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15.0.3.1 *Introduction*

This section of the report describes the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of the information provided in Chapter 15, "Transient and Accident Analysis," of the Site Safety Analysis Report (SSAR), contained in Part 2 of the PSEG Site early site permit (ESP) application. The information in Chapter 15 describes the radiological consequences of design basis accidents (DBAs) for four standard reactor designs: (1) Single Unit U.S. EPR; (2) Single Unit Advanced Boiling Water Reactor (ABWR); (3) Dual Unit Advanced Passive 1000 (AP1000); and (4) Single Unit U.S. Advanced Pressurized-Water Reactor (US-APWR) to demonstrate that one or two 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 in Title 10 of the *Code of Federal Regulations* (10 CFR), Section 52.17, "Contents of Applications," and 10 CFR Part 100, "Reactor Site Criteria."

15.0.3.2 *Summary of Application*

As provided in the SSAR, the applicant used the design parameter source terms associated with each of the four chosen standard designs in conjunction with site characteristic atmospheric dispersion factors to demonstrate the suitability of the proposed ESP site. As part of the plant parameter envelope (PPE), the applicant used the source term developed for each of the following design-basis accidents (DBAs) for each of the standard designs (as applicable):

- Pressurized Water Reactor (PWR) steam system piping failures inside and outside of containment
    - (AP1000, U.S. EPR, and US-APWR)
- Boiling Water Reactor (BWR) and PWR coolant pump shaft seizure (locked rotor)
    - (ABWR, AP1000, U.S. EPR, and US-APWR)
- PWR rod ejection accident
    - (AP1000, U.S. EPR, and US-APWR)
- BWR spectrum of rod drop accidents
    - (ABWR)
- BWR and PWR failure of small lines carrying primary coolant outside containment
    - (ABWR, AP1000, U.S. EPR, and US-APWR)

- PWR steam generator tube rupture
  - (AP1000, U.S. EPR, and US-APWR)
- BWR main steam line break
  - (ABWR)
- BWR and PWR loss-of-coolant accident
  - (ABWR, AP1000, U.S. EPR, and US-APWR)
- BWR and PWR fuel handling accident
  - (ABWR, AP1000, U.S. EPR, and US-APWR)

In SSAR Chapter 15, the applicant addressed: (1) The selection of the above DBAs related to four standard designs; (2) the evaluation methodology for DBAs; (3) the source terms; and (4) the radiological consequences of each DBA pertaining to each standard design.

The applicant calculated and provided site characteristic short-term accident atmospheric dispersion factors (χ/Qs) at the Exclusion Area Boundary (EAB) and Low Population Zone (LPZ), using methodology in Regulatory Guide (RG) 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," and site-specific meteorological data. The applicant also presented the dose assessment results for the postulated DBAs listed above at the proposed EAB and the LPZ in SSAR Tables 15.4-2 (US-APWR), 15.4-4 (ABWR), 15.4-10 (AP1000), and 15.4.-19 (U.S.EPR), which demonstrate that the potential doses would be within the radiological consequence evaluation factors set forth in 10 CFR 50.34(a)(1) and 10 CFR 52.17(a)(1). In SSAR Tables 15.3-1 through 15.3-33, the applicant provided accident-specific source terms (release rates of radioactive materials to the environment for each DBA pertaining to each standard reactor design). The resulting site-specific dose consequences are also presented in the SSAR for each DBA and standard design.

15.0.3.3 *Regulatory Basis*

The applicable NRC regulatory requirements for the radiological dose consequences analyses of DBAs include the following:

- 10 CFR 52.17, "Contents of applications; technical information," as it relates to the assessment that must contain 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 paragraphs (a)(1)(ix)(A) and (a)(1)(ix)(B) of this section.

- 10 CFR Part 100, "Reactor Site Criteria," as it relates to considering evaluation factors for stationary power reactor Site Applications on or after January 10, 1997, to demonstrate that the radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34(a)(1) for type of facility proposed to be located at the PSEG Site.

- 10 CFR 50.34, “Contents of applications; technical information,” as it relates to a description and safety assessment of the site and safety assessment of facility.

The acceptance criteria adequate to meet the above requirements are located in the following guidance and reference documents:

- RG 1.145, “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants,” as it relates to providing an acceptable methodology for determining site-specific relative concentrations (χ/Q) that include considerations of plume meander, directional dependence of dispersion conditions, and wind frequencies for various locations around actual exclusion area and LPZ boundaries.

- RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” as it relates to providing guidance to licensees of operating power reactors’ acceptable applications of alternative source terms (AST); the scope, nature, and documentation of associated analyses and evaluations; considerations of impacts on analyzed risk; and content of submittals; and also identifies acceptable radiological analysis assumptions for use in conjunction with the accepted AST.

- Review Standard (RS)-002, “Guidance for Processing Applications for Early Site Permits,” as it relates to providing guidance on the staff’s process for reviewing an ESP application and developing the Safety Evaluation Report (SER) with specific technical and format guidance.

- RG 1.3, “Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors,” as it relates to providing guidance with acceptable assumptions that may be used in evaluating the radiological consequences of loss of coolant accident (LOCA) for a boiling water reactor.

- 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,” as it relates to providing guidance with acceptable assumptions that may be used in evaluating the radiological consequences of a fuel handling accident in the fuel handling and storage facility resulting in damage to fuel cladding and subsequent release of radioactive material for boiling and pressurized water reactors.

- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” as it relates to providing guidance to staff to perform safety reviews of applications to construct or operate nuclear power plants and the review of applications to approve standard designs and sites for nuclear power plants, to assure the quality and uniformity of staff safety review.

- Technical Information Document (TID)-14844, “Calculation of Distance Factors for Power and Test Reactor Sites” (March 23, 1962, Agencywide Documents Access and Management System (ADAMS) Accession number ML083380438), as it relates to providing guidance in siting evaluations and in using source terms in other design basis applications and being cited in 10 CFR Part 100 as a source of further guidance on siting analyses.

As required in 10 CFR 52.17(a)(1), ESP applications must contain an analysis and evaluation of the major systems, structures, and components (SSCs) of the facility that bear significantly on the acceptability of the site under the radiological consequence evaluation factors identified in the requirements of 10 CFR 52.17(a)(1)(ix). In addition, the ESP site characteristics must comply with the requirements of 10 CFR 100.21, “Non-Seismic Siting Criteria,” which states that radiological dose consequences of postulated accidents shall meet the criteria set forth in 10 CFR 50.34(a)(1). The radiological dose reference values in 10 CFR 50.34(a)(1) and 10 CFR 52.17(a)(1) for a postulated fission product release based on a major accident are as follows:

- 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 roentgen equivalent man (rem) total effective dose equivalent (TEDE).
- An individual located at any point on the outer 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.

15.0.3.4 *Technical Evaluation*

Using the guidance listed above, the staff reviewed SSAR Chapter 15 for compliance with the applicable regulations. Although the applicant is using the PPE approach, for the DBA radiological consequence analyses source terms for DBAs from four standard reactor designs (i.e., U.S. EPR, ABWR, US APWR, and AP1000) were evaluated individually. The applicant evaluated the suitability of the site using reactor source terms and radiological consequences based on each of the reactor technology designs, as well as site characteristic atmospheric dispersion factor (χ/Q) values.

15.0.3.4.1 Selection of Design Basis Accidents

The applicant assessed each of the DBAs that are evaluated in the design control document for each of the standard reactor designs considered. These DBAs are categorized in Section 15.0.3.2 of this report. The staff finds that the applicant selected DBAs consistent with the DBAs listed in NUREG 0800, Chapter 15 for large light-water reactors. 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 52.17(a)(1).

15.0.3.4.2 Site Characteristic Short-Term Atmospheric Dispersion Factors

Site characteristic short-term atmospheric dispersion factors are used in the radiological consequences analyses to characterize the effect of the site-specific meteorological conditions, topography, and distance to either EAB or LPZ on dose at the offsite receptors for purposes of siting. The applicant calculated short-term accident χ/Qs using RG 1.145 methodology and site-specific meteorological data. The staff’s evaluation of the site characteristic short term χ/Q values is described in Section 2.3.4 of this report. Table 15.0.3.4.2-1 of this report lists the site characteristic short-term χ/Q values calculated by the applicant.

Table 15.0.3.4.2-1 Site Characteristic Short-Term χ/Q Values

Location	Time (hr)	Site Characteristic χ/Q (sec/m^3)
EAB	0-2	4.71×10^{-4}
LPZ	0-8	8.47×10^{-6}
LPZ	8-24	5.50×10^{-6}
LPZ	24-96	2.15×10^{-6}
LPZ	96-720	5.60×10^{-7}

15.0.3.4.3 Radiological Consequences

The DBA radiological consequences analyses in the design control document (DCD) for each standard design used design reference values for the accident atmospheric dispersion factors in place of site specific values. The χ/Q values are the only input to the DBA radiological consequences analyses that are affected by the site characteristics. The estimated DBA dose calculated for a particular site is affected by the site characteristics through the calculated χ/Q input to the analysis; therefore, the resulting dose would be different than that calculated generically for the standard design in the DCD. All other inputs and assumptions in the radiological consequences analyses remain the same as in the DCD. Smaller χ/Q values are associated with greater dilution capability, resulting in lower radiological doses.

For each standard design considered, the applicant provided the postulated time-dependent release rate of radionuclides (source terms) to the environment during each DBA. Descriptions of these design-specific source terms are found in the design control document (DCD) for each standard design. The applicant incorporated these source terms into SSAR Tables 15.3-1 through 15.3-33. Different standard designs use different source terms and approaches to define the activity releases. The ABWR source terms, methodologies, and assumptions are based on the guidance in NUREG-0800, RG 1.3, and RG 1.25, and the AP1000, U.S. EPR, and US-APWR source terms are based on the alternative source term guidance outlined in RG 1.183. Because the applicant used DBA source terms derived from analyses from DCDs that are either from certified standard designs or from DCDs that are undergoing NRC review, the staff finds the PSEG SSAR DBA source terms to be not unreasonable as part of the PPE for showing compliance with requirements of 10 CFR 52.17(a)(1)(ix).

To determine the potential doses resulting from DBAs at the proposed site, the applicant used the site characteristic χ/Q values in conjunction with the DBA doses calculated using site parameter χ/Q values that were provided in each DCD. The estimated site characteristic χ/Q values for the proposed site are lower than the corresponding site parameter χ/Q values, as summarized in Tables 15.0.3.4.3-1 through 15.0.3.4.3-4 of this report.

Table 15.0.3.4.3-1 Site Parameter Short Term χ/Q Values for ABWR and Comparison to Site Characteristic χ/Qs

Location	Release Time (hr)	Site Parameter χ/Q (sec/m^3)	Site Characteristic χ/Q (sec/m^3)	χ/Q Ratio (Characteristic: Parameter)
EAB	0-2	1.37×10^{-3}	4.71×10^{-4}	0.344
LPZ	0-8	1.56×10^{-4}	8.47×10^{-6}	0.054
LPZ	8-24	9.61×10^{-5}	5.50×10^{-6}	0.057
LPZ	24-96	3.36×10^{-5}	2.15×10^{-6}	0.064
LPZ	96-720	7.42×10^{-6}	5.60×10^{-7}	0.075

Table 15.0.3.4.3-2 Site Parameter Short-Term χ/Q Values for AP1000 and Comparison to Site Characteristic χ/Qs

Location	Release Time (hr)	Site Parameter χ/Q (sec/m^3)	Site Characteristic χ/Q (sec/m^3)	χ/Q Ratio (Characteristic: Parameter)
EAB	0-2	5.1×10^{-4}	4.71×10^{-4}	0.924
LPZ	0-8	2.2×10^{-4}	8.47×10^{-6}	0.039
LPZ	8-24	1.6×10^{-4}	5.50×10^{-6}	0.034
LPZ	24-96	1.0×10^{-4}	2.15×10^{-6}	0.022
LPZ	96-720	8.0×10^{-5}	5.60×10^{-7}	0.007

Table 15.0.3.4.3-3 Site Parameter Short-Term χ/Q Values for U.S. EPR and Comparison to Site Characteristic χ/Qs

Location	Release Time (hr)	Site Parameter χ/Q (sec/m^3)	Site Characteristic χ/Q (sec/m^3)	χ/Q Ratio (Characteristic: Parameter)
EAB	0-2	1.00×10^{-3}	4.71×10^{-4}	0.471
LPZ	0-8	1.35×10^{-4}	8.47×10^{-6}	0.063
LPZ	8-24	1.00×10^{-4}	5.50×10^{-6}	0.055

LPZ	24-96	5.40×10^{-5}	2.15×10^{-6}	0.040
LPZ	96-720	2.20×10^{-5}	5.60×10^{-7}	0.025

Table 15.0.3.4.3-4 Site Parameter Short-Term X/Q Values for US-APWR and Comparison to Site Characteristic χ/Qs

Location	Release Time (hr)	Site Parameter χ/Q (sec/m^3)	Site Characteristic χ/Q (sec/m^3)	χ/Q Ratio (Characteristic: Parameter)
EAB	0-2	5.0×10^{-4}	4.71×10^{-4}	0.942
LPZ	0-8	2.1×10^{-4}	8.47×10^{-6}	0.040
LPZ	8-24	1.3×10^{-4}	5.50×10^{-6}	0.042
LPZ	24-96	6.9×10^{-5}	2.15×10^{-6}	0.031
LPZ	96-720	2.8×10^{-5}	5.60×10^{-7}	0.020

The applicant used the ratios of the site characteristic χ/Q values to the site parameter χ/Q values to demonstrate that the radiological consequences at the proposed site are within the calculated doses for each of the standard designs and, therefore, meet the requirements of 10 CFR 52.17. Site-specific DBA doses for the ABWR as given in SSAR were expressed as whole body and thyroid doses consistent with 10 CFR 100.11, which was applicable at the time of the certification of the ABWR design. Site-specific DBA doses for all other technologies evaluated are expressed in total effective dose equivalent (TEDE), consistent with 10 CFR 50.34 and 10 CFR 52.17.

The applicant provided the AP1000 site parameter χ/Q values for DBA accidents other than LOCA by referencing AP1000 DCD, Revision 17. The staff was unable to locate the site parameter χ/Q values for "All Other Accidents" accident in AP1000 DCD, Revision 17. Therefore, in RAI 4, Question 15.00.03-1, the staff requested that the applicant provide additional information about the source of "All Other Accidents" χ/Q values in SSAR Table 15.4-9. In a February 25, 2011, response to RAI 4, Question 15.00.03-1, the applicant stated that Westinghouse did provide "All Other Accidents" values in AP1000 DCD, Revision 18, including the 0-2 hour value for the EAB of 1.00E-3, instead of 8.00E-04. The applicant also stated that the larger EAB value in the AP1000 DCD will also bound the site characteristic χ/Q value for the PSEG Site. The staff finds that the site parameter χ/Q values for the AP1000 presented in SSAR Table 15.4-9 bound the more recent values in AP1000 DCD, Revision 19, and are acceptable. Therefore, the staff considers RAI 4, Question 15.00.03-1 resolved.

Currently, the U.S. EPR DCD uses two averaging periods (0-2 hours and 2-8 hours) to calculate atmospheric dispersion at the outer boundary of the LPZ, rather than the 0-8 hour value recommended in RG 1.70, "Standard Format and Content for Safety Analysis Reports for Nuclear Power Plants: LWR Edition," and RG 1.206, "Combined License Applications for

Nuclear Power Plants." The applicant calculated a site characteristic χ/Q using a 0-8 hour period, as stated in RS-002. Due to the difference in time averaging values, the applicant decided to compare its site characteristic 0-8 hour LPZ χ/Q value to the U.S. EPR site parameter 2-8 hour LPZ χ/Q value. The result is a more conservative estimate of the ratio than if the applicant had compared its site characteristic 0-8 hour LPZ χ/Q value to the U.S. EPR site parameter 0-2 hour χ/Q value. The staff finds this comparison appropriate in this case, because it leads to a more conservative ratio.

For each of the DBAs for each of the standard designs considered, the site characteristic χ/Q values for each time averaging period are less than the design's comparable site parameter χ/Q values used in the referenced DCD radiological consequences analyses. Since the result of the radiological consequences analysis for a DBA during any time period of radioactive material release from the plant is directly proportional to the χ/Q for that time period, and because the PSEG site characteristic χ/Q values are less than the comparable DCD site parameter χ/Q values for all time periods and all accidents, then the PSEG site-specific estimated total dose for each DBA is, therefore, less than the estimated total dose for each DBA for all standard designs considered.

Since each of the AP1000, U.S. EPR and US-APWR DCD Chapter 15 DBA radiological consequences analyses show that the offsite radiological consequences meet the regulatory dose requirements of 10 CFR 52.47(a)(2), and since, by the logic above, the PSEG site-specific DBA radiological consequences are estimated to be less than those calculated in the referenced design DCDs, then the applicant has sufficiently shown that the DBA offsite radiological consequences meet the requirements of 10 CFR 52.17(a)(1).

Since the ABWR DCD Chapter 15 DBA radiological consequences analyses show that the offsite radiological consequences meet the regulatory dose requirements of 10 CFR 100.11, and since, by the logic above, the PSEG site-specific DBA radiological consequences are estimated to be less than those calculated in the referenced design DCDs, then the applicant has sufficiently shown that the DBA offsite radiological consequences meet the requirements of 10 CFR 52.17(a)(1).

Based on its evaluation of the applicant's DBA radiological consequences analysis methodology and the inputs to that analysis, the staff finds that the applicant correctly concluded that the radiological consequences for each of the considered design technologies comply with the radiological dose reference values set forth in 10 CFR 50.34(a)(1) and 10 CFR 52.17(a)(1).

15.0.3.5 *Conclusion*

As set forth above, the applicant presented the radiological consequence analyses using PPE values of source terms for each of four different standard designs (U.S. EPR, ABWR, US-APWR, and AP1000) and site characteristic χ/Q values; the applicant concluded that the proposed site meets the radiological dose reference values identified in 10 CFR 50.34(a)(1) and 10 CFR 52.17(a)(1) for the PPE. Based on the technical evaluation presented in Section 15.0.3.4 of this report, the staff finds that the applicant's PPE values for source terms are not unreasonable. Furthermore, the staff finds the applicant's dose consequence evaluation methodology acceptable. In accordance with 10 CFR 52.79(b)(1), a combined license (COL) applicant referencing this ESP must either include or incorporate by reference the ESP SSAR, and the COL application must contain, in addition to the information and analyses otherwise required, information sufficient to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP.

The staff further concludes that the applicant's determined site characteristic distances to the EAB and the LPZ outer (i.e., outermost) boundary of the proposed ESP site in SSAR Table 2.0-1, in conjunction with the PPE design parameter source terms, are adequate to provide reasonable assurance that the radiological consequences of postulated DBAs for a light-water reactor of design similar to those used as a basis for the PPE will be within the radiological dose reference values set forth in 10 CFR 50.34(a)(1) and 10 CFR 52.17(a)(1).