five years of data (2003-2007) were used for evaluation of site meteorological characteristics and cooling tower plume modeling. JFDs of wind speed, wind direction, and atmospheric stability from the onsite MMP for both the 10-meter (33-foot) and 60-meter (197-foot) levels are provided in FSAR Tables 2.3-269 through 2.3-284 for the period 2003 through 2007.

- Six years of data (2002-2007) were used for calculating the short-term off-site and the long-term atmospheric dispersion estimates. JFDs for the 10-meter (33-foot) level are provided in FSAR Tables 2.3-292 through 2.3-299 for the period 2002 through 2007. The applicant used the data in these tables as input to the dispersion analyses discussed in FSAR Sections 2.3.4 and 2.3.5.

- Seven years of data (2001-2007) were used for calculating the short-term on-site atmospheric dispersion estimates. The applicant provided an hourly listing of the original 2001-2007 onsite meteorological database in its response to environmental RAI AQ2.7-3 dated October 30, 2009.

The staff asked the applicant in RAI 02.03.03-5 to explain apparently data discrepancies within Revision 0 to FSAR Tables 2.3-269 through 2.3-284. In particular, the number of hourly observations reported in these tables (17,533 hours for the 10-meter (33-foot) level and 17,520 hours for the 60-meter (197-foot) level) was considerably less than the 43,842 hours contained in the five-year period 2003-2007. Also, the number of hours reported for each stability category did not total the number of hours reported for all stability categories combined. In its response to RAI 02.03.05-5, dated February 8, 2010 (ADAMS Accession No. ML100960472), the applicant stated that the JFDs in FSAR Tables 2.3-269 through 2.3-284 were incorrect and provided a revised set of tables that were eventually incorporated into Revision 2 to the FSAR. This revised set of tables reported 43,018 hours of data for the 10-meter (33-foot) level and 42,956 hours of data for the 60-meter (197-foot) level. The number of hours reported for each stability category also totaled the number of hours reported for all stability categories. Because the revised set of Tables 2.3-269 through 2.3-284 presented in FSAR Revision 2 addresses the staff’s concerns, RAI 02.03.03-5 is considered to be resolved.

The applicant provided a copy of the original 2001-2007 hourly database to the staff in its response to environmental RAI AQ2.7-3. The staff performed a quality review of this database using the methodology described in NUREG–0917, “Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data,” issued in July 1982. The staff used computer spreadsheets to further review the data. As expected, the staff’s examination of the data revealed generally stable and neutral atmospheric conditions at night and unstable and neutral conditions during the day. Wind speed, wind direction, and stability class frequency distributions for each measurement channel were reasonably similar from year to year.

The staff performed a comparison of stability category frequency distributions (based on the onsite meteorological tower ΔT measurements) between the 1974-1975 period of record reported in the Fermi 2 FSAR Table 2.3-11 and the 2002-2007 period of record reported in Fermi 3 FSAR (Revision 0), Tables 2.3-292 through 2.3-298 and found the following:

Stability Category Frequency Distribution (Values in Percent)

Stability Category	Period of Record	
	1974–1975	**2002–2007**
A (extremely unstable)	9.2	20.1
B (moderately unstable)	2.1	5.4
C (slightly unstable)	2.4	5.2
D (neutral)	30.3	30.7
E (slightly stable)	40.5	24.5
F (moderately stable)	10.3	9.4
G (extremely stable)	5.3	4.6

In its review of the original 2001-2007 hourly ΔT measurements, the staff also found that during the period 2004-2007 there were approximately 420 occurrences per year (on average) when the autoconvective lapse rate of -3.4 °C per 100 meters was exceeded (the autoconvective lapse rate represents severe extremely unstable conditions when the density of the atmosphere increases with height). Many of these hours exceeded a lapse rate of -5.0 °C per 100 meters. Consequently, the staff issued RAI 02.03.03-6 requesting that the applicant explain the almost 11 percent annual increase in A stability occurrences (from 9.2 percent to 20.1 percent) and the almost 16 percent annual decrease in E stability occurrences (from 40.5 percent to 24.5 percent) from 1974-1975 to 2002-2007. The staff also requested the applicant in RAI 02.03.03-6 to explain the relatively frequent occurrence (approximately five percent of the time annually) of autoconvective lapse rate conditions during 2004-2007.

In its response to RAI 02.03.03-6 dated February 8, 2010 (ADAMS Accession No. ML100960472), the applicant stated that it evaluated the atmospheric stability category frequency distribution for each year from 1995 through 2007 in an effort to correlate any possible data inconsistencies with instrumentation replacements or modifications. The applicant found a noticeable decreasing trend in the frequency of neutral (stability category D) conditions with a corresponding trend in increasing frequency of both stable (stability categories E, F, and G) and unstable (stability Category A, B, and C) conditions. The applicant also reviewed stability information from the Detroit Metropolitan Airport for the same time period and found similar trends in stability conditions. The applicant concluded that although it found a trend in the Fermi onsite stability frequencies, no correlations with instrumentation change-outs were evident and the stability classification trend was also verified to be consistent with other local meteorological data.

The applicant also reported in its response to RAI 02.03.03-6 that approximately 3.9 percent of the hourly ΔT measurements for the years 2001 through 2007 exceeded the autoconvective lapse rate. The applicant found that most of these occurrences were at times when the wind direction was onshore from Lake Erie when strong cold advection is affecting the 60-meter (197-foot) tower level more than the 10-meter (33-foot) tower level. This occurs because the lower portion of the onshore flow is heated first by the land surface as it comes ashore.

In its supplemental response to RAI 02.03.04-3 dated March 30, 2010 (ADAMS Accession No. ML100960474), the applicant stated that it performed further reviews of the original 2001-2007 hourly database submitted to the staff in its response to environmental RAI AQ2.7-3. Included in this evaluation was a review of the hourly data for cases when the ΔT measurements exceeded the autoconvective lapse rate. The applicant found that most of the occurrences when the wind direction was not onshore from Lake Erie to be improbable and removed these occurrences from the analysis.

The staff has determined that the Fermi onsite meteorological data trends in decreasing frequency of neutral conditions with corresponding increasing frequencies of both stable and unstable conditions is plausible based on similar data trends observed at the Detroit Metropolitan Airport for the same time period. The staff also finds that the applicant's explanation that autoconvective lapse rate occurs during onshore flows with rapid heating at the surface to be plausible. Consequently, the staff considers RAI 02.03.03-6 to be resolved.

The applicant also stated in its supplemental response to RAI 02.03.04-3 that it performed other data reviews to confirm the validity of the original 2001-2007 Fermi onsite meteorological data submitted in response to environmental RAI AQ2.7-3. The applicant also found 460 occurrences where either the 10-meter (33-foot) or the 60-meter (197-foot) measurements were deemed too improbable because of unreasonable ratios between the 10-meter (33-foot) and 60-meter (197-foot) wind speeds and removed these occurrences from the analysis.

As a result of its review of the Fermi onsite meteorological data discussed above, the applicant proposed numerous changes to the FSAR. Included in these proposed revisions were updates to the JFDs presented in FSAR Tables 2.3-269 through 2.3-284 and Tables 2.3-292 through 2.3-299 and the wind roses presented in FSAR Figures 2.3-230 through 2.3-255. The applicant incorporated these revised tables and figures into Revision 4 of the FSAR.

The applicant also provided a copy of the 1985-1989 Fermi onsite meteorological database in its supplemental response to RAI 02.03.03-1, dated March 30, 2010 (ADAMS Accession No. ML100960472). The applicant stated that aerial photographs of the area surrounding the Fermi meteorological tower in 1981 and 1991 confirm the absence of significant air flow obstructions to wind measurements at the 10 meter (33-foot) elevation. Therefore the applicant presented the 1985-1989 meteorological database as an alternative for performing dispersion analysis in those situations where it is not apparent that lower wind speeds measured at the 10-meter (33-foot) level produce conservative results.

The staff generated a JFD from the 1985-1989 data for comparison with the revised 2002-2007 JFD presented by the applicant in its supplemental response to RAI 02.03.04-3 (ADAMS Accession No. ML100960474). The staff found similar 10-meter (33-foot) and 60-meter (197-foot) wind direction frequency distributions between the two JFDs. However, the staff found that the 1985-1989 JFD had a lower frequency of (1) 10-meter (33-foot) low wind speed conditions (the frequency of winds less than 1.5 meters per second (m/s) increased from 9.1 percent in the 1985-1989 data to 17.0 percent in the 2002-2007 data) and (2) extremely unstable (stability category A) conditions (the frequency of extremely unstable conditions increased from 7.1 percent in the 1985-1989 data to 19.3 percent in the 2002-2007 data). Discrepancies in wind speed and stability class frequency distributions between these two databases create uncertainty as to which meteorological data set (1985-1989 versus 2002-2007) is most representative of long-term site conditions. Given the uncertainty in the data, the staff believes the dispersion analyses presented in FSAR Subsections 2.3.4 and 2.3.5 should be evaluated using both sets of data and the more conservative (bounding) dispersion estimates be used. This topic is discussed in more detail in Sections 2.3.4 and 2.3.5 of this SER.

Site Preparation and Construction, Pre-Operational, and Operational Onsite Meteorological Monitoring Program

FSAR Subsection 2.3.3.2 states that because the NDCT for Fermi Unit 3 will be built in the approximate location of the current (pre-application) onsite meteorological tower, a new meteorological tower will be erected in the southeast corner of the Fermi site. The applicant has made a commitment (COM 2.3-003) in FSAR Subsection 2.3.3.2 that the new tower will be operational for at least one year prior to the decommissioning of the existing onsite meteorological tower.

> **[START COM FSAR-2.3-003]**. The new meteorological tower will be operational for at least one year prior to the decommissioning of the existing onsite meteorological tower. The meteorological data recorded concurrently from the current and new onsite meteorological towers will undergo a detailed analysis to ensure the meteorological parameters measured at the new meteorological tower are representative of the atmospheric conditions at the Fermi site **[END COM FSAR-2.3-003]**.

The meteorological data recorded concurrently from the current (pre-application) and new (operational) onsite meteorological towers will undergo a detailed analysis to ensure the meteorological parameters measured at the new meteorological tower are representative of the atmospheric conditions at the Fermi site.

The proposed operational onsite meteorological monitoring program is described in greater detail in the following sections.

a. Tower and Instrument Siting

The NDCT for Fermi 3 will be built in the approximate location of the current onsite meteorological tower. Thus, the applicant states that a new meteorological tower will be erected in the southeast corner of the Fermi site (approximately 1268 meters (4160 feet)) from the existing meteorological tower) prior to the construction of Fermi 3. The new meteorological tower will be a guyed open-latticed tower that will be 60 meters (197 feet) tall.

FSAR Subsection 2.3.2.2 discusses the possible influence of Fermi 3 and its facilities on the proposed location of the new meteorological tower. That discussion is reviewed here.

Wind flow may be altered immediately adjacent to and downwind of larger site structures, but these effects will likely dissipate within ten structure heights downwind. The applicant states that the large structures associated with the operation of Fermi Unit 3, such as a 182.9-meter (600-foot) tall NDCT, the two multi-cell mechanical-draft cooling towers (MDCTs), and the 48.2-meter (158-foot) tall RB, will influence the airflow trajectories downwind of the new structures. Revision 1 to RG 1.23 states that a meteorological tower should be located at a distance of at least ten times the height of any nearby obstructions (e.g., large structures, trees, and nearby terrain) to avoid airflow modifications by the obstructions. The building wakes from the Fermi 3 RB and MDCTs should not impact the new meteorological tower since the new tower will be located more than ten times the heights of these obstructions downwind.

The ten-building-height distance of separation is typically applied to square or rectangular structures, whereas rounded and sloping structures such as hyperbolic NDCTs can be expected to produce a smaller wake zone. According to the applicant, the NDCT will be built to a height of 182.3 meters (600 feet) above plant grade, the tallest structure at the Fermi site. The NDCT will be hyperbolically shaped with a maximum width at the base of 140.2 meters (460 feet) and will be located at a distance of approximately 1268 meters (4160 feet) northwest of the new meteorological tower.

Section 123 of the Clean Air Act as amended in 1990 defines good engineering practice stack height as the height necessary to ensure that emissions from a stack do not result in excessive concentrations of any air pollutant in the immediate vicinity of a source as a result of atmospheric downwash, eddies, and wakes which may be created by the source itself, by nearby structures, or by nearby terrain obstacles. The EPA defines "nearby structures" in its regulations (40 CFR 51.100(jj)(1)) as that distance up to five times the lesser of the height or the width dimension of a structure; that is, the downwind distance in which a structure is presumed to have a significant influence as a result of downwash, eddies, and wakes extends downwind approximately five times either the height or width (whichever is less) of the structure. The EPA regulatory guidance document for determining good engineering practice stack heights (EPA-450/4-80-023R, June 1985) also states that this area of influence becomes significantly smaller as the height to width ratio of a structure increases. Based on the EPA guidance for this type of structure, which will have a maximum width of 140.2 meters (460 feet), the outermost boundary of influence exerted by the proposed NDCT is estimated to be approximately 701 meters (2300 feet). Since this distance is shorter than the 1268 meters (4160 feet) separation between the proposed NDCT and the new meteorological tower, the staff concludes that the proposed NDCT will not adversely affect measurements made at the new meteorological tower.

The applicant states in FSAR Subsection 2.3.3.2.1 that other structures near the location of the new meteorological tower include a water tower with a height of 44.2 meters (144.9 feet) and a maximum width of approximately 16.2 meters (53.3 feet). The water tower is circular and the tank head is spherical with a sloping surface. Based on the EPA guidance for this type of structure (as discussed above), the outermost boundary of influence exerted by the water tower with a maximum width of 16.2 meters (53.3 feet) is estimated to be approximately 81 meters (266 feet). Since this distance is shorter than the 210.9 meter (692 foot) separation between the water tank and the new meteorological tower, the staff concludes that the water tank will not adversely affect measurements made at the new meteorological tower.

The applicant states that the operational meteorological tower will have meteorological sensors located at the 10-meter (33-foot) and 60-meter (197-foot) elevations to estimate dispersion conditions. Wind sensors will be mounted at a distance equal to at least twice of the longest horizontal dimension of the triangular tower. Temperature sensors will be oriented such that the aspirated temperature shields are either pointed downward or laterally towards the north and the shield inlet is at least 1½ times the tower horizontal width away from the nearest point on the tower.

The applicant states that influence of terrain near the base of the new meteorological tower on temperature measurements is expected to be minimal because the area surrounding the new meteorological tower will not be paved or contain temporary land disturbances such as plowed fields and rock piles. The applicant further states that the tower will be situated in a relatively flat area that will be at a similar elevation as the plant structures. Because the location of the new meteorological tower is wooded and contains trees that would influence wind measurements if left at their current height, the applicant states the trees will be trimmed to a height outwards to a distance that satisfies the ten-obstruction-height distance separation criterion stated in Revision 1 to RG 1.23.

The staff finds that the new meteorological tower will be appropriately located such that it can measure the onshore flow conditions that could affect gaseous effluent releases from Fermi Unit 3. The staff finds the tower location complies with the recommendations provided in Revision 1 to RG 1.23 and is therefore acceptable to the staff.

b. Instrumentation

In FSAR Subsection 2.3.3.2.2, the applicant states that the new meteorological tower instrumentation will consist of wind speed and wind direction sensors at the 10-meter and 60-meter levels, a temperature sensor at the 10-meter (33-foot) level, a ΔT system between the 60-meter (197-foot) and 10-meter (33-foot) levels, and a dew-point temperature sensor at the 10-meter (33-foot) level. A heated tipping bucket precipitation gauge surrounded by a windscreen will be located at ground level at the base of the meteorological tower. External heaters will be installed on the primary wind sensors to minimize data loss during ice storms. Redundant secondary wind and temperature sensors will also be installed at the 10-meter (33-foot) and 60-meter (197-foot) levels. The applicant states the accuracies and thresholds for each sensor on the new meteorological tower will be within the values specified in RG 1.23.

Revision 2 to FSAR Subsection 2.3.3.2.2 states the new meteorological tower will use meteorological instrumentation that matches the manufacturer and model numbers used on the current tower and FSAR Table 2.3-289 provides the accuracies for each meteorological sensor located on the current meteorological tower. Revision 2 to FSAR Table 2.3-289 shows that the system accuracy for the differential temperature instrumentation is ±0.15 degrees °C (± 0.27 degrees F) which exceeds the Revision 1 to RG 1.23 specified accuracy of ±0.1 degrees °C ((± 0.18 degrees F). Consequently, the staff requested the applicant in RAI 02.03.03-9 to justify why the differential temperature instrumentation accuracy for the new meteorological tower that will be erected to support the operational MMP will exceed the Revision 1 to RG 1.23 criterion of ±0.1 degrees °C (± 0.18 degrees F).

In its response to RAI 02.03.03-9 dated January 10, 2011 (ADAMS Accession No. ML110110550), the applicant clarified that the reference to Table 2.3-289 in FSAR Subsection 2.3.3.2.2 was intended to present the accuracies for the current instrumentation and was not intended to imply that these same accuracies would be used for the new meteorological tower instrumentation. The applicant revised Subsection 2.3.3.2.2 in Revision 4 of the FSAR to clarify that the accuracies and thresholds for each sensor on the new meteorological tower will be within the values specified in Revision 1 to RG 1.23. The staff finds this response to be acceptable and considers RAI 02.03.03-9 to be resolved.

The applicant also states that the data recording process planned for the new meteorological tower will mirror the data recording process for the existing (preoperational) meteorological tower. The staff finds this acceptable.

c. Instrument Calibration, Service, and Maintenance

The applicant states the instrumentation, service, and maintenance procedures in place for the existing (pre-application) MMP as described in FSAR Subsections 2.3.3.1.3 and 2.3.3.1.4 will continue for the new MMP. The staff finds this acceptable.

d. Data Reduction, Transmission, Acquisition, and Processing

The applicant states the method of data reduction, transmission, acquisition, and processing described in FSAR Subsections 2.3.3.1.5 and 2.3.3.1.6 for the pre-application monitoring program will be used for the new MMP. The staff finds this acceptable.

The staff requested the applicant in RAI 02.03.03-7**,** in accordance with criteria specified in Section C.8 of RG 1.23, to discuss any provisions that will be in place to obtain representative meteorological data (e.g., wind speed and direction representative of the 10-meter (33-foot) level and an estimate of atmospheric stability) from alternative sources during an emergency, if the site meteorological monitoring system should be unavailable.

The applicant provided a response to RAI 02.03.03-7, dated February 8, 2010 (ADAMS Accession No. ML100960472) in which it was stated that there is sufficient redundancy built into the meteorological measurement system such that only under the most unusual circumstances would data be unavailable. Should any of the parameters required for dose assessment become unavailable, supplementary meteorological data will be available via the corporate computer system. As indicated in Section H, Sections 6 and 7, of the Fermi 3 Emergency Plan, in the unlikely event that both the primary and backup meteorological systems become inoperable during an emergency, Detroit Edison maintains a contract with a vendor to provide pertinent weather and forecast data. In addition, ambient temperature, wind direction, wind speed, and estimated atmospheric stability data will be available by contacting the nearest NWS office.

The staff finds that sufficient provisions are in place for Fermi 3 to obtain representative meteorological data from alternative sources in the event of an emergency when meteorological data from the site are unavailable. The staff considers RAI 02.03.03-7 to be resolved.

The staff's review finds that the applicant has described an onsite meteorological monitoring program and generated a resulting database, which are acceptable and meet the requirements of 10 CFR 100.20 and 100.21 with respect to determining the acceptability of the site.

2.3.3.5 *Post Combined License Activities*

The applicant identifies the following commitment:

- **Commitment (COM 2.3-003)** – The new meteorological tower will be operational for at least one year prior to the decommissioning of the existing onsite meteorological tower. The meteorological data recorded concurrently from the current and new onsite meteorological towers will undergo a detailed analysis to ensure the meteorological parameters measured at the new meteorological tower are representative of the atmospheric conditions at the Fermi site.

Table 2.3-1 of Part 10 of the COLA contains EP inspection, test, analysis, and acceptance criteria (ITAAC). The following EP-ITAAC involve demonstrating that the operational onsite MMP appropriately supports the emergency plan:

- EP Program Element 8.6: The means exists to provide meteorological information, consistent with Appendix 2 of NUREG-0654/FEMA-REP-1, Revision 1. The acceptance criterion is that the means to obtain meteorological information described in Section II.H.7 of the Fermi 3 COLA Emergency Plan are addressed in emergency plan implementing procedures, “Dose Assessment Methodology.”

- EP Program Element 9.3: The means exist to continuously assess the impact of the release of radioactive materials to the environment, accounting for the relationship between effluent monitor readings, and onsite and offsite exposures and contamination for various meteorological conditions. The acceptance criterion is that Emergency Plan implementing procedure, “Dose Assessment Methodology,” and the ODCM calculate the relationship between effluent monitor readings and offsite exposures and contamination for various meteorological conditions.

- EP Program Element 9.4: The means exists to acquire and evaluate meteorological information. The acceptance criteria are (1) the specified meteorological data (i.e., wind speed at 10 meters and 60 meters, wind direction at 10 meters and 60 meters, and ambient air temperature at 10 meters and 60 meters) are available at the control room, technical support center (TSC), and emergency operations facility and (2) the specified meteorological data are transmitted to and received by the offsite NRC center and State of Michigan.

EP and EP-ITAAC are addressed in SER Section 13.3, “Emergency Planning.”

2.3.3.6 *Conclusion*

The NRC staff has reviewed the application and checked the referenced DCD. The staff’s review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 2.3.3 of NUREG–0800, and the applicable NRC regulatory guides. The NRC staff’s review confirms that the applicant has presented and substantiated information pertaining to the onsite MMP and the resulting database. The staff’s review finds that the applicant has established the structure for the onsite MMP and the resulting database, which are acceptable and meet the requirements of 10 CFR 100.20 and 100.21 with respect to determining the acceptability of the site.

The staff concludes that the onsite data also provide an acceptable basis for estimating atmospheric dispersion for design-basis accident and routine releases from the plant. The data meet the requirements of GDC 19, 10 CFR 100.20, 10 CFR 100.21, 10 CFR Part 20, and Appendix I to 10 CFR Part 50. Finally, the equipment for measuring meteorological parameters during the course of accidents is sufficient to reasonably predict atmospheric dispersion of airborne radioactive materials, in accordance with 10 CFR 50.47(b) and Appendix E to 10 CFR Part 50.

The staff's review confirms that the applicant has adequately addressed the COL license information item in accordance with Section 2.3.3 of NUREG–0800.

2.3.4 Short-Term (Accident) Diffusion Estimates

The consequence of a design basis accident in terms of personnel exposure is a function of the atmospheric dispersion conditions at the site of the potential release. Atmospheric dispersion conditions are represented by relative air concentration (χ/Q) values. This FSAR section describes the development of the short-term dispersion estimates that are used to evaluate design basis accident radiological exposures for the EAB, the outer boundary of the LPZ, and the control room.

2.3.4.1 *Introduction*

Section 2.3.4 of the Fermi 3 FSAR addresses the atmospheric dispersion factor (χ/Q or relative concentration) estimates at the EAB, the outer boundary of the LPZ, the control room, and TSC for postulated design-basis accidental radioactive airborne releases. Appendix 2A of the Fermi 3 COL FSAR addresses the use of the ARCON96 atmospheric dispersion model to derive site-specific control room and TSC χ/Q values.

Dispersion estimates from the onsite and/or offsite airborne releases of hazardous materials such as flammable vapor clouds, toxic chemicals, and smoke from fires are reviewed in SER Section 2.2.3.

2.3.4.2 *Summary of Application*

Section 2.3.4 and Appendix 2A of the Fermi 3 COL FSAR, Revision 7, describes the atmospheric dispersion factor (χ/Q or relative concentration) estimates at the EAB, the outer boundary of the LPZ, the control room, and TSC for postulated design-basis accidental radioactive airborne releases. In addition, the applicant provides the following:

<u>*COL Items*</u>

- EF3 COL 2.0-10-A Short-Term Dispersion Estimates for Accidental Atmospheric Releases

  Section 2.3.4 describes the development of the short-term atmospheric dispersion estimates for the EAB, outer boundary of the LPZ and the control room.

- EF3 COL 2A.2-1-A Confirmation of the ESBWR χ/Q Values

  Section 2.3.4 and Appendix 2A describe the development of the short-term atmospheric dispersion estimates for the control room and TSC. Section 2.0 compares the resulting control room and TSC χ/Q values with the corresponding ESBWR DCD site parameter values.

- EF3 COL 2A.2-2-A Confirmation of the Reactor Building χ/Q Values

  Appendix 2A states that the doors and personnel air locks on the east sides of the reactor building and fuel building are administratively controlled to remain closed during movement of irradiated fuel.

2.3.4.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the short-term atmospheric dispersion estimates for accident releases, and the associated acceptance criteria, are in Section 2.3.4 of NUREG–0800. The acceptance criteria for identifying short-term atmospheric dispersion estimates for accident radiological releases are based on meeting the relevant requirements of 10 CFR Parts 52 and 100. The staff considered the following regulatory requirements in reviewing the applicant's discussion of site location and description:

- 10 CFR Part 50, Appendix A, GDC 19, "Control Room," with respect to the meteorological considerations used to evaluate the personnel exposures inside the control room during radiological accident conditions.

- 10 CFR 52.79(a)(1)(vi), with respect to a safety assessment of the site, including consideration of major SSCs of the facility and site meteorology, to evaluate the offsite radiological consequences at the EAB and LPZ.

- 10 CFR 100.21(c)(2), with respect to the atmospheric dispersion characteristics used in the evaluation of EAB and LPZ radiological dose consequences for postulated accidents.

NUREG–0800, Section 2.3.4 specifies that an application meets the above requirements if the application provides the following information:

- A description of the atmospheric dispersion models used to calculate χ/Q values for accidental releases of radioactive materials into the atmosphere.

- Meteorological data used for the evaluation (as inputs to the dispersion models), which represent annual cycles of hourly values of wind direction, wind speed, and atmospheric stability for each mode of accidental release.

- A discussion of atmospheric diffusion parameters, such as lateral and vertical plume spread (σ_y and σ_z), as a function of distance, topography, and atmospheric conditions, should be related to measured meteorological data.

- Hourly cumulative frequency distributions of χ/Q values from the effluent release point(s) to the EAB and LPZ constructed to describe the probabilities that these χ/Q values will be exceeded.

- Atmospheric dispersion factors used for the assessment of consequences related to atmospheric radioactive releases to the control room for design-basis accidents.

- For control room habitability analysis, a site plan drawn to scale showing true North and potential atmospheric accident release pathways, control room intake, and unfiltered in-leakage pathways.

In addition, the short-term atmospheric dispersion estimates for accident radiological releases should be consistent with the appropriate sections from the following RGs:

- RG 1.23, Revision 1, "Meteorological Monitoring Programs for Nuclear Power Plants," provides criteria for an acceptable onsite meteorological measurements program; these data are used as inputs to atmospheric dispersion models.

- RG 1.145, Revision 1, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," presents criteria that characterize atmospheric dispersion conditions and evaluate the consequences of radiological releases to the EAB and LPZ.

- RG 1.194, "Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Nuclear Power Plants," presents criteria that characterize atmospheric dispersion conditions and evaluate the consequences of radiological releases to the control room.

When independently assessing the acceptability of the information presented by the applicant in FSAR Tier 2, Section 2.3.4, the NRC staff applied the same methodologies, models, and techniques cited above.

2.3.4.4 *Technical Evaluation*

The NRC reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information from the applicant regarding short-term atmospheric dispersion estimates for accident releases. The staff followed the procedures described in Section 2.3.4 of NUREG–0800 as part of this review.

<u>*COL Items*</u>

- EF3 COL 2.0-10-A Short-Term Dispersion Estimates for Accidental Atmospheric Releases

  This COL information item states that the applicant supply site-specific information, in accordance with SRP Subsection 2.3.4, to show that the site's meteorological dispersion values as calculated in accordance with RG 1.145 and RG 1.194 and compared to dispersion values in Chapter 15, result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and the applicable portions of SRP Sections 11 and 15.

In response to this COL information item, the applicant describes (1) the atmospheric dispersion models to calculate atmospheric dispersion factors for postulated accidental radioactive airborne releases, (2) the meteorological data and other assumptions used as inputs to atmospheric dispersion models, (3) the derivation of diffusion parameters (σ_y and σ_z), and (4) the determination of conservative χ/Q values used to assess the consequences of postulated design-basis atmospheric radioactive releases to the EAB, LPZ, control room, and TSC.

The NRC reviewed the applicant's resolution to EF3 COL 2.0-10-A related to the determination of conservative χ/Q values used to assess the consequences of postulated design-basis atmospheric radioactive releases to the EAB, LPZ, control room, and TSC in accordance with RGs 1.145 and 1.194. The staff's review of the applicant's offsite (i.e., EAB and LPZ) and onsite (i.e., control room and TSC) meteorological dispersion estimates is discussed later in this subsection.

The staff also reviewed the applicant's atmospheric dispersion values to ensure that they result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15. This review involves demonstrating that the Fermi 3 meteorological dispersion (accidental release) site characteristic values fall within the corresponding ESBWR DCD meteorological dispersion site parameter values. Section 2.0 of the Fermi 3 COL FSAR evaluated whether the Fermi 3 site characteristics fall within the ESBWR DCD site parameter values. A comparison of the ESBWR DCD accidental atmospheric dispersion factors with the Fermi 3 accidental atmospheric dispersion factors is in Fermi 3 COL FSAR, Table 2.0-201. Smaller χ/Q values are associated with a greater dilution capability, resulting in lower radiological doses. When comparing an ESBWR DCD site parameter χ/Q value and a Fermi 3 site characteristic χ/Q value, the Fermi 3 site is acceptable for the ESBWR design if the Fermi 3 site characteristic χ/Q value is smaller than the corresponding ESBWR site parameter χ/Q value. Such a comparison shows that the Fermi 3 site has better dispersion characteristics than the ESBWR reactor design requires.

The staff reviewed this comparison to ensure the applicant appropriately compared the ESBWR DCD site parameter values with the Fermi 3 site characteristics. The staff issued RAI 02.03.04-6, requesting that the applicant justify the values selected as the Fermi 3 RWB unfiltered in-leakage and air intake χ/Q site characteristic values for the control room.

In its response to RAI 02.03.04-6 dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant stated that the Fermi 3 site characteristic values used for comparison with the ESBWR DCD control room RWB unfiltered in-leakage and air intake χ/Q site parameter values are the same values used for the PCCS vent releases. The applicant pointed out that the relevant analysis in the ESBWR DCD that uses χ/Q values from the RWB is the liquid-containing tank failure described in DCD Tier 2, Section 15.3.16. The applicant stated that the ESBWR DCD used the PCCS vent χ/Q values in this analysis because the PCCS vent χ/Q values are assumed to bound any release from the RWB based on distance and direction to the control room receptors. The applicant therefore concludes that its use of the PCCS vent release site characteristic χ/Q values to represent releases from the RWB is consistent with the ESBWR DCD.

The staff reviewed the Fermi 3 RWB site characteristic χ/Q values and confirmed that they are bounded by the Fermi 3 PCCS vent site characteristic χ/Q values. Consequently, the staff finds the use of the PCCS vent release site characteristic χ/Q values to represent releases from the RWB to be conservative and therefore acceptable and considers RAI 02.03.04-6 to be resolved.

Fermi 3 COL FSAR, Table 2.0-201 shows that the Fermi 3 EAB, LPZ, control room, and TSC site characteristic χ/Q values are all less than the corresponding ESBWR DCD site parameter χ/Q values, thereby demonstrating that site meteorological dispersion conditions result in doses less than those stipulated in 10 CFR 52.79(a)(1)(vi) and in the applicable portions of SRP Sections 11 and 15.

- EF3 COL 2A.2-1-A Conformation of the ESBWR χ/Q Values

  This COL information item states that when referencing the ESBWR DCD to confirm that site characteristics at a given site are bounded by the ESBWR DCD site parameter values per 10 CFR 52.79, the COL applicant shall perform ARCON96 determinations for all source/receptor pairs listed in ESBWR DCD Tables 2A-3 and 2A-4 using site-specific meteorological data. The applicant responded to this COL information item by calculating and presenting control room and TSC χ/Q values in FSARs Tables 2.3-301 and 2.3-378 and comparing them to the corresponding ESBWR DCD site parameter values in FSAR Table 2.0 201.

The staff's review of the applicant's resolution to COL Information Item EF3 COL 2A.2-1-A is discussed later in this section.

- EF3 COL 2A.2-2-A Conformation of the Reactor Building χ/Q Values

  This COL information item states that if the χ/Q values for a release from any door on the east sides of the reactor building or fuel building have χ/Q values that would result in doses greater than the bounding dose consequence reported for the fuel handling accident (DCD Tier 2, Table 15.4-4), the affected doors or personnel air locks are administratively controlled to remain closed during movement of irradiated fuel bundles. The applicant responded to this COL information item by stating that the doors and personnel air locks on the east sides of the RB and FB are administratively controlled to remain closed during movement of irradiated fuel.

The NRC staff has reviewed the applicant's resolution to EF3 COL 2A.2-2-A and finds it acceptable because the applicant is going to administratively control the doors on the east sides of the RB and FB to remain closed during the movement of irradiated fuel bundles regardless of the RB or FB χ/Q values.

Offsite Dispersion Estimates

a. Atmospheric Dispersion Model

The applicant used the computer code PAVAN (NUREG/CR–2858, "PAVAN: An Atmospheric Dispersion Program for Evaluating Design-Basis Accidental Releases of Radioactive Materials from Nuclear Power Stations") to estimate χ/Q values at the EAB and at the outer boundary of the LPZ for potential accidental releases of radioactive material. The PAVAN model implements the methodology outlined in RG 1.145.

The PAVAN code estimates χ/Q values for various time-averaged 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 through PAVAN are based on the theoretical assumption that material released into the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all distances for which χ/Q values are calculated.

For each of the 16 downwind direction sectors (N, NNE, NE, ENE, etc.), PAVAN calculates χ/Q values for each combination of wind speed and atmospheric stability at the appropriate downwind distance (i.e., the EAB and the outer boundary of the LPZ). The χ/Q values calculated for each sector are then placed in order from the greatest to the 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 will have a corresponding cumulative frequency equal to the wind direction frequency for that particular sector. PAVAN determines for each sector an upper envelope curve based on the derived data (plotted as χ/Q versus probability of being exceeded), so that no plotted point is above the curve. From this upper envelope, the χ/Q value, which 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 0–2 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 no more than 5.0 percent of the total time. This value is known as the 0–2 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 from the PAVAN output by the user to represent the χ/Q value for the 0–2 hour time interval. Note that this resulting χ/Q value is based on 1-hour averaged data, but it is conservatively assumed to apply for 2 hours.

To determine LPZ χ/Q values for longer time periods (e.g., 0–8 hours, 8–24 hours, 1–4 days, and 4–30 days), PAVAN performs a logarithmic interpolation between the 0–2 hour χ/Q values and the annual average (8,760 hours) χ/Q values for each of the 16 sectors and the overall site. For each time period, the highest among the 16-sector and overall site χ/Q values is identified and becomes the short-term site characteristic χ/Q value for that time period.

b. Release Characteristics and Receptors

The applicant modeled one ground-level release point 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 for a flat terrain site such as Fermi 3. A ground-level release assumption that does not take credit for building wake effects is therefore acceptable to the staff.

Revision 0 to FSAR Subsection 2.3.4.1 stated the EAB and outer boundary of the LPZ are both circles centered at the RB, with radii of 892 m and 4824 m (0.55 mi and 3 mi), respectively. The staff requested the applicant in environmental RAI AQ2.7-5 to describe and justify the methodology used to determine the distances to the EAB and LPZ. It was not apparent to the staff that the applicant followed the guidance in RG 1.145 in determining the distances to the EAB and LPZ. RG 1.145 states that, for ground-level releases through vents or building penetrations, the distances for each of the 16 downwind sectors for the EAB and LPZ χ/Q calculations should be based on the nearest point on the building to the EAB or LPZ within a 45-degree sector centered on the compass direction of interest.

In its response to environmental RAI AQ2.7-5, dated August 25, 2009, the applicant defined an effective (dose calculation) EAB and LPZ for the purposes of determining χ/Q values. The applicant drew a circle from the center of the RB which encompasses all the postulated design basis accident release locations and defined the dose calculation EAB and LPZ as the distance between this circle and the EAB and LPZ, respectively. The resulting distances for the dose calculation EAB and LPZ were 740 m and 4670 m (0.46 mi to 2.9 mi), respectively. The staff found that the applicant's revised approach for calculating distances to the EAB and LPZ acceptable because it follows the guidance of RG 1.145. The applicant also provided the revised PAVAN input and output files in its response to environmental RAI AQ2.7-4 dated September 30, 2009.

The staff subsequently issued RAI 02.03.04-1 requesting that the applicant revise FSAR Section 2.3.4 and Table 2.0-201 to present the higher of either the 0.5 percentile maximum sector or 5 percentile overall site χ/Q values (pursuant to RG 1.145) resulting from the new dose calculation EAB and LPZ distances presented in environmental RAI AQ2.7-5. The applicant provided the requested information in Revision 2 to the FSAR. Therefore, the staff considers RAI 02.03.04-1 to be resolved.

c. Meteorological Data Input

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 2002 through 2007. The wind data were obtained from the 10-meter level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-T) measurements taken between the 60-m (197-ft) and 10-m (33-ft) levels on the onsite meteorological tower.

d. Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145 as a function of atmospheric stability for the PAVAN model runs. The EAB extends over Lake Erie in the east-northeast clockwise to the southeast sectors and outer boundary of the LPZ extends over Lake Erie in the northeast clockwise to the southwest sectors. Subsequently, the staff requested the applicant in RAI 02.03.04-2 to discuss the impact of changes in surface temperature and roughness resulting from over-water trajectories on the resulting offsite short-term atmospheric dispersion estimates. Dispersion parameters obtained over land and classified according to overland stabilities may not be directly applicable over water. The smooth water surface can result in less mechanically generated turbulence than over land, while the air-water temperature difference can either enhance or hinder convective turbulence.

In its response to RAI 02.03.04-2, dated February 8, 2010 (ADAMS Accession No. ML100960472), the applicant stated it did not consider it necessary to specifically account for potential impacts to the atmospheric dispersion factors due to surface temperature and roughness resulting from over-water trajectories. The response to RAI 02.03.04-2 states that the applicant used the default open terrain correction factors provided by the PAVAN atmospheric dispersion model to account for spatial and temporal variations in airflow resulting from recirculation and stagnation effects. The staff notes the PAVAN model only uses the open terrain correction factors in calculating the annual average χ/Q values that are used in the logarithmic interpolation to derive the intermediate time period (0-8 hours, 8-24 hours, 1-4 days, and 4-30 days) LPZ χ/Q values. The open terrain correction factors also do not account for changes in surface temperature and reduced surface roughness resulting from over water trajectories.

The response to RAI 02.03.04-2 also stated that the PAVAN maximum atmospheric dispersion values chosen as site characteristics for comparison with the ESBWR site parameters occurred in the ESE direction over Lake Erie and not over habitable locations. The applicant considers this to be a conservative approach. The staff disagrees in that the EAB and outer boundary of the LPZ are both hypothetical boundaries; it makes no difference in the dose analysis whether these boundaries are over land or over water.

Although the applicant did not specifically account for potential impacts to the atmospheric dispersion factors due to surface temperature and roughness resulting from over-water trajectories, the staff finds that the applicant has presented conservative short-term atmospheric dispersion estimates by using the 2002-2007 JFD. As discussed in the applicant's supplemental response to RAI 02.03.03-1 dated March 30, 2010 (ADAMS Accession No. ML100960474), the potential exists for the 2002-2007 wind speed measurements to be lower than the actual wind speed at the 10-meter elevation. This is especially true for the ESE downwind sector, where the PAVAN maximum atmospheric dispersion values chosen as site characteristics occurred, because the meteorological tower is downwind of the nearby trees in this sector. The use of lower wind speeds at the 10-meter elevation produces higher (more conservative) χ/Q values from the PAVAN model which compensates for potential impacts to the atmospheric dispersion factors resulting from over-water trajectories. Therefore, the staff considers RAI 02.03.04-2 to be resolved.

e. Resulting Relative Concentration Factors

The staff performed an independent evaluation of the applicant's PAVAN results by generating a JFD from the original 2002-2007 hourly onsite meteorological database provided in response to environmental RAI AQ2.7-3 dated October 30, 2009 and rerunning the PAVAN computer code. The staff's JFD was based on the wind speed classes presented in Table 3 of Revision 1 to RG 1.23 (i.e., calm, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0 and > 10.0 meters per second). The staff's results were more conservative (i.e., higher) than those generated by the applicant's PAVAN run. The staff believes its more conservative results were primarily due to the difference in the frequency of calm winds between the applicant's JFD and the staff's JFD. The staff issued RAI 02.03.04-3 requesting that the applicant explain the difference in the number of calm winds presented in FSAR (Revision 0), Tables 2.3-292 through 2.3-299 versus the number of hours of calm winds reported in the 2002-2007 hourly database. The staff also asked the applicant to explain how the calm winds presented in FSAR (Revision 0), Tables 2.3-292 through 2.3-299 were assigned to wind direction sectors for executing PAVAN and justify any deviations from the methodologies presented in RG 1.23 and RG 1.145. RG 1.23 states that the starting threshold for the wind sensors should be less than 0.45 meters per second and RG 1.145 states that wind directions during calm conditions should be assigned in proportion to the directional distribution of non-calm winds with speeds less than 1.5 meters per second.

In its supplemental response to RAI 02.03.04-3, dated March 30, 2010 (ADAMS Accession No. ML100960474), the applicant stated that it performed further reviews of the original 2001-2007 hourly Fermi onsite meteorological database submitted to the staff in its response to environmental RAI AQ2.7-3 and revised the database accordingly. A copy of the revised 2001-2007 database (in RG 1.23 format) was provided as part of the applicant's supplemental response to environmental RAI AQ2.7-3 dated March 30, 2010; a copy of the revised 2002-2007 database (in RG 1.194 format) was also provided as part of the applicant's supplemental response to RAI 02.03.04-4 dated March 30, 2010 (ADAMS Accession No. ML110960474). The applicant used the revised 2002-2007 database to derive a new JFD assuming a wind sensor starting threshold of 0.45 meters per second (one mile per hour) and assigning wind directions during calm conditions consistent with the guidance in RG 1.145. This new JFD was included in the supplemental response to RAI 02.03.04-3 as proposed revisions to FSAR Tables 2.3-292 through 2.3-299. The staff generated its own JFD frequency distribution from the revised 2002-2007 database submitted in the supplemental response to RAI 02.03.04-4 and obtained similar results.

Because the applicant provided a revised JFD and assigned wind directions during calm conditions consistent with the guidance provided in RG 1.145, RAI 02.03.04-3 is considered to be resolved. The applicant incorporated the revised FSAR Tables 2.3-292 through 2.3-299 into Revision 4 of the FSAR.

The applicant reran the PAVAN atmospheric dispersion model for the dose calculation EAB (740 meters) and LPZ (4670 meters) using the revised 2002-2007 JFD distribution and presented the results in a proposed revision to FSAR Section 2.3.4 as part of its supplemental response to RAI 02.03.04-3. The staff independently reran the PAVAN code using a JFD it derived from the revised 2002-2007 database submitted in the supplemental response to RAI 02.03.04-3 and obtained similar results (± 2 percent). The applicant incorporated the revised PAVAN results into Revision 4 of the FSAR.

In its supplemental response to RAI 02.03.04-3 (ADAMS Accession No. ML100960474), the applicant also proposed a revision to FSAR Subsection 2.3.4.2 stating that the meteorological tower is located east of a grove of trees that is situated less than ten times the obstruction height recommended in RG 1.23. The impact of the trees is to reduce the measured wind speed at the 10-meter level for upwind sectors. The proposed FSAR revision further states that the use of lower measured wind speeds provides conservative results for the PAVAN model. In order to test this hypothesis, the staff independently reran the PAVAN model using a JFD derived from the 1985-1989 database submitted in the applicant's supplemental response to RAI 02.03.03-1. The applicant stated that aerial photographs of the area surrounding the Fermi meteorological tower during this time period confirm the absence of significant air flow obstructions to wind measurements at the 10 meter elevation. The staff found that its resulting short-term atmospheric dispersion values using the 1985-1989 JFD were lower (less conservative) than the site characteristic values selected by the applicant using the revised 2002-2007 JFD. The staff therefore concludes that the applicant has selected conservative EAB and LPZ short-term atmospheric dispersion factors as site characteristic values by using the revised 2002-2007 JFD.

Atmospheric Dispersion Factors for On-Site Doses

a. Atmospheric Dispersion Model

The applicant used the computer code ARCON96 (NUREG/CR–6331, "Atmospheric Relative Concentrations in Building Wakes") to estimate χ/Q values at the control room and TSC for potential accidental releases of radioactive material. The ARCON96 model implements the methodology outlined in RG 1.194.

The ARCON96 code estimates χ/Q values for various time-averaged periods ranging from 2 hours to 30 days. The meteorological input to ARCON96 consists of hourly values of wind speed, wind direction, and atmospheric stability class. The χ/Q values calculated through ARCON96 are based on the theoretical assumption that material released into the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the release points and receptors. The diffusion coefficients account for an enhanced dispersion under low wind speed conditions and in building wakes.

The hourly meteorological data are used to calculate hourly relative concentrations. The hourly relative concentrations are then combined to estimate concentrations ranging in duration from 2 hours to 30 days. Cumulative frequency distributions are prepared from the average relative concentrations and the relative concentrations that are exceeded no more than 5 percent of the time for each averaging period are selected.

b. Meteorological Data Input

The meteorological input to ARCON96 used by the applicant consisted of hourly onsite wind speed, wind direction, and atmospheric stability data from two periods of record: 1985 through 1989 and 2001 through 2007. The wind data were obtained from the 10-meter and 60-meter levels of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-T) measurements taken between the 60-meter and 10-meter levels on the onsite meteorological tower.

c. Diffusion Parameters

The diffusion coefficients used in ARCON96 have three components. The first component, the diffusion coefficient, is used in other NRC models such as PAVAN. The other two components are corrections to account for the enhanced dispersion under low wind speed conditions and in building wakes. These components are based on an analysis of diffusion data collected in various building wake diffusion experiments, under a wind range of meteorological conditions. Because the diffusion occurs at short distances within the plant's building complex, the ARCON96 diffusion parameters are not affected by nearby topographic features, such as bodies of water. Therefore, the NRC staff found that the applicant's use of the ARCON96 diffusion parameter assumptions is acceptable.

d. Resulting Relative Concentrations

Appendix 2A to ESBWR DCD, Tier 2 provides the source/receptor inputs required to execute the ARCON96 model using site-specific meteorological data. Included in Appendix 2A is Figure 2A-1 which shows the location of potential atmospheric accident release pathways and the control room and TSC receptors. Note that the Fermi 3 site plan in FSAR Figure 2.1-204 shows that true north is approximately nineteen degrees counter-clockwise from plant north. True north is the basis for the wind direction data recorded by the Fermi 3 onsite meteorological program whereas plant north is the basis for the source/receptor directions presented in Table 2A-4 in Appendix 2A of ESBWR DCD, Tier 2. Therefore, the applicant adjusted the source-to-receptor data presented in ESBWR DCD, Tier 2, Table 2A-4 by nineteen degrees to account for the difference in angle between the ESBWR plant north and the Fermi 3 true north.

The staff attempted to independently confirm the applicant's ARCON96 atmospheric dispersion model results by executing the ARCON96 model using the meteorological data provided in response to environmental RAI AQ2.7-3. Because the meteorological data provided in response to environmental RAI AQ2.7-3 were in a format compatible to Appendix A to RG 1.23, the staff had to convert these data into RG 1.194 format for input into the ARCON96 model. The staff executed the ARCON96 model using its converted meteorological database and obtained ARCON96 results that, in some cases, differed from the applicant's results reported in the FSAR. Subsequently, the staff requested the applicant in RAI 02.03.04-4 to provide in electronic form the meteorological input file and all the output files associated with these ARCON96 computer code runs. These files were necessary for the staff to complete its assessment of the applicant's resulting onsite χ/Q estimates.

The applicant provided the requested information in its supplement response to RAI 02.03.04-4, dated March 30, 2010 (ADAMS Accession No. ML100960474). The supplemental response to RAI 02.03.04-4 provided a revised set of 2001-2007 ARCON96 meteorological input files based on the review of the original 2001-2007 database described in the supplemental response to RAI 02.03.04-3. The supplemental response to RAI 02.03.04-4 also provided a revised set of input and output files associated with rerunning the ARCON96 computer code with the revised 2001-2007 meteorological data. Because the applicant provided the requested files, the staff considers RAI 02.03.04-4 to be resolved.

The staff believes that there were numerous data discrepancies in the applicant's original 2001-2007 RG 1.194 formatted meteorological database that the applicant used to run ARCON96 and that these data discrepancies resulted in the staff obtaining ARCON96 results that were different from the applicant's results. These data discrepancies appear to have been resolved by the applicant with the revised set of ARCON96 input files provided in the applicant's supplemental response to RAI 02.03.04-4. To verify this hypothesis, the staff generated a JFD from the revised 2002-2007 ARCON96 database for comparison with the revised 2002-2007 JFD presented in the applicant's response to RAI 02.03.04-3. The staff found the two JFDs to be similar. The staff also reran the ARCON96 computer code with the revised 2001-2007 ARCON96 database and obtains results that were similar to the applicant's.

In its supplemental responses to RAI 02.03.03-1 and RAI 02.03.04-3, the applicant explains that the meteorological tower is located east of a grove of trees that is situated less than ten times the obstruction height recommended in RG 1.23. The impact of these trees is to reduce the measured wind speed at the 10-meter level for upwind sectors. Because the ARCON96 diffusion coefficients are a function of a low wind speed correction and a building wake correction, the limiting ARCON96 χ/Q values may not occur at the lowest wind speeds. Therefore, the applicant generated control room and TSC χ/Q values using two sets of meteorological data: 1985-1989 and the revised 2001-2007. The applicant concluded that χ/Q values from both data sets are bounded by the corresponding DCD site parameter values. Nonetheless, in its response to RAI 02.03.04-3, the applicant proposed presenting only ARCON96 χ/Q values derived from the revised 2001-2007 meteorological data as control room and TSC site characteristics in the FSAR.

The applicant provided a copy of the 1985-1989 data from the Fermi meteorological tower in its supplemental response to RAI 02.03.03-1. The staff compared these data against the 2001-2007 dataset and found the older dataset had lower frequencies of (1) low wind speed conditions at the 10-meter elevation and (2) extremely unstable (stability class A) conditions. Discrepancies in wind speed and stability class frequency distributions create uncertainty as to which meteorological data set (1985-1989 versus 2001-2007) is most representative of site conditions. Given the uncertainty in the data, the staff requested the applicant in RAI 02.03.04-5 to justify why both sets of control room and TSC atmospheric dispersion factors should not be presented in FSAR Subsection 2.3.4.3 and the more conservative resulting χ/Q values be presented in FSAR Table 2.0-201 as Fermi 3 site characteristic values.

In its response to RAI 02.03.04-5, dated September 2, 2010 (ADAMS Accession No. ML102570700), the applicant agreed to revise FSAR Section 2.3.4.3 to include χ/Q values calculated with both the 1985-1989 data base and the 2001-2007 data base and to include the more conservative results in FSAR Table 2.0-201. The applicant also recalculated the 1985-1989 and 2001-2007 control room and TSC χ/Q values using revised input parameters to the ARCON96 model as specified in Revision 8 of Appendix 2A to ESBWR DCD, Tier 2, Chapter 2. The applicant implemented these proposed changes in Revision 4 of the FSAR. Because the applicant revised the FSAR to include χ/Q values calculated with both the 1985-1989 and 2001-2007 data sets, RAI 02.03.04-5 is considered to be resolved.

Included in the response to RAI 02.03.04-5 were ARCON96 input and output files for both the 1985-1989 and 2001-2007 meteorological data sets. The staff reviewed the applicant's inputs to the ARCON96 code and finds them consistent with the information presented in Appendix 2A of Revision 8 to ESBWR DCD, Tier 2, Chapter 2.

Because the FSAR included χ/Q values calculated with both the 1985-1989 data base and the 2001-2007 data base, the staff accepts the control room and TSC χ/Q values presented by the applicant.

The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(2).

2.3.4.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.3.4.6 *Conclusion*

The NRC staff has reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 2.3.4 of NUREG–0800, and the applicable NRC regulatory guides. The NRC staff's review finds that the applicant has presented and substantiated information regarding short-term atmospheric dispersion estimates for accident releases. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(2). This conclusion is based on the conservative assessments of post-accident atmospheric dispersion conditions that have been made by the applicant and the staff from the applicant's meteorological data and appropriate dispersion models. These atmospheric dispersion estimates are appropriate for the assessment of consequences from radioactive releases for design basis accidents in accordance with 10 CFR 52.79(a)(1)(vi) and GDC 19.

The staff's review confirms that the applicant has adequately addressed the COL license information items in accordance with Section 2.3.4 of NUREG–0800.

2.3.5 Long-Term (Routine) Diffusion Estimates

For a routine release, the concentration of radioactive material in the surrounding region depends on the amount of effluent released, the height of the release, the momentum and buoyancy of the emitted plume, the wind speed, atmospheric stability, airflow patterns of the site, and various effluent removal mechanisms.

2.3.5.1 *Introduction*

Section 2.3.5 of the Fermi 3 FSAR addresses the atmospheric dispersion factor (χ/Q or relative concentration) and atmospheric deposition factor (D/Q or relative deposition) estimates to a distance of 80 kilometers (50 miles) from the plant for releases of radiological effluents to the atmosphere during normal plant operation for annual average release limit calculations and offsite dose estimates. Appendix 2B of the Fermi 3 COL FSAR presents the gaseous effluent release pathway information for each of the three ventilation stacks for use in generating site-specific long-term χ/Q and D/Q values.

2.3.5.2 *Summary of Application*

Subsection 2.3.5 and Appendix 2B of the Fermi 3 COL FSAR, Revision 7 address site-specific information on long-term atmospheric dispersion estimates for routine releases. In addition, in FSAR Section 2.3.5, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-11-A Long-Term Diffusion Estimates

  This COL information item states that the applicant supply site-specific information in accordance with SRP Section 2.3.5; that is, the COL applicant should provide χ/Q and D/Q estimates for calculating concentrations in the air and the amount of material deposited on the ground as a result of routine releases of radiological effluents into the atmosphere during normal plant operation.

2.3.5.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the long-term atmospheric dispersion estimates for routine releases, and the associated acceptance criteria, are in Section 2.3.5 of NUREG–0800. The acceptance criteria are based on meeting the relevant requirements of 10 CFR Parts 20, 50, and 100. The NRC staff considered the following regulatory requirements in reviewing the applicant's discussion of site location and description:

- 10 CFR Part 20, Subpart D, with respect to establishing atmospheric dispersion site characteristics for demonstrating compliance with dose limits for individual members of the public.

- 10 CFR 50.34a and Sections II.B, II.C and II.D of Appendix I of 10 CFR Part 50, with respect to establishing atmospheric dispersion site characteristics for evaluating the numerical guides for design objectives and limiting conditions for operation to meet the requirements that radioactive material in effluents released to unrestricted areas be kept as low as is reasonably achievable.

- 10 CFR 100.21(c)(1), with respect to establishing atmospheric dispersion site characteristics so that radiological effluent release limits associated with normal operation can be met for any individual located offsite.

NUREG–0800, Section 2.3.5 specifies that an application meets the above requirements if the application provides the following information:

- A detailed description of the atmospheric dispersion and deposition models used by the applicant to calculate annual average concentrations in the air and the amount of material deposited as a result of routine releases of radioactive materials into the atmosphere.

- A discussion of atmospheric diffusion parameters, such as a vertical plume spread (σ_z), as a function of distance, topography, and atmospheric conditions.

- Meteorological data summaries (onsite and regional) used as input to the dispersion and deposition models.

- Points of routine release of radioactive material into the atmosphere, including the characteristics (e.g., location and release mode) of each release point.

- The specific location of potential receptors of interest (e.g., nearest vegetable garden, nearest resident, nearest milk animal, and nearest meat cow in each 22½-degree direction sector within a 5-mile [8-kilometer] radius of the site).

- The χ/Q and D/Q values to be used for assessing the consequences of routine airborne radiological releases described in Section 2.3.5.2 of RG 1.206:

  1. Maximum annual average χ/Q values and D/Q values at or beyond the site boundary and at specific locations of potential receptors of interest utilizing appropriate meteorological data for each routine venting location, and

  2. Estimates of annual average χ/Q values and D/Q values for 16 radial sectors to a distance of 50 miles (80 kilometers) from the plant using appropriate meteorological data.

In addition, the long-term atmospheric dispersion estimates for routine releases should be consistent with appropriate sections from the following RGs:

- RG 1.23, provides criteria for an acceptable onsite meteorological measurements program; the program data are used as inputs to atmospheric dispersion models.

- RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," presents criteria for identifying specific receptors of interest.

- RG 1.111, Revision 1, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," provides acceptable methods for characterizing atmospheric transport and diffusion conditions and for evaluating the consequences of routine effluent releases.

- RG 1.112, Revision 1, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," provides criteria for identifying release points and release characteristics.

When independently assessing the acceptability of the information presented by the applicant in FSAR Tier 2, Section 2.3.5, the NRC staff applied the same methodologies, models, and techniques cited above.

2.3.5.4 *Technical Evaluation*

The NRC staff reviewed the application and the applicant's responses to RAIs to verify the accuracy, completeness, and sufficiency of the information regarding long-term atmospheric dispersion estimates for routine releases. The staff followed the procedures described in Section 2.3.5 of NUREG–0800 as part of this review.

COL Item

- EF3 COL 2.0-11-A Long-Term Diffusion Estimates

In FSAR Section 2.3.5, the applicant states:

> For a routine release, the concentration of radioactive material in the surrounding region depends on the amount of effluent released, the height of the release, the momentum and buoyancy of the emitted plume, the wind speed, atmospheric stability, airflow patterns of the site, and various effluent removal mechanisms. Annual average relative concentration, χ/Q, and annual average relative deposition, D/Q, for gaseous effluent routine releases were, therefore, calculated.

In response to this COL information item, the applicant describes the following:

- Atmospheric dispersion models used to calculate concentrations in air and the amount of material deposited as a result of routine releases of radioactive material into the atmosphere

- The characteristics assumed for each release point and the location of potential receptors for dose computations

- Meteorological data and other assumptions used as inputs to the atmospheric dispersion models

- Diffusion parameters (σ_z)

- χ/Q and D/Q values used to assess the consequences of routine airborne radioactive releases

The NRC staff reviewed the applicant's resolution to EF3 COL 2.0-11-A related to supplying site-specific information in accordance with SRP Subsection 2.3.5. The staff's review of the applicant's χ/Q and D/Q estimates for calculating concentrations in the air and the amount of material deposited on the ground as a result of routine releases of radiological effluents into the atmosphere during normal plant operation is described below.

a. Atmospheric Dispersion Model

The applicant used the NRC-sponsored computer code XOQDOQ (described in NUREG/CR-2919, "XOQDOQ Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations") to estimate χ/Q and D/Q values resulting from routine releases. The XOQDOQ model implements the constant mean wind direction model methodology outlined in RG 1.111.

The XOQDOQ model is a straight-line Gaussian plume model based on the theoretical assumption that material released into the atmosphere will be normally distributed (Gaussian) about the plume centerline. In predictions of χ/Q and D/Q values for long time periods (i.e., annual averages), the plume's horizontal distribution is assumed to be evenly distributed within the downwind direction sector (e.g., "sector averaging"). A straight-line trajectory is assumed between the release point and all receptors.

Because geographic features such as hills, valleys, and large bodies of water can potentially influence dispersion and airflow patterns, terrain recirculation factors can be used to adjust the results of a straight-line trajectory model such as XOQDOQ to account for terrain-induced flows, recirculation, or stagnation. In order to account for possible lake breeze and land breeze effects from Lake Erie on the long-term atmospheric dispersion estimates for routine releases, the applicant used default open terrain correction factors from the XOQDOQ dispersion model. This means that all χ/Q and D/Q values out to a distance of one kilometer were multiplied by a factor of four and all χ/Q and D/Q values between one and ten kilometers were multiplied by a factor that deceased logarithmically from four at one kilometer to one at ten kilometers.

The staff has agreed with the applicant that the use of the default XOQDOQ open terrain correction factors conservatively account for possible recirculation due to land-water boundaries at the proposed Fermi 3 site.

b. Release Characteristics and Receptors

The ESBWR standard design employs three ventilation stacks that are routine airborne release points: the RB/FB vent stack, the turbine building (TB) vent stack, and the RWB vent stack. Two of these stacks, the RB/FB vent stack and the TB vent stack, qualify as mix-mode (part-time elevated, part-time ground-level) releases pursuant to RG 1.111 because their release points (52.8 meters and 71.3 meters above finished ground level, respectively) are above the height of adjacent solid structures (i.e., the 52.0-meter high turbine building), but less than two times the height of adjacent solid structures. The third stack, RWB vent stack, qualifies as a ground-level release because its release point (18.2 meters above finished ground level) is below the height of adjacent solid structures.

The applicant executed the XOQDOQ computer code assuming a mix-mode release for both the RB/FB vent stack and the TB vent stack. The RB/FB vent stack was modeled assuming a release height of 52.77 meters, an adjacent FB height of 48.2 meters, an inside vent diameter of 2.4 meters, and an average vent exit velocity of 17.78 meters per second. The TB vent stack was modeled assuming a release height of 71.3 meters, an adjacent turbine building height of 52 meters, an inside vent diameter of 1.95 meters, and an average vent exit velocity of 17.78 meters per second. The applicant also executed the XOQDOQ computer code assuming a ground-level release for the RWB vent stack with an adjacent building height conservatively set equal to zero.

Although the ESBWR standard design has three normal operation release pathways to the atmosphere, the applicant originally used one set of distances to the site boundary and special receptors of interest to model releases from all three pathways in Revision 0 to the FSAR. The locations for the special receptors of interest (i.e., nearest resident, garden, sheep, goat, meat cow, and milk cow) were based on the 2005 through 2007 land use census. The staff requested the applicant in RAI 02.03.05-1 to explain the methodology used to derive the one set of distances to each receptor location. If applicable, the staff asked the applicant to justify not using a “power block envelope” concept that encompasses all the normal operation release pathways for determining the distance to each receptor location.

In its response to RAI 02.03.05-1, dated November 4, 2009 (ADAMS Accession No. ML093130117), the applicant stated that the long-term χ/Q and D/Q values are based on the distance from the RB centerline to the various receptors. The applicant estimated the distances from each of the vent stacks to the site boundary in each direction and found that in many cases the distances from the vent stacks to the various receptors were shorter than the distances from the RB to the same receptors. Nonetheless, the applicant defended the selective use of long-term χ/Q and D/Q values based on the distance from the RB centerline to the various receptors depending on the analysis being performed.

However, in its subsequent responses to RAIs 02.03.05-3 and 02.03.05-4 dated July 26, 2010 (ADAMS Accession No. ML102180224), the applicant provided a revised set of long-term χ/Q and D/Q values to the site boundary and receptors of interest based on the distance from the outer edge of a circle, centered on the RB, which encompasses all possible release points to the receptors. Because the applicant eventually recalculated the long-term χ/Q and D/Q values using a "power block envelope" concept, the staff considers RAI 02.03.05-1 to be resolved.

The applicant added Appendix 2B, "Ventilation Stack Pathway Information for Long-Term χ/Q Values," to Revision 2 of the Fermi 3 FSAR. Table 2B-201 in FSAR Appendix 2B provides gaseous effluent release pathway information for each of the three ventilation stacks. The ventilation stack parameters presented in Revision 2 to FSAR Table 2B-201 reflected the values presented in Revision 7 to ESBWR DCD, Tier 2, Table 2B-1. Several of these parameter values were revised in Revision 7 to the ESBWR DCD. However, the applicant's letter dated November 9, 2010 which was submitted to identify proposed changes to the Fermi 3 COL FSAR to reflect ESBWR DCD Revision 7 and anticipated changes to ESBWR DCD Revision 8 did not identify these changes in FSAR Table 2B-201 ventilation stack parameter values. Consequently, the staff requested the applicant in RAI 02.03.05-5 to revise FSAR Table 2B-201 to reflect the gaseous effluent release pathway information presented in Revision 8 to the ESBWR DCD and revise FSAR Appendix 2B to identify any assumptions used in deriving the Fermi 3 long-term dispersion site characteristic values that differ from the information provided in the revised FSAR Table 2B-201.

In its response to RAI 02.03.05-5, dated January 10, 2011 (ADAMS Accession No. ML110110550), the applicant stated that FSAR Appendix 2B is intended to incorporate the information in ESBWR DCD, Tier 2, Appendix 2B with no site specific changes. Consequently, the applicant updated Revision 4 to FSAR Appendix 2B, including Table 2B-1, to indicate that DCD Tier 2, Appendix 2B is incorporated by reference with no departures or supplements. The staff finds this response acceptable and considers RAI 02.03.05-5 to be resolved.

c. Meteorological Data Input

The applicant originally executing the XOQDOQ model using a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from the 6-year period 2002-2007. The wind data were obtained from the 10-meter level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-T) measurements taken between the 60-meter and 10-meter levels on the onsite meteorological tower.

The supplemental response to RAI 02.03.03-1, dated March 30, 2010 (ADAMS Accession No. ML100960474) states that after a review of wind rose data spanning a period of over 30 years, the applicant concluded that the potential exists for recent wind speed measurements at the 10-meter elevation to be slower than the actual wind speeds at the 10-meter elevation due to trees located in the vicinity of the Fermi meteorological tower. The applicant further concluded that the slower wind speeds measured at the 10-meter elevation during 2002-2007 produces higher (more conservative) long-term χ/Q and D/Q values as compared to faster actual wind speeds at the 10-meter elevation. In its supplemental response to RAI 02.03.04-3, the applicant proposed a revision to FSAR Subsection 2.3.5.2 stating that the meteorological tower is located east of a grove of trees that is situated less than ten times the obstruction height recommended in RG 1.23. The impact of the trees is to reduce the measured wind speed at the 10-meter level for upwind sectors. The proposed FSAR revision further stated that the use of lower measured wind speeds provides conservative results for the XOQDOQ model.

The staff disagreed with the assessment that slower wind speeds at the 10-meter elevation produce higher χ/Q and D/Q values for mixed-mode (part-time ground, part-time elevated) releases. The applicant has modeled the RB/FB vent stack and the TB vent stack as mixed-mode releases pursuant to RG 1.111 because these two stacks are higher than the adjacent buildings. Regulatory position C.2.b of RG 1.111 states that mixed-mode releases can be considered to be elevated releases whenever the plume exit velocity is at least five times the horizontal wind speed at the height of the release. Because the wind speed provided as input to the XOQDOQ dispersion code is measured at 10-meters, the code corrects the 10-meter wind speed to the stack height. Providing faster 10-meter elevation wind speeds as input to the XOQDOQ dispersion code decreases the percent of time the plume is assumed to be an elevated release, potentially resulting in higher χ/Q and D/Q values.

The applicant provided a copy of the 1985-1989 data from the Fermi meteorological tower in its supplemental response to RAI 02.03.04-4, dated March 30, 2010 (ADAMS Accession No. ML100960474). The applicant stated that aerial photographs of the area surrounding the Fermi meteorological tower in 1981 and 1991 confirm the absence of significant air flow obstructions to wind measurements at the 10 meter (33-foot) elevation during this time period. The staff generated a JFD from the 1985-1989 data for comparison with the new 2002-2007 JFD presented by the applicant in its supplemental response to RAI 02.03.04-3. The staff found the 1985-1989 JFD has a lower frequency of (1) slow wind speed conditions (the frequency of wind speeds less than 1.5 meters per second increased from 9.1 percent in the 1985-1989 data to 17.0 percent in the 2002-2007 data) and (2) extremely unstable (stability class A) conditions (the frequency of extremely unstable conditions increased from 7.1 percent in the 1985-1989 data to 19.3 percent in the 2002-2007 data). These discrepancies in wind speed and stability class frequency distributions discussed above create uncertainty as to which meteorological data set (1985-1989 versus 2002-2007) is most representative of long-term site conditions. Given the uncertainty in the data, the staff requested the applicant in RAI 02.03.05-3 to justify why the long-term (routine) χ/Q and D/Q values should not be generated using both meteorological data sets and the more conservative resulting χ/Q and D/Q values be presented in FSAR Section 2.3.5.

In its response to RAI 02.03.05-3, dated July 26, 2010 (ADAMS Accession No. ML102180224), the applicant stated that it reran the XOQDOQ dispersion code using meteorological data from the 1985-1989 time frame to assess the influence of the trees on the χ/Q and D/Q values. The applicant compared the 1985-1989 χ/Q and D/Q values to the XOQDOQ results using the 2002-2007 meteorological data and found that in several cases the 1989-1989 meteorological data provided higher χ/Q and D/Q values than the 2002-2007 meteorological data. The applicant subsequently presented χ/Q and D/Q values from both sets of data in Revision 4 of the FSAR. For this reason, RAI 02.03.05-3 is considered to be resolved.

d. Diffusion Parameters

The applicant initially chose to implement the diffusion parameter assumptions outlined in RG 1.111, as a function of atmospheric stability for the XOQDOQ model runs.

The applicant did not generate estimates for site boundary χ/Q and D/Q values in the east-northeast clockwise through southeast sectors because the site boundary is directly overwater for these sectors. For the same reason, there are no special receptors of interest in these downwind sectors. However, the applicant did generate annual average χ/Q and D/Q values out to a distance of 80 kilometers (50 miles) in all downwind sectors as provided in FSAR Tables 2.3-328 through 2.3-339. These latter set of χ/Q and D/Q values are used by the applicant to generate population dose estimates for the 80 kilometer (50-mile) population in support of the gaseous radwaste system design basis cost benefit evaluation required by 10 CFR Part 50, Appendix I, Section II.D. Because some of these χ/Q and D/Q values represent plume transport over water for significant distances, the staff requested the applicant in RAI 02.03.05-2 to revise the FSAR as necessary to discuss the impact of changes in surface temperature and roughness resulting from over-water trajectories on the resulting long-term atmospheric dispersion and deposition estimates.

In its response to RAI 02.03.05-2, dated February 8, 2010 (ADAMS Accession No. ML093570220), the applicant stated that the majority (approximately 85 percent) of the collective population within 80 kilometers (50 miles) of the site resides in areas where the trajectory would not be over water. Another 13 percent of the collective population within 80 kilometers (50 miles) of the site resides in areas where the trajectory over water is 32 kilometers (20 miles) or less and therefore the deposition rate would not be significantly different than that over land. Less than two percent of the collective population within 80 kilometers (50 miles) resides in areas where the trajectory over water could extend up to the 80-kilometer (50-mile) radius. Therefore the applicant concluded that the potential impact to the collective population would be very small.

The staff reviewed the response to RAI 02.03.05-2 and determined that the question was closed but the issue remained unresolved. The staff subsequently issued RAI 02.03.05-4 stating that it found the response to RAI 02.03.05-2 incomplete. As discussed in the response to RAI 02.03.05-2, the overwater trajectories for the population living within 80 kilometers (50 miles) in the NE, ENE, E, SE, SSE, S and SSW sectors can range from 16 to 80 kilometers (10 to 50 miles). Air trajectories over such extensive water surfaces could affect atmospheric diffusion rates when compared with overland trajectories due to: (1) the generally smoother water surface decreasing the contribution to diffusion by mechanical turbulence and (2) cooler water temperatures (as compared to air temperatures) decreasing the contribution to diffusion from convectional turbulence. The staff asked the applicant to revise FSAR Section 2.3.5 to discuss the impact of changes in surface temperature and roughness resulting from over-water trajectories on the resulting long-term (routine) atmospheric dispersion and deposition estimates.

In its response (ML102180224) to RAI 02.03.05-4 dated July 26, 2010, the applicant stated that air trajectories over large water surfaces could reduce the rate of atmospheric dispersion due to differences in surface roughness and static stability as compared to transport over land. The applicant consequently adjusted the stability class for the direction sectors that are upwind to the water sectors (i.e., SW clockwise to NNE) in the JFDs to the next higher stability class level in order to model the potential decrease in the rate of atmospheric dispersion for over water trajectories; that is, the hours for the upwind sectors originally associated with stability class A were shifted to stability class B, stability class B hours were shifted to stability class C, etc., and the hours in stability class F were added to the hours originally identified in stability class G. The applicant performed this adjustment to both the 1985-1989 JFD and the 2002-2007 JFD and reran the XOQDOQ dispersion model. The applicant subsequently included both sets of revised χ/Q and D/Q values in Revision 4 of the FSAR. The staff considered the stability class adjustment to account for changes in atmospheric dispersion characteristics over water to be reasonable and therefore considers RAI 02.03.05-4 to be resolved.

e. Resulting Relative Concentration and Deposition Factors

FSAR Tables 2.3-307 through 2.3-327 and Tables 2.3-366 through 2.3-377 list the long-term atmospheric dispersion and deposition estimates for the site boundary and special receptors of interest that the applicant derived from the XOQDOQ model. The χ/Q values in these tables reflect several plume radioactive decay and deposition scenarios. Regulatory Position C.3 of RG 1.111 states that radioactive decay and dry deposition should be considered in radiological impact evaluations of potential annual radiation doses to the public that result from routine releases of radioactive materials in gaseous effluents. Regulatory Position C.3.a of RG 1.111 states that an overall half-life of 2.26 days is acceptable for evaluating the radioactive decay of short-lived noble gases, and an overall half-life of 8 days is acceptable for evaluating the radioactive decay for all iodines released into the atmosphere. Definitions for the χ/Q categories listed in the headings of FSAR Tables 2.3-307 through 2.3-327 are as follows:

- No Decay χ/Q values are χ/Q values used to evaluate ground level concentrations of long-lived noble gases, tritium, and carbon-14. The plume is assumed to travel downwind, without undergoing dry deposition or radioactive decay.

- 2.26-Day Decay χ/Q values are χ/Q values used to evaluate ground-level concentrations of short-lived noble gases. The plume is assumed to travel downwind, without undergoing dry deposition, but is decayed, assuming a half-life of 2.26 days, based on the half-life of xenon-133m.

- 8.00-Day Decay χ/Q values are χ/Q values used to evaluate ground level concentrations of radioiodine and particulates. The plume is assumed to travel downwind, with dry deposition, and is decayed, assuming a half-life of 8.00 days based on the half-life of iodine-131.

FSAR Tables 2.3-328 through 2.3-339 and Tables 2.3-366 through 2.3-377 list the applicant's long-term atmospheric dispersion and deposition estimates for all 16 radial sectors from the site boundary to a distance of 80 kilometers (50 miles) from the proposed facility.

The staff performed an independent evaluation of the applicant's XOQDOQ results by executing XOQDOQ with JFDs it generated from the 1985-1989 and 2002-2007 hourly onsite meteorological databases submitted in the supplemental response to RAI 02.03.04-4 and obtaining similar results for the site boundary and special receptors of interest (i.e., most values within ± 10 percent). The applicant presents the higher of either the 1985-1989 or the 2002-2007 χ/Q and D/Q values as site characteristic values in Section 2.0 of the Fermi 3 COL FSAR and used the higher values in its offsite airborne dose evaluation presented in FSAR Section 12.2.2.2. The staff finds the applicant's approach of using the higher (more conservative) of either the 1985-1989 or the 2002-2007 χ/Q and D/Q values in its offsite airborne dose evaluations to be acceptable.

The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(1).

2.3.5.5 *Post Combined License Activities*

There are no post COL activities associated with this FSAR section.

2.3.5.6 *Conclusion*

The NRC staff has reviewed the application and checked the referenced DCD. The staff's review confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. Pursuant to 10 CFR 52.63(a)(5) and 10 CFR Part 52, Appendix E, Section VI.B.1, all nuclear safety issues relating to this section that were incorporated by reference have been resolved.

In addition, the staff compared the information in the COL application to the relevant NRC regulations, the guidance in Section 2.3.5 of NUREG–0800, and the applicable NRC regulatory guides. The NRC staff's review finds that the applicant has presented and substantiated information regarding long-term atmospheric dispersion estimates for routine releases. The staff reviewed the information provided and, for the reasons given above, concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(1). Representative atmospheric dispersion and deposition factors have been calculated for 16 radial sectors from the site boundary to a distance of 50 miles (80 kilometers) as well as for specific locations of potential receptors of interest. The characterization of atmospheric dispersion and deposition conditions are appropriate for the evaluation to demonstrate compliance with the numerical guides for doses contained in 10 CFR Part 20, Subpart D and 10 CFR Part 50, Appendix I.

The staff's review confirms that the applicant has adequately addressed the COL license information item in accordance with Section 2.3.5 of NUREG–0800.

2.4 <u>Hydrology</u>

This section of the SER addresses the Fermi 3 COL FSAR, Revision 7, site-specific hydrological site parameters and site characteristics identified in Chapter 5 of Tier 1 and Chapter 2 of Tier 2 of the ESBWR DCD, Revision 10.

2.4.1 Hydrologic Description

2.4.1.1 *Introduction*

The hydrologic description of the nuclear power plant site includes the interface of the plant with the hydrosphere, hydrological causal mechanisms, surface and groundwater uses, hydrologic data, and alternate conceptual models. The review covers the following specific areas: (1) the interface of the plant with the hydrosphere including descriptions of site location, major hydrological features in the site vicinity, surface water and groundwater related characteristics, and the proposed water supply to the plant; (2) hydrological causal mechanisms that may require special plant design bases or operating limitations with regard to floods and water supply requirements; (3) current and likely future surface and groundwater uses by the plant and water users in the vicinity of the site that may impact safety of the plant; (4) available spatial and temporal data relevant for the site review; (5) alternate conceptual models of the hydrology of the site that reasonably bound hydrological conditions at the site; (6) potential effects of seismic and non-seismic data on the postulated design bases and how they relate to the hydrology in the vicinity of the site and the site region; and (7) any additional information requirements prescribed within the "Contents of Application" sections of the applicable Subparts to 10 CFR Part 52.

2.4.1.2 *Summary of Application*

Subsection 2.4.1 of the Fermi 3 COL FSAR, Revision 7, describes the site from the standpoint of hydrologic considerations and provides topographic and regional maps showing proposed changes to the site's natural drainage features and major hydrological features. In addition, in Section 2.4.1, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-12-A Hydrologic Description

  To address this COL item, the applicant described the site and all safety-related elevations, structures, and systems from the standpoint of hydrologic considerations and provided a topographic map of the site that showed proposed changes to natural drainage features.

  The applicant described the location, size, shape, and other hydrologic characteristics of streams, lakes, and shore regions influencing plant citing. Groundwater environments were not discussed in this section. The applicant stated that there are no known present or future water control structures in the vicinity of or at the site.

  The applicant provided a regional map showing major hydrologic features.

2.4.1.3 *Regulatory Basis*

Guidance relevant to the Commission's regulations for the hydrologic descriptions, and the associated acceptance criteria, are in Section 2.4.1 of NUREG-0800. The staff reviewed Section 2.4.1 of the FSAR for conformance with the applicable regulations and considered the corresponding regulatory guidance.

The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrologic features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 52.79(a)(1)(iii), as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Section 2.4.1:

- Interface of the Plant with the Hydrosphere: The application should provide a description of hydrology in the vicinity of the site and site regions and of how the plant interfaces with the hydrosphere.

- Hydrological Causal Mechanisms: The application should provide a description of hydrological causal mechanisms that affect the safety of the plant.

- Surface and Ground Water Uses: The application should provide a description of surface and ground water uses in the vicinity of the site that affect the safety-related water supply to the plant.

- Data: The application should provide a complete description of all spatial and temporal datasets used by the applicant in support of its conclusions regarding safety of the plant.

- Alternate Conceptual Models: The application should provide a description of alternate conceptual models of site hydrology.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity and of seismic and non-seismic information as they relate to hydrologic description in the vicinity of the proposed plant site and site regions are appropriately taken into account.

The description of hydrologic characteristics should correspond to those of the United States Geological Survey (USGS), Natural Resources Conservation Service (NRCS), U.S. Army Corps of Engineers (USACE), or appropriate State and river basin agencies.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RG 1.27, RG 1.29, "Seismic Design Classification," RG 1.59, "Flood Design Basis for Nuclear Power Plants," as supplemented by best current practices, and RG 1.102, "Flood Protection for Nuclear Power Plants."

2.4.1.4 *Technical Evaluation*

The NRC staff has reviewed Section 2.4.1 of the Fermi 3 COL FSAR, Revision 7. The staff conducted a site visit in accordance with the guidance provided in Section 2.4.1 of NUREG-0800. The staff used information from the site visit, USGS topographic maps, topographic maps of the site provided by the applicant, available references, and independent calculations to verify the hydrologic description provided in Section 2.4.1 of the Fermi 3 FSAR.

<u>*COL Item*</u>

- EF3 COL 2.0-12-A Hydrologic Description

  To address this COL item, the applicant described the site and all safety-related elevations, structures, and systems from the standpoint of hydrologic considerations and provided a topographic map of the site that showed proposed changes to natural drainage features.

  The applicant described the location, size, shape, and other hydrologic characteristics of streams, lakes, and shore regions influencing plant citing. Groundwater environments were not discussed in this section. The applicant stated that there are no known present or future water control structures in the vicinity of or at the site.

  The applicant provided a regional map showing major hydrologic features.

Site and Facilities

The staff has reviewed the information submitted by the applicant related to the hydrological parameters of the site and facilities. Throughout Section 2.4 of the FSAR, the applicant presented the elevations of various plant and flooding features using four different reference datums. The four datums referenced in the Fermi 3 FSAR include: the North American Vertical Datum of 1988 (NAVD 88), the Fermi plant grade datum (plant), the National Geodetic Vertical Datum of 1929 (NGVD 29), and the International Great Lakes Datum of 1985 (IGLD 85). The staff constructed the following table (Table 2.41-1) displaying elevations of important hydrological features in each of the four datums.

Table 2.4.1-1 Key Site Elevations According to Four Datum Systems

Feature	Elevations by Reference Datum (feet)[a]			
	NAVD 88	Plant	IGLD 85	NGVD 29
Current Fermi plant grade	581.8	583.0	581.5	582.4
Planned Fermi 3 plant grade	588.8	590.0	588.5	589.4
Fermi 3 safety structures	589.3	590.5	589.0	589.9
Lake Erie low water datum	569.5	570.7	569.2	570.1
Elevation of water intake pipe	553.3	554.5	553.0	553.9
100-year lake level calculated by the applicant (FSAR Section 2.4.5)	575.1	576.3	574.8	575.7
100-year lake level calculated by FEMA (2000)	578.2	579.4	577.9	578.8
Average elevation of Lake Erie	571.6	572.8	571.3	572.2
Flood elevation from probable maximum precipitation (PMP) at the Fermi 3 site	584.4	585.6	584.1	585.0
Flood elevation from PMP plus snowmelt at the Fermi 3 site	584.8	586.0	584.5	585.4
Applicant's Flooding Alternative I	579.4	580.6	579.1	580.0
Applicant's Flooding Alternative II	579.2	580.4	578.9	579.8
Applicant's Flooding Alternative III	585.4	586.6	585.1	586.0
Applicant's Flooding Alternative III plus snowmelt and PMF on Swan Creek	585.5	586.7	585.2	586.1
Staff's Flooding Alternative III plus snowmelt and Probable Maximum Flood (PMF) on Swan Creek	586.3	587.5	586.0	586.9
[a] To change feet to meters, multiply the values by 0.3048. NAVD = North American Vertical Datum	IGLD = International Great Lakes Datum NGVD = National Geodetic Vertical Datum FEMA = Federal Emergency Management Agency PMF = Probable Maximum Flood			

The staff uses the NAVD 88 coordinate system throughout this document to describe hydrological features. The applicant's information is presented herein using the datum referenced for that feature in the FSAR that was submitted.

Information Submitted by the Applicant

The applicant described the site hydrology, described the principal plant structures and their design elevations, and presented topographic maps showing changes in site drainage patterns between the existing conditions and the final grade.

According to Subsection 2.4.1.1 of the FSAR, the site is located in Monroe County, Michigan, on the west bank of Lake Erie. The Fermi 3 unit is located approximately 0.40 km (0.25 mi) west of the Lake Erie shoreline. The applicant provided a USGS topographic map with the site boundary delineated. The applicant stated that site elevations range from 577 to 600 ft NGVD 29. The majority of the Fermi plant facility, including the Fermi 2 unit, is located at elevation 583.0 ft plant grade datum, and the Fermi 3 unit is located on an area elevated to 590.0 ft plant grade datum, with safety-related facilities at a minimum of 590.5 ft plant grade datum.

The applicant referenced ESBWR DCD Section 1.2 to describe the seven principal plant structures including the RB/FB, Control Building and Fire Water Service Complex as the only seismic Category 1 structures of Fermi 3. The applicant described that Lake Erie is the primary source of makeup water for the Fermi 3 unit. Potable water needs and makeup demineralizer water is supplied by the Frenchtown Township municipal water supply. A new pump house is planned to be constructed to pump water from Lake Erie for Fermi 3, utilizing the intake bay currently used by Fermi 2. Discharge from Fermi 3 is through a new pipe to Lake Erie.

NRC Staff's Technical Evaluation

The NRC staff checked the referenced USGS Stony Point topographic map and found that elevations within the Fermi Property boundary were less than 575 ft to greater than 595 ft NAVD 88. According to NOAA (NOAA, 2009), the average elevation of Lake Erie is 571.6 ft NAVD 88. The applicant submitted elevation maps of the current plant grade as a response to RAI 2.4.1-1 (ADAMS Accession No. ML100830380). The staff used these maps to verify the elevations of the current Fermi plant facility. The staff has verified the applicant's stated plant grade elevation of 581.8 ft NAVD 88.

Also in RAI 2.4.1-1, the staff requested that the applicant provide proof in the form of a letter or other documentation that the Frenchtown Township municipal water supply is available for Fermi 3 potable water needs and makeup demineralizer water. In their response (ADAMS Accession No. ML100830380), the applicant stated that they have confirmed that the Frenchtown Township service and current utility infrastructure is adequate for the additional Fermi 3 water demand (Detroit Edison 2009b). The staff finds this response acceptable.

Hydrosphere

Information Submitted by the Applicant

The applicant described the local and regional hydrology surrounding the Fermi 3 site. Fermi 3 is contained within the Swan Creek Watershed. Swan Creek is a 106 square mile (mi^2) (about 274 km^2) watershed that drains into Lake Erie approximately 1 mi north of the Fermi Site.

The Fermi property is bordered by Lake Erie along its eastern edge. Lake Erie is a part of the Great Lakes Drainage Basin and is the shallowest and warmest of the Great Lakes with a water surface area of 9,910 mi^2 (25,665 km^2). The applicant stated that the drainage area of Lake Erie is approximately 23,400 mi^2 (60,600 km^2) and it has twelve main tributaries. The main tributaries of Lake Erie nearest to the Fermi site are the River Raisin to the south and the Detroit River to the north. The western basin of Lake Erie borders the Fermi property. The western basin of Lake Erie is very shallow basin with an average depth of 24 ft (7.3 m). A rock barrier is present along the eastern edge of the Fermi site at the shoreline to protect the Fermi site against the high water levels of Lake Erie. The rock barrier crest elevation is at 583.0 ft plant grade datum.

The applicant described the Detroit River as "the largest and most important tributary for the western basin of Lake Erie as it provides approximately 80 percent of Lake Erie's water inflow. The applicant provided a short description of the 126 mi^2 (326 km^2) Stony Creek Watershed, as it is adjacent to the Swan Creek Watershed to the south. The River Raisin Watershed has a drainage area of 1,070 mi^2 (2,770 km^2) and is south of the Stony Creek Watershed. The applicant discussed the River Raisin because it impacts "sediment and other water quality characteristics within the western basin of Lake Erie in the vicinity of the Fermi site." The applicant did not discuss the groundwater environment in the vicinity of the site in Section 2.4.1 but provided detailed information in Section 2.4.12 of the FSAR.

As Lake Erie is the primary source of water for the operation of Fermi 3, the applicant stated that Fermi 3 has been designed to operate at full capacity assuming the lowest recorded water level on Lake Erie at the intake pipe for the plant. The elevation of the base of the intake pump is 553 ft IGLD 85, which the applicant said is 10 feet below the lowest lake level for operation of 563.64 IGLD 85, as discussed in Section 2.4.11 of the FSAR. The applicant described the current and past surface water use of Lake Erie, following SRP Section 2.4.1. Tables 2.4-201 through 2.4-204 present water use information for Lake Erie for the years between 1998 and 2004. Tables 2.4-205 through 2.4-208 present water use information for Monroe County for the years between 2000 and 2006. Table 2.4-209 presents the net basin water supply of Lake Erie by month. Using data from the tables presented, the applicant stated that Monroe County, Michigan uses approximately 1.4 percent of the total water supply for Lake Erie.

NRC Staff's Technical Evaluation

The NRC staff could not verify the boundary of the Swan Creek Watershed with the information provided by the applicant. In response to RAI 2.4.1-1, dated September 18, 2008 (ADAMS Accession No. ML082730763) asking for a detailed topographic map of the Swan Creek Watershed, the applicant submitted the USGS Stony Point quadrangle. The staff reviewed this quadrangle. The mouth of Swan Creek is contained in the Stony Point quadrangle, but the majority of the watershed is not in the quadrangle. Adjacent USGS quadrangles, containing the rest of the Swan Creek Watershed include: Flat Rock, Monroe, Estral Beach, Rockwood, Carlton, Ypsilanti East, Belleville, and Maybee. To verify the watershed boundary, the staff requested that the digital elevation model (DEM) for the Swan Creek watershed be submitted. This was requested as RAI 2.4.1-2. The staff delineated the Swan Creek watershed boundary using the information submitted by the applicant. The watershed boundary submitted by the applicant by letter dated September 18, 2008 (ADAMS Accession No. ML082730763,) was found to be slightly larger than the watershed found by the review team. The entire Fermi site was found by the review team to be included in the Swan Creek Watershed and the total watershed area was calculated to be 101 mi^2.

The watershed area of Swan Creek is listed as 100 mi^2 (259 km^2) on the Michigan Department of Environmental Quality (MDEQ) Flood Discharge Request Record for Swan Creek (MDEQ, 2009). The applicant stated that the watershed area is slightly larger (106 mi^2), which makes an analysis of flooding more conservative. The staff verified the watershed area is accurate.

The staff confirmed that the River Raisin is the largest watershed in the vicinity of the site. The staff evaluated flooding levels on the River Raisin to determine if flooding on the River Raisin could impact the Fermi 3 site. The confluence of the River Raisin with Lake Erie is over six miles south of the location of Fermi 3. A Federal Emergency Management Agency (FEMA) report, “Flood Insurance Study Monroe County, Michigan,” (FEMA, 2000) provides flood elevations for the River Raisin approximately three miles inland from the river’s confluence with Lake Erie. The 100-year flood elevation for this location on the River Raisin is estimated to be 583.2 ft NAVD 88 considering ice-jam effects and 580.0 NAVD 88 ft without ice-jam impacts. The flood elevations downstream of this point are assumed to be lower. The elevations of the land surface between Fermi 3 and the River Raisin are up to 599.7 ft NAVD 88. Based on review of the topography of the area and the information contained in the local FEMA report (2000), the staff determined that there is no risk of flooding at Fermi 3 due to flooding on the River Raisin because the topography of the area restricts the flooding of the site from adjacent watersheds.

The Detroit River enters Lake Erie more than 6 miles (9.6 km) north of the Fermi 3 site. The USACE (1998) estimated that the 500-year flood elevation at the mouth of the Detroit River was approximately 578.3 ft NAVD 88. The staff has reviewed the topography and has determined that there is no risk of flooding at Fermi 3 due to flooding on the Detroit River because the plant is located at an elevation of 590.5 and in an adjacent watershed.

The applicant did not discuss substantive groundwater issues in Section 2.4.1 of the FSAR, but did address groundwater fully in Section 2.4.12 of the FSAR. The staff’s review of the information submitted by the applicant is located in Section 2.4.12, below.

SRP Section 2.4.1 states that flood maps should be provided, showing the areas to be inundated by floods of different magnitudes, with all plant structures and components identified on the maps. The staff identified FEMA maps showing the 100-yr and 500-yr flood plains in the vicinity of the site (FEMA, 2000). The applicant submitted the maps in response to an RAI filed for the Environmental Impact Statement, RAI HY2.3.1-10. The staff verified that the submitted maps were from the *Flood Insurance Study, Monroe County* (FEMA, 2000).

The applicant described the current and past surface water use of Lake Erie. The information about water use in the Lake Erie watershed presented in Tables 2.4-201 through 2.4-204 was verified by the staff using annual reports by the Great Lakes Commission (GLC, 1998; GLC, 1999; GLC, 2000; GLC, 2001; GLC, 2002; GLC, 2003; GLC, 2004). The information presented in Table 2.4-205 about water use in Monroe County from 2000-2006 was reviewed by the staff using sector-specific water use reports presented by the MDEQ (http://www.michigan.gov/deq/0,1607,7-135-3313_3684_45331-72931--,00.html). The staff verified the values presented in Table 2.4-205, however, the values presented for water withdrawn for agricultural irrigation in 2001 were not those found on the MDEQ website. According to the MDEQ, the surface water use was 2.27 million gallons per day (Mgd) and the groundwater use was 0.88 Mgd for agricultural irrigation in 2001. The information presented in Tables 2.4-206 through 2.4-208 could not be verified by the staff. The staff could not find the documents referenced in these tables and could not find other documents containing this information. Additionally, the source information presented in Table 2.4-209 was not clear. In RAI 2.4.1-3, dated March 19, 2010 (ADAMS Accession No. ML100830380), the staff requested the applicant to provide the references used to create Tables 2.4-206 through 2.4-208 related to Monroe County water supply and water use. The staff also requested that the data presented in Table 2.4-209 concerning the water supply of Lake Erie be further explained with detailed documentation of how the values in the table were determined. The response submitted by the applicant contained unpublished Monroe County water use data tables obtained from the MDEQ to produce FSAR Tables 2.4-206 through 2.4-208. DTE stated that this information was sent by the MDEQ in response to a request for data. The applicant also explained the derivation of the Lake Erie water balance values presented in Table 2.4-209. DTE downloaded the monthly hydrologic data from the Great Lakes Environmental Research Laboratory (GLERL) website. The applicant also stated that the data from the Detroit River was no longer available through GLERL, but pointed out that the data could be found through a USACE website. The staff downloaded the data from both websites and verified the values presented in Table 2.4-209. The staff therefore finds the response acceptable.

The applicant did not provide an estimate of future likely water use for Lake Erie in the FSAR. A discussion of future groundwater use was presented in Subsection 2.4.12.2.2 of the FSAR with reference to Table 2.4-277, which presents the estimates of future groundwater use by category through the year 2060. The groundwater use data for the year 2000 in FSAR Table 2.4-205 differed, in some instances, from the groundwater use data presented in Table 2.4-227. The staff requested that the applicant provide additional information on the material contained in the different tables as RAI 2.4.1-4, dated March 19, 2010 (ADAMS Accession No. ML100830380). The applicant responded with a detailed table comparing the sources of information for each category of groundwater use in Monroe County. The applicant selected the most conservative (largest) estimate of water use from all of the referenced sources to perform estimates of future water use. The staff finds this approach acceptable. In the response (ADAMS Accession No. ML100830380, dated March 19, 2010) to RAI 2.4.1-4, the applicant also provided the website address of the data that was used in the tables. The staff downloaded the groundwater use data and verified the values used in the tables. The staff finds the response to RAI 2.4.1-4 acceptable.

The applicant did not describe all of the datasets used in support of its conclusions regarding safety of the plant in this section, as called for in SRP Section 2.4.1. Datasets were described instead in FSAR Section 2.4.2. Lake Erie data was obtained by the applicant from the GLERL. The applicant provided this dataset electronically to the staff in response to RAI 2.4.5-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). Verification of this dataset by the staff is discussed in Section 2.4.5 below.

Alternate conceptual models of site hydrology are provided in Section 2.4.12 of the FSAR and are discussed below in Section 2.4.12 of this SER.

For the reasons given above, the staff concludes that the identification and consideration of the hydrology in the vicinity of the site and site regions are acceptable and meet the requirements of

10 CFR Part 50, 10 CFR 52.79, and 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

2.4.1.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.1.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.1 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed EF3 COL Item 2.0-12-A as it relates to the hydrologic description.

As set forth above, the applicant has presented and substantiated information relative to the hydrologic description in the vicinity of the site and site regions important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concluded that the identification and consideration of the hydrology in the vicinity of the site and site regions are acceptable and meet the requirements of 10 CFR Part 50, 10 CFR 52.79, and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff has accepted the methodologies used to determine the hydrologic description in the vicinity of the site and site regions reflected in site characteristics documented in the SER. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing sufficient margins for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concluded that the identified site characteristics meet the requirements of 10 CFR 52.79 and 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.2 <u>Floods</u>

2.4.2.1 *Introduction*

This subsection discusses the historical flooding at the proposed site or in the region of the site. The information summarizes and identifies the individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The discussion also covers the potential effects of local intense precipitation. The flood history and the potential for flooding are reviewed for the sources and events listed below. Factors affecting potential runoff (such as urbanization, forest fire, changes in agricultural use, erosion, and sediment deposition) are considered in the review. In addition to describing flood history, this subsection also determines the local intense precipitation on the site to estimate local flooding. Local intense precipitation is reported as a site characteristic used in site grading design.

2.4.2.2 *Summary of Application*

Section 2.4.2 of the Fermi 3 COL FSAR, Revision 7, addresses site-specific information on flood history at the Fermi 3 site. In addition, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-13-A Floods

  To address this COL item, the applicant discussed the flood potential from streams, reservoirs, adjacent watersheds, and site drainage and described the effects of local PMP on site drainage systems, including drainage from the roofs of structures. Additionally, the applicant provided a discussion of the effects of snow accumulation on site facilities where such accumulation could coincide with local probable maximum (winter) precipitation and cause flooding or other damage to safety-related facilities.

2.4.2.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the floods, and the associated acceptance criteria, are in Section 2.4.2 of NUREG–0800. The applicable regulatory requirements for identifying floods are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 52.79(a)(1)(iii), as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.2:

Local Flooding on the Site and Drainage Design: The application should include an estimate of local intense precipitation or local PMP and a determination of the capacity of site drainage facilities (including drainage from the roofs of buildings and site ponding).

- Stream Flooding: The application should include documentation of the potential sources of flood and flood response characteristics.

- Surges: The application should include the complete history of storm surges in the vicinity of the site.

- Seiches: The application should include the complete history of seiches in the vicinity of the site.

- Tsunami: The application should include the complete history of tsunami in the vicinity of the site.

- Seismically Induced Dam Failures (or Breaches): The application should include the flooding hazard at the plant site resulting from seismically induced dam failure upstream of the site location.

- Flooding Caused by Landslides: The application should include the flooding hazard at the plant site from flood waves induced by landslides and backwater effects due to stream blockage from landslides.

- Effects of Ice Formation in Water Bodies: The application should include information concerning potential flooding at the plant site due to flood waves resulting from the collapse of an ice dam or backwater effects due to stream blockage due to an ice dam or an ice jam downstream of the plant site.

- Combined Events Criteria: The application should include information concerning design basis flooding at the plant site, including consideration of appropriate combinations of individual flooding mechanisms in addition to the most severe effects from individual mechanisms themselves.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity, seismic, and non-seismic information as they relate to hydrologic description in the vicinity of the proposed plant site and site regions are appropriately taken into account.

In addition, the hydrologic characteristics should be consistent with appropriate sections in: RGs 1.27, 1.29, 1.59, as supplemented by best current practices and in RG 1.102.

2.4.2.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.4.2 of the Fermi 3 COL FSAR, Revision 7, related to flood history, flood design, and the effects of the PMP as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-13-A Floods

  Based on a review of the Fermi Unit 3 site grading plan and the FSAR, the design plant grade elevation is 588.8 ft NAVD 88, with the safety features planned at an elevation of 589.3 ft NAVD 88. The design plant grade is approximately 3.4 ft above the maximum flood level at the site calculated in the FSAR resulting from a probable maximum surge and seiche on Lake Erie corresponding with the 100-year lake level and coincident wave action (elevation 585.4 ft NAVD 88).

The NRC staff's evaluation of COL Item EF3 COL 2.0-13-A is presented below.

Flood History

<u>*Information Submitted by Applicant*</u>

The applicant stated that "Lake Erie is the primary surface-water body to potentially impact Fermi 3." Historical floods on Lake Erie were discussed in Subsection 2.4.2.1 of the FSAR.

The applicant states that Lake Erie water level data is available from 1860 to the present. The response to RAI 2.4.5-1, dated September 30, 2009 (ADAMS Accession No. ML092790561) provided additional explanation of the values presented in Table 2.4-210. Table 2.4-210 of the FSAR provides maximum and minimum water levels recorded at the Fermi Power Plant gaging station on Lake Erie from 1970 through 2007. The applicant also described storm events, some with winds gusting higher than 62 mph that caused peak water levels near the Fermi Site. Peak water levels, up to 0.5 ft above the values in Table 2.4-210, were also presented in this section of the FSAR.

The applicant presented peak flow rates for Swan Creek referencing an MDEQ website as the source of the information. The applicant also provides descriptions of and peak flow rates for the adjacent Stony Creek, the River Raisin, and the Detroit River.

NRC Staff's Technical Evaluation

RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561) included a request for records of water levels for Lake Erie from 1860 to present. The historical records prior to 1970 were not provided or discussed in the FSAR. In the response to RAI 2.4.2-1 (ADAMS Accession No. ML092790561, dated September 30, 2009), the applicant provided a table of average monthly water level observations for Lake Erie from 1918 to 2007 downloaded from the USACE website. The staff verified the data presented in the table by checking the referenced USACE website. The applicant compared the average monthly water levels from 1970 through 2007 to the water levels observed over the entire period of record, and found that the period from 1970 through 2007 included the highest water levels from this dataset. The averages of the monthly water levels for the period from 1970 through 2007 were also higher than the averages for the entire period of record, 1918 through 2007. The staff checked the referenced data and confirmed the conclusion that the period between 1970 and 2007 represents a conservative period to evaluate characteristic water levels for Lake Erie.

The staff requested an explanation of the values presented in Table 2.4-210 in RAI 2.4.5-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). The applicant responded that the values represent the maximum and minimum hourly observations of water levels on Lake Erie measured each year at the Fermi Site gage (ID 9063090). The applicant also submitted the hourly water level observations at the Fermi Site gage (in addition to 12 other Lake Erie gages) between 1966 and 2007. This data for the Fermi Site gage (ID 9063090) was submitted to the NRC staff in Microsoft Excel format as a response to RAI 2.4.5-1 requesting data used to develop the 100-year water level for Lake Erie. The staff used this data to verify the information presented in the Table 2.4-210. The staff found that the values presented in Table 2.4-210 did not correspond in to the yearly maximum or minimum values of the hourly observations presented in the Microsoft Excel file for the years between 1970 and 1996 (e.g., 1987 maximum lake level in the excel file is 576.04 ft IGLD 85 not 574.39 IGLD 85 as presented in Table 2.4-210). The values of maximum and minimum water elevations presented in the table for the years from 1997 to 2007 correspond with the data contained in the Microsoft Excel file. The staff requested further explanation of the values presented in Table 2.4-210 in RAI 2.4.5-9, dated May 7, 2010 (ADAMS Accession No. ML101320136). An updated table was submitted as part of the response to RAI 2.4.5-9, correcting the values in Table 2.4-210 for the years 1970 through 1996 to be the yearly maximum or minimum values of the hourly lake level data. The staff finds the response acceptable.

To verify the information presented about flow in Swan Creek, the staff performed a search of USGS gaging stations. The staff identified measurements taken from 12 locations in the upper watershed of Swan Creek, but data were limited to between one and four measurements per site. Data for 12 of the periods between 1971 and 1991 but could not be used to describe peak flows on the watershed. The data were also insufficient to describe statistically the properties of the discharge from the Swan Creek Watersheds. Therefore, staff reviewed the Monroe County FEMA report, which provided estimates of the 10, 2, 1, 0.5 and 0.2 percent Swan Creek peak flow rates based on data available for the other streams in the region (FEMA, 2000). The applicant reports these flow rates in the FSAR and references a MDEQ webpage as the source. However, in the response to RAI 2.4.3-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant referenced the FEMA report for the peak flow data which is a more accurate representation of the source of the data. Peak flow rates are also presented for the adjacent Stony Creek watershed and the largest watershed in the region, River Raisin.

Flood Design Considerations

<u>*Information Submitted by the Applicant*</u>

The applicant discussed the analysis and results of combined events in general in Subsection 2.4.2.2 of the FSAR and in detail in Subsection 2.4.3.3 of the FSAR. The applicant stated in Subsection 2.4.2.2 of the FSAR that the flooding possibilities applicable to the Fermi site include: the local PMP runoff, the PMF of streams and rivers, probable maximum surge and seiche flooding, and flooding due to ice effects. However, the applicant did not consider flooding due to ice effects on Swan Creek. In Subsection 2.4.3 of the FSAR, the applicant stated that snowmelt and ice effects are of minimal impact “due to the relatively flat topography of the area, seasonal Lake Erie water level data, and the historical climatology of the region.”

The applicant submitted a revised analysis of the PMF including snowmelt runoff at both the local Fermi 3 site and within the Swan Creek Watershed with the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). This analysis revised the flood information previously submitted by the applicant and is discussed further in Subsections 2.4.2.3 and 2.4.3.3, herein.

The three alternative flooding combinations considered by the applicant follow the guidelines of the *American National Standard for Determining Design Basis Flooding at Power Reactor Sites, ANSI/ANS-2.8-1992* (American Nuclear Society, 1992). Each of the alternatives considered has three stated combinations of events that could cause the highest flood level at the site. Alternative I included: 1) one-half PMF or 500-year flood, whichever is less; 2) surge and seiche from the worst regional hurricane or windstorm with wind wave activity; and 3) 100-year or maximum controlled level of water body, whichever is less. Alternative II examined: 1) the PMF within the Swan Creek Watershed; 2) 25-year surge and seiche with wind wave activity; and 3) 100-year or maximum controlled level of water body, whichever is less. Finally, Alternative III considered: 1) 25-year flood within the Swan Creek Watershed; 2) probable maximum surge and seiche with wind wave activity; and 3) 100-year or maximum controlled level of water body, whichever is less.

The applicant states that the most severe flooding combination of events results from a potential high surge from Lake Erie as considered in Alternative III. DCD Tier 1, Chapter 5, Table 5.1-1 requires that the maximum flood level be 1.0 ft below the design plant grade elevation. Based on a review of the Fermi 3 grading plan, the design plant grade elevation is 589.3 ft NAVD 88. The DCD maximum flood level corresponds to an elevation of 588.3 ft NAVD 88. The flood level calculated by the applicant for Alternative III is at 585.4 ft NAVD 88. The applicant also submitted a revised calculation of the PMF in the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561) that considers 1) the PMF on Swan Creek, 2) probable maximum snowmelt, 3) probable maximum surge and seiche on Lake Erie, and 4) 100-year elevation of Lake Erie. The flood level calculated by the applicant for this scenario is 585.5 ft NAVD 88, making it the highest elevation flood calculated for the site.

NRC Staff's Technical Evaluation

The NRC staff reviewed the application and verified information discussed in this section.

The staff checked the referenced ANSI/ANS-2.8-1992 guidelines to determine if the applicant's combinations meet the standards. The standards that the applicant referenced are for a *Streamside Location* (Section 9.2.3.2 of ANSI/ANS-2.8-1992). The staff verified that the applicant used the guidance properly in the determination of the highest possible flood level at a streamside location. The ANSI/ANS-2.8-1992 guidelines also include specifications for calculating floods at shoreline locations. The guidance suggests that floods may result from 1) the probable maximum surge and seiche and 2) the 100-year lake level. These floods were considered by the applicant as a part of Alternative III.

In order to verify the analysis and Alternative III, the staff independently calculated a maximum flood level at the site resulting from 25-year flood on Swan Creek, 100-year FEMA flood level on Lake Erie, and maximum surge on Lake Erie to be 585.4 ft NAVD 88, as discussed below. This provides additional assurance that the combination of events was correctly addressed in the application.

ANSI/ANS-2.8-1992 also provides guidance on determining the largest possible precipitation flood at the plant site. Three alternatives are provided that could produce the worst flooding at the site. Alternative I combines 1) mean monthly (base) flow; 2) median soil moisture; 3) antecedent (or subsequent) rain equal to 40 percent of the PMP or 500-year rain, whichever is less; 4) the PMP; and 5) the 2-year wind speed applied in the critical direction. Alternative II includes 1) mean monthly (base) flow; 2) probable maximum snowpack; 3) coincident snow season PMP; and 4) the 2-year wind speed applied in the critical direction. Alternative III combines 1) mean monthly (base) flow; 2) 100-year snowpack; 3) coincident snow season PMP; and 4) 2-year wind speed applied in the critical direction.

The staff compared the applicant's analysis of plant site flooding against the three Alternatives presented in ANSI/ANS-2.8-1992. The applicant calculated a combination of Alternatives II and III in response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). The applicant calculated the flood resulting from 1) the probable maximum snowpack, 2) the PMP, and 3) the 2-year wind speed. The applicant also assumed that the temperature was equal to the 100-year recurrence dew point temperature for April, 69.1 degrees Fahrenheit. The staff considers this to be a conservative assumption for the snowmelt calculation. The flood elevation associated with this combination of events was determined by the staff to be 584.8 ft NAVD 88, the same value as calculated by the applicant. The staff considers the applicant's analysis to be conservative as the PMP and the probable maximum snowmelt are considered in the same case.

Based on a review of the DCD, staff confirms that regulatory treatment of non-safety system (RTNSS) structures that meet Criterion B (i.e., for actions required beyond 72 hours and seismic events) are required to perform reliably in the event of hazards such as external flooding considering the PMF, PMP, seiche and other pertinent hydrologic factors. Staff performed a detailed review of all RTNSS features in Chapter 19 of this SER and Chapter 22 of the ESBWR FSER.

Effects of Local Intense Precipitation

Information Submitted by the Applicant

The applicant discussed the existing drainage patterns on the site shown on Figure 2.4-214 of the FSAR. Of the six areas described to handle existing storm discharge only one, the drainage outfall pipe, is called out on Figure 2.4-214. The remaining outlets were not called out on the map.

A map showing the final grade drainage areas and patterns was provided in the FSAR as Figure 2.4-215. The drainage area for the Fermi 3 final grade is less than 1 mi^2. The applicant described the runoff from the Fermi 3 final grade as primarily flowing into onsite drop inlets that discharge to the outfall pipe that drains into an overflow canal which then enters the North Lagoon. The applicant stated that the storm water may also "possibly flow toward two lagoons (North Lagoon and South Lagoon)." Flow from the North Lagoon reportedly flows to Swan Creek and flow from the South Lagoon flows directly to Lake Erie. A map showing the drainage of the Fermi 3 final grade assuming that all onsite drop inlets and drains blocked was provided in the FSAR as Figure 2.4-217.

The applicant calculated the discharge from the existing site sub-basins that are shown on Figure 2.4-214. Table 2.4-212 presents the discharge from the 22 sub-basins for the 10, 25, 50, and 100-year recurrence intervals. Table 2.4-213 presents the discharge from the sub-basins on final grade of the Fermi 3 (shown in Figure 2.4-215) for the 10, 25, 50, and 100-year recurrence intervals. An updated version of Table 2.4-213 was included with the response to RAI 2.4.2-1. The applicant used the rational method to calculate the runoff amounts for both the existing and final grade sub-basins. Table 2.4-214 presents total discharges for the 10, 25, 50, and 100-year recurrence intervals for both the existing condition and the final grade. An updated version of Table 2.4-214 was also presented with the response to RAI 2.4.2-1. The applicant compared the runoff from the existing condition to the final grade and estimated that runoff would be increased by 44 percent for the 10-year storm for the final grade and 88 percent for the 100-year storm.

The applicant calculated the PMF at the site using the rational method to determine peak runoff rates from the PMP. The applicant calculated the PMP for a 1 mi^2 area using the methods outlined in NOAA Hydro-Meteorological Report (HMR) 51 and HMR-52, as clarified by RAI 2.4.2-2, dated November 20, 2009 (ADAMS Accession No. ML092750405). The calculated PMP depths for storms lasting 12 hours or less are presented in Table 2.4-211. The investigated PMP is 69.6 inches per hour, which is the intensity that lasts for duration of 5 minutes. As a basis for selecting the 5-minute PMP duration, the applicant stated that this duration is shorter than the time of concentration and provides a more conservative estimate of runoff using the rational method. Time of concentration values for each of the final grade sub-basin areas are presented in Table 2.4-213.

In response to RAI 2.4.2-1, the applicant described calculation of the time of concentration for each of the individual Fermi 3 sub-basins, provided the equations used to calculate time of concentration, and presented a table with input values used in the equations. The equations used to calculate the time of concentration were from the USDA's *Urban Hydrology for Small Watershed, Technical Release 55* (TR-55) (USDA, 1986).

The applicant used the rational method to determine PMF from the PMP assuming all the storm drains at the site were blocked. The runoff coefficient was conservatively set to 1.0 representing completely impervious soil/concrete or saturated antecedent conditions. The applicant assumed the area of runoff included the Fermi 3 nuclear island, an area where the SSCs are located (18.1 acres) plus the area located to the southwest, termed N3 in the FSAR (see Figure 2.4-217 of the FSAR). This area is approximately 25.96 acres and is assumed to contribute to the site runoff because there may be backwater effects from this area to prevent water from draining from the Fermi 3 nuclear island.

The applicant calculated a peak flow of 3,066 cubic feet per second (cfs) resulting from the PMP over Fermi 3 safety-related area of 18.09 acres and the adjacent drainage area to the west and south of the Fermi 3 nuclear island of 25.96 acres, for a total of 44.05 acres. The adjacent area was included to address the effects of a backwater scenario due to the water running off the steeper sides of the nuclear island with the safety structures and onto the lesser sloped adjacent area. For this scenario, the runoff was assumed to drain off the slopes of the Fermi 3 final grade because the storm drains at the site are assumed to be blocked.

The applicant then used Manning's equation to predict a runoff depth of 2.55 ft resulting from the peak flow rate of 3,066 cfs. The applicant assumed a channel width of 75 ft, vertical sides, a slope of 0.006 ft/ft (the slope of the area adjacent to the Fermi 3 nuclear island), and a roughness coefficient of 0.013.

In response to a subsection of RAI 2.4.2-1, the applicant conducted an analysis of the impact of snowmelt in addition to the PMF at the site. The applicant revised the analysis to address snow pack and assumed an initial snowpack covering the entire site with no significant variation in snow temperature or snow depth. The applicant then calculated snowmelt as a function of wind velocity, rainfall rate, air temperature, and a wind coefficient using equation 5-19 presented in the USACE document, *Runoff from Snowmelt* (USACE, 1998). The applicant assumed the PMP rain on snow event would occur in April, as relatively high temperatures occurred historically after freezing during the month of April. The applicant used the observed dew point temperatures as representative of air temperature during a PMP rain on snow event. The wind velocity and temperature were derived from historical data from the Detroit Metropolitan Airport meteorological station. The applicant analyzed 34 years of data (1961-1995) for the month of April to determine the 2-year occurrence wind speed, 32.5 mph, and the 100-year occurrence dew point temperature, 69.1 degrees Fahrenheit. The applicant selected the highest hourly dew point temperature and the highest hourly wind speed from each April on record. The applicant stated an extreme frequency analysis was done with the resultant data, but did not describe the methodology taken to determine the values. The applicant assumed these values were constant through the entire storm.

For the 5-minute storm duration, the applicant calculated the snowmelt to be 1.54 inches. This runoff from snowmelt was then added on to the 5-minute precipitation value of 69.6 inches/hour, to produce an equivalent rainfall intensity of 88.1 inches/hour. The rational method was used to calculate a PMF runoff of 3,880 cfs from the 44.05 acre area including the Fermi nuclear island and the area to the south and west of the island. Using the same assumptions about the channel, the applicant used Manning's equation to calculate a flow depth of 2.97 ft resulting from the runoff.

RAI 2.4.2-1 requested information related to the potential erosion of the slopes of the Fermi 3 site. The applicant's response stated that erosion protection measures such as mulching, seeding, sodding, and other will be incorporated in the design of the slopes. The applicant stated that erosion protection measures will be taken following guidelines in *The Guidebook of Best Management Practices for Michigan Watersheds* (MDEQ, 1998). The applicant also stated that very little runoff is expected to occur on the slopes. The runoff from the Fermi 3 nuclear island will be routed to a stormwater collection system, so the only expected runoff on the slopes is what results from direct precipitation onto the slopes. The applicant stated that this runoff will be at low velocities and therefore will not cause erosion.

The applicant has made a commitment (COM 2.4-002) in FSAR Subsection 2.4.2.2 stating that a detailed design will incorporate best industry practices included in "The Guidebook of Best Management Practices for Michigan Watersheds

> **[START COM FSAR-2.4-002]** Detailed design will incorporate best industry practices included in "The Guidebook of Best Management Practices for Michigan Watersheds" to provide added erosion protection to the slopes, even though they are receiving very little runoff. These practices include mulching, seeding, sodding, soil management, trees, shrubs, and ground covers. To be conservative, erosion protection methods selected will be based on runoff velocities for a local PMP condition not taking credit for the storm water drains. Where necessary, erosion protection will be provided for breaking waves during a postulated surge/seiche event. **[END COM FSAR-2.4-002]**

NRC Staff's Technical Evaluation

The NRC staff reviewed the information submitted by the applicant concerning the flooding caused by the PMP at the site and verified that information by comparing it to results using the rational method. RAI 2.4.2-1 requested significant additional information about the calculation of the PMP and the local runoff resulting from the PMP. The staff verified from the literature that the 5-minute PMP duration provides a more conservative estimate of runoff using the rational method (Pilgrim and Cordery, 1993). The time of concentration is a key parameter in completing the rational method and is the time it takes for flow to travel from the top of the watershed to the downstream end where flow is measured (Lettenmaier and Wood, 1993). The staff checked the TR-55 reference and confirmed that the equations from TR-55 were appropriate to calculate the time of concentration. The staff also checked the values presented for input into the equations and confirmed the values were appropriate (USDA, 1986; US Weather Bureau, 1961; Engman, 1986). The staff independently confirmed that the time of concentration values presented in Table 2.4-213 were correct. Thus, the staff verified the applicant's calculation of time of concentration, as presented in the response to RAI 2.4.2-1, to be acceptable.

The staff independently developed rainfall intensities. First, the staff independently determined the 60-minute, 1 mi^2 PMP to be 17.3 inches from Figure 24 in HMR-52 (NOAA, 1982). The 5-minute, 1 mi^2 PMP was determined independently by the staff to be 5.8 inches using Figure 36 of HMR-52 (NOAA, 1982). The 5-minute PMP value of 5.8 inches corresponds to a rainfall intensity of 69.6 inches/hour. This verifies the applicant's calculation of the 5-minute, 1 mi^2 PMP that was presented in the response to RAI 2.4.2-1. The staff verified the value of PMP presented by the applicant.

The applicant used the rational method to determine PMF from the PMP assuming all storm drains are blocked. The staff considers this method of calculation to be conservative, as the Rational Method captures a snapshot in time of the worst potential precipitation of almost 6 inches in a 5 minute window. Also, the applicant assumed no infiltration or other losses of the PMP, which is a conservative assumption. The applicant assumed the area of runoff included the Fermi 3 nuclear island (18.1 acres) plus the area located to the southwest, termed N3 in the FSAR (see Figure 2.4-217 of the FSAR). This area is approximately 25.96 acres and is assumed to contribute to the site runoff because there may be backwater effects from this area to prevent water from draining from the Fermi 3 nuclear island. The staff confirmed that the runoff from this total area of 44.05 acres resulting from the 5-minute PMP is calculated to be 3,066 cfs.

To calculate the depth of flow potentially resulting from the peak runoff rates, the applicant used the Manning's equation. The staff evaluated the inputs to the equation. The Manning's roughness coefficient used for the analysis is appropriate for concrete or bare soil (Engman, 1986). The staff finds this value appropriate for roughness at the Fermi 3 site. The width of 75 feet is arbitrary, as there is currently no channel into which the flow is directed. The staff performed the calculation to determine the depth of flow using the applicant's stated assumptions and found a flow depth of 2.57 ft. This verified the applicant's calculation. The staff finds this analysis of runoff depth acceptable because the assumption of a 75 ft channel is conservative.

The staff reviewed the applicant's analysis of PMF plus snowmelt runoff when all storm drains were blocked as presented in the response to RAI 2.4.2-1. The staff verified the equation for snowmelt runoff by checking the applicant's reference (USACE, 1998). The equation used by the applicant is conservative because it assumes a constant snowpack that does not decrease during the PMF. Input values to the equation included wind velocity, air temperature, rainfall rate and a wind coefficient. The staff verified that the wind coefficient of 1 used by the applicant is a conservative assumption (USACE, 1998). The resulting snowmelt would have been reduced if the value was assumed to be lower than 1. The rainfall rate that the applicant used was the same as was used for the PMF calculation, 69.6 in/hour. The staff obtained Detroit Metro Airport climate data from the NCDC to verify the applicant's wind velocity and air temperature assumptions. The staff obtained average daily dew point temperature and average daily wind speed information from 1984 through 2009. For a conservative analysis the staff chose the highest wind speed and dew point temperature for the month of April from each of the 25 years on record. Both datasets were found to be normally distributed using the EPA's ProUCL software (USEPA, 2007). For each of the resultant datasets, a normal cumulative distribution function of the values was examined to determine the recurrence interval of the applicant's selected values. The staff found that the average daily wind speed of 32.5 mph (assumed by the applicant for snowmelt calculations) occurred less frequently than the 100-year wind speed. Thus, the staff verified that this is a conservative value for wind speed during the PMF with snowmelt. For the daily dew point temperature, the staff also found the value of 69.1 degrees Fahrenheit (assumed by the applicant for snowmelt calculations) occurred less frequently than the 100-year value for the month of April. The staff's calculations verified that the applicant selected a conservative value of dew point temperature for the calculation of snowmelt.

For the 5-minute storm duration, the staff verified that the snowmelt was calculated to be 1.54 inches using the applicant's conservative assumptions. The staff verified that the snowmelt added to the 5-minute precipitation value of 69.6 inches/hour produced an equivalent rainfall intensity of 88.1 inches/hour. The PMF runoff of 3,880 cfs was then calculated by the staff using the rational method. Using the same assumptions about the channel, the staff verified the flow depth calculation using Manning's equation. A flow depth of 2.97 ft was calculated by the staff, verifying the applicant's calculation. The flood elevation associated with this runoff depth was determined by the staff to be 584.8 ft NAVD 88, the same value as calculated by the applicant.

In the FSAR, the applicant did not discuss any erosion protection measures or the potential erosional impacts of PMP flooding on the slopes of the Fermi 3 elevated area containing the safety structures. RAI 2.4.2-1 requested information related to the potential erosion of the slopes of the Fermi 3 site. The applicant stated that the slopes are 8 percent and thus the staff does believe that erosion protection measures, such as described in *The Guidebook of Best Management Practices for Michigan Watersheds* (MDEQ, 1998) should be taken to prevent erosion on the slopes. Additionally, these erosion protection measures should be monitored and maintained to ensure that they are functioning properly. Additionally, NRC guidelines NUREG-1623 provide guidance on designing erosion protection along slopes that may be helpful to the applicant. In RAI 2.4.2-4, the staff requested additional information on the specific erosion protection measures to be used for the slopes of the Fermi 3 elevated area. The staff requested that (1) the applicant calculate the potential maximum velocity of runoff from the 8 percent slopes during the PMP at the site and (2) the applicant provide detailed information on specific erosion protection measures designed to resist erosion under the maximum predicted water velocities. The applicant used Manning's equation to calculate the potential velocities of water running down the slopes during the local PMF assuming all the drains are blocked. The maximum velocity calculated by the applicant was 5.64 ft per second (fps) and thus the applicant used this velocity as the design velocity to determine proper erosion protection measures for the slopes of the nuclear island. The applicant stated that grass cover established by sod or a riprap cover with a median diameter of 3 inches would comply with the requirements in *The Guidebook of Best Management Practices for Michigan Watersheds* (MDEQ, 1998). The staff checked the applicant's calculations and finds this response to be conservative and acceptable in determining erosion protection measures for the local PMP on the slopes of the nuclear island.

In the FSAR, the applicant did not consider potential impacts of PMP flooding at the Fermi 3 site on the adjacent Fermi 2 site. RAI 2.4.2-3, dated November 20, 2009 (ADAMS Accession No. ML093280179) requested an analysis of potential impacts of the PMP flood at the Fermi 3 site on the Fermi 2 safety facilities, assuming all runoff drop inlets are blocked (i.e., the worst case scenario). In the response, the applicant calculated the maximum additional depth of water at Fermi 2 to be 4 inches during the PMP flood. The Fermi 2 UFSAR (Detroit Edison, 2009a) states that the Fermi 2 safety structures are water tight to a minimum of 586.8 ft NAVD 88. The staff determined that there would be no impact to the Fermi 2 safety structures from the local PMP flooding at Fermi 3.

The applicant discussed predevelopment and final Fermi 3 plant site runoff for storms smaller than the PMP. The information presented concerning the 10-year through 100-year rainfall intensities and resulting runoff for the existing drainage and the final grade drainage (presented in Table 2.4-212, 2.4-213 and 2.4-214) was not considered to be essential to the staff's review of safety-related features, and this information was not reviewed by the staff. For the reasons given above, the staff concluded that the identification and consideration of the floods at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

2.4.2.5 Post Combined License Activities

The applicant idenfies the following commitment:

- **Commitment (COM 2.4-002)** – Detailed design will incorporate best industry practices included in "The Guidebook of Best Management Practices for Michigan Watersheds" to provide added erosion protection to the slopes, even though they are receiving very little runoff. These practices include mulching, seeding, sodding, soil management, trees, shrubs, and ground covers. To be conservative, erosion protection methods selected will be based on runoff velocities for a local PMP condition not taking credit for the storm water drains. Where necessary, erosion protection will be provided for breaking waves during a postulated surge/seiche event.

2.4.2.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.2 of NUREG–0800, and other NRC RGs. The staff's review concluded that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed EF3 COL Item 2.0-13-A as it relates to floods.

As set forth above, the applicant has presented and substantiated information relative to the floods important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the floods at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the locally intense precipitation flood event. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.3 Probable Maximum Flood on Streams and Rivers

2.4.3.1 *Introduction*

The PMF on streams and rivers is used to determine the extent of any flood protection required for those safety-related SSCs necessary to ensure the capability to shut down the reactor and maintain it in a safe shutdown condition. The specific areas of review are as follows: (1) design basis for flooding in streams and rivers, (2) design basis for site drainage, (3) consideration of other site-related evaluation criteria, and (4) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.3.2 *Summary of Application*

Section 2.4.3 of the Fermi 3 COL FSAR, Revision 7, addresses the need for information on site specific PMF on streams and rivers. In addition, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-14-A Probable Maximum Flood

  To address this COL item, the applicant discussed considerations of storm configuration, maximized precipitation amounts, time distributions, orographic effects, storm centering, seasonal effects, antecedent storm sequences, antecedent snowpack, and a snowmelt model in defining the PMP. The applicant described the absorption capability of the basin, including consideration of initial losses and infiltration rates as well as the hydrologic response characteristics of the watershed to precipitation and provided verification from synthetic procedures.

In addition, the applicant presented the controlling PMF runoff hydrograph at the plant site that would result from rainfall and described the translation of the estimated peak PMP discharge to elevation using cross-section and profile data, standard step methods, roughness coefficients, verification, and estimates of PMF water surface profiles. Finally, the applicant discussed setup, maximum wave heights, run-up, and resultant static and dynamic effects of wave action on each safety-related facility from wind-generated activity that may occur coincidentally with the peak maximum flood water level.

2.4.3.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the PMF on streams and rivers, and the associated acceptance criteria, are in Section 2.4.3 of NUREG–0800. The applicable regulatory requirements for identifying PMF on streams and rivers are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The related acceptance criteria are:

- Design Bases for Flooding in Streams and Rivers: To meet the requirements of 10 CFR Part 100, estimates of the following characteristics are needed, and should be based on conservative assumptions of hydrometeorologic characteristics in the drainage area: (a) the area of the watershed used to estimate flooding in streams and rivers, (b) the total depth of PMP and the PMP hyetograph, (c) the maximum PMF water surface elevation in streams and rivers with coincident wind-waves, and (d) hydraulic characteristics that describe dynamic effects of PMF on SSC important to safety. If a potential hazard to SSC important to safety exists, the applicant should document and justify the design bases of affected facilities.

- Design Bases for Site Drainage: To meet the requirements of 10 CFR Part 100, estimates of the following characteristics are needed: the runoff from the immediate site area and the drainage from areas adjacent to the site, including the roofs of safety-related structures. Flood response characteristics should be identified to estimate flooding adjacent to and on the plant site. The effects of erosion and sedimentation during the flooding should be identified and their effects on SSC important to safety should be determined. If a potential hazard to SSC important to safety exists, the applicant should document and justify the design bases of affected facilities.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100 information about the potential effects of site-related proximity, seismic, and non-seismic information as they relate to flooding in streams and rivers and local flooding adjacent to and on the plant site is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RGs:

- RG 1.27, describes the applicable UHS capabilities.

- RG 1.29, identifies seismic design bases for SSC important to safety.

- RG 1.59, as supplemented by current best practices provides guidance for developing the hydrometeorological design bases.

- RG 1.102, describes acceptable flood protection to prevent the safety-related facilities from being adversely affected.

2.4.3.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.4.3 of the Fermi 3 COL FSAR.

<u>COL Item</u>

- EF3 COL 2.0-14-A Probable Maximum Flood

  To address this COL item, the applicant discussed considerations of storm configuration, maximized precipitation amounts, time distributions, orographic effects, storm centering, seasonal effects, antecedent storm sequences, antecedent snowpack, and a snowmelt model in defining the PMP. The applicant described the absorption capability of the basin, including consideration of initial losses and infiltration rates as well as the hydrologic response characteristics of the watershed to precipitation and provided verification from synthetic procedures.

  In addition, the applicant presented the controlling PMF runoff hydrograph at the plant site that would result from rainfall and described the translation of the estimated peak PMP discharge to elevation using cross-section and profile data, standard step methods, roughness coefficients, verification, and estimates of PMF water surface profiles. Finally, the applicant discussed setup, maximum wave heights, run-up, and resultant static and dynamic effects of wave action on each safety-related facility from wind-generated activity that may occur coincidentally with the peak maximum flood water level.

2.4.3.4.1 Probable Maximum Precipitation

<u>Information Submitted by the Applicant</u>

In Subsection 2.4.3.1 of the FSAR, the applicant calculated the PMP over the entire Swan Creek Watershed. In the response to RAI 2.4.3-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant stated that the PMP was calculated using HMR-51. The applicant estimated a storm depth of 31.4 inches over a 72-hour period as the PMP. The applicant presented the distribution of rainfall during the 72-hour period in Table 2.4-216 of the FSAR and referenced the ANSI/ANS-2.8-1992 for this calculation. The applicant stated that an antecedent condition was assumed, but no further explanation is provided.

In response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant performed an analysis of snowmelt impacts in addition to the PMP in the Swan Creek Watershed. For this calculation, the applicant used the HMR-52 software program (USACE, 1984) to determine the PMP for the Swan Creek Watershed. The HMR-52 software determines the size of the storm and spatially orients the storm within the watershed to determine the worst possible scenario for the PMP. The applicant performed this storm orientation with the probable maximum storm in the Swan Creek Watershed. The applicant determined that a storm size of 100 mi^2 with an orientation of 311 degrees produced the largest precipitation values. Other inputs required for using the HMR-52 software include delineation of the watershed boundary, depth-area-duration data and the ratio of the 1-hour to 6-hour storm, as illustrated in Figure 39 of HMR-52 (NOAA, 1982). The applicant derived the depth-area-duration data from HMR-51 (NOAA, 1978). The applicant stated that the value of the ratio of the 1-hour to the 6-hour storm was 0.302.

Snowmelt resulting from rain on snow was calculated using the *Runoff from Snowmelt* guidance provided by the USACE (1998). The applicant used a lumped model approach assuming that all the parameters are constant across the watershed to simplify the problem. The applicant then calculated snowmelt as a function of wind velocity, rainfall rate, air temperature, and a wind coefficient using equation 5-19 of the USACE guidance. The applicant assumed the PMP rain on snow event would occur in April because, historically, relatively high temperatures have occurred after freezing during the month of April. The applicant used the observed dew point temperatures as representative of air temperature during a PMP rain on snow event. The wind velocity and temperature were derived from historical data from the Detroit Metropolitan Airport meteorological station. The applicant analyzed 34 years of data (1961-1995) for the month of April to determine the 2-year occurrence wind speed, 32.5 mph, and the 100-year occurrence dew point temperature, 69.1 degrees Fahrenheit. The applicant selected the highest hourly dew point temperature and the highest hourly wind speed from each April on record. The applicant stated an extreme frequency analysis was done with the resultant data, but did not describe the methodology taken to determine the values. The applicant assumed these values were constant through the entire storm.

NRC Staff's Technical Evaluation

The NRC staff checked the applicant's PMP calculation that was based on the HMR-51 and HMR-52 reports (NOAA, 1978; NOAA, 1982). First, the staff used the method described in HMR-51 to determine the PMP depth at the site. The staff found values of PMP depth corresponding to the location of Fermi 3 in Figure 18 through Figure 47 of HMR-51 (NOAA, 1978). Information developed by staff for standard increments and basin size is found below in Table 2.4.3-1 below.

Table 2.4.3-1. Depth-area-duration Tables for the Fermi site.

	Storm Depth (inches) per Storm Duration (hours)				
Basin Size (square miles)	6 hours	12 hours	24 hours	48 hours	72 hours
10	25.5	28.75	30.5	32.9	34.9
200	17.8	21.2	22.7	25.6	27.5
1000	12.9	15.6	17.4	20	21.95
5000	7.8	10.6	12.4	14.85	16.6
10000	6	8.5	10	13	14.7
20000	4.2	6.7	8.3	10.9	12.4
To convert square-miles to square-kilometers multiply the numbers by 2.59. To convert inches to centimeters multiply the numbers by 2.54.					

Smooth depth-area-duration curves were then graphed on semi-log paper. This graph was used to find the PMP depths for the 100 mi^2 Swan Creek Watershed. The staff determined that the 72-hour PMP depth for Swan Creek is 29.3 inches. The staff then used the USACE computer program HMR-52 to determine the probable maximum storm in Swan Creek Watershed. The HMR-52 software calculated the 72-hour PMP to be 28.9 inches.

The HMR-52 software requires several inputs including: points outlining the watershed, the ratio of the 1-hour to the 6-hour storm, the position of the maximum 6-hour rainfall increment, the temporal distribution of the PMP over the entire storm, the storm area, the storm center, the depth-area-duration information derived from HMR-51, and the preferred storm orientation information from HMR-51 (NOAA, 1978; USACE, 1984). The staff determined that the 1 to 6-hour ratio for the 20,000 mi^2 storm at the Fermi site was 0.302 by checking Figure 39 of HMR-52 (NOAA, 1982). The staff set the position of the maximum 6-hour precipitation increment to the 7th increment, following the ANSI/ANS-2.8-1992 guidance. The staff also followed the ANSI/ANS-2.8-1992 guidance to set the distribution of the PMP over the entire storm. The storm area size and the storm orientation were set as variables, so the HMR-52 program could change these parameters to maximize the probable maximum storm. The preferred storm orientation listed in HMR-51 of 245 degrees was also input into HMR-52. The staff ran the HMR-52 model to determine the PMP for Swan Creek. The resultant storm size was 100 mi^2 and the storm orientation was 309 degrees, the same storm properties that the applicant determined. The HMR-52 software calculated the 72-hour PMP to be 28.9 inches. The 12 rainfall intervals, 6 hours each, were calculated by the HMR-52 model. The intervals were reordered based on guidance from ANS 2.8 -1992. The information is tabulated below.

Table 2.4.3-2. Rainfall Distribution of Probable Maximum Storm for the Swan Creek Watershed

6-Hour Interval	Rainfall Depth (inch)	Order of Interval in Storm
1	19.76	7
2	2.70	6
3	1.50	8
4	1.04	5
5	0.80	9
6	0.65	4
7	0.55	10
8	0.47	3
9	0.42	11
10	0.37	2
11	0.34	12
12	0.31	1
To convert inches to centimeters multiply the numbers by 2.54.		

Table 2.4.3-2 can be directly compared to FSAR Tables 2.4-216 and 2.4-217 to see that the applicant's calculated probable maximum storm is larger and therefore more conservative than the staff calculated storm. The staff finds the applicant's calculation of PMP to be acceptable, because the applicant's PMP is higher (more conservative) than the value calculated by the staff.

The staff also checked the applicant's calculation of PMP with snowmelt, as submitted in the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). First, the applicant used the USACE HMR-52 software to define the PMP, similar to the method described by the staff, above. Second, the applicant calculated snowmelt for each time interval during the storm. The values for rainfall and snowmelt were combined for each time interval to become a total value of effective precipitation on the watershed.

The applicant's input and output values for the HMR-52 program were very similar to the staff's. Both the staff and the applicant used a value of 0.302 for the ratio of the 1 to 6 hour storm. The staff found a maximum storm orientation of 309 degrees and the applicant found a maximum storm orientation of 311 degrees. The depth-area-duration curves used by the applicant were slightly larger overall than those used by the staff, and thus the applicant's analysis was more conservative. Therefore, the applicant's input values were found to be acceptable. The applicant calculated a PMP of 28.9 from the HMR-52 software, the same value determined by the staff's calculation.

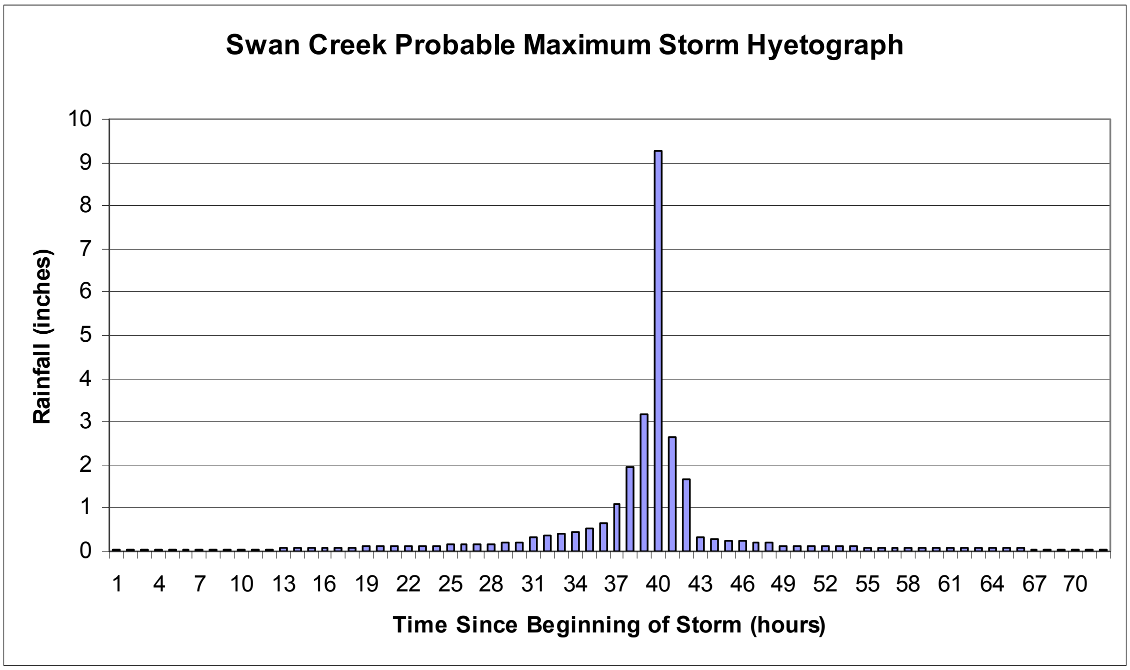


Figure 2.4.3-1. Hourly Distribution of the Probable Maximum Precipitation for the Swan Creek Watershed

The hourly distribution of the probable maximum storm was also calculated by HMR-52. The probable maximum storm for the Swan Creek Watershed shown in Figure 2.4.3-1 above can be directly compared to Figure 2.4-XX-2 submitted by the applicant with the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). The staff finds the applicant's calculation of PMP from HMR-52 to be acceptable, because the applicant's PMP is the same as the value independently calculated by the staff.

The applicant calculated snowmelt for each time step using Eequation 5-19 from the USACE manual *Runoff from Snowmelt* (USACE, 1998). A full discussion of the verification of the snowmelt calculations is presented in SER Subsection 2.4.2.4 above. The staff verified the results of the snowmelt calculations and independently calculated the same cumulative rain and snowmelt total of 70.3 inches over 72-hours.

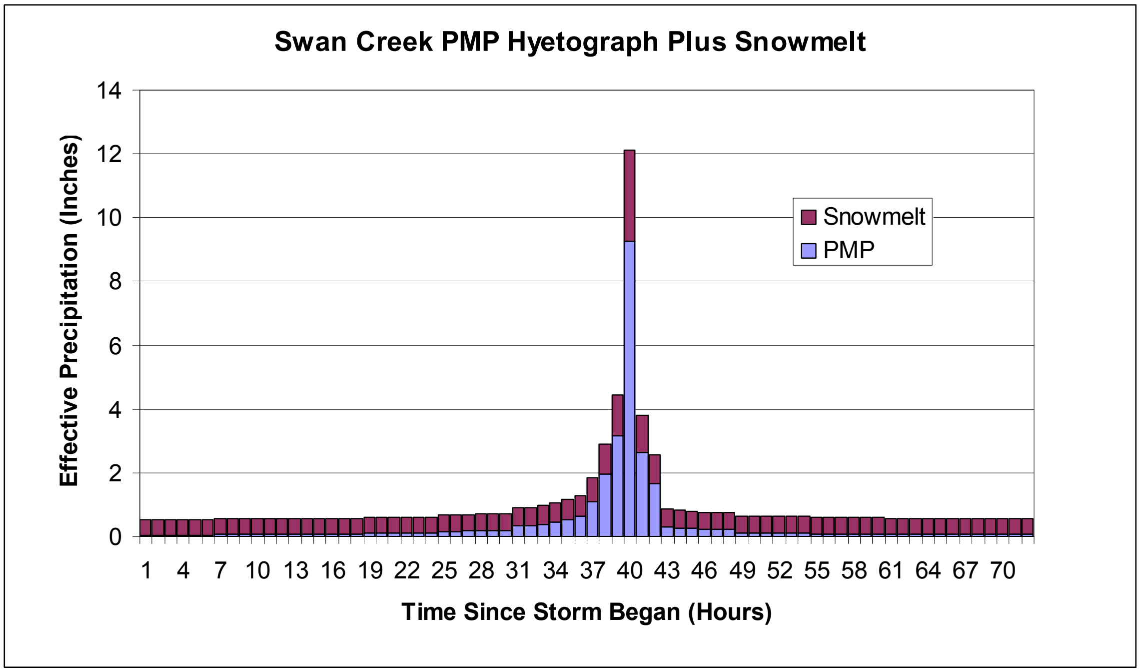


Figure 2.4.3-2. Hourly Distribution of the Probable Maximum Storm with Snowmelt for the Swan Creek Watershed

The staff-calculated PMP with snowmelt for the Swan Creek Watershed shown in Figure 2.4.3-1 above can be directly compared to Figure 2.4-XX-3 submitted by the applicant with the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). The staff finds the applicant's calculation of PMP with snowmelt to be acceptable, because the applicant's PMP is the same as the value calculated by the staff.

Precipitation Losses

Information Submitted by the Applicant

In Subsection 2.4.3.2 of the FSAR, and in the response to RAI 2.4.2-1 and RAI 2.4.3-1, dated September 30, 2009 (ADAMS Accession No. ML092790561) the applicant describes precipitation losses for the Swan Creek Watershed and how they were calculated. In the response to RAI 2.4.2-1, the applicant calculated initial losses using the NRCS default equation and a curve number of 98. The curve number of 98 was used to represent saturated conditions. The response to RAI 2.4.3-1 provided a different analysis of losses using curve numbers representative of different land use types to a stated composite curve number of 84.25. However, after discussing the calculation of this curve number, the applicant stated these losses were "not applied to the resultant hydrograph."

NRC Staff's Technical Evaluation

The NRC staff reviewed the information submitted by the applicant. A curve number of 98 is considered by the staff to be a conservative value because it assumes that the watershed is completely saturated from antecedent storm conditions. This assumption means that very little precipitation loss occurs and that almost all of the PMP is transmitted through the watershed. Using the NRCS default equation and a curve number of 98, the staff calculated an initial loss of

0.04 inches across the watershed. The staff finds the applicant used conservative assumptions for precipitation losses in the calculation of the PMF on Swan Creek.

Runoff and Stream Course Models

Information Submitted by the Applicant

In Subsection 2.4.3.3 of the FSAR, the applicant used the NRCS synthetic unit hydrograph method to transform the rainfall into runoff within the Swan Creek Watershed. The applicant provided the ordinates of the hydrograph in Table 2.4-218 of the FSAR. The applicant presented a graph of the 6-hour unit hydrograph for Swan Creek Watershed in Figure 2.4-219 of the FSAR. The applicant stated that the peak flow for the 6-hour, 1-inch storm was 4,690 cfs.

The applicant used the NRCS unit hydrograph method to transform the PMP into the PMF runoff from the Swan Creek Watershed. To transform rainfall into runoff using this method, an estimate of the basin lag time is required. The basin lag was calculated based on the time of concentration for the watershed. The applicant used the Kirpich equation to calculate the time of concentration for the basin. In the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant stated that the time of concentration was calculated to be 16.4 hours. The applicant provided an equation using the time of concentration to determine the basin lag of 9.84 hours (590 minutes).

An additional analysis of the PMF on the Swan Creek Watershed was submitted in response to RAI 2.4.2-1, which included analysis of the impacts of snowmelt. The applicant used the NRCS (also called the SCS) unit hydrograph method within the Hydological Engineering Centers Hydrological Modeling System (HEC-HMS) 3.1.0 rainfall-runoff model software package (USACE, 2006) to generate runoff in Swan Creek resulting from the PMP with snowmelt.

NRC Staff's Technical Evaluation

The NRC staff reviewed the information submitted by the applicant concerning the selection of runoff and stream course models. The NRC staff independently calculated the unit hydrograph for the Swan Creek watershed resulting from the 1 inch of rainfall falling over a 6-hour period and verified the applicant's results. The staff independently calculated the time of concentration to be 12.6 hours using the Kirpich equation, assuming a maximum travel length of 18 miles. The staff verified the Kirpich equation in the literature (Pilgrim and Cordery, 1993). The staff calculated a basin lag of 7.6 hours (455 minutes) using the equation provided by the applicant. The equation that the applicant presented for basin lag was found by the staff in TR-55 (NRCS, 1986) and verified. The staff also used two alternative equations to calculate the time of concentration and basin lag to determine if the equation that the applicant chose provided a conservative result. There are several methods available in the literature to determine the time of concentration of a watershed. Each watershed generates runoff uniquely, according to its features, such as slope and preciousness. Thus, the staff wanted to verify that the most conservative method was used to determine runoff in the Swan Creek Watershed. The staff used the Snyder method to calculate basin lag of 9 hours (550 minutes) and used the method presented in TR-55 to calculate a time of concentration of 11.5 hours and a basin lag of 413 minutes (Pilgrim and Cordery, 1993; NRCS, 1986).

The NRC staff checked the applicant's calculation of the 6-hour, 1 inch unit hydrograph for the Swan Creek Watershed by performing a unit hydrograph simulation in HEC-HMS. The staff used a basin lag of 413 minutes, the most conservative of the values found from the above analysis. The staff assumed no initial loss of rainfall to infiltration and used a curve number of 98. The staff calculated the peak runoff to be 4,300 cfs. The staff considers the applicant's calculation to be conservative because the runoff calculated by the applicant was higher than that calculated by the staff.

Probable Maximum Flood Flow

Information Submitted by the Applicant

In Subsection 2.4.3.4 of the FSAR the applicant used the NRCS synthetic unit hydrograph method to transform the rainfall into runoff within the Swan Creek Watershed. The applicant calculated a PMF peak flow of 113,000 cfs resulting from the PMP.

A modified analysis of the PMF was submitted in response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), which included analysis of the impacts of snowmelt on the PMF. The applicant used a curve number of 98 for the loss estimate in HEC-HMS to represent the saturated ground conditions. The applicant used 1-hour time steps for the calculation of flood discharge. The applicant calculated a PMF peak runoff of 168,000 cfs from the PMP with snowmelt. The RAI response also updated the analysis of water surface elevations using Hydrological Engineering Centers River Analysis System (HEC-RAS), as discussed in Section 2.4.3.5 below.

NRC Staff's Technical Evaluation

The NRC staff reviewed the information submitted by the applicant concerning the flow resulting from the PMF. The NRC staff independently calculated the PMF for Swan Creek using the SCS unit hydrograph method in HEC-HMS 3.1.0. The staff obtained a value of 134,000 cfs, which is approximately 18 percent higher than the value presented by the applicant. Though these (134,000 and 168,000 cfs) values (and the snowmelt values discussed below) are of an unreasonably large magnitude for Swan Creek, they result in highly conservative estimates using the applied methodology and are therefore useful for evaluation purposes. The staff used the smallest and most conservative time of concentration value calculated by the three methods presented above, 413 minutes. The staff also assumed a constant baseflow equivalent to the mean monthly flow for the month of April presented in Table 2-215 of the FSAR of 120 cfs.

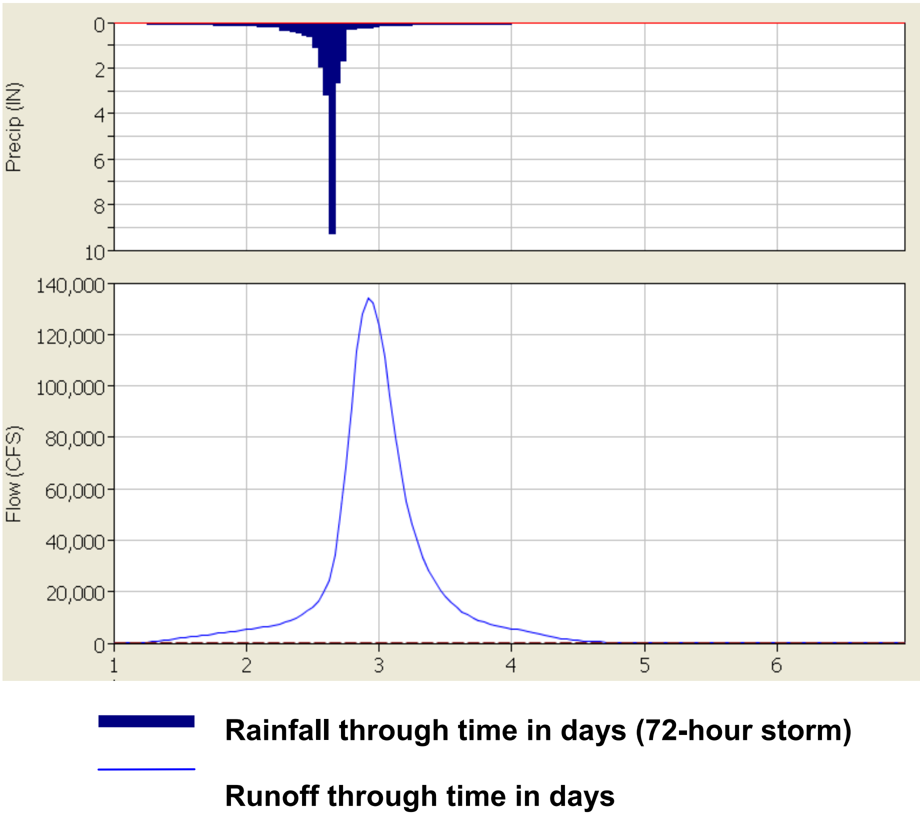
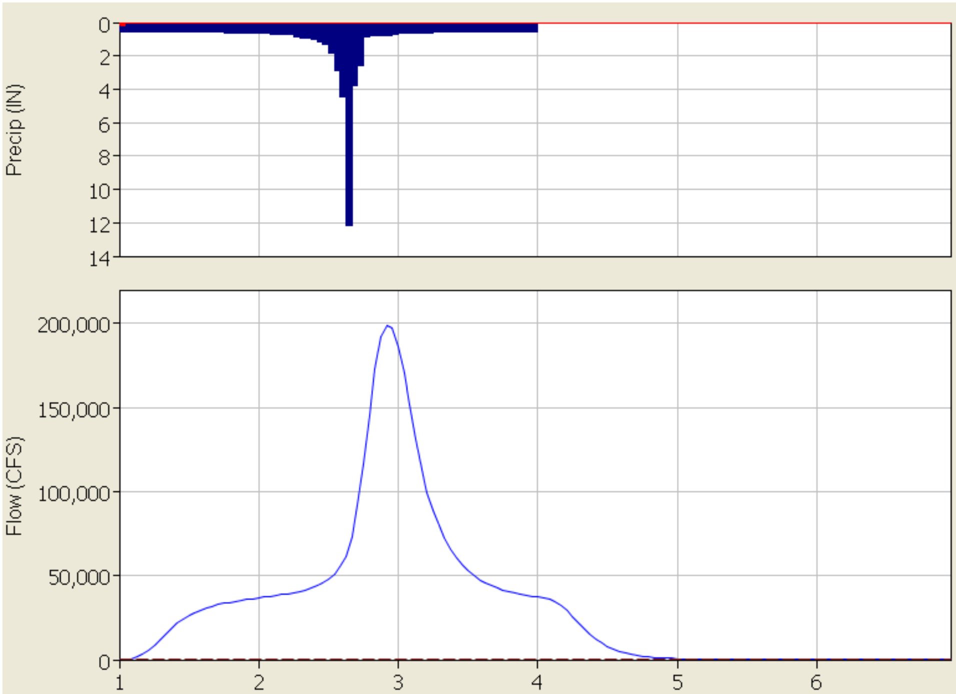


Figure 2.4.3-3. Probable Maximum Flood Runoff using HEC-HMS 3.1.0 Rainfall-runoff Model

In Figure 2.4.3-3, the staff developed flood hydrographs based on the parameters discussed above. By developing an independent hydrograph, Figure 2.4.3-3 can be directly compared with Figure 2.4-219 of the FSAR to examine the PMF runoff calculated by the staff versus the PMF runoff calculated by the applicant.

The NRC staff independently calculated the PMF with snowmelt for Swan Creek and obtained a value of 199,000 cfs, which is approximately 18 percent higher than the value presented in the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561).



Rainfall plus snowmelt through time in days (72-hour storm)

Runoff through time in days

Figure 2.4.3-4. Probable Maximum Flood with Snowmelt Runoff using HEC-HMS 3.1.0 Rainfall-Runoff Model

In Figure 2.4.3-4, the staff independently developed a flood hydrograph that include snowmelt. The staff hydrograph in Figure 2.4.3-4 can be directly compared with Figure 2.4-2-XX-4 of the response to RAI 2.4.2-1, dated September 30, 2009 (ADAMS Accession No. ML092790561) to examine the runoff from the PMF plus snowmelt calculated by the staff versus the PMF plus snowmelt runoff calculated by the applicant.

The runoff amounts for both the PMF and the PMF with snowmelt calculated by the staff are 18 percent larger than the applicant's calculated values. Although the precipitation inputs developed by staff are higher than the applicants, the resultant water surface elevations are not significantly impacted. Therefore, the staff finds the analysis performed by the applicant to be acceptable because the water levels determined by HEC-RAS from the NRC staff-calculated peak runoff do not vary significantly from the water levels calculated by the applicant (discussed in the following section).

Water Level Determination

Information Submitted by the Applicant

In Subsection 2.4.3.5 of the FSAR, the applicant used HEC-RAS Version 4.0.0 (USACE, 2008) to determine water surface profiles on Swan Creek resulting from the three possible maximum flooding scenarios: Alternative I, Alternative II, and Alternative III (see Section 2.4.2.4.2 above). The 500-year and 25-year flood levels on Swan Creek were derived from the *FEMA Flood Insurance Study for Monroe County* (FEMA, 2000). According to the response to RAI 2.4.3-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant created geometric cross-sections across Swan Creek using a 10-meter resolution DEM. The applicant created 8 cross-sections to represent approximately 11,000 feet of the downstream end of the Swan Creek channel. The applicant submitted input and output files to the NRC staff as a part of the response to RAI 2.4.1-1. The staff reviewed these files to examine the applicant's approach in detail. The applicant used a Manning's roughness coefficient of 0.02 for the channel and a value of 0.06 for the floodplain. The applicant assumed a constant water surface elevation in Lake Erie as the downstream boundary condition and a normal depth slope of 0.001 ft/ft as an upstream boundary condition. Each of the flooding alternatives has a different downstream elevation of Lake Erie and contributing flow from Swan Creek. The applicant provided detail on the derivation of the elevation of Lake Erie for each of the alternatives. Alternative I used the 100-year elevation of Lake Erie, 575.1 ft NAVD 88, combined with the estimate of the 100-year surge of 4.0 ft as presented in Table 2.4-222 of the FSAR. Alternative II used the 100-year elevation of Lake Erie, 575.1 ft NAVD 88, combined with the estimate of the 33-year surge of 3.2 ft as presented in Table 2.4-222 of the FSAR. Alternative III used the 100-year elevation of Lake Erie, 575.1 ft NAVD 88, combined with the estimate of probable maximum surge height of 10.3 ft. Table 2.4.3-3 summarizes the applicant's HEC-RAS inputs and the results.

Table 2.4.3-3. The Applicant's Inputs to HEC-RAS and Resulting Flood Elevations at the Fermi Site

Combined Events	**Input Parameters**		**Results**
Flood Scenario	**Flow in Swan Creek (cfs)**	**Calculated Lake Elevation (ft NAVD 88)**	**Resulting Fermi Flood Elevation (ft NAVD 88)**
Alternative I: • 500-yr flood in Swan Creek (5000 cfs) • Largest observed surge in Lake Erie (4.0 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	5,000	579.1	**579.4**

Alternative II: • PMF in Swan Creek (113,200 cfs) • 25-year surge in Lake Erie (3.2 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	113,200	578.3	**579.1**
Alternative III: • 25-year flood in Swan Creek (3100 cfs) • Probable maximum surge or seiche in Lake Erie (10.3 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	3,100	585.4	**585.4**
Sensitivity due to Snowmelt Alternative: • PMF in Swan Creek plus snowmelt runoff (168,000 cfs) • Probable maximum surge and seiche in Lake Erie (10.3 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	168,000	585.4	**585.5**
cfs = cubic-foot per second NAVD = North American Vertical Datum PMF = probable maximum flood	To convert feet to meters, multiply by 0.3048 To convert cfs to cubic-meter per second, divide by 35.315		

Table 2.4-219 of the FSAR presents the detailed HEC-RAS simulation results of flooding Alternative II, which included the PMF on Swan Creek. The applicant determined the flood elevation for the Fermi site to be the water elevation at the cross section approximately 1,900 feet upstream from Lake Erie. Detailed HEC-RAS results for Alternative I and Alternative III were presented in FSAR Tables 2.4-220 and 2.4-221, respectively. The flood elevations at Fermi 3 for Alternative I and Alternative III were constant at the downstream cross-sections of Swan Creek, according to the information in these tables.

NRC Staff's Technical Evaluation

The NRC staff reviewed the information submitted by the applicant. The staff finds the applicant's use of HEC-RAS 4.0.0 to be acceptable for estimating water levels in Swan Creek because the staff verified the geometric cross-sections in the HEC-RAS model of Swan Creek by comparing them with the USGS Stony Point topographic map. However, to fully verify the cross-sections, the staff compared them to the 10-m DEM requested by the staff as RAI 2.4.1-3, dated March 19, 2010 (ADAMS Accession No. ML100830380). The review team extracted cross sections from the DEM submitted by the applicant and evaluated the cross sections in comparison to those submitted by the applicant. This confirmed that the appropriate cross-sections were used in the applicant's model.

The staff verified that the Manning's coefficient values assumed for Swan Creek are conservative by varying the coefficient values and performing simulations. Reasonable values for the Manning's coefficient could range between 0.015 and 0.04 for Swan Creek (Shen and Julien, 1993; FEMA, 2000). Fermi flood elevations were the largest when a Manning's n value of 0.04 was assumed for Swan Creek. Therefore, the staff chose the value of 0.04 for Manning's n to compute the most conservative water levels resulting from the flooding alternatives.

The staff reviewed the *FEMA Flood Insurance Study for Monroe County* (2000), particularly the document's discussion of the Swan Creek Watershed. The staff verified that the 25-year flood is estimated to be 3,100 cfs and the 500-year flood level is estimated to be 5,000 cfs (FEMA, 2000). FEMA determined the flood levels for the Swan Creek watershed by plotting flood levels for streams in the region that have been monitored. The calculated flood levels for Swan Creek are then based on its size in comparison with the size of the monitored watersheds.

The staff reviewed the applicant's calculation of the water level for Lake Erie for each flooding alternative. For Alternative I, the applicant stated that a surge of 4.0 feet was assumed. The applicant used the 100-year recurrence interval surge for the month of December of 4.0 ft to estimate the "surge and seiche resulting from the worst regional hurricane or windstorm with wind-wave activity," as required by the ANSI/ANS-2.8-1992. The staff verified the height of the surge by checking the USACE website that the applicant referenced for the value (USACE, 2009). However, the applicant states in Section 2.4.5.2.2.3 of the FSAR that the maximum rise observed as a result of a seiche was 6.3 ft. In RAI 2.4.3-2, dated January 29, 2010 (ADAMS Accession No. ML092870355), the NRC staff requested that the applicant provide a rationale for choosing the 100-year surge as predicted by the USACE for flooding Alternative I rather than using the maximum recorded seiche at the site of 6.3 ft. The response included a calculation of flooding Alternative I using the maximum recorded seiche at the site. The flooding height was calculated to be 581.7 ft NAVD 88, which is lower than the flooding level of Alternative III. Thus, Alternative I, even with the maximum recorded seiche, would not produce the PMF.

For Alternative II, the applicant stated that a surge of 3.2 feet was assumed, based on the 33-year surge elevation as estimated by the USACE (2009). The staff verified the height of the surge by checking the applicant's reference. For Alternative III, the applicant stated that a surge of 10.3 feet was assumed, based on the calculation of probable maximum surge as discussed further below. However, upon review of the applicant's information submitted in Subsection 2.4.5 of the FSAR, a surge height plus wave action of 12.37 ft at the site was calculated by the applicant with the STWAVE model. This issue is discussed in greater detail in Subsection 2.4.5.

The verification of the Lake Erie elevation for each of the flooding alternatives is discussed below in Section 2.4.5. The verification of the calculation of the 100-year elevation of Lake Erie, the probable maximum surge and seiche, and the maximum observed surge elevation are discussed in Section 2.4.5, below.

Table 2.4.3-4 presents the staff's inputs and outputs of the HEC-RAS model.

Table 2.4.3-4. The Staff's Inputs to HEC-RAS and Resulting Flood Elevations at the Fermi Site

Combined Events	**Input Parameters**		**Results**
Flood Scenario	**Flow in Swan Creek (cfs)**	**Calculated Lake Elevation (ft NAVD 88)**	**Resulting Fermi Flood Elevation (ft NAVD 88)**
Alternative I: • 500-yr flood in Swan Creek (5000 cfs) • Largest observed surge in Lake Erie (4.0 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	5,000	579.1	**579.1**
Alternative II: • PMF in Swan Creek (134,000 cfs) • 25-year surge in Lake Erie (3.2 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	134,000	578.3	**581.5**
Alternative III: • 25-year flood in Swan Creek (3100 cfs) • Probable maximum surge or seiche in Lake Erie (10.3 ft) • 100-year elevation of Lake Erie	3,100	585.4	**585.4**

(575.1 ft NAVD)			
Sensitivity due to Snowmelt Alternative: • PMF in Swan Creek plus snowmelt runoff (199,000 cfs) • Probable maximum surge and seiche in Lake Erie (10.3 ft) • 100-year elevation of Lake Erie (575.1 ft NAVD)	199,000	585.4	**586.3**
cfs = cubic-foot per second NAVD = North American Vertical Datum PMF = probable maximum flood	To convert feet to meters, multiply by 0.3048 To convert cfs to cubic-meter per second, divide it by 35.315		

The highest flood level calculated by the staff is 586.3 ft NAVD 88 and resulted from the PMF plus snowmelt on Swan Creek coincident with the probable maximum surge and seiche in Lake Erie. However, this alternative was performed as a sensitivity analysis to determine the impact of a snowpack at the site. The ANSI/ANS-2.8-1992 guidelines state that the three alternatives are adequate for determining the maximum water level at the site. The staff finds that the maximum water level resulting from flooding is 585.4 ft NAVD 88 in Alternative III, which is 0.1 ft below the applicant's maximum water level is acceptable.

Coincident Wind Wave Activity

Information Submitted by the Applicant

In Subsection 2.4.3.6 of the FSAR, the applicant calculated the potential for wind-wave activity occurring with flooding Alternative III in Section 2.4.5 of the FSAR. The applicant stated that the wave run-up resulting from the probable maximum windstorm winds on Lake Erie was calculated with the Automated Coastal Engineering System (ACES) model. In Section 2.4.5 of the FSAR, the applicant calculated the wave run-up estimated to occur on top of the probable maximum surge in Lake Erie of 585.4 ft NAVD 88. The applicant stated that the breaking wave was calculated to be 9.48 ft at the toe of the seawall and 2.23 ft on the toe of the Fermi 3 nuclear island/berm. If waves run up to the slope of berm, the highest run-up level was found to be 3.01 ft.

NRC Staff's Technical Evaluation

The NRC staff reviewed the applicant's calculation of wave run-up presented in Section 2.4.5 of the FSAR. The staff requested additional information about the applicant's calculation of wave run-up in RAI 2.4.5-3, received November 20, 2009 (ADAMS Accession No. ML093280179), which is discussed below in Section 2.4.5.

Using the values presented by the applicant, the staff calculated the maximum elevation that waves would break to be 587.7 ft NAVD 88 at the toe of the berm and run up to be 588.41 ft along the slope of the Fermi 3 nuclear island/berm, caused by a combination of the probable maximum surge, wind set-up, and wave run-up. These elevations are 1.4 ft and 0.9 ft below the elevation of the Fermi 3 safety structures, respectively.

Additionally, in RAI 2.4.3-3, dated January 29, 2010 (ADAMS Accession No. ML092870355), the NRC staff requested that the applicant provide additional information on wind-wave activity coincident with a flood under Alternatives I and II. According to Subsection of 9.2.3.2 of the ANSI/ANS 2.8-1992, all alternatives need to be evaluated with wind-wave activity. The applicant calculated the wave runup for Alternative I to be 0.4 ft below the top of the seawall at the edge of Lake Erie, but the wave runup on the Fermi 2 plant grade was not calculated. The applicant stated that there would be some water splashing up on the Fermi 2 plant grade, but the runup would be much lower than the height of the Fermi 3 safety structures. The wave runup for Alternative II was calculated by the applicant to be 3.6 ft above the top of the seawall, so at an elevation of 585.4 ft NAVD 88, which is 3.9 ft below the elevation of the Fermi 3 safety structures. The applicant did not address potential impacts from the wind wave activity on the slopes of the nuclear island. To address this, the NRC staff transmitted RAI 2.4.2-5, dated May 7, 2010 (ADAMS Accession No. ML101320136) requesting that the applicant (1) evaluate potential erosion on the slopes of the nuclear island caused by wind wave activity and (2) describe the erosion protection measures that will be taken to prevent erosion on the slopes of the nuclear island. In the response to RAI 2.4.2-5, Detroit Edison provided an analysis of potential erosion on the slopes of the Fermi 3 nuclear island from wave run-up. The analysis showed that slopes would be protected from wave run-up velocities during the PMF event, using the slope protection methods discussed in the answer to RAI 2.4.2-4 (grassed slopes or rip-rap with a D50 of 0.25 ft). The applicant estimated that velocities of run-up wave along the slope and breaking waves hitting the slope prior to breaking are approximately 3.4 ft per second and 3.7 ft per second, respectively. Both velocities are below the permissible velocities for the erosion protection methods discussed in RAI 2.4.2-4. As the applicant indicated, however, the wave action on the slope of the Fermi 3 nuclear island could provide additional forces that result in erosion. To ensure no damage or displacement of the rip-rap on the slopes, the applicant found that a D50 of 0.5 ft would need to be used. The staff finds this analysis to be conservative and acceptable.

For the reasons given above, the staff concludes that the identification and consideration of the PMF on streams and rivers at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

2.4.3.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.3.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.3 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-12-A as it relates to probable maximum floods.

As set forth above, the applicant has presented and substantiated information relative to the probable maximum flooding on streams and rivers important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the probable maximum flooding on streams and rivers at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the probable maximum flooding on streams and rivers. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.4 Potential Dam Failures

2.4.4.1 *Introduction*

The potential dam failures are addressed to ensure that any potential hazard to the safety-related facilities due to the failure of onsite, upstream, and downstream water control structures is considered in the plant design. The specific areas of review are as follows: (1) flood waves resulting from a dam breach or failure, including those due to hydrologic failure as a result of overtopping for any reason, routed to the site and the resulting highest water surface elevation that may result in the flooding of SSCs important to safety; (2) successive failures of several dams in the path to the plant site caused by the failure of an upstream dam due to plausible reasons, such as a PMF, landslide-induced severe flood, earthquakes, or volcanic activity and the effect of the highest water surface elevation at the site under the cascading failure conditions; (3) dynamic effects of dam failure-induced flood waves on SSCs important to safety; (4) failure of a dam downstream of the plant site that may affect the availability of a safety-related water supply to the plant; (5) effects of sediment deposition or erosion during dam failure-induced flood waves that may result in blockage or loss of function of SSCs important to safety; (6) failure of onsite water control or storage structures such as levees, dikes, and any engineered water storage facilities that are located above site grade and may induce flooding at the site; (7) the potential effects of seismic and non-seismic data on the postulated design bases and how they relate to dam failures in the vicinity of the site and the site region; and (8) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.4.2 *Summary of Application*

Section 2.4.4 of the Fermi 3 COL FSAR, Revision 7, addresses the needs for site specific information on potential dam failures. In addition, in FSAR Section 2.4.4, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-15-A Potential Dam Failures

  To address this COL item, the applicant stated that there were no known dams on adjacent water bodies that would impact the Fermi 3 Site.

2.4.4.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the potential dam failures, and the associated acceptance criteria, are in Section 2.4.4 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Section 2.4.4:

- Flood Waves from Severe Breaching of an Upstream Dam: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), estimates of the following characteristics are needed, and should be based on conservative assumptions of hydrometeorological, geological, and seismic characteristics in the drainage area: (a) modes of assumed dam breaches or failures, (b) consideration of flood control reservoirs at full pool level, and (c) conservatism of coincident flow rates and water surface elevations.

- Domino-Type or Cascading Dam Failures: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an appropriate configuration of the cascade of dam failures and its potential to produce the largest flood adjacent to the plant site is needed.

- Dynamic Effects on Structures: To meet the requirements of 10 CFR Part 100, an estimate of dynamic effects of flood waves, such as velocities and momentum fluxes, on SSC important to safety is needed.

- Loss of Water Supply Due to Failure of a Downstream Dam: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an assessment regarding loss of safety-related water supply to the plant caused by failure of a downstream dam is needed.

- Effects of Sediment Deposition and Erosion: To meet the requirements of 10 CFR Part 100 and 10 CFR 100.23(d), an assessment is needed regarding loss of functionality of safety-related water supply to the plant caused by blockages due to sediment deposition or erosion during the dam failure-induced flood event.

- Failure of Onsite Water Control or Storage Structures: To meet the requirements of 10 CFR Part 100, an assessment is needed regarding the failure of any onsite water control or storage structures that may cause flooding of SSC important to safety.

- Consideration of Other Site-Related Evaluation Criteria: The potential effects of site-related proximity, seismic, and non-seismic information as they relate to flooding due to upstream dam failures and loss of safety-related water supply due to blockages and failures of downstream dam failures adjacent to and on the plant site and site regions are needed to meet the requirements of 10 CFR Part 100.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, and RG 1.102.

2.4.4.4 *Technical Evaluation*

NRC staff reviewed Section 2.4.4 of the Fermi 3 COL FSAR related to potential dam failures and their effects on the Fermi site as follows:

<u>COL Item</u>

- EF3 COL 2.0-15-A Potential Dam Failures

  To address this COL item, the applicant stated that there were no known dams on adjacent water bodies that would impact the Fermi 3 Site.

The staff reviewed FSAR Section 2.4.4, Potential Dam Failures. In Section 2.4.3.4 of the FSAR, the second paragraph states that “There are no dams existing within the Swan Creek watershed ...” In response to this statement, the NRC staff requested the applicant to provide additional information on the justification for the statement regarding dams in the watershed through RAI 2.4.4-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). The RAI specified that the applicant should demonstrate that a reasonable search of records or applicable databases has been conducted to support its conclusion. In response to RAI 2.4.4-1, the applicant referenced the USACE National Inventory of Dams database. The staff checked the National Inventory of Dams on October 21, 2009 and verified that there are no dams within the Swan Creek Watershed (USACE, 2007). The staff verified that the information in the dam inventory and finds that there is no risk of flooding due to a potential dam failure. For the reasons given above, the staff concludes that the identification and consideration of the effects of dam failures at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79, 100.23(d), and 100.20(c).

2.4.4.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.4.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.4 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-15-A as it relates to potential dam failures.

As set forth above, the applicant has presented and substantiated information relative to the effects of dam failures important to the design and citing of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the effects of dam failures at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79, 100.23(d), and 100.20(c).

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the effects of dam failures reflected in the site characteristics. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.23(d) and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.5 Probable Maximum Surge and Seiche Flooding

2.4.5.1 *Introduction*

The probable maximum surge and seiche flooding are addressed to ensure that any potential hazard to the safety-related facilities due to the effects of probable maximum surge and seiche is considered in plant design. The specific areas of review are as follows: (1) probable maximum hurricane (PMH) that causes the probable maximum surge as it approaches the site along a critical path at an optimum rate of movement; (2) probable maximum wind storm (PMWS) from a hypothetical extratropical cyclone or a moving squall line that approaches the site along a critical path at an optimum rate of movement; (3) a seiche near the site, and the potential for seiche wave oscillations at the natural periodicity of a water body that may affect flood water surface elevations near the site or cause a low water surface elevation affecting safety-related water supplies; (4) wind-induced wave run-up under a PMH or PMWS winds; (5) effects of sediment erosion and deposition during a storm surge and seiche-induced waves that may result in blockage or loss of function of SSCs important to safety; (6) the potential effects of seismic and non-seismic information on the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region; (7) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.5.2 *Summary of Application*

Section 2.4.5 of the Fermi 3 COL FSAR, Revision 7, addresses probable maximum surge and seiche flooding. In addition, in FSAR Section 2.4.5, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-16-A Probable Maximum Surge and Seiche Flooding

  The applicant discussed criteria of combined events that cause flood induced by probable maximum surge and seiche along the shore of the Lake Erie and presented the determination of probable maximum meteorological winds and associated parameters.

  The applicant provided historical data related to surges and seiches for the area of Lake Erie in the vicinity of the site and discussed the wind-generated wave activity that can occur independently or coincidentally with a surge or seiche.

  The applicant discussed the possibility of oscillations of waves at natural periodicity, such as lake reflection and harbor resonance phenomena, and any resulting effects at the site.

  The applicant discussed the location of, and design criteria for, any special facilities for the protection of intake, effluent, and other safety-related facilities against surges, seiches, and wave action.

2.4.5.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the probable maximum surge and seiche flooding, and the associated acceptance criteria, are in Section 2.4.5 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.5:

- Probable Maximum Hurricane: To meet the requirements of 10 CFR Part 100, estimates of the probable maximum hurricane and the probable maximum storm surge, i.e., the storm surge induced by the PMH, are needed.

- Probable Maximum Wind Storm: To meet the requirements of 10 CFR Part 100, estimates of the PMWS and the storm surge induced by the PMWS are needed.

- Seiche and Resonance: To meet the requirements of 10 CFR Part 100, estimates of seiche and resonance in water bodies induced by meteorological causes, tsunamis, and seismic causes are needed.

- Wave Run-up: To meet the requirements of 10 CFR Part 100, an estimate of wind-induced wave run-up under PMH or PMWS winds is needed.

- Effects of Sediment Erosion and Deposition: To meet the requirements of 10 CFR Part 100, an assessment of loss of functionality of safety-related water supply to the plant caused by blockages due to sediment deposition or erosion during the storm surge or seiche is needed.

- Consideration of Other Site-Related Evaluation Criteria: The potential effects of site-related proximity, seismic, and non-seismic information as they relate to flooding and loss of safety-related water supply due to surge and seiche adjacent to the plant site and site regions are needed to meet the requirements of 10 CFR Part 100.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices and RG 1.102.

2.4.5.4 *Technical Evaluation*

The staff reviewed Section 2.0 of the Fermi 3 COL FSAR, Revision 7, and checked the referenced ESBWR DCD to ensure that the combination of the information in the ESBWR DCD and the information in the Fermi 3 COL FSAR appropriately represents the complete scope of information relating to this review topic. The staff's review confirms that the information contained in the application and the information incorporated by reference address the relevant information related to this section.

The staff reviewed the information in the Fermi 3 COL FSAR, Revision 7, as follows:

<u>COL Item</u>

- EF3 COL 2.0-16-A Probable Maximum Surge and Seiche Flooding

In FSAR Section 2.4.5, the applicant states:

> The analyses discussed in this section are based on ANSI/ANS-2.8-1992 (Reference 2.4-248). ANSI/ANS-2.8-1992, Section 9.2.3, describes the combined events criteria for an enclosed body of water, which is appropriate for analyzing postulated flooding at the Fermi 3 power reactor site due to wind and wave conditions in Lake Erie. Specifically, ANSI/ANS-2.8-1992, Section 9.2.3.1, states that the following combination of flood causing events provides an adequate design base for shore locations.
>
> 1. Probable maximum surge and seiche with wind-wave activity.
> 2. 100-year or maximum controlled level in water body, whichever is less.

The staff's evaluations of the information in this FSAR section are provided below:

Probable Maximum Winds and Associated Meteorological Parameters

In Subsection 2.4.5.1 of the FSAR, the applicant discussed meteorological winds and parameters for the probable maximum windstorm (PMWS). The applicant stated, "According to Section 7.2.2 of ANSI/ANS-2.8-1992, for the area of the Great Lakes in the vicinity of the site, the probable maximum surge and seiche is calculated from the PMWS." The applicant implied that the other events, such as probable maximum hurricane (PMH) and moving squall line are not required for this area.

The applicant referenced Subsection 7.2.2.1 of ANSI/ANS-2.8-1992 to provide a set of parameters associated with PMWS in the area of Great Lakes as follows: (1) set maximum over-water wind speed at ~ 160 km/hr (100 mph); (2) set lowest pressure within the PMWS to ~950 mbar; (3) apply a most critical, constant translational speed during the life of the PMWS; (4) assume that wind speeds over water vary diurnally from 1.3 (day) to 1.6 (night) times the overland speed; and (5) assume that winds blow 10 degrees across the isobars over the water body.

According to Section 7 of ANSI/ANS-2.8-1992, probable maximum winds and parameters should be presented with three metrological events, respectively: (1) PMH, (2) PMWS, and (3) moving squall line. The NRC staff checked region of occurrence for each event as described in the Subsections of 7.2.1.1, 7.2.2.1, and 7.2.3.1 of ANSI/ANS-2.8-1992. The staff verified that the Fermi 3 site area is beyond influence of PMH, which is within 200 miles from the U.S. coastline. The moving squall line in western Lake Erie, however, was not discussed by the applicant, even though it is significant in Lake Michigan. RAI 2.4.5-5, dated November 20, 2009 (ADAMS Accession No. ML092870355) the NRC staff requested that the applicant provide an evaluation to justify or an analysis to demonstrate that the surge calculated for moving squall line does not result in the most severe flood condition in this area.

In response to RAI 2.4.5-5, dated November 20, 2009 (ADAMS Accession No. ML092870355), applicant provided additional analysis based on several references listed in ANSI/ANS-2.8-1992 standards (Detroit Edison, 2010a). The main results from the previous studies are as follows: (1) most of moving squall lines in the Great Lakes region move in a northwest to southwest direction, and (2) the highest storm surge induced by squall lines was predicted at South Haven along the Lake Michigan with propagation speed of 60 knots. Though the Fermi site is sheltered from the predominant direction of squalls in the region, a worst-case scenario was analyzed with assumptions of an 8-mbar pressure jump and a 65-knot speed. The maximum surge would be 5.6 ft under the worst-case scenario at Fermi site. The surge level induced by moving squall lines under the worst-case scenario is much smaller than the maximum surge height of 10.3 ft derived from analysis of storm surge induced by PMWS. Therefore, the staff considers RAI 2.4.5-5 closed.

According to Subsection 7.2.2.3.1 of ANSI/ANS-2.8-1992, the set of parameters used by the applicant are recommended for the Great Lakes region, in lieu of detailed meteorological study for the area. Therefore, it is acceptable for the applicant to use these parameters for surge calculation.

Surge and Seiche

Information Submitted by the Applicant,

In Subsection 2.4.5.2 of the FSAR the applicant discussed the determination of the maximum postulated still-water level at the site. It assumes a predicted storm surge developed on the Lake Erie 100-year lake level. As indicated in the Subsection of 2.4.3 of the FSAR, the applicant found that this probable maximum storm surge water level is a key element in flooding Alternative III, which determines the plant design elevation basis.

The applicant discussed the historical lake level data, their sources, and the method to establish the Lake Erie 100-year water level. The applicant concluded that the 100-year lake level is 5.64 ft above the chart datum (or low water datum) for Lake Erie. This lake level corresponds to 575.1 ft (175.3 m) NAVD 88.

The applicant indicated that the surge analysis was guided by USACE's Coastal Engineering Manual (CEM). A method developed by Bretschneider (1966) was used by the applicant for wave setup to generate storm surge. The Bretschneider method assumes wind setup in a rectangular basin of constant depth with a non-exposed bottom and a perimeter wall. The applicant did not discuss in details how to apply this method to derive storm surge level in the Lake Erie.

As a part of RAI 2.4.1-1, dated July 29, 2009 (ADAMS Accession No. ML100830380), the staff requested additional data packages that support the applicant's calculations. In response to RAI 2.4.1-1, the applicant provided data packages including wave calculations. The calculation file consisted of bathymetric data evaluation, tables for calculating stresses and surge height using the Bretschneider method, and input/output files for the STWAVE model and the ACES model. The derivation and selection of parameters, however, was not discussed for the Bretschneider equation, especially the key parameters fetch length and water depth.

In Subsection 2.4.5.2 of the FSAR regarding surge analysis, the applicant mainly described STWAVE, a numerical model requiring input of bathymetric soundings for Lake Erie and discussed a general model setup for wind wave generation. The results of STWAVE model, however, were not used for surge prediction in this section but in the following section regarding wave run-up (2.4.5.3).

The applicant discussed the bathymetric data for Lake Erie and described its sources and input format for the STWAVE model. However, the bathymetric data were also not used for the surge prediction discussed in Subsection 2.4.5.2 of the FSAR.

The applicant concluded that the maximum probable storm surge (10.3 ft) predicted by the Bretschneider method developed on the 100-year lake level (575.1 ft NAVD 88) defines the maximum postulated still-water level on Lake Erie (585.4 ft NAVD 88).

The applicant discussed the historical records of seiche in Lake Erie and identified maximum recorded rise was 1.9 m (6.3 ft) and the maximum recorded fall was 2.7 m (8.9 ft) for the period of 1941-1981. The applicant concluded that the level of the rise due to seiche is significantly less than the calculated surge height.

NRC Staff's Technical Evaluation

The NRC staff verified the approach to determine the maximum postulated still-water level at the site area boundary by combining the storm surge with antecedent water level (Lake Erie 100-year lake level), according to the Subsection 2.4.5 of the SRP and Section 7 of ANSI/ANS-2.8-1992.

The staff verified the applicant's calculation of the 100-year Lake Erie water elevation. The staff independently checked the calculation of the average lake elevation from the 13 gaging stations on Lake Erie for each hourly interval. The staff then used the Log Pearson Type III distribution to calculate the 100-year lake elevation. The staff calculated a value of 574.7 ft NAVD 88 for the 100-year Lake Erie water elevation. This value is lower than the value calculated by the applicant of 575.1 ft NAVD 88, making the applicant's assumption more conservative. Therefore, the staff finds the applicants value to be acceptable, and RAI 2.4.1-1 is closed.

In the FSAR Subsection of 2.4.5.2, the applicant presented a result of 10.3 ft estimated for the probable maximum surge for Lake Erie using the Bretschneider method. The applicant, however, did not provide any discussion on the method, assumptions, parameter selection, and derivation in this section. Instead, the applicant mainly discussed the STWAVE model, which was not used by the applicant for predicting probable maximum surge and its elevation but was used to calculated wave action in the following section (2.4.5.3). According to the Section 7.3 of ANSI/ANS-2.8-1992, any "method used for surge or seiche level determination should be addressed." In RAI 2.4.5-6, dated January 29, 2010 (ADAMS Accession No. ML092870355) the NRC staff requested that the applicant provide: (1) descriptions of the assumptions of the Bretschneider method used for calculating wind setup under the PMWS, (2) rationale of choosing the Bretschneider method as a conservative approach to predict the probable maximum surge for Lake Erie compared to other commonly used methods, (3) details of the derivation of the key parameters of fetch length and water depth used in the Bretschneider method, and (4) a copy of the reference.

In response to RAI 2.4.5-6, the applicant provided detailed descriptions on the Bretschneider method and its application to calculate the surge under the PMWS condition. Two other methods, Zeider Zee and Sibul methods, were reviewed by the applicant. The applicant indicates that Zeider Zee method was mainly developed for a long and narrow water body at a depth deeper than Lake Erie and Sibul method predicts less surge height. To improve its application of the Bretschneider method, the applicant incorporated variation of lake depth by segmenting the lake along its length. The staff verified the information in the RAI response by performing confirmatory calculations. Based on the information provided in the response and a literature review, the staff finds the Bretschneider method is conservative and acceptable for the surge calculation.

In applying the Bretschneider method, the key parameters that affect storm surge are the fetch length, water depth, and coefficients under the PMWS condition. The fetch length was estimated by the longest straight line from the Fermi 3 site across Lake Erie to the east coast of the lake. The staff verified its distance of 154,781 m along the straight line. Lake Erie is divided evenly by 10 segments to account for variations of the lake depth, and the average depth for each segment was used for the calculation. The coefficients used for the Bretschneider equation are derived by the Corps of Engineers based on studies conducted at Lake Okeechobee. These coefficients are applicable because they were derived from a lake with similar characteristics. Therefore, the results are acceptable and RAI 2.4.5-6 is closed.

The applicant discussed the calculation of surge smaller than the probable maximum surge in FSAR Subsection 2.4.3.3 for calculation of the flooding alternatives. For Alternative I, the applicant stated that a surge of 4.0 feet was assumed. The applicant used the 100-year recurrence interval surge of 4.0 ft for the month of December to estimate the “surge and seiche resulting from the worst regional hurricane or windstorm” as required by ANSI/ANS-2.8-1992. The staff verified the height of the surge by checking the value on the USACE website that the applicant referenced (USACE, 2009). However, the applicant states in Section 2.4.5.2.2.3 of the FSAR that the maximum rise observed as a result of a seiche was 6.3 ft. Therefore, in RAI 2.4.3-2, dated January 29, 2010 (ADAMS Accession No. ML092870355), the staff requested that the applicant provide a rationale for choosing the 100-year surge as predicted by the USACE rather than using the maximum recorded seiche for flooding Alternative I. The response included a calculation of flooding Alternative I using the maximum recorded seiche at the site. The flooding height was calculated to be 581.7 ft NAVD 88, which is lower than the flooding level of Alternative III. Thus, Alternative I, even with the maximum recorded seiche, would not produce the PMF. For Alternative II, the applicant stated that a surge of 3.2 feet was assumed, based on the 33-year surge elevation as estimated by the USACE (2009). The staff verified the height of the surge by checking the applicant’s reference.

The staff verified the bathymetric data for Lake Erie submitted by the applicant to be accurate and that the data were converted to a format and used in the STWAVE model appropriately. This information is used by the staff and the applicant to model parameters in the FSAR Subsection 2.4.5.3.

The NRC staff has reviewed the historical data for seiche in Lake Erie and confirms its effect is less than impact of surge under PMWS in the site area. The staff concludes that the information was accurate and applicable to the site.

Wave Action

Information Submitted by the Applicant

In Subsection 2.4.5.3 of the FSAR, the applicant discussed the wave action from the PMWS winds including wind-induced wave (surge) and wave run-up. The applicant used a two dimensional, steady-state finite-difference model STWAVE to determine the wind-induced wave and its characteristics (wave height and period) at a selected point, which is located at the beginning of the nearshore. As the wave moves across the shore profile, the wave run-up was calculated by using the ACES model to predict the highest wave run-up and overtopping rates on an impermeable structure. The breaking waves and their heights were also predicted by using the ACES model at the points along the shore profile. The applicant states that the calculation assumes the maximum water level combining 100-year lake level and increased wave height due to surge and seiche.

In the wave calculation submitted by the applicant as a part of the response to RAI 2.4.1-1, dated July 29, 2009 (ADAMS Accession No. ML100830380), the applicant discussed the model setup for STWAVE, which included three input files specifying bathymetric grid data, wind parameters, peak frequency, water level correction, incident wave spectrum, and observation points. In the model simulation, Lake Erie is considered as an enclosed water body. A zero incident wave spectrum was assigned to the shoreline. A constant wind speed and direction were assigned to each simulation. The applicant performed 15 simulations with various wind directions from -42^o to 42^o where 0^o is a wind pointed directly to the west toward the site. The model output file presents the parameters of the generated wave at selected 197 observation points. The applicant states that “Several points that were closest to the shore were examined to determine the highest waves generated.” Based on the selected point that was located about 61 m (200 ft) from shore at a depth of 1 m (3.3 ft) chart datum, the highest waves were 3.77 m (12.37 ft) high with a peak spectral period of 11.1 seconds.

For wave run-up on an impermeable embankment, the applicant’s analysis is based on general assumptions as follows: (1) waves are monochromatic, normally incident to the structure, and unbroken in the vicinity of the structure toe; (2) waves are specified at the structure location; (3) all structure types are considered to be impermeable; (4) for sloped structures the crest of the structure must be above the still-water level; (5) for vertical and composite structures, partial and complete submersion for the structure is considered; (6) run-up estimates on sloped structures require the assumption of infinite structure height and a simple plane slope; and (7) the expressions for the transmission by overtopping use the actual finite structure height.

The applicant presented the ACES model inputs including wave type, breaking criteria, wave height, wave period, structure slope, structure height, slope type, and roughness coefficient. The model outputs from the ACES model were presented. The applicant’s simulations using the ACES model provided the following results: (1) a 0.49 ft wave increase when the generated wave moves through the nearshore area, and (2) the non-breaking wave at the toe of the berm can generate a wave run-up on the slope to a height of 3.0 ft, and overtopping rate of 0.16 ft^2/s.

For the breaking waves across the shore profile, the maximum wave height was calculated by the modified 1951 Miche criterion. The applicant presented results showing that the height of the breaking wave is 2.89 m (9.47 ft) at seawall and 0.68 m (2.23 ft) at the berm. However, the FSAR Table 2.4-224 shows inconsistent values for wave height in meters and feet.

Based on the results above, the applicant concluded that the wave run-up and breaking wave could not directly impact Fermi 3.

NRC Staff's Technical Evaluation

The NRC staff reviewed the approaches, methodology, and selected models and formulas used by the applicant for simulating wave set up, transmission, run-up, and break across the defined shore profile.

The NRC staff reviewed the input files for the STWAVE model and independently ran all simulations using the given input files and examined all output files, including the wave parameters at 197 locations. Results for wave heights at 197 locations range from 0 m to 5.16 m (16.93 ft). However, the applicant indicated that the wave height predicted by STWAVE at the selected point (200 ft from the shore) is 3.77 m (12.37 ft). In order to clarify the difference between staff and applicant calculated wave heights, the staff requested, in RAI 2.4.5-3, dated November 20, 2009 (ADAMS Accession No. ML093280179), that the applicant provide a plan-view figure detailing the spatially distributed results of the STWAVE simulation from which the storm surge height of 3.77 m (12.37 ft) was derived and to note the locations of Fermi 3 and the point/model cell chosen to determine the storm surge height presented in the response. The response to RAI 2.4.5-3, dated November 20, 2009 (ADAMS Accession No. ML093280179) did not provide all of the necessary details; therefore the staff requested that the applicant provide a map showing the distribution of the wave height overlain on the contours of the bathymetric map in RAI 2.4.5-7. The applicant's response to RAI 2.4.5-7**,** dated January 29, 2010 (ADAMS Accession No. ML092870355) provided additional insight to review the surges generated by the STWAVE model and examine the relationship between water depth and wave height.

In the responses to RAI 2.4.5-3 and RAI 2.4.5-7, the staff verified the results derived by the applicant by modeling the entire area of Lake Erie using the model grid of 100 m using STWAVE. The resulting distribution of wave heights is shown in Figure 2.4.5-1.

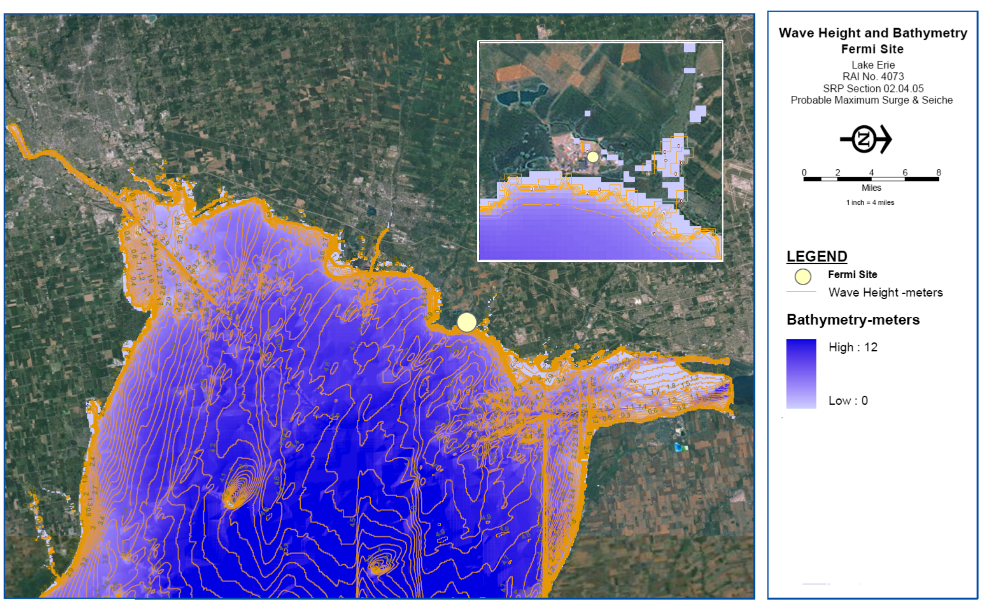


Figure 2.4.5-1. Wave Height and Bathymetry of the Western Lake Erie Derived by STWAVE

The STWAVE data points near the Fermi 3 are shown in Figure 2.4.5-2. The wave periods at all these points are 11.1 seconds. The wave height at the point near Fermi 3 is 3.7 m. The wave parameters selected by the applicant using STWAVE are conservative based on the staff's independent verification using additional data received in RAI responses. These parameters, including wave period and distribution of wave height, were used for further calculation of wave action across the shore.

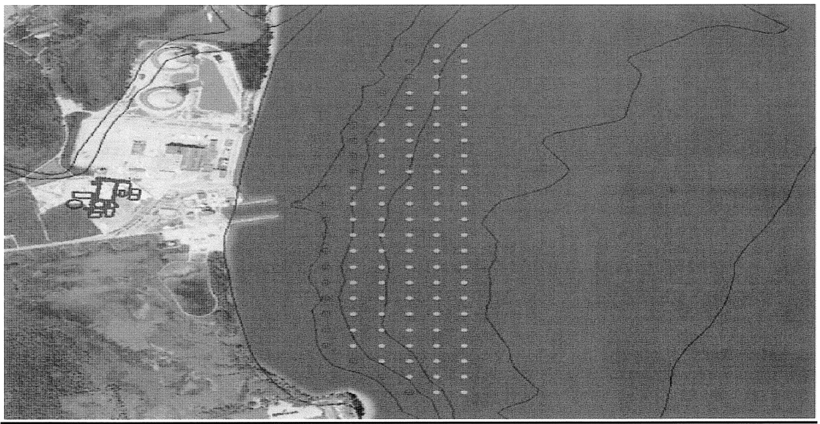


Figure 2.4.5-2. STWAVE Data Points Near Fermi 3

The NRC staff reviewed all of the inputs for simulations using the ACES model and equations 4 and 5 presented in Section 2.4.5.3.2 of the FSAR. To better examine the results, the staff summarized all elevations and the derived depths in Table 2.4.5-1 as shown in the shore profile in Figure 2.4.5-3

Table 2.4.5-1. Summary of Elevations, Water Depths, and Breaking Wave/Run-up Across the Shore Profile

Shore Profile Location	**Elevation (ft)**		**100-year Lake Level (ft, NAVD 88)**	**Surge Height (ft)**	**Probable Maximum Surge Water Level (ft, NAVD 88)**	**Water Depth (ft)**	**Breaking Wave (ft)**	**Wave Run-up (ft)**
	Plant Grade Datum	**NAVD 88**						
STWAVE Point	567.4	566.2	575.1	10.3	585.4	19.2	--	--
Nearshore	567.4 to 570.7	566.2 to 569.5	575.1	10.3	585.4	19.2 to 15.9	--	--
Chart Datum (low water datum)	570.7	569.5	575.1	10.3	585.4	15.9	--	--
Seawall	570.7 to 583	569.5-581.8	575.1	10.3	585.4	15.9 to 3.65	9.47	--
Onshore (Fermi 2 Plant Grade)	583 (flat)	581.8 (flat)	575.1	10.3	585.4	3.65	2.23	--
Toe of Berm to Fermi 3 Plant Grade	583 to 590.5	581.8 to 589.3	575.1	10.3	585.4	3.65 ft at toes of berm and 3.9 below Plant Grade	2.23	3.01
To covert feet to meters multiply the numbers by 0.3048					NAVD= North American Vertical Datum			

In summary, the applicant used the STWAVE model to perform wave set-up, which is developed on a maximum still lake level combining the 100-year lake level and probable surge level derived by the Bretschneider method. The results of STWAVE were used to estimate wave breaking and run-up. According to Chapter 4 of the Coastal Engineering Manual, the wave breaking and run-up mainly depended on the total water depth, which is sum of wave set-up and still water depth. The applicant, however, did not provide a discussion on the change in total water depth due to the wave set-up across the shore. Therefore, the staff requested that the applicant use graphs to illustrate the shore profile (from an STWAVE point to the Fermi 3 safety structures), wave characteristics across the shore (maximum still water level, wave length, wave height, breaking wave, run-up, etc.), their relationship, and quantitative information that supports conclusion of no impact to Fermi 3 safety structures. RAI 2.4.5-8, dated January 29, 2010 (ADAMS Accession No. ML092870355) was issued to the applicant.

In response to RAI 2.4.5-8 the applicant provided the information regarding the cross section from the STWAVE point to the Fermi 3 safety structures and the calculated the wave characteristics across the shore (Figure 2.4.5-3). The staff verified that all information is correct by checking the cross section data to that information used in the model. The shore profile data were used in the model input for the calculation of the breaking wave and wave run-up.

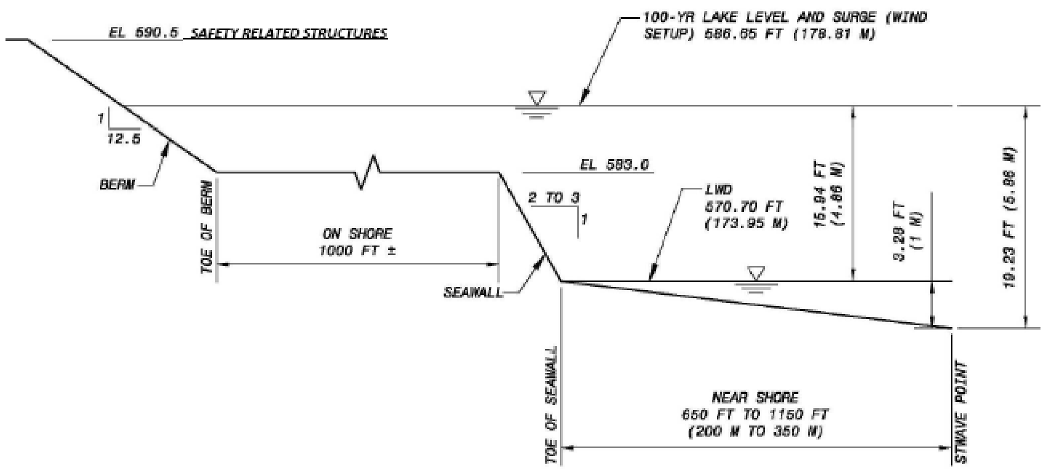


Figure 2.4.5-3. Cross Section from the STWAVE Point to the Fermi 3 Safety-Related Structure

The breaking wave was calculated using the ACES model at two points: the toe of seawall at a water depth of 15.9 ft and the toe of the berm at a depth of 3.65 ft. The wave characteristics were predicted by the model as shown in Figure 2.4.5-4, assuming a constant wave period as incoming wave at 11.1 second. The staff confirms that this assumption is conservative because a possible decreasing period of waves through the shore profile would result in a smaller wave length and height. In response to RAI 2.4.5-8 the applicant also corrected wave heights in the Table 2.4.224 of the FSAR. Based on a breaking wave calculated at the toe of the berm, the breaking wave developed on the probable maximum surge (585.4 ft NAVD 88) resulted in a water level of 587.6 ft NAVD 88, which is 1.7 ft below the nominal Fermi 3 plant grade of safety-related structures (589.3 ft NAVD 88). Thus, no breaking waves would impact safety-related structures.

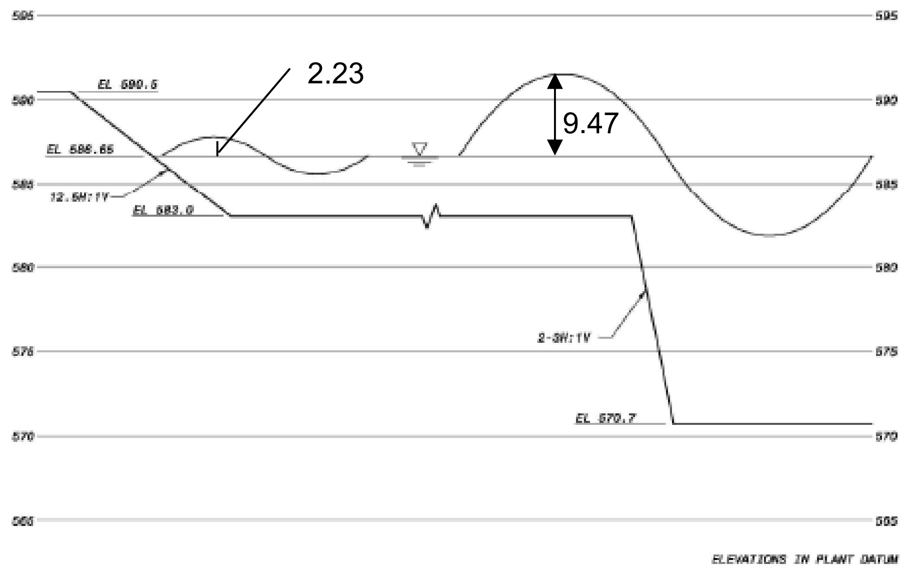


Figure 2.4.5-4. Characteristics of Breaking Waves at the Toes of the Seawall and Berm (Vertical Exaggeration, ~10:1; Elevation in Plant Datum).

The wave run-up was also calculated by the applicant using the ACES model to estimate the potential wave run-up developed on the slope of berm. The result of 3.01 ft of wave run-up is verified by the staff by independently running the model and comparing results. The potential highest level of wave run-up would be 588.41 ft (NAVD 88) based on the wave run-up developed on the probable maximum surge (585.4 ft NAVD 88). The highest level of the wave run-up is 0.9 ft below the nominal Fermi 3 plant grade of safety-related structures (589.3 ft NAVD 88). In response to RAI 2.4.5-8 the applicant showed wave characteristics of the potentially highest wave run-up on the shore cross section, demonstrating that no water would wash on to the nuclear island impacting the safety-related structures. The staff finds the conclusion acceptable because it meets the requirements of 10 CFR Part 100, 10 CFR 100.23(d), and 10 CFR 52.79(a)(1)(iii).

To ensure all information on methods, assumptions, and calculations is included the FSAR related to DTE responses to RAI 2.4.5-5, RAI 2.4.5-6, RAI 2.4.5-7, and RAI 2.4.5-8, the staff requested an update to the relevant sections in the FSAR. The staff reviewed DTE responses and finds the correction and updates to the FSAR to be acceptable because they meet the requirements of 10 CFR Part 100, 10 CFR 100.23(d), and 10 CFR 52.79(a)(1)(iii).

Resonance

Information Submitted by the Applicant

In Subsection 2.4.5.4 of the FSAR, the applicant states that the Fermi site's location next to the open water of Lake Erie "results in a natural period of oscillation of the flooded area that is much greater than that of the incident shallow-water storm waves. Consequently, resonance is not a problem at the site during PMWS occurrence."

NRC Staff's Technical Evaluation

The NRC staff reviewed this section and finds that the resonance in the enclosed water bodies induced by meteorological causes, tsunamis, and seismic causes were not well addressed. In RAI 2.4.5-4, dated November 20, 2009 (ADAMS Accession No. ML093280179), the staff requested that the applicant provide the quantitative basis and methodology for determining the natural period of oscillation of the flooded area and the incident shallow-water storm waves.

In response to RAI 2.4.5-4, the applicant estimated the first six modes of oscillation, which range from 29 to 124 seconds. The peak spectral period of the incoming waves is 11.1 seconds near Fermi 3, derived from the STWAVE model for the Lake Erie. The period of the incoming wave is much less than the period of oscillation. The staff verified the applicant's conclusion that resonance is not a problem at the site during PMWS occurrence.

Sedimentation and Erosion

Information Submitted by the Applicant

In Subsection 2.4.5.5, the applicant states that "Fermi 3 does not rely on Lake Erie for a safety-related water source. Therefore, the loss of functionality of a safety-related water supply to Fermi 3 caused by blockages due to sediment deposition or erosion during a storm surge or seiche event is not a concern."

NRC Staff's Technical Evaluation

The NRC staff finds that sedimentation and erosion are not problems at the site because safety related water would not be impacted and therefore the requirements of 10 CFR Part 100, 10 CFR 100.23(d), and 52.79(a)(1)(iii) are met.

Protective Structures

Information Submitted by the Applicant

On the basis of the wave run-up analysis presented in Subsection 2.4.5.6 of the FSAR, the applicant concluded that the waves under PMWS will not overtop the berm to adversely impact Fermi 3. Therefore, additional structures are not needed.

NRC Staff's Technical Evaluation

After the NRC staff reviewed the section and subsequent RAIs (RAI 2.4.5-3, RAI 2.4.5-6, RAI 2.4.5-7, RAI 2.4.5-8, and RAI 2.4.5-10), the wave run-up analysis was verified and found to be acceptable. As discussed in 2.4.5.3, the potential wave run-up (3.01 ft) developed on the probable maximum surge (585.4 ft NAVD 88) could result in a run-up level of 588.41 ft NAVD 88, which is 0.9 ft below the elevation of the safety structures. The waves under PMWS, therefore, would not overtop the berm and adversely impact Fermi 3.

For the reasons given above, the staff concludes that the identification and consideration of the probable maximum storm surge and its wave actions at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

2.4.5.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.5.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.5 of NUREG–0800, and other NRC RGs. The staff's review concluded that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-16-A as it relates to probable maximum surge and seiche flooding.

As set forth above, the applicant has presented and substantiated information relative to the probable maximum storm surge and its wave actions important to the design and siting of this plant. The staff has reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the probable maximum storm surge and its wave actions at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the probable maximum storm surge and its wave actions. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.6 Probable Maximum Tsunami Hazards

2.4.6.1 *Introduction*

The probable maximum tsunami (PMT) hazards are addressed to ensure that any potential tsunami hazards to the SSCs important to safety are considered in plant design. The specific areas of review are as follows: (1) historical tsunami data, including paleo tsunami mappings and interpretations, regional records and eyewitness reports, and more recently available tide gauge and real-time bottom pressure gauge data; (2) PMT that may pose hazards to the site; (3) tsunami wave propagation models and model parameters used to simulate the tsunami wave propagation from the source toward the site; (4) extent and duration of wave run-up during the inundation phase of the PMT event; (5) static and dynamic force metrics including the inundation and drawdown depths, current speed, acceleration, inertial component, and momentum flux that quantify the forces on any safety-related SSCs that may be exposed to the tsunami waves; (6) debris and water-borne projectiles that accompany tsunami currents and may impact safety-related SSCs; (7) effects of sediment erosion and deposition caused by tsunami waves that may result in blockage or loss of function of safety-related SSCs; (8) potential effects of seismic and non-seismic information on the postulated design bases and how they relate to tsunami in the vicinity of the site and the site region; (9) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.6.2 *Summary of Application*

Subsection 2.4.6 of the Fermi 3 COL FSAR, Revision 7, addresses PMT hazards. In addition, in Section 2.4.6, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-17-A Probable Maximum Tsunami Hazards

  To address this COL item, the applicant stated that there is no tsunami hazard in the vicinity of the Fermi 3 site.

2.4.6.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the PMT hazards, and the associated acceptance criteria, are in Section 2.4.6 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding areas and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.6:

- Historical Tsunami Data: The application should provide a complete description of historical tsunami data near the proposed plant site.

- Probable Maximum Tsunami: The application should provide an assessment of the PMT for the proposed site.

- Tsunami Propagation Models: The application should provide a description of the tsunami wave propagation models used in the applicant’s SAR.

- Wave Runup, Inundation, and Drawdown: The application should provide the extents and durations of inundation and drawdown near the proposed site.

- Hydrostatic and Hydrodynamic Forces. The application should provide a set of metrics that describes the hydrostatic and hydrodynamic forces caused by the PMT on the safety-related SSC.

- Debris and Water-Borne Projectiles. The application should provide an assessment of the debris and water-borne projectiles that may accompany PMT currents.

- Effects of Sediment Erosion and Deposition. The application should provide an assessment of the effects of sediment erosion and deposition near the proposed locations of safety-related SSC.

- Consideration of Other Site-Related Evaluation Criteria. The application should provide an evaluation of the potential effects of site-related proximity, seismic, and non-seismic information as they affect tsunamis near the plant site and site regions.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, and 1.102.

2.4.6.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.6 of the Fermi 3 COL FSAR, Revision 7, as follows:

COL Item

- EF3 COL 2.0-17-A Probable Maximum Tsunami Hazards

  To address this COL item, the applicant stated that there is no tsunami hazard in the vicinity of the Fermi 3 site.

Information Submitted by the Applicant

The applicant states that “Based on the history of the area, local seismic disturbances would result only in minor excitations in the lake. No tsunami has been recorded in Lake Erie; the only remotely similar phenomena observed have been low-amplitude seiches resulting from sudden barometric pressure differences.” The applicant concluded that there are no potential tsunamis or tsunami-like waves which could affect safety-related structures or components at Fermi 3.

NRC Staff's Technical Evaluation

To verify applicant's conclusion, the NRC staff searched tsunami database (National Geophysical Data Center, NOAA) and found two historical events: one in the northern end of Lake Erie and the other near the Detroit River. The staff requested that the applicant conduct a thorough search for historical tsunamis in the area providing an evaluation to support the applicant's conclusion in RAI 2.4.6-1.

In response to RAI 2.4.6-1, dated January 29, 2010 (ADAMS Accession No. ML100330612), the applicant provided additional information regarding historic records in the area, indicating that the recorded historical events were only minor disturbances or seiches and no actual tsunamis are evident. The applicant's review of historic data is complete and accurate, and the response is deemed acceptable because it meets the requirements of 10 CFR Part 100, 10 CFR 100.23(d), and 10 CFR 52.79(a)(1)(iii).

2.4.6.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.6.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.6 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-17-A as it relates to probable maximum tsunami hazards.

As set forth above, the applicant has presented and substantiated information relative to PMT important to the design and siting of this plant. The staff reviewed the available information provided. For the reasons given above, the staff concludes that the identification and consideration of the tsunamis at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR 52.79(a)(31) and 10 CFR 100.20(c), with respect to determining the acceptability of the site for the ESBWR design.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff accepts the methodologies used to determine the presence of tsunami. Accordingly, the staff concludes that the use of these methodologies results in design bases containing a sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified design bases meet the requirements of 10 CFR 100.20(c) with respect to establishing the design basis for SSCs important to safety.

2.4.7 Ice Effects

The emergency cooling system for Fermi 3 is provided by the UHS which does not rely on water sources external to the plant and is not affected by ice conditions.

2.4.7.1 *Introduction*

The ice effects are addressed to ensure that safety-related facilities and water supply are not affected by ice-induced hazards. The specific areas of review are as follows: (1) regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, frazil ice formation, etc.); (2) potential effects of ice-induced, high- or low-flow levels on safety-related facilities and water supplies; (3) potential effects of a surface ice-sheet to reduce the volume of available liquid water in safety-related water reservoirs; (4) potential effects of ice to produce forces on, or cause blockage of, safety-related facilities; (5) potential effects of seismic and non-seismic data on the postulated worst-case icing scenario for the proposed plant site; (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.7.2 *Summary of Application*

Section 2.4.7 of the Fermi 3 COL FSAR, Revision 7, addresses ice effects. In addition, in Section 2.4.7, the applicant provides the following:

COL Item

- EF3 COL 2.0-18-A Ice Effects

  To address this COL item, the applicant stated that there are no expected ice effects to safety-related facilities at the site of Fermi 3.

2.4.7.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the ice effects, and the associated acceptance criteria, are in Section 2.4.7 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 52.79(a)(1)(iii), as it relates to the hydrologic characteristics of the proposed site with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.7:

- Historical Ice Accumulation: The application should include a complete history of ice formation at and in the vicinity of the site.

- High and Low Water Levels: The application should include estimates of water levels resulting from potential ice flooding or low flows.

- Ice Sheet Formation: The application should include estimates of the most severe ice sheet formation in water storage reservoirs.

- Ice-induced Forces and Blockages: The application should provide estimates of the most severe ice-induced forces on safety-related SSC.

- Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity, seismic, and non-seismic information as they relate to worst-case icing scenarios adjacent to and on the plant site and site regions are appropriately take into account.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, and 1.102.

2.4.7.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.7 of the Fermi 3 COL FSAR, Revision 7, as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-18-A Ice Effects

  To address this COL item, the applicant stated that there are no expected ice effects to safety-related facilities at the site of Fermi 3.

No discussion was presented on ice effects in the FSAR. The staff issued RAI 2.4.3-1 requesting for information to support the conclusion that there would be no impacts to Fermi 3 safety-related features due to ice effects. In the response to RAI 2.4.3-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant cited checking the USACE ice jam database for historical occurrences of ice jams on Swan Creek. The applicant found no historic ice jams on Swan Creek in the ice jam database. Also, in the response to RAI 2.4.9-1, the applicant stated that no ice jams were observed on Swan Creek over the period from 1957 to the present, during which time the applicant managed the Fermi site.

To verify the applicant's response, the staff performed a search of the USACE ice jam database and found no evidence of an historical ice jam on Swan Creek (USACE, 2010). However, in the description of the ice jam database, the USACE stated that the historical records of ice jams are primarily limited to waterways that have USGS gaging stations (USACE, 2010). There have never been continuously recording USGS gaging stations on Swan Creek, so the likelihood of an historical ice jam being recorded on Swan Creek is low. However, the applicant stated that there have been no ice jams on Swan Creek since 1957. The gaging station on the River Raisin to the south has recorded several ice jams since that time, and records of this flooding are found both on the ice jam database and in local media sources. No personal accounts or media accounts of flooding in Swan Creek due to ice jams were found. Therefore, the staff finds that the applicant's answer is acceptable in that ice jams are not likely to contribute to flooding in Swan Creek.

2.4.7.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.7.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.7 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-18-A as it relates ice effects.

As set forth above, the applicant has presented and substantiated information relative to the ice effects important to the design and citing of this plant. The staff has reviewed the available information provided and, for the reasons given above, concludes that the identification and consideration of the potential for ice flooding, ice blockage of water intakes, ice forces on structures, and the minimum low water levels (from upstream ice blockage) are acceptable and meet the requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR 100.20(c), with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff has generally accepted the methodologies used to determine the potential for ice formation and blockage reflected in these site characteristics. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated.

2.4.8 Cooling Water Canals and Reservoirs

2.4.8.1 *Introduction*

The cooling water canals and reservoirs used to transport and impound water supplied to the SSCs important to safety are reviewed to verify their hydraulic design basis. The specific areas of review are as follows: (1) design bases postulated and used by the applicant to protect structures such as riprap, inasmuch as they apply to safety-related water supply; (2) design bases of canals pertaining to capacity, protection against wind waves, erosion, sedimentation, and freeboard and the ability to withstand a PMF (surges, etc.), inasmuch as they apply to a safety-related water supply; (3) design bases of reservoirs pertaining to capacity, PMF design basis, wind wave and run-up protection, discharge facilities (e.g., low-level outlet, spillways, etc.), outlet protection, freeboard, and erosion and sedimentation processes inasmuch as they apply to a safety-related water supply; (4) potential effects of seismic and non-seismic information on the postulated hydraulic design bases of canals and reservoirs for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.8.2 *Summary of Application*

Section 2.4.8 of the Fermi 3 COL FSAR, Revision 7, addresses the use of cooling water canals and reservoirs. In addition, in Section 2.4.8, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-19-A Cooling Water Canals and Reservoirs

  To address this COL item, the applicant describes in the FSAR that no cooling water canals or reservoirs are used for safety related features by Fermi 3. The staff confirmed that Fermi 3 does not use cooling water canals or reservoirs for plant safety.

2.4.8.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the cooling water canals and reservoirs, and the associated acceptance criteria, are in Section 2.4.8 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.8:

- Hydraulic Design Bases for Protection of Structures: To meet the requirements of 10 CFR Part 100, a complete description of the hydraulic design bases for protection of structures is needed.

- Hydraulic Design Bases of Canals: To meet the requirements of 10 CFR Part 100, a complete description of the hydraulic design bases related to the capacity, protection against wind waves, erosion, sedimentation, and freeboard, and the ability to withstand a PMF, surges, etc., is needed.

- Hydraulic Design Bases of Reservoirs: To meet the requirements of 10 CFR Part 100, a complete description of the design bases of safety-related reservoirs related to their capacity, PMF design basis, wind wave and run-up protection, discharge facilities (e.g., low-level outlet, spillways, etc.), outlet protection, freeboard, and erosion and sedimentation processes is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, a complete description of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated design bases of safety-related canals and reservoirs is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices, RG 1.102, and RG 1.125, "Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants."

2.4.8.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.8 of the Fermi 3 COL FSAR, Revision 7, as follows:

<u>*COL Items*</u>

- EF3 COL 2.0-19-A Cooling Water Canals and Reservoirs

Cooling Water Canals and Reservoirs to address this COL item, the applicant describes in the FSAR that no cooling water canals or reservoirs are used for safety related features by Fermi 3. The staff confirmed that Fermi 3 does not use cooling water canals or reservoirs for plant safety.

The NRC staff reviewed Subsection 2.4.8 of the Fermi 3 COL FSAR. The staff has confirmed that the information in the application addresses the relevant information related to this subsection is sufficient and appropriate.

The applicant describes in the FSAR that no cooling water canals or reservoirs are used for safety-related features by Fermi 3. The staff confirmed that Fermi 3 does not use cooling water canals or reservoirs for plant safety.

The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the design bases of canals and reservoirs is acceptable and meets the requirements of 10 CFR 100.20(c), with respect to determining the acceptability of the site.

2.4.8.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.8.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.8 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-19-A as it cooling water canals and reservoirs.

As set forth above, the applicant has presented and substantiated information relative to the design bases of canals and reservoirs important to the design and citing of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the design bases of canals and reservoirs is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d), with respect to determining the acceptability of the site.

2.4.9 Channel Diversions

No safety-related systems, structures, or components are impacted. The water supply for Fermi 3 is not obtained from channels; therefore, this section is not applicable from a water supply perspective.

2.4.9.1 *Introduction*

Plant and essential water supplies used to transport and impound water supplies were evaluated to ensure that they will not be adversely affected by stream or channel diversions. The review includes stream channel diversions away from the site (which may lead to a loss of safety-related water) and stream channel diversions toward the site (which may lead to flooding). In addition, in such an event, the applicant needs to show that alternate water supplies are available to safety-related equipment. The specific areas of review are as follows: (1) historical channel migration phenomena including cutoffs, subsidence, and uplift; (2) regional topographic evidence that suggests a future channel diversion may or may not occur (used in conjunction with evidence of historical diversions); (3) thermal causes of channel diversion, such as ice jams, which may result from downstream ice blockages that may lead to flooding from backwater or upstream ice blockages that can divert the flow of water away from the intake; (4) potential for forces on safety-related facilities or the blockage of water supplies resulting from channel migration-induced flooding (flooding not addressed by hydrometeorological-induced flooding scenarios in other sections); (5) potential of channel diversion from human-induced causes (i.e., land-use changes, diking, channelization, armoring, or failure of structures); (6) alternate water sources and operating procedures; (7) potential effects of seismic and non-seismic information on the postulated worst-case channel diversion scenario for the proposed plant site; (8) any additional information requirement prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.9.2 *Summary of Application*

Section 2.4.9 of the Fermi 3 COL FSAR, Revision 7, addresses channel diversions. In addition, in FSAR Section 2.4.9, the applicant provides the following:

<u>COL Items</u>

- EF3 COL 2.0-20-A Channel Diversions

  To address this COL item, the applicant stated that there is no potential for upstream diversion or rerouting of the source of cooling water with respect to seismic, topographical, geologic, and thermal evidence in the region. Fermi 3 does not rely on channels for water supply, so this section is not applicable.

2.4.9.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the channel diversions, and the associated acceptance criteria, are in Section 2.4.9 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d) sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves the site.
- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.9:

- Historical Channel Diversions: To meet the requirements of 10 CFR Part 100, a complete history of channel diversions at and in the vicinity of the site is needed.
- Regional Topographic Evidence: To meet the requirements of 10 CFR Part 100, a description of regional topographic evidence as it relates to channel diversions is needed.
- Ice Causes: To meet the requirements of 10 CFR Part 100, estimates of the most severe ice-induced channel diversion are needed.
- Flooding of Site Due to Channel Diversions: To meet the requirements of 10 CFR Part 100, estimates of the most severe channel diversion induced forces on SSC important to safety are needed.
- Human-Induced Causes of Channel Diversion: To meet the requirements of 10 CFR Part 100, an assessment of the potential for human-induced channel diversions, in the vicinity of the site (e.g., land-use changes, diking, channelization, armoring or failure of such structures) is needed.
- Alternate Water Sources: To meet the requirements of 10 CFR Part 100, assessments of alternate water sources and operating procedures are needed.
- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, a description of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated worst-case channel diversion scenario for the proposed plant site is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27, 1.29, 1.59, as supplemented by best current practices and 1.102.

2.4.9.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.9 of the Fermi 3 COL FSAR, Revision 7, as follows:

<u>COL Item</u>

- EF3 COL 2.0-20-A Channel Diversions

  To address this COL item, the applicant stated that there is no potential for upstream diversion or rerouting of the source of cooling water with respect to seismic, topographical, geologic, and thermal evidence in the region. Fermi 3 does not rely on channels for water supply, so this section is not applicable.

The NRC staff reviewed the information submitted by the applicant related to potential channel diversions at the Fermi 3 site.

In the FSAR, the applicant stated that this section is not applicable to Fermi 3, as Fermi 3 does not rely on channels for water supply. The staff issued RAI 2.4.9-1 requesting information supporting the conclusion that a diversion along Swan Creek from an ice jam, a landslide, or another mechanism is unlikely. In the response to RAI 2.4.9-1, dated September 30, 2009 (ADAMS Accession No. ML092790561), the applicant provided a discussion supporting the conclusion that a diversion along Swan Creek is unlikely. The applicant stated that the geology and topography of the Swan Creek watershed are not conducive to large scale landslides that could cause a channel diversion. First, the applicant described the geology as being a sequence of bedrock overlain by glacial till deposits overlain by lacustrine deposits. Then the applicant stated that the deposits increase in strength with depth and that the topography of the watershed is not steep, making the chances of a large area landslide caused by a failing lower layer small. The applicant stated that the banks of Swan Creek do experience small failures, but they would not be of large enough size to divert Swan Creek. Then the applicant referred to FSAR Section 2.4.7 and the response to RAI 2.4.3-1 (ADAMS Accession No. ML092790561, dated September 30, 2009) to support the conclusion that it is unlikely that an ice jam would occur on Swan Creek and cause a diversion. The applicant also stated that no manmade or natural diversions were observed over the period from 1957 to the present, during which time the applicant managed the Fermi site. The staff found the applicant’s response acceptable.

2.4.9.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.9.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.9 of NUREG–0800, and other NRC RGs. The staff’s review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-20-A as it relates to channel diversions.

As set forth above, the applicant has presented and substantiated information relative to the channel diversion effects important to the design and citing of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the potential for channel diversion is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d), with respect to determining the acceptability of the site.

2.4.10 Flooding Protection Requirements

2.4.10.1 *Introduction*

The flooding protection requirements address the locations and elevations of safety-related facilities and those of structures and components required for protection of safety-related facilities. These requirements are then compared with design-basis flood conditions to determine whether flood effects need to be considered in the plant's design or in emergency procedures. The specific areas of review are as follows: (1) safety-related facilities exposed to flooding; (2) type of flood protection (e.g., "hardened facilities," sandbags, flood doors, bulkheads, etc.) provided to the SSCs exposed to floods; (3) emergency procedures needed to implement flood protection activities and warning times available for their implementation reviewed by the organization responsible for reviewing issues related to plant emergency procedures; (4) potential effects of seismic and non-seismic information on the postulated flooding protection for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.10.2 *Summary of Application*

Subsection 2.4.10 of the Fermi 3 COL FSAR, Revision 7, addresses the site specific information on flooding protection requirements. In addition, in FSAR Section 2.4.9, the applicant provides the following:

COL Item

- EF3 COL 2.0-21-A Flooding Protection Requirements

  To address this COL item, the applicant stated that the safety-related features of the Fermi 3 plant are designed to be above the probable maximum flood elevation and thus no flooding protection is required.

2.4.10.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the flooding protection requirements, and the associated acceptance criteria, are in Section 2.4.10 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Subsection 2.4.10:

- Safety-related Facilities Exposed to Flooding: To meet the requirements of 10 CFR Part 100, identification of all SSC exposed to flooding is needed.

- Type of Flood Protection: To meet the requirements of 10 CFR Part 100, an evaluation of the applicant's proposed flood protection measures is needed.

- Emergency Procedures: To meet the requirements of 10 CFR Part 100, a listing of proposed emergency procedures is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, an assessment regarding the potential effects of site-related proximity, seismic, and non-seismic information on the postulated flooding protection is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.29, 1.59, as supplemented by best current practices, and RG 1.102.

2.4.10.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.10 of the Fermi 3 COL FSAR, Revision 7, as follows:

COL Item

- EF3 COL 2.0-21-A Flooding Protection Requirements

  To address this COL item, the applicant stated that the safety-related features of the Fermi 3 plant are designed to be above the probable maximum flood elevation and thus no flooding protection is required.

The NRC staff reviewed Subsection 2.4.10 of the Fermi 3 COL FSAR. The elevation of the design plant grade for Unit 3 is 589.3 ft NAVD 88. The NRC staff confirms that this elevation is 3.9 ft above the maximum flood level at the site determined by Alternative III, which is the worst scenario among Alternatives I, II, and III specified by the ANSI/ANS-2.8-1992 guidelines. The Alternative III includes 25-year flood in Swan Creek, probable maximum surge and seiche in Lake Erie, and 100-year elevation of Lake Erie. The staff verified analysis of wave actions caused by the probable maximum storm surge developed on the 100-year lake level and finds that the highest levels of wave breaking and run-up are below the design plant grade.

2.4.10.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.10.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.10 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-21-A as it relates to flooding protection requirements.

As set forth above, the applicant has presented and substantiated information relative to the flood protection measures important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the flood protection measures is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 100.20(c), and 100.23(d), with respect to determining the acceptability of the site.

2.4.11 Low Water Considerations

2.4.11.1 *Introduction*

The low water considerations address natural events that may reduce or limit the available safety-related cooling water supply. The applicant ensures that an adequate water supply will exist to shut down the plant under conditions requiring safety-related cooling. The specific areas of review are as follows: (1) worst drought considered reasonably possible in the region; (2) effects of low water surface elevations caused by various hydrometeorological events and a potential blockage of intakes by sediment, debris, littoral drift, and ice because they can affect the safety-related water supply; (3) effects on the intake structure and pump design bases in relation to the events described in FSAR Sections 2.4.7, 2.4.8, 2.4.9, and 2.4.11, which consider the range of water supply required by the plant (including minimum operating and shutdown flows during anticipated operational occurrences and emergency conditions) compared with availability (considering the capability of the UHS to provide adequate cooling water under conditions requiring safety-related cooling); (4) use limitations imposed or under discussion by Federal, State, or local agencies authorizing the use of the water; (5) potential effects of seismic and non-seismic information on the postulated worst-case low water scenario for the proposed plant site; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.11.2 *Summary of Application*

Subsection 2.4.11 of the Fermi 3 COL FSAR, Revision 7, addresses the impacts of low water on water supply. In addition, in FSAR Section 2.4.11, the applicant provides the following:

COL Item

- EF3 COL 2.0-22-A Low Water Considerations

  To address this COL item, the applicant described that the no external water sources are relied upon for operation of the UHS, therefore low water levels in Lake Erie and Swan Creek are not critical to the operation safety related features of Fermi 3.

2.4.11.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for low water considerations, and the associated acceptance criteria, are in Section 2.4.11 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Section 2.4.11:

- Low Water from Drought: To meet the requirements of 10 CFR Part 100, a complete history of low water conditions at and in the vicinity of the site is needed.

- Low Water from Other Phenomena: To meet the requirements of 10 CFR Part 100, a complete history of low water conditions, caused by phenomena other than a drought, at and in the vicinity of the site is needed.

- Effect of Low Water on Safety-Related Water Supply: To meet the requirements of 10 CFR Part 100, a thorough description of all safety-related water supply requirements and the effects of the most severe low water event reasonably possible at or in the vicinity of the site is needed.

- Water Use Limits: To meet the requirements of 10 CFR Part 100, a thorough description of water use and discharge limitations (both physical and legal), already in effect or under discussion by responsible Federal, regional, State, or local authorities, that may affect water supply at the plant that have been considered and are substantiated by reference to reports of the appropriate agencies is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR Part 100, the applicant should provide an assessment of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated worst-case low-flow scenario for the proposed plant site.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.27 and 1.29.

2.4.11.4 *Technical Evaluation*

The staff reviewed the information in Section 2.4.11 of the Fermi 3 COL FSAR, Revision 7, as follows:

<u>*COL Item*</u>

- EF3 COL 2.0-22-A Low Water Considerations

  To address this COL item, the applicant described that the no external water sources are relied upon for operation of the UHS, therefore low water levels in Lake Erie and Swan Creek are not critical to the operation safety related features of Fermi 3.

The NRC staff reviewed Subsection 2.4.11 of the Fermi 3 COL FSAR. The applicant stated that no external water sources are used for safety-related cooling of Fermi 3. Low water elevations in Lake Erie or Swan Creek pose no safety-related risk to Fermi 3.

The applicant stated that Lake Erie provides the make-up cooling water for Fermi 3. The lowest recorded water level at the Fermi gage was 563.9 ft NAVD 88. The invert elevation of the pump suction at the water intake for the Fermi 2 plant is at 553.3 ft NAVD 88, which is 10 feet below the lowest recorded elevation of Lake Erie at the Fermi gage. The applicant then stated that low lake levels would not impact pump suction, due to the depth at which the pump suction occurs.

The NRC staff reviewed the lake level data at the Fermi gage submitted by the applicant in response to RAI 2.4.5-1 dated September 30, 2009 (ADAMS Accession No. ML092790561). The staff confirmed that the lowest water elevation at the Fermi gage was 563.9 ft NAVD 88. The staff therefore finds the applicant has addressed low water considerations at Fermi 3 because low water level elevation will not impact safety-related functions.

The staff's review confirms that the information in the application addresses the relevant information related to this subsection.

2.4.11.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.11.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.11 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-22-A as it relates to low water considerations.

As set forth above, the applicant has presented and substantiated information relative to the low water effects important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the potential for low water conditions is acceptable and meets the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d), with respect to determining the acceptability of the site.

2.4.12 Groundwater

2.4.12.1 *Introduction*

The groundwater description includes the hydrogeological characteristics of the site, and the evaluation includes the effects of groundwater on plant foundations and the reliability of safety-related water supply and dewatering systems. The specific areas of review are as follows: (1) identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals and known and likely future withdrawals, flow rates, travel time, gradients (and other properties that affect the movement of accidental contaminants in groundwater), groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and manmade changes that have the potential to cause long-term changes in local groundwater regime; (2) effects of groundwater levels and other hydrodynamic effects of groundwater on design bases of plant foundations and other SSCs important to safety; (3) reliability of groundwater resources and related systems used to supply safety-related water to the plant; (4) reliability of dewatering systems to maintain groundwater conditions within the plant's design bases; (5) potential effects of seismic and non-seismic information on the postulated worst-case groundwater conditions for the proposed plant site; and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.12.2 *Summary of Application*

Subsection 2.4.12 of the Fermi 3 COL FSAR, Revision 7, addresses the groundwater in terms of impacts on structures and water supply. In addition, in FSAR Section 2.4.12, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-23-A Groundwater

  To address this COL item, the applicant described the regional and local ground water aquifers, formations, sources, and sinks. The Fermi site does not use groundwater for any purposes, and Fermi 3 does not require a dewatering system.

The applicant described the present and projected future regional water use, relying on reports and databases of the USGS, the USEPA, and the State of Michigan. The applicant provided discussion and illustrations of water levels and flow directions both regionally (bedrock aquifer) and on site (bedrock and overburden aquifers).

2.4.12.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the groundwater, and the associated acceptance criteria, are in Section 2.4.12 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).

- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Section 2.4.12:

- Local and Regional Groundwater Characteristics and Use: To meet the requirements of 10 CFR 50.55a, 10 CFR 100.20(c)(3), 10 CFR 100.23(d), and 10 CFR 100.20(c), a complete description of regional and local groundwater aquifers, sources, and sinks, local and regional groundwater use, present and known and likely future withdrawals, regional flow rates, travel time, gradients, and velocities, subsurface properties that affect movement of contaminants in the groundwater, groundwater levels including their seasonal and climatic fluctuations, groundwater monitoring and protection requirements, and any man-made changes with a potential to affect regional groundwater characteristics over a long period of time is needed.

- Effects on Plant Foundations and other Safety-Related Structures, Systems, and Components: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of the effects of groundwater levels and other hydrodynamic effects on the design bases of plant foundations and other SSC important to safety is needed.

- Reliability of Groundwater Resources and Systems Used for Safety-Related Purposes: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of all SSC important to safety that depend on groundwater is needed.

- Reliability of Dewatering Systems: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), a complete description of the site dewatering system, including its reliability to maintain the groundwater conditions within the groundwater design bases of SSC important to safety is needed.

- Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR 50.55a, 100.20(c)(3), 100.23(d), and 100.20(c), the applicant's assessment of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated worst-case scenario related to groundwater effects for the proposed plant site is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RG 1.27.

2.4.12.4 *Technical Evaluation*

The NRC staff reviewed Section 2.4.12 of the Fermi 3 COL FSAR and participated in site visits. The staff's review confirms that the information contained in the application and incorporated by reference addresses the relevant information related to this subsection.

COL Item

- EF3 COL 2.0-23-A Groundwater

  To address this COL item, the applicant described the regional and local ground water aquifers, formations, sources, and sinks. The Fermi site does not use groundwater for any purposes, and Fermi 3 does not require a dewatering system.

The applicant described the present and projected future regional water use, relying on reports and databases of the USGS, the USEPA, and the State of Michigan. The applicant provided discussion and illustrations of water levels and flow directions both regionally (bedrock aquifer) and on site (bedrock and overburden aquifers).

Description and Onsite Use

Information Submitted by the Applicant

The applicant described the hydrogeologic setting based on USGS reports pertinent to the site location and on their own site subsurface investigation. This study included 28 additional monitoring wells installed in the unconsolidated materials and the bedrock. The unconsolidated materials comprise rock fill, lacustrine deposits of peaty silt and clay, and two clayey glacial till units. The uppermost bedrock is the dolomitic Bass Islands Group aquifer (Bass Islands Dolomite).

Fermi 3 does not use groundwater, as the plant obtains potable water from Frenchtown Township, which has an intake in Lake Erie. Following the construction phase, no permanent dewatering system is needed at Fermi 3.

NRC Staff's Technical Evaluation

The NRC staff reviewed the information provided in the FSAR and has determined it to be complete in terms of description of local and regional hydrogeology and its description of the lack of onsite groundwater use.

Sources

Information Submitted by the Applicant

The applicant described present groundwater use in the region, including quarry dewatering, private wells, community water systems, non-community systems, and a municipal system. The locations of these users are presented. Irrigation is mentioned but no details are included. Groundwater flow directions in the overburden and the Bass Islands Dolomite are illustrated in a series of maps. For the overburden materials, these maps and discussion describe perched groundwater in some southern monitoring wells attributed to the effect of clay fill materials. As the applicant states in Section 2.5.4, the existing fill will be removed and replaced with engineered granular fill with a hydraulic conductivity consistent with that of the existing engineered fill used for the adjacent units.

For the bedrock, the applicant describes a change in flow directions in the Bass Islands Dolomite from pre-development flow to the east (toward Lake Erie) to varied flow directions due to the effects of quarry dewatering in Monroe County. The distribution of hydraulic conductivity values in the overburden and bedrock aquifers was illustrated and qualified in terms of heterogeneities. Hydraulic conductivity measured by slug tests ranged from 9.9E-6 to 5.8E-3 cm/s (0.028 to 16.5 ft/d) for quaternary deposits, 1.3E-5 to 1.6E-5 cm/s (0.036 to 0.046 ft/d) for clay fill, and 0.089 to 0.63 cm/s (251 to 1,776 ft/d) for rock fill. Hydraulic conductivity of the bedrock measured by packer tests ranged from 5.3E-5 to 1.4E-2 (0.15 to 40.07 ft/d).

In a response to RAI 2.4.13-6, dated September 1, 2009 (ADAMS Accession No. ML092470230), the applicant provided information on the porosity of the bedrock based on independent regional reports. MRCSP (2007) described the porosity of the Bass Island Dolomite. Dunning et al. (2004) analyzed groundwater flow in a Midwestern carbonate aquifer with similar porosity, and determined an effective porosity of 1 percent. On the basis of the information sources, and to be conservative in the calculations, the applicant initially selected an effective porosity of 1 percent. However, in a later response to RAI 2.4.13-11 and RAI 2.4.13-12, dated October 19, 2010 (ADAMS Accession No. ML102940218), the applicant provided a summary of a revised determination of site-specific bedrock porosity based on a method relying on hydraulic conductivity and Rock Quality Designation data. The low end of the range of values, 0.1 percent, was selected for the effective porosity value. This value was used in calculations in revised text in the FSAR and in Environmental Report Section 2.3.1.2.3.2.

The Bass Islands Dolomite is part of an important regional bedrock aquifer system in the Midwest. No sole source aquifer systems are located in the region of the Fermi site. The nearest sole source aquifer is located in Catawba Island, Ohio, over 48 km (30 miles) southeast of the Fermi property. At that location, a portion of the Bass Islands Group aquifer is identified as a sole source aquifer.

NRC Staff’s Technical Evaluation

The NRC staff reviewed the FSAR material, RAI response information, and regional reports, and finds the material to be acceptable. The revised, lower value for effective porosity increases the calculated groundwater velocity in the bedrock, thereby increasing the conservatism of subsequent analyses.

Subsurface Pathways

Information Submitted by the Applicant

The applicant described groundwater flowpaths in the overburden materials, groundwater – surface water interactions, and the flowpaths in the Bass Islands Dolomite. Regional data from the USGS representing pre-development groundwater conditions and recent conditions impacted by quarry operations were presented, along with site-specific measurements for the overburden and the bedrock aquifer.

The applicant presented estimates of the groundwater velocities under present conditions in both the rock fill overburden and the Bass Islands Dolomite aquifer in the FSAR, with additional information on the assumed starting point for groundwater movement provided in the response to RAI 2.4.12-1, dated September 30, 2009 (ADAMS Accession No. ML092790561). For the bedrock, groundwater velocities were revised on the basis of a decreased effective porosity value, as explained in the response to RAI 2.4.13-11 and RAI 2.4.13-12, dated October 19, 2010 (ADAMS Accession No. ML102940218). The applicant used Darcy's law to determine the average linear velocity of 0.996 m/day (3.27 ft/day) in the overburden based on a hydraulic conductivity of 357 m/day (1,170 ft/day), a gradient of 0.0007, and a porosity of 25 percent. Travel time from the center of the RB to the overflow canal, a distance of 250 m (820 ft), was estimated to be 250 days. For the Bass Islands Dolomite aquifer, the applicant calculated flow rates and travel times based on assumed high and low hydraulic conductivity values along with a gradient of 0.002 and an effective porosity of 0.1 percent. Calculations pertained to the 1,450 m (4,760 ft) distance from the center of the RB to the offsite well west of the site. For the high hydraulic conductivity case of 5.4 m/d (17.6 ft/d), the velocity is 11 m/d (35 ft/d) or a time of travel of 0.37 years. For the low hydraulic conductivity case of 0.034 m/d (0.11 m/d), the velocity is 0.06 m/d (0.2 ft/d) or a time of travel of 65 years.

The applicant also submitted a calculation of the groundwater velocity in the Bass Islands Dolomite aquifer assuming a pre-development condition with groundwater flowing eastward towards Lake Erie. This represents conditions that could occur if high-rate pumping from quarries west of the site were stopped. Using the hydraulic parameters described above, but with a gradient of 0.001, the applicant calculated a maximum groundwater velocity of 5 m/day (17.6 ft/day). Travel time from the center to the RB to the edge of Lake Erie was then calculated to be a minimum of 0.23 years.

NRC Staff’s Technical Evaluation

The NRC staff reviewed the available data. The flowpaths in the overburden are complex due to the arrangement of low-permeability muck sediments and glacial tills with high-permeability rock fill. This may result in localized, seasonal, perched groundwater. The dolomitic Bass Islands Group aquifer has localized complexities due to stratigraphic variation and fracturing. Water levels at pairs of shallow and bedrock monitoring wells generally indicate downward flow from the overburden to the Bass Islands Dolomite. Several forms of field observations (water level comparisons between paired shallow and deep wells, heat pulse analyses in selected wells) suggest continued downward flow within the Bass Islands Dolomite and into the underlying Salina Group. Lateral flow in the overburden at the site is generally toward the canals and Lake Erie. Because of large-scale dewatering pumping at quarries west of the site, regional flow in the Bass Islands Dolomite in Monroe County has changed from pre-development eastward flow toward Lake Erie to a more complex flow pattern with locally varying flow directions. Bedrock aquifer flow at the Fermi site has a complex pattern of flow mostly to the south and west.

To clarify the applicant's discussion of pathways for potential radioactive contaminants, the staff issued RAI 2.4.12-1 to obtain information on the assumed release point. The staff reviewed the applicant's response to RAI 2.4.12-1, dated September 30, 2009 (ADAMS Accession No. ML102940218), in which the applicant removed all references to "release" and reframed the discussion to examine groundwater velocity and pathways, without reference to contaminant transport. The staff verified that the equations are appropriate to determine groundwater velocity. The staff verified the gradients used in the applicant's calculation of groundwater velocity by checking the submitted groundwater gradient maps.

Groundwater Monitoring

Information Submitted by the Applicant

The applicant described a network of monitoring wells and piezometers, including 17 overburden wells and 11 bedrock wells installed for Fermi 3 and additional wells from other Fermi projects. Water levels were measured monthly from June 2007 to May 2008. The FSAR presents four quarterly maps for the overburden, and four for the bedrock, to depict seasonal variations in water levels and flow directions.

The applicant has made a commitment (COM 2.4-12-001) in FSAR Subsection 2.4.12.4 stating that the monitoring well network will be evaluated prior to commencement of construction.

> **[START COM 2.4-12-001]** However, prior to the commencement of construction activities, the monitoring well network will be evaluated to determine if any significant data gaps are created by the abandonment of existing wells. As part of the detailed design for Fermi 3, the present groundwater monitoring programs will be evaluated with respect to the addition of Fermi 3 to determine if any modification of the existing programs is required to adequately monitor plant effects on the groundwater. **[END COM 2.4-12-001]**

NRC Staff's Technical Evaluation

The NRC staff reviewed the monitoring well network and has determined that it is generally suitable for water level measurements to assess changes in water levels and flow directions due to offsite (e.g. quarry operations) and onsite (e.g. temporary excavation dewatering) impacts. In the future, it would be generally suitable for groundwater quality monitoring, though it may need to be augmented with additional wells depending on the placement of Fermi 3 facilities, and because certain wells may need to be abandoned because of construction activities. The staff finds the applicant's information acceptable based on the existing spatial distribution of the monitoring network and the monitoring data and information provided.

Design Basis for Subsurface Hydrostatic Loadings

Information Submitted by the Applicant

The applicant described the DCD's requirement of a (maximum) groundwater level to be at least 0.6 m (2 ft) below the Fermi 3 plant grade, which is at an elevation of 179.5 m (588.8 ft) NAVD 88. The historical high groundwater level in any well under non-flood conditions was 175.6 m (576.11 ft) NAVD 88 at MW-7, which is 3.9 m (12.7 ft) below the planned Fermi 3 grade. The applicant further described the PMF elevation of 178.4 m (585.4 ft) NAVD 88, which is relevant to the discussion because high-permeability rock fill may allow onsite groundwater levels to reach the PMF level. This flood elevation is 1.1 m (3.4 ft) below the planned Fermi 3 plant grade. Seismic events are not anticipated to affect groundwater conditions.

NRC Staff's Technical Evaluation

The NRC staff concludes that the identified design bases meet the requirements of 10 CFR 50.55a, 10 CFR 100.20(c)(3), 10 CFR 100.23(d), and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety. This addresses EF3 COL 2.0-23-A. In conclusion, the applicant has provided sufficient information on water elevation with respect to plant grade to satisfy corresponding requirements of 10 CFR 52.79(a)(1)(iii), 100.20(c), and 100.23(d).

2.4.12.5 *Post Combined License Activities*

The applicant idenfies the following commitment:

- **Commitment (COM 2.4-12-001) –** However, prior to the commencement of construction activities, the monitoring well network will be evaluated to determine if any significant data gaps are created by the abandonment of existing wells. As part of the detailed design for Fermi 3, the present groundwater monitoring programs will be evaluated with respect to the addition of Fermi 3 to determine if any modification of the existing programs is required to adequately monitor plant effects on the groundwater.

2.4.12.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.12 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed COL Item EF3 2.0-23-A as it relates to groundwater.

As set forth above, the applicant has presented and substantiated information relative to the groundwater effects important to the design and siting of this plant. The staff has reviewed the available information provided and, for the reasons given above, concludes that the identification and consideration of the potential effects of groundwater in the vicinity of the site are acceptable and meet the requirements of 10 CFR 50.55, 10 CFR 50.55a, 10 CFR 100.20(c)(3), 10 CFR 100.23(d), and 10 CFR 100.20(c), with respect to determining the acceptability of the site.

2.4.13 Accidental Release of Radioactive Liquid Effluent in Groundwater and Surface Waters

2.4.13.1 *Introduction*

This section considers the potential effects of relatively large accidental releases from systems that handle liquid effluents generated during normal plant operations. Such releases would have relatively low levels of radioactivity, but could be large in volume. Normal and accidental releases are also considered in the applicant's environmental report.

The accidental release of radioactive liquid effluents in ground and surface waters is evaluated based on the hydrogeological characteristics of the site that govern existing uses of groundwater and surface water and their known and likely future uses. The source term from a postulated accidental release is reviewed under SRP Section 11.2 following the guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures." The source term is determined from a postulated release from a single tank inside the RWB, but outside of the reactor containment structure.

The specific areas of review are (1) alternate conceptual models of the hydrology at the site that reasonably bound hydrogeological conditions at the site inasmuch as these conditions affect the transport of radioactive liquid effluent in the ground and surface water environment; (2) bounding set of plausible surface and subsurface pathways from potential points of an accidental release to determine the critical pathways that may result in the most severe impact on existing uses and known and likely future uses of ground and surface water resources in the vicinity of the site; (3) ability of the groundwater and surface water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport; (4) assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events (e.g., assessing effects of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow); and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.13.2 *Summary of Application*

Subsection 2.4.13 of the Fermi 3 COL FSAR, Revision 7, addresses the accidental release of radioactive liquid effluents in ground and surface waters. In addition, in Section 2.4.13, the applicant provides the following:

<u>COL Item</u>

- EF3 COL 2.0-24-A — Accidental Releases of Liquid Effluents in Ground and Surface Waters

  The applicant described the ability of the ground and surface water environment to delay, disperse, dilute, or concentrate liquid effluents, as related to existing or potential future water users.

2.4.13.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the accidental releases of liquid effluents in ground and surface waters, and the associated acceptance criteria, are in Section 2.4.13 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.
- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The following related acceptance criteria are summarized from SRP Section 2.4.13:

- Alternate Conceptual Models: Alternate conceptual models of hydrology in the vicinity of the site are reviewed.
- Pathways: The bounding set of plausible surface and subsurface pathways from the points of release are reviewed.
- Characteristics that Affect Transport: Radionuclide transport characteristics of the groundwater environment with respect to existing and known and likely future users should be described.
- Consideration of Other Site-Related Evaluation Criteria: The applicant's assessment of the potential effects of site-proximity hazards, seismic, and non-seismic events on the radioactive concentration from the postulated tank failure related to accidental release of radioactive liquid effluents to ground and surface waters for the proposed plant site is needed.
- Branch Technical Position BTP 11-6 provides guidance in assessing a potential release of radioactive liquids following the postulated failure of a tank and its components, located outside of containment, and impacts of the release of radioactive materials at the nearest potable water supply, located in an unrestricted area, for direct human consumption or indirectly through animals, crops, and food processing.

In addition, the hydrologic characteristics should be consistent with appropriate sections from RG 1.113, "Estimating Aquatic Dispersions of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I."

2.4.13.4 *Technical Evaluation*

The NRC staff reviewed the resolution to the COL specific items related to the accidental release of radioactive liquid effluents in ground and surface waters included under Section 2.4.13 of the EF3 COLA. The staff's review confirmed that the information in the application addresses the relevant information related to this subsection.

COL Item

- EF3 COL 2.0-24-A Accidental Releases of Liquid Effluents in Ground and Surface Waters

  The applicant described the ability of the ground and surface water environment to delay, disperse, dilute, or concentrate liquid effluents, as related to existing or potential future water users.

Sources and Mitigating Design Features

A liquid radioactive waste tank is assumed to be the source of release to groundwater, as analyzed in the following section. The applicant assessed the scenario of the rupture of an equipment drain collection tank, with the liquid reaching groundwater. Three of these tanks are located below ground level in the RWB, which is designed to seismic requirements as specified in DCD Table 3.2-1. Compartments containing the liquid radwaste tanks are steel lined to a height capable of containing the release of all liquid radwaste. Releases as a result of major cracks in the tanks would result in the release of the liquid radwaste to the compartment and then to the building sump system for containment in other tanks or emergency tanks.

The applicant states that the release scenario is conservative because of the steel liner and seismic design described above, plus it ignores the basemat concrete barrier and assumes failure of the floor drain system.

The only above-grade tank containing radioactivity outside of the containment is the condensate storage tank. The basin surrounding this outdoor tank is sized to contain the total tank capacity, a design intended to prevent uncontrolled runoff in the event of a tank failure and to collect tank overflow. A sump located inside the retention basin has provisions for sampling collected liquids before routing them to the liquid waste management system or the storm sewer per sampling and release requirements.

Because the key potential release is from an underground tank, the analysis focuses on transport in groundwater. Groundwater discharge to Lake Erie is one flowpath that is investigated, but direct release to surface water from a source is not considered.

Groundwater Analysis

Although mitigating design features are included in the Fermi 3 plant design, as described in the previous section, the applicant analyzed the migration, through groundwater, of radioactive contaminants originating from a postulated underground release of radioactive liquid waste. The source of this release is a tank that was selected based on guidance in Branch Technical Position (BTP) 11-6, "Postulated Radioactive Releases Due to Liquid-containing Tank Failures." Although the postulated release is highly unlikely because of the mitigating design features described above, this analysis provides insight into the possible migration of radioactive contaminants that might originate from other, less severe releases.

Because of the mitigating design features provided for the above-grade condensate storage tank, and the fast response to releases that they would allow, the staff considers that only potential releases to groundwater from an underground liquid radwaste tank represents a significant enough risk to call for detailed analysis.

Information Submitted by Applicant

The below-ground equipment drain collection tank selected as the source is located at a floor elevation of approximately 164.6 m (540 ft) NAVD88 (about 15 m (49 ft) below Fermi 3 plant grade) and has a volume of 140 cubic meters (m^3) (37,000 gallons). The applicant noted that the floor elevation of the source tank is approximately 8.2 m (27 ft) below the ambient groundwater level at the location of the source tank. The tank is postulated to release its volume (112 m^3 or 30,000 gallons) instantaneously due to failure of the tank and its liners at the same time as failure (cracking) of the RWB's basemat and/or exterior walls (described in the response to RAI 2.4.13-11 and RAI 2.4.13-12, dated October 19, 2010 (ADAMS Accession No. ML102940218). The combined tank contents and influent groundwater are then used as the source in the applicant's analysis.

Two alternative hydrogeological conceptual models were proposed by the applicant. Both assume conservative, straight-line flowpaths to the nearest receptor. The first is based on currently observed flow directions in the Bass Islands Dolomite aquifer. Flow is assumed to be westward due to continued quarry dewatering operations in Monroe County, and the assumed flowpath is to the nearest private supply well, approximately 1,450 m (4,756 ft) away. The second analysis assumes a future case in which quarry dewatering has ceased, and groundwater flow returns to the pre-development case of flowing eastward toward Lake Erie, approximately 450 m (1,476 ft) away.

In FSAR Revision 0, mitigating design features were cited as justification for not performing a release analysis. The applicant made several subsequent analyses. In FSAR Revision 1, calculations are described for the analysis of contaminant transport involving radioactive decay, but without including dispersion or retardation of the plume through sorption. In this conservative (i.e. promoting transport) scenario, the containment systems are assumed to fail, a maximum groundwater flow velocity is assumed, no adjustments to concentrations are made for dilution in lake water, and continuous ingestion for a year is assumed. The resulting calculated concentrations at the receptors of several radionuclides (hydrogen-3 or tritium [H-3], manganese-54 [Mn-54], iron-55 (Fe-55), cobalt-60 [Co-60], zinc-65 [Zn-65], strontium-90 [Sr-90], yttrium-90 [Y-90], ruthenium-106 [Ru-106], cesium-134 [Cs-134], Cs-137, and cerium-144 [Ce-144]) exceeded the ECLs specified in 10 CFR Part 20, Appendix B, Table 2, Column 2. The highest exceedance was Co-60, which exceeded the ECL by a factor of 4,170. The sum of fractions (maximum calculated values relative to the 10 CFR limits) is used as a point of comparison. In this case, the sum of fractions far exceeded the limit of unity. The FSAR Revision 1 discussion concludes by citing the mitigation measures in the design features.

In RAI 2.4.13-6, the staff requested an analysis of groundwater contaminant transport that used the most conservative of plausible conceptual models of the conditions that govern transport of radioactive contaminants from the source to potential receptors. The applicant's second response to RAI 2.4.13-6, dated February 16, 2009 (ADAMS Accession No. ML090610219) was based on modeling conducted using RESRAD-OFFSITE (Yu et al. 2007) to determine concentrations at the receptor locations. This analysis relied on the same conservative assumptions as the prior analysis (maximum groundwater flow velocity), and included the effects of dispersion and retardation. For the sorption component, the analysis used the minimum distribution coefficient (K_d) value from analyses newly performed on Bass Islands Dolomite rock samples (detailed in the response to EIS RAI HY2.3.1-16, Attachment 6 to NRC3-10-0004, DTE response letter dated January 29, 2010). In this case, the ECLs for all radionuclides were below ECLs and satisfied the sum of fractions at both the well and the lake. However, the applicant's RESRAD-OFFSITE input files provided along with the RAI show some inconsistencies between the stated assumptions and their implementation in RESRAD-OFFSITE.

To meet the requirements of 10 CFR 100.20(c) and 10 CFR 52.79(a)(1)(iii), and to support the staff's review of the application and the inconsistencies identified above, the staff requested in RAI 2.4.13-9 additional information related to the RESRAD-OFFSITE simulations as follows:

1. The RESRAD-OFFSITE simulation as performed by the applicant assumes that the contaminants are present initially (i.e. immediately after the release) in a volume of contaminated soil 56 m^2 by 2 m deep. The rates at which contaminants leach from the soil are not explicitly specified in the model input, so that the model uses the supplied K_d values to calculate leaching rates. For radionuclides with large K_d values (e.g. Co-60), this means that very little of the contamination would be leached from the soil and enter the groundwater). Staff requested that the applicant perform RESRAD-OFFSITE simulations in which the contaminants enter the groundwater quickly.

2. The staff requested that the applicant provide additional justification for the well pumping rate. The value of about 5,000 m^3/yr (1,300,000 gal/yr) in the application was based on an agricultural scenario. Staff requested using a more reasonable pumping rate from a residential well.

3. Staff requested that a "risk-informed" section is added that discusses the uncertainty in the estimates of radionuclide concentrations at the receptor points and include sensitivity and/or uncertainty analyses.

The applicant's response to RAI 2.4.13-9, dated January 29, 2010 (ADAMS Accession No. ML100330612) addresses the three issues above. The response to the second issue is acceptable because the applicant; evaluated a more conservative pumping rate and revised the RESRAD-OFFSITE simulation consistent with a residential well. The response to the third issue is also acceptable because a series of analyses investigated variation in key input parameters.

For the first issue, the RAI response described the conceptual model:

- 112 cubic meters of liquid from the equipment drain collection tank escapes to the aquifer due to a combined failure of the tank and the basement floor and/or walls, and

- The 112 cubic meters of liquid is assumed to enter the aquifer instantly, and is modeled "as a volume of contaminated soil 56 square meters by 2 meters deep" (so, a contaminated aquifer volume of 112 cubic meters).

However, the implementation in RESRAD-OFFSITE was inconsistent with the conceptual model:

- The applicant's description ignored the relationship between void volume and solid volume in the setup of the RESRAD source. Porosity needed to be accounted for; an aquifer volume much larger than 112 cubic meters would comprise the source volume.

- The description mentioned the leaching of contaminants from the contaminated zone to the aquifer by assigning a high leach rate value in RESRAD-OFFSITE. This implied that the contaminated soil is in the unsaturated zone, which is not the case for the described failure scenario. The scenario is the instant release of contaminated water into a pristine aquifer, rather than leaching with an initial release rate set to the equilibrium desorption release rate. Contaminant transport analysis would include the dynamics of sorption/desorption, starting with an initial sorbed mass of zero.

Updated text was presented in FSAR Revision 2 (Detroit Edison 2010b), including a summary of the RESRAD-OFFSITE modeling effort. The calculations included the use of minimum K_d values, and the results had sum of fractions below unity for the bedrock pathways to both the well and the lake.

Because of the inconsistency between the conceptual model described and the implementation of that scenario in an appropriate code, additional information was requested in RAI 2.4.13-10. In the response, the applicant adequately modified the source volume to account for porosity. The applicant also provided details on the leach rate. A very high leach rate of 525,600/yr was assigned to the source area in an attempt to mimic a catastrophic release to the aquifer. The analysis included not only the transport to the lake and the well via the Bass Islands aquifer, but also via the rock fill. For the rock fill, minimum measured K_d values were assigned, while for the dolomite, K_d values of zero were used. Of these four scenarios, low concentrations (satisfying the sum of fractions) were calculated for the rock fill to Lake Erie scenario, while the other scenarios had zero concentrations at the receptors. The RESRAD-OFFSITE input files were provided for review. Inspection of the OFFSITE output file SUMMARY.REP indicated that the code found the assigned leach rate unattainable and substituted a significantly smaller leach rate (1.8/yr). The analysis was therefore adding contaminants to the aquifer at a much lesser rate than presumed. In addition, the selection of the Do Not Disperse Vertically option resulted in clean infiltration along the flowpath, unless particular input parameter values are selected. Clean infiltration in this case caused the plume to be driven downward and not intercepted by the receptor, given the Depth of Aquifer Contributing input. In addition, the RESRAD-OFFSITE analysis erroneously used the values of the DCD's tank concentrations (activity per volume of liquid) as input values for OFFSITE's source (activity per gram of soil).

The status of the groundwater scenario analysis relying on RESRAD-OFFSITE led to two additional RAIs. The first (RAI 2.4.13-11) noted the discrepancies concerning the leach rates and the vertical dispersion aspects of the model (as described above), and called for a revised analysis. The second (RAI 2.4.13-12) described the inability of RESRAD-OFFSITE to model an instantaneous release, and called for revised input parameter values or selection of an alternative method (which had also been suggested in RAI 2.4.13-10). The applicant provided a combined response to RAI 2.4.13-11 and RAI 2.4.13-12, dated October 19, 2010 (ADAMS Accession No. ML102940218). The response included a summary of past analysis approaches, an explanation of a revised approach, and proposed text changes for the FSAR. In the revised approach, the applicant used the following process:

- All contents of the Equipment Drain Collection Tank are released into its underground room, and groundwater floods the room, thereby initially diluting the tank liquid by a factor of at least three.

- Effective porosity is now set to the low end of a range of measurements determined by a method relying on site-specific hydraulic conductivity and Rock Quality Designation measurements. Its value is now decreased from 1 percent to 0.1 percent.

- Fate and transport calculations (without the use of RESRAD-OFFSITE) then followed a conservative approach.

- An initial analysis relied only on advective transport and radioactive decay. Radionuclides with an activity concentration above 1 percent of their ECL were evaluated in the next step.

- A second analysis added the effect of sorption, conservatively using the minimum site-specific distribution coefficients. Radionuclides with an activity concentration above 1 percent of their ECL were evaluated in the next step.

- For the pathway to Lake Erie, the third analysis considered the calculated groundwater discharge relative to the tremendous dilution capacity of an appropriate local volume of Lake Erie (on the order of a factor of 3,500). A conservative factor of 10 was used in the analysis. All radionuclides were below ECLs, and the sum of fractions was less than 1.

- For the pathway to a well, the third analysis added the effect of longitudinal dispersion. Results for radionuclide activity concentrations were below ECLs, but the sum of fractions was greater than 1.

- The final step for the pathway to the well added the effect of transverse dispersion. In this case, the sum of fractions was less than 1.

NRC Staff's Technical Evaluation

The NRC staff reviewed the available information in FSAR revisions and RAI responses submitted by the applicant, as summarized above. The ultimate approach and results summarized in the combined response to RAI 2.4.13-11 and RAI 2.4.13-12 (ML102940218, dated October 19, 2010) was found acceptable. The analysis clearly described the highly conservative (i.e. promoting transport and high activity concentrations) aspects of the approach. These included

- Instantaneous release of the complete contents of the tank with the highest radionuclide activity concentrations (generally by several orders of magnitude) according to the DCD (Rev. 06, Table 12.2-13a),

- Rapid groundwater flow, achieved in part by assuming the lowest effective porosity value obtained through a determination on field samples,

- Limited sorption taking place, achieved by assuming the lowest distribution coefficients from laboratory work on site samples,

- Appropriate careful consideration of realistic transport processes and additional modeling complexity for key radionuclides,

- Only minor dilution of groundwater discharging to Lake Erie, and
- A constant concentration source term over the operating life of 60 years for the case of transport to well.

The 60-year constant concentration source used in the well scenario is an unnecessary conservatism, but does not affect the final conclusions.

The NRC staff confirmed the calculated results to the receptors by performing independent analyses relying on conservative assumptions. The process, assumptions, and overall results resembled those ultimately provided by the applicant in the combined response to RAI 2.4.13-11 and RAI 2.4.13-12, dated October 19, 2010 (ADAMS Accession No. ML102940218).

As described above, the dilution of groundwater discharging to Lake Erie is extreme, and the applicant's assumed dilution factor of 10 is a highly conservative low value, yet resulted in sufficiently low radionuclide activity concentrations in lake water. The analysis for the well also produced sufficiently low concentrations once the effect of two-dimensional dispersion was included. Concentrations at the well, however, would be further reduced in actuality because the cone of depression caused by pumping would draw clean groundwater into the well from cross-gradient portions of the Bass Islands aquifer.

The results of the applicant’s conservative analyses, and the staff’s confirmatory analysis, provide confidence that a catastrophic release of the tank's contents to the Bass Islands aquifer would not result in an exceedance of ECLs or the sum of fractions at the two possible receptors. Therefore, the staff concludes the applicant’s response is acceptable.

2.4.13.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.13.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.13 of NUREG–0800, and other NRC RGs. The staff’s review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed EF3 COL Item 2.0-24-A as it relates to accidental releases of liquid effluents in ground and surface waters.

The review confirms that the applicant has satisfactorily addressed the potential for radionuclides to impact receptors under two possible conceptual models for the groundwater flow system. The release scenario considered was a worst-case release to groundwater resulting from a catastrophic release of the contents of an underground equipment drain collection tank, the tank which has the highest anticipated radionuclide activities. A series of conservative (i.e. promoting transport and high concentrations) assumptions were used in an approach to determine the activity concentrations of radionuclides at receptors relative to the effluent concentration limits (ECLs) specified in 10 CFR Part 20, Appendix B, Table 2, Column 2. As described above, the calculated activity concentrations satisfied the ECLs and sum-of-fractions criteria at each receptor. The staff concludes that the analysis and its results provide sufficient information to satisfy the requirements of 10 CFR 100.20(c), 10 CFR 100.23(d), and 10 CFR 52.79(a)(1)(iii).

Mitigating design features, while not considered in the analysis, would further reduce the potential impact to groundwater or surface water for the worst-case scenario described above as well as for other release scenarios.

2.4.14 Technical Specification and Emergency Operation Requirements

2.4.14.1 *Introduction*

The technical specifications and emergency operation requirements described here implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available. The specific areas of review are (1) controlling hydrological events, as determined in previous hydrology sections of the SAR, to identify bases for emergency actions required during these events; (2) the amount of time available to initiate and complete emergency procedures before the onset of conditions while controlling hydrological events that may prevent such action; (3) reviewing technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications; (4) potential effects of seismic and non-seismic information on the postulated technical specifications and emergency operations for the proposed plant site; and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.14.2 *Summary of Application*

Subsection 2.4.14 of the Fermi 3 COL FSAR, Revision 7, addresses technical specifications and emergency operation requirements. In addition, in FSAR Section 2.4.14, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-25-A   Technical Specifications and Emergency Operation Requirements

  To address this COL item, the applicant identified that the elevation of exterior access openings, which are above the PMF and local PMP flood levels, and the design of exterior penetrations below design flood and groundwater levels, which are appropriately sealed, result in a design and site combination that do not necessitate emergency procedures or meet the criteria for Technical Specification LCOs to ensure safety-related functions at the plant.

2.4.14.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the technical specifications and emergency operation requirements, and the associated acceptance criteria, are in Section 2.4.14 of NUREG–0800. The applicable regulatory are as follows:

1. 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).

2. 10 CFR 100.23(d), sets forth the criteria to determine the citing factors for plant design bases with respect to seismically induced floods and water waves at the site.

3. 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding areas and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR 50.36, as it relates to identifying limiting conditions on technical specifications for safe operation of the plant.

The following related acceptance criteria are summarized from SRP Section 2.4.14:

1. Bases for Emergency Actions: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, an assessment of the hydrological bases for emergency actions is needed.

2. Available Response Time: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, estimates of available response times to initiate and complete emergency procedures are needed.

3. Technical Specifications: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, the applicant's proposed technical specifications related to emergency procedures are reviewed.

4. Consideration of Other Site-Related Evaluation Criteria: To meet the requirements of 10 CFR 50.36 and 10 CFR Part 100, the applicant's assessment of the potential effects of site-related proximity, seismic, and non-seismic information on the postulated technical specifications and emergency operations is needed.

In addition, the hydrologic characteristics should be consistent with appropriate sections from: RGs 1.29, 1.59, and 1.102.

2.4.14.4 *Technical Evaluation*

The NRC staff reviewed Subsection 2.4.14 of the Fermi 3 COL FSAR and checked the referenced DCD to ensure that the combination of DCD site parameters and the information in the applicant's COL represent the complete scope of information relating to this review topic.

<u>COL Item</u>

- EF3 COL 2.0-25-A — Technical Specifications and Emergency Operation Requirements

The NRC staff's evaluation of COL Item EF3 COL 2.0-25-A is presented below.

Information Submitted by the Applicant

The applicant stated that the safety-related features at Fermi 3 are all located at above the maximum flooding level estimated for the site and the maximum groundwater elevation. The applicant also refers to Section 3.4 of the FSAR for a discussion on flood protection for safety-related structures, systems and components (SSCs). The applicant states that technical specifications and emergency procedures are not necessary due to the design of the plant.

NRC Staff's Technical Evaluation

The NRC staff reviewed the information contained in COL FSAR Subsection 2.4.14 and reviewed the information in Section 3.4 of the FSAR referred to by the applicant. Section 3.4 of the FSAR incorporates by reference Section 3.4 of the ESBWR DCD. The DCD Section 3.4.1 states that "safety-related systems and components of the ESBWR standard plant are located in the seismic Category I structures that provide protection against external flood and groundwater damage." The staff reviewed the details in Subsection 3.4.1 of the DCD to verify that the plant design is sufficient to prevent the need for technical specifications and emergency procedures. The DCD specifies that the elevation of the safety-related features must be at least 1 ft above the maximum design flood elevation. The Fermi 3 safety-related features are designed to be at an elevation of 589.3 ft NAVD 88. The staff determined the maximum flood elevation to be 585.4 ft, 3.9 ft lower than the elevation of the safety-related features of Fermi 3. If the predicted maximum height of wind wave at the berm is added on to the flood elevation in Alternative III, the maximum elevation is 587.63 ft NAVD 88, which is 1.67 ft below the elevation of the safety-related features.

The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the technical specifications and emergency operations is acceptable and meets the requirements of 10 CFR 50.36 and 10 CFR 100.20(c) with respect to determining the acceptability of the site.

2.4.14.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.4.14.6 *Conclusion*

The NRC staff has reviewed the application and confirms that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. The staff confirmed that RTNSS structures that meet Criterion B (i.e., for actions required beyond 72 hours and seismic events) are required to perform reliably in the event of hazards such as external flooding considering the PMF, PMP, seiche and other pertinent hydrologic factors.

In addition, the staff compared the additional information in the COLA to the relevant NRC regulations, the guidance in Section 2.4.14 of NUREG–0800, and other NRC RGs. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff has determined that the applicant has adequately addressed EF3 COL Item 2.0-25-A as it relates to technical specifications and emergency operation requirements.

As set forth above, the applicant has presented and substantiated information relative to the technical specifications and emergency operations important to the design and siting of this plant. The staff has reviewed the available information provided and for the reasons given above, concludes that the identification and consideration of the technical specifications and emergency operations is acceptable and meets the requirements of 10 CFR 50.36, 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c), and 10 CFR 100.23(d) with respect to determining the acceptability of the site.

2.5 Geology, Seismology, and Geotechnical Engineering

This FSAR section describes geologic, seismic, and geotechnical engineering properties of the proposed Fermi 3 site. Following the NRC guidance in RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," and in RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion," the applicant defined the following four zones around the Fermi 3 site and conducted investigations within those zones:

- Site region – Area within 320 km (200 mi) of the site location.
- Site vicinity – Area within 40 km (25 mi) of the site location.
- Site area – Area within 8 km (5 mi) of the site location.
- Site location – Area within 1 km (0.6 mi) of the proposed Fermi 3 location.

Since the proposed Fermi 3 is located adjacent to the existing Fermi 2, the applicant used the previous site investigations for the Fermi 2 facility as its starting point for the characterization of the geologic, seismic, and geotechnical engineering properties of the site. As such, the material in Fermi 3 FSAR Section 2.5 focuses on any information published since the Fermi 2 FSAR, which was issued in 1985. The material in COL FSAR Section 2.5 also focuses on any recent geologic, seismic, geophysical, and geotechnical investigation performed for the COL site.

The applicant used seismic source models previously published by the Electric Power Research Institute (EPRI 1986, 1989) as the starting point for characterizing potential regional seismic sources and the resulting vibratory ground motion. The applicant then updated these EPRI seismic source and ground motion models in light of more recent data and evolving knowledge pertaining to seismic hazard evaluations in the central and eastern United States (CEUS). The applicant then employed the performance-based approach described in RG 1.208 to develop the ground motion response spectrum (GMRS) for the site.

NRC staff performed an extensive review of Fermi 3 COL FSAR Revision 5, Section 2.5, interacted with the applicant on many occasions through public meetings; and requested additional information to substantiate and support the applicant's conclusions in the FSAR. Because of the Fukushima Dai-ichi nuclear power plant accident after the Great Tohoku earthquake and the subsequent tsunami in Japan in 2011, the NRC issued an information request letter dated March 12, 2012, requesting all operating nuclear power plants in the U.S. to re-evaluate seismic hazards using the most recent information and methodologies available. The NRC Near-Term Task Force (NTTF) issued a series of recommendations for improving nuclear power plant safety in the U.S. following the Fukushima Dai-ichi accident. The information request letter stated that nuclear power plant sites in the CEUS will be able to use the newly published seismic source model in NUREG–2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," to characterize seismic hazards related to their plants. Following the issuance of this information request letter to the operating nuclear power plants, the staff also requested all COL and Early Site Permit (ESP) applicants to address this issue.

The NRC issued RAI 01.05-1 requesting the applicant to provide additional information to address Recommendation 2.1 of the Fukushima NTTF in SECY-12-0025, “Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami,” as it pertains to the seismic hazard evaluation. The NRC staff asked the COL applicant to reassess the calculated seismic hazard for the Fermi 3 site using the newly published NUREG-2115 seismic source model and to modify its GMRS and the foundation input response spectra (FIRS) as needed. The applicant’s initial response to RAI 01.05-1 dated August 24, 2012 (ADAMS Accession No. ML12243A455), replaced the EPRI (1986, 1989) base seismic source model used for the seismic hazard analysis with the newly published NUREG–2115 seismic source model. In addition, the applicant committed to address the impact of the RAI 01.05-1 response in conjunction with the site-specific soil-structure interaction (SSI) analyses. On January 25, 2013, the applicant provided a response to RAI 01.05-1 (ADAMS Accession No. ML13032A378) that included a revised FSAR Section 2.5. Particularly significant are the calculations in revised FSAR Section 2.5.2, “Vibratory Ground Motion.” The applicant then submitted FSAR Revision 5 on February 14, 2013. This change in the base seismic source model made many of the staff’s previous RAIs irrelevant. The staff's technical evaluations only discuss those RAIs that remain applicable in the context of the applicant’s changes, in addition to new RAIs related to this most recent version of the FSAR.

2.5.1 Basic Geologic and Seismic Information

2.5.1.1 *Introduction*

This FSAR section describes geologic, seismic, and geotechnical information. This technical information incorporates results from surface and subsurface investigations performed in increasing levels of detail for distances closer to the site. These investigations comprised four distinct circumscribed areas corresponding to the previously defined site region, site vicinity, site area, and site location. The primary purposes for conducting these investigations were (1) to determine the geologic and seismic suitability of the site; (2) to provide the bases for the plant design; and (3) to determine whether there is significant new tectonic or ground motion information that could impact the seismic design bases as determined by a probabilistic seismic hazard analysis (PSHA). The basic geologic and seismic information in FSAR Section 2.5.1 addresses the regional and site geology and includes a description of the tectonic setting and the potential for tectonic and non-tectonic deformation, as well as conditions caused by human activities.

2.5.1.2 *Summary of Application*

Section 2.5.1 of the Fermi 3 COL FSAR describes site-specific geologic, seismic, and geotechnical information. In addition, in FSAR Section 2.5.1, the applicant provides the following:

<u>*COL Item*</u>

- EF3 COL 2.0-26-A Basic Geologic and Seismic Information

In FSAR Section 2.5.1, the applicant provided information on the geologic and seismic setting for the Fermi 3 site and region. This information included four levels of investigations, each completed with additional scientific data encompassing 320 km (200 mi), 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi). FSAR Subsection 2.5.1.1 describes the regional geologic and tectonic setting across a radius of 320 km (200 mi) from the site; and FSAR Subsection 2.5.1.2

describes the site geology and tectonic setting across a radius of 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) from the site.

FSAR Section 2.5.1 is based on information derived from the applicant's review of earlier reports prepared for the Fermi 2 power plant and published geologic literature, in addition to new boreholes drilled for the proposed Fermi 3. The applicant also used recently published literature, reports, and maps to supplement and update existing geologic and seismic information.

Based on these Fermi 3 investigations, the applicant concluded in FSAR Section 2.5.1 that no geologic conditions exist at the site that would negatively impact the construction or operation of safety-related buildings or structures. The applicant further concluded that any hazards at the Fermi 3 site will be mitigated during construction or designed for appropriately. A summary of the geologic and seismic information provided by the applicant in Fermi 3 COL FSAR Section 2.5.1 is presented below.

2.5.1.2.1 Regional Geology

FSAR Subsection 2.5.1.1 discusses the physiography, geomorphology, geologic history, stratigraphy, and tectonic setting within a 320-km (200-mi) radius of the Fermi 3 site. The following subsections summarize the information provided by the applicant in FSAR Subsection 2.5.1.1.

Physiography and Geomorphology

FSAR Subsection 2.5.1.1.1 includes the applicant's descriptions of the regional physiography and geomorphology surrounding the Fermi 3 site. The applicant stated that the site is located in the Eastern Lake section of the Central Lowlands physiographic province. The applicant explained that the Fermi 3 site region comprises portions of two other physiographic provinces: the Appalachian Plateaus and St. Lawrence Lowlands. Figure 2.5.1-1 in this SER shows the location of the Fermi site in relation to the physiographic provinces.

The applicant stated that the Central Lowlands physiographic province is subdivided into eight sections. The Eastern Lake and Till Plains sections are located in the site region (a radius of 320 km [200 mi]). The Fermi 3 site is located in the Eastern Lake section, which is characterized by glacial landforms and beach and lacustrine (produced or formed in a lake) deposits. The applicant stated that the Fermi 3 site is located in a lake plain formed during the Lake Erie water level fluctuation, and Lake Erie occupies three basins that increase in depth from west to east. The applicant indicated that the western Erie basin extends to depths of 10 to 11 m (33 to 36 ft), the central basin to depths of 24 to 25 m (79 to 82 ft), and the eastern basin to depths exceeding 40 m (131 ft). The Till Plains section is dominated by glacial landforms that include end moraines, ground moraines, recessional moraines, outwash plains, and some lacustrine deposits.

The physiographic province of the Appalachian Plateaus is subdivided into seven sections. Two of those sections, the Kanawha and Southern New York, are within the 320-km (200-mi) radius of the Fermi site. The Kanawha section is described as a dissected plateau containing Pleistocene (2.6 million years ago [Ma] to 10,000 years ago) lacustrine deposits within the valleys and broadly folded Paleozoic (359 to 251 Ma) sediments. The Southern New York section is dominated by glacial landforms and lacustrine deposits underlain by broadly folded

Paleozoic sediments. The applicant described the St. Lawrence physiographic province as low plains with distributed glacial landforms along with beach and lacustrine landforms.

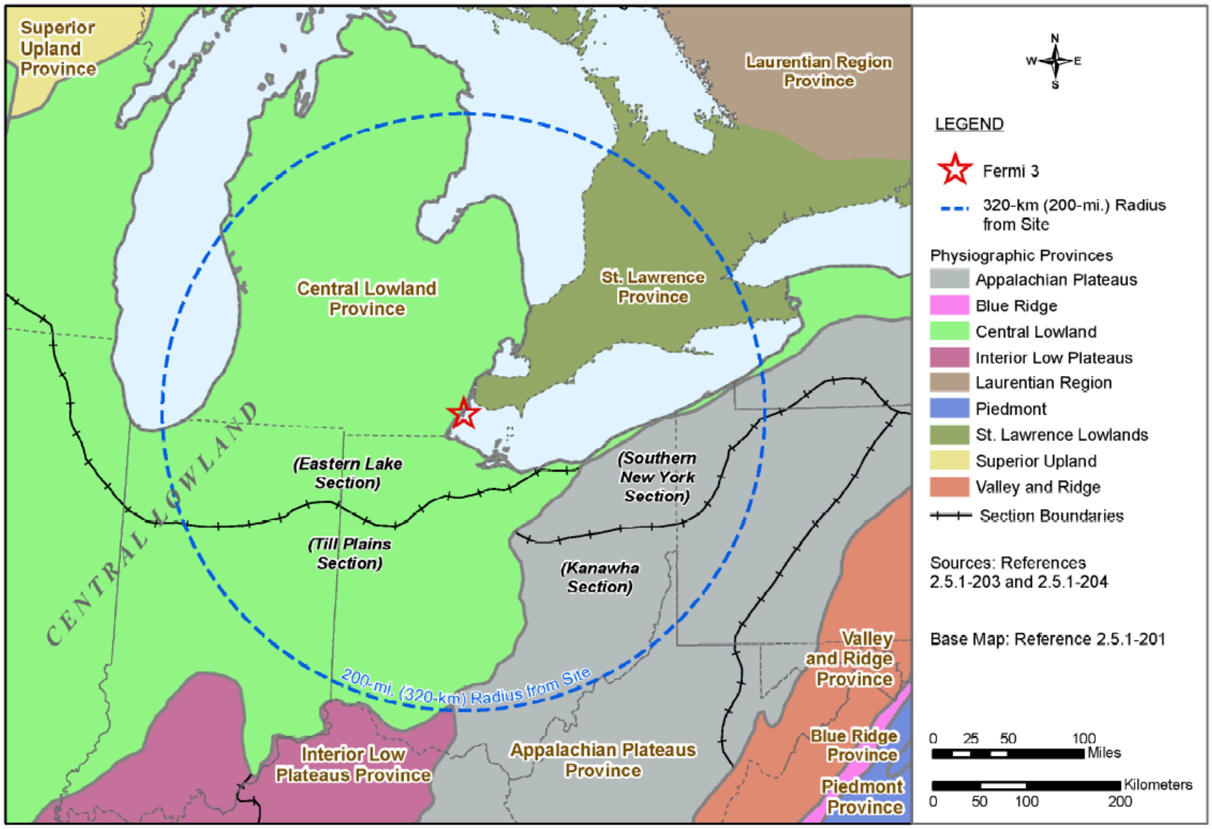


Figure 2.5.1-1 Fermi 3 Site Regional Physiographic Map
(Reproduced from Fermi 3 COL FSAR Figure 2.5.1-202)

Regional Geologic History

In FSAR Subsection 2.5.1.1.2, the applicant described the geologic and tectonic history of the Fermi site region. The applicant stated that the major tectonic events in the site region include several transgressions and regressions of epeiric (inland) seas, widespread subsidence in the continental basins, extensive uplifting in arches, and minimal activity on preexisting basement faults. The applicant stated that the last major tectonic event in the site region was rifting related to the Midcontinent Rift and Grenville Orogeny about 1.2 to 1.0 billion years ago (Ga).

In FSAR Subsections 2.5.1.1.2.3.2 and 2.5.1.1.2.3.3, the applicant described the Mesozoic (252-66 Ma) and Cenozoic (66 Ma to present) geologic history of the site. The applicant explained that no Mesozoic or early Cenozoic rock record is preserved in the site region except for some Jurassic (201 to 145.5 Ma) sedimentary rocks. According to the applicant, the missing rock record, if it did once exist, is likely due to widespread erosion between the late Paleozoic and middle Cenozoic Eras. The applicant stated that the site region is considered tectonically stable during the Cenozoic Era, except for vertical crustal movement associated with glacial isostatic adjustments.

In FSAR Subsection 2.5.1.1.2.3.4, the applicant provided detailed information on the Quaternary (2.6 Ma to present) geologic history of the site region. The applicant explained that the main geologic event in the site region during the Quaternary period is related to the growth and expansion of the continental Laurentide ice sheet. The applicant correlated major glaciation to stages of the marine oxygen isotope record (referred to as marine isotope stage, or MIS) and explained that the current interglacial period, the Holocene (12,000 years ago to present), is correlated as MIS 1; whereas the most recent glaciation, the Late Wisconsinan, is correlated to MIS 2. The most significant Wisconsinan ice sheet advances occurred between 25,000 and 12,000 years ago. Periods of low to no ice volume are recognized during the approximately 130000 years prior to the late Wisconsinan (MIS 3 to 5). The preceding Illinoian glacial period, which is correlated to MIS 6, culminated approximately 160,000 years ago. Pre-Illinoian glacial events are only referred to by their MIS number, with even numbers identifying periods of higher ice volumes. The applicant stated that surficial sediments in the site region are mostly composed of Illinoian (MIS 6) and Late Wisconsinan age (MIS 2) glacial sediments, which is further evidence that mostly ice-free conditions existed between MIS 2 and MIS 6.

Regional Stratigraphy

In FSAR Subsection 2.5.1.1.3, the applicant discussed the succession of geologic units in the site region. The applicant stated that no rocks older than the Ordovician period (488 to 444 Ma) are exposed at the surface in the site region. The applicant explained that all of the physiographic provinces in the site region enclose comparable sequences of sedimentary rocks and since the Fermi 3 site is located on the Michigan basin side of the Findlay arch, more emphasis will be given to the stratigraphy of this basin.

The applicant stated that deposition of sediments during the Paleozoic and Mesozoic eras was controlled by several transgressions (high sea levels) and regressions (low sea levels) of epeiric seas (seas on the continental shelf or interior) over the North American Craton (part of the Earth's crust that has attained stability). Each major transgression and regression is referred to as a cratonic sequence, and six cratonic sequences are recognized for the North American Craton starting in the Proterozoic period (greater than 541 Ma) to present time. The applicant explained that five of the six cratonic sequences are identified within the Fermi site region. The rocks that the applicant identified during subsurface investigations for the Fermi 3 site are part of the Tippecanoe cratonic sequence and include rocks of the Salina Group overlain by rocks of the Bass Island Group. The Bass Islands Group is composed of dolomitic rocks with some interbedded shales and provides the foundation rock for the proposed Fermi 3 nuclear island. Both the Salina Group and the Bass Islands Group were deposited during the Silurian period (441 to 419 Ma).

In FSAR Subsection 2.5.1.1.3.3, the applicant discussed the Quaternary stratigraphy of the 320 km (200 mi) in the site region. The applicant explained that Pleistocene (2.6 Ma to 10,000 years ago) features in the site region are incising bedrock valleys and their associated valley fills. Glacial sediments as well as tills of Illinoian age lie on bedrock and were deposited by ice that advanced into the eastern portion of the Lake Erie basin. Glacial lake deposits of the early to middle Wisconsinan age pertaining to the Tyrconnell Formation were deposited in a proglacial lake in the Erie basin. The applicant stated that evidence of a long ice-free period is confirmed by significant soil development in the site region following the Illinoian glaciation and prior to the late Wisconsinan glacial period.

Regional Tectonic Setting

In FSAR Subsection 2.5.1.1.4, the applicant described the regional tectonic setting of the Fermi 3 site that is relevant to the characterization of seismic sources used in the development of the Central and Eastern United States Seismic Source Characterization for Nuclear Facilities (CEUS-SSC) project (NUREG–2115) discussed in FSAR Section 2.5.2. Fermi 3 is located within a compressive midplate stress province characterized by a fairly uniform east-northeast compressive stress field, which extends from the midcontinent east toward the Atlantic continental margin and probably into the western Atlantic basin. The applicant explained that glacial isostatic adjustment (GIA) is believed to be the basis of deformation within continental plates and perhaps is a trigger of seismicity in eastern North America and in previously glaciated regions. The applicant stated that these effects on seismicity rates in the site region are not expected to vary significantly in the future due to the GIA. The applicant based this assertion on Mazzotti and Adams (2005) and on modeling of the strain and the resulting changes in seismic stress caused by the GIA in other areas.

Based on historical measurements, Larsen (1985) concluded that the uplift of Lake Erie continues to the present. The applicant noted that the glacial and post-glacial GIA is evident by deformation (tilting and warping of glacial lake strandlines) and the most appropriate geodynamical model that reconstructs related Holocene deformation accounts for the northward migration of a collapsing forebulge for the Great Lakes. The applicant explained that the directional trend in the uplift of Lake Erie does not exactly correlate with the isostatic rebound trend but is less than 64 mm/century (2.52 in/century). The applicant added that recent GIA observations indicate that the hinge line marking the boundary between regions of vertical rebound to the north and subsidence to the south is close to the northern margin of the site region; and the residual velocity field shows subsidence of 1 to 2 mm/yr (0.039 to 0.078 in/yr) along most of the site region with a possible slight uplift near the western end of Lake Erie. The applicant stated that the monitoring of present-day tilting of the Great Lakes region illustrates uplift in the northeast and subsidence in the south, which indicates a pattern of land tilting upward to the northeast that is consistent with GIA. The applicant also stated that according to the data, the Fermi 3 site and the surrounding region are not characterized by strong vertical gradients or anomalies.

Regional Geophysical Data

In FSAR Subsection 2.5.1.1.4.2.1, the applicant discussed the regional gravity and magnetic data in relation to the Fermi 3 site region. Figure 2.5.1-2 in this SER shows various anomalies covering the site region including the mid-Michigan Gravity Anomaly (MGA), the East Continent Gravity High (ECGH), the Anorthosite Complex Anomaly (ACA), the Seneca anomaly, and the Butler anomaly. The applicant stated that some of these anomalies are associated with the midcontinent rift system (MRS) and the east continent rift system (ECRS).

In FSAR Subsection 2.5.1.1.4.2.2, the applicant provided information on seismic profiles of the midcontinent region using data from the Consortium for Continental Reflection Profiling and some of the seismic line data collected by the Great Lakes International Multidisciplinary Program on Crustal Evolution. The seismic line data collected in the Lake Superior area illustrate a segmented rift structure constituted by inverted, normal faulted asymmetric half grabens. Other features defined by the seismic profile lines were the Granite-Rhyolite province, the Grenville Front Tectonic Zone (GFTZ), and the Grenville Province.

Regional Tectonic Structures

In FSAR Subsection 2.5.1.1.4.3, the applicant stated that the Fermi 3 site is located in the continental region of the North American Craton, which is characterized by low seismic activity and low stress. A transition zone lies between the Michigan interior cratonic basin and the central Appalachian foreland within the 320-km (200-mi) radius of the Fermi site. This transition zone contains structural features that were occasionally active through the Paleozoic period. However, no evidence suggests that a reactivation of Mesozoic structures occurred within the site region. Previous reports for Fermi 2 concluded that there were no capable tectonic faults within the Fermi 2 site region. In addition, the applicant indicated that the CEUS-SSC study did not identify any repeated large-magnitude earthquake (RLME) seismic sources within 320 km (200 mi) of the Fermi 3 site. The applicant discussed the following regional tectonic structures by dividing them into three groups: basins and arches, principal faults, and seismic zones.

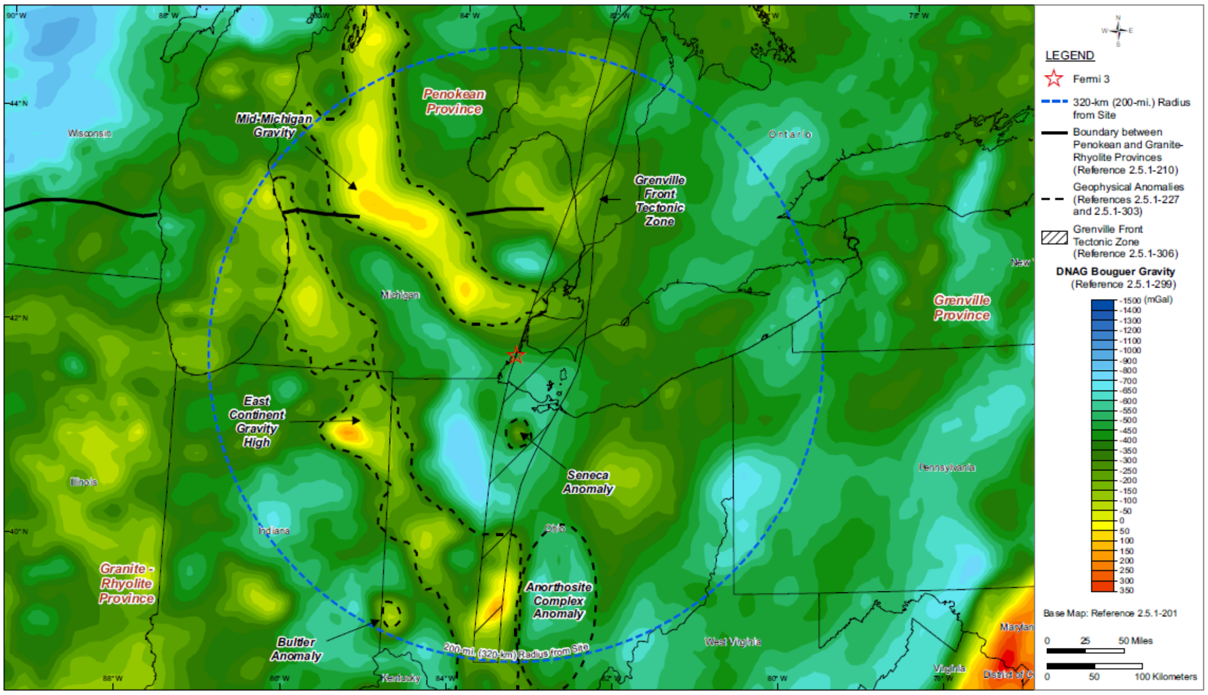


Figure 2.5.1-2 Bouguer Gravity Map of the Fermi 3 Site Region
(Reproduced from Fermi 3 COL FSAR Figure 2.5.1-220)

1. Basins and Arches

In FSAR Subsection 2.5.1.1.4.3.1, the applicant indicated that the most significant basins and arches in the site region are the Michigan basin and the Findlay and Algonquin arches. The applicant stated that the result of a long period of subsidence and deposition combined with effects from distal orogenic events along the margin of the craton resulted in a series of structural features in the basin, which range from closed anticlines to complex horst and grabens. Other structures observed in the basin are differential compaction anticlines and solution collapse features located over covered topographic highs and reefs. The applicant cited Fisher's findings (Fisher 1983) that the main structures in the Michigan basin are the result of vertical tectonics.

The Findlay arch in western Ohio and southeast Michigan and the Algonquin arch in Canada divide the Michigan basin from the Appalachian basin. The applicant explained that the Findlay and Algonquin arches influenced Paleozoic sedimentary deposition into the Middle Devonian.

2. Principal Faults

In FSAR Subsection 2.5.1.1.4.3.2, the applicant described the principal faults and tectonic features in the Fermi 3 site region. The closest faults to the Fermi 3 site area are the Bowling Green (Lucas-Monroe) anticline/fault, the Howell (Howell-Northville) anticline/fault, and the Maumee fault.

a. Bowling Green (Lucas-Monroe) Fault/Monocline

The closest distance of the Bowling Green fault to the site is about 40 km (24 mi). The Bowling Green fault is also known as the Lucas-Monroe monocline or fault and is composed of three segments: central, northern, and southern. The central (Late Cretaceous) segment is called the Bowling Green fault and is an approximately 10-m (33-ft) wide near-vertical zone of heavily sheared rock with secondary faulting. The applicant stated that the central segment of the fault coincides with the GFTZ and the Findlay arch. Citing Onash and Kahle (1991), the applicant stated that recurrent displacement may have occurred on the Bowling Green fault, in response to stress associated with the migration of the Findlay arch during the Acadian or Alleghanian events.

The applicant noted that the southern segment is composed of steeply dipping fault splays in Ohio extending to the southern boundary of Marion County in Michigan, which includes the Outlet and the Marion faults. The Outlet fault zone trends northwest and extends from Wyandot County to Wood County. The applicant stated that based on the sense of folding and the nature of displacement between the Outlet and Bowling Green faults, the Outlet fault is interpreted as a large synthetic shear zone to the Bowling Green fault. The applicant indicated that the vertical displacement on the Outlet fault zone ranges from approximately 6 to 30 m (20 to 100 ft). In addition, the applicant described the Marion fault as one of several small faults recognized on the basis of well data. The applicant indicated that the structural trends of the Marion and other faults are supported by (1) subsurface data on the top of the Trenton limestone, (2) unpublished lineament analyses by the Ohio Geological Survey, (3) an analysis of proprietary seismic data, and (4) anomalies in gravity and magnetic maps.

The northern segment of the fault is also known as the Lucas-Monroe monocline/fault. It consists of steeply dipping to vertical right and left stepping faults that extend from Lenawee and Monroe Counties to Livingstone County, where the segment apparently merges with the Howell anticline.

The applicant stated that a magnitude 3.4 earthquake occurred in 1994 approximately 130 km (90 mi) northwest of the Fermi site. Citing Faust et al. (1997), the applicant stated that the earthquake was on a hypothetical fault associated with the Lucas-Monroe fault or a shallow dipping feature related to the MRS and the Mid-Michigan Gravity High (MMGH). Structure contour maps of Paleozoic units, however, do not sustain the extension hypothesis of the Lucas-Monroe fault because the epicenter and the intense shaking zone of this earthquake were about 25 km (15.5 mi) southwest of the MRS/MMGH margin. Based on this information, the applicant concluded it is not likely that the earthquake is related to the Lucas-Monroe fault. Figure 2.5.1-3 in this SER shows the location of the Bowling Green fault. Figure 2.5.1-4 in this SER shows a summary of the displacement history of the fault that ranges from Late Ordovician to Post-Middle Silurian.

Figure 2.5.1-3 Fermi 3 Site Region Map of Tectonic Structures
(Reproduced from Fermi 3 COL FSAR Figure 2.5.1-203)

SUMMARY OF DISPLACEMENT HISTORY OF BOWLING GREEN FAULT

Episode	Sense	Displacement	Evidence	Age
I	East-down	32 m	Greater thickness of strata between top of Trenton Ls. and top of Lockport Dol. on east side of fault	Late Ordovician-Early Silurian
II	West-down	50 m	Greater thickness of strata between top of Lockport Dol. and top of Tymochtee Dol. on west side of fault	Early-Middle Silurian
III	Left (?) lateral	?	Slickenlines in Tymochtee Dol. and Bass Islands Gp. in fault zone	Post-Middle Silurian
IV	West-down	>70 m	Slickenlines in Tymochtee Dol. and Bass Islands Gp. in fault zone; offset of Tymochtee-Bass Islands contact	Post-Middle Silurian
V	East-down	Depends on IV	Slickenlines, drag folds, minor fault sense in Tymochtee Dol. and Bass Islands Gp. in fault zone	Post-Middle Silurian
VI	Thrust	<5 m	Slickenlines, offset of bedding in Tymochtee Dol. and Bass Island Gp. in fault zone	Post-Middle Silurian-Cenozoic

Source: Reference 2.5.1-332

Abbreviations:
Dol. = Dolomite
Gp. = Group
Ls. = Limestone
? = uncertain

Figure 2.5.1-4 Summary of Displacement History of Bowling Green Fault
(Reproduced from Fermi 3 COL FSAR Figure 2.5.1-223)

b.	Howell Anticline

The Howell (Howell-Northville) anticline is a Precambrian, northwest-southeast trending anticline about 45 km (28 mi) north of the Fermi 3 site. The applicant explained that the southwest limb of the anticline is a steep normal fault and that no deformation associated with the Howell anticline has been observed after the early Mississippian.

c.	Maumee Fault

The applicant described the Maumee fault as a northeast-southwest trending normal fault about 34 km (21 mi) south of Fermi. The applicant stated that the fault is offset (about 2 km [1.2 mi]) left laterally by the Bowling Green fault. The fault also coincides with a moderate lineament formed by the Maumee River.

Seismic Zones

In FSAR Subsection 2.5.1.1.4.3.3, the applicant explained that two seismic zones are within the site region: the Northeast Ohio Seismic Zone and the Anna Seismic Zone. Both seismic zones are classified as Class C structures.

The applicant defined the Northeast Ohio Seismic Zone as a zone of earthquakes south of Lake Erie about 50 km (30.5 mi) long. The largest seismic event in this zone was a magnitude 5 event about 40 km (24.4 mi) east of Cleveland on January 31, 1986, followed by 13 aftershocks within the subsequent 3 months. The applicant stated that the earthquakes and the aftershocks were within 12 km (7.3 mi) of deep waste disposal injection wells that may be associated with the cause of this earthquake and the aftershocks. However, the applicant indicates that the characteristics of these earthquakes would suggest that a natural origin for these events is likely. The applicant discussed events (magnitude 2.3 to 4.5) of a lesser magnitude that occurred from 1987 to 2003 in the Northeast Ohio Seismic Zone. Citing Seeber and Armbruster (1993), the applicant stated that the Northeast Ohio Seismic Zone is associated with the Akron magnetic anomaly or lineament, which could be related to the “Niagara-Pickering magnetic lineament/Central Metasedimentary Belt boundary zone as a continental-scale Grenville-age structure.”

The applicant stated that for the CEUS, the most common types of surficial evidence of large prehistoric earthquakes are liquefaction features and faults that offset young strata. Obermeier (1995) conducted a paleoseismic liquefaction field study along two of the larger drainages in northeast Ohio and documented that no evidence of liquefaction was observed along the river. Crone and Wheeler (2000) later classified the Northeast Ohio Seismic Zone as a Class C feature. Those features have insufficient geologic evidence demonstrating the existence of a tectonic fault, Quaternary slip, or deformation associated with those features. The applicant indicated that the CEUS-SSC model uses broad regional seismic source zones to represent the occurrence of distributed seismicity in the CEUS. In addition, the applicant stated that the Northeast Ohio Seismic Zone appears as an area with higher seismicity rates within the larger regional source zones in which it lies.

The Anna Seismic Zone, also known as the Western Ohio Seismic Zone, has experienced around 40 earthquakes since 1875. The applicant stated that the strongest event recorded since the 1937 earthquake occurred in July 1986 with a magnitude of 4.5. Historic records show a maximum magnitude of 5, suggesting that events in this zone are able to produce a magnitude of 6 to 7. The applicant explained that researchers have found no evidence of paleoliquefaction features in the vicinity of Anna, Ohio; or in portions of the Auglaize, Great Miami, Stillwater, and St. Mary's rivers. The Anna Seismic Zone is a Class C feature based on the occurrence of significant historical earthquakes and absence of paleoseismic evidence. The applicant indicated that the Anna Seismic Zone is represented in the CEUS-SSC model as an area of a higher seismicity rate within the larger regional source zones in which it lies.

FSAR Subsection 2.5.1.1.4.4 describes significant seismic sources at a distance greater than 320 km (200 mi) from the site. The applicant described in detail the New Madrid Seismic Zone (NMSZ) and the Wabash Valley Seismic Zone (WVSZ) located 800 km (500 mi) and 500 km (300 mi) from the Fermi 3 site, respectively. The applicant explained the origin of stresses that seem to be driving the active deformation in the CEUS by describing several of the models that includes explanations for the localization of seismicity and the recurrence of large-magnitude events in the NMSZ. The applicant indicated that the CEUS-SSC characterized the RLME seismic sources in the NMSZ and the WVSZ; both of these seismic sources contribute to the seismic hazard at the Fermi 3 site.

Non-Seismic Geologic Hazards

In FSAR Subsection 2.5.1.1.5, the applicant described non seismic geologic hazards—including landslides and karst—within the Fermi 3 site region (320-km [200-mi] radius). The applicant explained that the Kanawha Section of the Appalachian Plateau is an area of moderate to high landslide susceptibility. In the Great Lakes area, landslide susceptibility was moderate and occurred mostly in lacustrine deposits. Landslides were also associated with wave erosion at the base of cliffs.

Karst features in the area are observed in limestones and dolomites of Silurian age (441 to 419 Ma) and consist of fissures, tubes, and caves that are usually less than 300 m (1,000 ft) long. The applicant explained that carbonate rock areas in northwestern Ohio covered by less than 6 m (20 ft) of glacial deposits developed large karstic features. Evaporite karst associated with halite and gypsum occurs mostly in the central area of the Michigan basin.

2.5.1.2.2 Site Geology

FSAR Subsection 2.5.1.2 describes the physiography, geologic history, stratigraphy, and structural geology of the site vicinity (40 km [25 mi]); site area (8 km [5 mi]); and site location of Fermi 3 (1 km [0.6 mi]). In addition, the FSAR includes subsections on site engineering geology and effects of human activity.

Site Physiography and Geomorphology

FSAR Subsection 2.5.1.2.1 states that the Fermi 3 site lies within the Eastern Lake section of the Central Lowlands physiographic province. FSAR Subsection 2.5.1.1.1 describes the regional physiographic provinces. The 1-km (0.6-mi) radius of the site is characterized by lacustrine deposits overlying glacial till, with an elevation that ranges from 173 to 180 m (570 to 590 ft).

The applicant indicated that geomorphic features have been identified and characterized in the western Lake Erie basin using both recent bathymetry and previous results of high-resolution seismic survey studies. The applicant described key geomorphic observations of Holcombe et al. (1987) regarding the lake-floor geomorphology of the western basin of Lake Erie.

<u>Site Area Geologic History</u>

In FSAR Subsection 2.5.1.2.2, the applicant described the site area geologic history during the Paleozoic and Quaternary periods. The applicant explained that units exposed in the site vicinity are from the Silurian and Devonian eras overlain by Quaternary sediments. During the Quaternary time, three ice lobes (Michigan, Saginaw, and Erie) coalesced on the lower peninsula of Michigan. The ice advance of the Port Huron stade affected the site region by creating high lake levels and proglacial lake areas such as the Glacial Lake Whittlesey and Warren Lake. Sedimentary deposits from these two lakes form the bulk of the glacial-age sediments deposited in the site vicinity.

<u>Site Area Stratigraphy</u>

In FSAR Subsection 2.5.1.2.3, the applicant described the site area stratigraphy during the Paleozoic and Quaternary periods. The applicant stated that the stratigraphy in the site vicinity is comparable to the regional stratigraphy, with the exception of sediment deposition associated with the Findlay arch in the Fermi site vicinity.

<u>Paleozoic Stratigraphy of the Site Area</u>

In FSAR Subsection 2.5.1.2.3.1, the applicant stated that three Paleozoic units are observed at the surface in the site vicinity: the Silurian Bass Islands Group, the Devonian Garden Islands Formation, and the Sylvania Sandstone.

The Silurian-age Salina Group is in the center of the Michigan basin and is subdivided into seven units identified as A through G. Unit A is further divided into four additional units: A-1 Evaporite, A-1 Carbonate, A-2 Evaporite, and A-2 Carbonate. The applicant described these units in detail and explained that the Fermi site is located in a region with no halite in the Salina and Bass Island groups. The applicant explained that the Silurian Bass Islands group is the uppermost bedrock unit found during the Fermi 3 subsurface investigation. The Bass Islands Group that the applicant encountered during its subsurface investigations is predominantly dolomite. The Devonian Garden Islands formation is described as dolomitic sandstone, dolomite, and cherty dolomite with a thickness of about 6.1 m (20 ft). The Devonian Sylvania Sandstone is a quartz sandstone cemented with dolomite and has a thickness of 6.1 m (20 ft). The Sylvania Sandstone overlies the Bois Blanc and Garden Islands formations and is exposed in the (8-km [5-mi] radius) site area.

<u>Quaternary Stratigraphy and Geomorphology</u>

In FSAR Subsection 2.5.1.2.3.2, the applicant described the glacial and postglacial lake strandlines and related geomorphic features, Quaternary deposits and soils in the site vicinity and site area, and the Quaternary stratigraphy of the site location. The applicant stated that the exposed Quaternary surficial geologic units in the site vicinity consist of Wisconsinan age till overlain by a thin mantle of lacustrine and eolian sands or locally thicker beach dune ridge deposits.

The applicant discussed the paleo-shoreline features in the site vicinity associated with Lakes Maumee, Arkona, Whittlesey, Warren, and Wayne. In addition, the applicant discussed the most prominent beach ridges south of Lake Erie. Totten (1982) concluded that before the most recent late Wisconsinan ice advance (Woodfordian), the major activity was wave erosion that formed wave-cut cliffs and terraces. The applicant stated that at the various lake levels following the Woodfordian glaciation, the major geomorphic activity was the deposition of beach and dune ridges rather than cliff and terrace cutting. The applicant indicated that based on the geomorphic position and elevation, the mapped paleoshorelines in the site vicinity are correlated to glacial and postglacial lake levels that postdate the most recent major glacial advance about 14,800 years ago.

1. Quaternary Units

FSAR Subsection 2.5.1.2.3.2.3 describes the glacial till, lacustrine deposits, and fill. The applicant explained that the glacial till overlies the bedrock throughout the entire site location and ranges in thickness from 1.8 to 5.8 m (6 to 19 ft). Glacial till consists of fine grained sediments with variable amounts of sand, gravel, and cobbles.

Lacustrine deposits and shoreline deposits overlie the glacial till in most of the site. The thickness of the lacustrine deposits ranges from 0 to 2.7 m (0 to 8.7 ft) and the deposits consist of laminated silt and clay. The applicant stated that the top of the lacustrine deposits may have been removed and replaced with fill at the Fermi 2 and 3 sites.

Site Area Geologic Structures

In FSAR Subsection 2.5.1.2.4.1, the applicant stated that the major Precambrian structures in the site vicinity are the MRS and the GFTZ. The applicant stated that there no known Quaternary faults in the site vicinity. The applicant explained that the Bowling Green fault and the Maumee fault are bedrock faults mapped within 40 km (25 mi) of the Fermi site. The youngest evidence for displacement on the Bowling Green fault takes place in the Silurian Bass Island Group. The applicant stated the Maumee fault has no geomorphic expression; it is offset in an apparent left lateral sense by the Bowling Green fault. The applicant indicated that offshore of where the Maumee River enters Lake Erie, a linear northeast trending channel was excavated and dredged for shipping traffic entering the Toledo Harbor. The dredged channel includes 11 km (7 mi) of channel on the Maumee River and 29 km (18 mi) on the bay. The applicant also described the Howell anticline and explained that this structure consists of en-echelon folds and other associated faults.

In FSAR Subsection 2.5.1.2.4.2, the applicant explained that recent and previous borings at the Fermi site show that the rocks underlying the site area, the Silurian Salina and Bass Islands Groups, are folded into a wide shallow syncline. FSAR Subsection 2.5.1.2.4.3 states that two joint sets were mapped at a quarry located about 1.6 km (1 mi) from the site and similar trends of joints were observed at quarries and outcrops in Michigan, Ohio, and Ontario, Canada. The applicant explained that some joint sets in the region are related to contemporary stress. Boring data from the Fermi 2 site showed that the Bass Islands dolomite is highly jointed. The applicant described the joints as relatively tight with minor solution activity. During the Fermi 3 subsurface investigations, the applicant observed jointing throughout the Bass Islands Group and Salina Group Unit F. The applicant stated that these joints vary from isolated joints to groups of closely spaced joints with orientations that fluctuate from near horizontal to near vertical and joint apertures up to several inches. The applicant added that joint density decreases below the Salina Group Unit F and only a few joints are observed in Salina Group Units C and B. However, there are joints filled with minerals such as anhydrite even in the deepest formations.

Site Area Geologic Hazard Evaluation

In FSAR Subsection 2.5.1.2.5, the applicant discussed the potential geologic hazards in the 40-km (25-mi) radius of the Fermi 3 site. Based on the Landslide Overview Map of the conterminous United States, the applicant stated that the site area and site location are in a region of moderate landslide vulnerability based on the presence of lacustrine deposits. The lacustrine deposits at the site are about 3 m (9 ft) thick, and the site area is relatively flat with no steep slopes. However, the applicant stated that even though the natural slopes are not landslide prone, "the stability of the lacustrine deposits should be considered in excavation design."

The applicant stated that some karst features may be present in the site vicinity, site area, and site location. Research performed by Davies et al. (1984) reflects active karst areas near northwestern Ohio that take place in zones where the noncarbonated overburden is less than 6 m (20 ft). The applicant thus concluded that the probability for karst in the 1-km (0.6-mi) radius of the site is low considering that the combined thickness of the till and lacustrine deposits is more than 6 m (20 ft). The applicant stated that there are no sinkholes in the 8-km (5-mi) site area radius, but sinkholes were observed outside of this radius.

The applicant explained that a possible reason for the presence of breccias and soft zones at the site is related to paleokarst occurrences and the associated dissolution of evaporite minerals. The applicant explained that only minor amounts of gypsum and anhydrite and no halite exist at the site. Thus, the potential for modern evaporite karst is small.

Site Engineering Geology Evaluation

FSAR Subsection 2.5.1.2.6 discusses the applicant's evaluation of the site engineering geology, including potential effects of human activities at the Fermi 3 site. The applicant stated that the engineering behavior of the soils and rock is discussed in FSAR Subsection 2.5.4.2. In FSAR Section 2.5.1.2.6, the applicant explained several engineering aspects of the soil and rocks such as zones of alterations, residual stresses in bedrock, unstable subsurface conditions, deformational zones, and prior earthquake effects.

FSAR Subsection 2.5.1.2.6.7 discusses the effects from human activities in the Fermi site such as oil and gas production, subsurface gas storage, and dissolution mining of salt. The applicant stated that various producing wells are within the Ohio site vicinity. No producing oil wells are within the 8-km (5-mi) radius of the site. The applicant indicated that no subsurface gas storage facilities or salt deposits are within the 8-km (5-mi) radius of the site area, and no mining is anticipated.

The applicant explained that the Fermi site has surface deposits composed of artificial fill that overlies the lacustrine and glacial till, which are less permeable. These less permeable materials formed a confined layer over the Silurian Bass Islands and Salina Groups that are considered bedrock aquifers at the site. The applicant discussed groundwater in more detail in FSAR Section 2.4.12.

2.5.1.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the basic geologic and seismic information, and the associated acceptance criteria, are in Section 2.5.1 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR 52.79(a)(1)(iii) as it relates to identifying geologic site characteristics with appropriate consideration of the most severe of the natural phenomena historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and period of time that the historical data were accumulated.

- 10 CFR Part 100, Section 100.23, "Geologic and Seismic Siting Criteria," for evaluating the suitability of a proposed site based on consideration of geologic, geotechnical, geophysical, and seismic characteristics of the proposed site. Geologic and seismic siting factors must include the safe-shutdown earthquake (SSE) ground motion for the site and the potential for surface tectonic and non-tectonic deformation. The site-specific GMRS satisfies requirements of 10 CFR 100.23 with respect to the development of the SSE ground motion.

The related acceptance criteria from Section 2.5.1 of NUREG–0800 are as follows:

- Regional Geology: In meeting the requirements of 10 CFR 52.79 and 10 CFR 100.23, FSAR Subsection 2.5.1.1 will be considered acceptable if a complete and documented discussion is presented for all geologic (including tectonic and nontectonic), geotechnical, seismic, and geophysical characteristics; as well as conditions caused by human activities that are deemed important for the safe siting and design of the plant.

- Site Geology: In meeting the requirements of 10 CFR 52.79 and 10 CFR 100.23 and the regulatory positions in RG 1.208, RG1.132, RG1.138, RG1.198, and RG1.206, FSAR Subsection 2.5.1.2 will be considered acceptable if it contains a description and evaluation of geologic (including tectonic and non- tectonic) features; geotechnical characteristics; seismic conditions; and conditions caused by human activities in appropriate levels of detail within areas defined by circles drawn around the site using radii of 40 km (25 mi) for site vicinity, 8 km (5mi) for the site area, and 1 km (0.6 mi) for the site location.

In addition, the geologic characteristics should be consistent with the appropriate sections from RG 1.208, "A Performance-Based Approach to Define Site-Specific Earthquake Ground Motion"; RG 1.132, Revision 2, "Site Investigations for Foundations of Nuclear Power Plants"; RG 1.138, Revision 2, "Laboratory Investigations of Soils for Engineering Analysis and Design of Nuclear Power Plants"; RG 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites"; and RG 1.206, "Combined License Applications for Nuclear Power Plants - LWR Edition."

2.5.1.4 *Technical Evaluation*

NRC Staff reviewed the information in Section 2.5.1 of the Fermi 3 COL FSAR, related to the site basic geologic and seismic information as follows:

COL Item

- EF3 COL 2.0-26-A Basic Geologic and Seismic Information

NRC staff reviewed the applicant's information on the resolution of COL Item EF3 COL 2.0-26-A related to the evaluation of the geologic, seismic, and geophysical information included under Section 2.5.1 of the Fermi 3 COL FSAR.

The technical information in FSAR Section 2.5.1 was based on the applicant's surface and subsurface geologic, seismic, and geotechnical investigations, which were undertaken in increasing levels of detail for distances closer to the site. The NRC staff reviewed FSAR Section 2.5.1 to determine whether the applicant had complied with the applicable NRC regulations and had conducted investigations with the appropriate levels of detail within the four circumscribed areas designated in RG 1.208. These areas are defined according to various distances from the site specified as 320 km (200 mi), 40 km (25 mi), 8 km (5 m), and 1 km (0.6 mi).

Fermi 3 FSAR Section 2.5.1 contains geologic and seismic information collected by the applicant in support of the vibratory ground motion analysis and the site-specific GMRS in FSAR Section 2.5.2. RG 1.208 recommends that applicants update the geologic, seismic, and geophysical databases and evaluate any new data to determine whether revisions to the existing seismic source models are necessary. Consequently, the staff's review focused on geologic and seismic data published since the mid- to late-1980s to assess whether these data indicate a need to update the existing seismic source models.

During the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic, and geotechnical investigations conducted for the Fermi 3 COL application. To thoroughly evaluate these investigations, the staff obtained additional assistance from experts at the United States Geological Survey (USGS) and participated with the USGS in a site audit at the Fermi 3 site in November 2009 (ADAMS Accession No. ML14112A212). The purpose of that visit was to confirm the applicant's interpretations, assumptions, and conclusions related to potential geologic and seismic hazards. The staff's evaluation of the information presented by the applicant in COL FSAR Section 2.5.1 and of the applicant's responses to RAIs is presented below. As discussed earlier under the introduction to Section 2.5 of this SER, the staff had asked several RAIs and had evaluated the responses received earlier in the review process. However, following the issuance of the NRC's NTTF after the Fukushima accident in Japan in March 2011, and the subsequent submissions of an RAI to all COL and ESP applicants, the COL applicant revised the FSAR—including FSAR Section 2.5.1. As part of this FSAR revision, the applicant replaced the EPRI (1986) seismic source models previously used in the seismic hazard calculations with the newly published NUREG–2115 CEUS-SSC model. As a result of this change, some of the earlier RAIs became irrelevant and were closed. The staff's evaluations of some of these earlier RAIs are therefore not discussed in this report. However, several of the original RAIs are still applicable to the staff's review and they are discussed below.

The staff reviewed the resolution to COL Item EF3 COL 2.0-26-A that addresses regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activities included under Section 2.5.1 of the Fermi 3 COL FSAR. The staff's review is provided below:

2.5.1.4.1 Regional Geology

The staff's review of FSAR Subsection 2.5.1.1 focused on the applicant's description of the regional physiography, geomorphology, geologic history, stratigraphy, tectonic setting, and non-seismic geologic hazards within a 320-km (200-mile) radius of the Fermi 3 site. The following SER subsections present the staff's evaluation of the information in FSAR Subsection 2.5.1.1 and the applicant's responses to the staff's RAIs.

Regional Physiography and Geomorphology

In FSAR Subsection 2.5.1.1.1, the applicant described the three physiographic provinces and associated geomorphologies found in the Fermi 3 site region—the Central Lowlands province; the St. Lawrence province; and the Appalachian Plateaus province. The Fermi 3 site lies in the Eastern Lake subprovince of the Central Lowlands province. The staff's review of FSAR Subsection 2.5.1.1.1 focused on the applicant's descriptions of the effects from glaciations and lake level fluctuations on the surrounding landforms. The staff performed an independent review of the published geologic information and concluded that the applicant has provided a thorough and accurate description of the regional physiography and geomorphology surrounding the Fermi 3 site to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Regional Geologic History

FSAR Subsection 2.5.1.1.2 describes the Precambrian (greater than 542 Ma), Paleozoic (542 to 251 Ma), Mesozoic (251 to 65.5 Ma), and Cenozoic (65.5 Ma to present) geologic history of the Fermi 3 site region. The applicant's discussions in this subsection concentrated on the early tectonic evolution of the site region before 251 Ma and on the glacial events of the Quaternary period (2.6 Ma to the present). Based on the applicant's descriptions in FSAR Subsection 2.5.1.1.2, the site region has not experienced major tectonic activity in the last 1 to 1.2 billion years (Ga).

The applicant documented that (1) sequences of collisions and rifting events took place before 542 Ma, (2) these sequences contributed to the formation of the basement structure within the site region, and (3) the site region was tectonically stable during the Paleozoic era. The applicant described the formation of the Michigan basin and the Findlay and Algonquin arches that developed in the site region during the Paleozoic era. The applicant documented that only minor sedimentary deposition in the Michigan basin occurred during the Mesozoic era (251 to 65.5 Ma); there is no Tertiary geologic history preserved in the site region; and much of the Quaternary period before about 10,000 years ago was dominated by glacial activity.

The staff's review of FSAR Subsection 2.5.1.1.2 focused on the applicant's descriptions of the Quaternary geologic history of the site region, because this period represents the most recent geologic activity that could affect potential hazards at the site. The staff also focused on the depositional history of the site region, because the geologic units beneath the proposed site also contribute to the safety at the site. The staff performed an independent review of the applicant's data sources and of additional geologic literature to verify the applicant's descriptions and conclusions in the FSAR. The staff concluded that the applicant's documentation of the geologic and tectonic history of the Fermi 3 site region is consistent with the most recent geologic literature. The staff found that there is no major evidence for tectonic activity or deformation in the site region during the Quaternary period. Furthermore, the staff concluded that the applicant has provided a thorough and accurate description of the geologic and tectonic history in the site region to support the Fermi 3 COL application. The staff found that the applicant's documentation is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Regional Stratigraphy

FSAR Subsection 2.5.1.1.3 describes Precambrian (greater than 542 Ma), Paleozoic (542 to 251 Ma), Mesozoic (251 to 65.5 Ma), and Quaternary (less than 2.6 Ma) sedimentary units in the site region. The applicant focused on those units that make up the Michigan Basin and noted that there are no exposed rocks older than 488 Ma at the surface in the Fermi 3 site region. The applicant documented five Paleozoic-Mesozoic cratonic sequences in the site region that represent sequences of inland sea transgressions and regressions. Of particular interest to the staff are the applicant's descriptions of the Tippecanoe II cratonic sequence that was deposited during the Silurian and early Devonian periods (444-398 Ma) and the 183-m (600-ft) thick Bass Islands Group, which is the foundation unit for the proposed Fermi 3 nuclear island structures and is composed of mostly dolomite with some interbedded shales. The applicant's subsurface investigations for the Fermi 3 site are in FSAR Section 2.5.4. The staff's evaluation of these investigations is in Subsection 2.5.4.4 of this SER and includes the Tippecanoe II sequence rocks.

The staff reviewed FSAR Subsection 2.5.1.1.3 and performed an independent review of the geologic literature describing the regional stratigraphy of the Michigan Basin and surrounding areas. In addition, to verify the applicant's stratigraphic descriptions in the FSAR, the staff visited the Fermi 3 site in November 2009 and evaluated rock core samples obtained during the applicant's subsurface investigations of the Fermi 3 site. Based on this review, the staff concluded that the applicant has provided a thorough and accurate description of the stratigraphic history of the Fermi 3 site region to support the Fermi 3 COL application. The staff found that the applicant's documentation is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Regional Tectonic Setting

In FSAR Subsection 2.5.1.1.4, the applicant discussed the regional tectonic setting of the Fermi 3 site that includes a description of the regional tectonic stress environment; an overview of the regional gravity, magnetic, and seismic profile data; and descriptions of the regional tectonic structures and seismic zones, in addition to significant seismic sources located beyond the 320-km (200-mi) site radius. Finally, the applicant also discussed regional non-seismic geologic hazards. The topics related to the regional tectonic setting follow, and include both glacial isostatic adjustments and regional tectonic structures.

Glacial Isostatic Adjustments

In FSAR Subsection 2.5.1.1.4.1.1, the applicant discussed the GIA in relation to the local tectonic stress environment. The GIA is also known as the post-glacial rebound and is the response of the earth's surface to glacial changes, such as the melting of large glaciers. The applicant stated that based on GPS measurements, the effects of the GIA on tectonic stress in the Fermi site region are mostly small. The applicant noted minor subsidence throughout most of the site region on the order of 1–2 mm/yr (0.039–0.078 in./yr) and some minor uplifts in the western portion of Lake Erie on the order of 64 mm per hundred years (0.026 in./yr). In RAI 02.05.01-03, the staff asked the applicant to provide additional information on the effects of the GIA in the site region with respect to the potential GIA effects on seismic hazards at the Fermi 3 site.

In the response to RAI 02.05.01-03 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant referenced the 2005 paper by Mazzotti and Adams (Mazzotti and

Adam 2005). According to these authors, research conducted during the previous 25 years documents that the GIA is likely responsible for only a very small number of earthquakes. The applicant's RAI response also includes an explanation and figures documenting the distribution and rates of geodetic strain, which is dominated by the effects of the GIA. The applicant stated that modeled strain rates for parts of the central United States and eastern Canada suggest that seismicity rates will likely remain constant in the next few hundred to thousands of years and will not "vary significantly in the future due to the GIA."

The staff reviewed the applicant's response to RAI 02.05.01-03 and performed an independent assessment of the geologic literature including papers by Mazzotti and Adams (2005), James and Bent (1994), Clark et al. (1994), Grollimund and Zoback (2001), and Sella et al. (2007). The staff concluded that the applicant has adequately evaluated the potential for seismicity in the Fermi 3 site region resulting from the effects of the GIA. In addition, the staff noted that no significant geodetic anomalies exist in the site region when the current deformation field is compared with the deformation field predicted by the GIA models. The staff concluded that the applicant's interpretation that the GIA has little effect on any changes to the regional seismicity is technically defensible. Finally, the staff concluded that there is no evidence in the geologic literature—including available data on strain rates in the central United States and eastern Canada—to suggest a likely increase in the seismic hazard at the proposed Fermi 3 site from future effects of the GIA. Therefore, RAI 02.05.01-03 is resolved and closed.

In RAI 02.05.01-04, the staff asked the applicant to provide additional information on the deformation of old shorelines attributable to the GIA in the Fermi site region—including any evidence for uplift or subsidence along identified old shorelines. In addition, the staff asked the applicant to provide figures or maps to help illustrate deformation attributable to the GIA along old shorelines in the Fermi 3 site region. In the response to RAI 02.05.01-04 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant referenced its response to RAI 02.05.01-03, which included a figure (FSAR Figure 2.5.1-251) plotting the elevation versus the distance from the raised and uplifted relict shorelines of multiple lake sequences in the Lake Erie basin within the 320-km (200-mi) site radius. The applicant also provided FSAR Figure 2.5.1-252, which illustrates the location of the Fermi 3 site with respect to areas of higher deformation due to the GIA effects. This figure shows that the Fermi 3 site vicinity is located outside of the uplift zone. The applicant stated that the deformation of relict glacial lake shorelines is consistent with expected deformation due to the GIA.

The staff conducted an independent review of the available geologic literature and noted that the Fermi 3 site is located in an area known as the "zone of horizontality" (or the zone of "zero isobase"), which is away from the hinge line that separates zones of higher uplift due to the GIA. Because of this location, the staff concluded that the Fermi 3 site is more likely to experience minor subsidence rather than uplift and is not expected to experience any significant uplift or deformation attributable to the GIA effects. The staff noted that the applicant had used the USGS 10-m (33-ft) digital elevation model to determine that there is no obvious warping of glacial lake shorelines within the 40-km (25-mile) site vicinity. The staff also noted that the lack of deformation along glacial lake shorelines within the site vicinity is consistent with the geologic literature that assumes little to no deformation in much of the site region related to the effects of GIA. Furthermore, the staff observed that actual GPS measurements described by Sella et al. (2006) and shown in FSAR Figure 2.5.1-253 suggest that the site vicinity may be experiencing subsidence rather than uplift on the order of 0 to 2 mm/yr (0 to 0.078 in/yr).

The staff concluded that the applicant's response is consistent with the available geologic literature and current state of knowledge. The staff further concluded that there is no geologic evidence to suggest significant deformation attributable to the effects of the GIA at the proposed Fermi 3 site. Therefore, RAI 02.05.01-04 is resolved and closed.

Regional Tectonic Structures

FSAR Subsection 2.5.1.1.4.3 discusses significant geologic structures in the proposed Fermi 3 site region including basins, arches, faults, and seismic zones. The applicant described 14 principal geologic faults and tectonic features in the site region and stated that there is no evidence of Quaternary tectonic faulting in the states of Michigan and Ohio. For most of the 14 structures, the applicant discussed limits on the timing of the most recent deformation.

1. Basins and Arches

FSAR Subsection 2.5.1.1.4.3.1 describes Paleozoic basins and arches, including the Michigan basin and the Findlay and Algonquin arches near the Fermi site. NRC staff reviewed this information and performed an independent review of the available geologic literature. The staff concluded that the applicant has provided a thorough and adequate description of the geologic basins and arches consistent with the current knowledge and available literature. The staff further concluded that there is no geologic evidence to suggest that any of these features represent recent geologic deformation, and therefore they would not be expected to pose a geologic hazard at the site.

2. Principal Faults within the Site Region

FSAR Subsection 2.5.1.1.4.3.2 describes 14 tectonic faults or features in the Fermi 3 site region. FSAR Table 2.5.1-201 summarizes these features and discusses the evidence for geologic deformation associated with each feature. In RAI 02.05.01-06, the staff asked the applicant to further discuss information on the timing of the most recent deformation for three faults in the site region—the Peck fault, the Sharpsville fault, and the Transylvania fault.

In the response to RAI 02.05.01-06 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant performed a more thorough search of the geologic literature and contacted regional geologic experts concerning these faults. The Peck Fault is located approximately 133 km (82 miles) north of the Fermi 3 site. Although the youngest evidence of deformation is early Mississippian (359-347 Ma), Fisher (1981) concludes that the deformation on this fault may have occurred through the end of the Paleozoic age (252 Ma). However, the applicant noted that there is no evidence in the available geologic literature to suggest that the Peck fault deformed units younger than the Mississippian age. For the Sharpsville Fault, the applicant noted that the youngest deformation is Devonian age (greater than 359 Ma).

The Transylvania Fault Extension comprises multiple geologic structures in the site region. The applicant contacted Mark Baranoski of the Ohio Geological Survey who stated that there was no evidence of Mesozoic or Cenozoic deformation on the Transylvania Fault Extension. This expert noted that although the age of the youngest deformation is not clear, it is likely from the Devonian age. As part of the response to RAI 02.05.01-6 the applicant updated FSAR Table 2.5.1-201; this describes regional tectonic structures within the 320-km (200-mi) radius of the Fermi 3 site region. Based on the staff's review of RAI 02.05.01-6 and the staff's independent literature review, the staff concluded that the applicant's response to RAI 02.05.01-6 adequately resolves the issues surrounding the age of the most recent deformation among the Peck, Sharpsville, and Transylvania faults. The staff noted that there is no documented evidence for a Quaternary deformation along the Peck, Sharpsville, and

Transylvania faults or evidence that would contradict the applicant's characterization of these faults. Therefore, RAI 02.05.01-6 is resolved and closed.

The staff noted that FSAR Table 2.5.1–201 summarizes the faults and folds in the Fermi site region, including the youngest faulted or deformed unit for most structures. However, the applicant did not explicitly discuss the oldest unfaulted unit associated with each fault or fold. In RAI 02.05.01-7, the staff asked the applicant to revise FSAR Table 2.5.1-201 and to discuss the oldest unfaulted geologic units associated with each of the major tectonic faults that the applicant described in FSAR Subsection 2.5.1.1.4.3.2.

In the response to RAI 02.05.01-7 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant revised FSAR Table 2.5.1-201 to reflect a more thorough literature review. The applicant also contacted experts at four state agencies in Michigan, Ohio, and Indiana for additional information. Based on these additional reviews, the applicant concluded that there is no evidence for Quaternary tectonic faulting in the Fermi 3 site region. The applicant also observed an unconformity between the Paleozoic and the overlying Quaternary glacial, fluvial, and lacustrine sediments. In general, the faulted Paleozoic rocks are overlain by Quaternary sediments, which are not known to be faulted in the site region according to information reported in the literature.

The staff reviewed the applicant's response to RAI 02.05.01-7 and noted that not one of the 14 faults that the applicant described in FSAR Subsection 2.5.1.1.4.3.2 shows evidence of Quaternary geologic deformation that would increase the seismic hazard at the proposed Fermi 3 site. The staff also noted that the applicant's descriptions of the faults are consistent with those in the available literature. Furthermore, FSAR Figure 2.5.1-203 illustrates tectonic structures in the Fermi site region. The applicant described most of these tectonic features in FSAR Subsection 2.5.1.1.4.3.2 with the exception of the Outlet, Marian, and Colchester faults.

In RAI 02.05.01-24, the staff asked the applicant to describe the three faults depicted in FSAR Figure 2.5.1-203 but not described in the FSAR text. In the response to RAI 02.05.01-24 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant explained that the Outlet and Marion faults are part of the Bowling Green fault zone that the applicant described in FSAR Subsection 2.5.1.1.4.3.2.3. The Bowling Green fault zone is located approximately 40 km (25 mi) from the Fermi site at its closest point. There is no evidence of Quaternary age faulting along any of the faults within the Bowling Green system. The applicant revised FSAR Subsection 2.5.1.1.4.3.2.3 to differentiate the faults in the Bowling Green fault zone.

Also in the response to RAI 02.05.01-24 is the applicant's revision of the FSAR to include a description of the Colchester fault. The Colchester fault shows no evidence of Quaternary geologic faulting. The staff reviewed the applicant's response to RAI 02.05.01-24 and concluded that the applicant has adequately evaluated all known potential fault sources in the Fermi site region based on the most current geologic literature. Following the applicant's response to RAI 02.05.01-24 and the applicant's revisions to FSAR Subsection 2.5.1.1.4.3.2 and FSAR Table 2.5.1-201, the staff concluded that the applicant has provided an adequate discussion of known geologic faults in the Fermi site region. Therefore, RAI 02.05.01-24 and RAI 02.05.01-07 are resolved and closed.

NRC Staff's Conclusions Regarding Faults within the Site Region

Based on information in FSAR Subsection 2.5.1.1.4.3.2 and the applicant's responses to the staff's RAIs, the staff concludes that the applicant has provided a thorough and adequate description of known geologic faults in the Fermi 3 site region. The staff concludes that there is no evidence of a Quaternary deformation on these faults to suggest a hazard at the site. Finally, the staff determined that the applicant has provided a sufficient characterization of faults in the site region to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

3. Seismic Zones within the Site Region

FSAR Subsection 2.5.1.1.4.3.3 describes two seismic zones in the Fermi 3 site region—the Anna and the Northeast Ohio Seismic Zones. In the 2000 USGS Quaternary Fault and Fold Database, Crone and Wheeler (2000) designated these two zones as Class C features. Crone and Wheeler define Class C features as "those for which geologic evidence is insufficient to demonstrate the existence of a tectonic fault, Quaternary slip, or deformation associated with the feature."

a. Northeast Ohio Seismic Zone

The staff noted that FSAR Subsection 2.5.1.1.4.3.3.1 does not discuss earthquake-induced paleoliquefaction studies in the Northeast Ohio Seismic Zone. However, Crone and Wheeler (2000) cite Obermeier's 1995 examination of stream banks in the Northeast Ohio Seismic Zone for liquefaction features. Paleoliquefaction investigations are relevant to evaluating the possibility that magnitude 6 or larger earthquakes may have occurred in the past. Paleoliquefaction information may also indicate the potential for future earthquakes. Given the proximity of the Northeast Ohio Seismic Zone to the Fermi site, an earthquake of magnitude 6 or larger may impact the seismic hazard at the Fermi site. The staff therefore asked the applicant in RAI 02.05.01-10 to describe any paleoseismic investigations conducted in the Northeast Ohio Seismic Zone, including the locations investigated and the level of detail of the investigations.

In the response to RAI 02.05.01-10 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant described paleoseismic liquefaction field studies that Obermeier had conducted in 1995 along the Grand and Cuyahoga Rivers in northeast Ohio (Obermeier 1995). Dr. Obermeier investigated approximately 25 km (15.5 mi) of stream bank exposures along each of these rivers in search of evidence for earthquake-induced liquefaction features. Obermeier investigated Holocene sediments from the past 8,000 to 10,000 years that he considered to be moderately susceptible to earthquake-induced liquefaction and found no evidence of previously liquefied deposits. The applicant provided a table summarizing the field locations that Obermeier had visited in 1995 in addition to details about the geology, age of deposits, and liquefaction susceptibility for each location. The applicant also described unsuccessful searches for liquefaction evidence in the area near the Perry Nuclear Power Plant in Perry, Ohio. The applicant confirmed through research and through discussions with the Ohio Geological Survey that no additional paleoseismic field investigations have been conducted in northeast Ohio since the 1995 investigations by Obermeier.

The staff reviewed the applicant's response to RAI 02.05.01-10 and the results of the letter report from Obermeier to the NRC in May 1996 (Obermeier 1996). The staff determined that the applicant's information adequately describes the extent of paleoseismic investigations conducted in the Northeast Ohio Seismic Zone. RAI 02.05.01-10 is therefore resolved and closed.

FSAR Subsection 2.5.1.1.4.3.3.1 describes a series of earthquakes that occurred between 1987 and 2001 near Ashtabula County, Ohio, and also discusses the proximity of the 1987 earthquakes to an injection well. The staff noted that a series of earthquakes in 2001 were precisely recorded by the Ohio seismic network. However, the applicant did not provide any additional details of the larger 2001 event or the associated smaller events, including their location or the basis for linking the 1987 and 2001 events. The staff also noted that FSAR Figure 2.5.1-207 does not differentiate between the 1987 and 2001 events. In RAIs 02.05.01-12 and 02.05.01-28, the staff asked the applicant to provide additional information describing (1) the linkage between the 1987 and 2001 earthquakes near Ashtabula County; (2) evidence regarding whether or not these earthquakes are related to fluid injection; and (3) the potential for these earthquakes to produce magnitude greater than 5 earthquakes.

In the responses to RAI 02.05.01-12, and RAI 02.05.01-28, both dated February 11, 2010 (ADAMS Accession No. ML100570304), the applicant explained that earthquakes occurring between 1987 and 2003 near Ashtabula County, Ohio, are in close proximity to waste fluid injection wells that were active from 1986 to 1994. The earthquake sequences that took place between 1987 and 2003 were recorded by three short-term deployments of portable seismographs and by regional broadband seismographs. Based on an analysis of the recorded seismicity, Seeber et al. (2004) interpreted that these earthquakes had occurred along two existing subparallel faults due to increased pore pressures that are likely associated with the nearby fluid injection. The 1987 and 1992 earthquake sequences likely occurred along a strike slip fault close to the injection well activity. The increased pore pressures propagated outward from the fluid injection source and over time, the pressure led to induced seismicity (associated with the later 2001 and 2003 earthquakes) along a second favorably oriented fault further from the injection source (Seeber et al. 2004). These investigators concluded that the evidence for increased pore pressures along multiple faults provides evidence that these faults would not likely produce earthquakes with a magnitude greater than 5 (Seeber et al. 2004).

As a result of RAIs 02.05.01-12 and 02.05.01-28, the applicant revised FSAR Subsection 2.5.1.1.4.3.3.1 to include a more thorough description of the sequence of earthquakes that occurred near Ashtabula County, Ohio. The applicant provided a more complete description of the evidence linking these earthquakes to nearby fluid injection, as well as evidence linking these earthquakes to multiple pre-existing fault structures. The applicant also updated FSAR Figure 2.5.1-207 to include the timing of earthquakes identified in the Northeast Ohio Seismic Zone. The applicant also added FSAR Figure 2.5.1-266 to show the earthquakes and inferred fault planes associated with the Ashtabula seismic events. The staff reviewed the applicant's responses to RAIs 02.05.01-12 and 02.05.01-28, as well as the evidence and conclusions from Seeber and Armbruster (1993) and Seeber et al. (2004). The staff concludes that the applicant has provided a more thorough characterization of the Ashtabula seismicity in the RAI responses and in the revised FSAR descriptions. Therefore, RAIs 02.05.01-12 and 02.05.01-28 are resolved and closed.

In RAI 02.05.01-11, the staff asked the applicant to identify any other locations in the Fermi site region where large volumes of fluid are being injected or withdrawn. In the response to RAI 02.05.01-11 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant provided a table of active waste disposal wells located in the site region in Michigan, Ohio, and Indiana. The table identifies when the wells were drilled as well as the depth of the wells and the affected subsurface units. Triggered seismicity is only correlated with the fluid injection wells near Ashtabula County, Ohio. The staff reviewed the applicant's response to RAI 02.05.01-11 and determined that the tables in the applicant's response adequately detail the locations and history of injection wells in the Fermi 3 site region. Accordingly, RAI 02.05.01-11 is resolved and closed.

b. Anna Seismic Zone

FSAR Subsection 2.5.1.1.4.3.3.2 states that Obermeier (1995) performed paleoliquefaction surveys along stream banks surrounding the Anna, Ohio, area to evaluate evidence or the lack of evidence for large historic or prehistoric earthquakes. The applicant stated that Obermeier (1995) discovered no evidence for magnitude 7 earthquakes during the past several thousand years.

In RAI 02.05.01-14, NRC staff asked the applicant to more thoroughly describe Obermeier's paleoliquefaction investigations conducted in the Anna Seismic Zone. In the response to this RAI dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant's detailed description of those investigations included the locations that Obermeier had surveyed. Obermeier investigated more than 100 km (62 mi) of deposits along multiple rivers and streams to the south and southwest of the Fermi 3 site. The applicant also included a figure showing the locations of the rivers in the investigation, most of which are within the 320-km (200-mi) radius of the Fermi 3 site region but at least 100 km (62 miles) from the Fermi 3 site. The applicant also contacted Dr. Stephen Obermeier, USGS geologists Drs. Russ Wheeler and Richard Harrison, and geologists with the Ohio Geological Survey and the University of Indiana who are familiar with the Obermeier studies. The applicant also noted that there are no known surviving maps of Obermeier's field investigations to identify the exact locations of the paleoliquefaction studies.

The staff reviewed the RAI response and performed an independent evaluation of the Obermeier (1995) field investigations, which describe the types of deposits encountered along the rivers that were studied. Obermeier noted that although the quality of the outcrop locations along many of the stream banks was poor, there were sufficient exposures to evaluate the likelihood that larger, magnitude 7, earthquakes had occurred within the Anna Seismic Zone. Obermeier found no such evidence of earthquake activity during his paleoliquefaction field investigations in the Anna Seismic Zone. The staff observed that the Obermeier report does not preclude the possibility that smaller (magnitude 5 or less) earthquakes have occurred the Anna Seismic Zone.

The NRC staff's review found that the applicant's response to RAI 02.05.01-14 provides sufficient information regarding paleoliquefaction evaluations in the Anna Seismic Zone to assure the staff that the applicant had adequately evaluated the potential for large damaging earthquakes in the Fermi 3 site region. Furthermore, the staff concludes that based on published data of field investigations along several rivers in and surrounding the Anna Seismic Zone, there is no paleoliquefaction evidence to suggest that large magnitude earthquakes had occurred in the Anna Seismic Zone. Therefore, RAI 02.05.01-14 is resolved and closed.

<u>NRC Staff's Conclusions Regarding Seismic Zones within the Site Region</u>

Based on information in FSAR Subsection 2.5.1.1.4.3.3, the applicant's responses to the staff's RAIs, and the staff's independent literature investigations, the staff concludes that the applicant has provided a thorough and accurate description of the seismic zones located in the site region to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Seismic Zones outside of the Site Region

FSAR Subsection 2.5.1.1.4.4 describes two seismic zones outside of the site region: the NMSZ and the WVSZ. The NMSZ is located approximately 800 km (500 mi) from the Fermi 3 site, while the WVSZ is located approximately 500 km (300 mi) from the site. The applicant indicated that the CEUS-SSC model characterizes both zones as seismic sources of a RLME. The applicant also noted that both of these seismic sources contribute to the seismic hazard at the Fermi 3 site.

New Madrid Seismic Zone

FSAR Subsection 2.5.1.1.4.4.1 discusses the NMSZ, which is located approximately 800 km (500 mi) from the Fermi 3 site. The CEUS-SSC developed an RLME source to represent the central faults in the NMSZ. The applicant described a publication by Forte et al. (2007) proposing a mechanism to explain the occurrence of earthquakes in the NMSZ. Furthermore, the staff is aware of additional recent publications proposing other faulting mechanisms in the New Madrid region. In RAI 02.05.01-15, the staff asked the applicant to discuss the mechanisms considered as part of the NMSZ evaluation and to explain whether there is a consensus that favors one mechanism over another.

In the response to RAI 02.05.01-15, dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant explained that there are several proposed models to help explain seismicity in the New Madrid region. The applicant provided a comprehensive description of the many mechanisms various researchers have proposed to explain New Madrid earthquakes and updated the FSAR to include these discussions. The applicant emphasized that there is considerable uncertainty regarding the causative mechanisms and long-term behavior of fault sources in the New Madrid region, and no single hypothesis is widely accepted. What is widely accepted is the evidence of large earthquakes with a magnitude greater than 7 in the NMSZ at various times in the last 2,000 years, regardless of the mechanism.

The staff reviewed the applicant's response to RAI 02.05.01-15, in addition to more than 15 published resources that discuss possible mechanisms for earthquakes in the New Madrid region. The staff concludes that the applicant has performed a thorough review of these mechanisms and the varied possible explanations for NMSZ seismicity. The applicant evaluated the effects of earthquakes in the NMSZ as part of the PSHA for the Fermi 3 site. SER Section 2.5.2 provides the NRC staff's evaluation of the applicant's PSHA for the site. RAI 02.05.01-15 is therefore resolved and closed.

Wabash Valley Seismic Zone

The staff reviewed the applicant's description of the WVSZ in FSAR Subsection 2.5.1.1.4.4.2, in addition to published resources that discuss possible mechanisms for earthquakes in the Wabash Valley region. The staff concludes that the applicant has performed a thorough review of these mechanisms and the varied possible explanations for WVSZ seismicity. The applicant evaluated the effects of earthquakes in the WVSZ as part of the PSHA for the Fermi 3 site. SER Section 2.5.2 provides the NRC staff's evaluation of the applicant's PSHA for the site. The staff did not request any additional information from the applicant with respect to the WVSZ.

NRC Staff's Conclusions Regarding Seismic Zones outside of the Site Region

Based on the information in FSAR Subsection 2.5.1.1.4.4 and the applicant's response to RAI 02.05.01-15, NRC staff concludes that the applicant has provided a thorough and accurate description of seismic zones located outside of the site region that have the potential to affect hazards at the Fermi 3 site. The staff found that the applicant's information is sufficient to support the Fermi 3 COL application. The staff concludes that the applicant's description is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Regional Non-seismic Geologic Hazards

In FSAR Section 2.5.1.1.5, the applicant discussed landslide hazards and the occurrence of karst in the Fermi 3 site region. The staff's review concludes that the applicant has provided an adequate evaluation of non-seismically related geologic hazards in FSAR Subsection 2.5.1.1.5 to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23. The staff's evaluation of the potential for landslide and karst hazards at the Fermi 3 site is under the "Site Geological Hazard Evaluations" later in this SER.

2.5.1.4.2 Site Geology

The staff's review of Fermi 3 COL FSAR Subsection 2.5.1.2 focused on the applicant's description of the site physiography, geologic history, stratigraphy, and structural geology within the site vicinity (40-km [25-mile] radius), site area (8-km [5-mile] radius), and site location (1-km [0.6-mi] radius) of the Fermi 3 COL site. The following section presents the staff's evaluation of the applicant's information in FSAR Subsection 2.5.1.2 and the applicant's responses to the staff's RAIs.

Site Physiography and Geomorphology

FSAR Subsection 2.5.1.2.1 discusses the site physiography. The applicant stated that the Fermi 3 site is located in the Eastern Lake section of the Central Lowlands physiographic province. The site vicinity is also located in the St. Lawrence Lowlands physiographic province. These provinces are described in more detail in FSAR Subsection 2.5.1.1.1. The applicant also described the Maumee Lake plains section of the Eastern Lake and the St. Clair Clay Plains section of the St. Lawrence Lowlands.

The staff reviewed the site physiography in FSAR Subsection 2.5.1.2.1 and performed an independent review of the published geologic information. The staff concluded that the applicant has provided a thorough and accurate description of the physiography and geomorphology surrounding the Fermi 3 site to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with the guidance of RG 1.208 and meets the requirements of 10 CFR 100.23.

Site Geologic History

The applicant discussed the regional geologic history of the Fermi 3 site in FSAR Subsection 2.5.1.1.2. The staff's evaluation of the regional geology is provided above under "Regional Geologic History."

FSAR Subsection 2.5.1.2.2 describes the Paleozoic and Quaternary geologic history, including an unconformity between the Pennsylvanian and Pliocene periods. The applicant also described the glacial history of the Fermi 3 site area and vicinity during the Quaternary and more specifically, during the past 25,000 years. The applicant described the relationships between lake phases, glacial lake shorelines, and ice margin positions in the site vicinity. The applicant also described the predecessor of Lake Erie, Glacial Lake Leverett, whose shoreline may have been within the site vicinity limits.

In RAI 02.05.01-17, the staff asked the applicant to explain any correlations that may exist between mapped glacial shorelines in the site vicinity and possible relict shorelines associated with Glacial Lake Leverett. In the response to RAI 02.05.01-17 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant summarized the sequence of glacial events affecting the preservation of the Lake Leverett shorelines. The applicant noted that the lake levels associated with Glacial Lake Leverett were affected by subsequent ice advances. These younger ice advances, in addition to subsequent lake level fluctuations from transgressions and regressions, explain the very limited evidence of Lake Leverett shorelines in the Fermi 3 site vicinity.

The staff reviewed the applicant's response to RAI 02.05.01-17 as well as a number of publications that discuss the glacial history of the Great Lakes region. The staff concluded that the applicant's response to RAI 02.05.01-17 is sufficient to clarify that subsequent glacial-related processes have mostly overridden evidence for former Glacial Lake Leverett shorelines. RAI 02.05.01-17 is therefore resolved and closed.

FSAR Subsection 2.5.1.2.2.2 suggests that glacial lakes formed in the last 14,000 years "have surface expression continuity and preserved landforms that document the rebound history of the area." In RAI 02.05.01-18, the staff asked the applicant to describe the post-glacial rebound history in the site vicinity in order to better understand the history of vertical deformation at and near the Fermi 3 site. In the response to RAI 02.05.01-18 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant referred to the response to RAI 02.05.01-03 that discussed the evidence for vertical deformation of glacial and post-glacial lake shoreline features that record the GIA in the site region. The applicant also referenced its response to RAI 02.05.03-6, which is discussed in Section 2.5.3 of this SER. The applicant summarized the history of Lake Erie levels during the past approximately 10,000 years based on recent interpretations by Holcombe et al. (2003), whose historic descriptions of Lake Erie post-glacial levels are based on the latest detailed bathymetric and water budget data. The applicant noted that relict shorelines in the site region and vicinity are near the hinge line between uplift to the northeast and a zone of horizontality to the southwest.

The applicant noted that the elevations of lake strand lines in the site vicinity indicate that isostatic adjustments are relatively uniform. The applicant also updated the FSAR to clarify those landforms and features associated with young glacial lakes reflect the "cumulative response of the site vicinity to glacial isostatic adjustments."

The staff reviewed the applicant's response to RAI 02.05.01-18. The staff also performed an independent review of the pertinent geologic literature relating to glacial landforms in the Great Lakes region and the vertical deformation of glacial shorelines. The staff concluded that the applicant has provided an adequate description of the glacial rebound history of the Fermi 3 site vicinity. Therefore, RAI 02.05.01-18 is resolved and closed.

NRC Staff's Conclusions Regarding Site Geologic History

Based on the information in FSAR Subsection 2.5.1.1.2 and the applicant's responses to the staff's RAI's, NRC staff concludes that the applicant has provided a thorough and accurate description of the site geologic history to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Site Stratigraphy

FSAR Subsection 2.5.1.2.3 describes the site area and site location stratigraphy based on the applicant's subsurface investigations conducted for the Fermi 3 COL application. The staff's review of FSAR Subsection 2.5.1.2.3 focused on the applicant's descriptions of the Silurian-age Bass Islands Group and Salina Group units that underlie the proposed Fermi 3 site. In particular, the Bass Islands Group is the foundation-bearing unit for the proposed Fermi 3 nuclear island and is predominantly composed of dolomite with interbedded shale. The applicant also described the Quaternary stratigraphy and geomorphology in the Fermi 3 site vicinity. Glacial and lake deposits overlie the Paleozoic Bass Islands and Salina Groups. The applicant's descriptions of the stratigraphic and geomorphic history in the Fermi 3 site vicinity correlates with the regional descriptions that the applicant provided in FSAR Subsection 2.5.1.1. FSAR Section 2.5.4 discusses the applicant's subsurface investigations. The NRC staff's technical evaluation of FSAR Section 2.5.4 is in SER Subsection 2.5.4.4.

The staff reviewed FSAR Subsection 2.5.1.2.3 and performed an independent review of the geologic literature describing the regional and the site stratigraphy of the Fermi 3 site. In addition, in November 2009, the staff visited the Fermi 3 site and evaluated rock core samples obtained during the applicant's subsurface investigations of the site to verify the applicant's stratigraphic descriptions included in the FSAR. Based on this review, the staff concludes that the applicant has provided a thorough and accurate description of the stratigraphic and geomorphic history of the Fermi 3 site vicinity, site area, and site location to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Site Structural Geology

In FSAR Subsection 2.5.1.2.4, the applicant described the structural geology of the site vicinity. FSAR Subsection 2.5.1.2.4.1 states that there is no evidence of Quaternary faulting in the site vicinity. However, the applicant described two mapped bedrock faults in the Fermi 3 site vicinity: the Bowling Green and Maumee faults. The staff also noted that the Howell anticline and the Howell fault lie just outside of the site vicinity within 45 km (28 mi) of the Fermi 3 site.

FSAR Subsection 2.5.1.2.4.1 states that the Maumee fault is a northeast-southwest trending normal fault that follows the Maumee River and extends to the Lake Erie shore. FSAR Figures 2.5.1-230 and 2.5.1-231 show the trend of the Maumee fault and its location with respect to the Lake Erie shoreline while also showing the lake bottom bathymetry, including a northeast-southwest trending linear feature from the mouth of Lake Erie toward the lake basin. In RAI 02.05.01-20, the staff asked the applicant to explain the linear feature shown in the Lake Erie bathymetry with respect to the similar trending Maumee fault. In the response to RAI 02.05.01-20 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant explained that the linear feature represents an excavated and dredged channel used to facilitate shipping traffic in order to permit barges to enter the Toledo Harbor. The applicant provided additional documentation of the dredging history and annual dredging activity. The staff reviewed the applicant's response to RAI 02.05.01-20 and concludes that the applicant has adequately described the linear feature shown in the Lake Erie bathymetry and has adequately justified that this linear feature is not a likely extension of the onshore Maumee fault. Therefore, RAI 02.05.01-20 is resolved and closed.

During the NRC staff's visit to the Denniston Quarry in Monroe County, Michigan, as part of a November 2009 Fermi 3 COL site audit, the staff noted at least three zones of disrupted bedding exposed in the quarry walls. These disrupted zones suggest possible faulting of the Bass Islands Group. In one location, disrupted bedding exists beneath an interpreted paleokarst feature (located near the top of the geologic section) and suggests that the paleokarst development may be associated with faulting at depth. Figure 2.5.1-5 in this SER shows this paleokarst feature above a zone of disrupted bedding in the Bass Islands Group. In a second quarry location, a zone of disrupted bedding exists with mostly undisturbed bedding on either side. This second zone appears to be at least seven to ten meters wide; contains disrupted bedding from the top to the bottom of the exposed wall; and is flanked by relatively undisturbed bedding on both sides. The third zone of possible disturbed bedding was visible in a distant wall and could be related to vertical offsets within the Bass Islands Group.

RAI 02.05.01-29 asked the applicant to further evaluate the disturbed zones and the apparent offset beds visible at the Denniston Quarry, including a determination of whether or not the disturbed bedding and apparent offsets are fault related. In addition, the staff asked the applicant to evaluate the overlying Quaternary units and to determine whether these younger deposits were deformed by the underlying structures.

In the response to RAI 02.05.01-29 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant provided a 56-page Technical Memorandum that comprehensively discusses the studies in the Denniston Quarry. The applicant's quarry studies included trenches in the Quaternary deposits across the traces of the faults, sample descriptions of Quaternary deposits, and light detection and ranging (LiDAR) mapping of selected walls in the quarry. The applicant documented all of the evaluations, provided photographs and maps of the exposures, and included information such as a description of the oldest and youngest deformed strata that established the ages of the deformation. In one case, the applicant documented deformation in the Bass Islands Group that was traceable to the top of the bedrock. However, the applicant provided no evidence for faulting or deformation in the overlying Quaternary deposits from the past 12,000 years. The applicant's investigations identified no open caves or modern karst features at the Denniston Quarry that would indicate karst activity within the past 12,000 years. In the response to RAI 02.05.01-29 and as a result of the field investigations at the Denniston Quarry, the applicant updated the FSAR to document the results of the investigations.

The staff reviewed the applicant's response to RAI 02.05.01-29 and the applicant's field investigation report from the Denniston Quarry. The staff concludes that the applicant had conducted a thorough investigation of the evidence for Quaternary faulting and karst activity in the exposures at the Denniston Quarry. Based on this review, the staff noted that the applicant's investigations had revealed no evidence for faulting, deformation due to subsurface faulting, or karst activity in the overlying quaternary sediments at the Denniston Quarry. Based on the applicant's investigations and the information detailed in the applicant's report, the staff concludes that the applicant has provided a thorough characterization of the deformation features at the Denniston Quarry in the response to RAI 02.05.01-29. Thus, RAI 02.05.01-29 is resolved and closed.

NRC Staff's Conclusions Regarding Site Structural Geology

Based on information in FSAR Subsection 2.5.1.2.4, the applicant's responses to the staff's RAIs, and the staff's independent assessment, NRC staff concludes that the applicant has provided a thorough and accurate description of the structural geology at the site to support the Fermi 3 COL application. The staff found that the applicant's information is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

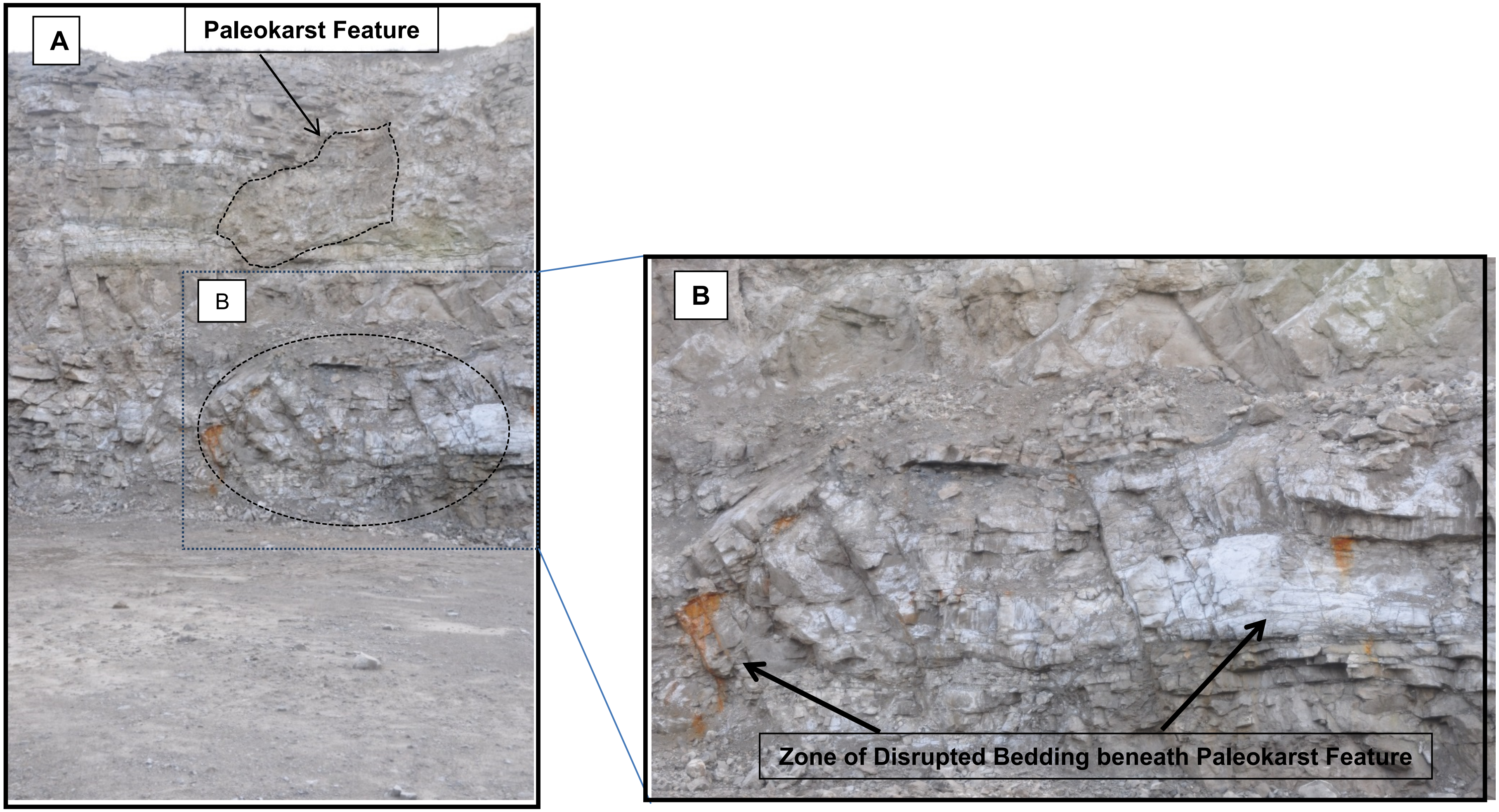


Figure 2.5.1-5 Photographs of Strata in the Denniston Quarry, Monroe, Michigan.

Note: A. Exposure of paleokarst feature in the Bass Islands Group and disrupted bedding beneath the feature.
B. Insert of disrupted bedding beneath paleokarst feature.]

Site Geologic Hazard Evaluation

FSAR Subsection 2.5.1.2.5 describes non-seismically related geologic hazards in the Fermi 3 site vicinity. FSAR Figure 2.5.1-227 illustrates potential landslide hazards in the Fermi 3 site region, and FSAR Figure 2.5.1-228 illustrates the potential for karst in the site region.

1. Site Landslide Hazard Evaluation

FSAR Figure 2.5.1-227 shows a high-incidence landslide area near the Fermi 3 site. In RAI 02.05.01-21, the staff asked the applicant to define the location of the high-incidence landslide probability in relationship to the Fermi 3 site and to explain whether any potential landslide hazards exist at the Fermi 3 site. In the response to RAI 02.05.01-21 dated February 11, 2010 (ADAMS Accession No. ML100570306), the applicant noted that the high-incidence landslide zone highlighted in FSAR Figure 2.5.1-227 is located approximately 50 km (31 mi) southwest of the Fermi 3 site, outside of the site vicinity. The applicant stated that the landslide area is associated with steep banks of the Maumee River and thick glacial deposits. The applicant noted, however, that a landslide hazard in the site vicinity is "low incidence, moderate susceptibility." The local relief along the Maumee River that is prone to landslides is approximately 15 m (50 ft) high, but the local relief along the streams near the Fermi 3 site is less than 3 m (10 ft). The applicant noted that this lower relief along the streams close to the site decreases the landslide probability of those stream banks. Based on the applicant's response to RAI 02.05.01-21 and the staff's field visit to the Fermi 3 site and the surrounding area in November 2009, the staff concluded that the applicant has sufficiently considered the potential for landslides. The applicant's response confirmed that the high incidence landslide area is outside of the site vicinity. Furthermore, the staff confirmed that landslide hazard at the site is likely low because of less relief along the stream banks and thinner glacial deposits. Therefore, RAI 02.05.01-21 is resolved and closed.

2. Site Karst Hazard Evaluation

FSAR Subsection 2.5.1.2.5 discusses the probability of karst within the 8-km (5-mile) radius of the Fermi 3 site, with respect to existing karst features in similar Silurian-age rock found in northwestern Ohio. The staff noted that FSAR Figure 2.5.1-228 shows an area of extensive subsidence near the Fermi 3 site. The applicant stated that the probability for karst development is low at the Fermi 3 site because the foundation-bearing Bass Islands Group is covered by more than 6 m (20 ft) of glacial till and lacustrine deposits. The applicant also stated that although the probability for karst is low at the site, karst features in units of a similar age in northwestern Ohio are "large enough to cause engineering problems." In RAI 02.05.01-30, the staff asked the applicant to provide a thorough discussion justifying the applicant's conclusion that the probability of karst at the Fermi 3 site is low.

In the response to RAI 02.05.01-30 dated February 11, 2010 (ADAMS Accession No. ML100570307), the applicant provided three lines of evidence to support its conclusion that there is a low probability of karst at the Fermi 3 site. The applicant first noted that karst formation is less likely in areas that have been formerly covered by ice sheets and are now covered by glacial deposits, because glaciers typically eroded away carbonate material or filled in existing karst features. Second, the applicant noted the absence of large voids or cavities due to dissolution in the subsurface investigations into the Salina and Bass Islands Groups at the Fermi 3 site. Finally, the applicant noted the absence of any large voids and cavities in bedrock exposures at the nearby Denniston Quarry. The applicant further explained that karst features typically form in the site region in Silurian-age carbonate rocks where they are not overlain by thick glacial deposits.

The staff reviewed the applicant's response to RAI 02.05.01-30 and reviewed local and regional karst studies surrounding the Fermi 3 site region. The staff determined that the applicant has adequately justified the conclusion that the evidence supports a low probability of karst formation at the site. The staff also reviewed the subsurface samples collected during the applicant's boring program and evaluated rock units exposed in the Denniston Quarry during a visit to the site in November 2009. The staff did not see any evidence for large cavities or voids due to dissolution in the subsurface foundation units observed by the staff. As a means of verifying that there are no subsurface faults or deformation features that could cause a hazard to the Fermi 3 site, the staff implemented a geologic license condition requiring the applicant to geologically map and evaluate all excavations for nuclear island structures and to evaluate all excavations for safety-related structures other than the nuclear island. License Condition 02.05.03-1 is defined in Subsection 2.5.3.5 of this SER. The staff's evaluation of cavities and voids in subsurface borings is in Section 2.5.4 of this SER. RAI 02.05.01-30 is therefore resolved and closed.

NRC Staff's Conclusions Regarding Site Geologic Hazard Evaluation

Based on information in FSAR Subsection 2.5.1.2.5 and the applicant's responses to the staff's RAIs, NRC staff concluded that the applicant has provided a thorough and accurate description of the site geologic hazards to support the Fermi 3 COL application. The staff found that the applicant's documentation is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

Site Engineering Geology

FSAR Subsection 2.5.1.2.6 describes the potential for engineering issues within the Fermi 3 site vicinity. The applicant evaluated zones of alteration, weathering, and structural weakness within the Bass Islands and Salina groups. The applicant also evaluated the potential for impacts from unrelieved residual stresses in bedrock and for weak or unstable subsurface conditions. The applicant evaluated deformational zones, the effects of human activities, and site groundwater conditions. The staff reviewed FSAR Subsection 2.5.1.2.6 and concluded that the applicant has adequately characterized potential engineering issues for the Fermi 3 site to support the Fermi 3 COL application. The staff found that the applicant's documentation is in accordance with RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.1.5 *Post Combined License Activities*

There are no post COL activities related to FSAR Section 2.5.1. However, in SER Subsection 2.5.3.5, the staff identifies a geologic mapping License Condition for Fermi 3 as the responsibility of the applicant and specifies it as License Condition 2.5.3-1.

2.5.1.6 *Conclusion*

NRC staff reviewed the application and confirmed that the applicant has addressed the required information relating to the basic geologic and seismic information, and no outstanding information is expected to be addressed in the Fermi 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COL application to the relevant NRC regulations, the guidance in Section 2.5.1 of NUREG–0800, and other applicable NRC RGs. The staff's review concluded that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determined that the applicant has adequately addressed COL Item EF3 COL 2.0-26-A, as it relates to the basic geologic and seismic information.

The staff found that the applicant has provided a thorough characterization of the geologic and seismic characteristics of the Fermi site, as required by 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii). In addition, the staff concluded that the applicant has identified and appropriately characterized all seismic sources significant to determining the GMRS for the Fermi site, in accordance with NRC regulations in 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance in RG 1.208. Based on the applicant's geologic investigations of the site vicinity and the site area, the staff determined that the applicant has properly characterized regional and site lithology, stratigraphy, geologic and tectonic history, and structural geology, as well as subsurface soil and rock units at the site. The staff concluded that there is no potential for the effects of human activities (e.g., mining activity or groundwater injection or withdrawal) to compromise the safety of the site. Therefore, the staff concludes that the proposed COL site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 100.23.

2.5.2 Vibratory Ground Motion

2.5.2.1 *Introduction*

The vibratory ground motion is evaluated based on seismological, geological, geophysical, and geotechnical investigations carried out to determine the site-specific GMRS, which must meet the SSE regulations in 10 CFR 100.23. The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the plant site. The development of the GMRS is based on a detailed evaluation of earthquake potential that takes into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site's subsurface material. The specific investigations necessary to determine the GMRS include the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that have any part within 320 km (200 mi) of the site must be identified. More distant sources that have a potential for earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources. Specific areas covered in the review are (1) seismicity; (2) geologic and tectonic characteristics of the site and region; (3) the correlation of earthquake activity with seismic sources; (4) a probabilistic seismic hazard analysis and controlling earthquakes; (5) seismic wave transmission characteristics of the site; (6) site-specific GMRS; and (7) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.5.2.2 *Summary of Application*

Section 2.5.2 of the Fermi 3 COL FSAR describes potential vibratory ground motion at the Fermi 3 site. In addition, in FSAR Section 2.5.2, the applicant provides the following:

COL Item

- EF3 COL 2.0-27-A Vibratory Ground Motion

In FSAR Section 2.5.2, the applicant provided site-specific information in accordance with SRP Section 2.5.2 to address COL Item EF3 COL 2.0-27-A.

The applicant developed the GMRS using the recommended performance-based approach in RG 1.208. Based on the evaluation, the applicant presented the following details related to the vibratory ground motion information for the Fermi 3 site.

2.5.2.2.1 Seismicity

FSAR Subsection 2.5.2.1 documents that the applicant used the most recent earthquake catalog published as part of NUREG–2115, in the seismic hazard assessment at the Fermi 3 site. The NUREG–2115 earthquake catalog covers earthquakes in the CEUS region from 1568 through 2008. The applicant stated that the NUREG–2115 catalog is the starting point for developing an updated earthquake catalog for the Fermi 3 site region. The applicant developed the updated catalog for the portion of the NUREG–2115 catalog (between latitude 39° and 45°N and longitude 79° and 87.5°W) covering the time period from January 1, 2009, through December 31, 2012. Furthermore, the applicant followed the process used in NUREG–2115 for developing an earthquake catalog. Consistent with the NUREG–2115 catalog, E[**M**] is the expected value of the true moment magnitude (**M**) and was calculated for all post-CEUS-SSC catalog earthquakes in the updated catalog. The applicant obtained updated earthquake information from the USGS National Earthquake Information Center (NEIC) Web site, the Advanced National Seismic System (ANSS) Web site, the Ohio Seismic Network Web site operated by the Ohio Geologic Survey, as well as the National Earthquake Database (NEDB) operated by the Geologic Survey of Canada.

Figure 2.5.2-1 in this SER shows the seismicity of the Fermi 3 site region and its surroundings. The applicant noted that the earthquakes occurring since 2008 have similar spatial distributions and do not indicate new concentrations of seismicity. In FSAR Subsection 2.5.2.1.2, the applicant noted that several significant earthquakes had occurred beyond the 320-km (200-mi) site radius in the period following the completion of the NUREG–2115 catalog—including the August 23, 2011, E[**M**] 5.73 earthquake near Mineral, Virginia; and the November 6, 2011, E[**M**] 5.66 earthquake in central Oklahoma. The applicant evaluated the impact of these earthquakes on the Fermi 3 seismic hazard is in FSAR Subsection 2.5.2.4.1.2.

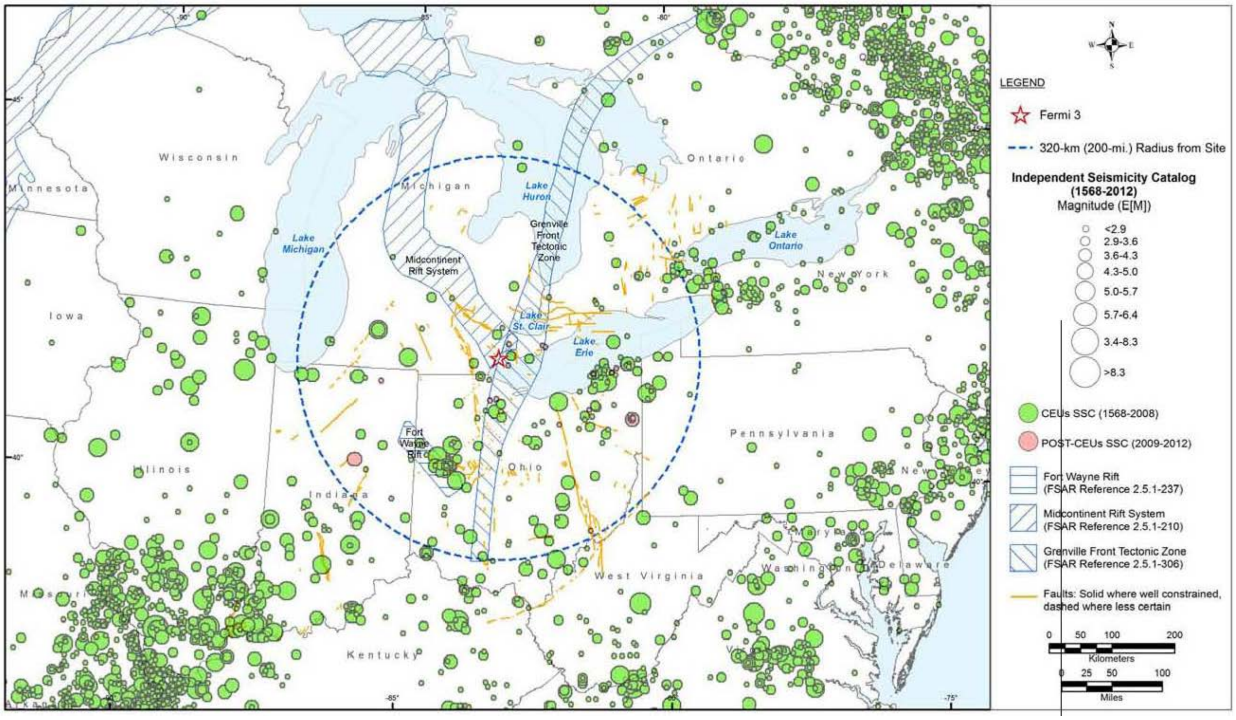


Figure 2.5.2-1 Seismicity of the Site Region of the Fermi 3 Site (taken from COL FSAR markups in the March 15, 2013, response to RAI 01.05-1; Figure 2.5.2-202 [ML13079A493])

2.5.2.2.2 Geologic and Tectonic Characteristics of the Site and Region

FSAR Subsection 2.5.2.2 describes the seismic sources and seismic model parameters that the applicant used to calculate the seismic ground motion hazard at the Fermi 3 site. The applicant used the NUREG–2115 regional seismic source characterization model developed for the CEUS region as a starting point for its seismic ground motion hazard. It took 3 years to develop the NUREG–2115 seismic source model, which was published in January 2012. The development of the model followed the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 procedures as outlined in NUREG/CR–6372, “Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.” It is a regional seismic source model to be used as a starting model in seismic hazard calculations for nuclear facilities in the CEUS region. In FSAR Subsections 2.5.2.2.1 and 2.5.2.4.3.1, the applicant conducted a review of the CEUS-SSC model to identify which seismic sources are relevant to the assessment of the seismic hazard at the Fermi 3 site and whether there is a need to update any of the seismic sources. Based on this review, the applicant stated that the regional model as published is adequate for use in seismic hazard calculations for the Fermi 3 site. The following summary of the CEUS-SSC model includes the source selection process the COL applicant used.

<u>Summary of the NUREG–2115 Seismic Source Model</u>

The applicant stated that the CEUS-SSC model described in NUREG–2115 contains two types of seismic sources: distributed seismicity sources and RLME sources. While the distributed seismicity sources are based on available earthquake locations and regional geologic/tectonic characterizations, the RLME sources are based on geologic and paleoearthquake records. The RLME source records describe the zones where the occurrence of repeated (two or more) large magnitude earthquakes (**M** > 6.5) are documented.

The CEUS-SSC model categorizes the distributed seismicity sources into two subgroups: M_{max} zones and seismotectonic zones. These subgroups represent uncertainties in source characterizations and differences of opinions regarding the identification of seismic sources in this region. In hazard estimates, the M_{max} and seismotectonics sources are weighted by 40 percent and 60 percent, respectively, to determine their contributions to the total seismic hazard at the site. The M_{max} zones are broad seismic sources that were identified based on limited tectonic information and represent potential seismic sources of future earthquakes. The seismotectonic sources are those that were developed using extensive analyses of regional geology, tectonics, and seismicity for the CEUS region. Both the M_{max} and the seismotectonics zones also include alternative source geometries that accommodate inherent uncertainty in seismic source characterization.

In FSAR Subsection 2.5.2.4.3, the COL applicant stated that the PSHA conducted for the Fermi 3 site includes the contributions from all or parts of each distributed seismicity model (i.e., M_{max} and seismotectonic source zones) that lie within 1,000 km (620 mi) of the site. As a result, the applicant used the following alternative seismic source configurations for the M_{max} zones: the Study Region, NMESE-N, NMESE-W, MESE-N, and MESE-W. The Study Region is the largest seismic source in the CEUS model, and it represents the entire area of the CEUS region. MESE and NMESE represent regions where the Mesozoic-aged tectonic extension did (MESE) or did not (NMESE) take place. The MESE-N, MESE-W, NMESE-N, and NMESE-N represent alternative configurations of these two overall classifications. Narrow “N” or wide “W” extensions represent varying alternative geometries of these sources. The applicant noted that the Fermi 3 site is located in the NMESE M_{max} source zone in both interpretations.

The applicant stated that the following nine seismotectonic source zones are included in the seismic hazard model for the Fermi 3 site: Atlantic Highly Extended (AHEX) Crust; Extended Continental Crust – Atlantic Margin (ECC-AM); Great Meteor Hotspot (GMH); Illinois Basin Extended Basement (IBEB); Midcontinent-Craton (MIDC) including MIDC -A, MIDC-B, MIDC-C, and MIDC-D; Northern Appalachian (NAP); Paleozoic Extended Crust Zone (PEZ) including PEZ-N and PEZ-W; Reelfoot Rift (RR) and Reelfoot Rift-Rough Creek Graben (RR-RCG); and St. Lawrence Rift (SLR). FSAR Figures 2.5.2-209, 2.5.2-210, 2.5.2-211, and 2.5.2-212 depict these seismotectonic zones. The applicant stated that the region within 320 km (200 mi) of the site is almost entirely contained within the MIDC seismotectonic zone. The MIDC seismic source is a large zone encompassing the regions of the continental interior. Tectonically, the MIDC represents a region with very little or no significant tectonic deformation in the past several hundred million years. Because the MIDC zone boundaries are uncertain, four alternatives define this zone: MIDC-A; MIDC-B; MIDC-C; and MIDC-D. Accordingly, FSAR Figures 2.5.2-211 and 2.5.2-212 show that the PEZ-W falls within a small eastern portion of the 320-km (200-mi) site region radius for the MIDC-C and MIDC-D source zone alternatives. The western boundary of this zone, however, is not well constrained. Therefore, the CEUS-SSC model has two alternative geometries for this source—PEZ-W and PEZ–N—that represent the wide zone geometry and the narrow zone geometry, respectively. Specifically, the PEZ-W alternative geometry falls within the 320-km (200-mi) site region radius, (see Figure 2.5.2-2 in this SER).

The applicant stated that in addition to the alternative geometries, the characterization of the distributed seismicity source zones includes the use of three alternative magnitude ranges for computing seismicity parameters; alternative values for seismogenic crustal thickness; rupture geometry; maximum magnitude distributions for each source; and seismicity parameter distributions for each source. The applicant stated that FSAR Subsection 2.5.2.4.1.2 includes the applicant's evaluation of the impact from earthquakes occurring after the completion of the CEUS-SSC model catalogued with an E[**M**] greater than or equal to 4.3 on the maximum magnitude distributions for the distributed seismicity source zones.

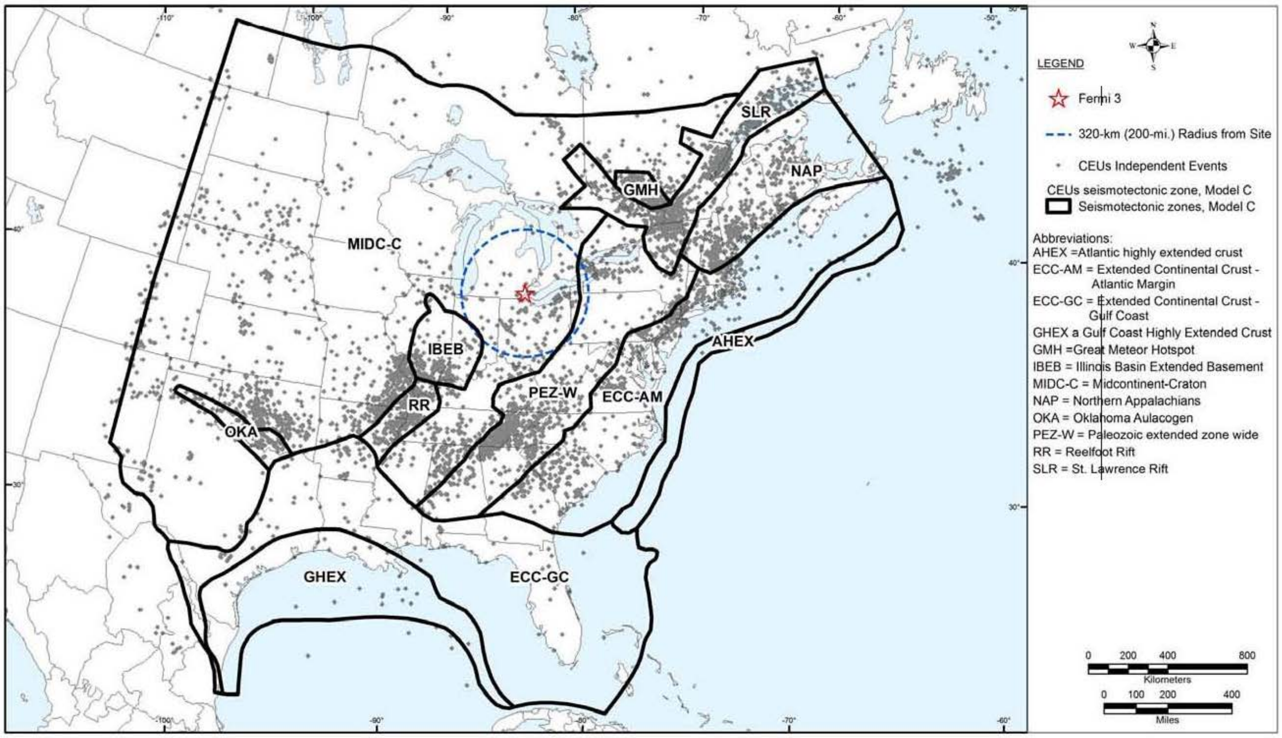


Figure 2.5.2-2 Map Showing the CEUS-SSC Seismotectonic Zones where the Rough Creek Graben Is Not Part of the Reelfoot Rift (RR) and the Wide Paleozoic Extended Crust (PEZ-W)
(taken from COL FSAR markups in the March 15, 2013, response to RAI 01.05-1; Figure 2.5.2-211 [ML13079A493])

[Note: The source configuration shown is one of the four alternative models for the MIDC seismotectonic zone.]

In the response to RAI 01.05-1 dated March 15, 2013 (ADAMS Accession No. ML13079A491), FSAR Revision 5, Subsection 2.5.2.2.4 summarizes the RLME sources used in the Fermi 3 seismic hazard calculations. The CEUS-SSC model requires contributions from the RLME sources to be added to seismic hazard estimates obtained from the distributed seismicity models. Figure 2.5.2-3 in this SER shows the locations of the RLME sources characterized in the CEUS-SSC model. The applicant identified the following RLMEs that were used in the Fermi Unit 3 seismic hazard calculations and are listed in order of significance to the Fermi 3 site hazard: New Madrid fault system (NMFS), Wabash Valley (WV), Charlevoix (CHV), and Charleston (CHS) RLME seismic sources. FSAR Subsection 2.5.2.4.3.1 provides the details regarding the RLME selection process, which are summarized in Subsection 2.5.2.4 of this SER.

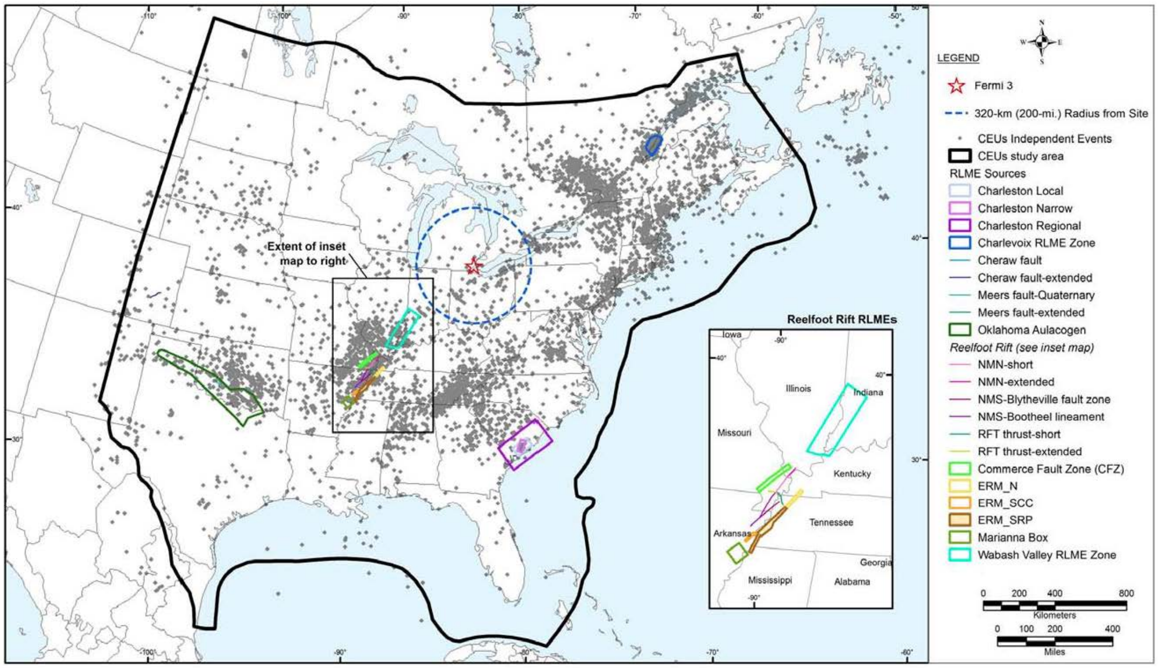


Figure 2.5.2-3 Map Showing the Repeated Large Magnitude Earthquake Sources in the CEUS-SSC Model (taken from COL FSAR markups in the March 15, 2013, response to RAI 01.05-1; Figure 2.5.2-213 [ML13079A493])

[Note: Nine primary RMLE sources and their alternative geometries are shown.]

2.5.2.2.3 Correlation of Earthquake Activity with Seismic Sources

FSAR Subsection 2.5.2.3 describes the correlation between the updated seismicity with the CEUS-SSC model sources. The applicant compared the distribution of earthquake epicenters from the NUREG–2115 earthquake catalog with the CEUS-SSC model sources and also with the updated earthquake catalog. The applicant concluded that the updated catalog does not show a pattern of seismicity that would require a new seismic source or significant revisions to the geometry of the seismic sources defined in the CEUS-SSC model that are in the Fermi 3 site region. The applicant also concluded that the updated CEUS catalog of the site region cannot be associated with a known geologic structure with the exception of the Anna and Northeast Ohio Seismic Zones, which lie at distances greater than 150 km (90 mi) from the Fermi 3 site. The applicant stated that seismicity in the Anna Seismic Zone occurs near the Ft. Wayne rift and seismicity in the Northeast Ohio Seismic Zone is associated with the Akron Magnetic Boundary; the CEUS-SSC model considers both areas.

2.5.2.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

FSAR Subsection 2.5.2.4 describes the applicant's PSHA calculations for the Fermi 3 site. The hazard curves generated by the applicant's PSHA represent the hazard calculated for generic hard rock conditions [characterized by a shear wave velocity (S-wave) of 2.8 km/s (9,200 fps)]. FSAR Subsection 2.5.2.4 also describes the earthquake potential for the Fermi site in terms of the most likely earthquake magnitudes and source-to-site distances, which are referred to as "deaggregation earthquakes." In this subsection, the applicant also determined the low-frequency (1 and 2.5 Hz) and high-frequency (5 and 10 Hz) deaggregation earthquakes by deaggregating the PSHA—in accordance with RG 1.208—at the specified probability levels of 10^{-4} and 10^{-5}.

PSHA Inputs

The applicant's PSHA calculations used the recently published CEUS-SSC model in NUREG–2115 in addition to the ground motion model in EPRI Technical Reports 1009684 and 1014381 (EPRI 2004, 2006).

Seismic Source Model

The applicant stated that the PSHA inputs for the Fermi 3 site consist of the distributed seismicity sources (M_{max} and seismotectonic zones) or portions of these zones that are within 1,000 km (620 mi) of the Fermi 3 site. The applicant conducted PSHA sensitivity calculations to aid in the selection of an appropriate set of RLME sources to include in the PSHA from the CEUS-SSC model. Based on these results, the applicant included CHV, CHS, NMF, and WV RLME sources because they contribute close to or greater than 1 percent to the total mean hazard at the Fermi 3 site. The seismic sources used in the PSHA calculations are summarized earlier under "Geologic and Tectonic Characteristics of the Site and Region" in this SER.

Seismicity Rates

The applicant evaluated the effect of the updated NUREG–2115 earthquake catalog on recurrence estimates within the 320-km (200-mi) site region. According to the applicant, two earthquakes of E[**M**] equal to or greater than 2.9 occurred within 320 km (200 mi) of the Fermi 3 site in the updated catalog (i.e., E[**M**] 3.79 and 3.66). The applicant conducted a one-side exact Poisson test of the hypothesis that the observation of two earthquakes in the 4-year period from 2009 through 2012 is consistent with the earthquake recurrence rates derived from the CEUS-SSC model. The results of the evaluation showed that the two observed earthquakes within 320 km (200 mi) of the Fermi 3 site are consistent with the distribution of earthquake recurrence rates derived from the CEUS-SSC model. Based on these results, the applicant concluded that it is not necessary to update the earthquake recurrence rates for the distributed seismicity source zones of the CEUS-SSC model in the Fermi 3 site region.

Maximum Magnitude Distributions

The applicant stated that FSAR Table 2.5.2-202 lists the earthquakes that have occurred after the completion of the CEUS-SSC model catalog in the time period from 2009 through 2012 with E[**M**] equal to or greater than 4.3. The applicant noted that these earthquakes potentially affect the M_{max} distributions for the following distributed seismicity zones that are applicable to the Fermi 3 PSHA: ECC-AM, GMH, MIDC-A, MIDC-B, MIDC-C, MIDC-D, MESE-N, and NMESE-W. The applicant used the procedure described in Section 5.2.1 of NUREG–2115 to compute the M_{max} distributions for the above source zones and considered the post NUREG–2115 catalog earthquakes listed in FSAR Table 2.5.2-202. The applicant's analysis indicated that forzones ECC-AM, MIDC-A, MIDC-B, MIDC-C, MIDC-D, and NMESE-W, incorporation of the updated earthquake catalog data results in a truncation of the lowest magnitude portion of the NUREG–2115 M_{max} distributions. For the NMESE-W and the MIDC zones, there is also an increase in the probability weight in the lower portion of the adjusted distributions. For the MESE-N and GMH zones, the additional earthquake data have an insignificant effect on the computed M_{max} distributions. As described in FSAR Subsection 2.5.2.4.3, the applicant performed sensitivity calculations using the updated M_{max} distributions in FSAR Table 2.5.2-203. The effect of including these adjusted M_{max} distributions in the hazard calculation produced a 0.3 percent maximum increase in the total mean hazard at 1 Hz and 10 Hz spectral accelerations for the Fermi 3 site. Even though this result indicates that the model does not need to be updated, the applicant conservatively performed the PSHA for the Fermi 3 site using the updated M_{max} distributions.

Ground Motion Prediction Equations

The applicant used the EPRI (2004, 2006) ground motion prediction equations (GMPEs) for the updated PSHA, in addition to the updated aleatory uncertainties and weights. The applicant stated that a number of GMPEs for the CEUS have been published since the completion of the EPRI ground motion median model. In FSAR Figures 2.5.2-239a, 2.5.2-239b, and 2.5.2-239c, the applicant compared these newer GMPEs to the EPRI (2004) 5th, 50th, and 95th percentile 10 Hz and 1 Hz ground motion median models according to the cluster in which they could be assigned. The applicant concluded that the median ground motions obtained using the newer GMPEs—specifically Silva et al. (2003), Atkinson and Boore (2011), and Pezeshk et al. (2011)—produce similar or lower ground motion amplitudes compared to the EPRI (2006) ground motion median models; so they are thus likely to produce lower hazard levels. Therefore, the applicant did not update the EPRI median ground motion models for the purpose of computing the hazard at the Fermi 3 site.

The applicant also discussed the aleatory variability models associated with more recent GMPEs. The applicant noted that the Pezeshk et al. (2011) GMPE uses an average of the Next Generation Attenuation (NGA) aleatory variability values from western North America (WNA). In addition, Atkinson and Boore's (2006) simulation-based aleatory variability value is similar to that for the empirical data in WNA. Atkinson (2013) concluded that aleatory variability models in WNA and central and eastern North America (CENA) should be similar. The applicant thus concluded that it is appropriate to use the EPRI (2006) aleatory variability model in the Fermi 3 PSHA, which is based on empirical ground motion data from active tectonic regions such as WNA.

PSHA Methodology and Calculation

Using the modified CEUS (with modified M_{max} distributions described in FSAR Subsection 2.5.2.4.3) and the EPRI GMPEs (2004, 2006), the applicant performed the PSHA calculations using a fixed lower bound magnitude of **M**5.0 and modeled earthquakes occurring in the CEUS-SSC-distributed seismicity sources as point sources. The applicant applied the EPRI (2004) models for distance adjustment and for additional aleatory variability resulting from the use of point sources (epicenter) to model earthquakes. The models assumed a random rupture location with respect to the epicenter. The applicant modeled earthquakes occurring in the RLME sources as extended ruptures and did not apply the distance adjustment and additional aleatory variability models to these sources. In calculating the magnitude-dependent rupture area of earthquakes for the RLME sources, the applicant made the adjustment to use the 4.35 value instead of 4.366 in Equation H-1 of NUREG–2115.

The applicant performed the above PSHA calculations for peak ground acceleration (PGA) and ground motion frequencies of 25, 10, 5, 2.5, 1, and 0.5 Hz, as described in RG 1.208.

PSHA Results

Figure 2.5.2-4 in this SER shows the mean hard rock uniform hazard response spectra (UHRS) for the 10^{-4}, 10^{-5}, and 10^{-6} annual frequencies of exceedance that the applicant generated using the PSHA results.

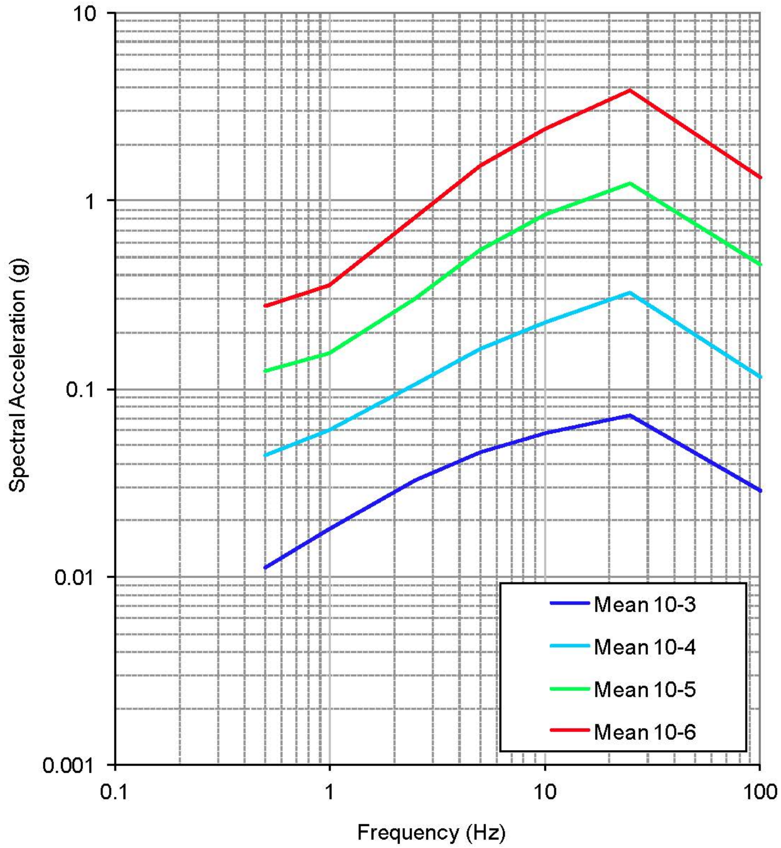


Figure 2.5.2-4 Mean Hard Rock UHRS for the Fermi 3 Site (taken from Fermi COL FSAR markups in the March 15, 2013, response to RAI 01.05-1; Figure 2.5.2-256 (ML13079A491)

To determine the low- and high-frequency controlling earthquakes for the Fermi 3 site, the applicant followed the procedure outlined in RG 1.208, Appendix D. This procedure involves the deaggregation of the PSHA results at a target probability level to determine the controlling earthquake in terms of a magnitude and source-to-site distance. Table 2.5.2-1 in this SER lists the mean magnitudes and geometric mean distances computed for the high- and low-frequency mean 10^{-4}, 10^{-5}, and 10^{-6} hazard results. Following Appendix D of RG 1.208, the applicant selected the controlling earthquake for the low-frequency ground motions from the distance calculation of greater than 100 km (62 mi). The applicant also referred to these controlling earthquakes as reference earthquakes (RE) because Approach 2B was followed for site response analyses described in NUREG/CR–6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines." As part of Approach 2B, the applicant also specified three high-frequency and three low-frequency deaggregation earthquakes (DE) in order to represent the distribution of earthquakes contributing to the hazard. These DEs are also listed in Table 2.5.2-1 in this SER and are designated as DEL, DEM, and DEH for the low-, middle-, and high-magnitude DEs, respectively. Table 2.5.2-1 shows that the high-frequency hazard is dominated by earthquakes with magnitudes of **M**5.5 occurring at short distances. At low frequencies, earthquakes that are several hundreds of kilometers away with magnitudes greater than **M**7 contribute significantly to the hazard.

Table 2.5.2-1 Rock Hazard Reference and Deaggregation Earthquakes

(based on information in Fermi COL FSAR Table 2.5.2-212)

Reference (Controlling) Earthquakes			Deaggregation Earthquakes			
Mean Hazard	**Magnitude (M)**	**Distance (km)**	**Designation**	**Magnitude (M)**	**Distance (km)**	**Weight**
Mean 10^{-4}, 5, and 10 Hz	6.0	48	DEL	5.5	25.8	0.616
			DEM	6.5	76	0.291
			DEH	7.6	585	0.093
Mean 10^{-4}, 1, and 2.5 Hz	7.4	457	DEL	5.5	22.5	0.240
			DEM	6.6	84	0.250
			DEH	7.6	585	0.510
Mean 10^{-5}, 5, and 10 Hz	5.9	15.1	DEL	5.5	10.8	0.657
			DEM	6.4	22.4	0.286
			DEH	7.4	73	0.057
Mean 10^{-5}, 1, and 2.5 Hz	7.6	468	DEL	5.5	11.5	0.295
			DEM	6.7	37	0.395
			DEH	7.7	594	0.310
DE = deaggregation earthquake DEL = DE low DEM = DE middle DEH = DE high			Km = kilometers To convert kilometers to miles divide the numbers by 1.609			

The applicant developed smooth response spectra to represent each RE and DE listed in FSAR Table 2.5.2-212 using the EPRI (2004) ground motion models and the EPRI (2006) aleatory variability models, as well as the spectral shape functions (average of the single and double corner spectral shape models for the CEUS) of the ground motions in NUREG/CR–6728. This involved the development of conditional mean spectral shapes based on Baker and Cornell (2006) and Baker and Jayaram (2008) and is described in more detail in FASR Subsection 2.5.2.4.4.3. The applicant also used the average of the single-corner and double-corner spectral shape models developed in NUREG/CR–6728 to (1) smooth the conditional mean spectral shapes between the seven frequencies defined in the EPRI (2004) ground motion models; and (2) extrapolate the EPRI median ground motion model from a frequency of 0.5 Hz down to a frequency of 0.1 Hz, specifically for the DEL and DEM events as well as the high-frequency (HF) RE events.

The applicant used constant velocity scaling to extend the DEH and low-frequency (LF) RE spectra from 0.5 Hz to 0.1 Hz (with a small decrease from constant velocity scaling from 0.2 Hz to 0.1 Hz) based on recently developed ground motion models (Somerville et al. 2001; Pezeshk et al. 2011; Atkinson and Boore 2011; and Silva et al. 2008a and 2008b). The applicant also extended the EPRI (2006) aleatory variability models down to a frequency of 0.1 Hz using a linear increase in aleatory variability with a decreasing log frequency from 0 percent to 0.5 Hz to 14 percent at 0.1 Hz, which was based on ground motion models developed as part of the Pacific Earthquake Engineering Research (PEER) Center's NGA Project (Abrahamson and

Silva 2008; Boore and Atkinson 2008; Campbell and Bozorgnia 2008; Chiou and Youngs 2008; and Idriss 2008).

FSAR Figures 2.5.2-262 through Figure 2.5.2-265 shows the resulting DE and RE response spectra.

2.5.2.2.5 Seismic Wave Transmission Characteristics of the Site

FSAR Subsection 2.5.2.5 describes the method the applicant used for develop the Fermi 3 site free-field soil UHRS. Those resulting from the applicant's PSHA are defined for generic, hard rock conditions characterized by an S-wave of 2.8 km/s [9,200 fps]). According to the applicant, these hard rock conditions exist at an elevation of 48 m (156 ft) NAVD 88 at the Fermi 3 site. To determine the near-surface soil UHRS, the applicant first developed soil/rock profile models for the Fermi 3 site; selected representative hard rock ground motions based on a hard rock seismic hazard calculation; and performed site response analyses to obtain the free-field soil UHRS at the competent layer level beneath the Fermi 3 site.

Site Response Model

According to the applicant, the geology at the Fermi 3 site consists of thin layers of fill, lacustrine deposits, and glacial till overlying dolomite of the Bass Islands and Salina groups. The applicant intends to remove the upper ~4 m (13 ft) of fill, ~1.5 m (5 ft) of low velocity lacustrine deposits, and ~3.4 m (11 ft) of glacial till. The applicant also proposed to locate the GMRS at the top of the Bass Islands group, which corresponds to an average elevation of 168.2 m (551.7 ft) NAVD 88. The applicant performed P-S (compression [P] - shear [S]) suspension logging, downhole seismic testing, and SASW surveys to obtain an S-wave velocity profile for the Fermi 3 site—as shown in Figure 2.5.2-5 of this SER. The applicant used the P-S suspension logging results to obtain the S-wave velocities of the soil and bedrock units. The applicant also used the downhole seismic test results to obtain bedrock S-wave velocities. The applicant encountered CEUS generic hard rock conditions (i.e., an S-wave velocity of about 2.8 km/s [9,200 fps]) at a depth of approximately 143.3 m (470 ft) or an elevation of 48 m (156 ft)—which corresponds to the Salina Group Unit B.

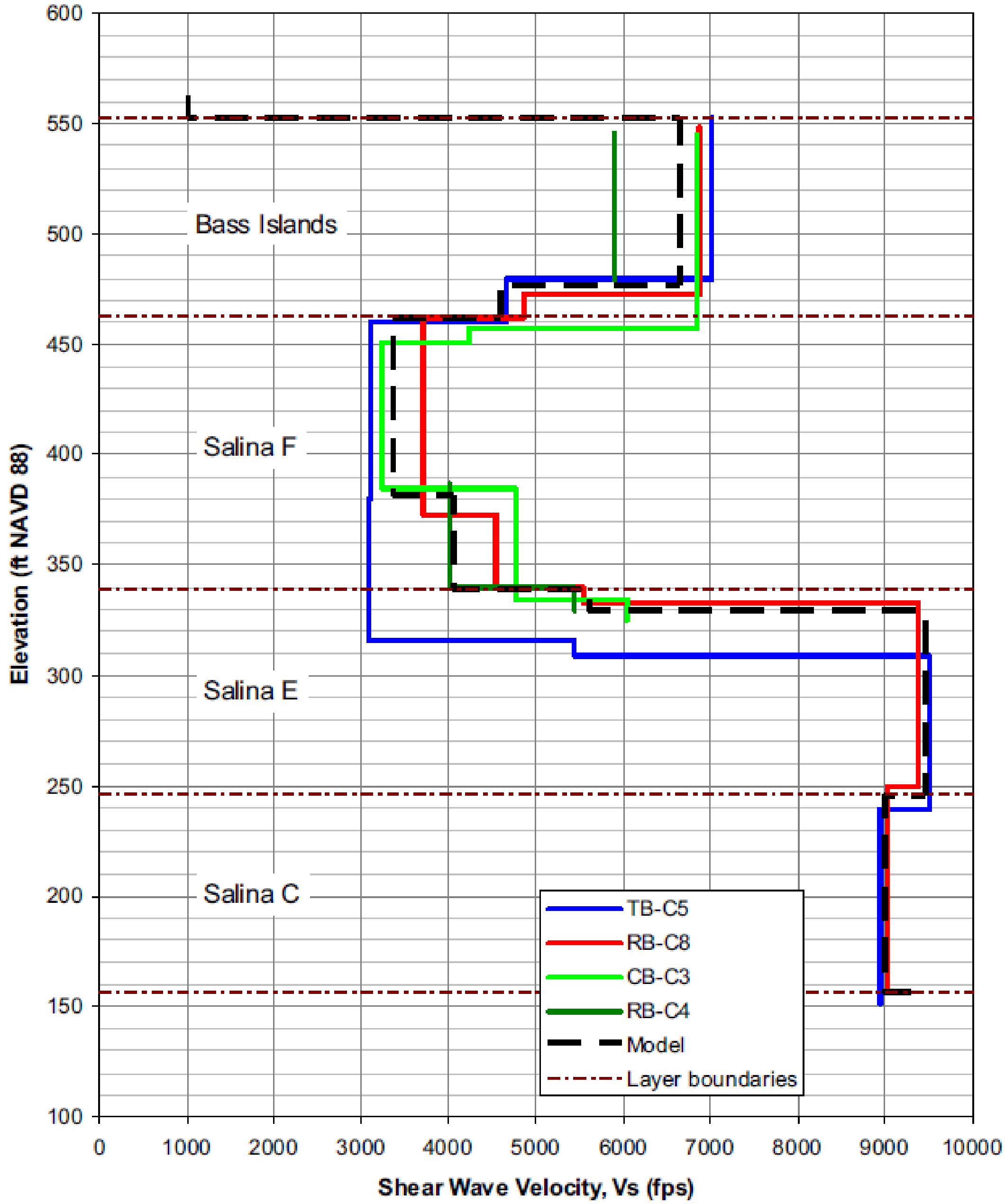


Figure 2.5.2-5 S-Wave Velocity Profile
(taken from Fermi COL FSAR markups in the March 15, 2013, response to RAI 01.05-1: Figure 2.5.2-270 [ML13079A491])

[Note: The curves labeled TB-C5, RB-C8, CB-C3, and RB-C4 corresponds to the mean S-wave velocity profiles developed for each boring. The curve denoted as "Model" corresponds to the geometric mean of the velocity profiles developed for each boring.]

In addition to the S-wave velocity profile, the applicant noted that the other material parameters used as inputs to the site response analysis included material unit weight, shear modulus, and damping. The applicant obtained soil and rock unit weights for the site response profile from laboratory test results and the site characterization. In summary, the applicant stated that unit weights for the rock units beneath the site range from 2,402.8 kg/m^3 to 2,562.95 kg/m^3 (150 pounds per cubic-foot [pcf] to 160 pcf). The applicant assigned a value of 2,707.12 kg/m^3 (169 pcf) to the unit weight of the underlying bedrock.

The applicant stated that the site response profile consists of dolomites and claystones with S-wave velocities exceeding 910 m/s (3,000 fps). The applicant expects the behavior of these materials to remain essentially linear at the expected levels of shaking (as defined by the rock hazard). The applicant determined the damping within these materials using the following procedure involving kappa (κ), a near-surface damping parameter, which is an estimate of the seismic energy dissipation at the site during an earthquake caused by damping within soil/rock layers and waveform scattering at layer boundaries. The applicant used estimates of the kappa to determine an appropriate damping ratio value for the rock layers below the glacial till.

The applicant stated that the kappa is an additive for soil/rock layers and is dependant on the individual layers. The applicant assigned the EPRI CEUS hard rock shallow crustal kappa of 0.006 seconds to shallow crust below an elevation of 48 m (156 ft). The applicant noted that the material above this elevation will contribute an additional damping and will thus add to the total site kappa. The applicant used a relationship between the kappa and the site S-wave velocity from EPRI (2005) to estimate the kappa above an elevation of 48 m (156 ft). Using an average S-wave velocity value of 1,737 m/s (5,700 fps), the applicant obtained a kappa of 0.013 seconds. The applicant then subtracted this value from the hard rock value of 0.006, which yielded a remaining kappa of 0.007 seconds for the top 121 m (396 ft) of dolomite. The applicant's conversion to damping, however, constrained the low strain damping for the Salina Group Unit F to a range of 1 to 3 percent based on values from the literature (Silva et al. 1996; EPRI 2005); and Silva 2007. The applicant then computed the damping values for the remaining rock layers using Equations 1, 2, and 4 in FSAR Subsection 2.5.2.5.1.2. The applicant noted that these assigned damping values add an additional kappa of 0.001 to 0.003 seconds. The applicant's conversion from kappa to material damping, made corrections to account for scattering effects due to velocity reversals present in the velocity model, as well as reversals introduced by randomizing the velocity profiles. The applicant assigned a damping value of 0.1 percent to the halfspace.

The applicant determined the appropriate soil and rock dynamic properties and then modeled the variability in the site data by randomizing the S-wave velocity profile. The applicant generated randomized profiles using the S-wave velocity correlation model developed by Silva et al. (1996). The applicant computed the damping in the sedimentary rocks beneath the glacial till using the randomized sedimentary rock layer velocities and thicknesses, as well as the selected kappa values. These artificial profiles represent the soil column from the top of the bedrock (with a bedrock S-wave velocity of 2.8 km/s [9,200 fps]) to the top of the Bass Islands Group bedrock for calculating the GMRS. The applicant used these randomized profiles as input to the site response calculations, which are summarized below in this SER.

In addition to the GMRS, the applicant developed foundation input response spectra (FIRS) at the base of the RB/FB, the control building (CB), and the fire water service complex (FWSC) that are presented in FSAR Section 3.7.1.

<u>Site Response Input Time Histories</u>

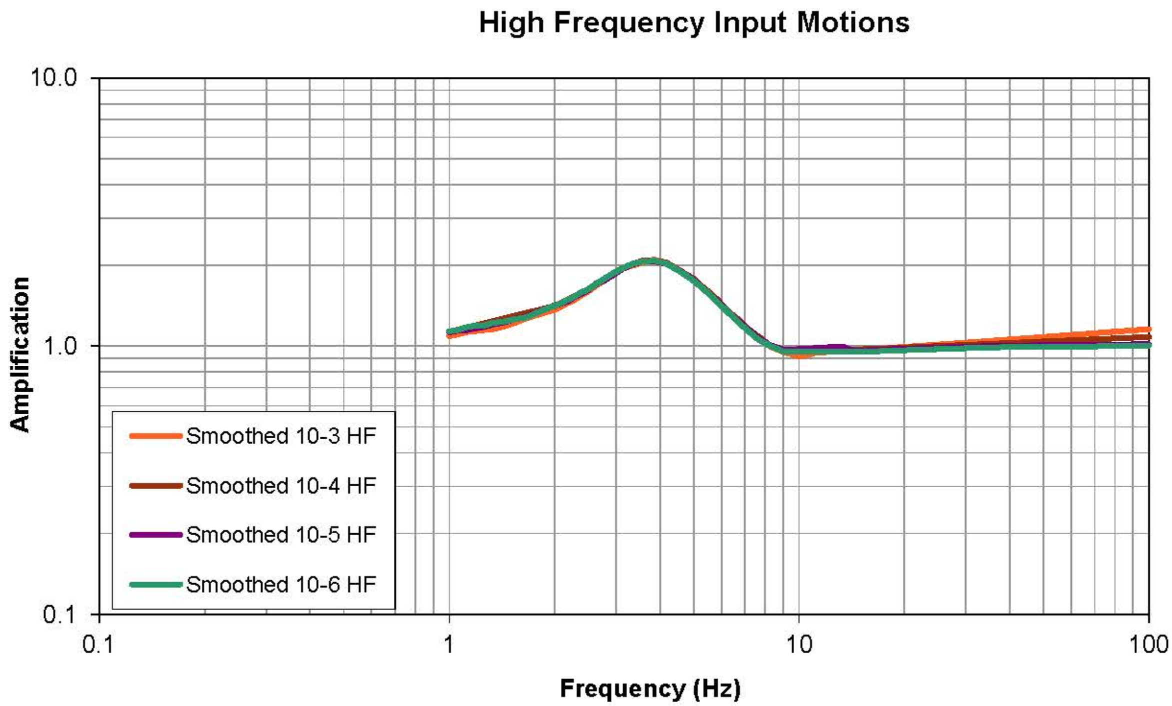
In order to develop rock input time histories for the Fermi 3 site response, FSAR Subsection 2.5.2.5.2 refers to the applicant's response spectra developed for each DE in FSAR

Subsection 2.5.2.4.4.3. The applicant stated that 30 time histories were developed for each DE (i.e., three DEs for each HF and LF 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} hazard level). The applicant selected time histories from NUREG/CR–6728 and scaled them to approximately match the target DE spectrum using the routine RSPM06, which implements the time domain spectral matching approach developed by Lilhanand and Teng (1988). The applicant concluded that the weak scaling produced records that have, in general, the desired relative frequency content of the DE spectra while maintaining a degree of natural variability.

Site Response Methodology and Results

The applicant used an updated version of the SHAKE computer program to calculate the site response at the Fermi 3 site. To calculate the final site amplification effects of the soil, the applicant divided the response spectrum for the computed surface motion by the corresponding response spectrum for the hard rock input motion. The applicant paired the 60 randomized S-wave velocity profiles with the 30 scaled time histories to compute the response of two profiles. The applicant then computed the arithmetic mean of the 60 individual response spectral ratios to define the amplification function.

In addition, for each DE, the applicant computed mean amplification functions for the three sets of rock damping values (1, 2, and 3 percent). For each annual exceedance probability level, the results from the three DEs (DEL, DEM, and DEH) are then combined to produce a weighted mean amplification function. The corresponding weights are in FSAR Table 2.5.2-215. FSAR Figure 2.5.2-277 shows the applicant's results for the different rock damping values that were used (1, 2, and 3 percent) for the 10^{-4} exceedance level. The applicant noted that the range in the damping leads to less than a 15 percent difference in the mean amplification at 100 Hz, which is less than a 25 percent difference near 40 Hz and decreases to less than a difference of 6 percent at 10 Hz. This difference continues to decrease for frequencies below 10 Hz. In addition, based on the results in FSAR Figure 2.5.2-278, the applicant concluded that the site amplification functions are insensitive to the differences in the DEs. Figure 2.5.2-6 in this SER plots the resulting high- and low-frequency amplification functions for the 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} hazard levels. According to the applicant, the site amplification is insensitive to the level of input motion from the presence of relatively hard rock that is modeled as linear material.



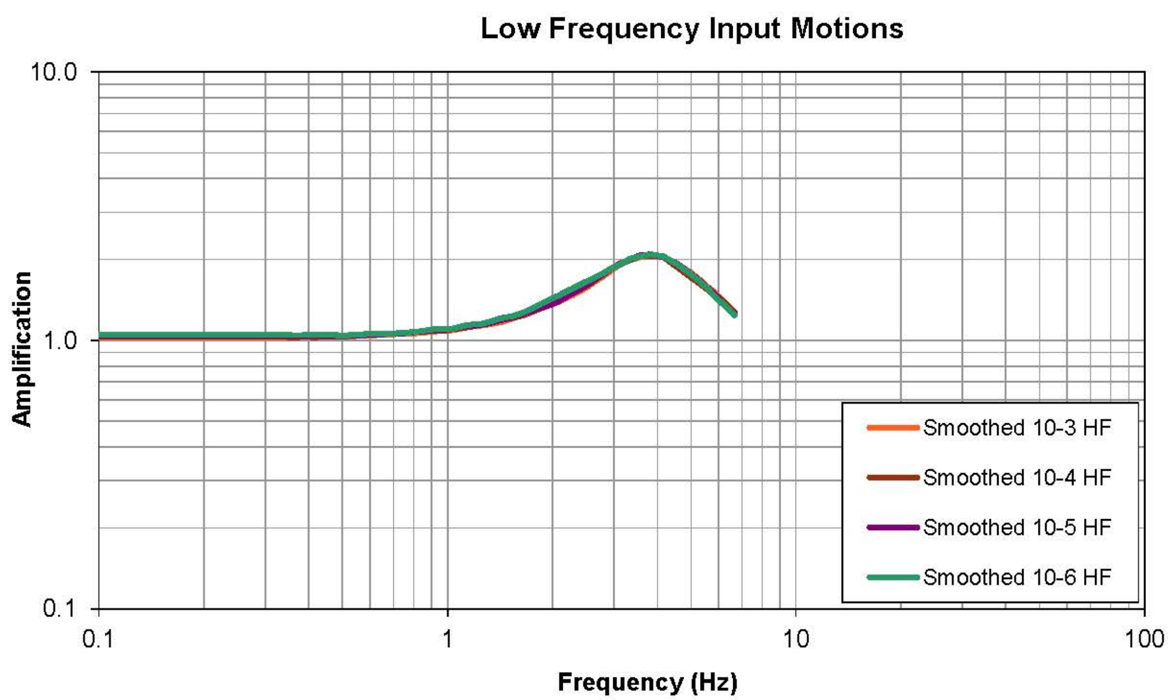


Figure 2.5.2-6 Mean Amplification Functions Corresponding to the Four Levels of Input Motion (i.e., annual probability of exceedance levels of 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}) (taken from Fermi COL FSAR markups in the March 15, 2013, response to RAI 01.05-1: Figure 2.5.2-279 [ML13079A491])

2.5.2.2.6 Ground Motion Response Spectra

FSAR Subsection 2.5.2.6 describes the method the applicant used to develop the horizontal and vertical site-specific GMRS. To obtain the horizontal GMRS, the applicant used the performance-based approach in RG 1.208 and in ASCE/SEI Standard 43–05, “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities.” The applicant developed the vertical GMRS using vertical-to-horizontal response spectral ratios for generic CEUS hard rock sites in NUREG/CR–6728.

The applicant first described the development of the hazard-consistent surface spectra using the 10^{-4} hazard level ground motions as an example. The applicant defined the surface spectra as free-field outcropping motions at an elevation of 168 m (551.7 ft) NAVD88. In summary, the applicant scaled the high- and low-frequency RE spectra by the appropriate smoothed amplification function. The applicant also scaled the generic hard rock UHRS using the appropriate low- and high-frequency amplification functions. Before applying the amplification functions, the applicant interpolated the rock UHRS between 10 and 100 Hz using the approach in FSAR Subsection 2.5.2.4.4.3. This approach was also summarized earlier in this SER section because there is a sharp peak at 25 Hz, which is an artifact of the PSHA computed for a limited number of frequency values (10, 25, and 100 Hz).

The final surface 10^{-4} UHRS is defined by the smooth envelope of the two spectra described above. The applicant conservatively removed the dip observed in the surface UHRS in the frequency range of 4 to 20 Hz that had resulted from (1) peaks in the site amplification function near 4 Hz from the overall rock profile, and (2) the peak near 25 Hz in the hard rock UHRS.

The applicant repeated the above procedure for the 10^{-5} and 10^{-6} exceedance level motions and then used the resulting surface spectra to develop the Fermi 3 horizontal and vertical GMRS.

Horizontal GMRS

The applicant calculated a horizontal, site-specific, performance-based GMRS using the method in RG 1.208. The performance-based method achieves the annual target performance goal (P_F) of 10^{-5} per year for the frequency of onset of significant inelastic deformation. This damage state (i.e., deformation) represents a minimum structural damage state—or essentially elastic behavior—and falls well short of the damage state that would interfere with functionality. The GMRS was calculated using the following relationship:

$$\text{GMRS} = \text{DF}^* \ \text{UHRS}(10^{-4})$$

Where:

$$\text{DF} = \max\{1.0,\ 0.6\,(A_R)^{0.8}\}$$

$$A_R = \text{UHRS}(10^{-5})/\text{UHRS}(10^{-4})$$

The applicant noted that when the value of A_R exceeds 4.2, RG 1.208 specifies that it is appropriate to use a GMRS value equal to 45 percent of the mean 10^{-5} UHRS. The applicant calculated the GMRS using the two approaches and developed the final GMRS from the envelope of the two, which corresponds to the 10^{-4} UHRS multiplied by the DF. Figure 2.5.2-7 of this SER shows the resulting horizontal GMRS.

Vertical GMRS

The applicant obtained the vertical GMRS by deriving V/H ratios and applying them to the horizontal GMRS. The applicant used the V/H spectral ratios for the generic CEUS hard rock sites in NUREG/CR–6728. The applicant justified the use of the generic CEUS hard rock V/H ratios by pointing out that the S-wave velocity of the Fermi 3 site is relatively high, and the kappa value of the assessed site is not significantly greater than the generic hard rock value. Figure 2.5.2-7 in this SER shows the resulting vertical GMRS.

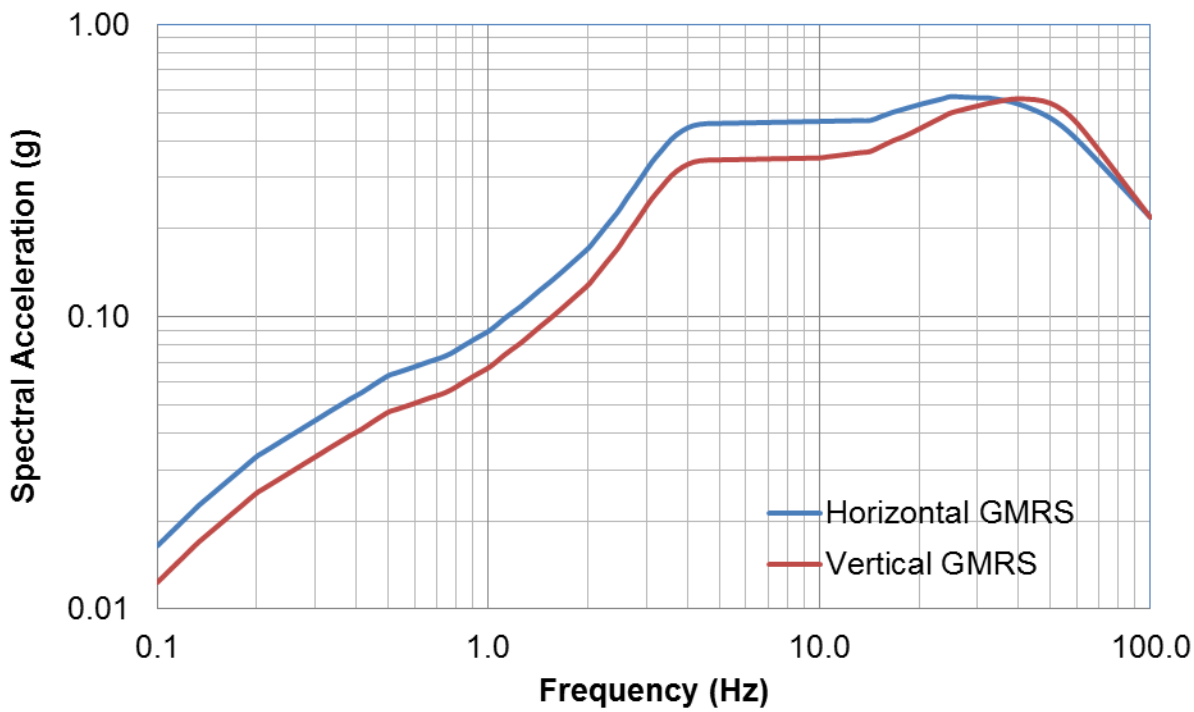


Figure 2.5.2-7 Fermi 3 Horizontal and Vertical GMRS (plot generated from data in Attachment 1 to the response to RAI 01.05-1 dated February 22, 2013 [ML13070A339])

2.5.2.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the vibratory ground motion, and the associated acceptance criteria, are in Section 2.5.2 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR 100.23 with respect to obtaining geologic and seismic information necessary to determine site suitability and to ascertain that any new information derived from site-specific investigations does not impact the GMRS derived from a probabilistic seismic hazard analysis. In complying with this regulation, the COL applicant also meets the guidance in RG 1.132 and RG 1.208.

- 10 CFR 52.79(a)(1)(iii) as it relates to considerations of the most severe of the natural phenomena historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and period of time when the historical data were accumulated.

The related acceptance criteria from NUREG–0800, Section 2.5.2, are summarized as follows:

- Seismicity: To meet the requirements in 10 CFR 100.23, this section is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.

- Geologic and Tectonic Characteristics of Site and Region: Seismic sources identified and characterized in NUREG–2115 were used.

- Correlation of Earthquake Activity with Seismic Sources: To meet the requirements in 10 CFR 100.23, the acceptance of this section is based on the development of the relationship between the history of earthquake activities and the seismic sources of the region.

- Probabilistic Seismic Hazard Analysis and Controlling Earthquakes: For CEUS sites that rely on the NUREG–2115 seismic source characterization model, the staff will review the applicant's PSHA including the underlying assumptions, how the results of the site investigations are used to update the existing sources in the PSHA, and how these site investigation results are used to develop additional sources or to develop a new database.

- Seismic Wave Transmission Characteristics of the Site: In the PSHA procedure described in RG 1.208, the controlling earthquakes are determined for generic rock conditions.

- Ground Motion Response Spectra: In this section, the staff reviews the COL applicant's procedure for determining the GMRS.

In addition, the geologic and seismic characteristics should be consistent with the appropriate sections in: RG 1.60 Revision 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants"; RG 1.132; RG 1.208; and RG 1.206.

2.5.2.4 *Technical Evaluation*

The staff reviewed the information in COL FSAR Section 2.5.2 related to vibratory ground motion in the response to RAI 01.05-1 as follows:

COL Items

- EF3 COL 2.0-27-A Vibratory Ground Motion

NRC staff reviewed Fermi COL FSAR Section 2.5-2 related to COL Item 2.0-27A. This COL item addresses the provision for site-specific information related to the vibratory ground motion aspects of the site including: seismicity, geologic and tectonic characteristics, the correlation of earthquake activity with seismic sources, a probabilistic seismic hazard analysis, seismic wave transmission characteristics, and the SSE ground motion.

The staff also reviewed the applicant’s information that addresses the provision for performing site-specific evaluations, (1) if the site-specific GMRS at the foundation level exceeds the response spectra in DCD Figures 2.0-1 and 2.0-2 at any frequency; or (2) if soil conditions are outside the range evaluated for the ESBWR DCD.

This SER section provides the NRC staff's evaluation of the seismic, geologic, geophysical, and geotechnical investigations carried out by the applicant to determine the site-specific GMRS or the SSE ground motion for the site. The development of the GMRS is based on a detailed evaluation of the potential for an earthquake that takes into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site subsurface material.

During the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic, and geotechnical investigations conducted for the Fermi 3 COL application. To thoroughly evaluate the applicant's geologic, seismic, and geophysical information, the staff obtained additional assistance from experts at the USGS. With the USGS advisors, the staff made an additional visit to the Fermi 3 site in November 2009 (ML14112A212) to confirm the applicant's interpretations, assumptions, and conclusions related to potential geologic and seismic hazards. As discussed in the introduction to Section 2.5 of this SER, the staff had submitted several RAIs to the applicant and had evaluated the responses during the review process conducted during the past several years. However, following the NTTF that the NRC issued after Japan's Fukushima accident in March 2011, and the subsequent submissions of an RAI to all COL and ESP applicants (RAI 01.05-1), the applicant significantly revised the COL FSAR—especially COL FSAR Section 2.5.2 related to seismic hazard calculations. As part of this COL FSAR revision, the COL applicant replaced the previously used EPRI (1986) seismic source models in the seismic hazard calculations with the newly published NUREG–2115 CEUS seismic source characterization model. With this change in the base seismic source model, many of the earlier RAIs became irrelevant and were closed. Therefore, the staff's evaluations of many of these earlier RAIs are not part of this report. However, several of the original RAIs are still applicable to the staff's review. They are discussed below, in addition to the new RAIs that the staff developed in response to the revised COL FSAR.

2.5.2.4.1 Seismicity

FSAR Subsection 2.5.2.1 states that the earthquake catalog used for the Fermi 3 site seismic hazard assessment is the NUREG–2115 earthquake catalog. The earthquake catalog is published as part of the NUREG–2115 seismic source model and covers the entire CEUS region, from 1568 through 2008, and includes a uniform moment magnitude scale for all earthquakes listed in the catalog. The staff recently reviewed the NUREG–2115 earthquake catalog. The staff's technical evaluation of COL FSAR Subsection 2.5.2.1 focused on the applicant's efforts to update the original NUREG–2115 earthquake catalog to use in the PSHA of the Fermi 3 site.

The applicant stated that the NUREG–2115 catalog is the starting point for developing an updated earthquake catalog for the Fermi 3 site region. The applicant developed the updated catalog for the portion of the NUREG–-2115 catalog between latitude 39° and 45°N and longitude 79° and 87.5°W, from January 2009 through December 2012. Furthermore, the applicant followed the process used in NUREG–2115 to develop an updated earthquake catalog that FSAR Figure 2.5.2-202 depicts. According to the applicant, the updated catalog shows that from 2009 through 2012, two earthquakes of E[**M**] equal to or greater than 2.9 occurred within 320 km (200 mi) of the Fermi 3 site. The first of these earthquakes had a magnitude of E[**M**] 3.79; the second had a magnitude of E[**M**] of 3.66. The applicant's updated catalog showed that no significant (E[**M**] ≥ 4) earthquakes have occurred in the 320-km (200-mi) site region. The applicant also evaluated earthquakes that have occurred beyond the 320-km (200-mi) site radius.

As shown in FSAR Table 2.5.2-202 and FSAR Figure 2.5.233, the applicant identified 12 earthquakes in the updated NUREG–2115 catalog with the potential to impact CEUS-SSC distributed seismicity sources (E[**M**] ≥ 4.3). This list included the August 23, 2011, E[**M**] 5.73 earthquake near Mineral (Virginia) and the November 6, 2011, E[**M**] 5.66 earthquake in central Oklahoma.

The staff developed a supplementary earthquake catalog covering the CEUS region from 2009 through 2012, in order to evaluate the completeness of the applicant's updated catalog and subsequent conclusions. The staff used the USGS ANSS, which is in Figure 2.5.2-8 in this SER. The staff compared this recent seismicity with the applicant's updated catalog in FSAR Figures 2.5.2-202 and 2.5.2-203. The staff concluded that the recent seismicity does not show any significant deviations from the applicant's updated seismicity catalog. Therefore, the staff concludes that the Fermi 3 earthquake catalog adequately characterizes the regional and local seismicity through 2012.

NRC Staff's Conclusions Regarding Seismicity

After reviewing FSAR Subsection 2.5.2.1, the staff concludes that the applicant has developed a complete and accurate earthquake catalog for the region surrounding the Fermi 3 site and that the earthquake catalog as described in FSAR Subsection 2.5.2.1 forms an adequate basis for the seismic hazard characterization of the site and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

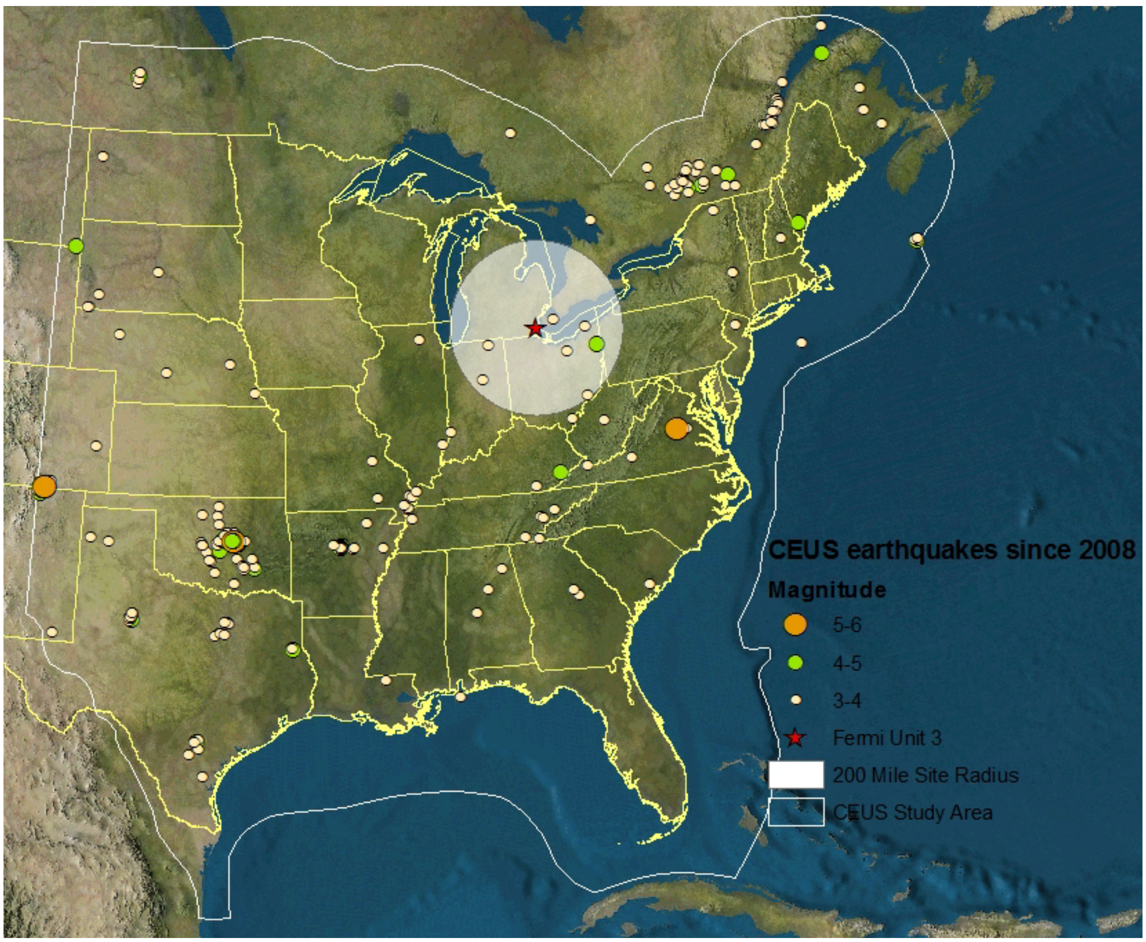


Figure 2.5.2 -8 Earthquakes with Magnitudes Equal to or Greater than 3.0 in the CEUS between 2009 and 2012

2.5.2.4.2 Geologic and Tectonic Characteristics of the Site and Region

FSAR Subsection 2.5.2.2 describes the seismic sources the applicant used to calculate the seismic ground motion hazard for the Fermi 3 site. Specifically, the applicant described the seismic source model published as part of NUREG–2115. The staff previously reviewed the NUREG–2115 seismic source model and approved its use as a starting regional model for nuclear power plant applications. However, NUREG–2115 specifically states that a regional mode should be compared against the local data and information. If needed, there must also be appropriate local adjustments. However, FSAR Subsection 2.5.2.4.1 describes the applicant's investigation of potential local seismic sources and source parameter adjustments to the NUREG–2115 model. The staff's review in this SER section therefore focused on the applicant's selection of the appropriate seismic sources from the CEUS-SSC model. The staff's detailed review of potential local seismic sources and source parameter adjustments to the NUREG–2115 model is in Subsection 2.5.2.4.4 of this SER.

NUREG–2115 Seismic Source Model

The CEUS-SSC model is published as part of NUREG–2115 and contains two types of seismic sources—distributed seismicity sources and RLME sources. The total seismic hazard at a given site is calculated by adding the hazard contributions of the distributed seismicity sources to those obtained using the RLME sources. Whereas the distributed seismicity sources are based on available earthquake locations and regional geologic/tectonic characterizations, the RLME sources are primarily based on geologic and paleoearthquake records. The NUREG-2115 model incorporates uncertainties in source geometries and model parameters by using logic trees and by assigning varying degrees of weights to the branches of the logic trees based on supporting data and evidence.

RLME Sources

The RLME sources describe seismic zones where there are documented occurrences of repeated (two or more) large magnitude earthquakes (**M** > 6.5). There are nine RLME sources defined in the NUREG–2115 model covering the entire CEUS region; they are all depicted in Figure 2.5.2-3 of this SER. These seismic sources are the CHV, CHS, Cheraw fault, Meers fault, NMF system, Eastern Rift margin fault, Marianna, Commerce fault zone (CFZ), and WV seismic sources. The applicant conducted PSHA sensitivity calculations to aid in the selection of an appropriate set of RLME sources to include in the PSHA. The applicant examined the following RLME sources closest to the Fermi 3 site: the CFZ, CHS, CHV, Eastern Rift Margin, Marianna, WV, and NMF system. Based on the results of sensitivity calculations, the applicant only included the CHV, CHS, NMF system, and WV RLME sources in the final PSHA because they contribute close to or greater than 1 percent to the total mean hazard at the Fermi 3 site.

The staff evaluated the applicant's rationale for selecting four out of the nine RLME sources for use in the PSHA calculations and finds that the applicant's selection of only the RLME sources that contribute close to or greater than 1 percent of the total mean hazard is adequate for the Fermi 3 PSHA calculations, because the remaining RLME source would not contribute significantly to the total mean hazard.

Distributed Seismicity Sources

The distributed seismicity sources are the second type of seismic sources described in the NUREG–2115 model, which classifies the distributed seismicity sources into two main subgroups: M_{max} zones and seismotectonic zones. These subgroups reflect the fact that there are differing views about seismic source characterizations in the CEUS region. The M_{max} zones represent the view that large magnitude earthquakes may occur anywhere in the CEUS region, and the tectonics of the region contribute minimally to the occurrence of medium and large earthquakes. The M_{max} zones are broad seismic sources with limited tectonic information; they represent areas with potential sources of future earthquakes. Seismotectonic sources represent an alternative view of variations in the occurrence of medium and large magnitude earthquakes based on tectonic environments. The seismotectonic sources result from extensive analyses of regional geology, tectonics, and seismicity in the CEUS region. Both the M_{max} and the seismotectonic zones also include alternative source geometries that accommodate inherent uncertainties in seismic source characterizations. Seismic hazard contributions are calculated for both subgroups, and the results of the M_{max} sources and the seismotectonic sources are weighted by 40 percent and 60 percent, respectively, to determine the total seismic hazard contributions of the distributed seismic sources at a given site.

The applicant included all or parts of each M_{max} source zone that is located within 1,000 km (620 mi) of the Fermi 3 site. Therefore, the applicant's PSHA is comprised of the following five alternative M_{max} seismic source configurations: Study Region, MESE-W, MESE-N, NMESE-W, and NMESE-N. The Study Region seismic source is the largest seismic source in the CEUS model, and it represents the entire area of the CEUS region. The MESE and NMESE sources represent regions where either the Mesozoic-aged (250 million years) or the younger tectonic extension did (MESE) or did not (NMESE) take place. The subgroups of the MESE and NMESE seismic sources—MESE-W, NMESE-N, and MESE-N—represent alternative configurations for each of these sources. The extension "N" represents the "narrow" and the extension "W" represents the "wide" alternative source geometries. The staff confirmed the applicant's choice of the M_{max} sources because they are adequate and satisfy the guidance in RG 1.208, which states that all seismic sources within the 320-km (200-mi) radius of the site should be investigated.

The NUREG–2115 seismic source characterization model also identifies 12 primary seismic sources within the seismotectonic subcategory of the distributed seismicity sources. Because there are uncertainties in source geometry definitions, some of these sources also have defined alternative geometries. The applicant used the same criteria of 1,000 km (620 mi) used for the M_{max} source zone selection, in order to determine which seismotectonic sources to include in the PSHA. Among the 12 seismotectonic-based seismic sources identified in NUREG–2115, the applicant identified the following sources as contributors to the seismic hazard estimates at the Fermi 3 site: AHEX; ECC–AM; GMH; IBEB;,MIDC-A, MIDC-B, MIDC-C, and MIDC-D; NAP; PEZ-N and PEC-W; RR and RR-RCG; and SLR.

The staff reviewed all of the CEUS-SSC seismic sources described in NUREG–2115 that occur within the 1,000-km (620-mi) site radius and confirmed that the applicant's choices of seismic source models are adequate and conform to the guidance in RG 1.208.

<u>NRC Staff's Conclusions of the Geologic and Tectonic Characteristics of the Site and Region</u>

Based on the review of the seismic sources described in the NUREG–2115 model, the staff concluded that the applicant has selected all of the appropriate CEUS-SSC RLME, M_{max}, and seismotectonic sources for inputs into the PSHA of the Fermi 3 site. The staff found that the applicant's has selected all sources that lie well beyond the 320-km (200-mi) site radius and also selected all RLMEs that contribute close to or greater than 1 percent of the total mean hazard. Therefore, the staff concludes that the applicant's seismic source zone model forms an adequate basis for the seismic hazard calculation of the site and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.2.4.3 Correlation of Earthquake Activity with Seismic Sources

FSAR Subsection 2.5.2.3 describes the correlation of updated seismicity with the CEUS-SSC model sources. The applicant compared the distribution of earthquake epicenters in the NUREG–2115 earthquake catalog with the CEUS-SSC model sources and also with its updated earthquake catalog. Based on this comparison, the applicant concluded that the updated catalog does not show a pattern of seismicity that would require a new seismic source or significant revisions to the geometry of the seismic sources defined in the CEUS-SSC model of the Fermi 3 site region. The applicant also concluded that the updated CEUS catalog does not show any earthquakes in the site region that can be associated with a known geologic structure, with the exception of the Anna and Northeast Ohio Seismic Zones, which lie at distances greater than 150 km (90 mi) from the Fermi 3 site. The applicant stated that seismicity in the Anna Seismic Zone occurs near the Ft. Wayne rift, while seismicity in the Northeast Ohio Seismic Zone is associated with the Akron Magnetic Boundary; the CEUS-SSC model considers both areas.

In Subsection 2.5.2.4.1 of this SER, the staff evaluated the completeness of the applicant's updated earthquake catalog and the applicant's subsequent conclusions, by comparing the applicant's earthquake catalog to a compilation catalog derived from the USGS ANSS seismicity catalog. Based on the spatial distribution of earthquakes in the updated catalog, the staff concurred with the applicant's conclusion that significant revisions to the existing CEUS-SSC source geometries are not warranted. The staff found that the applicant has adequately evaluated the potential for new seismic sources or for revisions to existing source geometries based on seismicity patterns. Therefore, the applicant's analysis meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.2.4.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

FSAR Subsection 2.5.2.4 presents the applicant's PSHA results and estimates of potential earthquakes for the Fermi 3 site in terms of deaggregation earthquakes. The applicant determined the high- and low-frequency deaggregation earthquakes by deaggregating the PSHA results at selected probability levels, in accordance with the guidance in RG 1.208. Before conducting the PSHA calculations and determining the deaggregation earthquakes, the applicant investigated the local and regional geologic and tectonic features and any potential adjustments to the seismic sources and their model parameters. Subsection 2.5.1.4 of this SER describes the staff's assessments of the local and regional geological features and concludes that no additional updates are needed. Therefore, the staff's review focused on the applicant's PSHA procedures for and the calculation of the Fermi 3 site deaggregation earthquakes.

PSHA Calculation

FSAR Subsection 2.5.2.4.1 states that the applicant used the NUREG–2115 seismic model for the probabilistic seismic hazard calculations of the Fermi 3 site and also outlines the procedures. Because the NUREG–2115 model covers the entire CEUS region, it may be unnecessary to use seismic sources in the PSHA calculations that are farther away and have lower seismicity rates. The applicant first identified seismic sources that will impact the seismic hazard calculations at the Fermi 3 and then used those selected seismic sources and the EPRI (2004, 2006) ground motion model (GMM) to calculate generic hard rock seismic hazard curves at the seven frequencies defined by the EPRI (2004, 2006) GMM. Using the hard rock seismic hazard curves, the applicant obtained uniform hazard response spectra at the annual frequency of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}. Using the procedures outlined in RG 1.208, the applicant also developed the magnitudes and distances of deaggregation earthquakes. The following discussion describes the staff's assessment of the applicant's PSHA calculations and the determination of the deaggregation earthquakes and their parameters.

PSHA Inputs

Among the distributed seismicity sources described in the NUREG–2115 model, Subsection 2.5.2.4.2 of this SER notes that the applicant used those sources with boundaries that are intersected by the 1,000-km (620-mi) site radius—which is well beyond the 320-km (200-mi) region specified by RG 1.208. The applicant also screened the RLME sources based on their potential contribution to the total seismic hazard. Specifically, the applicant included the RLME sources if they contribute close to or greater than 1 percent to the total mean hazard at the Fermi 3 site. RG 1.208 states that if seismic sources are completely beyond the 320-km (200-mi) site region radius but are large enough seismic sources with the potential to contribute to the total seismic hazard, the seismic sources should be considered in the seismic hazard calculations. Thus, the staff concludes that the applicant's source zone selection criteria are adequate.

The applicant used the EPRI (2004, 2006) GMM and the updated aleatory uncertainties and weights for the PSHA. Since the development of the EPRI (2004, 2006) GMM, several GMPEs for the CEUS have been published. In RAI 02.05.02-4, the staff requested the applicant to evaluate the impacts from including more recent GMPEs in the Fermi 3 seismic hazard—such as Tavakoli and Pezeshk (2005) and Atkinson and Boore (2006). Based on comparisons of the newer GMPEs with the EPRI (2004) model, the applicant concluded that the median ground motions obtained using the newer GMPEs—specifically Silva et al. (2003), Atkinson and Boore (2011), and Pezeshk et al. (2011)—produce similar or lower ground motion amplitudes compared to the EPRI (2004) GMMs, and are thus likely to produce lower hazard levels. Therefore, the applicant did not update the EPRI (2004, 2006) GMM for the purpose of computing the hazard levels for the Fermi Unit 3 site.

The staff reviewed the applicant's comparisons of the EPRI (2004, 2006) GMM with more recent GMPEs and determined that the applicant's conclusions are supported by the recently updated EPRI (2004, 2006) GMM (EPRI 2013) conducted in accordance with the SSHAC process. In a letter dated August 28, 2013 (ADAMS Accession No. ML13233A102), the NRC determined that the Updated GMM is an acceptable ground motion model to use for CEUS plants in developing plant-specific, ground motion response spectra until the NGA project for eastern North America (NGA-East) is complete and NRC staff has reviewed and approved it (NRC 2013).

Chapter 8 of the EPRI (2013) report provides the results of demonstration hazard calculations performed using the updated EPRI (2004, 2006) GMM and the EPRI (2004, 2006) GMPE for seven test sites; including the Central Illinois test site, which is the closest test site to the Fermi 3 site. The resulting UHRS are in Figures 8.2-1h, 8.2-2h, 8.2-3h, 8.2-4h, 8.2-5h, 8.2-6h, and 8.2-7h in the EPRI (2013) report. All of the test site comparisons show that the updated EPRI (2004, 2006) GMPEs produce equivalent or lower spectral accelerations when compared to the EPRI (2004, 2004) GMPEs. Furthermore, the spectral shapes remain consistent between both the earlier and the updated models, with the exception of very low hazard sites (e.g., the Houston test site) at frequencies below ~1 Hz. The staff therefore concludes that the applicant's use of the EPRI (2004, 2006) GMPEs is adequate for the Fermi 3 PSHA calculation.

PSHA Methodology and Calculation

Using the NUREG–2115 CEUS-SSC model and the EPRI (2004, 2006) GMPEs, the applicant performed PSHA calculations for the PGA and ground motion frequencies of 25, 10, 5, 2.5, 1, and 0.5 Hz, as described in RG 1.208. Before performing the final PSHA calculation for the Fermi 3 site, the applicant first conducted sensitivity calculations in order to (1) determine which set of RLMEs to include in the final calculation; and (2) evaluate the impacts of more recent earthquakes and determine whether or not updates to the associated CEUS-SSC seismic sources are necessary.

In FSAR Subsection 2.5.2.4.3.1, the applicant described the selection process used to identify which RLME sources to include in the PSHA model for the Fermi 3 site. The applicant examined the source contributions at 1 Hz and 10 Hz spectral accelerations for the eight RLME sources closest to the Fermi 3 site (the CFZ, CHS, CHV, Eastern Rift Margin – North [ERM-N], Eastern Rift Margin – South [ERM-S], Marianna Zone [MAR], NMF, and the WV sources). Based on the results of these sensitivity calculations, which are shown in FSAR Figures 2.5.2-240 and 2.5.2-241, the applicant decided to include the NMF, WV, CHS, and CHV RLME sources because they contributed close to or greater than 1 percent to the total mean hazard at the Fermi 3 site. The applicant did not include the remaining RLMEs because they contribute to less than 1 percent of the total mean hazard. The staff reviewed the applicant's results in FSAR Figures 2.5.2-240 and 2.5.2-241 and concurred with the applicant that inclusion of only the NMF, WV, CHS, and CHV RLME sources is adequate, because the remaining RLME sources would not produce a significant contribution to the total mean hazard at the Fermi 3 site.

As described in FSAR Subsection 2.5.2.4.3, the applicant performed PSHA sensitivity calculations using the updated M_{max} distributions shown in FSAR Table 2.5.2-203. These updated M_{max} distributions are based on the earthquakes with an E[**M**] equal to or greater than 4.3 that have occurred after completion of the CEUS-SSC model catalog in the time period from 2009 through 2012. The applicant found that the effect of including these adjusted M_{max} distributions in the hazard calculation produces a 0.3 percent maximum increase in total mean hazard at 1 Hz and 10 Hz spectral accelerations for the Fermi 3 site. Even though this result indicated that the model did not need to be updated, the applicant conservatively performed the PSHA for the Fermi 3 site using the updated M_{max} distributions. Based on the applicant's discussion of the results, the staff concurs that updating the M_{max} distributions did not result in any significant change in the seismic hazard calculation results. Therefore, updates to the CEUS-SSC model source zone are not warranted at the Fermi 3 site.

NRC PSHA Confirmatory Analyses

To determine the adequacy of the applicant's PSHA calculations, the staff performed its own confirmatory PSHA calculation for the Fermi 3 site. The staff used the CEUS-SSC model (NUREG–2115) along with the EPRI (2004, 2006) GMM. The staff conducted the PSHA for the Fermi site using a source distance radius of 1,000 km (620 mi) for the CEUS-SSC-distributed seismicity sources. The staff's calculation did not include the RLME source zones. Therefore, the staff compared its confirmatory 0.5, 1, 2.5, 5, 10, 25, and 100 Hz hazard curve results with the applicant's results for the distributed seismicity sources and determined that the two sets of results are almost identical. This finding is illustrated in Figures 2.5.2-9 through Figure 2.5.2-11 in this SER showing the PSHA hard rock hazard curve results for 1, 10, and 100 Hz, respectively, for the distributed seismicity sources.

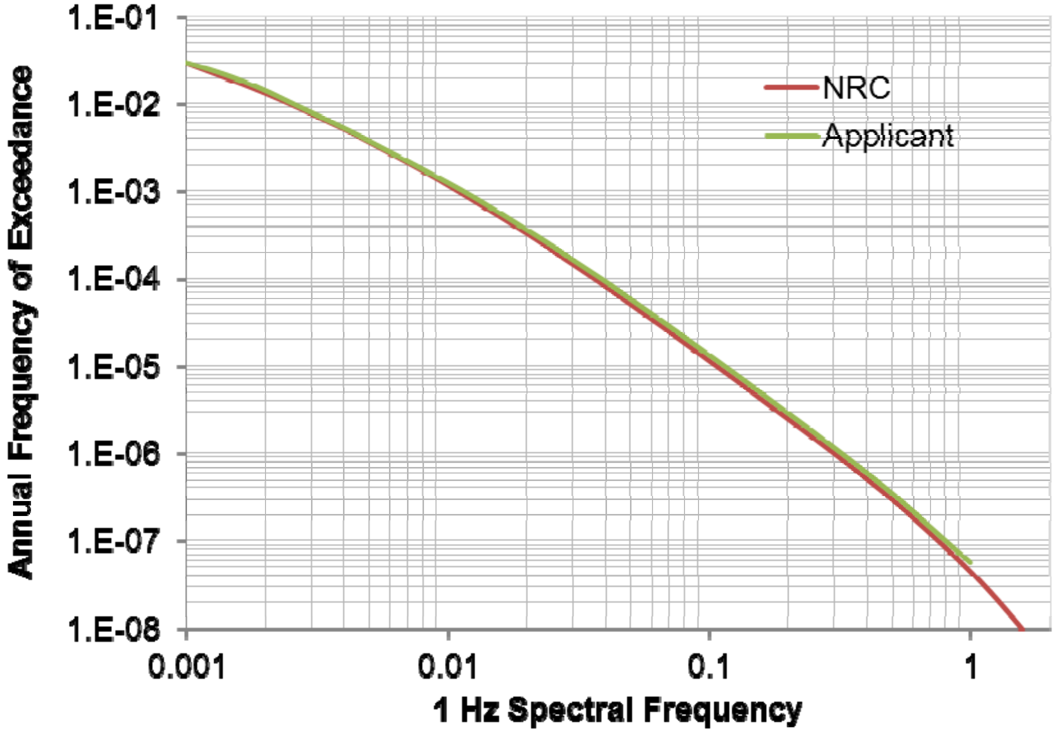


Figure 2.5.2-9 Plot Comparing the Staff's and the Applicant's 1-Hz Total Mean Hazard Curves for the Distributed Seismicity Source Zones

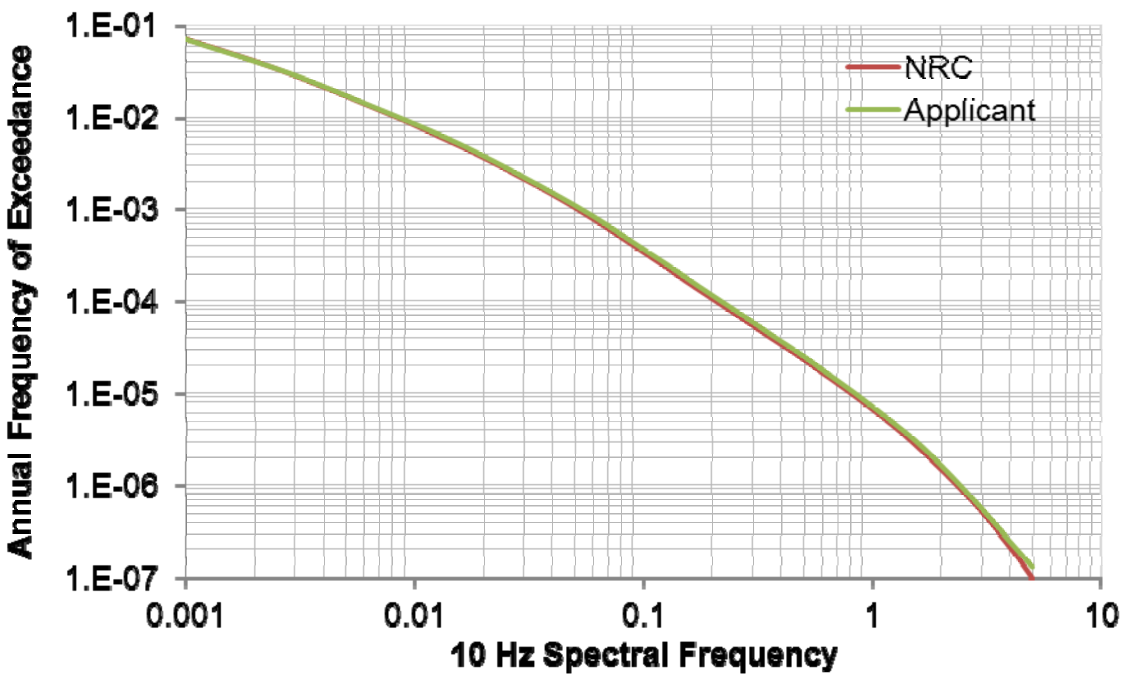


Figure 2.5.2-10 Plot Comparing the Staff's and the Applicant's 10-Hz Total Mean Hazard Curves for the Distributed Seismicity Source Zones

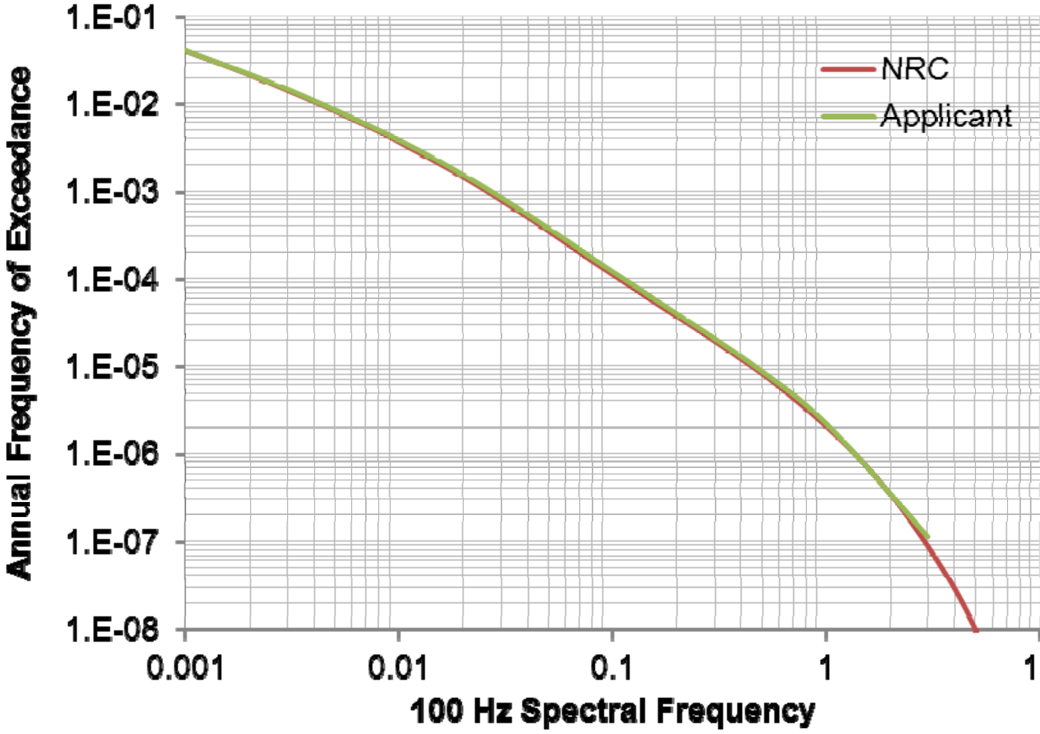


Figure 2.5.2-11 Plot Comparing the Staff's and the Applicant's 100-Hz Total Mean Hazard Curves for the Distributed Seismicity Source Zones

Based on the above assessment, the staff concluded that the applicant's PSHA calculations adequately characterize the seismic hazard at the Fermi 3 site in terms of the contribution from the distributed seismicity sources. Because the staff's calculation did not include the RLMEs, the staff determined that the applicant had selected the appropriate RLME sources (i.e., the NMFS, WA, CHV, and CHS) based on their contribution of 1 percent or greater to the total mean hazard.

Controlling Earthquakes

To determine the low- and high-frequency controlling earthquakes, the applicant used a procedure called deaggregation of the seismic hazard. The applicant followed the deaggregation procedures in RG 1.208, Appendix D. The deaggregation results showed that local seismic sources within approximately 30 km (18.6 mi) of the Fermi site are the primary contributors to the high-frequency seismic hazard at the site, while the NMFS RLME is a significant contributor to the low-frequency seismic hazard at the Fermi site. Table 2.5.2-1 of this SER shows the applicant's deaggregation results for the mean 10^{-4} and 10^{-5} PSHA results. Because the applicant used the guidance in RG 1.208 to determine the reference and deaggregation earthquakes and their magnitudes and distances, the staff concludes that the procedures used by the applicant are adequate and the resultant deaggregation earthquake parameters are representative of the deaggregation earthquakes in this region.

In FSAR Subsection 2.5.2.4.4.3, the applicant also described how it developed smooth response spectra to represent each reference earthquake and deaggregation earthquake listed in FSAR Table 2.5.2-212, for the purpose of developing input time histories for the site response analysis, which is reviewed by the staff in Subsection 2.5.2.4.5 of this SER. The applicant used the EPRI (2004, 2006) GMM as well as the spectral shape functions (specifically, the average of the single and double corner spectral shape models) for CEUS ground motions developed in NUREG/CR–6728. The applicant also used Baker and Cornell's (2006) response spectral correlation method to extrapolate spectral shapes. However, the Baker and Cornell method used worldwide recordings from both the National Earthquake Hazards Reduction Program (NEHRP) B/C (rock/very dense soil and soft rock) type soil boundary and the first story of structures. In RAI 02.05.02-6, the staff thus requested the applicant to (1) explain why the free-field and first-story recordings can be mixed together to predict the correlation; and (2) why the correlation from the B/C boundary can be used to represent the other soil types.

In the response to part (1) of the RAI dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant explained that Baker and Cornell's method requires a model for correlation between response spectral amplitudes at different spectral periods. The applicant used Baker and Jayaram (2008), which uses all of the residuals resulting from the NGA GMPE development (i.e., the correlation model is not specific to the B/C boundary condition). Furthermore, Baker and Jayaram (2008) determined that the correlation is not sensitive to site subsurface conditions.

In the response to part (2) of the RAI, the applicant stated that the NGA GMPE developers included recordings from instrument shelters and first-story recordings in small buildings (i.e., light one-to-two story structures without basements) in their data sets that were used to develop ground motion models for free-field conditions and indicated that recordings in larger buildings are not representative of free-field motions. Furthermore, the applicant stated that it is common practice to include recordings from the first floor of small buildings in data sets used to develop empirically based, free-field ground motions (e.g., Boore et al. 1997; Campbell 1997; Sadigh et al. 1997; Spudich et al. 1997; and Campbell and Bozorgnia 2003).

After reviewing the applicant's responses to both questions in this RAI, the staff agreed with the applicant that because the correlation models are not sensitive to site subsurface conditions and the NGA developers used the instrument recordings from the first story of small buildings, it is appropriate to develop the correlation model using those relevant data sets. Therefore, the staff concludes that the applicant developed appropriate response spectra to represent the reference and controlling earthquakes resulting from the PSHA calculations. Therefore, RAI 02.05.02-6 is closed.

<u>NRC Staff's Conclusions Regarding the PSHA and Controlling Earthquakes</u>

The staff concludes that the applicant's PSHA inputs, methodology, and results (including the resulting reference and deaggregation earthquakes) are acceptable because the applicant's PSHA calculation followed the general guidance in RG 1.208. The staff's confirmatory analysis also indicated that the applicant's results are adequate. Thus, the staff concludes that the applicant's seismic hazard calculation meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.2.4.5 Seismic Wave Transmission Characteristics of the Site

FSAR Subsection 2.5.2.5 describes the method the applicant used to develop the Fermi 3 site free-field UHRS. The applicant's seismic hazard curve calculations are defined for generic hard rock conditions characterized by a shear-wave velocity of at least 2.8 km/s (9,200 fps).

According to the applicant, these hard rock conditions exist at a depth of about 130 m (425 ft) below the ground surface at the Fermi 3 site. To determine the impact of the soil column between the hard rock and the surface, the applicant performed a site response analysis. The output of the applicant's site response analysis is site amplitude functions (AFs), which are then used to determine the soil UHRS at three hazard levels (10^{-4}, 10^{-5}, and 10^{-6} annual frequency of exceedances).

The Fermi 3 site consists of thin layers of fill, lacustrine deposits and glacial till overlying dolomite of the Bass Islands and Salina groups. The applicant intends to remove the upper ~4 m (13 ft) of fill, ~1.5 m (5 ft) of low-velocity lacustrine deposits, and ~3.4 m (11 ft) of glacial til, and proposed to locate the GMRS at the top of the Bass Islands group, which corresponds to an average elevation of 168.2 m (551.7 ft) NAVD 88. The staff noted that in previous FSAR revisions, the applicant had defined the GMRS at the top of the glacial till. With this change in the GMRS location, several of the staff's earlier RAIs related to glacial till are no longer relevant and were closed. The staff's evaluations of those RAIs are therefore not part of this SER.

Additionally, the staff noted that the applicant's site response calculations for the RB/FB, CB, and FWFC FIRS are in FSAR Section 3.7.1 instead of in FSAR Section 2.5.2, as in earlier revisions of the FSAR. Therefore, the staff's evaluations of RAIs 02.05.02-20 and 02.05.02-21 are in Subsection 3.7.1.4 of this SER. In Subsection 2.5.2.4 of this SER, the staff noted that many earlier RAIs have become irrelevant or closed as a result of the applicant's significant revisions of the COL FSAR as a result of the replacement of the EPRI (1986) seismic source models previously used in the seismic hazard calculations with the newly published CEUS-SSC model. With this change in the base seismic source model, several of the earlier RAI responses related to the applicant's site response calculations also needed to be revised. Instead, however, the staff performed detailed site response confirmatory analyses to determine the adequacy of the applicant's site response inputs and calculations. These calculations are discussed below in Subsection 2.5.2.4.5.2, while Subsection 2.5.2.4.5.1 of this SER presents the staff's evaluation of the original RAIs that are still applicable to the staff's review.

Site Response Model

FSAR Subsection 2.5.2.5.1 summarizes the applicant's low-strain S-wave velocity, material damping, and strain-dependent properties of the base case soil and rock profile, which the applicant used as the input model for the site response calculations. The applicant performed P-S suspension logging, downhole seismic testing, and spectral analysis of surface wave (SASW) surveys to obtain an S-wave velocity profile for the Fermi 3 site, which is shown in Figure 2.5.2-5 of this SER. The applicant used the P-S suspension logging results to obtain the S-wave velocities of the soil and bedrock units. The applicant also used the downhole seismic testing results to obtain bedrock S-wave velocities, while the SASW survey results provided S-wave velocities for the glacial till. The applicant encountered CEUS generic hard rock conditions (i.e., an S-wave velocity of about 2.8 km/s [9,200 fps]) at a depth of approximately 143.3 m (470 ft) or an elevation of 48 m (156 ft), which corresponds to the Salina Group Unit B.

The applicant stated that the site response profile consists of dolomites and claystones with S-wave velocities exceeding 910 m/s (3,000 fps). The applicant expects the behavior of these materials to remain essentially linear at the expected levels of shaking (as defined by the rock hazard). The applicant determined the damping within these materials by using the following procedure that involved kappa, a near-surface damping parameter that is an estimate of the dissipation of seismic energy of the site during an earthquake due to damping within soil/rock layers and waveform scattering at layer boundaries. The applicant used estimates of kappa to determine an appropriate damping ratio value for the rock layers below the glacial till.

In FSAR Subsection 2.5.2.5.1.2, the applicant stated that ground motion models for the CEUS assume a shallow crustal kappa value of 0.006 seconds, which refers to the point at the elevation of 48 m (156 ft) at the Fermi 3 site. The FSAR further states that the material above this elevation will contribute additional damping and add to the total site kappa value. The applicant used Equation 11 in FSAR Section 2.5.2 Revision 5, (or Equation 5 in the FSAR markups in the March 15, 2013, response to RAI 01.05-1), to calculate an additional kappa value of 0.013 seconds based on an average S-wave velocity of 1,737 m/s (5,700 fps) for the materials above an elevation of 48 m (156 ft). The applicant then subtracted the hard rock kappa value of 0.006, which yielded a remaining kappa of 0.007 seconds. In RAI 02.05.02-13, the staff asked the applicant to confirm whether the kappa value of 0.013 seconds represents an additional damping contribution from the material above the elevation of 48 m (156 ft); and why the two kappa values were then subtracted.

Based on the applicant's response to RAI 02.05.02-13 dated August 6, 2010 (ADAMS Accession No. ML102210351), FSAR Equation 5 represents the relationship between the average S-wave velocity and the total site kappa value—not an additional damping contribution from the material above the elevation of 48 m (156 ft). Therefore, a shallow crustal kappa value was subtracted from the total kappa and the difference of 0.007 seconds is the kappa contributed by the materials above an elevation of 48 m (156 ft). The staff concluded that RAI 02.05.02-13 is closed because the applicant has provided adequate clarification regarding how the kappa value was obtained for the materials above an elevation of 48 m (156 ft). Furthermore, the staff calculated a kappa value for the material above an elevation of 48 m (156 ft) and assumed a quality factor, Q_s, of 40 (EPRI 2013). The resulting kappa value of 0.00774 seconds is very similar to the applicant's value of 0.007 seconds. Figure 2.5.2-13 in this SER shows that the effect of using a kappa value based on Q_s of 40 is similar to the applicant's kappa value in the site response calculations.

The applicant used an updated version of the SHAKE computer program to calculate the Fermi 3 site response. The use of the time series approach is mentioned in RG 1.208 as an acceptable approach given that an appropriate set of earthquake time histories for each of the target response spectra is used, and a sufficient number of time histories are used to obtain a consistent behavior from the dynamic site response analysis. FSAR Subsection 2.5.2.4.4.3 states that the applicant developed 30 time histories for each target DE, which equated to a total of 3 DEs for each HF and LF 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6} hazard level. The applicant then selected time histories from NUREG/CR–6728 and scaled them to approximately match the target DE spectrum using the routine RSPM06, which implements the time domain spectral matching approach developed by Lilhanand and Teng (1988). The applicant concluded that the weak scaling produced records that have, in general, the desired relative frequency content of the DE spectra, while maintaining a degree of natural variability. The staff performed confirmatory site response calculations in order to determine the adequacy of the applicant's approach. In comparison, the staff used a Random Vibration Theory (RVT) method that characterizes the input rock motion using a Fourier amplitude spectrum, instead of earthquake time histories. The use of the RVT in site response calculations is mentioned in RG 1.208 as an acceptable alternative to the time series approach. As shown in Figure 2.5.2-12 of this SER, the staff's site amplification calculated using RVT is very similar to the applicant's time history-based results.

FSAR Subsection 2.5.2.5.1.3 describes the randomized S-wave velocity profiles used in the site response analyses to account for variations in these profiles. The correlation model described in Silva et al. (1996) is the model developed from analyses of shear wave data taken at the Savannah River site, a relatively deep soil site (composed primarily of sands, silty sands, and silts) of approximately 244 m to 305 m (800 ft to 1,000 ft) depth over hard rock. In RAI 02.05.02-17, the staff asked the applicant to explain why this model is appropriate for use at the Fermi site and to also evaluate the impact on site amplification. In the response to this RAI dated March 1, 2012 (ML12065A194), the applicant stated that since the principal geologic units that immediately underlie the Fermi 3 site are relatively flat-lying sedimentary rocks that have not been subject to severe deformation, the current correlation structure for S-wave velocities is expected to reflect the correlation structure present when the sediments were first deposited. For this reason, the applicant selected the correlation model described in Silva et al. (1996) for USGS Category C, a relatively deep soil site, rather than the model for rock sites —USGS Category A. In Figure 1 of the RAI response, the applicant compared the predicted correlations between the natural log of the S-wave velocity in two adjacent layers for the stiff soil site model used in FSAR Subsection 2.5.2.5.1.3 with those predicted by the model developed by Silva et al. (1996) for rock sites (USGS Category A). The applicant stated that the USGS Category C model used in the FSAR shows higher correlations than the rock site model for USGS Category A. Furthermore, the applicant stated that a fully correlated model is not supported by the subsurface S-wave velocity data collected at the Fermi 3 site. The applicant added that Figure 2 in the RAI response, which shows velocity profiles for the four borings in which the individual P-S suspension log data were used to compute hyperbolic mean (travel time averaged) velocities for individual sublayers, shows that the S-wave velocity profiles cross each other frequently indicating that the Fermi 3 site profile is not fully correlated.

The staff also performed confirmatory site response calculations in order to investigate the effect of using a fully correlated model. The staff performed calculations comparing the correlation model for USGS Category C and USGS Category A, which are shown by the red and purple curves, respectively, in Figure 2.5.2-13 in this SER, and found that the resulting amplification functions are very similar. As shown in Figure 2.5.2-13 in this SER, differences in mean amplification observed in the frequency range of 4 to 6 Hz is less than 7 percent. Thus, the staff concluded that RAI 02.05.02-17 is closed, because the staff's sensitivity calculations demonstrated that the correlation model used does not significantly impact the amplification functions when compared to a fully correlated model.

<u>NRC Site Response Confirmatory Analyses</u>

To determine the adequacy of the applicant's site response calculations, the staff performed confirmatory site response calculations. As input, the staff used the static and dynamic soil properties in FSAR Section 2.5.4 and summarized in FSAR Table 2.5.2-213. The staff performed site response calculations using the RVT methodology with 7 spectral frequencies and 11 input rock amplitudes. The use of RVT in site response calculations is mentioned in RG 1.208 as an acceptable alternative to the time series approach. The staff's site amplification function results are compared with the applicant's results in Figure 2.5.2-12 in this SER.

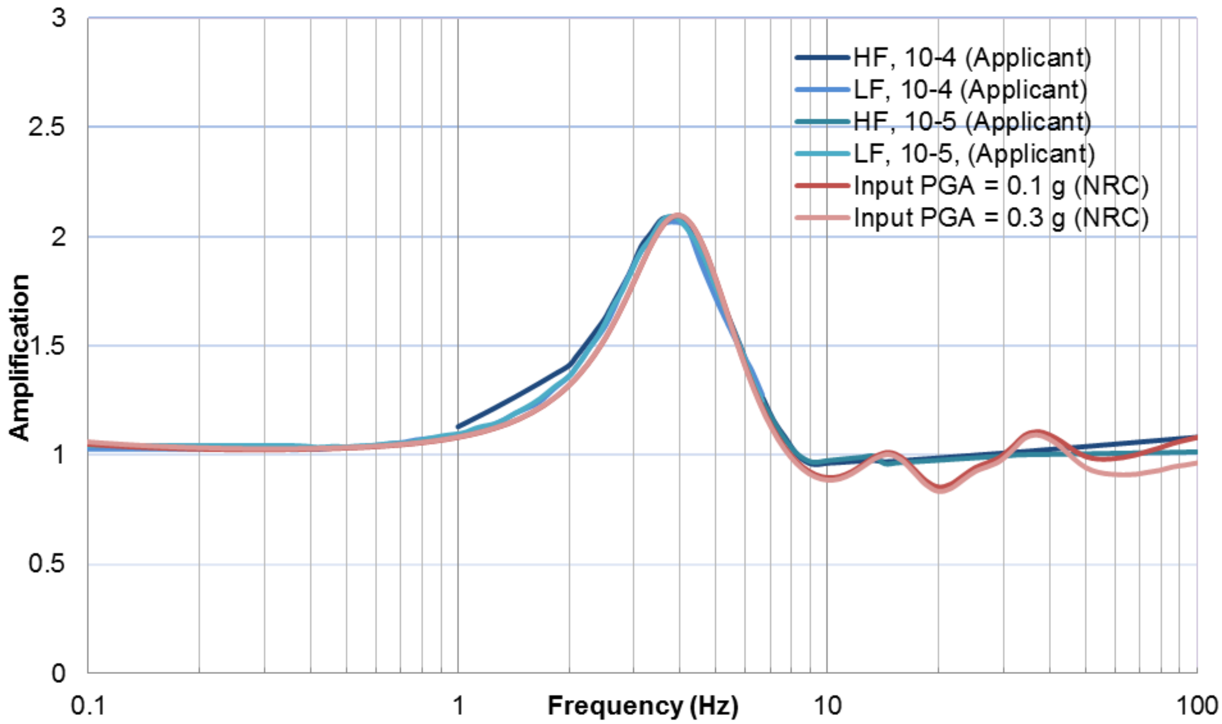


Figure 2.5.2-12 Comparisons of the Staff's Site Response Amplification Functions with the Amplification Functions Determined by the Applicant

[Note: The staff's amplification functions for respective input PGA values of 0.1 g and 0.3 g are depicted by the light and dark red lines, and the COL applicant's results are depicted by the blues lines.]

As Figure 2.5.2-12 in this SER shows, the applicant's amplification functions are similar to the staff's confirmatory calculations; and the very small difference observed between ~1 and 100 Hz are within the limits of uncertainties. Similar to the applicant's results, the staff's confirmatory calculations also show that the Fermi 3 site response is not strongly sensitive to the level of input motion. Figure 2.5.2-12 also shows that there are only small differences in the site amplification (at frequencies greater than ~40 Hz) using input PGAs of 0.1 g and 0.3 g.

In addition to confirming the applicant's calculations, the staff conducted an additional sensitivity calculation to confirm the applicant's selected damping values in FSAR Table 2.5.2-214. Figure 2.5.2-13 in this SER compares the staff's amplification functions calculated using the applicant's damping values, with the staff's amplification functions calculated assuming a shear-wave quality factor, Q_s, of 40. Because the average S-wave velocity of the material above an elevation of 48 m (156 ft) is 1,737 m/s (5,700 fps), and the thickness of these materials is only ~121 m (396 ft), the kappa contributed by the profile can be computed by assuming a Q_s of 40 according to EPRI Report 1025287, "Seismic Evaluation Guidance," (EPRI 2012). As illustrated in Figure 2.5.2-13 of this SER, the staff's amplification functions calculated by assuming a Q_s of 40 is only slightly higher than the staff's calculated amplification functions that used the damping values developed by the applicant between frequencies of ~3 to 5 Hz and at frequencies above 30 Hz.

The staff's results are slightly higher than the applicant's at frequencies between 3 and 5 Hz. However, these differences are less than 10 percent.

Based on the above assessment, the staff concludes that the applicant's site response calculations adequately characterize the Fermi 3 site effects.

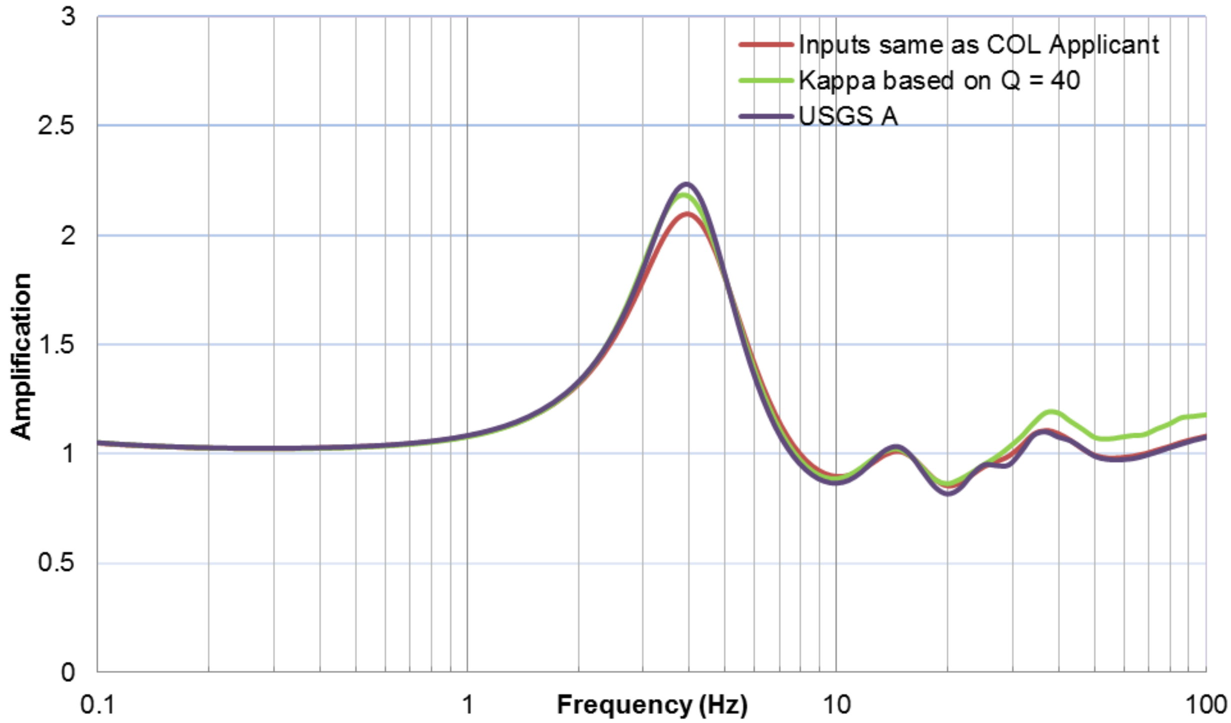


Figure 2.5.2-13 Comparisons of the Staff's Site Response Amplification Function Using Damping Values Selected by the Applicant with the Staff's Site Response Amplification Functions Based on a Q_s of 40 and also Using a Correlation Model for USGS Category A

[Note: The staff's amplification functions using the same inputs as COL applicant used are depicted by the red lines; and the staff's amplification functions based on a Q_s of 40 and a correlation model for USGS Category A are depicted by the green and purple lines, respectively.]

NRC Staff's Conclusions Regarding Seismic Wave Transmission Characteristics of the Site

The staff concludes that the applicant's site response methodology and results are acceptable, because the applicant has followed the general guidance in RG 1.208 in the site response calculations and used an adequate range of input parameters. The staff's confirmatory analysis also indicates that the COL applicant's results are adequate.

2.5.2.4.6 Ground Motion Response Spectra

FSAR Subsection 2.5.2.6 describes the method the applicant used to develop the horizontal and vertical, site-specific GMRS. As stated in Subsection 2.5.2.1 of this SER, RG 1.208 defines the GMRS as the site-specific SSE to distinguish it from the CSDRS (certified seismic design response spectra), the design ground motion for the ESBWR certified design.

FSAR Subsection 2.5.2.6 describes the method the applicant used to develop the horizontal and vertical site-specific GMRS. To obtain the horizontal GMRS, the applicant used the performance-based approach in RG 1.208 and ASCE/SEI Standard 43-05. FSAR Subsection 2.5.2.6 states that the horizontal GMRS (for each spectral frequency) is obtained by scaling the soil 10^{-4} UHRS by the design factor specified in RG 1.208. To develop the vertical GMRS, the applicant multiplied the horizontal GMRS by V/H ratios for generic CEUS hard rock sites in NUREG/CR–6728. Because the S-wave velocity of the Fermi 3 site is relatively high, and the assessed site kappa value is not much greater than the generic hard rock value, the staff concludes that the applicant's use of V/H ratios for generic CEUS hard rock sites is appropriate.

NRC Staff's Conclusions Regarding the Ground Motion Response Spectra

The applicant used the standard procedures outlined in RG 1.208 to calculate the final horizontal and vertical GMRS. The staff thus concludes that the applicant's GMRS adequately represents the site ground motion, and the applicant's calculated GMRS meets the requirements of 10 CFR 100.23.

2.5.2.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.5.2.6 *Conclusion*

NRC staff reviewed the COL application and confirmed that the applicant has adequately addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COL application to the relevant NRC regulations, the guidance in Section 2.5.2 of NUREG–0800, and applicable NRC regulatory guides. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determined that the applicant has adequately addressed COL Item COL Item EF3 2.0-27-A related vibratory ground motion.

2.5.3 Surface Faulting

2.5.3.1 *Introduction*

This FSAR section describes the potential for surface deformation due to faulting, and addresses the following topics related to surface faulting: geologic, seismic, and geophysical investigations; geologic evidence, or absence of evidence, for tectonic surface deformation; correlation of earthquakes with capable tectonic sources and characterization of those sources; ages of most recent deformation; relationships between tectonic structures in the site area and regional tectonic structures; designation of zones of Quaternary (less than 2.6 Ma) deformation in the site region; and the potential for surface deformation at the site. The applicant collected the information during site characterization investigations.

2.5.3.2 *Summary of Application*

Section 2.5.3 of the Fermi 3 COL FSAR, describes the potential for tectonic and non-tectonic surface faulting at the Fermi 3 site. In addition, in FSAR Section 2.5.3, the applicant provided the following:

COL Item

- EF3 COL 2.0-28-A Surface Faulting

To address this COL item, the applicant developed FSAR Section 2.5.3 based on reviews of relevant published geologic literature; aerial photographic interpretations; lineament analyses; interviews with experts familiar with the geology, seismology, and tectonics of the site region; a review of seismicity data; and geologic field investigations. The applicant performed field investigations that included geologic field reconnaissance, aerial reconnaissance, and geologic mapping of rock units and Quaternary deposits at the site. Also, the applicant used the previous UFSAR for the existing Fermi 2 (DTE 2006); in addition to construction reports and interactions with involved personnel to supplement recent geologic and seismic investigations on the site.

In the context of these efforts, the applicant concluded that there are no capable tectonic sources within the 8-km (5-mi) site area radius. The applicant also concluded that there is no evidence for Quaternary tectonic surface fold deformation or faulting within the 1-km (0.6-mi) radius of the Fermi site.

2.5.3.2.1 Geologic, Seismic, and Geophysical Investigations

In FSAR Subsection 2.5.3.1, the applicant described the investigations performed to evaluate the potential for surface deformation at the Fermi 3 site. The applicant compiled and reviewed existing data from the investigations for the operating Fermi 2 site, as well as published and unpublished literature regarding tectonics and geomorphology for southeast Michigan and northwest Ohio. The applicant also analyzed previous and updated seismicity data for the site vicinity, analyzed and interpreted aerial photographic and remote sensing imagery for the Fermi 3 site vicinity, and conducted multiple field and aerial reconnaissance investigations at and surrounding the site. Finally, the applicant contacted experts at the Ohio, Michigan, and Canadian geological surveys to obtain the most current information related to geologic investigations within the Fermi 3 site region.

2.5.3.2.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

FSAR Subsection 2.5.3.2 discusses the geologic evidence, or absence of evidence, for tectonic and non-tectonic surface deformation in the Fermi 3 site area. The applicant concluded that there are no faults at or close to the ground surface in the Quaternary sediments within 40 km (25 mi) of the site. Using boring and geophysical data, the applicant indicated that the faults in the subsurface of the site vicinity are in Paleozoic rocks; the closest tectonic features to the site are (1) the Bowling Green fault and the Maumee fault (within 40 km [25 mi]), (2) the Howell anticline and associated fault (45 km [28 mi]), (3) a series of folds in the subsurface bedrock units along the southeastern trend of the Howell anticline and two possible fault trends located on the southwestern flank of these folds that are possibly associated with oil and gas pools, and (4) shorter faults located in southwestern Ontario (one of which is possibly associated with oil and gas fields). The applicant observed two minor faults in the Silurian Bass Islands Group at the Denniston Quarry 16 km (10 mi) south of the Fermi 3 site; each fault has a displacement of less than 1.4 m (4.6 ft). The applicant stated that the second fault extends to the top of the Bass Island Group, but the latest Pleistocene (approximately 13–12 thousand years ago [ka]) Quaternary till and lacustrine deposits overlying the projected trends of both faults are not deformed. The applicant indicated that only one possible fault extends within the 8-km (5-mi) radius of the site, and that fault trend is associated with the Sumpter Pool as mapped by Cohee (1948) and postulated as a fault in 1962 by Ells (Ells 1962). However, there is no supporting documentation regarding the existence of this structure, and no faults were identified within the basement rocks or overlying sediments at the Fermi 2 site.

The applicant stated that non-tectonic deformation agents, such as glacial and periglacial processes, sometimes look like surface tectonic fault ruptures. However, there is no evidence of surface deformation in the site associated with these non-tectonic processes. The applicant explained that other observed non-tectonic deformation processes in the Michigan basin are associated with the dissolution and subsequent collapse of carbonate rock, and there are reports of karst-related problems within the 320-km (200-mi) radius of the site.

In FSAR Subsection 2.5.3.2.3, the applicant described the lineaments in the Fermi 3 site and explained that most apparently coincide with paleoshorelines as well as with linear stream segments. The applicant concluded that no evidence indicates the presence of post-glacial surface faulting or continuing tectonic deformation.

2.5.3.2.3 Correlation of Earthquakes with Capable Tectonic Sources

In FSAR Subsection 2.5.3.3, the applicant concluded that there is no record of earthquakes or earthquake alignments within 40 km (25 mi) of the Fermi 3 site that could be associated with mapped bedrock faults.

2.5.3.2.4 Ages of Most Recent Deformations

In FSAR Subsection 2.5.3.4, the applicant concluded that the major bedrock deformation in the site vicinity occurred during the Paleozoic epoch. The applicant also stated that limited geologic history exists in the site region during the Mesozoic era, and no Mesozoic pluton or rift-related sediments are present to suggest that the Mesozoic extension affected the site region. The applicant concluded that there is no evidence of paleoliquefaction or deformation on the lacustrine plain that overlies the postulated faults within the site vicinity.

2.5.3.2.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Sources

In FSAR Subsection 2.5.3.5, the applicant stated that folding occurred in the Silurian and Devonian rocks on the Fermi site. Folds are recognized along the southeastern margin of the Michigan basin and they coincide with the mid-Michigan gravity high, which is associated with the mid-continent rift system.

2.5.3.2.6 Characterization of Capable Tectonic Sources

In FSAR Subsection 2.5.3.6, the applicant stated that the mapped bedrock faults within a 40-km (25-mi) radius and the lineaments within the 8-km (5-mi) radius of the site are not considered capable tectonic sources. The applicant based this conclusion on the study of geomorphic evidence, determination of surface or near-surface deformation of landforms or geologic deposits, evaluation of the association with one or more moderate earthquakes and the structural association with capable tectonic structures.

2.5.3.2.7 Designation of Zones of Quaternary Deformation in the Site Region

In FSAR Subsection 2.5.3.7, the applicant stated that no zones of Quaternary tectonic deformation exist in the Fermi 3 site region.

2.5.3.2.8 Potential for Surface Tectonic Deformation at the Site

In FSAR Subsection 2.5.3.8, the applicant stated that no capable tectonic faults exist in the Fermi 3 site vicinity. The applicant added that there is no evidence of potential deformation associated with non-tectonic deformation such as glacially induced faulting, salt migration, and dissolution collapse associated with karst.

2.5.3.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the surface faulting, and the associated acceptance criteria, are in Section 2.5.3 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR 52.79(a)(1)(iii) as it relates to identifying geologic site characteristics with appropriate consideration of the most severe natural phenomena historically reported for the site and surrounding area and with a sufficient margin for the limited accuracy, quantity, and period of time that the historical data were accumulated.

- 10 CFR 100.23 as it relates to determining the potential for surface tectonic and non-tectonic deformations in the region surrounding the site.

The related acceptance criteria from Section 2.5.3 of NUREG–0800 are as follows:

- Geologic, Seismic, and Geophysical Investigations: To meet the requirements of 10 CFR 100.23 and the guidance in RG 1.208, RG 1.132, and RG 1.198, this area of review is acceptable if the discussions of Quaternary tectonics, structural geology, stratigraphy, geo-chronologic methods used for age dating, paleoseismology, and geologic history of the site vicinity, site area, and site location are complete, compare well with the studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant.

- Geologic Evidence, or Absence of Evidence, for Surface Tectonic Deformation: To meet the requirements of 10 CFR 100.23 and the guidance in RG 1.208, RG 1.132, RG 1.198, and RG 4.7 "General Site Suitability Criteria for Nuclear Power Stations," this area of review is acceptable if the applicant‘s discussion about sufficient surface and subsurface provides information that includes the site vicinity, site area, and site location to confirm the presence or absence of surface tectonic deformation (i.e., faulting) and if present, to demonstrate the age of the most recent fault displacement and the ages of previous displacements.

- Correlation of Earthquakes with Capable Tectonic Sources: To meet the requirements of 10 CFR 100.23, this area of review is acceptable if all reported historical earthquakes within the site vicinity are evaluated with respect to accuracy of hypocenter location and source of origin, and if all capable tectonic sources that could, based on fault orientation and length, extend into the site area or site location are evaluated with respect to the potential for causing surface deformation.

- Ages of Most Recent Deformation: To meet the requirements of 10 CFR 100.23, this area of review is acceptable if every significant surface fault and feature associated with a blind fault, or any part of which lies within the site area, is investigated in sufficient detail to demonstrate or to allow relatively accurate estimates of the age of the most recent fault displacement and to identify geologic evidence for previous displacements (if such evidence exists).

- Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures: To meet the requirements of 10 CFR 100.23, this area of review is acceptable if the discussion includes the structural and genetic relationships between site area faulting or other tectonic deformation and the regional tectonic framework.

- Characterization of Capable Tectonic Sources: To meet the requirements of 10 CFR 100.23, this area of review is acceptable is the applicant's investigative techniques are sufficiently sensitive to identify all potential capable tectonic sources, such as faults or structures associated with blind faults, within the site area; and the discussion provides the fault geometry, length, sense of movement, amount of total displacement and displacement per faulting event, age of latest and any previous displacements, recurrence rate, and limits of the fault zone for each capable tectonic source.

- Designation of Zones of Quaternary Deformation in the Site Region: To meet the requirements of 10 CFR 100.23 regarding the designation of zones of Quaternary deformation in the site region, the discussion is acceptable if the zone (or zones) designated by the applicant as requiring detailed faulting investigations is of sufficient length and width to include all Quaternary deformation features potentially significant to the site, as described in RG 1.208.

- Potential for Surface Tectonic Deformation at the Site Location: To meet the requirements of 10 CFR 100.23, this subsection must take into account potential for surface tectonic deformation if the applicant's field investigations reveal a surface or near-surface tectonic deformation along a known capable tectonic structure (i.e., a known capable tectonic feature related to a fault or blind fault).

In addition, the geologic characteristics should be consistent with the appropriate sections from: RG 1.208, RG 1.132, RG 1.198, and RG 1.206.

2.5.3.4 *Technical Evaluation*

NRC staff reviewed the information in Section 2.5.3 of the Fermi 3 COL FSAR related to surface faulting as follows:

COL Item

- EF3 COL 2.0-28-A Surface Faulting

The staff reviewed the applicant's information in FSAR Section 2.5.3 addressing COL Item EF3 COL 2.0-28-A. Fermi 3 COL FSAR Section 2.5.3 addresses the potential for surface or near-surface tectonic and non-tectonic deformation within an 8-km (5-mi) radius of the Fermi 3 site.

The technical information in FSAR Section 2.5.3 resulted from the applicant's surface and subsurface geologic investigations performed for the site area and supplemented by aerial and field reconnaissance studies of the site vicinity, or within a 40-km (25-mi) radius of the site. The staff reviewed Fermi 3 COL FSAR Section 2.5.3 to determine whether the applicant had complied with the applicable regulations and had conducted investigations with an appropriate level of detail in accordance with the guidance in RG 1.208.

The staff's review focused on FSAR Section 2.5.3, which include the applicant's descriptions of previous studies and data collection and the applicant's own investigations conducted within the site area to assess the potential for surface tectonic deformation at the site. During the early site investigation stage, the staff visited the site and interacted with the applicant regarding the geologic, seismic, and geotechnical investigations conducted for the Fermi 3 COL application. To thoroughly evaluate the applicant's geologic, seismic, and geophysical information, the staff obtained additional assistance from experts at the USGS. The staff and the USGS advisors made an additional visit to the Fermi 3 site in November 2009 to confirm the applicant's interpretations, assumptions, and conclusions related to the potential for surface or near-surface faulting and non-tectonic deformation.

The staff's review of Fermi 3 COL FSAR Section 2.5.3 is presented below.

2.5.3.4.1 Geologic, Seismic, and Geophysical Investigations

NRC staff reviewed the applicant's descriptions of the site geologic, seismic, and geophysical investigations in FSAR Subsection 2.5.3.1. The staff verified the results of the applicant's field investigations as well as the applicant's interpretations of existing aerial photographic and remote sensing imagery. Specifically, the staff evaluated core borings and subsurface investigation reports in addition to field imagery; the visit included field locations at and near the site during a site audit in November 2009 (ADAMS Accession No. ML14112A212). After reviewing FSAR Subsection 2.5.3.1 and verifying current literature and findings from observations made during the November 2009 site audit, the staff concluded that the applicant has performed adequate investigations to evaluate the potential for surface deformation at the Fermi 3 site. The staff further concluded that the applicant's information in FSAR Subsection 2.5.3.1 is adequate to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

NRC staff reviewed the applicant's evaluations and conclusions described in FSAR Subsection 2.5.3.2 regarding geologic evidence, or absence of evidence, for surface deformation at the Fermi 3 site. The staff's review of FSAR Subsection 2.5.3.2 focused on evidence to support the applicant's conclusion that there is no record of faulting or fault-related deformation in Quaternary age (less than 2.6 Ma) sediments within the site vicinity. To verify the applicant's results, the staff performed an independent literature review; reviewed the results of the applicant's lineament analysis; and visited locations in and around the Fermi 3 site, including the Denniston Quarry. The staff also reviewed the applicant's analysis of Paleozoic age faults identified within the site vicinity (including the Bowling Green and Maumee faults), in order to verify that there is no evidence for Quaternary deformation associated with these faults.

The staff noted that although FSAR Revision 1, Subsection 2.5.3.2.1 contained a brief description of the Quaternary stratigraphy at the site, the description did not provide details of field observations that relate to deformation or lack of deformation of Quaternary deposits revealed in stratigraphic exposures. Therefore, in RAI 02.05.03-3, the staff asked the applicant to describe any field observations of the local stratigraphic exposures that would assist in constraining any post-glacial deformation that may have occurred in the last 10,000 years in the site vicinity, especially with respect to lake deposits.

The response to RAI 02.05.03-3 dated February 11, 2010 (ADAMS Accession No. ML100570307), identified publications, reports, maps, and available electronic data the applicant had compiled and used as the basis for evaluations of the stratigraphy and geomorphology at the site. The applicant used this information to determine locations for conducting field and aerial reconnaissance investigations. Part of the applicant's response to RAI 02.05.03-3 also included a collection of maps, field photographs, and soil profiles the applicant had used as part of the site evaluation of the stratigraphy. The applicant explained that good exposures to view Quaternary stratigraphic relationships in the site vicinity are limited by the low-relief topography, incision by local streams, and thick vegetation covering stream banks. The applicant evaluated more than 244 m (800 ft.) of continuous lateral exposure of Quaternary deposits at the nearby Denniston Quarry. The applicant conducted three backhoe excavations at the quarry in December 2009 after the staff's visit to the site. During the November 2009 visit, NRC staff identified deformations in the underlying Paleozoic Bass Islands Group. As a result of RAI 02.05.01-29, which is discussed in Subsection 2.5.1.4 of this SER, the applicant provided a technical report that comprehensively evaluated the applicant's field studies at the Denniston Quarry. The applicant identified no evidence for deformation of Quaternary age sediments in the exposures at the Denniston Quarry.

The staff reviewed the information in the applicant's responses to RAI 02.05.03-3 and RAI 02.05.01-29, including the applicant's detailed description of the exposed Quaternary deposits in the Fermi 3 site vicinity. The staff visited a number of field exposures, including local streams and the Denniston Quarry, and found no evidence at or near the site for Quaternary deformation on the field visits or in the applicant's Denniston Quarry field investigation. Based on the review of the applicant's response to RAI 02.05.03-3, the staff's independent literature review, and the staff's visit to field locations surrounding the Fermi 3 site, the staff determined that the applicant had adequately evaluated evidence for Quaternary deformation based on stratigraphic exposures at or near the Fermi 3 site. The applicant also provided a more thorough description of the Quaternary deposits at and surrounding the Fermi 3 site, including the most recent post-glacial lake deposits. Therefore, RAI 02.05.03-3 is resolved and closed.

FSAR Revision 1, Subsection 2.5.3.2.3 discussed a lineament analysis that the applicant conducted to evaluate evidence for surface deformation in the site vicinity. As part of the analysis, the applicant used the USGS 10-m (33-ft) digital elevation model to identify topographic and linear stream segments in the site vicinity. In RAI 02.05.03-4, the staff asked the applicant to discuss the vertical accuracy of the digital elevation model data and the suitability of the data in a geologic environment with low strain rates and young surficial deposits. In the response to RAI 02.05.03-4 dated February 11, 2010 (ADAMS Accession No. ML100570307), the applicant referenced Gesch (2007) and stated that the relative vertical accuracy of the USGS digital elevation model data is 1.64 m (5.38 ft) and the absolute vertical accuracy is 2.44 m (8.0 ft). The applicant further stated that the objective in performing the lineament analysis was to identify linear anomalies in the site topography that may have developed as a result of tectonic or non-tectonic deformation at or near the surface. The applicant expected that the surface rupture due to faulting would be expressed at the surface as erosional remnants or vegetation anomalies. The applicant was confident that the digital elevation model data would be suitable to identify topographic anomalies if they did exist. The applicant found no evidence of surface disruption above two postulated subsurface faults (the Sumpter Pool and the New Boston Pool faults). In addition, the applicant supplemented the digital elevation model analysis with field and aerial investigations.

The staff also asked the applicant in RAI 02.05.03-4 to discuss the availability of light detection and ranging (LiDAR) high-resolution topographic data sets for the site vicinity and whether these data would be useful for evaluating post-glacial deformation at or near the site. The applicant stated that at the time of the Fermi 3 field studies, there were no LiDAR data sets available for the site vicinity. The applicant also stated that although a small strip of LiDAR data now exists along the Lake Erie shoreline, the data would not be useful for adequately evaluating geomorphic features in the site vicinity. Additional LiDAR data were being collected for various counties surrounding the site that may be useful in future evaluations once the data become available. The applicant noted that the USGS 10-m (33-ft) digital elevation model was the highest resolution topographic data available for analyzing surface lineaments at the time that the field investigations were conducted for the Fermi 3 site.

The staff evaluated the applicant's response to RAI 02.05.03-4 and the applicant's lineament analysis conducted in support of the Fermi 3 COL application. In November 2009, the staff visited multiple locations surrounding the Fermi 3 site to verify the geomorphic features identified in the applicant's lineament analysis and in field and aerial reconnaissance investigations. The staff determined that the applicant had adequately evaluated potential surface deformation features at the site using multiple means of verification. The staff found the resolution of the USGS topographic digital elevation model to be an adequate source for evaluating potential deformation in the Fermi 3 site vicinity. RAI 02.05.03-4 is therefore resolved and closed.

In RAI 02.05.03-5, NRC staff asked the applicant to discuss any relevant marine seismic and bathymetric data for Lake Erie as a basis for evaluating the presence or absence of recent tectonic deformation in the site region. The response to RAI 02.05.03-5 dated February 11, 2010 (ADAMS Accession No. ML100570304), stated that the applicant had relied on the highest-resolution bathymetric data available for Lake Erie to characterize the Fermi 3 site. The U.S. NOAA and the Canadian Hydrographic Service developed the bathymetric data using 1-m (3.3-ft) contour intervals. The applicant also described the results of high-resolution seismic reflection data collected in the western basin of Lake Erie by the Geological Survey of Canada in cooperation with the Ohio Geological Survey. Finally, the applicant discussed seismic reflection surveys conducted in the Ohio waters of Lake Erie. These high-resolution seismic surveys focused on mapping bedrock topography, sediment thickness, and stratification. The applicant stated that the present lake bottom topography results from the latest Pleistocene and Holocene glacial and lacustrine processes and added that there is no evidence suggestive of tectonic activity. The applicant stated that the most prominent features visible in the western Lake Erie basin topography are related to shipping and dredging activities. In the response to RAI 02.05.03-5, the applicant also updated FSAR Subsections 2.5.1.1.1 and 2.5.1.2.1 with additional topographic and geomorphic information based on the bathymetric and high-resolution seismic reflection data analyses relevant to Lake Erie.

The staff reviewed the applicant's response to RAI 02.05.03-5 and performed an independent evaluation of the references cited in this response and other available literature. Based on the applicant's information in response to RAI 02.05.03-5 and the applicant's FSAR updates, the staff determined that the applicant had adequately evaluated the presence or absence of deformation features in the Lake Erie site vicinity and region. Therefore, RAI 02.05.03-5 is resolved and closed.

In FSAR Revision 1, Subsection 2.5.3.2.3, the applicant stated that paleoshoreline features in the Fermi 3 site vicinity cross possible subsurface fault trends with no apparent disruption. In RAI 02.05.03-6, the staff asked the applicant to provide additional details regarding the basis for the conclusion that paleoshoreline features do not display evidence for deformation due to faulting. The staff also asked the applicant to discuss whether there is evidence of broad-scale regional deformation expressed in the paleoshoreline data. In the response to RAI 02.05.03-6 dated February 11, 2010 (ADAMS Accession No. ML100570307), the applicant stated that strandlines (former shorelines) and related features such as wave-cut bluffs and beach ridges provide important geomorphic information for evaluating vertical deformation in the past several thousand years and more. The applicant referenced the response to RAI 02.05.01-3 for a discussion of regional glacial-related deformation. The applicant focused the response to RAI 02.05.03-6 on geomorphic characterizations of paleoshorelines in the site vicinity.

The applicant clarified that the mapped paleoshorelines in the Fermi 3 site vicinity correlate with glacial and post-glacial lake levels from the past 14,800 years, or since the last major glacial advance. The applicant's response to RAI 02.05.03-6 systematically described the shoreline features associated with each significant lake-level phase for seven lakes identified within the Fermi 3 site vicinity—Lake Maumee, Lake Arkona, Lake Whittlesey, Lake Warren, Lake Wayne, Lake Grassmere and Lake Lundy. The applicant used the USGS 10-m (33-ft) digital elevation model to evaluate evidence for possible vertical deformation of paleoshoreline features within the Fermi site vicinity. The applicant used the digital elevation model data to construct a series of topographic profiles across the locations of mapped possible faults. Specifically, the applicant focused on the possible subsurface Sumpter Pool and New Boston Pool faults. The applicant's analyses of the paleoshoreline profiles and the digital elevation model data in combination with the applicant's lineament analyses identified no evidence for tilting or deformation along paleoshorelines located in the site vicinity. The applicant's conclusion regarding the lack of deformation on these features further confirms earlier published observations that concluded there was a lack of evidence for deformation along paleoshorelines in southeast Michigan. In this response, the applicant also provided extensive revisions to the FSAR as well as supporting figure updates documenting the paleo-shoreline analysis.

NRC staff reviewed the applicant's response to RAI 02.05.03-6, conducted an independent literature review, visited paleoshoreline locations evaluated by the applicant near the Fermi 3 site, and reviewed the applicant's lineament analysis. The staff determined that the applicant has conducted a thorough and systematic review of paleoshoreline features within the site vicinity, in order to evaluate the potential for surface deformation at the site. The staff also determined that the applicant has provided sufficient information to address the staff's questions in RAI 02.05.03-6. Therefore, RAI 02.05.03-6 is resolved and closed.

Based on the review of the information in FSAR Subsection 2.5.3.2 and the applicant's responses to the staff's RAIs, the staff concluded that the applicant has adequately evaluated evidence of surface deformation at the Fermi 3 site. The staff found that the applicant has presented thorough and accurate descriptions of information related to geologic evidence, or lack of evidence, for surface deformation from tectonic or non-tectonic processes within the site vicinity to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.3 Correlation of Earthquakes with Capable Tectonic Sources

In FSAR Subsection 2.5.3.4.3, the applicant stated that there is no evidence in the seismic record for earthquakes that can be associated with bedrock faults mapped within the Fermi 3 site vicinity. The applicant referenced FSAR Subsection 2.5.2.1 for a discussion of the regional seismic history. The staff reviewed FSAR Subsection 2.5.3.4.3 in combination with the applicant's review of regional and site tectonic descriptions in FSAR Subsections 2.5.1.1.4.3 and 2.5.1.2.4, and the applicant's description of the local seismicity in FSAR Subsection 2.5.2.1. Based on this review, the staff determined that the applicant has adequately evaluated the correlation of earthquakes with possible tectonic sources. The applicant's conclusion that there is no correlation between earthquakes and known faults of any geologic age within the site vicinity is reasonable. The staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.3.3 to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.4 Ages of Most Recent Deformations

In FSAR Subsection 2.5.3.4, the applicant concluded that there is no evidence for surface deformation from at least the last 200 million years within the site vicinity. The applicant also stated that there is no evidence for earthquake-induced paleoliquefaction and no geomorphic expression of surface deformation across the broad surface or along paleoshoreline features. The staff noted that throughout much of the central and eastern United States, large earthquakes tend not to produce fault ruptures at the surface but may produce liquefaction features in potentially suitable areas. The staff also noted that the combination of a high water table and the presence of interbedded fine-grained and sandy sedimentary deposits in the site vicinity could indicate optimal conditions for liquefaction.

In RAI 02.05.03-2, the staff asked the applicant to provide additional bases for the determination that there is no evidence for paleoliquefaction in the Fermi 3 site vicinity. Specifically, the staff asked the applicant to describe paleoliquefaction investigations conducted in the site vicinity to support the applicant's conclusion that such features do not exist. In the response to RAI 02.05.03-2 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant stated that paleoliquefaction investigations were conducted in the Fermi 3 site region. However, there are no published or unpublished reports documenting paleoliquefaction investigations in the site vicinity. The applicant confirmed the findings with the Ohio and Michigan Geological Survey staffs. The applicant stated that favorable geologic conditions to support the formation, preservation, or recognition of liquefaction features are not present in the Fermi 3 site vicinity, and this conclusion was verified through the applicant's observations during field reconnaissance investigations. Furthermore, the applicant identified several key field observations that provide the basis for its conclusion—including overall low relief across the site vicinity as well as shallow, over-vegetated stream banks.

NRC staff reviewed the applicant's response to RAI 02.05.03-2 and visited multiple field locations at and surrounding the Fermi 3 site in November 2009. The staff visited floodplain and stream locations in the site vicinity to observe stratigraphic exposures and noted unfavorable conditions for conducting paleoliquefaction investigations. The staff also reviewed the applicant's field investigation results and lineament analysis and concluded that the site conditions are not conducive to the development of liquefaction features. The staff determined that the combination of limited and poor exposures, relatively shallow bedrock, and unsuitable Quaternary stratigraphy contribute significantly to the difficulty in relying on paleoliquefaction studies to evaluate strong ground shaking in the Fermi 3 site vicinity. Accordingly, the applicant provided an adequate response to RAI 02.05.03-2. Therefore, this RAI is resolved and closed.

Based on the information in FSAR Subsection 2.5.3.4, the applicant's response to RAI 02.05.03-2, the staff's independent literature review, and observations made during the staff's visit to the site in November 2009, the staff determined that the applicant has adequately evaluated the evidence for the most recent deformations at the Fermi 3 site. The staff found that the applicant's conclusion of a lack of evidence for Quaternary tectonic and non-tectonic surface deformation is reasonable, as is the conclusion that the ages of the most recent deformations in the site vicinity are older than the Quaternary Period. The staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.3.4 to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.5 Relationship of Tectonic Structures in the Site Area to Regional Tectonic Structures

NRC staff reviewed the applicant's information in FSAR Subsection 2.5.3.5 related to the correlation of Paleozoic subsurface structures in the site area with regional tectonic structures. The staff independently reviewed the geologic literature referencing Paleozoic and Precambrian structures in the site region. The applicant provided a reasonable basis to conclude that tectonic structures in the site area are related to regional tectonic structures, which preserve deformation that occurred before the Quaternary Period. The staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.3.5 to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.6 Characterization of Capable Tectonic Sources

NRC staff reviewed FSAR Subsection 2.5.3.6 and the applicant's basis for concluding that no capable tectonic sources exist in the Fermi 3 site vicinity in accordance with criteria defined in RG 1.208. The applicant noted that Paleozoic rocks older than 250 million years are overlain by glacial and lacustrine (lake) deposits that are younger than 30,000 years. The applicant identified no geomorphic evidence for deformation in the overlying glacial and lacustrine deposits.

In RAI 02.05.03-7, the staff asked the applicant to provide a more detailed discussion of the basis for concluding in FSAR Subsection 2.5.3.6 that no bedrock faults within the Fermi 3 site vicinity are capable tectonic sources. In the response to RAI 02.05.03-7 dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant explained the use of multiple observations to assess the capability of postulated faults within the site vicinity. The applicant's analyses focused on evaluating the evidence for deformation associated with two possible bedrock faults that extend into the Fermi 3 site area—the New Boston and the Sumpter Pool faults. The applicant analyzed well log data for 20 oil wells within the vicinity of these two possible structures that were useful for providing elevation constraints across the tops of Paleozoic subsurface formations. The applicant determined that there was no evidence for vertical displacement across either of these postulated faults in the Devonian age (~359 Ma) top of bedrock units associated with the Dundee Formation.

The applicant also relied on analyses of the overlying Quaternary sediments in the Fermi 3 site vicinity to evaluate the potential for surface deformation above the postulated faults. The applicant explained that a series of late-glacial lakes occupied the entire site vicinity about 12,000 to 13,000 years ago. Geomorphic and stratigraphic indicators associated with glacial lake levels are useful indicators of and evidence for vertical displacement and deformation. The applicant analyzed the lake level deposits across the site vicinity and determined that there is no evidence for deformation within these units. The results of these analyses strongly suggest a lack of deformation in the site vicinity within at least the past 13,000 years. The applicant stated that neither of these possible faults within the site vicinity shows any evidence of activity in the past 12,000 years, and the low rate and scattered pattern of seismicity further supports a conclusion that the possible New Boston and Sumpter Pool faults are not capable tectonic structures. As a result of RAI 02.05.03-7, the applicant provided Fermi 3 FSAR updates that more thoroughly document the analyses of the New Boston and Sumpter Pool faults.

NRC staff reviewed the applicant's response to RAI 02.05.03-7, the applicant's analysis of well logs, and the applicant's revisions to FSAR Sections 2.5.1 and 2.5.3. The staff determined that the applicant's response provides a thorough analysis of evidence for capable tectonic structures within the site vicinity. The applicant also clarified unclear statements in previous FSAR versions related to analyzing surface and near-surface deposits in the site vicinity. The staff concluded that the applicant's discussion in the response to RAI 02.05.03-7, including markups of the updated FSAR, adequately address the staff's concerns and provide a more thorough basis to support the applicant's conclusions. Therefore, RAI 02.05.03-7 is resolved and closed.

Based on the information in FSAR Subsection 2.5.3.6, the applicant's response to RAI 02.05.03-7, the staff's independent review, and the staff's observations during a visit to the Fermi 3 site in November 2009, the staff determined that the applicant has adequately characterized capable tectonic sources within the Fermi 3 site vicinity. The applicant provided sufficient information to support the conclusion that tectonic faults in the site vicinity have not experienced deformation since at least the Quaternary Period, thus demonstrating that these faults should not be considered capable tectonic sources. The staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.3.6 to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.4.7 Designation of Zones of Quaternary Deformation in the Site Region

In FSAR Subsection 2.5.3.7, the applicant concluded that there are no zones of Quaternary deformation in the Fermi 3 site region. Based on the staff's independent reviews of the FSAR and the applicant's various RAI responses related to FSAR Sections 2.5.1 and 2.5.3, literature cited in the FSAR, and the results of the field investigations performed by the applicant for the Fermi 3 site, as well as direct field observations made by staff during a site visit in November 2009, the staff determined that the applicant has adequately evaluated the Fermi site region for evidence of Quaternary deformation zones. The staff finds that the applicant's conclusion that no zones of Quaternary deformation exist in the site region is reasonable. Therefore, the staff concludes that the applicant has provided sufficient information in FSAR Subsection 2.5.3.7 to support the Fermi 3 COL application, and that this information is in accordance with regulatory guidance in RG 1.208 and regulatory requirements in 10 CFR 100.23

2.5.3.4.8 Potential for Surface Deformation at the Site

In FSAR Subsection 2.5.3.8, the applicant concluded that the potential for tectonic or non-tectonic surface deformation at the Fermi 3 site is negligible. The NRC staff reviewed the information in FSAR Sections 2.5.1 and 2.5.3 and the applicant's response to the staff's RAIs as the basis for the applicant's conclusions that negligible tectonic or non-tectonic surface deformation potential exists at the site. Based on the staff's review of the FSAR, the staff's independent literature review, the staff's review of the applicant's field investigations in the Fermi 3 site vicinity, and the staff's observations during a site visit in November 2009, the staff determined that the applicant has adequately evaluated the Fermi 3 site for evidence of tectonic or non-tectonic surface deformation. The staff found that the applicant's conclusion that Quaternary tectonic and non-tectonic surface deformation are absent at the site is reasonable, as is the conclusion that existing structures represent deformation processes that occurred before the Quaternary Period. Thus, the applicant has reasonably supported the conclusion that there is a negligible potential for future surface deformation at the site. It is the responsibility of the applicant to perform detailed geologic mapping of the Fermi 3 excavation for nuclear island structures, to examine and evaluate geologic features in excavations for other safety-related structures, and to inform the NRC once the excavations are open for examination by NRC staff. In Subsection 2.5.3.5 of this SER, the staff defines this responsibility as License Condition 2.5.3-1. The staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.3.8 to support the Fermi 3 COL application. The applicant's information is in accordance with the guidance in RG 1.208 and meets the requirements of 10 CFR 100.23.

2.5.3.5 *Post Combined License Activities*

The staff identified the following geologic mapping license condition as the responsibility of the COL licensee:

License Condition (2.5.3-1): The applicant shall perform detailed geologic mapping of excavations for safety-related structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff.

2.5.3.6 *Conclusion*

The NRC staff reviewed the application and confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COL application to the relevant NRC regulations, the guidance in Section 2.5.3 of NUREG–0800, and applicable NRC regulatory guides. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determined that the applicant has adequately addressed COL Item EF3 COL 2.0-28-A, as it relates to the surface faulting.

As set forth above, the staff found that the applicant has provided a thorough characterization of the potential for surface deformation at the Fermi 3 site, as required by 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii). The staff considered the information gathered by the applicant during the regional and site-specific investigations. Therefore, the staff concludes that the applicant had performed these investigations in accordance with the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) by following the guidance in RG 1.208. The staff concludes that the applicant has provided an adequate basis to establish that there is no potential for surface tectonic or non-tectonic deformation that may affect the design and operation of the proposed nuclear power plant. The staff concludes that the site is suitable from the perspective of surface deformation and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii).

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 *Introduction*

This FSAR section presents the stability of subsurface materials and foundations that relate to the Fermi 3 site. The properties and stability of the soil and rock underlying the site are important to the safe design and siting of the plant. The information in this FSAR section addresses (1) geologic features in the site vicinity; (2) static and dynamic engineering properties of soil and rock strata underlying the site; (3) the relationship of the foundations for safety-related facilities and the engineering properties of underlying materials; (4) results of seismic refraction and reflection surveys, including in-hole and cross-hole explorations; (5) safety-related excavation and backfill plans and engineered earthwork analyses and criteria; (6) groundwater conditions and piezometric pressure in all critical strata as they affect the loading and stability of foundation materials; (7) responses of site soils or rocks to dynamic loading; (8) liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations; (9) earthquake design bases; (10) results of investigations and analyses conducted to determine foundation material stability, deformation, and settlement under static conditions; (11) criteria, references, and design methods used in static and seismic analyses of foundation materials; (12) techniques and specifications to improve subsurface conditions, which are to be used at the site to provide suitable foundation conditions, and any additional information deemed necessary in accordance with 10 CFR Part 52.

2.5.4.2 *Summary of Application*

Section 2.5.4 of the Fermi 3 COL FSAR describes the stability of subsurface materials and foundations. In addition, in FSAR Section 2.5.4, the applicant provides the following:

COL Item

- EF3 COL 2.0-29-A Stability of Subsurface Materials and Foundations

In FSAR Section 2.5.4, the applicant provides site-specific information in accordance with SRP Section 2.5.4 to address COL Item EF3 COL 2.0-29-A. Specifically, the information addresses the (1) localized liquefaction potential under other than Seismic Category I structures; and (2) settlement and differential settlement.

2.5.4.2.1 Geologic Features

FSAR Subsection 2.5.4.1 refers to FSAR Section 2.5.1 for a complete description of the regional and site geology, including discussions of the potential for surface and subsurface weathering and deformation.

2.5.4.2.2 Properties of Subsurface Materials

FSAR Subsection 2.5.4.2 presents the static and dynamic engineering properties of subsurface materials based on the applicant's field investigation and sampling program and on laboratory testing. Table 2.5.4-1 of this SER summarizes the engineering properties of subsurface materials at the Fermi 3 site.

Table 2.5.4-1 Summary of Engineering Properties of Soils and Bedrocks
(Reproduced from Fermi COL FSAR Table 2.5.4-202)

Stratum	Quarry Fill	Lacustrine Deposits	Glacial Till	Bass Islands Group	Salina Group Unit F	Salina Group Unit E	Salina Group Unit C	Salina Group Unit B
USCS Symbol	GP/GW	CL/CH	CL	-	-	-	-	-

Total Unit Weight kg/m^3 (pcf)	2,002 (125)	2,082 (130)	2,162 (135)	2,402 (150)	2,402 (150)	2,402 (150)	2,402 (150)	2,402 (150)
Fines Content, %	-	93	68	-	-	-	-	-
Natural Water Content, %	-	27	15	0.1	0.4	3.9	0.9	0.2
Atterberg Limits								
Liquid Limit %	-	44	29	-	-	-	-	-
Plastic Limit %	-	17	15	-	-	-	-	-
Plasticity Index %	-	27	14	-	-	-	-	-
Adjusted SPT N60-value, bpf	11	7	47	-	-	-	-	-
Undrained Shear Strength kPa (ksf)	-	43 (0.9)	129 (2.7)	-	-	-	-	-
Effective Shear Strength Parameters								
Effective Cohesion kPa (ksf)	0	0	0	-	-	-	-	-
Effective Friction Angle	36	29	31	-	-	-	-	-
Rock Quality Designation	-	-	-	54	13	72	97	97
Unconfined Compressive Strength MPa (ksf)	-	-	-	89 (1,870)	45 (940)	84 (1,760)	86 (1,800)	73 (1,540)
Poisson Ratio	0.35	0.35/0.49	0.35/0.49	0.33	0.39	0.30	0.28	0.29
Modulus of Elasticity based on Hoek-Brown criterion								
Upper Bound Modulus MPa (ksf)	-	-	-	5,242 (109,500)	1,517 (31,700)	23,560 (492,100)	29,830 (623,000)	63,430 (1,324,700)
Mean Modulus MPa (ksf)	-	-	-	3,863 (80,700)	1,160 (24,200)	20,310 (424,200)	26,780 (559,300)	58,810 (1,228,400)
Lower Bound Modulus MPa (ksf)	-	-	-	2,868 (59,900)	924 (19,300)	16,710 (349,000)	23,080 (482,100)	52,800 (1,102,700)

Modulus of Elasticity based on Laboratory Test MPa (ksf)	-	-	-	43,030 (898,600)	25,340 (529,200)	32,150 (671,500)	36,540 (763,200)	72,050 (1,504,800)
Modulus of Elasticity based on V_s MPa (ksf)	-	-	-	26,630 (556,200)	6,350 (132,600)	36,190 (755,800)	48,240 (1,007,600)	55,390 (1,156,900)
Average V_s m/s (fps)	-	-	243 to 350 (800 to 1,150)	2,042 to 2,225 (6,700 to 7,300)	975 to 1,219 (3,200 to 4,000)	2,407 to 2,773 (7,900 to 9,100)	2,712 to 2,743 (8,900 to 9,000)	2,895 to 3,017 (9,500 to 9,900)
Average V_p m/s (fps)	-	-	-	4,023 to 4,389 (13,200 to 14,400)	2,438 to 2,865 (8,000 to 9,400)	4,663 to 4,937 (15,300 to 16,200)	4,846 to 4,907 (15,900 to 16,100)	5,334 to 5,577 (17,500 to 18,300)
Shear Modulus at very small strain levels, G_{max} MPa (ksf)	-	-	129 (2,700)	10,010 (209,100)	2,283 (47,700)	13,920 (290,700)	18,850 (393,600)	21,470 (448,400)
bpf = blows per foot; fps = foot per second; kg/m^3 = kilograms per cubic-meter; kPa = kilopascal; ksf=kip (1000 pound force) per square-foot; m/s= meters per second; MPa= megapascal; pcf = pounds per cubic-foot								

Engineering Properties of Subsurface Materials

FSAR Subsection 2.5.4.2.1 provides an overview of the subsurface soil and rock at the Fermi 3 site. The applicant stated that there are approximately 9.0 m (30 ft) of overburden material consisting of fill, lacustrine deposits, and glacial till overlying the bedrock at the site. The applicant described plans to remove all overburden material beneath and adjacent to Seismic Category I structures during excavation. The bedrock unit below the overburden consists of the Bass Islands Group and Units F, E, C, and B (from the top to the bottom) of the Salina Group. The applicant noted that the site is relatively flat with an average elevation of 177 m (581 ft) NAVD 88. Table 2.5.4-2 of this SER summarizes the approximate elevation ranges and average thickness for each of the subsurface layers. FSAR Appendix 2.5DD lists a total of 68 borings, which the applicant performed to obtain the engineering properties of both soils and rocks.

Table 2.5.4-2 Approximate Elevation Ranges for Each Subsurface Material Encountered at Fermi 3

(Reproduced from Fermi COL FSAR Table 2.5.4-201)

Subsurface Material	Approximate Range in Elevation NAVD 88, m (ft)	Average Thickness, m (ft)
Fill	177 to 173 (581 to 568)	3.9 (13)
Lacustrine Deposits	173 to 171 (568 to 563)	1.5 (5)

Glacial Till	171 to 168 (563 to 552)	3.3 (11)
Bass Islands Group	168 to 141 (552 to 462)	27 (90)
Salina Group Unit F	141 to 103 (462 to 339)	37 (123)
Salina Group Unit E	103 to 75 (339 to 246)	28 (93)
Salina Group Unit C	75 to 47.5 (246 to 156)	27 (90)
Salina Group Unit B	47.5 to * (156 to *)	*
*The bottom of the Salina Group Unit B was not encountered during the geophysical investigations. ft= foot; m = meter		

Engineering Properties of Soils

FSAR Subsection 2.5.4.2.1.1 discusses the engineering properties of the upper 30 m (90 ft) of overburden materials present at the Fermi 3 site. The applicant stated that the overburden is comprised of fill, lacustrine deposits, and glacial till, all of which will fully excavate beneath and adjacent to all Seismic Category I structures.

The applicant further stated that although the fill and lacustrine deposits are not suitable for foundation support or structural backfill, their static engineering properties are suitable for the stability analysis and design of temporary excavation support systems and slopes. Since the fill and lacustrine deposits will be removed at the site, the applicant did not consider the dynamic engineering properties of these materials in the GMRS.

Finally, the applicant considered the static and dynamic properties of the approximately 3.4-m (11-ft) thick glacial till at the base of the overburden; because this material may be used to support non-Seismic Category I structures. The applicant noted that shear wave velocity (V_s) measurements of the glacial till range from 244 to 351 m/s (800 to 1,150 fps). The applicant used these values to calculate the shear modulus behavior of the glacial till and considered the glacial till the uppermost competent material present at the Fermi 3 site.

Engineering Properties of Bedrock

FSAR Subsection 2.5.4.2.1.2 describes the characteristics, properties, and classification of the two primary bedrock units beneath the Fermi 3 site: the Bass Islands Group and Units F, E, C, and B of the Salina Group. FSAR Subsections 2.5.1.2.3.1.2 and 2.5.1.2.3.1.1 provide detailed descriptions of these units. The applicant estimated the strength and deformation characteristics of the bedrock units using the Hoek-Brown criterion (Hoek 2007).

1. Bass Islands Group

The applicant stated that it will found the Fermi 3 Seismic Category I structures on the Bass Islands Group, or on fill concrete overlying the Bass Islands Group, the uppermost bedrock unit with an elevation of approximately 168 to 141 m (552 to 462 ft) NAVD 88. Based on field testing, the applicant stated that the average rock quality designation (RQD)—a measure of the rock's integrity—is 54 percent. The applicant lab-tested 20 intact rock samples and determined an average unconfined compressive strength (q_u) and elasticity modulus (E) of 89.5 megapascals (MPa) (1,870 kips per square-foot (ksf)) and 43,000 MPa (898,600 ksf), respectively. The applicant based the Poisson's ratio, which varies from 0.33 to 0.34, on the mean V_s and compression wave velocity (V_p), which varies from 2,012 to 2,225 m/s (6,600 to 7,300 fps) and 4,023 to 4,389 m/s (13,200 to 14,400 fps), respectively.

2. Salina Group

FSAR Subsections 2.5.4.2.1.2.2 through 2.5.4.2.1.2.5 describe the general characteristics for Salina Group Units F, E, C, and B. The applicant described Salina Group Unit F as bedrock localized at an elevation of 140 to 103 m (462 to 339 ft) NAVD 88, with an average RQD of 13 percent. In order to determine the characteristics of the intact bedrock, the applicant performed thirteen unconfined compression (UC) laboratory tests to obtain an average q_u of 45 MPa (940 ksf) and an average E of about 25,300 MPa (529,300 ksf). The applicant performed an in situ pressuremeter test and obtained an average E of 996 MPa (20,800 ksf). The applicant calculated a Poisson's ratio of 0.39 to 0.40 from the mean Vp of 2,438 to 2,865 m/s (8,000 to 9,400 fps) and the mean Vs of 975 to 1,219 m/s (3,200 to 4,000 fps).

The applicant observed the Salina Group Unit E between elevation 103 and 75 m (339 and 246 ft) NAVD 88, with an average RQD of 72 percent. The applicant performed UC laboratory tests on eight intact bedrock samples with an average q_u and E of 84 MPa and 32,100 MPa (1,750 ksf and 671,400 ksf), respectively. The applicant calculated a Poisson's ratio of 0.27 to 0.32 based on the mean V_s and V_p that vary from 4,115 to 4,938 m/s (15,300 to 16,200 fps) and 2,408 to 2,774 m/s (7,900 to 9,100 fps), respectively.

FSAR Subsection 2.5.4.2.1.2.4 states that the Salina Group Unit C was found between elevations of 75 to 47.5 m (246 to 156 ft) NAVD 88, with an average RQD of 97 percent. The applicant noted that only two borings penetrated Unit C. The applicant performed an UC laboratory test on two intact bedrock samples, and the resultant q_u and E had averages of 86 MPa and 36,542 MPa (1,790 ksf and 763,200 ksf), respectively. The applicant calculated a Poisson's ratio of 0.26 to 0.28 from the mean V_p of 4,846 to 4,907 m/s (15,900 to 16,100 fps) and the mean V_s of 2,713 to 2,743 m/s (8,900 to 9,000 fps).

FSAR Subsection 2.5.4.2.1.2.5 specifies that the top of Salina Group Unit B is at an elevation of 47.5m (156 ft), but the bottom was not found during the subsurface investigation. The applicant noted that the average RQD was 97 percent and considered an average q_u of 74 MPa (1,540 ksf) and an average E of 72,000 MPa (1,504,800 ksf) to be representative of the engineering behavior of the rock mass of Salina Group Unit B. The applicant used the mean V_p, which varied from 5,334 to 5,578 m/s (17,500 to 18,300 fps); and the mean V_s, which varied from 2,896 to 3,018 m/s (9,500 to 9,900 fps), to calculate a Poisson's ratio of 0.29.

Field Investigations

FSAR Subsection 2.5.4.2.2 states that the applicant conducted field investigations in accordance with an approved quality assurance program. The applicant used two phases to complete the investigation: a hydrogeological phase and a geotechnical phase.

Hydrogeological Investigation Program

The applicant conducted a hydrogeological investigation that consisted of piezometers and monitoring wells installation, packer and slug testing, downhole geophysics and sampling, and groundwater testing. The applicant's investigation focused on the unconfined surficial groundwater and the confined Bass Islands Group aquifer. The applicant installed 17 shallow and 11 deep piezometers and monitor wells east and west of the overflow canal. The applicant utilized the shallow wells to monitor the unconfined groundwater and the deeper wells to monitor the confined Bass Islands Group aquifer. FSAR Section 2.4.12 discusses the existing Fermi piezometers and monitoring wells in greater detail. The applicant recorded the groundwater or drilling fluid level at the start of each workday for borings in progress and at the completion of drilling, in accordance with the guidance in RG 1.132. The groundwater levels were measured monthly for a period of 1 year. The applicant performed downhole logging in areas of poor bedrock core recovery to aid in the selection of packer test zones, understand the hydrology, and correlate the bedrock geology across the site. The applicant referred to FSAR Section 2.4.12 for the results of packer and slug testing performed to estimate the permeability of selected intervals of bedrock and the hydraulic conductivity in the overburden, respectively.

FSAR Subsection 2.5.4.2.2.1.7 presents the types of chemical testing conducted on the groundwater and surface water samples to establish baseline conditions at the site.

Geotechnical Investigation Program

The applicant conducted a geotechnical investigation to obtain surface information, characterize site conditions, develop site specific seismic design criteria, and evaluate the potential for geotechnical hazards.

In accordance with RG 1.132, the applicant collected soil samples at depth intervals no greater than 1.5 m (4.92 ft). The applicant used a combination of split–barrel samplers, thin-walled tubes, or sonic sampling depending on the soil type. The applicant concluded that because it will found all safety-related structures at the Fermi 3 site on bedrock or fill concrete over bedrock, the continuous sampling requirement was satisfied by the continuous sonic sampling from the ground surface to the top of the bedrock and by continuous rock coring in bedrock.

The applicant conducted P-S suspension logging, downhole seismic testing and SASW surface geophysics to obtain a V_s profile to use in a seismic response analysis of the site.

FSAR Subsection 2.5.4.2.2.2.5 describes the procedure and results of additional pressuremeter testing the applicant performed at the Salina Group Unit F location to provide a direct in situ measurement of the E for Unit F. The applicant selected rock pressuremeter locations in Boring RB-C6, at the location planned for the reactor, to test a range of bedrock qualities and types to provide a range of E values for Unit F. The applicant stated that the material being tested was a very complex geological unit consisting of interbedded limestone, dolomite, claystone, siltone, shale and breccias with variable degrees of induration. Even with the limitation of full classification of interbedded materials, the applicant successfully conducted pressuremeter testing and concluded that the test results should provide a conservative estimate of the in situ E. FSAR Table 2.5.4-219 contains the details of the test results.

The applicant backfilled the boreholes in the overburden or the Bass Islands Group with either bentonite chips within 0.3 to 0.6 m (1 to 2 ft) of the ground surface or cement/bentonite grout, and the top 0.3 to 0.6 m (1 to 2 ft) was backfilled with gravel.

Storage, Handling, and Transportation of Soil and Bedrock Samples

In FSAR Subsection 2.5.4.2.2.3, the applicant stated that the collected soil and bedrock samples were documented and stored in a way that will permit future retrieval for future examination and index testing. In addition, the applicant implemented American Society of Testing and Materials (ASTM) Standards D4220–95 and D5079–02; clearly labeled the samples; used a sample custody record form completed by a field engineer or geologist for storage and documentation; and delivered the samples to a temporary storage facility on a daily basis.

Laboratory Testing

FSAR Subsection 2.5.4.2.3 describes the goal of the laboratory testing program. The applicant stated that this program fully complies with the guidance of RG 1.138, and the testing was performed in accordance with standard test procedures. As part of the static laboratory testing, the applicant included different types of tests, such as the natural moisture content; specific gravity; Atterberg limits; mechanical sieve analysis; hydrometer analysis; percent finer than No. 200 sieve; consolidated-undrained triaxial compression test; unconsolidated-undrained triaxial compression test; unconfined compression test on soil and rock; one-dimensional consolidation test; direct shear test on soil and rock; hydraulic conductivity; and chemical analysis of soils. The applicant concluded that no dynamic testing was required for several bedrock units (the Bass Islands Group and Salina Group Units E, C, and B) because the V_s were equal to or greater than 2,042 m/s (6,700 fps). The applicant also concluded that no dynamic testing was required for Salina Group Unit F because the estimated shear strain levels were less than 0.03 percent, thus indicating a negligible modulus reduction for the Unit F bedrock. The applicant stated that because of poor core recovery and poor RQD for Salina Group F, the testable samples represent the more intact portion of the bedrock and testing under static or dynamic loading conditions will produce high values not representative of the overall unit. The applicant performed four resonant column torsional shear (RCTS) dynamic tests on samples of glacial till to obtain the modulus reduction and damping as a function of strain up to shear strain of approximately 0.3 percent. FSAR Section 2.5.4.7.3 presents the RCTS results.

2.5.4.2.3 Foundation Interfaces

FSAR Subsection 2.5.4.3 describes the geologic cross sections for Seismic Category I structures, including the detailed relationship of the foundations of structures to the subsurface materials. The applicant noted that the base of the RB/FB foundation lies in the Bass Islands Group, with an embedment depth of 20 m (65.6 ft) below the finished grade and a base elevation of 159.6 m (523.7 ft) NAVD 88. The base of the CB foundation also lies in the Bass Islands Group, with an embedment depth 14.9 m (48.9 ft) below the finished grade and an elevation of 164.7 m (540.4 ft) NAVD 88. For the FWSC, the applicant indicated an embedment depth of 2.35 m (7.7 ft) at an elevation of 177.3 m (581.6 ft) NAVD 88. The applicant will use fill concrete to backfill the gap between the RB/FB and CB and excavated bedrock up to 168.2 m (552 ft) NAVD 88. The applicant will remove and replace the glacial till underneath the TB with fill concrete to reduce the interaction between the TB and the RB as a result of the close proximity between the buildings. FSAR Appendix 2.5DD includes a list of the boring logs, monitoring well logs, piezometer logs, and test pit logs.

2.5.4.2.4 Geophysical Surveys

FSAR Subsection 2.5.4.4 refers to FSAR Subsection 2.5.4.2.2.2.4 for a list of the geophysical surveys performed. The details of the testing are discussed below in this section.

Geophysical Surveys for Dynamic Characteristics of Subsurface Materials

In FSAR Subsection 2.5.4.4.1, the applicant measured the dynamic characteristics of soils and bedrock using different types of testing that includes P-S suspension logging to obtain the V_s

and V_p of the soil and bedrock; surface SASW to obtain the V_s in the soil; and downhole seismic testing to obtain the V_s and V_p in bedrocks. The applicant considered the P-S suspension logging method as the primary method for obtaining the V_s and V_p and used the downhole seismic method to validate the results.

P-S Suspension Logging and Downhole Seismic Testing in Bedrock Units

Initially the applicant experienced a repeated collapse of the boreholes at depths of 33.5 to 62.5 m (110 to 205 ft) in Salina Group Unit F that resulted in an oversized borehole and irregular borehole shapes. The applicant overcame the problem by using temporary steel casing and by conducting P-S suspension logging and downhole seismic testing below and above the borehole collapsing zone and at select locations within the Salina group Unit F.

The applicant obtained variable readings in Salina Group Unit F and in the Bass Islands Group between depths of 9.1 and 36.6 m (30 and 120 ft). The applicant compared the V_s and V_p measurements with the RQD, caliper, natural gamma, and optical televiewer (OTV) information to understand whether the measured velocities were representative of the actual subsurface conditions. FSAR Figure 2.5.4-213 and Figure 2.5.4-214 show that the variability in the measured V_p and V_s correlates with the variability in the natural gamma logs, where the lower gamma indicates the presence of dolomite or limestone, the measured V_p and V_s increase. The applicant concluded that the variability in the measured V_p and V_s is caused by geologic features and that the measured V_p and V_s are representative of the actual ground conditions. The applicant stated that the measured V_p at Fermi 3 is in agreement with the V_p measured at Fermi 2 for the Bass Islands Group and for Salina Group Units F and E. But the V_p measured at Fermi 2 for Salina Group Units C and B have a difference of less than 15 percent lower than the V_p measured for Fermi 3. Figure 2.5.4-1 of this SER shows all of the V_p and V_s measurements at different borehole locations using both the P-S and downhole seismic methods. The applicant concluded that the results from P-S suspension logging are acceptable for all purpose of analysis.

P-S Suspension Logging and Spectral Analysis of Surface Wave in Soil Layers

FSAR Subsection 2.5.4.4.1.2 states that the results of the SASW method are acceptable because the soil shear wave velocities measured using the P-S suspension method agree with the SASW method. The applicant measured the seismic wave velocities in the overburden at boring RB-C6.

Natural Gamma, 3-Arm Caliper, Heat Pulse Flowmeter, and Optical Televiewer Logging

FSAR Subsection 2.5.4.4.2 describes the details of the various logging methods used. The applicant referenced the Black and Veatch report (Black and Veatch 2008) for the results of borehole loggings using the natural gamma, the 3-arm caliper, the heat pulse flowmeter, and the OTV. The applicant conducted all of the loggings in the same 18 boreholes except for the heat pulse flowmeter logging that was performed on borings RB-C8 and TB-C5.

Borehole Deviation Survey

In FSAR Subsection 2.5.4.4.3, the applicant conducted a borehole deviation survey in 22 steel-cased boreholes and recorded a maximum deviation of less than 1.5 degrees in the borings surveyed. The applicant utilized the EZ-Trac tool with the multi-shot function for most boreholes and the OTV probe for boring locations RB-C8 and TB-C5.

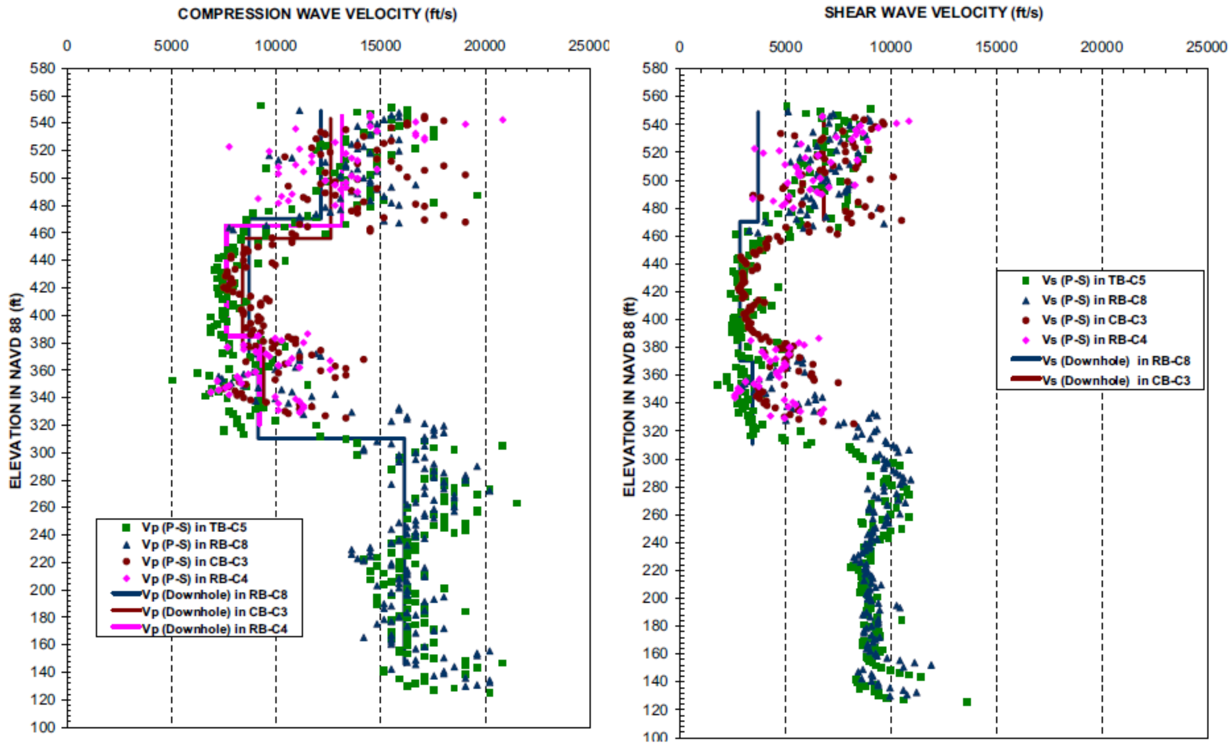


Figure 2.5.4-1 V_p and V_s measurements using P-S and Downhole Methods
(Reproduced from Fermi 3 COL FSAR Figure 2.5.4-215 and 2.5.4-216)

2.5.4.2.5 Excavation and Backfill

FSAR Subsection 2.5.4.5 describes source and quantities of backfill and borrow materials, excavation methods and stability. The applicant will commence all excavation activities for the power block structures from the existing ground surface elevation of approximately 177.1 m (581.0 ft) NAVD 88. FSAR Subsection 2.5.4.5.4.2 addresses the details of engineered granular backfill.

Source and Quantities of Backfill and Borrow Materials

In FSAR Subsection 2.5.4.5.1, the applicant indicated that the excavated material meeting gradation requirements will be used as engineered granular backfill. The applicant conducted laboratory and chemical testing and determined the static and dynamic properties to verify compliance with the design requirements of the proposed engineering granular backfill. The applicant indicated that the backfill surrounding Seismic Category I and II structures will be a well-graded engineered granular material and fill concrete. The applicant also stated that the backfill underneath the FWSC and the TB will be fill concrete. The applicant plans to complete the site excavation using vertical side wall excavation in soils and bedrocks. The total cut volume is estimated to be 313,000 cubic meters (m^3) (410,000 cubic yards [yd^3]) of which 256,000 m^3 (335,000 yd^3) are soil excavation and 57,000 m^3 (75,000 yd^3) are bedrock excavation. The total estimated backfill volume for full site development is 344,000 m^3 (450,000 yd^3), the volume of granular backfill from onsite excavation is approximately 180,000 m^3 (235,000 yd^3), and the amount of the engineered granular backfill within the perimeter of the reinforced concrete diaphragm wall is approximately 153,000 m^3 (200,000 yd^3). Since the potential total onsite source of granular material is greater than the quantity required to backfill within the perimeter of the reinforced concrete diaphragm wall, the applicant concluded that an onsite source will be used for backfill adjacent to the Seismic Category I structures. The applicant will apply the bulking and shrinkage factor during the final design.

Extent of Excavations, Fills, and Slopes

In FSAR Subsection 2.5.4.5.2, the applicant addressed the vertical cut-off as an excavation system possibility, which consists of a reinforced diaphragm wall system around the entire excavation. Figures 2.5.4-2 and 2.5.4-3 of this SER present the excavation site plan view and excavation cross-section D-D' for Fermi 3 using the vertical cut-off excavation system. The applicant stated that if the vertical cut-off excavation is used, this excavation system will be installed from the existing ground surface. The applicant assumed that the cut-off walls are 24.4 m (80 ft) deep with an embedment depth of 15.2 m (50 ft) into the bedrock, between elevations of 168.2 and 153.5 m (552.0 and 503.7 ft) NAVD 88. The applicant stated that the reinforced concrete diaphragm wall will act as a perimeter of the soil excavation and will provide vertical support for the portion of the excavation within the soil. FSAR Subsection 2.5.4.5.2 explains the considerations taken regarding the distance between the wall and the Seismic Category I structures. The applicant stated that the Seismic Category I structures are designed to resist all static and dynamic soil and bedrock loads and will not be adversely affected by the diaphragm wall. The applicant also stated that the concrete diaphragm wall will be designed to ensure that it will not adversely affect the seismic Category 1 structures.

Excavation Methods and Stability

Excavation in Soil

FSAR Subsection 2.5.4.5.3.1 states that the applicant may use conventional excavation methods to remove soil layers to the lines and grades shown on the excavation cross sections.

Excavation in Bedrock

FSAR Subsection 2.5.4.5.3.2 states that the applicant will use blasting, mechanical excavation, or a combination of both methods for the bedrock excavation. FSAR Figures 2.5.4-201 through 2.5.4-204 present lines and grades where the bedrock stratum will be excavated. The applicant indicated that all of the blasting will be designed by a qualified blasting professional in order to ensure the protection of all existing adjacent structures, including Fermi 2. The applicant stated that the mechanical excavation could include roadheaders, terrain levelers, rockwheels, and rock trenchers, among other excavation techniques.

Foundation Bedrock Grouting

In FSAR Subsection 2.5.4.5.3.3, the applicant indicated that a similar foundation bedrock grouting program used for Fermi 2 may be used for Fermi 3, as part of the excavation support and seepage control system. The applicant explained that for Fermi 2, the foundation bedrock grouting program was successful in reducing groundwater flow through the rock mass into the excavation during construction.

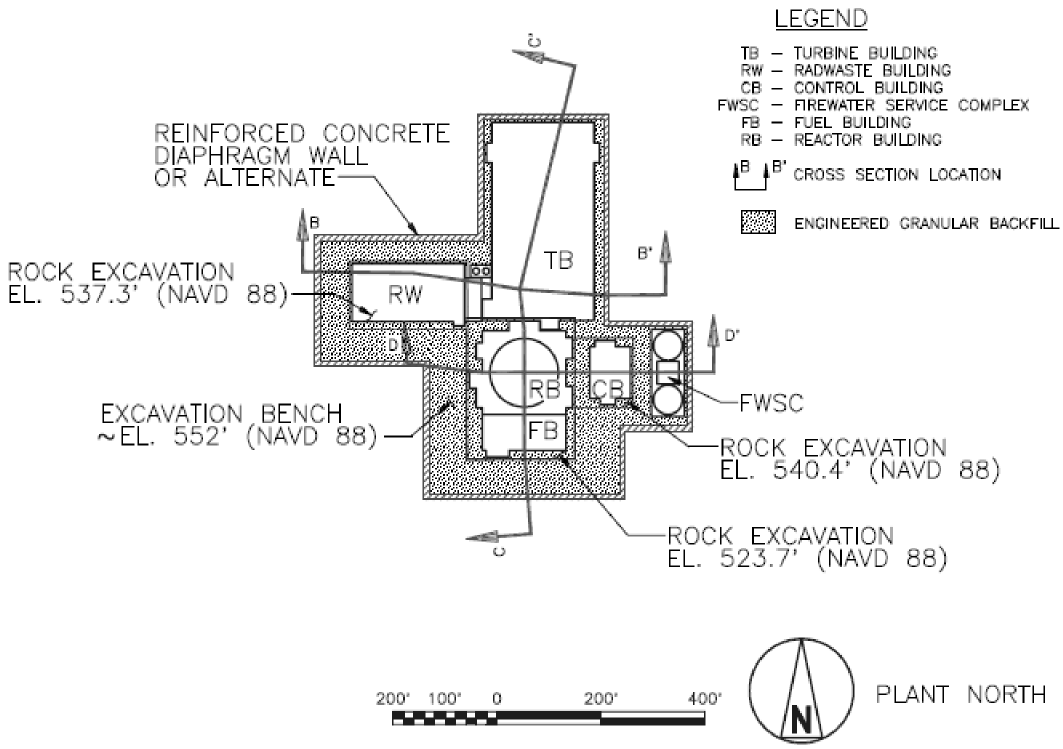


Figure 2.5.4-2 Excavation Site Plan
(Reproduced from Fermi 3 COL FSAR Figure 2.5.4-201)

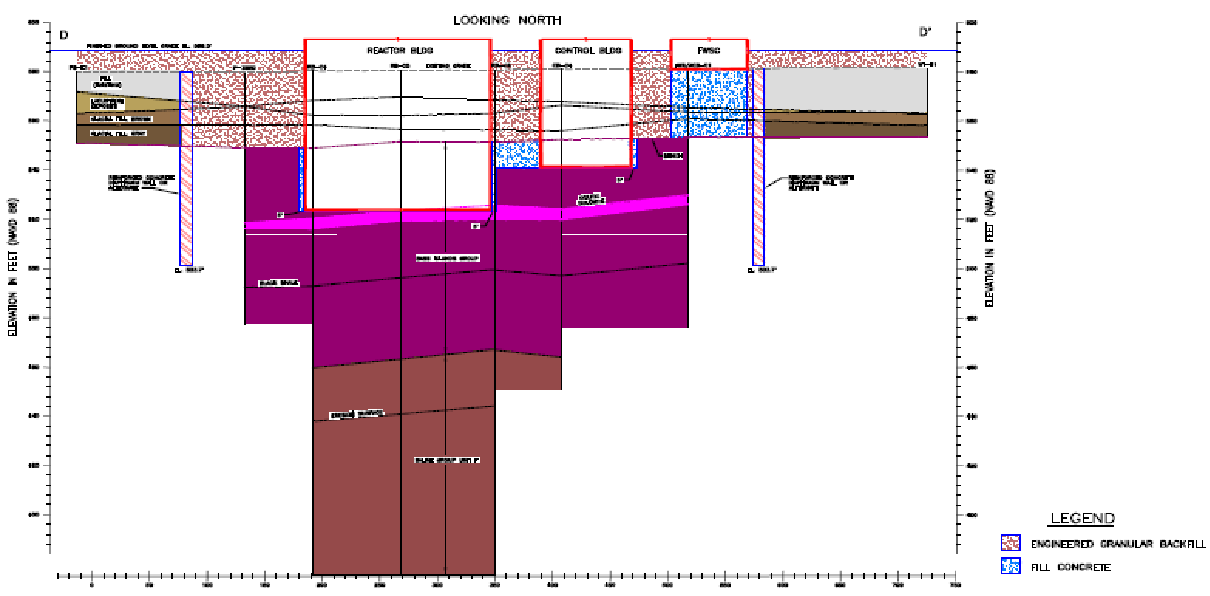


Figure 2.5.4-3 Excavation Cross Section D-D'
(Reproduced from Fermi 3 COL FSAR Figure 2.5.4-202)

Compaction Specifications and Quality Control

FSAR Subsection 2.5.4.5.4 describes the methods and procedures used for verification and quality control of foundation materials.

FSAR Subsection 2.5.4.5.4.1 describes methods used for quality control of foundation bedrock. FSAR states that the applicant plans to conduct a visual inspection of the final bedrock excavation surface to confirm that it conforms with the expected foundation materials based on borings loggings. In addition, the applicant will conduct visual inspections of the exposed bedrock subgrade to confirm the proper completion of the cleaning and surface preparations. The design specification includes details of quality control and quality assurance for the foundation bedrock.

FSAR Subsection 2.5.4.5.4.2 presents the consistency of the backfill materials and quality control for Fermi 3. The backfill will consist of fill concrete or a sound, well-graded granular backfill. FSAR Section 3.7.2 details the results of the site-specific SSI analyses for the RB/FB and CB, with fill concrete included as the backfill below the top of the Bass Islands Group bedrock and with and without the engineered granular backfill above the top of the bedrock. The applicant will place fill concrete as the supporting material below the FWSC, with a mean compressive strength of 31 MPa (4,500 psi). The applicant concluded that the FWSC sliding of not an issue when neglecting the engineered granular backfill surrounding the basemat, and the engineered granular backfill surrounding the basemat for the FWSC is not Seismic Category I backfill. In addition, the applicant specified that the engineered granular backfill surrounding the Seismic Category I structures will comply with the following criteria:

(a) Product of peak ground acceleration in g, α, Poisson's ratio, ν, and density, γ:
α (0.95ν +0.65) γ: 1220 kg/m3 (76 pcf) maximum

(b) Angle of internal friction equal to or greater than 35 degrees when properly placed and compacted

(c) Soil density, γ, is 2,000 kg/m^3 (125 pcf) minimum

FSAR Figures 2.5.4-202 through 2.5.4-204 show the extent of the fill concrete and granular backfill. The applicant will use the concrete fill to backfill the gap between the bedrock and the foundation mats of the R/FB and the CB. The applicant will use the design specifications to address the concrete fill mix design. For quality control testing requirements for the bedrock, the applicant will use visual inspection and geologic mapping. The applicant will conduct laboratory testing on the in-place engineered backfill adjacent to Seismic Category I structures during the detailed design phase in order to comply with the design requirements for the required density. The applicant will compact the engineered granular backfill surrounding the Seismic Category I structures above the top of the Bass Islands Group bedrock using a mean of 95 percent of the modified Proctor density or a mean of 75 percent of the maximum relative density. The applicant will compact the engineered granular backfill to achieve a minimum of 35 degrees for the angle of friction (φ). FSAR Subsections 2.5.4.8 and 2.5.4.10 discuss liquefaction issues related to soil backfill materials and lateral pressures applied against foundation walls, respectively. In FSAR Part 10 Section 2.4.2, the applicant described a site-specific ITAAC for backfill surrounding Seismic Category I structures which states that the engineering properties of backfill material surrounding Seismic Category I structures will be equal to or exceed the FSAR Subsection 2.5.4.5.4.2 requirements.

The applicant will follow American Concrete Institute (ACI) 349 for concrete exposed to sulfate-containing solutions and will use fill concrete with a mean 28-day compressive strength greater than 31 MPa (4,500 psi) and with a mean V_s equal or greater than 2,175 m/s (7,140 ft/s) as fill under the FWSC, Seismic Category II structures, and surrounding the RB/FB and the CB. The applicant indicated that the mix design developed for the fill concrete will control erosion and leaching and will limit settlement to specified tolerances. The quality control program for fill concrete includes requirements for compressive strength testing, and the quality control program for engineered granular backfill includes requirements for in-place field density and index testing. The applicant will adhere to the ASTM standards for testing the aggregate of concrete for deleterious expansive alkali-silica reaction. The applicant will follow ACI 207.1R, 207.2R, and 207.4R to address thermal cracking control of the fill concrete adjacent to and underneath Seismic Category I and II structures. The applicant stated that the quality control program for fill concrete includes requirements for compressive strength testing. The applicant will perform verification to confirm that compressive strength testing results comply with mix design, minimum strengths, and placement requirements. The applicant will prepare design specifications as part of the detailed design phase of the project, including the details for the quality control and quality assurance programs for the fill concrete and engineered granular backfill. In FSAR Part 10 Section 2.4.1, the applicant described a site-specific ITAAC for fill concrete under Seismic Category I Structures, which states that the compactable backfill will not be placed under Fermi 3 Seismic Category I structures and that the fill concrete placed under Seismic Category I structures to a thickness greater than 5 feet will be designed and tested as specified in FSAR Subsection 2.5.4.5.4.2.

Control of Groundwater during Excavation

FSAR Subsection 2.5.4.5.5 refers to Subsection 2.5.4.6.2 for the discussion of the control of groundwater and dewatering during excavation.

Geotechnical Instrumentation

FSAR Subsection 2.5.4.5.6 states that the instrumentation and monitoring program developed during the project's detailed design phase includes inclinometers, piezometers, seismograph survey points, and construction inspection documentation. The applicant expected a rebound or heave of less than 12.7 mm (0.5 inch) from the foundation excavation. The applicant predicted that the settlement would be within the ESBWR DCD design limits and would occur during the construction phases instead of post construction. The applicant based this prediction on the confirmation that the Seismic Category I structures are founded on bedrock that will compress elastically as the loads are applied. The applicant will confirm these settlement predictions by implementing a benchmark monitoring program.

2.5.4.2.6 Groundwater Condition

FSAR Subsection 2.5.4.6 presents information on the groundwater conditions at the site relative to foundation stability for the safety-related structures.

Groundwater Measurements

FSAR Subsection 2.5.4.6.1 refers to FSAR Subsection 2.5.4.2.2 for a discussion of the field investigation program for groundwater measurements and to FSAR Section 2.4.12, which presents the monitoring wells and piezometers data.

Construction Dewatering and Impact of Dewatering

FSAR Subsection 2.5.4.6.2 states that the applicant will use localized sump pumping systems and foundation bedrock grouting in order to control groundwater seepage through soils and bedrock during the excavation. For the sump pumping system, the applicant will place pumps at low points with water pumped to a location outside the excavation. The applicant will test the pumps and will use the results to evaluate the need for bedrock grouting before excavation. As needed, the applicant will perform foundation bedrock grouting to control groundwater inflow from zones of high permeability within the rock mass during excavation. The applicant will base the thickness of the grouted zone on the need to minimize inflow into the excavation and to resist any uplift pressures at the base of the excavations. The applicant will complete the design of the foundation grouting program during the detailed design phase of the project.

Seepage during Construction

FSAR Subsection 2.5.4.6.3 refers to FSAR Subsection 2.4.12.2.5 for a discussion of the impact of seepage into the excavation and groundwater control measures during construction. The applicant concluded that there is no potential for piping due to seepage in the bedrock, and the seepage will be minimized by excavation support and by a seepage control system. The applicant also confirmed that the potential for settlement on Fermi 2 associated with the Fermi 3 dewatering operation is negligible, because Fermi 2 has foundation on bedrock. Before beginning the construction of Fermi 3, the applicant will develop a monitoring program during the Fermi 3 design stage (Commitment COM 2.5.4-001) to assess groundwater levels and settlement at existing Fermi 2 structures.

Permeability Testing

FSAR Subsection 2.5.4.6.4 refers to FSAR Section 2.4.12 for the results of the packer and slug testing and laboratory hydraulic conductivity testing performed to estimate the hydraulic conductivity of the bedrock and soil.

Impact of Groundwater Conditions on Foundation Stability

FSAR Subsection 2.5.4.6.5 states that the applicant will found the Seismic Category I structures on bedrock or concrete fill and will found other major structures in the power block area either on bedrock or structural fill. The applicant will design the foundations of all Fermi 3 structures to account for a short-term construction with a lowered groundwater level and a long-term operational in-service condition with a rebounded natural groundwater elevation.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loadings

Effect of Past Earthquakes

FSAR Subsection 2.5.4.7.1 refers to FSAR Subsection 2.5.1.1.4.3 for the discussion of the historical earthquake events. The applicant stated that no reports or studies exist on liquefaction and paleoliquefaction in the 40-km (25-mi) radius of the site vicinity.

Seismic Wave Velocity Profiles

FSAR Subsection 2.5.4.7.2 refers to FSAR Subsection 2.5.4.4 for details on the geophysical surveys used for the dynamic characterizations of soils and bedrock. The applicant generated

60 randomized soil profiles for soil amplification analyses for the RB/FB, CB, and FWSC, in order to consider variations and uncertainties in the dynamic soil profiles. The applicant sorted the iterated V_s for each layer of the 60 randomized profiles into rank order (from the lowest to highest value) and determined the 16^{th}, 50^{th}, and 84^{th} percentile V_s profiles at the seismic strains. The applicant indicated that the 16^{th} percentiles of the randomized V_s at the seismic strains represent the mean minus one standard deviation, and the 16^{th} percentiles for the foundation materials below the RB/FB, CB, and FWSC are greater than 300 m/s (1,000 fps).

Dynamic Laboratory Testing

FSAR Subsection 2.5.4.7.3 discusses the RCTS tests performed on glacial till. The applicant conducted four RCTS tests on glacial till using undisturbed samples, after evaluating sample disturbance and quality by reviewing of X-ray radiography and performing a one-dimensional consolidation test. The applicant performed RCTS tests on samples with an acceptable specimen quality designation, which indicates relatively undisturbed samples.

Shear Modulus Reduction and Damping Curves for Rocks

FSAR Subsection 2.5.4.7.4 refers to FSAR Subsection 2.5.2.5 for a discussion of the shear modulus reduction and damping curves for bedrock.

Shear Modulus Reduction and Damping for Soils

FSAR Subsection 2.5.4.7.5 explains the shear modulus reduction and damping on soils even though Fermi 3 does not have a Seismic Category I structure founded on soil. The applicant performed RCTS testing for the glacial till to provide measured shear modulus reduction and damping data. FSAR Figure 2.5.4-226 provides the glacial till shear modulus reduction and damping data.

Shear Modulus Reduction and Damping Curves for Granular Backfill and Fill Concrete

FSAR Subsection 2.5.4.7.6 states that engineered granular backfill is not used to support any Seismic Category I structures. The applicant will use engineered granular backfill to surround the embedded walls of structures or to backfill beneath other structures with foundation levels above bedrock, except Seismic Category II structures, which will be founded on fill concrete. FSAR Subsection 3.7.1.1.4.1.1 discusses related information for fill concrete and engineered granular backfill.

Ground Motion and Response Spectra

FSAR Subsection 2.5.4.7.7 refers to FSAR Subsection 2.5.2.6 and Section 3.7.1 for a discussion of the GMRS and FIRS, respectively. The applicant's calculations of the GMRS and FIRS are based on the seismic velocity profiles in FSAR Figures 2.5.4-220 through 2.5.4-225.

2.5.4.2.8 Liquefaction Potential

FSAR Subsection 2.5.4.8 states that the bedrock and concrete fill are not susceptible to liquefaction. The applicant did not consider the upper 4 m (13.1 ft) of the engineered granular backfill for a liquefaction potential, because the maximum historical groundwater level is approximately 4 m (13.1 ft) below the plant grade. The applicant conducted a liquefaction analysis based on a standard penetration test (SPT) that considered the engineered granular backfill. The applicant estimated N_{60} to be 30 blows per foot (bpf) at the ground surface that increased linearly to 60 bpf at a depth of 19.8 m (65 ft). The applicant used this distribution and a groundwater level at 0.61 m (2 ft) below the finished ground level grade to conclude that at all engineered granular backfill depths, N_{60} was greater than 30 bpf for the full depth of the deepest Seismic Category I structures. Therefore, the granular backfill adjacent to all Seismic Category I structures is not susceptible to liquefaction. The applicant stated that liquefaction analyses were not necessary for the existing fill, lacustrine deposits, and glacial till because they will be removed from under and adjacent to all Seismic Category I structures. The applicant stated that because the backfill below Seismic Category II structures from the base of the foundation to the top of bedrock is fill concrete, a liquefaction analysis for soil below Seismic Category II structures is not necessary. The applicant will use glacial till and/or engineered backfill as the foundation support under non-Seismic Category I and II structures that cannot strike a Seismic Category I structure in case of a seismic event. The applicant stated that glacial till is not susceptible to liquefaction because it is classified as lean clay with fine contents greater than 30 percent.

2.5.4.2.9 Earthquake Design Basis

FSAR Subsection 2.5.4.9 states that the top generic bedrock is 129 m (425 ft) below the existing ground surface where the V_s of the bedrock in Salina Group Unit B is greater than 2.8 km/s (9,200 fps). The applicant performed a site response analysis to develop the GMRS, and FSAR Subsection 2.5.2.6 describes the development of the GMRS.

2.5.4.2.10 Static Stability

FSAR Subsection 2.5.4.10 evaluates the static stability of safety-related structures. The applicant conducted analyses of the foundation-bearing capacity, settlement, excavation rebound, lateral earth pressures, and hydrostatic pressures.

Bearing Capacity

In FSAR Subsection 2.5.4.10.1, the applicant conducted a bearing capacity analysis for the Bass Islands Group and Salina Group Unit F. The two independent methods the applicant used to evaluate the bearing capacity are (1) ultimate bearing capacity using Terzaghi's approach in the UASCE EM 1110-2908 (USACE 1994); and (2) an allowable bearing pressure using the Uniform Building Code (Peck, Hanson, and Thornburn 1974). The applicant used Terzaghi's approach to compute the ultimate bearing capacity for the FWSC:

$$q_{ult} = cN_c + 0.5\gamma' B N_\gamma + \gamma' D N_q \qquad \text{(Equation 1)}$$

Where:

q_{ult} = the ultimate bearing capacity
γ' = effective unit weight
B = width of the foundation
D = depth of foundation below the ground surface
C = cohesion intercept for the bedrock mass

N_c, N_γ, and N_q are the bearing capacity factors dependent on the internal angle of friction, which the applicant assumed to be 52 degrees for the Bass Islands Group and 28 degrees for the Salina Group. For the ultimate bearing capacity of the RB/FB and the CB, the applicant indicated that because the bedrock contained fractures, cohesion was not relied upon to provide a resistance to failure. Thus, the applicant used Terzaghi's equation excluding the first term (cN_c) in Equation 1 above. The applicant used the Uniform Building Code as a second method to calculate the allowable bearing pressure on rock as 20 percent of q_u. In FSAR Table 2.5.4-227, the applicant reported 13,450 kPa (281 ksf) as the ultimate bearing capacity for the RB/FB using Terzaghi's approach and the allowable bearing capacity of 12,400 kPa (259 ksf) using the Uniform Building Code method. The applicant concluded that the allowable bearing capacities calculated using both methods were greater than the maximum static bearing demand required in the ESBWR DCD. The applicant also concluded that the allowable dynamic bearing demand based on Terzaghi's approach is greater than the maximum dynamic bearing demand required in the ESBWR DCD and in the site-specific SSI dynamic bearing demand. Table 2.5.4-3 of this SER provides a comparison of the results for both methods to those listed in the ESBWR DCD.

Table 2.5.4-3 Results of Bearing Capacity Analysis
(Reproduced from Fermi COL FSAR Table 2.5.4-227)

Structure	Terzaghi Approach			Uniform Building Code	Required Maximum Static and Dynamic Bearing Demand from DCD	
	Bearing Capacity					
	Ultimate	Allowable Under Static Loading	Allowable Under Dynamic Loading	Allowable Loading Condition	Static Loading Condition	Dynamic Loading Condition
Reactor Building/Fuel Building	13,450 (281)	4,500 (94)	5,985 (125)	12,400 (259)	699 (14.6)	1,101 (23)
Control Building	42,090 (879)	14,030 (293)	18,720 (391)	17,910 (374)	292 (6.1)	421 (8.8)
Firewater Service Complex	4,596 (96)	1,530 (32)	2,060 (43)	2,060 (43)	165 (3.45)	1,201 (25.1)
*All units are kPa (ksf); Ksf = kip per square-foot; kPa = kilopascal						

Rebound due to the Excavation and Settlement Analysis

FSAR Subsection 2.5.4.10.2 states that because all Seismic Category I structures are founded on bedrock or lean concrete overlying bedrock, the applicant only considered a linear elastic deformation for the settlement analysis in which the parameter of interest is E (elastic modulus). For the settlement analysis, the applicant selected the lower bound E based on the Hoek-Brown criterion (Hoek 2007) for each bedrock unit.

Because the arrangement and loading conditions of the Seismic Category I structures were not symmetrical, the applicant conducted a finite element analysis using the PLAXIS 3D Version 2.1

foundation computer program in order to estimate the settlements of Seismic Category I structures. The first stage of the analysis was used to define the initial states of stress in the ground. The second stage simulated the rebound associated with the load removal when the excavation was performed to foundation elevations or to the top of bedrock. The remaining stages were simulated to estimate settlement after applying the loadings. The applicant stated that there is no long-term or post-construction settlement anticipated at the Fermi 3 site.

FSAR Subsection 2.5.4.2.1.2 explains the E of bedrock selected for rebound and the settlement analysis. Table 2.5.4-4 of this SER presents the settlement analysis results for excavation rebound and the total foundation settlements.

Lateral Earth Pressures

FSAR Subsection 2.5.4.10.3 describes the static and seismic lateral earth pressures applied to the site's below-ground walls. The applicant concluded that the lateral at-rest pressure applied to the RB/FB and the CB does not cause yielding in the buildings. Therefore, the applicant conducted an analysis that assumed the engineered granular backfill was resting on the RB/FB and CB walls from the finish grade to the bottom of the foundations. For this assumption, the applicant used a 35-degree angle of internal friction and a saturated and unsaturated unit weight of 21.2 and 20.4 kilonewtons per cubic-meter (kN/m^3) (135 and 130 pcf), respectively.

Table 2.5.4-4 Settlement Results for Excavation Rebound and Total Foundation Settlements

(Reproduced from Fermi COL FSAR Tables 2.5.4-230 and 2.5.4-231)

Building	**Northwest Corner**	**Southwest Corner**	**Southeast Corner**	**Northeast Corner**	**Average of Four Corners**	**Center or close to Center**
Rebound due to Excavation at Foundation Corners and Center, cm (in.)						
Reactor Building/Fuel Building	0.78 (0.31)	0.63 (0.25)	0.78 (0.31)	0.81 (0.32)	-	1.09 (0.43)
Control Building	0.84 (0.33)	0.89 (0.35)	0.74 (0.29)	0.71 (0.28)	-	0.86 (0.34)
Firewater Service Complex	0.66 (0.26)	0.66 (0.26)	0.53 (0.21)	0.53 (0.21)	-	0.61 (0.24)
Total Settlements due to Backfilling and Applied Loads, cm (in.)						
Reactor Building/Fuel Building	1.19 (0.47)	1.06 (0.42)	1.32 (0.52)	1.29 (0.51)	1.22 (0.48)	1.91 (0.75)
Control Building	1.29 (0.51)	1.42 (0.56)	1.04 (0.41)	0.99 (0.39)	1.19 (0.47)	1.19 (0.47)
Firewater Service Complex	0.41 (0.16)	0.46 (0.18)	0.30 (0.12)	0.29 (0.11)	0.35 (0.14)	0.38 (0.15)
cm= centimeter; in. = inch						

Static Lateral Earth Pressures

The applicant used the following equation to calculate the at-rest static lateral earth pressure:

$$\sigma_h = K_0 \sigma'_0 + u \qquad \text{(Equation 2)}$$

Where:

K_0 = coefficient of at-rest earth pressure = 1-sin φ
φ = angle of internal friction
u = pore water pressure
σ'_0 = effective vertical subsurface stress

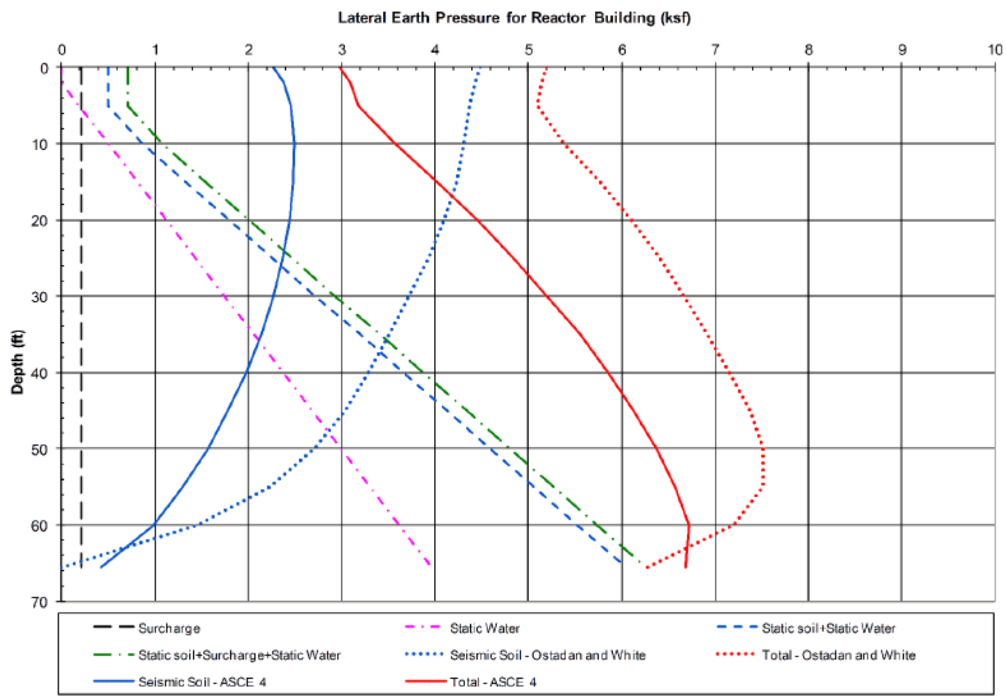
Dynamic Lateral Earth Pressures

The applicant used Ostadan and White (1988), and ASCE 4-98 methodologies to compute seismic lateral earth pressure on RB/FB and CB embedded walls. For the Ostadan and White method the applicant used a peak response horizontal ground acceleration of approximately 0.41g for both the RB/FB and CB. For the ASCE 4-98 method, the applicant used a peak ground acceleration of 0.24g at the finished ground level grade to compute seismic lateral earth pressure on RB/FB and CB embedded walls.

The applicant stated that for both methods, the engineered granular backfill is considered to extend the full depth of the RB/FB and CB; and that below the top of the Bass Islands Group bedrock the excavations will be backfilled with fill concrete. The applicant stated that once cured, the fill concrete will not apply lateral pressure to the RB/FB or CB.

Results of Lateral Earth Pressures Analyses

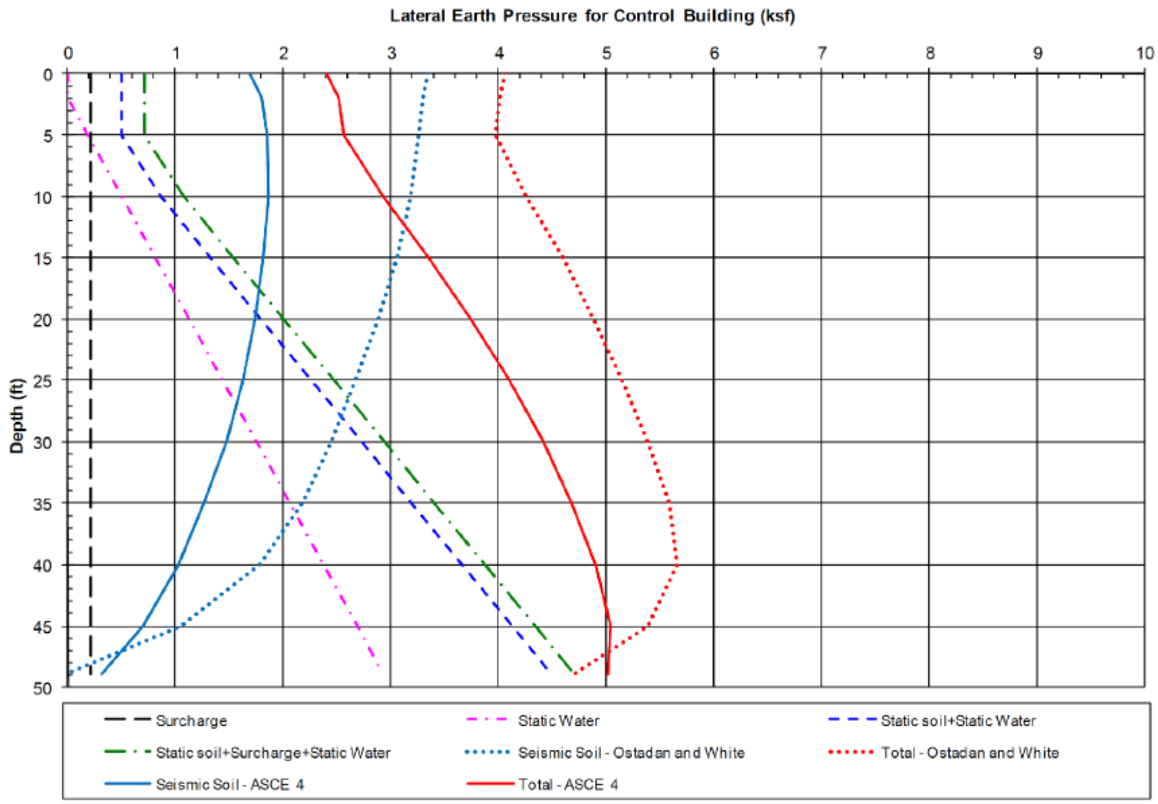
Figures 2.5.4-4 and 2.5.4-5 of this SER present the results of the static soil and seismic soil lateral earth pressures for the RB/FB and CB. The applicant stated that the results of the Ostadan and White method are generally greater than the ASCE 4-98 method, because a higher acceleration is used with the Ostadan and White method.



Notes:

1. Lateral load of 500 psf due to compaction is included in the static soil pressure.
2. Total = Static Soil + Static Water + Surcharge + Seismic Soil.

Figure 2.5.4-4 Lateral Earth Pressures on Reactor Building Walls
(Reproduced from Fermi 3 COL FSAR Figure 2.5.4-229)



Notes:

1. Lateral load of 500 psf due to compaction is included in the static soil pressure.
2. Total = Static Soil + Static Water + Surcharge + Seismic Soil.

SER Figure 2.5.4-5 Lateral Earth Pressures on Control Building Walls
(Reproduced from Fermi 3 COL FSAR Figure 2.5.4-230**)**

2.5.4.2.11 Design Criteria

FSAR Subsection 2.5.4.11 refers to ESBWR DCD Table 2.0-1 for a description of standard site parameters such as the allowable static and dynamic bearing capacities, liquefaction potential, angle of internal friction, maximum settlement values, and V_s. FSAR Subsection 2.5.4.10.1 addresses the criteria for minimum static and dynamic bearing capacities. The applicant concluded that the factor of safety (FS) for the static bearing capacity is at least 3, and it is at least 2.25 for the dynamic bearing capacity. FSAR Subsection 2.5.4.7.2 presents the minimum V_s of greater than 300 m/s (1,000 fps) for the supporting foundation material associated with seismic strains for lower bound soil properties at minus one sigma from the mean. The applicant indicated that the fill concrete surrounding the RB/FB and the CB embedded walls below the top of the bedrock and below the FSWC meets the DCD V_s requirements. The applicant stated that based on the SSI analysis, the DCD minimum V_s requirements are not required for the backfill above the top of the Bass Island Group bedrock surrounding Seismic Category I embedded walls. The applicant will place fill concrete as the supporting material below the FWSC, with deep shear keys extending into the fill concrete. The applicant's calculations neglected the engineered granular backfill surrounding the basemat and encountered no sliding issues for the FWSC. The applicant concluded that the DCD criteria for the engineered granular backfill surrounding the FWSC are not required.

FSAR Subsection 2.5.4.10 presents the design criteria for the static stability analyses. FSAR Subsection 2.5.4.8 discusses the liquefaction potential of soils. The applicant concluded that there are no liquefiable soils under and adjacent to all Seismic Category I structures. FSAR Subsection 2.5.4.10.2 discusses the design criteria for the foundation settlements. The applicant concluded that the calculated foundation settlements were less than the maximum specified in the ESBWR DCD.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

Based on the stability analysis in FSAR Subsection 2.5.4.10, the applicant concluded that no subsurface improvement is needed. In FSAR Subsection 2.5.4.12, the applicant stated that the exposed foundation bedrock in the RB/FB and the CB will be examined by a qualified geologist to ensure that no excessive natural fracturing or blasting back-break exists and areas with open fractures will be filled with concrete backfill. The applicant will remove and replace all of the soils from below the foundation to the top of the bedrock with fill concrete for the FWSC and the Seismic Category II structures.

2.5.4.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the stability of subsurface materials and foundations, and the associated acceptance criteria, are in Section 2.5.4 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 50, Appendix A, GDC 2, "Design bases for protection against natural phenomena," relates to a consideration of the most severe natural phenomena historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time when the historical data were accumulated.

- 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," applies to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

- 10 CFR 100.23 provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and to identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from Section 2.5.4 of NUREG–0800 are as follows:

- Geologic Features: To meet the requirements of 10 CFR Parts 50 and 100, the section defining geologic features is acceptable if the discussions, maps, and profiles of the site stratigraphy, lithology, structural geology, geologic history, and engineering geology are complete and are supported by site investigations sufficiently detailed to obtain an unambiguous representation of the geology.

- Properties of Subsurface Materials: To meet the requirements of 10 CFR Parts 50 and 100, the description of properties of underlying materials is considered acceptable if state-of-the-art methods are used to determine the static and dynamic engineering properties of all foundation soils and rocks in the site area.

- Foundation Interfaces: To meet the requirements of 10 CFR Parts 50 and 100, the discussion of the relationship of foundations and underlying materials is acceptable if it includes (1) a plot plan or plans showing the locations of all site explorations such as borings, trenches, seismic lines, piezometers, geologic profiles, and excavations with the locations of the safety-related facilities superimposed thereon; (2) profiles illustrating the detailed relationship of the foundations of all Seismic Category I and other safety-related facilities to the subsurface materials; (3) logs of core borings and test pits; and (4) logs and maps of exploratory trenches in the COL application.

- Geophysical Surveys: To meet the requirements of 10 CFR 100.23, the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical investigations are performed at the site and are presented in detail.

- Excavation and Backfill: To meet the requirements of 10 CFR Part 50, the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable if (1) they identify the sources and quantities of backfill and borrow and show that they were adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static) and the data are included, interpreted, and summarized; (2) they clearly show the extent (horizontally and vertically) of all Category I excavations, fills, and slopes on plot plans and profiles; (3) they justify compaction specifications and embankment and foundation designs by field and laboratory tests and analyses to ensure stability and reliable performance; (4) they incorporate the impact of compaction methods into the structural design of the plant facilities; (5) they discuss the quality control methods and describe and reference the quality assurance program; and (6) they describe and reference the control of groundwater during excavation to preclude the degradation of foundation materials and properties.

- Groundwater Conditions: To meet the requirements of 10 CFR Parts 50 and 100, the analysis of groundwater conditions is acceptable if the information in this subsection or cross-referenced to the appropriate subsections in SRP Section 2.4 of the SAR includes (1) a discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant; (2) plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures; (3) an analysis and interpretation of seepage and potential piping conditions during construction; (4) records of field and laboratory permeability tests as well as dewatering-induced settlements; and (5) a history of groundwater fluctuations determined by the periodic monitoring of 16 local wells and piezometers.

- Response of Soil and Rock to Dynamic Loading: To meet the requirements of 10 CFR Parts 50 and 100, descriptions of the soil and rock responses to dynamic loading are acceptable if (1) an investigation is conducted and discussed to determine the effects of prior earthquakes on soils and rocks in the vicinity of the site; (2) there are field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) and the data are presented and interpreted to develop bounding P and S wave-velocity profiles; (3) dynamic tests are performed in the laboratory on undisturbed samples of the foundation soils and rocks and they are sufficient to develop strain-dependent modulus reductions and hysteretic damping properties of the soils and the results are included.

- Liquefaction Potential: To meet the requirements of 10 CFR Parts 50 and 100, the foundation materials at the site adjacent to and under Category I structures and facilities are saturated soils; the water table is above the bedrock; and a required analysis of the liquefaction potential at the site is conducted.

- Static Stability: To meet the requirements of 10 CFR Parts 50 and 100, the discussions of static analyses are acceptable if the stability of all safety-related facilities were analyzed from a static stability standpoint that included bearing capacity; rebound; settlement; differential settlements under dead loads of fills and plant facilities; and lateral loading conditions.

- Design Criteria: To meet the requirements of 10 CFR Part 50, the discussion of the criteria and the design methods is acceptable if the discussion describes the criteria used for the design; the design methods; and the factors of safety obtained in the design analyses and presents a list of references.

- Techniques to Improve Subsurface Conditions: To meet the requirements of 10 CFR Part 50, the discussion of techniques to improve subsurface conditions is acceptable if it describes plans; summaries of specifications; and methods of quality control for all techniques used to improve foundation conditions (such as grouting, vibroflotation, dental work, rock bolting, or anchors).

In addition, geologic characteristics should be consistent with the appropriate sections in RG 1.27 Revision 2, "Ultimate Heat Sink for Nuclear Power Plants"; RG 1.28, Revision 3, "Quality Assurance Program Requirements (Design and Construction)"; RG 1.132; RG 1.138; RG 1.198; and RG 1.206.

2.5.4.4 *Technical Evaluation*

NRC staff reviewed Section 2.5.4 of the Fermi 3 COL FSAR related to the stability of subsurface materials and foundations. The staff reviewed Fermi 3 COL FSAR Section 2.5.4 to determine whether the applicant has complied with the applicable regulations and has conducted its investigations at an appropriate level of detail, in accordance with RG 1.132 as described below:

COL Item

- EF3 COL 2.0-29-A Stability of Subsurface Materials and Foundations

NRC staff reviewed COL Item EF3 COL 2.0-29-A included in Fermi 3 FSAR Section 2.5.4. This COL item addresses site-specific information that includes (1) localized liquefaction potential under other than Seismic Category I structures, and (2) settlement and differential settlements at the site. The NRC staff's evaluation of COL Item EF3 COL 2.0-29-A is presented below.

2.5.4.4.1 Geologic Features

FSAR Subsection 2.5.4.1 refers to FSAR Section 2.5.1 for a complete description of the regional and site geology. Subsection 2.5.1.4 of this SER presents the staff's evaluation of the regional and site geology.

2.5.4.4.2 Properties of Subsurface Material

FSAR Subsection 2.5.4.2 describes the static and dynamic engineering properties of the soil and rock strata underlying the Fermi 3 site, as well as the methods the applicant used to determine the site engineering properties including field investigations and laboratory testing. The staff conducted a geology/seismology/geotechnical site audit from November 3, 2009, to November 5, 2009 (ADAMS Accession No. ML14112A212). During the audit, the geotechnical staff looked at core samples that included the units of the Bass Islands Group, Salina Group Unit F, and Salinas Group Unit E, as well as oolitic dolomite samples to confirm the FSAR's descriptions. The staff specifically checked full core samples from RB-C8 and some core samples from TB-C5, RB-C4, and CB-C2. The staff also discussed specific details on shear wave velocity determinations, settlement calculations, slope stability analyses, lean concrete backfill, and the process for excavation to reach the Bass Islands foundation layer. The staff reviewed sample calculations of complete settlement and earth pressure against embedded walls (static and dynamic) and the engineering properties used to perform settlement analysis and dynamic and static earth pressure analysis. The staff also reviewed shear wave velocity data from downhole and SASW investigations.

During these reviews, the staff issued several RAIs addressing specific technical issues related to the Fermi 3 site investigations. The staff's evaluations of the applicant's responses to these RAIs are discussed below. The staff also prepared a number of editorial RAIs and clarification RAIs that the staff does not discuss in the technical evaluation. Because of the applicant's FSAR revisions several RAIs are no longer applicable and are not discussed in further detail in this technical evaluation.

Engineering Properties of Subsurface Materials

FSAR Subsection 2.5.4.2.1 discusses the engineering properties of soils and rocks at the Fermi 3 site based on 68 borings that the applicant performed. FSAR Figures 2.5.1-235 and 2.5.1-236 show the locations of the borings drilled for the COL application. The boring logs are in FSAR Appendix 2.5DD. The applicant stated that fill, lacustrine deposits, and glacial till comprise the site overburden deposits, all of which the applicant will fully excavate beneath and adjacent to all Seismic Category I structures. If needed, the applicant can process the fill material to produce gradation suitable for use as engineered granular backfill surrounding Seismic Category I structures.

Engineering Properties of Soils

The staff reviewed FSAR Subsection 2.5.4.2.1.1 related to the engineering properties of soils at the Fermi 3 site. The staff issued RAIs 02.05.04-1, 02.05.04-14a, 02.05.04-17, and 02.05.04-28b related to the general gradation constraints needed for processing the fill that the applicant may reuse for engineered granular backfill. These RAIs also address the expected static and dynamic properties of the as-specified compacted borrow material including compaction ratio, density, shear strength, and V_s. The staff asked the applicant to justify whether the static and dynamic properties of the processed fill would affect the results of the safety analysis in FSAR Section 2.5.4.

In the responses to RAIs 02.05.04-1, 02.05.04-14a, and 02.05.04-17 dated January 11, 2010 (ADAMS Accession No. ML100130382); and RAI 02.05.04-28b dated February 15, 2010 (ML100540502); the applicant stated that it will follow the DCD requirements to perform tests to verify the gravel backfill and will establish gradation constraints for the backfill. The applicant indicated that the rebound, settlement, and bearing capacity results in FSAR Subsection 2.5.4.10 are not affected by the engineered granular backfill material properties because the Fermi 3 Seismic Category I structures will be directly founded on the Bass Islands Group or on the fill concrete overlying the Bass Islands Group. The applicant stated that the change in the angle of internal friction for the engineered granular backfill affects the at-rest static lateral earth pressure. Also, the applicant mentioned that the change in the V_s affects the soil column frequency and the resulting horizontal ground acceleration. The applicant stated in revised FSAR Subsection 2.5.4.10.3.2 that the peak response horizontal ground acceleration based on the FIRS for the RB/FB and the CB is approximately 0.58 g based on revised FSAR Figure 3.7.1-228 and Figure 3.7.1-229. The applicant further stated that acceleration of 0.41g was used with the Ostadan and White method for the seismic lateral earth pressure calculation by considering a correction factor of 0.7. The applicant also used the ASCE 4 method with the peak ground acceleration of 0.2368 g at the finished ground level grade, from FSAR Table 3.7.1-205, to compute seismic lateral earth pressure on RB/FB and CB embedded walls.

The staff reviewed the responses to RAIs 02.05.04-1, 02.05.04-14a, 02.05.04-17, 02.05.04-28b, and the revised FSAR Subsections 2.5.4.10.3.2 and 3.7.1.1.4.4. The staff noted that the applicant plans to crush the excavated fill and bedrock to a well-graded, angular/sub-angular gravel backfill that will meet the requirements specified in ESBWR DCD Table 2.0-1. The staff also noted that within confined areas or close to the foundation walls, the applicant plans to use smaller compactors to prevent excessive lateral pressures against the walls due to the stress caused by heavy compactors.

As for using the Ostadan and White (1988) method to compute seismic lateral earth pressure, the staff acknowledged that the acceleration response spectrum at the basemat level in the free-field at 30 percent damping needs to be developed for applying this method. The staff reviewed the site-specific horizontal FIRS of RB/FB and CB shown on FSAR Figure 3.7.1-228 and Figure 3.7.1-229, and noted that the acceleration response spectra are associated with 5 percent damping. The staff also noted, from the spectra, that the peak spectral accelerations of approximately 0.58 g of for RB/FB and CB are between frequencies of 20 Hz to 30 Hz. The staff further noted that SRP Section 3.7.2 limits the composite modal damping to a maximum of 20 percent. The staff reviewed the applicant's cited reference ("Damping Correction Factors for Horizontal Ground-Motion Response Spectra," by Cameron, W.I. and Green, R.G, [2007]). Based on this review, the staff agrees that damping correction factors (DCFs), as a function of general site classification, earthquake magnitude, and tectonic setting, can be reasonably applied to adjust response spectral values corresponding to damping 5 percent of critical to other damping levels. The staff confirmed that a DCF of 0.7, as suggested by the applicant, is in accordance with the recommendation from cited reference for a ratio of 20 to 5 percent damping. Because of the SRP Section 3.7.2 limitation in which the damping is to a maximum of 20 percent, the staff concluded that a DCF of 0.7 developed from a 20 percent damping will lead to a conservative computation on seismic lateral earth pressure against a DCF developed by a 30 percent damping. Therefore, the staff agrees that it is appropriate to use a peak response horizontal ground acceleration of approximately 0.41g for the Ostadan and White method to compute seismic lateral earth pressure on RB/FB and CB embedded walls.

As a result of the RAIs, the applicant revised the seismic lateral earth pressure calculation by selecting the peak horizontal ground acceleration of 0.58 g based on the site-specific FIRS, and a DCF of 0.7, to adjust the acceleration corresponding to 5 percent damping to 20 percent level in order to simulate the maximum seismic pressures that can develop at the Fermi 3 site. The staff confirmed that this adjustment leads to reasonable and conservative estimates of seismic lateral soil pressures, and Fermi 3 FSAR reflects the adjustment. In addition, the staff verified the applicant's seismic lateral earth pressure calculations. The staff concluded that the applicant's method and procedures used for the calculations are appropriate, because they are based on the current knowledge of computing dynamic lateral soil pressures. Finally, the staff compared the static and seismic lateral soil pressures that the applicant computed to the results in Appendix 3G to Chapter 3 of the ESBWR DCD, Tier 2. The staff concurred that both the static and seismic evaluations of soil pressures are less than the lateral earth pressures required in the ESBWR DCD. The applicant demonstrated that it can achieve the DCD requirements related to backfill and static and seismic lateral pressures by using the appropriate engineered granular backfill. RAIs 02.05.04-1, 02.05.04-14a, 02.05.04-17, and 02.05.04-28b are therefore, resolved and closed.

Engineering Properties of Bedrock

FSAR Subsection 2.5.4.2.1.2 describes the two primary bedrock units beneath the Fermi 3 site: the Bass Islands Group and Salina Group Units F, E, C, and B. The applicant characterized the parameter values in terms of upper and lower bound values or minimum, maximum, standard deviation, mean, and median values. These parameters are specified in terms of a single number associated with the entire bedrock unit or for each borehole. In RAI 02.05.04-3a, the staff asked the applicant to explain why it is appropriate to provide a single value of each parameter for the entire bedrock group instead of providing an inferred spatial variation of these parameter values.

In the response to RAI 02.05.04-3a dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant stated that FSAR Figures 2.5.4-220 through 2.5.4-223 show that the V_s and V_p are relatively uniform within each bedrock unit. The staff reviewed the response to RAI 02.05.04-3a and FSAR Figures 2.5.4-220 through 2.5.4-223. The staff compared the measured V_s and V_p from P-S suspension logging and downhole seismic tests at different locations across the site. The staff noted that the relatively consistent V_s and V_p indicate the uniformity of each bedrock unit across the site. Based on this consistency, the staff concurred with the applicant's conclusion that it is appropriate to use a single value of each parameter for the entire bedrock group. Therefore, RAI 02.05.04-3a is resolved and closed.

The applicant estimated the strength and deformation characteristics of the bedrock units using the Hoek-Brown criterion (Hoek 2007). The applicant converted the Hoek-Brown criterion into the equivalent Mohr-Coulomb values. In RAI 02.05.04-3b, the staff asked the applicant to justify the use of the Hoek-Brown criterion and to describe each bedrock unit as applied to specify the Hoek-Brown parameters. The staff also asked the applicant to specify the relationship between the residual friction angle values associated with discontinuities in the Bass Islands Group and the parameters in the Hoek-Brown criterion for that material. In addition, the staff asked the applicant to explain how the effects of oolitic dolomite are reflected in the Hoek-Brown criterion for the Bass Islands Group. In RAI 02.05.04-3c, the staff asked the applicant to provide the effective confining pressure ranges and the rationale for the selected effective confining pressure range used to convert the Hoek-Brown criterion to the Mohr-Coulomb values.

In the response to RAI 02.05.04-3b dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant indicated that the Hoek-Brown criterion is based on an assessment of interlocking rock blocks and on the conditions of the surfaces between these blocks. The applicant mentioned that the shear strength along the discontinuities is not one of the input parameters used in the Hoek-Brown criterion methodology. The applicant presented the compressive strength and the elastic modulus of the oolitic dolomite and stated that these parameters are comparable with the average strength and elastic modulus of the remainder of the Bass Islands Group. The response to RAI 02.05.04-3c (ADAMS Accession No. ML100040548) included a table with the effective confining pressure ranges used to convert the Hoek-Brown criterion to the Mohr-Coulomb parameters. The applicant discussed the rationale for determining the upper limit of the confining stress (σ'_{3max}) for slopes with the selected range of effective confining pressures that adhered to the guidelines of the Hoek-Brown criterion.

The staff noted that the applicant's response to RAI 02.05.04-3 applies an equation of σ'_{3max}, and an equation developed for slopes to the evaluation of foundation behavior beneath key structures. In RAI 02.05.04-30, the staff asked the applicant to explain why the use of the σ'_{3max} equation provides an adequate representation of the Hoek-Brown criterion for evaluating the foundation behavior beneath key structures. The applicant's response to RAI 02.05.04-30 dated August 6, 2010 (ADAMS Accession No. ML102210351), is based on Hoek's (2007) two options for establishing $\sigma'_{3\text{max}}$ that are a slope condition or a tunnel condition. The applicant stated that foundation of the Category I structures will be on exposed bedrock at the bottom of the excavation, thus providing a similar stress regime in the bedrock to that of the slopes exposed at the ground surface rather than a tunnel bored through the bedrock.

The staff reviewed the responses to RAIs 02.05.04-3b, 02.05.04-3c, and 02.05.04-30 and the related sections of Hoek (2007). The staff verified that the applicant has provided the appropriate information related to the Hoek-Brown criterion input parameters that were used to estimate rock mass strength for each bedrock unit. The staff verified that the applicant has based the input parameters for q_u and E on laboratory tests in accordance with ASTM D7012-07, "Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperature." The applicant obtained the input parameters of material index (m_i) and the geological strength index (GSI) based on bedrock descriptions and classifications from exploratory borings. The applicant conservatively selected the input parameter of the disturbance factor (D) based on the degree of disturbance from blast damage and stress relaxation. The staff determined that the applicant has appropriately selected these input parameters based on the laboratory tests and appropriate interpretations of the Hoek-Brown criterion.

As for the effects of oolitic dolomite reflected in the Hoek-Brown criterion for the Bass Islands Group, the staff noted that the compressive strength from the oolitic dolomite samples varies from 71 to 99 MPa (1,490 to 2,070 ksf), with an average of 82 MPa (1,707 ksf), and that the elastic modulus varies from 38,600 to 51,000 MPa (806,400 to 1,065,600 ksf) with an average of 46,660 MPa (974,400 ksf). Because the test results from the oolitic dolomite samples are analogous to the overall average compressive strength of 79 MPa (1,650 ksf) and to the overall elastic modulus of 40,330 MPa (842,400 ksf) for the Bass Islands Group, the staff found that the compressive strength and elastic modulus for the oolitic dolomite are integrated into the overall strength and modulus for the Bass Islands Group. The staff also noted that the physical descriptions of the oolitic dolomite are similar to the descriptions of the dolomite within the Bass Islands Group, as shown in the Fermi 3 boring logs. Based on the above discussion, the staff concluded that the effects of the oolitic dolomite were appropriately considered in the Hoek-Brown criterion for the Bass Islands Group.

Furthermore, the staff noted that because the geotechnical bearing capacity is calculated in terms of the Mohr-Coulomb failure criterion, it is necessary to determine equivalent angles of friction and cohesive strengths for each rock mass and stress range by fitting an average linear relationship to the curve generated by the Hoek-Brown criterion. The staff concluded that it is appropriate to follow the guidelines specified in Hoek (2007) to estimate the tensile strength of the rock mass σ_t and the upper limit of the confining stress σ'_{3max}. In addition, the staff agreed with the applicant's determination that using σ'_{3max} based on the equation developed for slopes is appropriate, because the Category I structures are founded on exposed bedrock at the bottom of the excavation. Therefore, the stress in the bedrock is similar to that of slopes exposed at the ground surface rather than a tunnel bored through the bedrock. Based on the evaluation of the applicant's responses RAIs 02.05.04-3b, 02.05.04-3c, and 02.05.04-30 are therefore, resolved and closed.

In FSAR Subsection 2.5.4.2.1.2.1, the applicant conducted 12 rock direct shear tests along sample discontinuities in the Bass Islands Group to obtain the residual friction angle along the discontinuities. The applicant's test resulted in a friction angle that ranges from 33 to 74 degrees, with a mean of 52 degrees. In RAI 02.05.04-2, the staff asked the applicant to provide information on the prevalence of these discontinuities, and whether they involve any preferential directions. In addition, the staff asked the applicant to explain the extent to which these discontinuities, which are provided by the twelve rock direct shear tests, are representative of discontinuities observed within the Bass Islands Group.

In the response to RAI 02.05.04-2 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant provided figures that show the 12 pairs of photos of the core/discontinuity before laboratory testing along with the OTV log corresponding to the sample log. The applicant indicated that the observed orientations of discontinuities in the Bass Islands Group vary from horizontal to vertical, with near horizontal and near vertical joints dominating. However, the applicant further stated that the orientation of the discontinuities tested was nearly horizontal, except for the orientation of samples CB-C4 at 17.3 m (57.0 ft) and RB-C3 at 14.3 m (46.9 ft), which were at inclined angles. Finally, the applicant concluded that the results for the discontinuities tested were representative of the discontinuities observed within the Bass Islands Group. In RAI 02.05.04-29, the staff asked the applicant to justify why the test results from mostly horizontal discontinuities (one dominant orientation) can be representative of vertical discontinuities (another dominant orientation) and to provide the basis for this conclusion. In the response to RAI 02.05.04-29 dated August 6, 2010 (ADAMS Accession No. ML102210351), the applicant explained that because of the higher potential for weaker material and the lower roughness of the horizontal fractures, the strength along the horizontal fractures will be lower. In addition, the applicant stated that the friction angle measured on core samples is in agreement with the friction angle estimated for the bedrock mass using the Hoek-Brown criterion. The applicant concluded that this agreement with the friction angle indicates that, for the bedrock mass, the testing was representative of fractures at all orientations.

The staff reviewed the responses to RAIs 02.05.04-2 and 02.05.04-29, as well as related figures and references. The staff noted that the Bass Islands Group dolomite is an undeformed sedimentary bedrock at the site. Therefore, horizontal to near horizontal fractures formed along depositional features in sedimentary bedrock are more likely than vertical fractures are to be present. Based on the fact that most direct shear tested samples had horizontal or near horizontal fractures, the staff concluded that the results of the applicant's tests represent strength values for the horizontal fractures. The staff also noted that horizontal fractures along depositional features tend to have a more consistent orientation and less roughness, while vertical fractures break across depositional features that which most likely result in a rougher fracture surface. The staff further concluded that the rougher surfaces or irregularities produce interlocks between discontinuity surfaces, which can contribute significantly to their shear strength (Patton 1966, Barton 1973). Therefore, the staff concluded that it is reasonable to deem that the test results from samples with horizontal or near horizontal fractures are representative of the lower bound strength for the vertical fractures, because the waviness and roughness on a natural joint surface increase the shear strength. The staff further concluded that the shear strength from mostly horizontal discontinuities can be conservatively representative of vertical discontinuities. Therefore, RAI 02.05.04-2 and RAI 02.05.04-29 are resolved and closed.

In FSAR Subsections 2.5.4.2.1.2.1 and 2.5.4.2.1.2.2, the applicant indicated that the RQD of the Bass Island Group and Salina Group Unit F are low with average RQD values of 54 percent and 13 percent, respectively, indicating that in situ rock masses in these layers are highly fractured. Furthermore, in these FSAR subsections, the applicant calculated Poisson's ratios based on the mean V_p and V_s varying from 0.33 to 0.34 for the Bass Islands Group and from 0.39 to 0.40 for Salina Group Unit F. Consequently, in RAI 02.05.04-41, the staff asked the applicant to justify whether these ranges of Poisson's ratio are appropriate for such highly fractured rocks.

In the response to RAI 02.05.04-41 dated March 29, 2012 (ML12093A004), the applicant discussed the approach of the Poisson's ratio calculation for the in situ shear and compression wave velocities. The applicant compared the calculated Poisson's ratios with similar materials from literature sources, demonstrating the calculated Poisson's ratios are in the range of values provided in literature sources for both the Bass Islands Group bedrock and the Salina Group Unit F bedrock. The applicant also performed a literature search to evaluate whether the fracturing of bedrock typically results in an increase or decrease in Poisson's ratio, indicating the lack of a direct relationship between the extent of bedrock fracturing and Poisson's ratio. The applicant concluded that the Poisson's ratios calculated on the basis of measured shear and compression wave velocities are considered the most appropriate for the Fermi 3 site.

The staff reviewed the responses to RAI 02.05.04-41 and the applicant's cited references. The applicant referred to Jaeger, J.C. and Cook, N. G. W., "Fundamentals of Rock Mechanics" (1979) to indicate that bedrock fracturing can either increase or decrease Poisson's ratio based on orientation and aperture of the fracturing. Because the in situ measurements of shear and compression wave velocities represent the more general condition of rock mass, the staff concluded that the Poisson's ratios calculated using the in situ measured shear and compression wave velocities are considered appropriate for the Bass Islands Group and Salina Group Unit F bedrock. Therefore, RAI 02.05.04-41 is resolved and closed.

<u>NRC Staff's Conclusions Regarding the Engineering Properties of Subsurface Materials</u>

Based on the staff's review of the information in FSAR Subsection 2.5.4.2.1 and the applicant's responses to RAIs associated with the engineering properties of subsurface materials discussed above, the staff concludes that the applicant has adequately characterized the static and dynamic engineering properties of the rock layers underlying the Fermi 3 site by appropriately following the guidance in RG 1.132, Revision 2, for satisfying the applicable requirements in 10 CFR Parts 50 and 100. These layers include the Bass Islands Group and Salina Group Units F, E, C and B, which are the foundation-bearing layers for the nuclear island.

<u>Field Investigations</u>

The applicant employed a hydrogeological phase investigation and a geotechnical phase investigation to complete the field analyses. The hydrogeological investigation consisted of piezometers and monitoring wells installation, packer and slug testing, downhole geophysics, and sampling and groundwater testing. The applicant performed OTV logging to gather information on the bedrock where the rock core was not recovered. The applicant used the results from the downhole logging to correlate the bedrock geology across the site.

Hydrogeological Investigation Program

The staff reviewed FSAR Subsection 2.5.4.2.2.1 related to the hydrogeological investigation program at the Fermi 3 site. In RAI 02.05.04-4, the staff asked the applicant to clarify whether the results of the downhole logging provided additional information as to where the applicant did not obtain good core recovery.

In the response to RAI 02.05.04-4 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant summarized how the results from the downhole logging were used to provide additional information in regions where there was not good core recovery. The applicant observed a poor recovery in some intervals of the Bass Islands Group, throughout most of the Salina Group Unit F, and in some intervals of the Salina Group Unit E. FSAR Figures 2.5.4-209 through 2.5.4-212 indicates that the poor RQD in the Bass Islands Group was from the fractured nature of the bedrock unit. The applicant also referenced these figures to point out a good correlation between the geologic feature and the variability of the measured compression and shear wave velocities. The applicant used the results of the OTV, the natural gamma, and the caliper logging to provide information regarding core loss; voids; cavities and tool drops that occurred in the Bass Islands Group and Salina Group Units F and E. The applicant also used the downhole logging to identify sediments in Salina Group Units E and F. The applicant confirmed the existence of joints and fractured zones using results from the OTV logging. Finally, the applicant indicated a correlation between the variability of the V_p and V_s with the natural gamma value in the selected borings within the Salina Group Unit F.

The staff reviewed the response to RAI 02.05.04-4. The staff also reviewed the OTV images shown on FSAR Figures 2.5.4-209 through 2.5.4-212, and the results from the OTV, natural gamma and caliper logging described in FSAR Section 2.5.1.2.3.1. The staffed agreed that the poor RQD was from the fractured nature; core loss was due to either soft weathered rock that washed away during drilling, or when harder layers became stuck in the core barrel and ground the softer or fractured rock; and cavities or voids were limited to a depth of 23.8 m (78 ft) below ground surface. The cavities or voids encountered were narrow, generally 3 cm (0.1 ft) along fractures. Based on the applicant's additional information related to the downhole logging, the staff concludes that the results from the OTV, the natural gamma, and the 3-arm caliper provide an acceptable alternative for understanding the bedrock geology where the applicant had not obtained good core recovery. Therefore, RAI 02.05.04-4 is resolved and closed.

FSAR Subsection 2.5.4.2.2.1.7 presents a list of the chemical tests for groundwater and surface water performed to establish baseline conditions at the site, but the subsection does not include the test results or discussions. Because the foundation and/or sub-foundation concrete may be exposed to the groundwater, the staff asked the applicant in RAI 02.05.04-5 to address whether or not the chemicals in groundwater are aggressive and to provide a discussion of these results.

In the response to RAI 02.05.04-5 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant provided chemical test results for groundwater sulfate and chloride concentrations and indicated, based on ACI 349, that all sample results for sulfate concentrations from the monitoring wells fell into the categories of "moderate" and "severe" sulfate exposure for concrete. Therefore, in RAI 02.05.04-31, the staff asked the applicant to evaluate the potential aging effects on concrete fill resulting from groundwater conditions, to capture this evaluation in the FSAR, and to provide groundwater pH values because concrete is highly alkaline and strong acid degrades it. In addition, the staff requested the applicant to update the FSAR to ensure that the ACI 349 requirements will be followed—including cement type; the water-cement ratio; and the minimum compressive strength for concretes exposed to sulfate-containing solutions. In the response to RAI 02.05.04-31 dated August 6, 2010 (ADAMS Accession No. ML102210351), the applicant indicated that the pH of the groundwater was monitored during purging until the pH values stabilized, and the applicant had presented the last pH values measured during purging from the monitoring wells. The applicant concluded that the concrete will not be negatively impacted, because the overburden groundwater and the Bass Islands aquifer groundwater had a measured pH greater than 7.0, thus not acidic.

Regarding the potential aging effects, the applicant indicated that the only constituent of concern for concrete is the sulfate, and the concrete will not experience adverse aging effects from the high sulfates in the groundwater with the use of the correct cement—a well-designed concrete mix—and good construction control. The applicant stated that ACI 349 requirements for concrete exposed to solutions containing sulfate will be implemented during the detailed design phase.

The staff reviewed the responses to RAI 02.05.04-5 and RAI 02.05.04-31. The staff noted that based on the definition in ACI 349, all of the sampled results for sulfate concentrations from the monitoring wells fell into the categories of “moderate” and “severe” sulfate exposure for concrete. The staff also noted that the applicant will implement the ACI 349 requirements for concrete exposed to solutions containing sulfate by using a low water-to-cement ratio, an adequate cement content, a plasticizer or super plasticizer, a silica fume (fly ash), and an air entrainment. The staff found the applicant’s response acceptable and verified that the applicant had revised the FSAR to reflect that the fill concrete will meet the ACI 349 requirements for concrete exposed to solutions containing sulfate. Therefore, RAIs 02.05.04-5 and 02.05.04-31 are resolved and closed.

In RAI 02.05.04-40, the staff asked the applicant to provide the inspections, tests, and analyses and acceptance criteria (ITAAC) to be used to ensure that the fill concrete placed underneath any Category I structure to a thickness greater than 1.5 m (5 ft) meets the design, construction, and testing of the applicable ACI standards.

In the response to RAI 02.05.04-40 dated February 16, 2012 (ADAMS Accession No. ML12052A031), the applicant added the associated ITAAC to indicate that the mean 28-day compressive strength of the fill concrete will be equal to or greater than 31 MPa (4,500psi).

The staff reviewed the response to RAI 02.05.04-40, as well as FSAR Subsection 2.5.4.5.4.2. The staff noted that FSAR Subsection 2.5.4.5.4.2 includes compressive strength, shear wave velocity, and associated design and testing requirements for the fill concrete under any Seismic Category I structure to a thickness greater than 1.5 m (5 ft). In addition, the applicant committed to use the concrete fill with a 31 MPa (4.500 psi) compressive strength. The staff performed a confirmatory calculation based on the equations recommended by the ACI code. The staff found that the shear wave velocity for the fill concrete greatly exceeds the 300 m/s (1,000 ft/s) minimum shear wave velocity required in ESBWR DCD Revision 9 Table 2.0-1 for supporting foundation materials. The staff confirmed that the applicant had revised the Part 10 “ITAAC” of the application to include Section 2.4.1, “ITAAC for Fill Concrete under Seismic Category I Structures.” The staff concludes that the strength degradation of the fill concrete will be well managed because the applicant will follow the ACI 349 requirements to address the staff’s concern regarding concrete exposed to sulfate-containing solutions; and the applicant will follow the ACI 207.2R–07 requirements to address the staff’s concern regarding thermal cracking control of the fill concrete. Based on the evaluations of the shear wave velocity and the durability of fill concrete, the staff concludes that the proposed ITAAC for the fill concrete under Seismic Category I structures is acceptable. RAI 02.05.04-40 is therefore resolved and closed.

Geotechnical Investigation Program

The staff reviewed FSAR Subsection 2.5.4.2.2.2 related to the geotechnical investigation program at the Fermi 3 site. Regarding site exploration plans for safety-related foundations, Appendix D of RG 1.132 suggests that borings should be performed beneath every safety-related structure—at least one boring per 900 m^2 (10,000 ft^2) (approximately 30 m (100 ft) spacing) for larger and/or heavier structures—in addition to a number of borings along the periphery at the corners and at other selected locations. In FSAR Figure 2.5.1-236, the staff noted that for the Seismic Category I CB and FSWC, the applicant had not followed the recommendation to drill borings along the periphery at the corners. Therefore, in RAI 02.05.04-7 the staff asked the applicant to justify the limited number of borings and whether that number is sufficient to adequately characterize the CB and FWSC foundations.

In the response to RAI 02.05.04-7 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant indicated that the subsurface investigations for both the CB and the FWSC were considered sufficient and in conformance with the guidance of RG 1.132. The applicant indicated that the stratigraphy in the immediate area of Fermi 3 is uniform, the test results are consistent with the subsurface material properties, and the density of borings in the area of the CB and the FWSC is adequate. The applicant stated that two borings are sufficient to characterize the subsurface conditions below the CB because the total area of the CB is approximately 717 m^2 (7,722 ft^2), which is less than the 900 m^2 (10,000 ft^2) specified in RG 1.1.32. The applicant concluded that one boring is sufficient to adequately characterize the foundation of the FWSC based on the uniformity of the stratigraphy and the subsurface properties.

The staff reviewed the response to RAI 02.05.04-7 with respect to the recommendations in Appendix D of RG 1.132. The staff noted that although the FWSC is classified as a Seismic Category I structure, it is listed as a nonsafety-related structure in Table 3.2-1 of the ESBWR DCD. And though there are no corner borings within the footprints of the safety-related CB and the nonsafety-related FSWC, there are two borings beneath the CB and one boring beneath the FSWC. They are therefore within the threshold of one boring beneath every safety-related structure and one boring per 900 m^2 (10,000 ft^2) as suggested in RG 1.132. In addition, the staff noted the lateral continuity of the subsurface bedding at the site from the boring data and the consistency of the subsurface material properties from the laboratory and in situ test results. Based on the above information, the staff concluded that the existing boring grid is adequate to define the site subsurface conditions, including the subsurface beneath the CB and the FSWC. Therefore, RAI 02.05.04-7 is resolved and closed.

FSAR Subsection 2.5.4.2.2.2.5.2 discusses the results from pressuremeter testing. The applicant performed three unload/reload cycles. The applicant found it reasonable to select the unload-reload modulus E_{ur} value from the last cycle as an estimate of the in situ modulus, because the condition of the bedrock at the highest pressure level was probably closer to the in situ undisturbed bedrock than at the lower pressure levels and in the previous unload/reload cycles. Also, the applicant indicated that the material being tested was a very complex geological unit consisting of interbedded limestone/dolomite/claystone/siltstone/shale and breccias with varying degrees of induration. The staff was concerned that an applicable strain range and applied unload/reload cycle could affect the values of $E_{ur,}$ and the possible effects of the macro-features may not be present within the influence zone of the pressuremeter test. Therefore, in RAI 02.05.04-8, the staff asked the applicant to provide additional information regarding the appropriate selection of E_{ur} to represent the modulus of in situ undisturbed bedrock. In addition, the staff asked the applicant to describe the use of the results and to identify the calculations that used these pressuremeter test values.

In the response to RAI 02.05.04-8 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant compared the typical pressure-displacement behavior in Salina Group Unit F with the ideal pressure-displacement curve for a pressuremeter test. In addition, the applicant compared the ideal pressuremeter test curves with several unload-reload loops. The applicant indicated that for the ideal pressuremeter test curves, the slopes of the unload-reload of the materials that are naturally or mechanically fractured during the drilling process increase with each successive unload-reload cycle performed at higher pressures. The applicant stated that the slopes of the three unload-reload loops for Salina Unit F become progressively steeper with the increasing strain, which is an indication of a fractured material. The applicant also indicated that in the ideal pressuremeter test, for a material that was mechanically fractured during the drilling process, the slope of the unload-reload loops continues to increase as the joints are closed. The applicant encountered this same scenario in tests performed for Salina Group Unit F. The applicant concluded that the E_{ur} from the last unload-reload cycle was an appropriate representation of the modulus of in situ undisturbed bedrock for Salina Group Unit F. The applicant compared the E obtained from the pressuremeter testing with the E based on the Hoek-Brown criterion. In order to provide a bounding estimate of settlement and rebound for Seismic Category I foundations, the applicant used the E obtained from the Hoek-Brown criterion because the E from the pressuremeter testing was higher.

The staff reviewed the response to RAI 02.05.04-8 and noted that in order to keep the material in the elastic range at any stage during the pressuremeter testing, the total pressure is controlled and maintained at less than 40 percent of the maximum pressure reached. The staff acknowledged that for homogeneous materials that contain no fractures, the successive unload-reload loops that performed at different pressure levels in the elastic range will be relatively parallel. The staff further noted that for materials that are fractured during the drilling process, the slope of the unload-reload loops increases until all of the joints have closed up. Beyond this point the slope of the unload-reload loops is presumably reached, but it does not exceed the slope for homogeneous materials. Based on the above rationale, the staff agreed with the applicant that the modulus based on the slope in the final unload-reload loop in the elastic range for material naturally or mechanically fractured during the drilling process will be a conservative estimate of the in situ modulus. In addition, the staff noted that the average E, based on the pressuremeter tests in Salina Group Unit F falls within the upper and lower bound E based on the Hoek-Brown criterion, which provides cross-references for the modulus between pressuremeter tests and the Hoek-Brown criterion. Finally, because the lower bound modulus from the Hoek-Brown criterion was used, the staff concluded that the calculated settlement and rebound of Seismic Category I foundations provides conservative estimates. The staff concluded that the E_{ur} obtained from the last unload-reload cycle is an appropriate representation of the in situ modulus for the Salina Group Unit F undisturbed bedrock, and the lower bound modulus from the Hoek-Brown criterion is appropriate to use. Therefore, RAI 02.05.04-8 is resolved and closed.

<u>NRC Staff's Conclusions Regarding Field Investigations</u>

The staff reviewed FSAR Subsection 2.5.4.2.2 and the applicant's response to RAIs associated with the Fermi 3 site field investigations discussed above. The staff concludes that the applicant has appropriately followed the guidance in RG 1.132, Revision 2. The applicant conducted an adequate boring exploration program based on the location and number of borings and the number and types of tests performed, in accordance with the appropriate ASTM standards.

Laboratory Testing

The staff reviewed FSAR Subsection 2.5.4.2.3 related to the laboratory testing program performed to identify, classify, and evaluate the physical and engineering properties of the soil and the bedrock. The applicant investigated the need to perform dynamic tests on Salina Group Unit F and concluded that no dynamic testing was required because the estimated shear strain for Salina Group Unit F was approximately 0.0252 percent, and the strain level for the till induced during the design earthquake would be less than 0.3 percent. The applicant also indicated that the testable samples would have been biased toward "the more intact portions of the bedrock and hence testing under static or dynamic loading conditions would possibly give high values not representative of the overall Unit F." The staff was concerned that the potential role of "weak" zones , which are the zones experiencing low recovery, within the Salina Group Unit F might have contributed to the overall characterization and performance of this group. FSAR Figure 2.5.4-208 shows P-S suspension logging results indicating missing V_s and V_p data in a significant portion of Salina Group Unit F. Consequently, in RAI 02.05.04-9 and RAI 02.05.04-13a, the staff asked the applicant to provide information on possible alternative means of sampling Salina Group Unit F; or if sampling was not feasible, to provide a non-laboratory testing alternative to obtain data regarding the potential effects of these conditions on the characterization of Salina Group Unit F. The staff also asked the applicant to explain how the induced seismic shear strains were conservatively estimated for the Salina Group Unit F and the till in order to be consistent with the postulated earthquake shaking conditions.

In the response to RAI 02.05.04-9 dated January 11, 2010 (ADAMS Accession No. ML100130382), and the response to RAI 02.05.04-13a dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant indicated that the data in the application are sufficient to characterize Salina Group Unit F and its weaker zones. The applicant stated that because of the poor recovery in the "weaker" zones of Salina Group Unit F, the collection of undisturbed bedrock core was considered unlikely in these zones and with a minimum V_s of 549 m/s (1,800 fps), the soil samples were not considered applicable. Regarding the induced shear strain estimates, the applicant indicated that the induced seismic shear strain estimates were performed for Salina Group Unit F using an assumed peak ground acceleration of 0.25g and a minimum V_s of 549 m/s (1,800 fps), which were measured at a depth of approximately 73.2 m (240 ft). The applicant estimated a shear strain of 0.0252 percent for the Salina Group Unit F, which indicates a G/G_{max} ratio of approximately 0.91. The applicant approximated the worst case based on sand between 36.6 and 76.2 m (120 and 250 ft) that resulted in a G/G_{max} ratio larger than that estimated before, thus indicating a negligible modulus reduction of bedrock. In FSAR Figures 2.5.2-280 and 2.5.2-281 the applicant showed that within the elevation range of Salina Group Unit F, the computed shear strains in the randomized site profiles are less than 0.03 percent, which confirms the previously estimated results. For the till, the applicant estimated an average V_s of 305 m/s (1,000 fps). The applicant further stated that the results of the RCTS testing provide the dynamic response of the till up to a shear strain of approximately 0.3 percent. However, as stated in its FSAR, the applicant decided that the till will be fully excavated under and adjacent to all Seismic Category I structures and backfill consisting of fill concrete will reestablish the foundation grade. The applicant did not consider the till in the ground motion response analysis.

The staff reviewed the responses to RAI 02.05.04-9 and RAI 02.05.04-13a. The staff noted that the mean V_s and V_p of Salina Group Unit F that were obtained using the P-S suspension logging method agree with the mean V_s and V_p of Salina Group Unit F, which were obtained using the downhole seismic method. These in situ methods either directly tested weaker zones in Salina Group Unit F or tested across Salina Group Unit F and included weaker zones in the averaged measurements. Therefore the staff concludes that the applicant's data are sufficient to adequately characterize Salina Group Unit F, including the weaker zones. In addition, the staff reviewed the applicant's subsurface stability analyses and noted that these factors have been considered. Regarding the induced shear strain estimates, the staff reviewed the results of the effective shear strains computed in the site response analyses for the 10^{-4} and 10^{-5} input ground motions from FSAR Figures 2.5.2-280 and 2.5.2-281. These figures show that the computed shear strains in the randomized site profiles were all less than or equal to 0.03 percent within the elevation range of Salina Group Unit F. Because the computed Salina Group Unit F shear strain range is based on site response analyses with an assumed peak ground acceleration of 0.25 g and a minimum V_s of 549 m/s (1,800 fps), which confirmed the shear strain level of approximately 0.0252 percent, the staff concludes that the seismic shear strain for Salina Group Unit F is appropriate. Therefore, the shear modulus reduction based on this shear strain is acceptable.

The staff confirmed that the applicant's revised FSAR Subsection 2.5.4.2.3 includes more detailed clarifications of how the induced seismic shear strains were estimated for Salina Group Unit F and for the till. Because the applicant provided reasonable justifications for the proper characterizations of Salina Group Unit F, including its weaker zones and the induced seismic shear strains for Salina Group Unit F, , and decided to remove the till from the vicinity of Seismic Category I structures, RAI 02.05.04-9 and RAI 02.05.04-13a are resolved and closed.

FSAR Section 2.5.4.4.1.1 states that repeated collapse of boreholes was experienced in the 33.5 to 62.5 m (110 to 205 ft) depth range in Salina Group Unit F and resulted in oversized borehole and irregular borehole shapes. This section also states that the limited measurements were performed in Salina Group Unit F in any of the borings due to oversized holes and irregular hole shapes. The staff was concerned about any potential existence of cavities or other unstable subsurface conditions. In RAI 02.05.04-13b and RAI 02.05.04-13c, the staff asked the applicant to provide a detailed comparison of the elevations for the collapse of the boreholes under all Seismic Category I foundation bases; to discuss whether or not a repeated collapse of the boreholes might not be indicative of cavities below foundation levels; and to explain why systematic rock grouting should not be applied at this site.

In the response to RAI 02.05.04-13b and RAI 02.05.04-13c dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant provided caliper logs—a measure of the borehole diameter—for borings under and adjacent to Seismic Category I foundation bases with larger diameters that indicate the locations of borehole collapses. The applicant performed OTV logging for each of the borings with caliper logs in order to allow for a visual inspection of the borehole walls to see if voids or cavities are present at the Fermi 3 site. For boring RB-C8, the applicant compared the OTV log and the caliper log. The applicant did not identify any cavities where a borehole collapse had occurred; but the applicant did note that the larger diameter size was caused by material falling off the side of the borehole wall into the boring. FSAR Subsection 2.5.1.2.3.1 presents boring log analyses performed from the OTV logs; and natural gamma and caliper logging that the applicant used to provide information regarding core loss, voids, cavities, and tool drops that occurred in the Bass Islands Group and Salina Group Units F and E. The applicant concluded that the nature of the fracture of Salina Group Unit F resulted in the repeated collapse of boreholes as material fell off the borehole walls into the boring, rather than from the presence of cavities below foundation levels. The applicant did not propose systematic rock grouting to enhance the stability of subsurface materials because no void or cavities are present below the Fermi 3 site, and the strength and stiffness of the bedrock are sufficient to provide adequate bearing capacity and to control the settlement.

The staff reviewed the responses to RAI 02.05.04-13b and RAI 02.05.04-13c, the caliper logs for the borings under and adjacent to Seismic Category I structures, and the OTV logs. Because the applicant's analysis of boring logs regarding core loss, voids, cavities, and tool drops that occurred during the Fermi 3 subsurface investigation included the comparison of available boring logs; photos of the recovered core; caliper and gamma logs; and the downhole OTV logs to determine an explanation of the conditions that were encountered, the staff did not suspect that voids, cavities, or other unstable subsurface conditions are present beneath the Fermi 3 site. Based on the information from the applicant's analysis, observations during drilling, and a review of the OTV logs, the staff agreed with the applicant that the nature of the fracture of Salina Group Unit F resulted in repeated collapses of the boreholes as material fell off the borehole walls into the boring, rather than from the presence of cavities below the foundation levels. Therefore, systematic rock grouting is not necessary, and RAI 02.05.04-13b and RAI 02.05.04-13c are resolved and closed.

The staff reviewed the information in FSAR Subsection 2.5.4.2.3 and the applicant's responses to the RAIs associated with laboratory testing described above. The staff concludes that the applicant's laboratory testing program was conducted in accordance with an approved quality assurance program that adhered to the guidance in RG 1.138, Revision 2. The staff also concludes that the applicant had conducted sufficient laboratory tests to adequately characterize the physical and engineering properties of the subsurface materials.

NRC Staff's Conclusions Regarding the Properties of Subsurface Materials

The staff found the applicant's description of the subsurface materials acceptable in that the applicant had followed the guidance in RG 1.132, Revision 2 and RG 1.138, Revision 2. The applicant investigated and tested the subsurface materials to determine the geotechnical engineering properties of the soil and rock at the planned Fermi 3 site. Furthermore, the staff concludes that the applicant had obtained sufficient undisturbed samples to allow for the adequate characterization of each of these soil/rock groups and had determined the extent, thickness, hardness, density, consistency, strength, and engineering and static design properties. Furthermore, the staff concludes that the applicant has provided sufficient information in the form of plots, plans, boring logs, and laboratory test results that enabled the staff to determine that the applicant had adequately characterized the subsurface soil and rock materials and adequately determined the engineering and design properties.

Therefore, the staff concludes that the applicant's description of the subsurface materials and properties at the proposed Fermi 3 site is acceptable and meets the requirements of 10 CFR 100.23.

2.5.4.4.3 Foundation Interfaces

The staff reviewed FSAR Figure 2.5.1-236, which is the site explorations locations including borings, monitoring wells, piezometers and the test pit, Figure 2.5.4-201, which is the plan view of the excavation for the RB/FB, CB, FWSC, TB and RW, and FSAR Figures 2.5.4-202 through 2.5.4-204, which are geologic cross sections illustrating the detailed relationship of the structural foundations to the subsurface materials. The staff also reviewed FSAR Table 2.5.4-224, which provides the foundation elevations of the major structures in the Power Block area.

The staff concluded that the applicant has adequately investigated the subsurface materials beneath the nuclear island construction zone for the Fermi 3 site. The staff's conclusion is based on the review of the: (1) plot plans showing the locations of all site explorations, such as borings, seismic and non-seismic geophysical explorations, piezometers, geologic profiles, and the locations of the safety-related facilities; (2) the applicant presented, illustrating the detailed relationship of the foundations of all Seismic Category I and other safety-related facilities to the subsurface materials; and (3) core borings, SPT borings, V_s profiles and non-seismic geophysical logging results. Accordingly, the staff concludes that the foundation interfaces as described in FSAR Subsection 2.5.4.3 form an adequate basis for the characterization of the foundation interfaces at the Fermi 3 site and meets the requirements of 10 CFR Parts 50 and 100.

2.5.4.4.4 Geophysical Surveys

The staff reviewed FSAR Subsection 2.5.4.4 focusing on the applicant's description of the geophysical surveys performed to identify the dynamic characteristics of soils and rocks. The applicant measured the dynamic characteristics of soils and bedrock using downhole P-S suspension logging, downhole seismic testing, and SASW logging. As a result, the applicant concluded that the downhole V_s values generally agree with the values obtained using P-S suspensions logging; and the soil V_s measured using the P-S suspension method agrees with the soil V_s measured using the SASW method. In RAI 02.05.04-11, the staff asked the applicant to provide test data for V_s in addition to the average values and to discuss how these data may vary with the depth. The staff also asked the applicant whether the variability observed in downhole seismic testing and the SASW logging needs to be considered in the characterization of the soil and bedrock.

In the response to RAI 02.05.04-11 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant provided detailed results of the V_p and V_s measurements in the Geovision Report 7297-01, Revision 0 (March 12, 2008). The applicant indicated that for the Bass Islands Group, the measured V_s and V_p were constant throughout the depth at a given boring location. For Salina Group Unit F, the applicant performed limited V_p and V_s measurements between the depths of 33.5 and 62.5 m (110 and 205 ft) resulting from oversized holes and irregular shapes of holes. The applicant measured the arrival time of the shear and compression waves above and below the interval of the oversized zones and indicated that for the RB-C8 and CB-C3 locations, the measured V_s and V_p were constant over a given interval at a given boring location. The applicant measured the V_s in the overburden using the SASW and P-S suspension logging and discussed the variability in FSAR Subsection 2.5.4.4.1.2. The applicant employed the V_s measurement using the SASW logging to establish the V_s of only the glacial till and used the P-S suspension logging to establish the bedrock V_s and V_p values for analysis. The applicant used the downhole results to validate the P-S suspension logging results. The applicant indicated that the V_p and V_s measured using the downhole method fall with the variability of the V_p and V_s measured using P-S suspension logging method. The applicant concluded that the overall results obtained from the P-S Suspension logging are acceptable for all purposes of analysis. But the staff noted that the V_s obtained from the P-S suspension logging method are generally greater than those from the downhole and SASW methods. In RAI 02.05.04-12, the staff asked the applicant to justify the exclusive use of the P-S suspension logging results rather than using the downhole, SASW, and P-S suspension logging results.

In the response to RAI 02.05.04-12 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant indicated that the clarity of the V_s wave form was better in the P-S suspension logging data than in the downhole seismic data and the variability of the P-S suspension logging data for the V_s and V_p could correlate well with the physical features observed in the bedrock. The applicant had more confidence in the ability to interpret the P-S suspension logging V_s data.

The staff reviewed the responses to RAIs 02.05.04-11 and 02.05.04-12 and noted that the applicant had applied the downhole seismic method to measure the V_p at boring locations RB-C8, CB-C3, and RB-C4 and the V_s at RB-C8 and CR-C3. The staff also noted that the V_p and V_s in the bedrock units were measured using the downhole seismic method and fall within the variability of the V_p and V_s, which were measured using the P-S suspension logging method except for the lower V_s, which was measured in RB-C8 in the Bass Islands Group and the applicant attributed to poor quality shear wave forms. In addition, the staff noted that the applicant had compared the V_s and V_p measurements obtained with other subsurface information such as RQD, caliper, natural gamma, and OTV logs. The staff also reviewed FSAR Figures 2.5.4-205 through 2.5.4-208 to compare the measured P-S suspension logging V_s and V_p with the RQD in boring locations TB-C5, RB-C8, CB-C3, and RB-C4, respectively. The staff also reviewed FSAR Figures 2.5.4-209 through 2.5.4-212 to compare the OTV logs and the measured velocities in boring locations TB-C5, RB-C8, CB-C3, and RB-C4, respectively. Furthermore, the staff reviewed FSAR Figures 2.5.4-213 and 2.5.4-214 to compare the natural gamma logs and the measured velocities in boring locations TB-C5 and CB-C3. The staff concurred with the applicant that the variability in the measured V_p and V_s within the Bass Islands Group is mainly caused by geologic features such as fractures, bedding planes, brecciation, oolitic rock, and a pitting of the bedrock. Because the clarity of the V_s forms was better for the P-S suspension logging data than for the downhole seismic data, and the variability of the P-S suspension logging V_s and V_p data could correlate well with the physical features observed in the bedrock, the staff concluded that the P-S suspension logging V_s data are more reliable than the V_s downhole seismic data, while the downhole results were used to validate the P-S suspension logging results. The staff further concluded that the V_s measurements using the SASW logging were used to establish the V_s of only the glacial till that will be removed from beneath the Seismic Category I structures. Therefore, RAI 02.05.04-11 and RAI 02.05.04-12 are resolved and closed.

The staff reviewed the information in FSAR Subsection 2.5.4.4 and the applicant's responses to RAIs 02.05.04-11 and 02.05.04-12. The staff concluded that the applicant has appropriately followed the guidance in RG 1.132, Revision 2, and has provided sufficient geophysical surveys to characterize the dynamic characteristics of soils and rocks.

2.5.4.4.5 Excavation and Backfill

The staff reviewed FSAR Subsection 2.5.4.5 related to the engineering granular backfill requirements, the extent of excavation fills and slopes, excavation methods, and the stability at the Fermi 3 site. Initially, the applicant was planning to use lean concrete and engineered granular fill as the backfill beneath and surrounding Seismic Category I structures. As a result of the revisions to the referenced DCD for the required soil properties surrounding Category I structures, the applicant later proposed to use roller-compacted concrete or a similar product near the ground surface to maintain the 300 m/s (1,000 ft/s) shear wave velocity. The staff issued several RAIs regarding the applicant's fills properties, criteria, and extent of excavation and backfill. However, these RAIs are not discussed in further detail in this technical evaluation because the applicant later concluded—while developing responses to the RAIs—that the design for the backfill surrounding the Category I structures would not meet the DCD soil property requirements. Consequently, the response to RAI 02.05.04-38 dated June 17, 2011

(ADAMS Accession No. ML111711175), reflects the applicant's final decision to use granular backfill to surround the Category I structures and to perform a site-specific SSI analysis to demonstrate the adequacy of the site and the standard plant design. The applicant did not credit the engineered granular fill surrounding the Category I structures for performing any safety-related function and clarified that only onsite backfill sources will be used for engineered granular backfill surrounding the Category I structures. The applicant concluded that no ITAAC are necessary for compactable backfill surrounding the embedment walls of the RB/FB and CB. The applicant also concluded that the site parameter values are not required, including the shear wave velocity requirement referenced in the DCD for compactable backfill surrounding the foundation basemat of the FWSC. In addition, the applicant decided to use fill concrete instead of lean concrete to backfill the volume between the RB/FB, CB, and excavated bedrock and to support the FWSC and TB foundations from the top of the bedrock to address the staff's concern about the chemical composition requirements for sulfate exposure conditions. For the FWSC, the applicant indicated that it is a surface-founded structure that will have no embedment walls and will be supported by concrete fill founded on top of the Bass Island Group bedrock, with a mean shear wave velocity of at least 2,175 m/s (7,140 ft/s).

Source and Quantities of Backfill and Borrow Materials

The staff reviewed FSAR Subsection 2.5.4.5.1 related to the sources of backfill and borrow materials that follow the guidance in NUREG–0800. Based on the information in the applicant's response to RAI 02.05.04-38, the staff asked the applicant in RAI 02.05.04-39 to provide the technical basis for eliminating the ESBWR DCD site parameter requirement for the product of at-rest pressure coefficient and density ($K_0\gamma \geq 750$ Kg/m^3 [47 lb/ft^3]) for backfill material surrounding Seismic Category I structures in FSAR Table 2.0-201. The staff also asked the applicant to explain why Design Commitment Item 2 in Table 2.4.2-1 of the COL application Part 10 is not applicable—engineering properties of backfill material surrounding Seismic Category I structures. The staff also asked the applicant to explain the basis for eliminating Item 2 of the site-specific ITAAC corresponding to the backfill adjacent to Seismic Category I structures.

In the response to RAI 02.05.04-39 dated February 16, 2012 (ADAMS Accession No. ML120520154), the applicant eliminated $K_0\gamma$ as a required parameter for Seismic Category I structures. Because of the strength of the bedrock and the fill concrete, the applicant did not credit the frictional resistance along the portion of the foundation and the walls of the structure parallel to the direction of sliding motion. In addition, the applicant indicated that an ITAAC for the backfill surrounding Seismic Category I structures will be included to specify the applicable requirements for the DCD backfill soil parameters.

The staff reviewed the responses to part 1 of RAI 02.05.04-38 and RAI 02.05.04-39. The staff noted that the applicant had elected to perform site-specific SSI analyses in lieu of meeting the soil property requirement in the ESBWR DCD table to maintain the 300 m/s (1,000 ft/s) shear wave velocity for backfill surrounding Seismic Category I structures. The staff also noted that the applicant had properly revised its plot plans and profiles to present the horizontal and vertical extent of all Seismic Category I fills, including the engineered granular backfill and fill concrete. The staff further noted that ESBWR DCD also allows applicants to demonstrate the adequacy of the standard plant design by performing site-specific analyses. Therefore, the staff considered the applicant's alternative approach proper and acceptable. The staff's detailed evaluation of the site-specific SSI analyses is documented is in Sections 3.7.1, 3.7.2, and 3.8.5 of this SER. The staff noted that the site-specific SSI analyses for the RB/FB and the CB were performed by considering the partial embedment of the structures into the Bass Islands Group bedrock and by not taking credit for the engineered granular backfill located above the top of the Bass Islands Group bedrock. Because the applicant's site-specific SSI analyses demonstrated the adequacy of the standard plant design, the staff agreed that the shear wave velocity requirement referenced in the DCD for the backfill surrounding Seismic Category I structures may not be considered. Consequently, the staff concurred that an ITAAC on shear wave velocity for engineered granular fill surrounding Seismic Category I structures is not necessary.

The applicant's assumption that the engineered granular backfill surrounding Seismic Category I structures are not attributed to resisting sliding forces in the site-specific SSI analyses is conservative. Furthermore, the staff reviewed DCD Tier 2, Subsection 3.8.5.5 and GEH Letter MFN 09-772 to the NRC, "Revised Response to portion of NRC RAI Letter No. 386 Related to ESBWR Design Certification Application – DCD Tier 2, Section 3.8 – Seismic Category I Structures; RAI Number 3.8-96 S05 Revision 1," dated January 20, 2010 (ADAMS Accession No. ML100220503), in order to understand the ESBWR DCD requirement for $K_0\gamma$ and how to determine the FS against sliding. The staff also reviewed FSAR Subsection 3.8.5.5.1, "Foundation Stability," to confirm that the stability calculations against sliding are executed according to the procedure in Referenced DCD Subsection 3.8.5.5. Based on the above reviews, the staff found that the DCD requirement for $K_0\gamma$ is related to at-rest soil forces that are normal to the basemat vertical surface, which develops skin friction resistance on the basement side parallel to the direction of the motion to resist sliding if necessary. The staff confirmed that the skin friction resistance force provided by the basemat side parallel to the direction of the motion is not taken into account in the applicant's analyses (i.e., $F_{us} = 0$). The staff agreed with the applicant that the great resistance force for sliding can be developed by the partial embedment of the structures into the bedrock. The staff noted that the calculated Fermi 3 site-specific FS against sliding for the Seismic Category I structures RB/FB, CB, and FWSC are 1.22, 1.10, and 15, respectively, which are equal to or greater than the minimum FS of 1.1 required by SRP Section 3.8.5. Therefore, the staff concluded that it is not necessary to take into account the DCD site parameter requirement $K_0\gamma \geq 750$ Kg/m^3 (47 lb/ft^3) for the Fermi 3 site. The staff further concluded that it is reasonable and acceptable to exclude an ITAAC item of $K_0\gamma \geq 750$ Kg/m^3 (47 lb/ft^3) from site-specific ITAAC for "Backfill Surrounding Seismic Category I Structures." Furthermore, the staff confirmed that the applicant has revised the ITAAC for "Backfill Surrounding Seismic Category I Structures" to reflect that (1) the DCD site parameter requirements of 300 m/s (1,000 ft/s) minimum shear wave velocity and $K_0\gamma \geq 750$ Kg/m^3 (47 lb/ft^3) for engineered granular fill surrounding Seismic Category I structures are no longer required design commitments; and (2) the other applicable DCD site parameter requirements for DCD backfill soil parameters are included in the ITAAC for "Backfill Surrounding Seismic Category I Structures" in Section 2.4.2 of COL application Part 10. Therefore, part 1 of RAI 02.05.04-38 and RAI 02.05.04-39 are resolved and closed.

In part 6 of RAI 02.05.04-38, the staff asked the applicant to specify the offsite backfill source(s) and to demonstrate the adequacy of the performed site and laboratory investigations.

In the response to part 6 of RAI 02.05.04-38 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant indicated that only onsite backfill sources using materials excavated from Fermi 3 will be used for the engineered granular backfill surrounding Seismic Category I structures. This decision reflects investigations using borings and test pits, in addition to laboratory and field tests.

The staff reviewed the applicant's response to part 6 of RAI 02.05.04-38 and noted that the quantity of engineered granular backfill within the perimeter of the reinforced concrete diaphragm wall is approximately 153,000 m^3 (200,000 yd^3), and the volume of granular backfill from the onsite excavation (onsite source) of Fermi 3 is an estimated 180,000 m^3 (235,000 yd^3). The staff concluded that the quantity of material excavated from the Fermi 3 site is adequate for the engineered granular backfill surrounding the Fermi 3 Seismic Category I structures. The staff also noted that the source of the onsite backfill was investigated using borings, test pits, and laboratory and field tests; FSAR Subsection 2.5.4.2 discusses the properties of the onsite backfill materials. Based on this information, the staff found that the applicant has (1) identified the sources and quantities of the backfill; (2) adequately investigated them using borings, pits, and laboratory tests (dynamic and static); and (3) included, interpreted, and summarized the data in the FSAR. The staff concluded that the applicant has adhered to the SRP Section 2.5.4 acceptance criteria regarding backfill sources, quantities, and laboratory properties. Therefore, part 6 of RAI 02.05.04-38 is resolved and closed.

Extent of Excavation, Fills, and Slopes

The staff reviewed FSAR Subsection 2.5.4.5.2 that focuses on the extent of the excavation, fills, and slopes within the soil and bedrock. The applicant stated that vertical excavation faces within the soil and bedrock could be achieved by using an excavation system consisting of a reinforced concrete diaphragm wall system 24.4 m (80 ft) deep with an embedment depth of approximately 15.2 m (50 ft) into the bedrock around the entire excavation. The reinforced concrete diaphragm wall will act as the perimeter of the soil excavation and will provide vertical support for the portion of the excavation within the soil. Overburden soils will be excavated from the ground surface to the estimated top of the bedrock surface at elevation of 168.2 m (552 ft) NAVD 88. Bedrock will be excavated to reach the required foundation design elevations. FSAR Figure 2.5.4-201 depicts the plan view of the excavation for Fermi 3 using the vertical cut-off wall option in the soil and bedrock; Figures 2.5.4-202 through 2.5.4-204 show the cross sections of the excavation. Because the applicant is committed to a structural design of the concrete diaphragm wall that is in accordance with ACI 318, the wall will be aligned to prevent the deflected wall from encroaching on the limits of Seismic Category I structures plus any construction limitations. And because the wall will be aligned to allow sufficient space for the placement of backfill outside the Seismic Category I structures, the staff agreed with the applicant’s conclusion that there are no impacts to the completed Seismic Category I structures from the presence of the concrete diaphragm wall.

The staff reviewed FSAR Subsection 2.5.4.5.2 and FSAR Figures 2.5.4-201 through 2.5.4-204. The staff concluded that the applicant has clearly illustrated the detailed relationships among the foundations of all Seismic Category I structures, backfill materials, and excavation boundaries created by the vertical cut-off reinforced concrete diaphragm wall. Therefore, the applicant’s assessment of the extent of all Category I excavations, fills, and slopes is acceptable and meets the requirements of 10 CFR Part 50.

Excavation Methods and Stability

While reviewing FSAR Subsection 2.5.4.5.3, the staff noted that the applicant plans to use blasting, mechanical excavation, or a combination of both methods for the bedrock excavation. The applicant assured the staff that the blasting would be designed by a qualified and experienced blasting professional and controlled blasting techniques can be used to ensure the protection of all existing adjacent structures, including Fermi 2. The applicant indicated that during construction, excavated subgrades in the bedrock of safety-related structures will be mapped and photographed by a qualified and experienced geologist to evaluate any unforeseen geologic features. The staff asked the applicant in RAI 02.05.04-15 to provide the specific criteria to be used to evaluate whether the excavated faces would be acceptable as foundation material. Also, the staff asked for an explanation as to how the applicant will use a geologic evaluation of open faces to confirm the engineering properties of bedrock material and to provide specifics for any engineering property tests planned for the excavated bedrock material.

In the response to RAI 02.05.04-15 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant indicated that the Seismic Category I structures at the Fermi 3 site are founded on bedrock or fill concrete over the bedrock. The applicant also indicated the intent to prepare during the development of the detailed design the specifications regarding the inspection and cleaning of the excavation that will ensure acceptable excavation faces. The applicant also committed to ensuring that a visual inspection of the final excavation surface will be performed to confirm that it is in general conformance with the expected foundation material based on boring logs. After fracturing from blasting, machine cleaning is followed by cleaning with hand tools and high-pressure water and air to remove unsuitable rock. The applicant pointed out that geologic mapping of the final exposed excavated bedrock surface will be performed before the placement of concrete fill and foundation concrete to determine the degree of fracturing in the excavated face after the surface has been cleaned. The applicant also stated that if the spacing between discontinuities is measured in feet, foundation treatment may be minimal or unnecessary. But if the spacing between fractures is measured in inches, removal or replacement with dental concrete or consolidation grouting may be required to improve the engineering properties of the bedrock at the excavated face. The applicant concluded by stating that the designer will identify specific engineering properties, tests, and the type and extent of the foundation treatment. The designer will thus confirm the condition of the excavation faces. The applicant added that there are no plans to test the excavated material.

The staff reviewed the response to RAI 02.05.04-15 and noted that the existing subsurface materials including fill, lacustrine, and glacial till will be removed to ensure that the Seismic Category I structures are founded on bedrock or concrete fill over bedrock. The staff also noted that the applicant will perform a visual inspection on the exposed bedrock foundation subgrade to confirm that cleaning and surface preparations were properly completed. In addition, the applicant will conduct the geologic mapping program after the surface is machine and hand cleaned and after there is a complete photographic documentation of the exposed surface to record significant geologic features. The applicant agreed to implement the foundation treatment where necessary, including removal and replacement with dental concrete or consolidation grouting to improve the engineering properties of the bedrock at the excavated face. The geologic mapping License Condition 2.5.3-1 is identified in the Subsection 3.5.3.5 of this SER as the responsibility of the COL applicant. The NRC will be notified once excavations for Fermi 3 safety-related structures are open for examination by NRC staff. Therefore, the staff found the applicant's response acceptable, and RAI 02.05.04-15 is resolved and closed.

Compaction Specifications and Quality Control

The staff reviewed FSAR Subsection 2.5.4.5.4 that focuses on the methods and procedures used for verification and quality control of foundation materials. Based on the information in the applicant's response to part 2 of RAI 02.05.04-38 (ADAMS Accession No. ML100040548), the staff confirmed that the applicant has properly revised the plot plans and profiles to present the horizontal and vertical extent of all Category I fills—including the engineered granular backfill and fill concrete. The staff noted that the engineered granular backfill surrounding the Seismic Category I structures will be compacted to 95 percent of the modified Proctor density or 75 percent of the maximum relative density. The staff concurred that the engineered granular backfill is adequate to prevent liquefaction.

The applicant identified that the sulfate concentration of the site's groundwater is in the "moderate" to "severe" sulfate exposure category based on ACI 349. In part 3 of RAI 02.05.04-38, the staff asked the applicant how the backfill on the side of and underneath the Seismic Category I structures is designed to resist chemical attack, particularly if roller compacted concrete (RCC) or controlled low-strength material (CLSM) is selected. The staff also asked the applicant to discuss control of the thermal cracking of fill materials.

In the response to part 3 of RAI 02.05.04-38 (ADAMS Accession No. ML111711175), the applicant stated that the RCC will not be used to surround Seismic Category I structures and that no CLMS will be used as backfill material for Seismic Category I structures. The applicant will follow ACI 349 to address the chemical composition requirements for sulfate exposure conditions and ACI 207.2R to address the thermal cracking control of mass concrete. The applicant concluded that the mean compressive strength for the fill concrete will be 31 MPa (4,500 psi).

The staff reviewed the response to part 3 of RAI 02.05.04-38, and verified that the applicant will not use the RCC, CLSM, or lean concrete as backfill material for Seismic Category I structures. The staff also confirmed that the fill concrete will be used to backfill the volume between the RB/FB and CB and excavated bedrock, and to support the FWSC and TB foundations from the top of the bedrock. In addition, the staff noted the ITAAC, which ensures that compactable backfill will not be placed under Fermi 3 Seismic Category I structures, and the fill concrete placed underneath any Category I structure will be a thickness greater than 1.5 m (5 ft) to the design, construction, and testing of applicable ACI standards. The staff validated that ACI 349 Chapter 4 addresses the concrete durability requirements including concrete to be exposed to sulfate containing solutions or soils. The staff verified that for a severe sulfate exposure such as the Fermi 3 groundwater condition, concrete durability can be achieved following the guidance in Table 4.3.1 of ACI 349 by providing concrete containing Type V cement; controlling a 0.45 maximum water-cementitious-material ratio; and maintaining a 31 MPa (4,500 psi) minimum concrete compressive strength. The staff further noted that ACI 207.2R-07 addresses the thermal cracking control of mass concrete by providing guidance for the selection of concrete materials, mixture requirements, and construction procedures necessary to control the size and spacing of cracks. Because the concrete durability of the fill and thermal cracking can be controlled by committing to proper ACI codes, the staff considered part 3 of RAI 02.05.04-38 resolved and closed.

NRC Staff's Conclusions Regarding Excavation and Backfill

The staff concluded that the applicant has (1) provided detailed information on engineered granular backfill and fill concrete properties and requirements; (2) provided applicable methods and procedures used for the verification and quality control of engineered granular backfill and concrete fill; and (3) described concrete fill properties that will ensure that the proposed fill concrete meet the strength and stability requirements. In addition the applicant provided two site-specific ITAACs that will ensure that concrete fill placed under Seismic Category I structures and compacted backfill surrounding the embedded walls for Seismic Category I structures are designed and tested as specified in FSAR Subsection 2.5.4.5.4.2 and properties of backfill material are equal to or exceed the FSAR Subsection 2.5.4.5.4.2 requirements. Therefore, the proposed fills for this site are adequate for meeting design and engineering standards. Regarding the applicant's excavation plans, the staff concluded that the applicant's plans to use conventional excavation methods (e.g., backhoe, front end loader, and dump truck) to remove soil layers and to use blasting with controlled blasting techniques (cushion blasting, pre-splitting, and line drilling; mechanical excavation including the use of roadheaders, terrain levelers, rockwheels, rock trenchers, and other mechanical excavation; or a combination of blasting and mechanical excavation) to excavate bedrock are adequate and feasible. In SER Subsection 2.5.3.5, the staff identifies License Condition 2.5.3-1 as the responsibility of the COL applicant for a detailed geologic mapping of the excavation of Fermi 3 nuclear island structures and to examine and evaluate geologic features discovered in excavations for safety-related structures. Furthermore, the staff concluded that the supporting foundation materials and/or qualified fill concrete will result in a solid foundation for the nuclear island that meets the requirements specified in ESBWR DCD Tier 1, Table 5.1-1 and 10 CFR Part 50.

2.5.4.4.6 Groundwater Conditions

FSAR Subsection 2.5.4.6 presents information on the groundwater conditions at the site relative to foundation stability for the safety-related structures. The applicant stated that a reinforced concrete diaphragm wall around the perimeter of the Fermi 3 excavation will control groundwater seepage through soils and bedrock, and localized sump pumping within the excavation may be used to supplement water control during excavation. The applicant also stated that foundation bedrock grouting may be performed at the base of the Fermi 3 excavation to aid in controlling groundwater seepage into the excavation. Regarding the impact of groundwater control measures during construction on the existing structures, the applicant stated that the potential for settlement associated with Fermi 3 dewatering operations is negligible because all Fermi 2 Seismic Category I structures are founded on bedrock. However, the applicant provided a regulatory commitment (COM 2.5.4-001) to develop a Contingency Plan for mitigating any settlement of existing Fermi 2 structures before the start of Fermi 3 construction.

The staff reviewed the groundwater information in the FSAR including the conditions before, during, and after excavation and the associated dewatering plan, as well as the proposed measures to minimize drawdown effects on the surrounding environment. The staff concluded that the applicant's assessment of groundwater conditions is acceptable and satisfies the requirements of 10 CFR Part 50 and 10 CFR 100.23.

2.5.4.4.7 Response of Soil and Rock Dynamic Loadings

FSAR Subsection 2.5.4.7 describes the response of soil and bedrock to dynamic loading and the effects of past earthquakes. In RAI 02.05.04-19, the staff asked the applicant to demonstrate that the ratio of the largest to the smallest V_s over the mat foundation does not exceed ESBWR DCD Criterion 1.7. In the response to this RAI dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant calculated the smallest and largest mean V_s for each bedrock unit (Bass Islands Group and Salina Group Units F, E, C and B) based on various boreholes. The applicant stated that the ratios obtained ranged from 1.01 to 1.44 and therefore concluded that Criterion 1.7 in the ESBWR DCD was achieved for all bedrock units in question. The staff reviewed the response to RAI 02.05.04-19, including the calculated range of ratios. The applicant demonstrated that the ratio of the largest to the smallest mean V_s for full unit thickness based on various boreholes is less than 1.7. The staff concluded that the V_s ratio over the mat foundation width is enveloped by the requirement specified in the ESBWR DCD. Therefore, RAI 02.05.04-19 is resolved and closed.

Based on the above review, the staff concluded that the applicant has developed soil and rock dynamic properties for the Fermi 3 site based on field and laboratory tests that are in accordance with the guidance in RGs 1.132 and 1.138. In addition, the staff concluded that the applicant has conducted sufficient tests to determine soil and rock dynamic properties. The applicant's analyses considered variations of these properties and parameters. Therefore, the soil and rock dynamic property parameters used in the design are appropriate.

2.5.4.4.8 Liquefaction Potential

During the review of FSAR Subsection 2.5.4.8, the staff evaluated the applicant's description of the liquefaction potential at the Fermi 3 site. The staff focused on the applicant's conclusions and justifications that fill materials placed within excavated areas are not susceptible to liquefaction. In addition, the staff's review focused on the applicant's evaluation of localized liquefaction potential under other than Seismic Category I structures.

In RAI 02.05.04-20, the staff asked the applicant to demonstrate that the backfill adjacent to Seismic Category I structures is not susceptible to liquefaction per the requirements in 10 CFR Parts 50 and 100. In the response to RAI 02.05.04-20 dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant referenced various sources. FSAR Subsection 2.5.4.5.4.2 states that all engineered granular backfills, including the ones in question, will be placed in controlled lifts and compacted. The applicant stated that the engineered granular backfill will consist of well-graded and dense granular soils that will be compacted up to a dense or a very dense consistency, thus reducing the probability of liquefaction.

To further demonstrate this point, the applicant performed a liquefaction analysis based on the SPT method. The applicant postulated that the expected N_{60} value at the ground surface will be 30 bpf and will increase linearly to 60 bpf at a depth of 20 m (65 ft). Based on Youd et al. (2001), the applicant normalized the N_{60} value to a $(N1)_{60}$ value, which is a function of a normalized overburden pressure of 100 KPa (2.1 ksf) and the effective vertical stress. The applicant found that all normalized $(N1)_{60}$ values obtained from this method were greater than 30 bpf, which greatly reduces the possibility of liquefaction according to Youd et al. (2001). Therefore, the applicant concluded that the engineered granular backfill adjacent to the Seismic Category I structures is not susceptible to liquefaction. In RAI 02.05.04-34, the staff asked the applicant to capture this liquefaction evaluation in the FSAR and to provide details of and a commitment on how it will verify the assumed N_{60} values. Also, the staff asked the applicant to provide the expected field backfill compaction and to include this commitment in the FSAR.

In the response to RAI 02.05.04-34 dated August 6, 2010 (ADAMS Accession No. ML102210351), the applicant stated that laboratory testing will be implemented during the detailed design phase to establish the required density necessary to meet the design requirements of the engineered granular backfill adjacent to Seismic Category I structures. The applicant will implement a program for in-place testing of the engineered granular backfill to confirm that the density selected is based on laboratory test results and thus satisfies the design requirements.

The staff reviewed the responses to RAI 02.05.04-20 and RAI 02.05.04-34. The staff's review focused on the liquefaction potential to ensure that engineered granular backfill adjacent to all Seismic Category I structures is not susceptible to liquefaction. The staff noted that a well-graded granular backfill will be placed in controlled lifts with compaction, which will result in a dense to very dense consistency granular backfill. The staff also noted that the applicant's liquefaction analysis indicated that the backfill adjacent to Category I structures is not susceptible to liquefaction if it is compacted to a $(N_1)_{60}$ value equal to or greater than 30 bpf. Because the granular backfill has not yet been placed, the staff found that the applicant will implement (1) the laboratory testing during the detailed design phase to establish the required density to meet the design requirements of the engineered granular backfill adjacent to Seismic Category I structures; and (2) a program to test the in-place engineered granular backfill, which could consist of the construction of one or more test pads to further confirm the density selected based on laboratory test results that meet the design requirements. The staff thus concluded that the applicant had provided reasonable assurance that the engineered granular backfill adjacent to Seismic Category I structures will not be susceptible to liquefaction. The staff further noted that the applicant has revised the FSAR to provide more information on the liquefaction assessment demonstrating that there is no liquefaction potential for engineered granular backfill adjacent to Seismic Category I structures. Therefore, RAI 02.05.04-20 and RAI 02.05.04-34 are resolved and closed.

To comply with the DCD requirement of COL 2.0-29-A, the staff asked the applicant in RAI 02.05.04-35 to evaluate the localized liquefaction potential under other than Seismic Category I structures and to assess the potential safety implications, especially for those buildings that are adjacent to Seismic Category I structures. In the response to RAI 02.05.04-35 dated September 21, 2010 (ADAMS Accession No. ML102660141), the applicant indicated that all non-Seismic Category I SSCs—including the TB, RWB, service building, and ancillary diesel building—are all designed to meet the third criterion of ESBWR DCD, Tier 2, Subsection 3.7.2.8, in order to prevent a failure under SSE ground motion conditions. The applicant also stated that they will meet the first criterion of the ESBWR DCD, Tier 2, Subsection 3.7.2.8 that specifies the requirements for all site-specific, non-Seismic Category I structures outside the scope of the DCD and assures that if they should collapse, the non-Seismic Category I SSCs will not strike any Seismic Category I SSCs.

The applicant may use the glacial till to support non-Seismic Category I structures outside the scope of the DCD. The applicant classified the glacial till as lean clay with an average fines content of 68 percent and a plasticity index of 14. The applicant verified that the glacial till satisfies the RG 1.198 guidance for liquefaction, in which cohesive soils with fines contents greater than 30 percent and fines that are classified as clays are either based on the Unified Soil Classification System or have a plasticity index of more than 30 percent and should generally not be considered susceptible for liquefaction. The applicant confirmed that if backfill is placed above the glacial till to the base of a foundation, it will be an engineered backfill with no potential for liquefaction and with quality control and testing.

The staff reviewed the response to RAI 02.05.04-35 (ADAMS Accession No. ML102660141). The staff noted that non-Seismic Category I structures within the scope of the ESBWR DCD (also called Seismic Category II structures)—including the TB, RWB, service building, and ancillary diesel building—are analyzed and designed to prevent their failure under SSE ground motion conditions in a manner where the margin of safety of these structures is equivalent to that of Seismic Category I structures. The staff further noted that non-Seismic Category I structures outside the scope of the ESBWR DCD are located at least a distance equal to its above-grade height away from Seismic Category I structures. The staff thus concluded that the collapse of any site-specific, non-Seismic Category I SSC will not strike a Seismic Category I SSC. In addition, the staff noted that for the non-Seismic Category I structures that could strike a Seismic Category I structure if the non-Seismic Category I structure were to fail during a seismic event, the subsurface and/or backfill materials founded underneath are not susceptible to liquefaction because it is fill concrete. The staff also noted that the applicant has revised FSAR Subsection 2.5.4.8 to include the assessment of the potential safety implications from localized liquefaction potential under other than Seismic Category I structures. All non-Category I structures are designed to satisfy either the first criterion specified in Subsection 3.7.2.8 of the ESBWR DCD to provide a sufficient distance between the non-Category I structures and the

Seismic Category I structures; or the third criterion to prevent a failure under SSE ground motion conditions. The staff concluded that the potential safety implications resulting from localized liquefaction under other than Seismic Category I structures are not likely to occur. Therefore, RAI 02.05.04-35 is resolved and closed.

Based on the bedrock or fill concrete under Seismic Category I structures and properties of the engineered granular backfill adjacent to Seismic Category I structures described in the above RAI responses, the applicant concluded that liquefaction is not a concern. The staff found the applicant's conclusion reasonable that the liquefaction potential for supporting materials of Seismic Category I structures will not be a concern at the site, because of the fact that the engineered granular backfill will be placed in controlled lifts and compacted to achieve a very dense consistency with relatively high blow counts and V_s value. Regarding the localized liquefaction potential under other than Seismic Category I structures, the staff concluded that the potential safety implications from localized liquefaction under other than Seismic Category I structures are not likely because all non-Seismic Category I structures outside the scope of the DCD are designed to be a sufficient distance from the Seismic Category I structures and non-seismic Category I structures in the scope of the DCD are founded on fill concrete to avoid a failure under SSE ground motion conditions. The staff further concluded that the requirement of COL Item COL 2.0-29-A to evaluate the localized liquefaction potential under other than Seismic Category I structures is met. Therefore, the staff concluded that the assessment of the liquefaction potential at the planned Fermi 3 site is adequate and satisfies the requirements of 10 CFR Part 50, Appendix A; 10 CFR Part 50, Appendix S; GDC 2, and 10 CFR 100.23.

2.5.4.4.9 Earthquake Design Basis

The applicant conducted a field exploration using geophysical testing to determine the V_s of soils and bedrock and performed a site response analysis to develop the GMRS for the site. In FSAR Subsection 2.5.4.9, the applicant referred to FSAR Subsection 2.5.2.6 for a description of the methods used to develop the performance-based, site-specific GMRS developed for the Fermi 3 site. The applicant determined the GMRS is in accordance with the guidance in RG 1.208. Subsection 2.5.2.4 of this SER provides the staff's technical evaluation and a complete description of the performance–based GMRS for the Fermi 3 site.

2.5.4.4.10 Static Stability

The staff reviewed FSAR Subsection 2.5.4.10. The staff's review focused on the applicant's analyses performed to evaluate the stability of safety-related structures, including the foundation-bearing capacity and settlement analyses, excavation rebound lateral earth pressures, and hydrostatic pressures.

Bearing Capacity

In FSAR Subsection 2.5.4.10.1, the applicant used Terzaghi (USACE 1994) and the Uniform Building Code (Peck, Hanson, and Thornburn 1974) approaches when evaluating the bearing capacity. In RAI 02.05.04-23, the staff asked the applicant to explain the appropriateness of these two methods by considering the weaker Salina Group Unit F beneath the Bass Islands Group. In the response to RAI 02.05.04-23 dated December 23, 2009 (ADAMS Accession No. ML100040548), the applicant indicated that both approaches account for the influence of Salina Group Unit F. The applicant stated that the Terzaghi approach takes into consideration the effect of the weaker zones below the Bass Islands Group and is based on general bearing capacity failure behavior. The Uniform Building Code approach considers the allowable contact pressure on unweathered bedrock under a uniaxial loading condition to assure that the foundation bedrock has sufficient capacity against rupture. In the Uniform Building Code approach, the applicant used a weighted average of the unconfined compression strength of the Bass Islands Group and Salina Group Unit F. The staff asked the applicant in RAI 02.05.04-33 to provide an additional basis for selecting these two approaches for possible failure modes of the foundation rock unit at the site. The staff asked the applicant to take into consideration that the Terzaghi approach is based on a particular class of potential failure mode that involves a homogenous material, and the Uniform Building Code approach is based on information mainly for buildings.

In the response to RAI 02.05.04-33 dated August 6, 2010 (ADAMS Accession No. ML102210351), the applicant indicated that these two methods allow evaluations of two general potential bedrock failure modes. The applicant stated that the Terzaghi approach ignores the effects of cohesion and the interlocking of bedrock blocks, which makes it a conservative method for estimating the bearing capacity. The applicant further indicated that the Terzaghi approach addresses a general shear failure, and the Uniform Building Code approach addresses the potential against a rupture of intact bedrock resulting from the foundation loading. The applicant stated that both techniques were applied to account for the variations in bedrock properties.

The staff reviewed the responses to RAI 02.05.04-23 and RAI 02.05.04-33. The staff's review focused on the applied methods for evaluating the bearing capacity, in order to ensure that the approaches are appropriate and adequate to capture bearing capacities associated with possible failure modes for the Fermi 3 site. The staff noted that the bearing capacity evaluations accounted for variations in the depth of bedrock properties by using weighted average properties of the subsurface layers within the foundation zone of influence. Because the average fracture spacing in the bedrock is much smaller than the foundation width based on the RQD for the Fermi 3 site, the staff concurred with the applicant that a general shear failure is a possible failure mode. Therefore, the Terzaghi approach is reasonably applicable. And because the effects of cohesion and the interlocking of bedrock blocks were not taken into account for the evaluation of a general shear failure, the staff found that the result from the Terzaghi approach represents a conservative bearing capacity. As for the Uniform Building Code approach, the staff noted that it encompasses an empirical relationship by using 20 percent of the unconfined compressive strength to estimate the allowable pressure on the bedrock. Finally, after reviewing the Terzaghi and Uniform Building Code approaches and the information in Table 2.5.4-3 of this SER, the staff concluded that the bearing capacities evaluated with both approaches exceed the safety margins when compared to the bearing demands of the ESBWR DCD. Therefore, RAI 02.05.04-23 and RAI 02.05.04-33 are resolved and closed.

The staff asked the applicant in RAI 02.05.04-22 to justify the use of the upper bound Hoek-Brown effective angle of friction and cohesion for the Bass Islands Group bearing capacity but the lower bound values for the Salina Group Unit F bearing capacity. In the response to RAI 02.05.04-22 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant compared the average elastic modulus based on pressuremeter testing to the elastic modulus using the Hoek-Brown criterion for Salina Group Unit F, and concluded that the measured elastic modulus was close to the lower elastic modulus based on the Hoek-Brown criterion. However, for the Bass Islands Group, the applicant indicated that the upper bound Hoek-Brown effective angle of friction of 53 degrees matches well with the mean residual friction angle of 52 degrees, which was measured from a direct rock shear test of discontinuities.

In RAI 02.05.04-32, the staff asked the applicant to discuss why a lower value of measured effective friction angle φ'—such as mean φ' minus one standard deviation— was not used to account for the variability of the test and to provide the basis for concluding that using the upper bound Hoek-Brown cohesion is appropriate for the Bass Islands Group in terms of matching well with the measured mean φ'. In the response to RAI 02.05.04-32 dated August 6, 2010 (ADAMS Accession No. ML102210351), the applicant calculated the mean residual friction angle of the Bass Islands Group using the test results for the fractures. The applicant considered the measured values from the direct testing of bedrock discontinuities to be representative of the lower values of strength along fractures. The applicant concluded that the calculated mean residual friction angle is appropriate for establishing the design shear strength parameter, because it represents the friction angle on a fracture after enough displacement has occurred to reach the steady-state resistance along the fracture, making it representative of the lower bound value for a fracture. In addition, the applicant indicated that the disturbance of the fractures during bedrock coring and preparation for testing resulted in reduced measured friction angles, and that further reduction in the measured residual friction angles by one standard deviation is not considered necessary. The applicant conducted the bearing capacity analyses of the RB/FB and CB without considering cohesion, and therefore removed the reference to the cohesion values for the Bass Islands Group and the Salina Group Unit F bedrock.

Furthermore, in RAI 02.05.04-21, the staff asked the applicant to provide information regarding the appropriateness of normal stress values used in the direct shear stress tests and applied to find the φ' for the Bass Islands Group. In the response to RAI 02.05.04-21 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant indicated that the applied normal stresses selected for the direct shear test were the estimated in situ vertical stresses at the time of subsurface investigation. The applicant added that the normal stress used falls within the range of confining pressure used to estimate Mohr-Coulomb parameters using the Hoek-Brown criterion.

The staff reviewed the responses to RAI 02.05.04-21, RAI 02.05.04-22, and RAI 02.05.04-32 with the focus on confirming that the Hoek-Brown criterion is properly and conservatively applied to determine the Mohr-Coulomb parameters for bearing capacity evaluations. Based on the review of the responses to RAI 02.05.04-2 and its followup RAI 02.05.04-29, as described in Subsection 2.5.4.4.2 of this SER, the staff concluded that the direct shear test results from samples with horizontal or near horizontal fractures are representative of lower bound strength within the Bass Islands Group. Accordingly, the staff also concluded that the mean residual friction angle of the Bass Islands Group that was calculated from the test results of the fractures is also appropriate and conservative for establishing the friction angle φ' parameter. The staff also noted that the measured friction angle φ' values were not available for the Salina Group Unit F bedrock because samples of representative material could not be collected. The staff further noted that the average measured elastic modulus based on pressuremeter testing is close to the lower elastic modulus based on the Hoek-Brown criterion. Therefore, the staff concluded that it is reasonable to assume the lower bound friction angle φ' from the Hoek-Brown criterion for the Salina Group Unit F bedrock. Regarding the cohesion property, the staff noted that the cohesion is not taken into account for the bearing capacity analyses of the RB/FB and the CB. As a result of the RAIs, the applicant removed the reference to the cohesion values for the bearing capacity evaluation for the Bass Islands Group and Salina Group Unit F bedrock. The staff confirmed that this change was made in the revised FSAR. The staff also reviewed the normal stress values applied to the direct shear stress tests and noted that the applied normal stresses fall within the range of lower and upper bound confining pressures estimated using the Hoek-Brown criterion. Therefore, the staff concluded that the normal stresses used represent the in situ effective vertical stresses and the direct shear test results are dependable. Finally, the staff concluded that the calculated bearing capacities based on these conservatively assumed parameters still provide large safety margins against the bearing demands. RAI 02.05.04-21, RAI 02.05.04-22, and RAI 02.05.04-32 are therefore resolved and closed.

Rebound due to Excavation and Settlement Analyses

The staff reviewed Subsection 2.5.4.10.2 related to the methods and practices used by the applicant to evaluate the excavation rebound and the potential settlement of the foundations. For the settlement analysis, the applicant selected the lower bound E based on the Hoek-Brown criterion for each bedrock unit because the average E of the bedrock units will be greater than the lower bound E from the aforementioned criterion. Therefore, in RAI 02.05.04-24, the staff asked the applicant to provide information on how the modulus values were developed and to provide the basis for the assumption that the average E of the bedrock units will be greater than the lower bound E from the Hoek-Brown criterion. Also, the staff asked the applicant to explain any unconfined compression tests conducted under the safety-related foundations, and to provide additional information on the appropriateness of the selected modulus values in affecting the result of the differential settlement evaluation and total rebound.

In the response to RAI 02.05.04-24 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant explained the rationale as to why the average E of the bedrock units is greater than the lower bound E from the Hoek-Brown criterion (1) by providing the ratio of E based on laboratory tests to the E based on the average V_s for the Bass Islands Group and Salina Group Units F, E, C and B; and (2) by comparing the ratios to the lower and upper bound of the Hoek- Brown criterion. The applicant concluded that for Salina Group Units F, E, and C and the Bass Islands Group, the calculated E from average V_s and laboratory tests are both greater than the upper bound E based on the Hoek-Brown criterion. The applicant concluded that the calculated E based on the average V_s falls within the upper and lower bound E based on the Hoek-Brown criterion for Salina Group Unit B, which was also the same for Salina Group Unit F based on the pressuremeter test. FSAR Table 2.5.4-222 presents the unconfined compression test conducted close to or below the safety-related foundations. Table 2.5.4-5 of this SER summarizes the values of the average elastic modulus based on laboratory unconfined compression test results (E_{lab}) and the lower bound elastic modulus based on the Hoek-Brown criterion (E_{HBlow}). The applicant indicated that for bedrock with an RQD greater than 70 percent, E_{lab} is 1.4 to 1.9 times higher than E_{HBlow}. The applicant concluded that as the RQD decreases, the ratio E_{lab} / E_{HBlow} increases. The applicant also performed the settlement analysis using a 3D finite element program capable of calculating settlement caused by non-symmetrical loading induced by adjacent buildings in the power block area. The applicant reaffirmed the appropriateness and conservativeness of the selected modulus values, thus indicating that the site stratigraphy is relatively uniform; the subsurface material properties are consistent; and the obtained lower bound elastic modulus based on the Hoek-Brown criterion is significantly lower than the average elastic modulus obtained based on laboratory and in situ measurements.

Table 2.5.4-5 Average Elastic Modulus and Lower Bounds Elastic Modulus
(Reproduced from Table 1 in the response to RAI 02.05.04-24 dated January 11, 2010 [ADAMS Accession No. ML100130382])

Rock Unit		Average RQD	Average Modulus of Elasticity based on Laboratory Tests (E_{lab})	Lower Bound Elastic Modulus based on Hoek-Brown Criterion ($E_{HB,low}$)	Ratio $E_{lab}/E_{HB,low}$
		%	MPa (ksf)	MPa (ksf)	
Bass Island Group		54	43,025 (898,600)	2,870 (59,900)	15.0
Salina Group	Unit F	13	25,340 (529,200)	924 (19,300)	27.4
	Unit E	72	32,150 (671,500)	16,710 (349,000)	1.9
	Unit C	97	36,540 (763,200)	23,080 (482,100)	1.6
	Unit B	97	72,050 (1,504,800)	52,800 (1,102,700)	1.4
Ksf = kip per square-foot; MPa = megapascal					

The staff's review of the response to RAI 02.05.04-24 focused on the E values of the bedrock units to ensure that these values were realistically but conservatively estimated for settlement evaluation. The staff noted that the applicant had used four different methods to determine the E values of the bedrock units including the stress-strain curve from laboratory unconfined compression tests, the wave equation obtained by solving 3D equations of motion using mean V_s from P-S suspension, an empirical approach using the Hoek-Brown criterion, and the stress-strain curve from the results of in situ pressuremeter testing. Because these methods are commonly applied in evaluations of the rock mass E values, the staff concluded that the methods the applicant had employed to estimate E values are appropriate and adequate. The staff also found that the E values from different methods tend toward conformity as their RQD increases, which indicates that the applied methods are reliable. The staff further noted that among the four different methods, the lower bound E from the Hoek-Brown criterion provides the lowest value, as indicated in Table 2.5.4-6 of this SER. Accordingly, the staff concluded that it is conservative to estimate the settlements using the lower bound elastic modulus obtained based on the Hoek-Brown criterion. In addition, the staff noted that unconfined compression tests were conducted with bedrock samples from ten borings that are located close to or below the safety-related foundations based on the sample depths. Therefore, the staff also agreed with the applicant that the settlement estimates based on the lower bound elastic modulus obtained using the Hoek-Brown criterion represent the upper limit estimates, which meet the acceptance criteria required in the ESBWR DCD. Therefore, RAI 02.05.04-24 is resolved and closed.

The applicant based the settlement calculation on the referenced excavated level (rebounded position). Because the soil under the FWSC to the top of the bedrock will be removed, and noting that the referenced position is important to determine the FWSC settlements, the staff asked the applicant in RAI 02.05.04-25 to provide the rebound values at the excavated level and to clarify the referenced position of the settlement analysis for the FWSC. The staff also asked the applicant to describe the loading and construction procedures and to explain how the rebound at the excavation level is taken into account at the FWSC. In the response to RAI 02.05.04-25 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant provided the rebound values for the excavation of the FWSC at the top of the Bass Islands Group and stated that the settlement of the FWSC was not calculated from the rebound position with the excavation level at the top of the bedrock. In a finite element analysis, the applicant simulated the FWSC construction sequence to estimate the settlement and stress changes. The first stage of the sequence was to simulate the excavation, the second stage to simulate the backfill placement, third stage to introduce loads of structures at the foundation level, and the fourth stage to introduce the engineered granular backfill around the FWSC and other structures. The applicant indicated that the settlement associated with the backfill should not be accounted for in the total settlement of the FWSC foundation because, it occurs as the backfill is placed before the construction of the FWSC.

Table 2.5.4-6 Summary of Modulus of Elasticity of Bedrock Units based Test Results, and Hoek-Brown Criterion

(Reproduced from Fermi COL FSAR Table 2.5.4-228)

Rock Unit		Average Modulus of Elasticity based on Laboratory Test	Elastic Modulus of Elasticity based on Average V_s	Elastic Modulus based on Hoek-Brown Criterion			Average Modulus of Elasticity based on Pressuremeter Test
				Upper Bound	Mean	Lower Bound	
Bass Island Group		43,025 (898,600)	26,630 (556,200)	5,240 (109,500)	3,860 (80,700)	2,870 (59,900)	Not measured
Salina Group	Unit F	25,340 (529,200)	6,350 (132,600)	1,520 (31,700)	1,160 (24,200)	924 (19,300)	995 (20,800)
	Unit E	32,150 (671,500)	36,190 (755,800)	23,560 (492,100)	20,310 (424,200)	16,710 (349,000)	Not measured
	Unit C	36,540 (763,200)	48,240 (1,007,600)	29,830 (623,000)	26,780 (559,300)	23,080 (482,100)	
	Unit B	72,050 (1,504,800)	55,390 (1,156,900)	63,430 (1,324,700)	58,820 (1,228,400)	52,800 (1,102,700)	

*All units are in MPa (ksf)
Ksf = kip per square-foot; MPa= megapascal

The staff reviewed the response to RAI 02.05.04-25, including the impact on rebound and settlement calculations for the FWSC from the excavation and the construction sequence. The staff noted that the applicant had applied an appropriate excavation and construction sequence for the FWSC to calculate the rebound at the top of the Bass Islands Group bedrock during the excavation. The staff also noted that the applicant had clarified that the presented total foundation settlement for the FWSC is referenced to the top of concrete backfill and not to the rebound position. Therefore, the staff agreed with the applicant that the settlement of the FWSC foundation is triggered by the loadings of the FWSC structure and the backfill above the foundation level; and the rebound position at the top of the bedrock under the FWSC is not used to estimate the FWSC settlements. Because the applicant had clarified the excavation and construction sequence for the FWSC, the staff concluded that the total settlement analysis of the FWSC is not influenced by the rebound position at the excavation level. Consequently, RAI 02.05.04-25 is resolved and closed.

Lateral Earth Pressures

The staff's review of FSAR Subsection 2.5.4.10.3 focused on the lateral earth pressures calculation. The applicant used a surcharge pressure of 24 kPa (500 psf) to represent the compaction of the backfill behind the rigid retaining wall. In RAI 02.05.04-26, the staff asked the applicant to provide information regarding the basis for adopting a surcharge pressure of 24 kPa (500 psf). In the response to RAI 02.05.04-26 dated January 11, 2010 (ADAMS Accession No. ML100130382), the applicant presented a figure to illustrate the configuration of the increase in the lateral earth pressure associated with compaction and the formula used to evaluate the lateral pressure on the wall due to backfill compaction. The applicant's calculation showed that the lateral earth pressure was approximately 23 kPa (484 psf), assuming a small size vibratory soil compactor. Based on Black and Veatch (2007), the applicant stated that the 24 kPa (500 psf) compacted surcharge was appropriate for the additional compaction surcharges that are developed, thus indicating that the calculated lateral earth pressure of 23 kPa (484 psf) was less than those proposed. The applicant will apply at-rest lateral earth pressure at depths where the at-rest lateral earth pressures are greater than 24 kPa (500 psf).

The staff's review of the response to RAI 02.05.04-26 focused on the lateral earth pressure attributable to a surcharge pressure from compaction of backfill to ensure that the lateral earth pressure associated with compaction is adequately and appropriately taken into account. The staff reviewed the detailed calculation and found that the lateral earth pressure induced by small size compaction equipment was considered in the evaluation of the lateral earth pressure.

<u>NRC Staff's Conclusion Regarding Static Stability</u>

Based on the staff's review of the information in FSAR Subsection 2.5.4.10 and the applicant's responses to RAIs described in Subsection 2.5.4.4.10 of this SER, the staff concluded that the applicant has provided sufficient information in FSAR Subsection 2.5.4.10 which includes a static and dynamic bearing capacity evaluation; total and differential settlement evaluation; and a lateral earth pressure evaluation to meet the standard design values and to satisfy the applicable requirements of 10 CFR Part 50, Appendix S; 10 CFR Part 50, Appendix A, GDC 2; and 10 CFR 100.23.

2.5.4.4.11 Design Criteria

FSAR Subsection 2.5.4.11 refers to ESBWR DCD, Tier 2, Table 2.0-1 for a description of the standard site parameters, such as the allowable static and dynamic bearing capacity, liquefaction potential; angle of internal friction; and maximum settlement values and V_s. The ESBWR DCD latest revision changed significantly from the revision first used by the applicant. Therefore, the staff asked the applicant in RAI 02.05.04-27 to demonstrate that the Fermi 3 site meets the revised ESBWR DCD requirements in terms of the friction angle; bearing capacity analysis; and minimum V_s. In the response to RAI 02.05.04-27 dated February 15, 2010 (ADAMS Accession No. ML100540502), the applicant demonstrated that the in situ material and backfill meet the requirement of the angle of internal friction of more than 35 degrees. The applicant indicated that the residual friction angle along the discontinuities had a mean of 52 degrees, and the estimated friction angle for the Bass Islands Group dolomite bedrock had a mean of 48 degrees. The applicant stated that the well-graded granular backfill will be placed in controlled lifts with compaction, and it will result in a dense to very dense engineered backfill.

In order to meet the criteria stipulated in Note 7 of the ESBWR DCD, Tier 2, Table 2.0-1, the applicant performed the corresponding changes to the values of the dynamic loading conditions to provide the correct data for the comparison between the maximum dynamic bearing demand and the allowable bearing pressure.

To be in accordance with Note 8 of the ESBWR DCD, Tier 2, Table 2.0-1, the applicant demonstrated that the V_s at minus one sigma from the mean were enveloped by the site-related minimum V_s parameter. The applicant performed soil amplification analyses for the RB/FB, CB, and FWSC soil profiles and obtained the response motions at the foundation level. The applicant sorted the iterated V_s into rank order and obtained the 16^{th}, 50^{th}, and 84^{th} percentiles V_s profile at the seismic strain. The applicant stated that the 16^{th} percentiles represent the mean minus one standard deviation and meet the criteria for the minimum V_s parameter as referenced in the ESBWR DCD.

The staff's review of the response to RAI 02.05.04-27 focused on foundation materials to ensure their properties meet the updated requirements from the ESBWR DCD updates to the site parameters. The staff concluded that the applicant had addressed all changes needed according to the latest revision of the ESBWR DCD. Based on the applicant's information, the staff also concluded that the site foundation material properties meet the updated requirements of the ESBWR DCD. As a result of this RAI, the applicant updated the FSAR. The staff confirmed that these updates are reflected in the revised FSAR. Based on the fact that the updated requirements of the ESBWR DCD have been met, RAI 02.05.04-27 is resolved and closed.

The staff reviewed the sections of the FSAR containing the geotechnical design criteria and determined that they contained sufficient details to meet the requirements of 10 CFR Parts 50 and 100. Based on this review, the staff concluded that the applicant's design criteria for the Fermi 3 site are acceptable and meet the requirements of the applicable regulations.

2.5.4.4.12 Techniques to Improve Subsurface Conditions

In FSAR Subsection 2.5.4.12, the applicant stated that any area with open fractures in exposed foundation bedrock of the RB/FB and the CB will be filled with fill concrete. For the FWSC, the applicant stated that all soils will be removed below the foundation to the top of the bedrock and will be replaced with fill concrete to improve subsurface conditions. The staff reviewed this information and concluded that the plan for subsurface improvements will ensure the stability of the foundation and the structures to be built at this site. Therefore, the applicant's improvements satisfy the requirements of 10 CFR 100.23. The staff therefore concluded that the techniques presented to improve subsurface conditions of the Fermi 3 site are acceptable.

2.5.4.5 *Post Combined License Activities*

The applicant identifies the following commitment and ITAAC:

- Commitment (COM 2.5.4-001) – Develop a Contingency Plan for mitigation of any settlement before the start of the Fermi 3 construction.

- ITAAC Table 2.4.1-1 – Site-specific ITAAC for the fill concrete under Seismic Category I structures.

- ITAAC Table 2.4.2-1 – Site-specific ITAAC for the backfill surrounding Seismic Category I structures.

- License Condition 2.5.3-1- Geologic Mapping License Condition (see SER Subsection 2.5.3.5 for details)

2.5.4.6 *Conclusion*

NRC staff reviewed the application and confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the Fermi 3 COL FSAR related to this section.

In addition, the staff compared the additional information in the COL application to the relevant NRC regulations, the guidance in Section 2.5.4 of NUREG–0800, and applicable NRC regulatory guides. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determined that the applicant has adequately addressed COL Item EF3 COL 2.0-29-A, as it relates to the stability of subsurface materials and foundations.

The staff's review concludes that the applicant has adequately determined the engineering properties of the soil and rock underlying the Fermi 3 site through field and laboratory investigations. The applicant used the latest field and laboratory methods in accordance with the guidance in RGs 1.132, 1.138, and 1.198 to determine the required site-specific engineering properties for the Fermi 3 site and to ensure that those properties meet the design criteria outlined in the ESBWR DCD. Accordingly, the staff concludes that the applicant has performed sufficient field investigations and laboratory testing to determine the overall subsurface profile and the properties of the soil and rock underlying the Fermi 3 site. Specifically, the staff concludes that the applicant has adequately determined (1) the soil and rock dynamic properties through field investigations and laboratory tests; (2) the response of the soils and rocks to dynamic loading; and (3) the liquefaction potential of the soils.

As set forth above, the applicant presented and substantiated the necessary information to establish the geotechnical engineering characteristics of the Fermi 3 site. The staff reviewed the information and concludes that the applicant has performed sufficient investigations at the site to justify the soil and rock characteristics used in the ESBWR design, and the design analyses contain adequate margins of safety for the construction and operation of the nuclear power plant and meet the requirements of 10 CFR Parts 50, 52, and 10 CFR 100.23.

2.5.5 Stability of Slopes

2.5.5.1 *Introduction*

This FSAR section addresses the stability of all earth and rock slopes, both natural and manmade (cuts, fill, embankments, dams, etc.) whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The topics that the staff evaluated based on the data provided by the applicant in the FSAR and information available from other sources are (1) slope characteristics; (2) design criteria and design analyses; (3) results of the investigations including borings, shafts, pits, trenches, and laboratory tests; (4) properties of borrow material, compaction, and excavation specifications; and (5) any additional information to meet requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.5.5.2 *Summary of Application*

Section 2.5.5 of the Fermi 3 COL FSAR addresses the stability of all earth and rock slopes, both natural and manmade. In addition, in FSAR Section 2.5.5, the applicant provides the following:

COL Item

- EF3 COL 2.0-30-A Stability of Slopes

In FSAR Section 2.5.5, as summarized below, the applicant discusses the resolution of COL Item EF3 COL 2.0-30-A by providing site-specific information in accordance with SRP Section 2.5.5.

2.5.5.2.1 Slope Characteristics

FSAR Subsection 2.5.5.1 provides a general discussion of the slope characteristics including the slope materials, properties, groundwater, and seepage. The applicant indicated that in the Fermi 3 site area, there is no evidence of past instability or potentially unstable conditions. The applicant will place backfill in the water channels located west of the Fermi 3 site, and as a consequence, the applicant indicated that no natural or man-made slopes will be in the proximity of the site. The applicant established the grade for the power block area at an elevation of 179.6 m (589.3 ft) NAVD 88. The applicant used a slope of 12.5 horizontal to 1 vertical (12.5:1) and an 8 percent (4.5 degrees) slope angle away from the structures. The applicant concluded that slope stability in the fill will not impact Seismic Category I structures, because the foundations for all Seismic Category I structures are founded on bedrock or fill concrete that extends to the bedrock. The applicant's assumed groundwater level is at an elevation of 178.4 m (585.4 ft) NAV 88, which is equal to the flood level associated with the design basis Probable Maximum Flood (PMF). The applicant's estimated hydraulic conductivity is 76.5 to 541 m/day (251 to 1,776 ft/day). FSAR Subsection 2.5.5.1.1 refers to FSAR Subsection 2.5.4.2 and Section 2.4.12 for a detailed discussion of the subsurface material properties and the groundwater, respectively.

2.5.5.2.2 Design Criteria and Analyses

FSAR Subsection 2.5.5.2 states that the slope angle is 6.5 times less than the minimum required effective angle of internal friction for the engineered backfill or existing fill. The applicant concluded that the finished site grade has no impact on the site safety-related SSCs.

2.5.5.2.3 Boring Logs

FSAR Subsection 2.5.5.3 refers to FSAR Subsection 2.5.4.2 for a discussion of the exploration program and the drilling and sampling procedures. FSAR Appendix 2.5DD includes the soil and rock boring logs in the vicinity of the excavation.

2.5.5.2.4 Compacted Fill

The applicant will follow the backfilling and quality control requirements in the placement and compaction of the fill. The applicant indicated that the source of the fill material will be from the construction excavation or imported from local quarries.

2.5.5.3 *Regulatory Basis*

The relevant requirements of the Commission regulations for the stability of slopes, and the associated acceptance criteria, are in Section 2.5.5 of NUREG–0800. The applicable regulatory requirements are as follows:

- 10 CFR Part 50, Appendix A, GDC 2 as it relates to the consideration of the most severe natural phenomena historically reported for the site and surrounding area, with a sufficient margin for the limited accuracy, quantity, and period of time that the historical data were accumulated.

- 10 CFR Part 50, Appendix S, as it applies to the design of nuclear power plant structures, systems, and components important to safety to withstand the effects of earthquakes.

- 10 CFR 100.23 provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability and to identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from Section 2.5.5 of NUREG–0800 are as follows:

- Slope Characteristics: To meet the requirements of 10 CFR Parts 50 and 100, the discussion of slope characteristics is acceptable if the subsection includes (1) cross sections and profiles of the slope in sufficient quantity and detail to represent the slope and foundation conditions; (2) a summary and description of static and dynamic properties of the soils and rocks comprised of seismic Category I embankment dams and their foundations, natural and cut slopes, and all soil or rock slopes whose stability would directly or indirectly affect safety-related and Category I facilities; and (3) a summary and description of groundwater, seepage, and high and low groundwater conditions.

- Design Criteria and Analyses: To meet the requirements of 10 CFR Parts 50 100, the discussion of design criteria and analyses is acceptable if the criteria for the stability and design of all Seismic Category I slopes are described and valid static and dynamic analyses are presented to demonstrate that there is an adequate margin of safety.

- Boring Logs: To meet the requirements of 10 CFR Parts 50 and 100, the applicant should describe the borings and soil tests carried out for slope stability studies and dam and dike analyses.

- Compacted Fill: To meet the requirements of 10 CFR Part 50, the applicant should describe the excavation, backfill, and borrow material planned for any dams, dikes, and embankment slopes.

In addition, the geologic characteristics should be consistent with appropriate sections in RGs 1.27, 1.28, 1.132, 1.138, 1.198, and 1.206.

2.5.5.4 *Technical Evaluation*

NRC staff reviewed Section 2.5.5 of the Fermi 3 COL FSAR related to stability of slopes as follows:

COL Item

- EF3 COL 2.0-30-A Stability of Slopes

This COL item requires the applicant to provide site-specific information in accordance with SRP Section 2.5.5. The NRC staff's evaluation of COL Item EF3 COL 2.0-30-A is presented below.

2.5.5.4.1 Slope Characteristics

FSAR Subsection 2.5.5.1 provides the applicant's general discussion of the slope characteristics including the slope materials, properties, groundwater, and seepage. The applicant noted the existing water channels located west of the Fermi 3 site and plans to backfill them as part of the site development. The applicant therefore stated that there are no natural or manmade slopes, dams, embankments, or channels on or in the proximity of the Fermi 3 site. The applicant also stated that the finished grade for the Fermi 3 site will be relatively flat, with an 8 percent slope angle down from the periphery of the power block fill area without cut slopes. In addition, the applicant stated that slope stability in the fill will not impact Seismic Category I structures because the foundations for all Seismic Category I structures are founded on bedrock or concrete fill that extends to the bedrock. The applicant also discussed the groundwater and seepage conditions at the site.

The staff reviewed the site grade plan and foundation excavation sections as provided in FSAR Section 2.5.4. The staff also examined the site during the site audit (November 3–5, 2009, (ADAMS Accession No. ML14112A212). The staff also reviewed the site boring logs, the site subsurface soil profile, and the hydraulic conductivity properties of the soil to evaluate the seepage condition. The staff's analysis of these inputs is in Section 2.5.4 of this SER.

The staff's review determined that (1) all Seismic Category I structures will be founded on bedrock or fill concrete that extends to the bedrock, so a slope failure will not affect the safety of the structures; and (2) the existing water channels located west of the Fermi 3 site will be backfilled during construction; therefore, the water channels will not affect the safety of the structures. Based on these findings, the staff concluded that no slope failure at the site will adversely affect the safety of the nuclear power plant structures; and the applicant has provided sufficient information in FSAR Subsection 2.5.5.1 to satisfy the applicable criteria of 10 CFR Parts 50 and 100.

2.5.5.4.2 Design Criteria and Analyses

In FSAR Subsection 2.5.5.2, the applicant concluded that the finished site grade has no impact on the site safety-related system structures or components. In RAI 02.05.05.1, the staff asked the applicant to provide information on seismically induced lateral spreading and to discuss the monitoring plans during and after construction to detect occurrences that could affect the facility.

In the response to this RAI dated February 11, 2010 (ADAMS Accession No. ML100570311), the applicant stated that according to Youd et al. (2001), if the site is nonliquefiable, then a lateral spread will not occur. Also, the applicant stated that a liquefiable layer with all SPT $(N_1)_{60}$ values greater than 15 is too dense and dilative for a lateral spread to occur. Therefore, the applicant concluded that because the engineered granular backfill used in the site is not susceptible to liquefaction, lateral spreading will not occur at the Fermi 3 site. The applicant indicated that heave monitoring is not needed, because the expected rebound heave from the foundation excavation is less than 12.7 mm (0.5 in.). The applicant predicted that the settlement will be within the ESBWR DCD limits. To confirm the predictions, the applicant established benchmarks at the corners of selected Seismic Category I structures; at 1 m (3 ft) above the site grade; and connected to the sidewalls. The applicant indicated that the monitoring will continue until 90 percent of the expected settlement has occurred or until the rate of settlement has virtually stopped. The applicant stated that because there is no man-made earth or rock dams on the site and no anticipated seepage, no shallow sloping ground and no lateral spreading concern, the periodic examination of slopes, monitoring evidence for seepage and measurement of locals well and piezometer are not necessary after construction.

The staff's review of the response to RAI 02.05.05-1 focused on the potential for liquefaction-induced lateral spreading and its monitoring plans. The staff noted that all Seismic Category I structures are founded on either bedrock or fill concrete. The staff reviewed the applicant's response to RAI 02.05.04-20, which is documented in Subsection 2.5.4.4.6 of this SER. The staff concluded that the engineered granular backfill surrounding the Seismic Category I structures and used to develop the remainder of the site is not susceptible to liquefaction because of the $(N_1)_{60}$ values. Therefore, the staff concluded that seismically induced lateral spreading is not likely to occur. RAI 02.05.05-1 is therefore resolved and closed.

The staff considered the permanent slopes to be stable because the 8 percent (4.6 degrees) maximum permanent slope angle for the Fermi 3 site in the power block area or elsewhere is 7.6 times less than the minimum required effective angle of internal friction of 35 degrees for the engineered fill or existing fill. Based on this finding, the staff concluded that no slope failure at the site will adversely affect the safety of the nuclear power plant structures. Therefore, no slope stability analysis is necessary for the Fermi 3 site.

2.5.5.4.3 Boring Logs

The applicant provided boring logs in FSAR Appendix 2.5DD. The staff reviewed the applicant's exploration program, and the drilling and sampling procedures that are discussed in FSAR Subsection 2.5.4.2. The staff concluded that the applicant's information satisfies the requirements of 10 CFR Parts 50 and 100.

2.5.5.4.4 Compacted Fill

In FSAR Subsection 2.5.5.4, the applicant indicated that the source of the fill material will be from onsite the construction excavation or imported from local quarries. The staff reviewed FSAR Subsection 2.5.4.5, which describes the specific property requirements, site preparation, fill placement, compaction requirements, and the proper verification and installation of the engineered granular fill. The staff concluded that this information is an acceptable consideration of compacted fill properties and it satisfies the requirements of 10 CFR Part 50.

2.5.5.5 *Post Combined License Activities*

There are no post COL activities related to this section.

2.5.5.6 *Conclusion*

NRC staff reviewed the application and confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section.

In addition, the staff compared the additional information in the COL application to the relevant NRC regulations, the guidance in Section 2.5.5 of NUREG–0800, and applicable NRC regulatory guides. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determined that the applicant has adequately addressed COL Item EF3 COL 2.0-30-A, as it relates to the stability of slopes.

The staff's review concludes that the applicant has presented and substantiated information to assess the stability of all earth and rock slopes, both natural and man-made, at the Fermi 3 site. The staff reviewed the site investigations related to slope stability and concludes that (1) there are no natural or man-made slopes that could adversely affect the Fermi 3 Seismic Category I structures; (2) no safety-related retaining walls, bulkheads, or jetties are required for the site; and (3) no man-made earth or rock dams are on the site that could adversely affect the safety of the nuclear plant facilities. The staff further concludes that the applicant has provided sufficient information to meet the requirements of 10 CFR Part 50, Appendix A; GDC 2; 10 CFR Part 50, Appendix S; and 10 CFR 100.23.