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TERRAPOWER, LLC. – DRAFT SAFETY EVALUATION OF NAT-9391, "RADIOLOGICAL RELEASE CONSEQUENCES METHODOLOGY TOPICAL REPORT," REVISION 0 (EPID NO. L-2023-TOP-0055)

SPONSOR AND SUBMITTAL INFORMATION

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Brief Description of the Topical Report: By letter dated November 6, 2023, TerraPower, LLC (TerraPower) submitted Topical Report (TR), TP-LIC-RPT-0005, "Radiological Release Consequences Methodology Topical Report," (ML23311A139) for the U.S. Nuclear Regulatory Commission (NRC) staff's review. A separate TR, TP-LIC-LET-0093, "Radiological Source Term Methodology Report" (ML23223A235) documents the determination of the relevant radiological source terms for the proposed Natrium sodium fast reactor (SFR) nuclear power plant design.[1] The TR under review in this safety evaluation provides those three evaluation models (EMs), which can be used to determine the consequences of radiological release source terms for the proposed Natrium SFR nuclear power plant design.[2] On December 18, 2023, the NRC staff found that the material presented in the TR provides technical information in sufficient detail to enable the NRC staff to conduct a detailed technical review (ML23333A070). From May 7, 2024, through June 28, 2024, the NRC staff conducted an audit to gain a detailed understanding of the TR methodology and identify any additional information that required docketing to support the NRC staff's safety evaluation (SE) for the TR (ML24103A224). On July 26, 2024, TerraPower submitted a revision to TP-LIC-RPT-0005, renumbered as NAT-9391, Revision 0 (ML24208A181) that addressed items discussed during the NRC staff audit and other minor editorial corrections. The audit report summarizing the NRC staff's observations was issued on January 23, 2025 (ML25024A041).

For background, TerraPower's overall licensing approach for applications related to the proposed Natrium reactor design follows the Licensing Modernization Project (LMP) methodology described in Nuclear Energy Institute (NEI) 18-04, Revision 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing

[1] The referenced radiological source term methodology TR is under NRC review concurrently and has been revised and renumbered as NAT-9392, Revision 0, (ML24261B944).
[2] For clarity purposes, when this safety evaluation refers to the TR, it is referring to the TR under NRC review in this safety evaluation.

Enclosure

Basis Development" (ML19241A472). Regulatory Guide (RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," Revision 0 (ML20091L698) endorses the LMP methodology described in NEI 18-04. The EMs described in the TR are consistent with estimating the radiological consequences of accidental radiological releases to the environment to comply with relevant regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," including, in part, through the use of the LMP methodology.

REGULATORY EVALUATION

This TR was submitted in support of TerraPower's current and planned license applications under 10 CFR Part 50. Specific regulations relevant to TerraPower's radiological release consequences methodology include:

- The requirements in 10 CFR 50.34(a) describes the minimum information required for the preliminary safety analysis report (PSAR) supporting a construction permit (CP) application, including the following:
  - Title 10 CFR 50.34(a)(1)(ii)(D) requires that the PSAR provide a description and safety assessment of the site and a safety assessment of the facility. In doing this special attention must be directed to plant design features intended to mitigate the radiological consequences of accidents. This evaluation must determine that

    "(1) 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[ ] total effective dose equivalent (TEDE)

    "(2) An individual located at any point on the outer boundary of the low population zone [(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]."
  - Title 10 CFR 50.34(a)(3)(i) requires that the PSAR include the principal design criteria (PDC) for the facility. Natrium-specific PDC are provided in approved TerraPower TR NATD-LIC-RPRT-0002-A, "Principal Design Criteria for the Natrium Advanced Reactor," Revision 1 (ML24283A066). One EM in the radiological release consequences methodology is used to determine control room (CR) dose consequences to show that the design meets the radiological habitability requirements in Natrium PDC 19, "Control room." In this SE, the NRC staff is only evaluating this methodology, not PDC 19 and the corresponding CR dose criterion.
  - Title 10 CFR 50.34(a)(4) requires, in part, that "[a] preliminary analysis and evaluation of the design and performance of structures, systems, and components [(SSCs)] of the facility with the objective of assessing the risk to public health and safety resulting from operation of the facility and including determination of the margins of safety during normal operations and transient conditions anticipated during the life of the facility, and the adequacy of [SSCs]

provided for the prevention of accidents and the mitigation of the consequences of accidents."

- The requirements in 10 CFR 50.33(g)(2), requires, in part, that "[s]mall modular reactor, non-light-water reactor, or non-power production or utilization facility applicants complying with [10 CFR] 50.160 who apply for a [CP] or an operating license under [10 CFR 50] . . . must submit as part of the application the analysis used to determine whether the criteria in [10 CFR] 50.33(g)(2)(i)(A) and (B) are met and, if they are met, the size of the plume exposure pathway [(PEP) emergency planning zone (EPZ)]."

Specific guidance documents relevant to TerraPower's radiological release consequences methodology include:

- RG 1.233, Revision 0.
- RG 1.247 (For Trial Use), "Acceptability of Probabilistic Risk Assessment Results for Non-Light Water Reactor Risk-Informed Activities" (ML21235A008).
  - NEI 18-04 references the American Society of Mechanical Engineers (ASME)/American Nuclear Society (ANS) probabilistic risk assessment (PRA) standard, RA-S-1.4-2021, "Probabilistic Risk Assessment Standard for Advanced Non-Ligh Water Reactor Nuclear Power Plants," which is endorsed with exceptions in RG 1.247. The NRC staff's review was informed, in part, by guidance on the elements of a radiological consequence analysis contained in RG 1.247 and ASME/ANS RA-S-1.4-2021.
- RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," Revision 1 (ML23082A305). Specifically, section 4, "Dose Calculation Methodology" and section 5.3, "Atmospheric Dispersion Modeling and Meteorology Assumptions."
- RG 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Revision 1 (ML003740205).
- RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," Revision 0 (ML23226A036).
- RG 1.249, "Use of ARCON Methodology for Calculation of Accident-Related Offsite Atmospheric Dispersion Factors," Revision 0 (ML22024A241).
- RG 1.253, "Guidance for a Technology-Inclusive Content-of-Application Methodology to Inform the Licensing Basis and Content for Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," Revision 0 (ML23269A222).
  - Endorses NEI 21-07, Revision 1, "Technology Inclusive Guidance for Non-Light Water Reactors, Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology" (ML22060A190).

TECHNICAL EVALUATION

1.0 INTRODUCTION

TR section 1, "Executive Summary," TR section 2, "Introduction," and TR section 7, "References," provide a summary of the TR methodology which includes three EMs and an appendix describing modifications to the licensing basis event (LBE) EM for use in PEP EPZ sizing analysis, the TR objective and scope, and TR references, respectively. The remainder of the TR provides the radiological release consequences EMs for NRC staff's review and approval: section 3, "Licensing Basis Event Evaluation Model;" section 4, "Design Basis Accident Evaluation Model;" section 5, "Control Room Habitability Evaluation Model;" section 6, "Conclusions on Evaluation Models;" and the appendix, "Adaptation of Licensing Basis Event Evaluation Model to Emergency Planning Zone Sizing." For each EM described in TR sections 3 through 5, the section includes a subsection on the objective and scope of the EM, the relevant regulatory requirements and guidance, EM inputs, the computational model, and other topics pertinent to the EM. The appendix describes adjustments to the EM described in TR section 3 to provide the dose results for the PEP EPZ sizing analysis methodology as described in a separate TerraPower TR NAT-3056, "Plume Exposure Pathway Emergency Planning Zone Methodology" (ML24304B034).[3] For clarity, DBAs are a subset of the events determined to be LBEs through the NEI 18-04 LMP methodology and are handled differently from how the remainder of the LBEs are handled within this report

Notably, determination of LBE and DBA source terms for input to the EMs in the radiological release consequences methodology is outside the scope of this TR. The methodology to determine source terms for anticipated Natrium LBEs and DBAs is described in the TerraPower radiological source term methodology TR NAT-9392 (renumbered from TP-LIC-LET-0093), "Radiological Source Term Methodology Report."[4] For example, section 3.3, "Evaluation Model Inputs," of the TR describes the inputs to the LBE EM, which include information related to the LBE source term releases to the environment and site information. TR table 3-1, "Listing of Licensing Basis Event Evaluation Model Inputs," lists the model input items for which the specific values are developed through other methodologies. TR section 4.1, "Objective and Scope," similarly indicates that the determination of the DBA radiological source terms is outside the scope of the TR.

2.0 STAFF EVALUATION

2.1 Licensing Basis Event Evaluation Model

TR section 3.1, "Objective and Scope," states that the objective of the LBE EM is to determine, through a probabilistic approach, the radiological consequences of an LBE for which a representative source term has been determined. The TR states that the LBE EM is intended to be used by the applicant referencing the TR in the LMP methodology to address the 10 CFR 50.34(a)(4) requirement to provide, in part, a preliminary analysis and evaluation of the design and performance of SSCs. As described in NEI 18-04, the LMP methodology uses information from a facility-specific PRA, including consequences. The radiological source term treated in this EM defines the airborne radionuclides released from the proposed Natrium power plant design to the environment as the result of an LBE. Following the release of airborne radionuclides to the environment, this EM considers the transport of radionuclide plume segments through the atmosphere and determines the resultant consequences of exposure to the released radionuclides. The TR LBE EM analyses will produce the following radiological consequence quantities:

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[3] TR NAT-3056 is undergoing separate NRC staff review. NRC approval of TR NAT-9391, if appropriate, does not affect NRC approval or denial of TR NAT-3056.
[4] TR NAT-9392 is undergoing separate NRC staff review (ML24261B944). NRC approval of TR NAT-9391, if appropriate, does not affect NRC approval or denial of TR NAT-9392.

- TEDE to a receptor (i.e., adult individual) at the exclusion area boundary (EAB) for a 30-day exposure to the release plume and ground contamination, determined at the 5th and 95th percentile as well as the mean value.
- Integrated plant risk as the following:
    - Average individual risk of early fatality within 1 mile of the EAB,
    - Average individual risk of latent cancer fatality within 10 miles of the EAB, and
    - Probability of exceeding 100 mrem TEDE at the site boundary.

Because the LBE EM addresses the PRA-related consequence analysis information needs for the LMP methodology, the NRC staff used information in RG 1.247 on PRA consequence analysis to aid in the review and evaluate completeness of the methodology. Specifically, the NRC staff referred to section C.1.3.17, "Radiological Consequence Analysis Probabilistic Risk Assessment Element" of RG 1.247. As discussed in RG 1.247, the PRA analysis elements for a radiological consequence analysis are the following:

- radionuclide release characterization;
- site characterization;
- meteorological data analysis;
- atmospheric transport and diffusion analysis;
- protective action analysis;
- dosimetry;
- health effects analysis;
- economic factors; and
- conditional consequence quantification.

The NRC staff reviewed the LBE EM described in TR section 3 and determined that section 3 contained sufficient information to address the radiological consequence analysis PRA elements detailed in section C.1.3.17.

TR section 3.4, "Computational Model," states that the LBE EM determination of radiological consequences is performed using WinMACCS version 4.1.0,[5] or WinMACCS version 4.2.0.[6] WinMACCS is the Windows-based interface and framework for performing analyses with MELCOR Accident Consequence Code System (MACCS) computer code. MACCS is a fully integrated, engineering-level computer code developed at Sandia National Laboratories (SNL) for the NRC. MACCS simulates the impact of severe accidents at nuclear power plants and other nuclear facilities on the surrounding environment. The NRC staff also reviewed the LBE EM's use of MACCS to determine radiological consequences of an LBE source term. This review included all associated inputs and model parameters, technical rationale, and risk metrics, along with other pertinent details associated with MACCS model execution for the purposes of evaluating radiological release consequences for the proposed Natrium SFR nuclear power plant design.

SE sections 2.1.1, "Radionuclide release characterization," through 2.1.9, "Conditional consequence quantification," provide a brief description of and the NRC staff's evaluation of

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[5] SAND2022-7112, "MACCS (MELCOR Accident Consequence Code System) User Guide – Version 4.0, Revision 1," Sandia National Laboratories, 2022.
[6] SAND2023-01315, "MACCS User Guide – Version 4.2," Sandia National Laboratories, 2023.

each radiological consequence PRA analysis element outlined in RG 1.247, including the TR discussion on the use of MACCS.

2.1.1 Radionuclide release characterization

As stated in RG 1.247, section C.1.3.17, the objective of the radionuclide release characterization is to identify the attributes of the radionuclide release needed to evaluate radiological consequences. TR section 3.5, “Adaption of Release Matrix to MACCS,” describes the methods to prepare the LBE release information coming from the radiological source term methodology to provide the needed inputs to the MACCS consequence calculation code. TR table 3-1 states that the term “release matrix” refers to the time dependent, nuclide-specific release of airborne radionuclides to the environment. The NRC staff’s findings are given below for each of the topics comprising the adaptation of the release matrix for use in MACCS in subsections to TR section 3.5.

TR section 3.5.1, “Isotope Sensitivity Method,” describes the LBE EM screening approach to ensuring that all risk-significant isotopes are included in the radiological consequence analysis through an isotope sensitivity analysis. **[[**

]] The TR methodology use of DCFs from Federal Guidance Report (FGR) 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,” and FGR 12, “External Exposure to Radionuclides in Air, Water, and Soil,”[7] is consistent with the guidance in RG 1.183 for determining TEDE and is therefore acceptable. The screening approach also includes iterative MACCS runs to identify any pseudostable nuclides needed to terminate decay chains and to be added as MACCS input to complete the calculation. Therefore, the NRC staff determined that the screening approach modeling of radionuclide characteristics and biological effects is consistent with the determination of TEDE as defined in 10 CFR 50.2, “Definitions” and is therefore acceptable.

TR section 3.5.1.2, “General Isotope Sensitivity Results,” applies the screening method to sample Natrium core inventories to determine a set of important radionuclides applicable to any LBE source term that is representative of release from the proposed Natrium reactor core. This resulted in the list of **[[** **]]** in TR table 3-3, “Natrium Release Isotopes Selected for MACCS Calculations,” which represents **[[**

]] As stated in TR section 3.5.1.2, the TR table 3-3 list of radionuclides is based on sample core inventories and assumed effective release fractions and is only applicable to core damage events. The list of isotopes is not taken from the TerraPower radiological source term TR, but instead is given as a standard set that is anticipated to represent the proposed Natrium design radionuclides at risk of release and was found acceptable by the NRC staff through its engineering judgment. If a source term is input to the LBE EM that represents a significantly different inventory or effective release fractions than the ones analyzed, the methodology described in TR sections 3.5.1 and 3.5.1.1, “Pseudostable Radionuclides,” will be applied to develop an applicable set of important isotopes.

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[7] https://www.epa.gov/radiation/federal-guidance-report-no-11-limiting-values-radionuclide-intake-and-air-concentration

The NRC staff determined the screening approach described in TR section 3.5.1 is acceptable, because the isotope sensitivity calculation method used for determining the relative importance of including a given radionuclide in the radiological consequence analysis considers the radiological half-life, biological hazard, and relative abundance of the radionuclides in the core which is anticipated to result in a smaller list of radionuclides in the assessment without unacceptable loss in accuracy in dose and radiological risk results. The NRC staff determined that the iterative approach to determining the need for pseudostable radionuclide addition (e.g., radionuclides terminating decay chain) is also acceptable because it is consistent with how the guidance in RG 1.247 addresses radionuclide release characterization, and therefore, demonstrates appropriate characterization of source terms.

TR section 3.5.2, “Adaptive Plume Algorithm,” describes the LBE EM approach to modeling of radionuclide releases to the atmosphere over time (plume segments) within the MACCS calculation. The TR indicates that the adaptive plume algorithm was developed because the release matrix input to the LBE EM may include a large number of timesteps to model the release of radionuclides to the environment while version 4.1.0 of the MACCS code can only model up to 500 plume segments, requiring a consolidation in time to ensure the entire release is modeled adequately.

During the regulatory audit, the NRC staff asked for information to understand the adaptive plume algorithm as implemented in MACCS and its effect on the modeling of the plume radionuclide concentration. Specifically, the NRC staff audited TerraPower’s supporting study of the sensitivity of the dose result at the EAB to the LBE EM adaptive plume algorithm plume segment durations. The audited information confirmed the NRC staff’s understanding that modeling plume segments with longer time frames would likely result in less dispersion and therefore more conservative total dose results because the plume concentration, dispersion and heading are all held constant over the time period for the plume segment. The sensitivity study shows that doses are not significantly sensitive to varying plume segment duration in general. Therefore, the NRC staff determined that use of the adaptive plume algorithm is acceptable because it would likely result in conservative dose results and results have low sensitivity to the number of plume segments.

2.1.2 Site characterization

As stated in RG 1.247, section C.1.3.17, the objective of the site characterization is to provide information on the population distribution and patterns of land use and land cover in the vicinity and region of a site to a distance of 80 kilometers or 50 miles. TR section 3.6.4, “Plant Area,” indicates that site-specific population distribution information is user input to MACCS. The LBE EM states that instead, a uniform population distribution may be used if it is shown to be conservatively representative, i.e., results in more limiting consequences than the site-specific population distribution gives when used in the LBE EM. The TR also states that the area modeled in MACCS should be larger than the area for which consequences are determined to avoid the influence of boundary conditions. Data on land use and land cover information in the vicinity and region of a site is not provided as an input.

The NRC staff determined the LBE EM treatment of site characterization is acceptable because land use information has a negligible impact on the calculation of dose quantities, the use of a uniform population will be shown to be conservative, and the approach is consistent with previous NRC staff use of the MACCS code in reactor safety studies and the discussion of consideration of inputs for analyses using the MACCS code, as described in NUREG/CR-7270, “Technical Bases for Consequence Analyses Using MACCS (MELCOR Accident Consequence Code System)” (ML22294A091).

2.1.3 Meteorological data analysis

As stated in RG 1.247, section C.1.3.17, the objective of the meteorological data analysis is to evaluate and select the meteorological data used for the atmospheric transport and diffusion analysis. As noted in the MACCS user manual, the MACCS code requires at least one full annual cycle of hourly meteorological data as input to the atmospheric transport and dispersion model. TR table 3-1, item 3.7 identifies that the LBE EM requires input meteorological data including wind speed and direction, stability category, rain rate, and mixing height that is representative of weather conditions at the proposed Natrium power plant over the most limiting year (365 days). The NRC staff notes that this is acceptable consistent with previous NRC staff use of the MACCS code in reactor safety studies and the discussion of consideration of inputs for analyses using the MACCS code, as described in NUREG/CR-7270.

As described in TR section 3.6.1, “Data File Specifications,” in lieu of site-specific meteorological data, the user of the LBE EM may opt to use a generic meteorological data file if user shows the data to be conservatively representative of the site, i.e., results in more limiting radiological consequences than using site-specific data in the LBE EM does. Many relevant regulations reference site-specific meteorological data. In discussing the meteorological data analysis, RG 1.247 notes that the characteristics and attributes to achieve the objectives of the meteorological data analysis element are “[f]or PRAs performed prior to selecting a proposed site, postulated meteorological data . . . that are representative of a reasonable number of sites that have been or may be considered.” Although this TR is not a PRA, as noted above, the TR states that the LBE EM is intended to be used by an applicant referencing the TR in the LMP methodology, which uses information from a facility-specific PRA. Therefore, the NRC staff views the TR discussion of the methodology as the sort of analysis contemplated in the above-quoted language.

TR section 3.6.1 states that the generic meteorological data file is based on the Electric Power Research Institute (EPRI) Advanced Light Water Reactor Utility Requirements Document (URD)[8] that was developed using conservative weather characteristics from 91 U.S. reactor sites documented in NUREG/CR-2239, “Technical Guidance for Siting Criteria Development” (ML072320420). The NRC staff previously evaluated the meteorological data described in Annex B of the URD (revisions 1 through 5), for use in reactor licensing as documented in NUREG-1242, “NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document” (ML100610048). In NUREG-1242, the NRC staff discussed that the use of the URD Annex B meteorological data as a standardized set of meteorological site data is reasonable for the limited purpose of demonstrating that the design goal for dose at the site boundary has been met. The NRC staff notes that LMP uses for calculation of dose at the EAB are similar to the uses noted in the URD with respect to completeness of the data set. Given that the site information in both the URD and NUREG/CR-2239 were taken from reactor sites located within the contiguous U.S., the data may not be applicable to conditions in locations outside of the contiguous U.S. Therefore, the NRC staff imposes limitation and condition 1 described later in this SE, which limits the use of the TR to

[8] EPRI 3002003129, “Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document (URD), Revision 13,” EPRI, 2014.

sites within the contiguous U.S., with respect to the generic meteorological data file based on the URD. With limitation and condition 1, the NRC staff determined that the meteorological data in the TR LBE EM are representative of a reasonable number of sites in the contiguous U.S. that may be considered. Therefore, the TR LBE EM is acceptable because it follows the RG 1.247 guidance on site characterization performed prior to selecting a proposed site. The NRC staff notes, however, that this approval does not change the relevant regulations referencing site-specific meteorological data. It also does not constitute approval of the use of generic data instead of site-specific data in future analyses when addressing relevant regulations, including 10 CFR 50.34. Applicants referencing this TR should consider how this methodology may need to incorporate additional information in order to satisfy the regulatory requirements.

TR section 3.6.2.2, "Weather Sampling," describes the use of meteorological data in the MACCS computation to develop weather trials and capture the inherent uncertainty in the weather conditions assumed for the LBE radiological consequence analysis. The LBE EM specifies that the MACCS computation take non-uniform random samples of weather data from the meteorological data file in 36 weather bins. The NRC determined that the use of random weather sampling to assess uncertainty is acceptable because it is consistent with guidance on radiological consequence analysis for PRAs in RG 1.247.

2.1.4 Atmospheric transport and diffusion analysis

As stated in RG 1.247, section C.1.3.17, the objective of the atmospheric transport and diffusion analysis is to perform an evaluation that provides time dependent air and ground concentrations resulting from a release of radioisotopes. TR section 3.6.2, "Atmospheric Dispersion," describes the LBE EM use of the Gaussian plume segment model in MACCS. The NRC staff determined the use of the MACCS Gaussian plume segment model is acceptable because it is based on Gaussian plume dispersion algorithms found acceptable for use in other regulatory contexts requiring evaluation of atmospheric dispersion, as described in RG 1.145 and RG 1.249. However, the NRC staff also notes that the atmospheric dispersion models described in the accident-related guidance referenced above are based on weather conditions that are expected in the contiguous U.S. (i.e., the lower 48 states where the developmental field studies were conducted). Certain model algorithms may not be applicable to sites subject to more extreme weather or persistent cold conditions. See for example, the discussion in RG 1.249, regulatory position 2.1, "Meteorological Data Input." Therefore, consistent with the discussion above in SE section 2.1.3, the NRC staff also imposes limitation and condition 1 described later in this SE, which limits the use of the TR deterministic and probability-based atmospheric dispersion models to sites within the contiguous U.S. unless technical justification for their applicability is provided. Further, consistent with the discussion in SE section 2.1.3, this SE does not constitute approval of the use of generic meteorological data instead of site-specific meteorological data in future analyses when addressing relevant regulations, including 50.34.

The NRC staff evaluated the TR section 3.6.2 description of the MACCS input selections that define the computational model with respect to atmospheric dispersion modeling. The LBE EM includes the selection of dispersion parameters appropriate to the characteristics of the area and distance ranges under consideration. Nearfield effects, such as elevated releases of radioactive material; building wake effects such as wake-induced downwash and enhanced diffusion due to nearfield wake-induced turbulence; plume meander; and plume rise, are adequately characterized. The use of the Ramsdell and Fosmire model incorporated into

MACCS is consistent with other NRC-developed dispersion codes used for nearfield dispersion analysis, such as the ARCON[9] code.

In the LBE EM, dispersion parameters are supplied in the form of a Eimutis and Konicek (E&K) lookup-table based on the selection of the plume meander model for nearfield evaluation (i.e., atmospheric transport and dispersion within about 500 meters). This is consistent with the recommendation in SAND2021-6924, "Implementation of Additional Models into the MACCS Code for Nearfield Consequence Analysis" (ML21257A120), which describes how to use MACCS models, that the E&K parameterization of the Pasquill-Gifford diffusion curves, implemented via lookup-table, should be used to model nearfield dispersion. During the regulatory audit, the NRC staff confirmed that the diffusion coefficients specified in the LBE EM are the same as typically used in dispersion models acceptable to the NRC. The NRC staff notes that since the dispersion parameter input is implemented via a lookup-table rather than a power law, the propagation of uncertainties may be challenging. However, the NRC staff determined that the use of the lookup-table in the LBE EM is acceptable without an explicit assessment of uncertainty, because it is based on a widely used approximation to the Pasquill-Gifford diffusion curves, is consistent with Ramsdell and Fosmire model used in the EM, and the use of the E&K parameterization is consistent with implementation in NRC-developed atmospheric dispersion codes, as well as technical guidance for MACCS in NUREG/CR-7270

The deposition of airborne material on the ground by wet and dry deposition and the resulting depletion of the airborne material with downwind distance are discussed in TR section 3.6.3, "Plume Deposition." The LBE EM deposition modeling in dry conditions is dependent on the deposition velocity and is radionuclide-specific and dependent on aerosol size. Wet deposition is modeled according to the weather trial considered. Algorithms and coefficients used to estimate wet and dry deposition are based on particle sizes as described in the MACCS user guide description of the models. TR table 3-1, item 3.3 identifies that the element-specific aerosol particle size distribution of all radionuclides considered in each release matrix is a user input to the LBE EM. The NRC staff determined that the deposition modeling is acceptable because it is consistent with reactor risk analyses using the MACCS code described in NUREG/CR-7270.

TR section 3.6.3 also describes the LBE EM's use of the MACCS CHRONC module to evaluate the individual risk of latent cancer from long-term exposure to radionuclides deposited on the ground. The LBE EM models the effects of weathering on the ground contamination concentration, as well as resuspension of the radionuclides to the atmosphere by defining values to calculate weathering factors and resuspension coefficients to affect the radionuclide exposure in the groundshine and inhalation transport pathways. The NRC staff determined this modeling of long-term ground contamination is acceptable because it is consistent with reactor risk analyses using the MACCS code described in NUREG/CR-7270.

2.1.5 Protective action analysis

As stated in RG 1.247, section C.1.3.17, the objective of the protective action analysis is to characterize the impact of mitigation measures such as evacuation, sheltering, relocation, and interdiction of land, food, or water on doses resulting from releases of radioisotopes. TR section 3.6.5, "Protective Actions," describes the conservative approach taken for early phase

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[9] Pacific Northwest National Laboratory, "ARCON 2.0 User's Guide," dated May 24, 2021 (ML22004A219).

protective actions in the MACCS calculations, in which no credit is taken for ingestion of potassium iodide or evacuation. In other words, the TR LBE EM conservatively considers no evacuation in consequence calculations. The LBE EM describes that the relocation model in MACCS is effectively turned off by setting the relocation dose to an unphysically high value. The NRC staff determined this approach is acceptable because it results in a conservative determination of the radiological consequences.

TR section 3.6.5 also describes the LBE EM use of the MACCS CHRONC module to evaluate the individual risk of latent cancer from long-term exposure to radionuclides deposited on the ground. The LBE EM models the intermediate- and long-term phase protective actions such as land decontamination and condemnation based on reaching specified dose levels. The NRC staff determined that the description of the modeling of intermediate- and long-term phase protective actions is acceptable because it is consistent with recommendations in NUREG/CR-7270 and reflects the relevant Environmental Protection Agency (EPA) Protective Action Guides (PAGs).[10] In the regulatory audit TerraPower clarified that dose reduction factors associated with occupancy of structures or vehicles will be described, and their basis documented in the analysis supporting a license application, not in the TR methodology. TerraPower also stated in the audit that the values would generally be consistent with NUREG/CR-7270. The NRC staff will evaluate this in its review of a future license application referencing the TR methodology.

2.1.6 Dosimetry

As stated in RG 1.247, section C.1.3.17, the objective of the dosimetry PRA analysis element is to identify the analyses needed to estimate doses to offsite populations, arising from airborne and deposited radioisotopes. The TR discusses dosimetry in section 3.6.6., "Dosimetry," with supporting information in sections 3.1," Objective and Scope," 3.2, "Regulatory Requirements and Guidance," and 3.6.7, "Radiological Consequences." The TR states that radiological consequences in the LBE EM are modeled in the MACCS code in terms of organs of risk. These are organs for which DCFs are provided in the MACCS DCF data file prepended with either "A" to denote an acute dose or "L" to denote a lifetime dose. The organs of risk considered in the LBE EM are listed in TR table 3-5, "Listing of Organs of Risk for MACCS Calculations," including an effective organ to model the TEDE. The NRC staff determined that the information on organs of risk is acceptable because it is consistent with reactor risk analyses using the MACCS code described in NUREG/CR-7270, as well as the guidance in RG 1.183 on use of DCFs from FGR 11 and FGR 12 to calculate TEDE.

The risk of early fatality is computed using the hazard function given by equation 3-35 of the MACCS user guide. The factors for each organ considered in the LBE EM, to be used in equation 3-35 from the MACCS user guide, are given in TR table 3-6, "Early Fatality Parameters for MACCS Calculations." The MACCS code is capable of computing latent cancer fatality risk with a linear-quadratic model. The quadratic portion of this model is disabled by specifying a linear factor of one, a quadratic factor of zero, and a dose limit for the linear-quadratic relationship of zero for all organs. The risk of latent cancer fatality is then computed from the fraction of the population that is susceptible to the latent cancer, the lifetime risk factor for a

[10] The EPA PAGs are reference values for radiation doses that warrant preselected protective actions (e.g., evacuation or sheltering-in-place) for public protection, if the projected dose received by an individual in the absence of protective action exceeds the PAGs. The most recent version of the PAGs is given in the January 2017 EPA PAG Manual (EPA-400/R-17/001), available at https://www.epa.gov/radiation/protective-action-guides-pags.

cancer fatality, and the dose and dose-rate effectiveness factor. The values for these parameters are listed in TR table 3-7, "Latent Cancer Fatality Parameters for MACCS Calculations." The NRC staff determined the information on calculation of the risk of early fatality and risk of latent cancer fatality, including the parameter input values listed in TR tables 3-6 and 3-7, is acceptable because it is consistent with the reactor risk analyses using the MACCS code, as described in NUREG/CR-7270.

The TR description indicates that all relevant short- and long-term exposure pathways are identified and included as appropriate for the results of interest. The TEDE is computed considering inhalation dose, cloudshine, and groundshine. The NRC staff determined the calculation of TEDE as described in the LBE EM is acceptable because all pathways are identified and considered, as appropriate, in the MACCS calculation, consistent with the NRC regulatory guidance in RG 1.183 for estimating TEDE.

With respect to the calculation of individual risk of early fatality and latent cancer, the age and gender characteristics of the offsite population are not clearly identified in LBE EM, but dose coefficients consistent with FGR 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides," are used. This reflects an age- and gender-averaged adult population. The NRC staff determined the LBE EM calculation for the risk metrics acceptable because the dosimetry is based on FGR 13, which is a recognized information source developed by the EPA as a resource for the federal government.

TR section 3.1 states that the LBE EM consequences should be calculated by the user for a 30-day exposure period to determine the peak individual TEDE at the EAB, the probability of exceeding 100 mrem TEDE at the site boundary, and the average individual risk of early fatality within 1 mile of the EAB. Within the LBE EM, the average individual risk of latent cancer fatality within 10 miles of the EAB is calculated for a 51-year chronic exposure period in addition to the initial 30-day early exposure period. The NRC staff determined the LBE modeling of the exposure periods acceptable because it is consistent with the description in NEI 18-04 of the dose quantity to be compared to the LMP frequency-consequence target, the QHO figures of merit for early fatality risk and latent cancer fatality risk and is reasonable for the evaluation of the cumulative probability per plant-year of exceeding the 100 mrem TEDE at the site boundary as described in the LMP.

2.1.7 Health effects analysis

As stated in RG 1.247, section C.1.3.17, the objective of the health effects analysis is to assess the risk of early or latent health effects, either fatal or nonfatal, or both, arising from acute and chronic exposure to released radioisotopes. TR section 3.1 lists the four radiological consequences assessed in the LBE EM:

- The TEDE dose received by a receptor on the EAB considering the dose due to inhalation of airborne radionuclides, radiation shine from airborne radionuclides, and radiation shine from radionuclides deposited on the ground, determined at the 5th and 95th percentile as well as the mean value.
- The probability of exceeding 100 mrem TEDE at the site boundary.
- The average individual risk of early fatality within 1 mile of the EAB.
- The average individual risk of latent cancer fatalities within 10 miles of the EAB.

Additional information on the health effects modeling is given in TR sections 3.6.6, “Dosimetry,” and 3.6.7, “Radiological Consequences.” The LBE EM dose-response models use information from FGR 13 to estimate the risk of health effects. The LBE EM is based on the linear no-threshold (LNT) dose-effect model that serves as the basis for the NRC's radiation protection regulations. The NRC staff determined the LBE EM acceptable with respect to the health effects analysis because the list of cancer fatality sites in the human body is consistent with FGR 13 and the list of early fatality health effects is consistent with those identified in NRC reactor risk studies with consequence analyses which cover similar situations (i.e., NUREG-1150[11] and the State-of-the-Art Reactor Consequence Analyses (SOARCA)[12]), as well as in NUREG/CR-7270. In addition, the NRC staff determined the use of the MACCS code in the LBE EM to be acceptable because the MACCS code incorporates dose-response models from FGR 13.

2.1.8 Economic factors

As stated in RG 1.247, section C.1.3.17, the objective of the economic factors PRA analysis element is to assess the economic impact of releases of radioisotopes, including the economic impact of protective actions taken to limit exposure to released material. However, this PRA analysis element is not applicable to the evaluation of the LBE EM since the figures of merit in the LMP do not include economic costs. The LMP methodology, as endorsed in RG 1.233, does not use economic factors or cost-benefit analysis to determine events, classify SSCs, or evaluate the adequacy of defense-in-depth, consistent with the requirements in 10 CFR 50.34 which it addresses.

2.1.9 Conditional consequence quantification

As stated in RG 1.247, section C.1.3.17, the objective of the conditional consequence quantification is to integrate the models and data developed in the preceding technical elements to quantify results of interest. The NRC staff notes that the LBE EM uses the MACCS code for the purposes it was developed and well within the limits of its applicability as described in numerous published reports and documentation accompanying the code. The NRC staff determined that the MACCS model inputs and accompanying data files and specifications are acceptable for use in the LBE EM because they are well documented in the TR and are consistent with sample problems supplied with MACCS, input parameter guidance (i.e., NUREG/CR-7270), and accepted practices from published literature. Safety analysis code verification and validation is out of scope for the review of this TR.

The TR does not provide sufficient information for the NRC staff to determine if sources of model and parameter uncertainty for each element of the analysis are identified. However, based on its engineering judgment, the NRC staff determined that the uncertain parameters that contribute significantly to radiological consequences were analyzed and conservatively bounding values were prescribed in the LBE EM. TR section 3.7, “MACCS Analysis Uncertainty Methodology,” describes the LBE EM uncertainty methodology, including parameter sensitivity and uncertain parameter treatment. The TR states that the impact of significant sources of model and parameter uncertainty on results of interest were analyzed and that sensitivity analyses will be used to identify sensitive parameters, which will be addressed using Monte

[11] NUREG-1150, “Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants,” NRC, 1990 (ML120960691).
[12] NUREG-1935, Parts 1 and 2, “State-of-the-Art Reactor Consequence Analyses (SOARCA) Report,” NRC, 2012 (ML12332A053).

Carlo methods to sample from a probability distribution, in the analyses performed in support of future license applications that reference the TR methodology. The TR identifies NUREG/CR-7270 as one potential source of probability distributions for many MACCS input parameters. It also lists other sources that are consistent with NUREG-1855, “Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making,” (ML17062A466). The TR also states that, in order for an entity to use this TR, for the treatment of uncertainty with regard to the source term input, that entity will follow one of the methods described in TR section 3.7, depending on the treatment of uncertainty utilized in the development of the source term. The NRC staff determined the treatment of uncertainty is acceptable because it is consistent with the NRC’s approach in SOARCA and established approaches to uncertainty analyses (i.e., NUREG-1855).

TR section 3.6.2.2, “Weather Sampling,” describes the use of weather sampling to quantify the effect of the variability in meteorological conditions on the results of interest (e.g., TEDE at the EAB), as reflected in the input parameters related to meteorological observations. The LBE EM addresses the uncertainty in the weather in combination with the variability in meteorological conditions by specifying the use of meteorological data for the most limiting year if using site-specific data, as stated in TR table 3-1, Item 3.7. TR section 3.6.7 describes the use of MACCS outputs to estimate the mean, 5^{th}, and 95^{th} percentile results. The NRC staff determined that weather sampling approach is acceptable because it is consistent with the NRC’s approach in probabilistic consequence analyses (i.e., SOARCA).

2.1.10 NRC staff overall determinations on the LBE EM

Based on its review as discussed above, the NRC staff determined that the LBE EM is acceptable, subject to limitation and conditions described later in this SE, because it provides sufficient information for the user of the TR methodology to provide estimates of LBE radiological consequences for use in the LMP methodology consistent with the non-light water reactor radiological consequence analysis PRA elements detailed in section C.1.3.17 of RG 1.247. The NRC staff also determined that the LBE EM consequence analysis results when used in the LMP consistent with RG 1.233 are sufficient to address the analysis requirements in 10 CFR 50.34(a)(4). In addition, the NRC staff determined that the LBE EM identifies a PRA consequence analysis tool (MACCS) which is an acceptable tool for use in this EM because it is an NRC-developed, widely used PRA analytical tool specific to consequence analysis.

2.2 Design Basis Accident Evaluation Model

TR section 4, “Design Basis Accident Evaluation Model,” describes the TerraPower Natrium EM for DBA radiological consequence analysis. The TR states that the DBA EM provides a conservative, deterministic approach to determine the dose consequences of DBAs to be used in the LMP methodology. The dose consequences a future applicant would determine by using this EM are the highest TEDE dose received over any 2-hour period by a receptor on the EAB considering contributions due to inhalation and radiation shine from airborne radionuclides (i.e., inhalation and submersion dose) and the 30-day TEDE dose received by a receptor at the outer LPZ boundary also considering inhalation and submersion dose. Applicable criteria associated with the dose consequences are in 10 CFR 50.34(a)(1)(ii)(D)(1) and 10 CFR 50.34(a)(1)(ii)(D)(2) which specify a limiting dose of 25 rem TEDE for each DBA.

TR section 4.1, "Objective and Scope," states that the DBA source terms are derived from the design basis events (DBEs) evaluated in the LBE EM (TR section 3) by only taking credit for safety-related SSCs to mitigate dose consequences.

TR section 4.1 also states that the DBA EM does not include explicit treatment of atmospheric transport to receptor location. Instead, entities relying on this report would determine atmospheric dispersion factors separately and use them with the DBA EM. Therefore, methods to estimate atmospheric dispersion factors for evaluation of DBAs are outside the scope of the TR. The NRC staff will evaluate whether the applicants have acceptably used the referenced TR methodologies for the specific methods used to calculate DBA radiological source terms and atmospheric dispersion factors used as input to the DBA consequence analysis during the review of an application that references the TR and implements the DBA EM. Though outside the scope of the TR, the NRC staff anticipates that the atmospheric dispersion factors used in the DBA radiological consequence analyses will be shown to be representative of the specific site in the application that implements this TR.

TR section 4.3, "Evaluation Model Inputs," provides information on the inputs into the DBA EM radiological consequences methodology. Table 4-1, "Listing of Design Basis Accident Evaluation Model Inputs," states that the inputs are the time-dependent, nuclide-specific release of airborne radionuclides to the environment (release matrix) and release-specific atmospheric dispersion factors from the most limiting locations for the EAB and LPZ. TR section 4.3 also re-iterates that the determination of the DBA radiological source term and atmospheric dispersion factors used as input with DBA EM are outside the scope of the TR.

TR section 4.4, "Computation Model," states that the Released Radionuclide Consequence Analysis Tool (RRCAT) code version 1.0 is used to determine inhalation and submersion doses. The TR executive summary and TR section 4.4 state that the RRCAT code was developed to accept the radiological source term from the TerraPower radiological source term methodology as input and calculate doses equivalently to the NRC-developed RADTRAD[13] code, which is used by the NRC staff to evaluate DBA radiological consequence analyses. TR section 4.4 also states that RRCAT was used because it allows for timestep-specific releases, which RADTRAD is not capable of. The TR states that the models contained in RRCAT can calculate dose equivalently to RADTRAD since it follows the guidance contained in RG 1.183, uses DCFs from FGR 11 and 12, and uses half-life and decay progeny from FGR 12.

The NRC staff reviewed information in TR section 4 and supporting audit documentation on the RRCAT computer code to determine if the use of RRCAT is appropriate for DBA dose consequence analysis. Through audit of the RRCAT documentation, the NRC staff confirmed that the models within RRCAT are used to calculate receptor dose from airborne plume sources from inhalation and submersion in the release plume consistent with the guidance in RG 1.183 and similar to the RADTRAD code. TR section 6.1 also indicates that the RRCAT code is controlled through the user's approved quality assurance program in accordance with 10 CFR appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." The code requires the input of time-dependent radioisotope release information, nuclear data, DCFs, and **[[ ]]**. The NRC staff audit of the RRCAT documentation confirmed that the RRCAT computer code employs the same dose estimation models used by RG 1.183 and uses the breathing rates and DCFs consistent with RG 1.183, as described in TR section

[13] NUREG/CR-7220, "SNAP/RADTRAD 4.0: Description of Models and Methods," Information Systems Laboratory, Inc., 2016 (ML16160A019).

4.4. The NRC staff reviewed the RRCAT code only to determine if it implements the DBA EM consistent with the TR description and makes no conclusion as to the acceptability of the RRCAT code itself.

TR section 4.5, "Atmospheric Dispersion," describes the specific input of time-averaged atmospheric dispersion factor values to ensure that the most limiting dose is calculated. TR section 4.6, "Offsite Dose Consequences," discusses the use of assumed offsite breathing rates, as well as accident time periods from RG 1.183. The NRC staff determined that the calculation methods described in TR sections 4.5 and 4.6 are acceptable because they are consistent with RG 1.183 for DBA radiological consequence analysis assumptions and inputs.

Based on its review as discussed above, the NRC staff determined that the DBA EM described in the TR is acceptable because it provides sufficient information for the user of the methodology to calculate DBA radiological consequences for use in the LMP methodology, consistent with the DBA radiological consequence analysis guidance in RG 1.183. Therefore, the TR provides sufficient information such that a user applying the TR could demonstrate compliance with the safety analysis offsite dose criteria in 10 CFR 50.34(a)(1)(ii)(D). In addition, the NRC staff determined that the DBA EM identifies a DBA consequence analysis tool (RRCAT) which provides deterministic dose results and provides information on use of the tool to ensure that the dose results are appropriately representative of the proposed Natrium facility and are consistent with the guidance in RG 1.183.

Though outside the scope of this TR, the NRC staff notes that when dispersion factors are determined, the user should consider the basis for atmospheric dispersion models as discussed above in SE section 2.1.4.

2.3 Control Room Habitability Evaluation Model

TR section 5 describes the TerraPower Natrium EM for control room habitability (CRH) radiological consequence analyses. The TR states that this EM is used to determine the dose consequences required to demonstrate habitability in the CR in conformance with Natrium PDC 19 (ML24283A066).[14] As it relates to the dose criteria for control room radiological habitability analyses, Natrium PDC 19 states, in part: "Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent, as defined in § 50.2 for the duration of the accident." The specific dose consequences calculated in the CRH EM are the 30-day TEDE dose received by a CR receptor considering inhalation and submersion dose, as well as gamma radiation shine from airborne radionuclides external to the CR, built up on filtration equipment, and held in a compartment before release to the environment. Natrium PDC 19 would be met, in part, by limiting the CR dose consequences to 5 rem TEDE for each source term for which dose consequences are determined with this EM.

TR section 5.3 "Evaluation Model Inputs," provides a list of inputs as described in TR table 5-1, "Listing of Control Room Habitability Evaluation Model Inputs." This table states that the inputs to the CRH EM are the time-dependent, nuclide-specific release of airborne radionuclides to the environment, specification of releases as aerosols or vapors, the physical description of the

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[14] The NRC staff notes that approval of this TR, if appropriate, does not constitute approval of PDC 19. PDC 19 is outside the scope of this review and will be considered during the review of CP application for applicants referencing this TR.

compartment from which radionuclides are released to the environment, the atmospheric dispersion factors from the release location to each CR air intake location, and the description of the CR including the dimensions, the description of heating, ventilation, and air conditioning systems including all flow paths and in-leakage from the environment and filtration equipment.

Similar to the LBE and DBA EMs, the methods to determine the CRH EM input source terms and dispersion factors are outside the scope of the TR. As noted above in SE section 1.0, the methodology to determine radiological source terms is described in a separate TerraPower topical report TR NAT-9392, which is currently undergoing NRC staff review. NRC staff will evaluate the acceptability of the specific methods used to calculate CR atmospheric dispersion factors, and modeling of the CR used as input to the CRH consequence analysis during the review of an application that references this TR and implements the CRH EM. The NRC staff anticipates that the atmospheric dispersion factors used in the DBA radiological consequence analyses will be shown to be representative of the specific site in the application that implements this TR.

TR section 5.4, "Computational Model," states that the EM will be used to calculate the inhalation and submersion doses delivered to the receptor inside the CR. Like the DBA EM, the CRH EM utilizes the RRCAT code to calculate the CR doses. However, the CRH EM involves use of the **[[ ]]** with some additional methodology steps to result in evaluation of **[[ ]]** To understand if the use of **[[ ]]** and the additional factors to account for **[[ ]]** is appropriate for CR dose analysis, the NRC staff evaluated the information contained in TR section 5, along with an example calculation made available during the regulatory audit to enhance understanding of the TR discussion. The NRC staff's evaluation of the RRCAT code is described above in SE section 2.2 for the DBA EM. The NRC staff audit of the RRCAT documentation also confirmed that the RRCAT computer code employs the same dose estimation models used by the NRC-developed RADTRAD code and is consistent with guidance on CR dose analyses in RG 1.183, as described in TR section 5.4. The NRC staff reviewed the RRCAT code only to determine if it implements the CRH EM consistent with the TR description and makes no conclusion as to the acceptability of the RRCAT code itself.

TR section 5.5, "Shine Dose," describes the CRH EM proprietary approach to calculating shine dose to the CR receptor. As discussed in TR section 5.4, **[[ ]]**

The CRH EM utilizes **[[ ]]** to calculate gamma shine dose to the most limiting CR receptor location. **[[ ]]**.

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[15] **[[ ]]**

[16] **[[ ]]**

The NRC staff notes that **[[**

]] Therefore, the NRC staff determined that the use of these computer codes is acceptable for the purpose described in the CRH EM. In the regulatory audit, the NRC staff had access to an example calculation for determination of **[[ ]]**. The audited information showed an example of the use of the CRH EM, including potential inputs based on preliminary Natrium design information and conservative shine dose modeling. The NRC staff used the example calculation to confirm the information provided in the CRH EM method for calculating shine dose in the CR. The NRC staff determined that the method to calculate shine dose in the CR is acceptable because the method produces integrated CR dose results that include inhalation, submersion, and shine pathways using the stated computer codes.

TR section 5.6, "Control Room Dose Consequences," discusses the specific input of time-averaged atmospheric dispersion factor values to ensure that the most limiting dose is calculated, guidance on specifying the CR model assumption inputs, as well as the assumed breathing rate, and CR occupancy factors taken from RG 1.183. The NRC staff determined that the calculation methods described in TR section 5.6 are acceptable because they are consistent with RG 1.183 for CR radiological consequence analysis assumptions and inputs.

TR section 5.7, "Uncertainty Treatment," states that the LMP DBE and major accident source terms are input to the CRH EM to demonstrate conformance with the proposed Natrium PDC 19 CR radiological habitability criterion. The TR states that the proposed Natrium CR is non-safety-related with special treatment (NSRST). The CRH EM accounts for the uncertainty related to the behavior of the NSRST SSCs through use of bounding conservative assumptions to provide a deterministic dose assessment. The TR states that the conservative assumptions should bound realistically expected behavior of CRH EM credited NSRST SSCs. The NRC staff determined that the CRH EM treatment of uncertainty is acceptable because it is anticipated to result in a reasonably conservative estimate of the CR dose based on considering the uncertainty in the expected behavior of the CR by making bounding conservative assumptions. The NRC staff will evaluate the inputs and assumptions used to model the CR and other SSCs that are credited in the CR dose analyses in its review of an application which references this TR to implement the CRH EM.

Based on its review as discussed above, the NRC staff determined that the CRH EM described in the TR is acceptable because it is consistent with the DBA CR radiological consequence analysis guidance in RG 1.183. It also provides sufficient information for the user of the TR methodology to provide estimates of CR radiological consequences to show that the Natrium PDC 19 is met, in part. In addition, the NRC staff determined that the CRH EM identifies **[[**

]] to ensure that the dose results are appropriately representative of a Natrium facility.

Though outside the scope of this TR, the NRC staff notes that when dispersion factors are determined, the user should consider the basis for atmospheric dispersion models as discussed above in SE section 2.1.4.

2.4 Appendix – Adaptation of LBE EM for EPZ Sizing

TR section 8, "Appendix - Adaptation of Licensing Basis Event Evaluation Model to Emergency Planning Zone Sizing," describes minor changes to the LBE EM described in TR section 3 for use in the TerraPower PEP EPZ sizing methodology provided in TR NAT-3056, which is undergoing separate NRC review. These changes ensure that the dose results calculated at the proposed PEP EPZ boundary are relevant for comparison to the PEP EPZ sizing criteria in NAT-3056 which address the PEP EPZ size requirements in 10 CFR 50.33(g)(2). The NRC staff agrees that the changes to the LBE EM MACCS modeling described in TR section 8 would result in the output of mean and 95^{th} percentile TEDE for a 96-hour exposure, and 24-hour acute red bone marrow dose relevant for comparison to the PEP EPZ sizing criteria in NAT-3056. The NRC staff determined that the adapted LBE EM is acceptable because it provides dose results in the form of TEDE to an individual from a 96-hour exposure at various distances to address the PEP EPZ requirement in 10 CFR 50.33(g)(2). The NRC staff also notes that it provides information needed for the TerraPower's PEP EPZ sizing methodology with respect to dose aggregation and evaluation of early deterministic health effects. The NRC staff's determination of the acceptability of the TerraPower PEP EPZ sizing methodology with respect to the requirements in 10 CFR 50.33(g)(2) is currently under review.

LIMITATIONS AND CONDITIONS

The NRC staff identified the following limitations and conditions, applicable to any licensee or applicant referencing this TR.

1. Application of the methodology in this TR with respect to the described deterministic and probability-based atmospheric dispersion modeling analyses and use of generic meteorological data is limited to sites within the contiguous United States unless technical justification for their applicability is provided.

2. The conclusions reached in this SE are not valid if a process other than that described in NEI 18-04 is used to perform the Natrium safety analysis.

CONCLUSION

NRC staff determined that NAT-9391, Revision 0, subject to the limitations and conditions discussed above, provides an acceptable approach to develop analyses to aid in the determination of site-specific radiological release consequences for proposed Natrium reactor designs. Accordingly, the NRC staff concludes that the subject TerraPower TR can be used in developing radiological consequence analyses for DBAs and LBEs in accordance with the regulatory requirements in 10 CFR 50.34(a)(1) and (4), to assess the Natrium CR radiological habitability criteria in PDC 19 provided in accordance with the regulatory requirements in 10 CFR 50.34(a)(3)(i), and to support PEP EPZ sizing analysis in accordance with the regulatory requirements in 10 CFR 50.33(g)(2), for prospective TerraPower Natrium reactor CP or operating license applications under 10 CFR Part 50.

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