15. POSTULATED ACCIDENTS AND ACCIDENT DOSE CONSEQUENCES

15.1 Technical Information in the Application

In Section 3.3 of the site safety analysis report (SSAR) submitted by Systems Energy Resources, Inc. (SERI or the applicant), as part of the early site permit (ESP) application for the Grand Gulf Nuclear Station (GGNS) site, the applicant analyzed and provided the radiological consequences of design-basis accidents (DBAs) to demonstrate that a new nuclear unit(s) could be sited at the proposed ESP site without undue risk to the health and safety of the public, in compliance with the requirements of Title 10, Section 52.17, "Contents of Applications," of the *Code of Federal Regulations* (10 CFR 52.17) and 10 CFR Part 100, "Reactor Site Criteria." The applicant did not identify a particular reactor design to be considered for the proposed ESP site. Instead, SERI developed a set of reactor DBA source term parameters using surrogate reactor characteristics. The applicant used these parameters, in conjunction with site characteristics for accident analysis purposes, to assess the suitability of the proposed ESP site. These plant parameters collectively constitute a plant parameter envelope (PPE).

The applicant developed a PPE using seven reactor designs—five water-cooled reactors and two gas-cooled reactors—though it used source terms for only three of these designs as inputs to its DBA analyses. The water-cooled reactors included in the PPE were (1) a version of the Westinghouse Advanced Plant 1000 (AP1000), (2) the certified General Electric Advanced Boiling-Water Reactor (ABWR), (3) the Atomic Energy of Canada Advanced CANDU Reactor (ACR-700), (4) the General Electric Economic and Simple Boiling-Water Reactor (ESBWR), and (5) the Westinghouse-led International Reactor Innovative and Secure (IRIS) reactor. The ACR-700 is light-water cooled but heavy-water moderated. The two gas-cooled reactors were (1) the General Atomics Gas Turbine Modular Helium Reactor (GT-MHR) and (2) the Pebble Bed Modular Reactor (PBMR). The applicant stated that it did not intend to limit the PPE values to these reactor designs, but rather to provide a broad overall outline of a design concept and to include other potential reactor designs, if they fall within the PPE parameter values.

In selecting DBAs for dose consequence analyses, the applicant primarily focused on two light-water reactors (LWRs), the certified ABWR and a version of the AP1000[1], to serve as surrogates. The applicant stated that it selected these two reactor designs because they are (or are based on) previously certified standard designs and have recognized bases for postulated accident analyses. Using source terms developed from these two designs, the applicant performed and provided radiological consequence analyses for the following DBAs:

- pressurized-water reactor (PWR) main steamline break
- PWR feedwater system pipe break
- locked rotor accident

[1] As discussed later in this section, the applicant referenced a version of the AP1000 design available at the time the applicant submitted its ESP application. Westinghouse subsequently revised the AP1000 design before the U.S. Nuclear Regulatory Commission staff's issuance of a final safety evaluation report for the AP1000 design certification.

- reactor coolant pump shaft break
- PWR rod ejection accident
- boiling-water reactor (BWR) control rod drop accident
- failure of small lines carrying primary coolant outside containment
- PWR steam generator tube failure
- BWR main steamline break
- PWR and BWR loss-of-coolant accidents
- fuel-handling accident

The applicant presented the dose consequence assessment results in a series of tables found in SSAR Section 3.3 which provide the postulated radiological consequences of the DBAs identified above at the proposed exclusion area boundary (EAB) and the low-population zone (LPZ). The dose consequence assessment results in the tables also demonstrate that any potential doses would be within the radiological dose consequence evaluation factors set forth in 10 CFR 50.34(a)(1). The applicant provided the accident-specific source terms (release rates of radioactive materials from the ESP footprint (PPE values) to the environment) and resulting site-specific dose consequences for each DBA in Tables 3.3.2 through 3.3-28 of the SSAR.

In Request for Additional Information (RAI) 3.3-1, the staff asked the applicant to clarify whether the 0- to 2-hour EAB doses presented in the SSAR are for the 2-hour period with the greatest EAB doses. In its response, the applicant stated that the 0- to 2-hour EAB doses presented in the SSAR are for any 2-hour period with the greatest EAB doses. For the ABWR, the EAB doses are calculated for the first 2 hours of the accident. The applicant clarified and provided this information in Revision 2 of its application.

In RAI 3.3-2, the staff asked the applicant to provide references and explain the methodology it used to determine time-dependent activity releases for each DBA and to provide the curie content in such releases for each DBA. The applicant stated in its response that the methodologies used for calculating time-dependent activity releases for the ABWR and AP1000 appear in the respective design certification documents. In Revision 2 of the ESP application, the applicant provided new tables in Section 3.3 to show the time-dependent activity releases in curies for each DBA. The staff finds the methodologies used in the respective design certification documents and new tables to be acceptable.

In RAI 3.3-3, the staff asked the applicant to justify the use of the alternative source term methodology, in accordance with Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants,” issued July 2000, for evaluating ABWR radiological consequences, while the ABWR design is certified with Technical Information Document (TID)-14844, “Calculation of Distance Factors for Power and Test Reactor Sites,” issued March 1962, source term and with the dose criteria in thyroid and whole body doses. The applicant revised Section 3.3.3 in Revision 2 of the application to clarify that the ABWR radiological consequence analyses are based on the TID-14844 source term. Table 3.3-1 in Revision 2 of the application provides the offsite doses in thyroid and whole body doses.

In RAI 3.3-4, the staff noted that Westinghouse has revised its χ/Q values in the AP1000 design control document (DCD) since the applicant submitted the Grand Gulf ESP application and asked whether the applicant planned to use the updated values in revising its application. The

applicant responded that it elected not to update the ESP application to incorporate the latest χ/Q values in the AP1000 design certification, stating that the AP1000 certification is still undergoing U.S. Nuclear Regulatory Commission (NRC) review that may result in additional changes in the future. The staff finds that the assumed preliminary χ/Q values used by the applicant in its accident analyses are reasonable and, therefore, adequate for the purpose of demonstrating that a reactor with design characteristics similar to an AP1000 could be sited at the proposed ESP site.

In RAI 3.3-7, the staff asked the applicant to provide, for each DBA, the doses it used for the EAB and the LPZ for the AP1000 and the ABWR, as well as the ratios of site-specific χ/Q values to design certification χ/Qs used. In its response, the applicant stated that it would revise the dose tables in SSAR Section 3.3 to show the χ/Q values and doses from the AP1000 and ABWR DCDs, in addition to the ratios of site-specific χ/Q values to design certification χ/Q values. The applicant provided this information in the SSAR Section 3.3 tables in Revision 2 of its application.

In RAI 3.3-8, the staff noted that SSAR Section 3.3 provides total effective dose equivalent (TEDE) values for the ABWR design, while the ABWR design is certified with the thyroid and whole body doses specified in 10 CFR Part 100. The staff asked the applicant to explain how the doses compare. In its response, the applicant revised the SSAR in Revision 2 of its application to include the thyroid and whole body doses from the ABWR DCD, in addition to the estimated TEDE values. The thyroid and whole body doses met 10 CFR 100.11 dose criteria and its estimated TEDE values met 10 CFR 100.21, respectively. The staff finds the revised tables to be acceptable.

15.2 Regulatory Evaluation

In SSAR Sections 1.4 and 3.3, the applicant identified the following applicable NRC regulations and guidance regarding reactor accident radiological consequence analyses:

- 10 CFR 52.17
- 10 CFR Part 100
- 10 CFR 50.34, “Contents of Applications; Technical Information”
- RG 1.3, Revision 2, “Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors,” issued June 1974
- RG 1.25, “Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors,” issued March 1972
- RG 1.145, “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants,” issued November 1982
- RG 1.183

- NUREG-0800, Revision 3, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," issued July 1997

- TID-14844

The staff reviewed SSAR Sections 1.4 and 3.3 for conformance with the applicable regulations and considered the corresponding guidance, as identified above. In its evaluation, the staff used the dose consequence evaluation factors found in 10 CFR 50.34(a)(1) that are a factor in determining the acceptability of the site, in accordance with 10 CFR 52.17(a)(1).

The regulations at 10 CFR 52.17(a)(1) require that ESP applications contain an analysis and evaluation of the major structures, systems, and components of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1). In addition, the ESP site characteristics must comply with the requirements of 10 CFR Part 100. The regulations at 10 CFR 50.34(a)(1)(ii)(D) require the following for a postulated fission product release based on a major accident:

- An individual located at any point on the boundary of the exclusion area for any 2-hour period following the onset of the postulated fission product release would not receive a radiation dose in excess of 25 rem TEDE.

- An individual located at any point on the boundary of the LPZ who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a radiation dose in excess of 25 rem TEDE.

Because the applicant has not selected a reactor design to be constructed on the proposed ESP site, the applicant used a PPE approach to demonstrate that it meets these requirements. A PPE is a set of plant design parameters that are expected to bound the characteristics of a reactor(s) that may be constructed at a site, and it serves as a surrogate for actual reactor design information. As discussed in Review Standard (RS)-002, "Processing Applications for Early Site Permits," and in Chapter 1 of this SER, the staff considers the PPE approach to be an acceptable method for assessing site suitability. For the purposes of this analysis, the applicant proposed a fission product release from the ESP footprint to the environment; the staff reviewed the applicant's dose evaluation based on this release.

15.3 Technical Evaluation

The applicant evaluated the suitability of the site under the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1) using bounding reactor accident source terms and dose consequences as a set of PPE values based on two surrogate designs, as well as site-specific χ/Q values derived from the ESP footprint. The following sections describe the staff's review of each aspect of this evaluation.

15.3.1 Selection of DBAs

The applicant selected the DBAs listed in Section 3.3.1 of this SER on the basis of the proposed AP1000 reactor design and the certified ABWR reactor design, indicating that it chose these two reactor designs because they have (or are based on) previously certified

standard designs and have recognized bases for postulated accident analyses. The staff finds that the applicant selected DBAs that are consistent with the DBAs listed and analyzed in NUREG-0800 and RG 1.183. Therefore, the staff finds that the applicant provided an acceptable DBA selection for evaluating the compliance of the proposed ESP site with the dose consequence evaluation factors specified in 10 CFR 50.34(a)(1). The applicant stated that, because of their greater potential for inherent safety, it expects the DBAs of the other reactors under consideration for the proposed ESP site to be bounded by those DBAs analyzed in the proposed AP1000 and certified ABWR DCDs. While the staff has not reviewed these designs in detail, other than the proposed AP1000 and certified ABWR, it believes that conclusions drawn regarding the site's acceptability based on the AP1000 and ABWR designs are likely to be valid for the other reactor designs the applicant is considering. At the time of any combined license (COL) or construction permit (CP) application that might be filed with respect to construction and operation of a reactor at the Grand Gulf ESP site, the applicant will confirm, and the staff will evaluate, whether the analyses considered here bound the design proposed in the COL or CP application.

15.3.2 Design-Specific (Assumed) χ/Q Values

To support its accident analyses based on the ABWR as a surrogate design, the applicant used the assumed χ/Q values in the certified ABWR DCD. In evaluating the AP1000, the applicant used those χ/Q values in the proposed AP1000 DCD that were under review by the staff at the time the Grand Gulf ESP application was submitted. Westinghouse subsequently revised the χ/Q values in the AP1000 DCD. Consequently, the assumed χ/Q values and the calculated design-specific doses used in the Grand Gulf ESP application may differ from those associated with a certified AP1000 DCD. However, the staff determined that the PPE values for the assumed χ/Q values associated with the AP1000 design used by the applicant in its accident analyses are reasonable and, therefore, are adequate for the purpose of demonstrating that a reactor with design characteristics similar to an AP1000 could be sited at the proposed ESP site. In response to RAI 3.3-7, the applicant provided AP1000 and ABWR χ/Q values it used for the version of the AP1000 and the certified ABWR that it considered. Table 15.3-1 of this SER lists these χ/Q values.:

Table 15.3-1 Design-Specific (Assumed) χ/Q Values in s/m^3

Location and Time Interval	AP1000	ABWR
0 to 2 hour EAB	6.0×10^{-4}	1.37×10^{-3}
0 to 8 hour LPZ	1.35×10^{-4}	1.56×10^{-4}
8 to 24 hour LPZ	1.0×10^{-4}	9.61×10^{-5}
1 to 4 day LPZ	5.4×10^{-5}	3.36×10^{-5}
4 to 30 day LPZ	2.2×10^{-5}	7.42×10^{-6}

15.3.3 Site-Specific χ/Qs

The staff reviewed the applicant's site-specific χ/Q values and performed an independent evaluation of atmospheric dispersion in accordance with the guidance provided in Section 2.3.4 of RS-002. The staff finds the χ/Q values to be acceptable, as described in Section 2.3.4 of this SER. Table 15.3-2 of this SER lists the site-specific χ/Q values used by the applicant and reviewed by the staff. The staff intends to include these site-specific χ/Qs in any ESP that the NRC may issue for the Grand Gulf ESP site.

15.3.4 Source Terms and Radiological Consequence Evaluations

To evaluate the suitability of the site using the radiological consequence evaluation factors in 10 CFR 50.34(a)(1), the applicant provided the bounding reactor accident source terms as a set of PPE values based on (1) the surrogate AP1000 and ABWR designs, and (2) the site-specific χ/Qs based on the ESP footprint. The source terms are expressed as the timing and release rate of fission products to the environment from the proposed ESP site. The dose consequences are then derived from the source terms using established methods.

The AP1000 source terms are based on the guidance provided in RG 1.183. The methodologies and assumptions that the AP1000 vendor, Westinghouse, used in its radiological consequence analyses are consistent with the guidance provided in RG 1.183. The resulting doses calculated for the AP1000 design using assumed site parameters meet the dose consequence evaluation factors specified in 10 CFR 50.34(a)(1) (i.e., 25 rem TEDE). The methodologies and assumptions that the ABWR vendor, General Electric, used in its radiological consequence analyses for the ABWR design are consistent with the guidance provided in RGs 1.3 and 1.25. The guidance in TID-14844 forms the basis of the ABWR source terms. The resulting doses for the ABWR reactor design using assumed site parameters meet the dose consequence evaluation factors specified in 10 CFR 100.11, "Determination of Exclusion Area, Low Population Zone, and Population Center Distance," which are 300 rem to the thyroid and 25 rem to the whole body. While the requirements of 10 CFR 100.11 are not applicable to ESPs, the staff notes that the final rule at Appendix A, "Design Certification Rule for the U.S. Advanced Boiling Water Reactor," to 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," states the following:

> The Commission has determined that with regard to the revised design basis accident radiation dose acceptance criteria in 10 CFR 50.34, the ABWR design meets the new dose criteria, based on the NRC staff's radiological consequence analyses, provided that the site parameters are not revised.

Therefore, the staff concludes that the certified ABWR design, in conjunction with assumed site parameters, meets the dose consequence evaluation factors specified in 10 CFR 100.11, as well as those specified in 10 CFR 50.34(a)(1).

In determining the potential radiological consequence doses resulting from DBAs at the proposed site, the applicant used the site-specific atmospheric dispersion factors (χ/Q values), in conjunction with the DBA radiological consequence doses and the postulated χ/Q values provided in the SSAR of the certified ABWR (SSAR/ABWR) and the proposed AP1000 DCD.

The certified ABWR and the proposed AP1000 designs met the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1) with their postulated χ/Q values.

The χ/Q values indicate the atmospheric dilution capability. Smaller χ/Q values are associated with greater dilution capability, resulting in lower radiological doses. The radiological consequence doses are directly proportional to the χ/Q values. Table 1.9-1 of the SSAR provides the site-specific χ/Q values the applicant used in its radiological consequence analyses, and Section 2.3.4 of this SER discusses the staff's evaluation of these χ/Q values.

The applicant used the atmospheric dispersion computer code (PAVAN) to derive its site-specific χ/Q values. In RAI 2.3.4-2, the staff asked the applicant to provide a copy of the PAVAN computer code input and output files used to generate the EAB and LPZ χ/Q values presented in SSAR Section 2.3.4. The applicant complied with this request in its response to the RAI.

The applicant used the ratios of the site-specific χ/Q values to those postulated in the SSAR/ABWR and AP1000 DCD to determine and demonstrate that the radiological consequence doses at the proposed site meet the requirements of 10 CFR 50.34. The estimated site-specific χ/Q values for the proposed site are lower than those postulated in the SSAR/ABWR and AP1000 DCD. The certified ABWR and the proposed AP1000 designs met the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1) with their postulated χ/Q values. Accordingly, the resulting DBA radiological consequence doses at the proposed site are lower than those provided in the SSAR/ABWR and AP1000 DCD and, therefore, meet the requirements of 10 CFR 50.34.

The staff accepts that the radiological consequences of the DBAs at the proposed site based on the AP1000 and ABWR designs are likely to be valid for the other reactor designs the applicant is considering. Whether or not the final reactor design the applicant selects for use at the Grand Gulf ESP site is in fact bounded by the acceptance made here would be subject to review during the staff's consideration of any COL or CP application. In accordance with 10 CFR 52.79(a)(1), at the COL stage, the staff will evaluate whether the design of the facility falls within the parameters specified in an ESP, should the NRC issue one for the Grand Gulf ESP site.

The staff verified the design-specific source terms the applicant provided and finds them to be consistent with those evaluated as part of the design certification reviews. Further, the staff finds that the references provided by the applicant and the methodology it used to determine timing and release rate of fission product source terms to the environment (and consequent dose consequences) from the proposed ESP site are acceptable. Therefore, the staff finds the source terms from the PPE (i.e., the ESP footprint) themselves to be reasonable and acceptable. The staff intends to include the site-specific χ/Q values as site characteristics listed in Appendix A to this SER, for use in any ESP that the NRC might issue for the Grand Gulf site.

Based on its evaluation of the applicant's analysis methodology and inputs to that analysis, the staff finds that the applicant correctly concluded that the dose consequences for the chosen surrogate designs comply with the dose consequence evaluation factors of 10 CFR 50.34(a)(1). Table 15.3-2 of this SER identifies the following site χ/Q values as appropriate for inclusion in any ESP that the NRC might issue for the Grand Gulf ESP site.

Table 15.3-2 Staff's Proposed Short-Term (Accident Release) Atmospheric Dispersion Site Characteristics (Site-Specific χ/Q Values)

Location and Time Interval	χ/Q Value
0 to 2 hour EAB	5.95×10^{-4} s/m^3
0 to 8 hour LPZ	8.83×10^{-5} s/m^3
8 to 24 hour LPZ	6.16×10^{-5} s/m^3
1 to 4 day LPZ	2.82×10^{-5} s/m^3
4 to 30 day LPZ	9.15×10^{-6} s/m^3

RS-002 calls for the staff to perform a confirmatory radiological consequence calculation. However, the design-related inputs to the applicant's dose calculation were directly extracted from design documentation previously submitted to and reviewed by the NRC in connection with design certification applications. Because the applicant simply used the ratio of the site specific a/Q values to the postulated design χ/Q values, the staff did not consider an independent calculation to be useful or necessary and, therefore, did not perform one.

15.4 Conclusions

As set forth above, the applicant submitted its radiological consequence analyses using the site-specific χ/Q values and PPE source term values and concluded that the proposed site meets the radiological consequence evaluation factors identified in 10 CFR 50.34(a)(1). Based on the reasons set forth above, the staff finds that the applicant's PPE values for source terms included as inputs to the radiological consequence analyses are reasonable. Further, the staff finds that the applicant's site-specific χ/Q values and dose consequence evaluation methodology are acceptable.

Therefore, the staff concludes that the proposed distances to the EAB and the LPZ outer boundary of the proposed ESP site, in conjunction with the fission product release rates to the environment provided by the applicant as PPE values, are adequate to provide reasonable assurance that the radiological consequences of the DBAs will be within the dose consequence evaluation factors set forth at 10 CFR 50.34(a)(1) for the proposed ESP site. This conclusion is subject to confirmation at the COL or CP stage that the design of the facility specified by the COL or CP applicant falls within the ESP PPE values.

The staff further concludes that (1) the applicant demonstrated that the proposed ESP site is suitable for power reactors with source term characteristics bounded by those of the ABWR and AP1000 without undue risk to the health and safety of the public, and (2) the applicant complies with the requirements of 10 CFR 52.17 and 10 CFR Part 100.