Required Analyses for Informing Emergency Planning Zone Size Determinations

Task 1.4 Report for User Need NSIR-2017-002

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Contents

1 Introduction

In Task 1 of User Need NSIR-2017-002 dated 25 July 2017, the Office of Nuclear Security and Incident Response (NSIR) requested that the Office of Nuclear Regulatory Research (RES) undertake research to review the dose assessment methodologies that informed the plume exposure pathway (PEP) and ingestion pathway (IP) emergency planning zone (EPZ) size determinations in NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (Nuclear Regulatory Commission 1978); and, specifically, to determine if the probabilistic dose versus distance methodologies can be generalized to inform planning zones for various nuclear facilities. The first three subtasks of Task 1 were addressed in Compton, Barr and Esh 2018. The final three subtasks of Task 1 are as follows:

- Subtask 1.4 Provide a list of analyses that applicants would need to provide during licensing to justify their selected EPZ sizes.
- Subtask 1.5 Describe the methods of verifying and validating the analysis inputs (evaluating the licensing application).
- Subtask 1.6 Describe any qualitative and quantitative assessment errors or uncertainties, and sensitivities of the parameters to dose.

This report addresses subtask 1.4, focused on the analyses required for a both a PEP EPZ and an IP EPZ. At a high level, the analyses needed for determination of an ingestion planning zone would be similar to those for the plume exposure EPZ. However, estimating doses from ingestion pathways that could arise from accident releases can be challenging, requiring the development of a large number of model parameters. In addition, ingestion exposures would generally be a longer term problem, and there will generally be longer times available to identify and interdict contaminated food and water relative to plume exposure. These considerations may be important in dose assessments supporting the identification of an ingestion planning zone but would be challenging to capture quantitatively. In order to interdict food pathways effectively, contaminated areas need to be identified and the food producers in those areas need to be notified to limit distribution of potentially contaminated fresh produce to market. An assessment of the capabilities to carry out such dose projections and producer notifications in a time frame sufficient to avoid exceeding ingestion PAG doses is not evaluated in this report. Given these

considerations, only the general steps for determination of a potential IP EPZ are provided, should that be needed.

2 List of Required Analyses

The analyses needed to support a radiological dose assessment for an EPZ size evaluation consistent with the approaches used in NUREG-0396 are described in this section and summarized in the flow chart shown in Figure 1 of this report. This flowchart was adapted from Figure 1 of Compton, Barr and Esh 2018, which was intended to represent the methodologies employed in NUREG-0396.

To accommodate the range of potential technologies and potential analytical approaches, detailed prescriptive requirements are not provided. The analyst would develop the detailed specific requirements based on this general approach. Although the generalized methodology is based on NUREG-0396 — which only considered risks associated with large light water reactors — the list of analyses identified in this document are expected to be applicable to a wide range of nuclear facilities. The analyst may evaluate published sources of information to help structure the analysis and identify the detailed specific requirements for conducting the analysis for a specific design. For example, the ASME/ANS Level 3 Probabilistic Risk Assessment (PRA) Standard (American Society of Mechanical Engineers / American Nuclear Society 2017) may prove to be a useful source for the types of information needed to perform an analysis of the radiological consequences of accidents at nuclear facilities. It should be noted that most of the steps in the generalized methodology are subject to uncertainty. A characterization of the uncertainties in the elements supporting the assessment would be needed to evaluate the ability of the dose-distance assessment to support the intended application, and is therefore addressed in the final step of the methodology.

2.1 Key Assumptions

Key assumptions used to develop the list of required analyses include the following:

- The atmospheric release pathway is assumed to be the risk-dominant contributor to offsite doses (i.e., no consideration of direct exposures or releases to liquid pathways).
- Adequate information on radiological source terms is assumed to be available. For beyond design-basis-accident (BDBA) analyses requiring consideration of likelihood, adequate information from a PRA that is judged to be of acceptable scope, level of detail, and degree of

realism for its intended purpose or application on either the absolute or relative frequencies of these source terms is assumed available.

- The atmospheric release is assumed to consist of neutral density non-reactive aerosols or gasses (with radioactive decay and in-growth corrections as appropriate). If a release pathway requires more complex atmospheric transport modeling, additional analyses may be needed.
- Use of a straight-line Gaussian plume segment-type atmospheric dispersion model (with modifications as needed to account for near-field dispersion phenomena) to estimate atmospheric concentrations is assumed to be appropriate. Such models are generally most suitable for relatively simple transport situations, such as open and level terrain, relatively steady meteorology, and relatively close distances (<10 km) (AMS 1977 Committee on Atmospheric Turbulence and Dispersion 1978). If a more advanced method for dispersion modeling is used, the details of the methodology described in this document may need to be adapted to account for the use of such models.
- A specified exposure duration must be assumed to estimate doses, and no credit for protective actions is assumed over the specified exposure period.

2.2 Problem Formulation

The initial step is to identify dosimetric criteria and the associated dosimetric measures to be used to inform EPZ size determination, including the rationale for selecting the specific criteria. For the plume exposure pathway EPZ, the two sets of dosimetric criteria are those associated with EPA early phase protective action guides (total effective dose of 1-5 rem over an assumed four day exposure period as discussed in U.S. Environmental Protection Agency 2016) and the dose associated with the potential for early health effects (commonly taken as an acute whole body dose of 200 rad over 24 hours for the prevention of significant early health effects; cf. Nuclear Regulatory Commission 1978, as well as Table 3-2 of U.S. Environmental Protection Agency 2016). For ingestion pathways, the applicable dosimetric criteria would be based on FDA guidance of 0.5 rem committed effective dose equivalent or 5 rem committed dose equivalent to any specific organ due to ingestion of contaminated food, whichever is more limiting (Food and Drug Administration 1998). The criteria, or any surrogates for these criteria (such as using FDA derived intervention levels as surrogates for the ingestion PAGs), would need to be

identified with a sufficient level of detail to allow the analyst to identify assumptions needed in order to estimate the dose.

2.3 Source Term

For the source term evaluation, a NUREG-0396 based analysis would identify release scenarios for which doses would be assessed, considering a range of accident conditions from design basis accidents (DBA) to beyond DBA. For BDBA scenarios, the frequencies would need to be evaluated to allow quantitative consideration of the relative likelihood of a range of accidents. The analyses in NUREG-0396 used a limiting DBA source term, and appear to have considered all available sources terms from WASH-1400. Therefore, a technical basis for screening of any identified release scenarios from quantitative consideration (for example, on the basis of low likelihood or very long accident progression times) would need to be provided. The categorization of accidents, including any category bounds based on frequency including consideration of uncertainty, should be explained.

For each release scenario for which doses are assessed, a quantitative radiological source term would be developed by specifying atmospheric release characteristics such as the time dependent isotopic release rates to the atmosphere, release durations, release locations, physical/chemical form, plume buoyancy, etc. The accident radiological source terms should be estimated for the specific facility using accepted analysis methods and codes.

2.4 Meteorological Data Development

An analysis to develop meteorological data may be needed to evaluate a range of meteorological conditions in a probabilistic fashion. Alternately, conservative transport and dispersion conditions may be assumed, although the conservatism of the selected conditions would require evaluation to ensure that the combination of parameters selected for transport and dispersion modeling was in fact conservative. The data needs of the selected atmospheric transport model (see section 2.5) should be considered in the selection of meteorological data. Selection of a source of meteorological data would include evaluation of data such as wind speeds, atmospheric stability, precipitation, mixing height, etc., for temporal and geographical representativeness. The analysis of meteorological data would also require an assessment of the quality and completeness of the data. It should be noted that meteorological data is site specific. However, some applications could require assessments that are not site specific.

An explanation of the appropriateness of the meteorological data used for such assessments would be needed to evaluate the analysis.

2.5 Atmospheric Transport Model

An atmospheric transport model appropriate for the range of distances under consideration would be identified. In NUREG-0396, Gaussian-type models were used for atmospheric transport. For these types of models, dispersion parameters appropriate to the characteristics of the area and distance ranges under consideration should be identified, and conceptual approaches for the treatment of near-field effects such as elevated releases, building wake effects, plume meander, plume rise, etc., should also be identified. The selection of an atmospheric transport model would also require selection of a conceptual approach for treatment of wet and dry deposition. Any assumptions of the atmospheric transport model should be identified so that the analyst can evaluate the suitability of the model for their particular application.

2.6 Exposure Model

As part of this analysis the relevant exposure pathways should be identified; for example, exposure to both airborne and deposited radioactivity from atmospheric releases would involve both external (groundshine and cloudshine) and internal (inhalation of airborne material during cloud passage or as a result of resuspension) exposure. Exposure due to ingestion of contaminated foodstuffs requires an identification of the specific types of foodstuffs to be modeled (for example, dairy or meat animal pathways, leafy or non-leafy green vegetables, etc).

Assumptions regarding the geographic distribution of the receptor population, if any, should be identified. Estimation of peak centerline doses as a function of distance only implicitly assumes that no credit is being taken for the distribution of population around the site.

In order to assess the dose, the exposure parameters (e.g., shielding factors, breathing rates, exposure durations, etc.) would need to be characterized. In NUREG-0396, no credit for pre-planned protective actions such as evacuation or sheltering was assumed, and these would be reflected in how factors such as the exposure durations and shielding factors were selected. The selection of an exposure duration may be informed by the dosimetric criteria being evaluated, but would require identification.

For ingestion pathways, a large number of model parameters may require specification. For example, parameters related to transport of radionuclides through food chains would need to be identified, and

assumptions regarding dietary intake (consumption rates, fraction of foodstuffs assumed to be contaminated, etc) need to be identified. The duration over which ingestion is assumed to occur would be part of the specification of the exposure model.

2.7 Dose Estimation

The dose estimation is carried out by combining the results of the release, transport, and exposure assessment with a recognized source of dose conversion factors to estimate dose-distance curves for comparison to the dosimetric quantities identified in the problem formulation step. The distance(s) at which the dose is evaluated should be identified and explained. For example, the dose may simply be estimated at the site boundary to demonstrate that it is sufficiently low, or may be evaluated over a range of distances from the site boundary.

2.8 Probabilistic Dose Aggregation

The method for aggregating doses from different source terms, given consideration of their frequencies, should be identified. For example, analyses with DBA source terms may simply present dose-distance curves conditional upon the occurrence of the source term without consideration of frequency. For severe accidents (BDBA), dose-distance results may be aggregated using frequency information developed in step 2 to evaluate the likelihood of exceeding a particular dosimetric criteria as a function of distance.

The likelihood of exceeding the relevant dosimetric criteria due to variability in both accident sequences that give rise to radiological source terms and in meteorological conditions should be discussed. Methods used to compare the dose assessment results (which would be characterized by a distribution reflecting variability in meteorological conditions) to the dosimetric criteria (which is a single dose value) should be identified. For example, the dosimetric criteria may be compared to the mean, median, maximum, or some other statistic of the distribution.

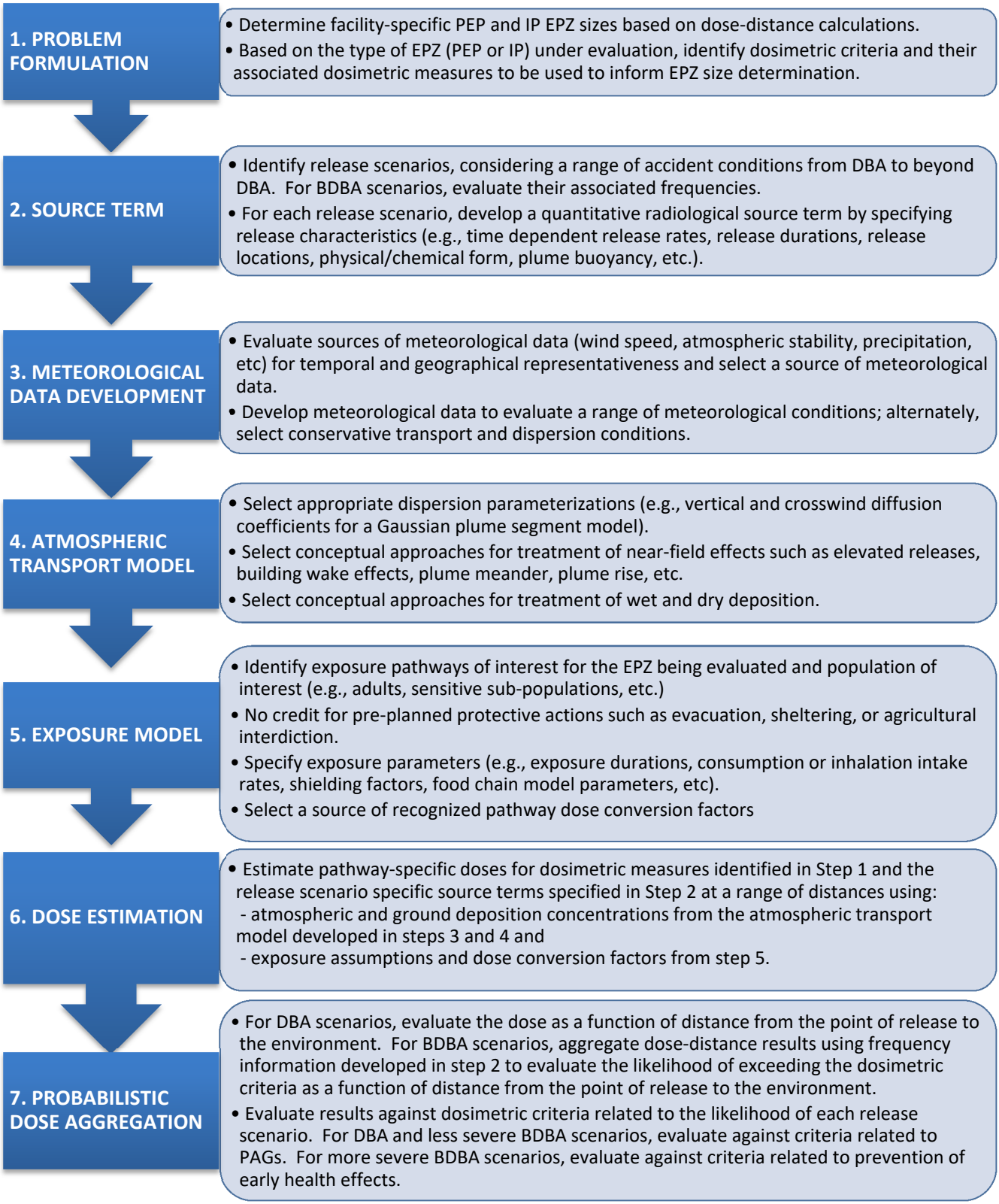
Because there can be uncertainties in each of the analyses supporting the evaluation, any significant uncertainties that could affect this comparison should be identified and qualitatively characterized.

3 Conclusions

The analyses needed to support a radiological dose assessment for an EPZ size evaluation consistent with the approaches used in NUREG-0396 are described in Section 2 and summarized in the flow chart shown in Figure 1 of this report. The figure was updated from Figure 1 of Compton, Barr and Esh 2018,

to reflect lessons learned in identifying analyses that would be needed in employing the methodologies. For example, it was determined that the identification of exposure pathways of interest was more appropriately captured under Step 5. Also, the wording of Step 7 (Probabilistic Dose Aggregation) was clarified to emphasize that the probabilistic dose aggregation step comprises a substep to aggregate doses and a subsequent substep to compare the results against the dosimetric criteria.

Figure 1: Required Analyses to Support a Radiological Dose Assessment for an EPZ Size Evaluation



List of Acronyms

PEP: Plume Exposure Pathway

IP: Ingestion Pathway

EPZ: Emergency Planning Zone

DBA: Design Basis Accident

BDBA: Beyond Design Basis Accident

PAG: Protective Action Guide

Bibliography

American Society of Mechanical Engineers / American Nuclear Society. *Standard for Radiological Accident Offsite Consequence Analysis (Level 3 PRA) to Support Nuclear Installation Applications (ASME/ANS RA-S-1.3-2017).* La Grange Park, IL: American Nuclear Society, 2017.

AMS 1977 Committee on Atmospheric Turbulence and Dispersion. "Accuracy of Dispersion Models." *Bulletin of the American Meteorological Society* 59, no. 8 (1978): 1025-1026.

Compton, K., J. Barr, and D. Esh. *Generalized Dose Assessment Methodology for Informing Emergency Planning Zone Size Determinations (ML18064A317).* Washington, DC: U. S. Nuclear Regulatory Commission, 2018.

Food and Drug Administration. *Accidental Radioactive Contamination Of Human Food And Animal Feeds: Recommendations For State And Local Agencies.* Rockville, MD: U.S. Department of Health and Human Services, Food and Drug Administration, 1998.

Nuclear Regulatory Commission. *Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans In Support Of Light Water Nuclear Power Plants (NUREG-0396 / EPA 520/1-78-016).* Washington, DC: U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, 1978.

U.S. Environmental Protection Agency. *PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents (EPA-400/R-16/001).* Washington, DC: U.S. Environmental Protection Agency, 2016.