Contract No.:

This manuscript has been authored by Savannah River Nuclear Solutions (SRNS), LLC under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

A COMPARISON OF TRITIUM DISPERSION METHODOLOGY FOR ACCIDENT ANALYSIS IN U.S. DEPARTMENT OF ENERGY COMPLEX FACILITIES

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Total number of pages: 26

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Fig. 3. TED Dose Results with Distance for Four Modeling Options of DOE-STD-3009-2014 with SRS Meteorological Data, and three-minute and two-hour averaging times applied for MACCS2 Option 2 and 3.

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ABSTRACT

A comparison of three United States (U.S.) Department of Energy (DOE) Standard DOE-STD-3009-2014 dispersion modeling protocol options has been performed assuming a ground-level release of tritium oxide source term. The options are characterized by differing sets of assumptions and inputs that allow incorporating greater user flexibility and realism into the modeling and subsequent analysis. The three options used to evaluate atmospheric dispersion include: (1) Use of U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145; (2) Application of a DOE-approved toolbox code and application of conservative input parameters; and (3) Use of site-specific methods and parameters as defined in a site/facility specific DOE-approved modeling protocol.

Option 1 dose results are the lowest of the three sets of results at close-in distances, but are the highest for distances beyond approximately 3,000 m, reflecting the distance-dependent NRC plume meander model. Option 1 doses also reflect a lower minimum wind speed and

consideration of G stability. Option 3 dose results are consistently lower than the Option 2 results by a factor of 2.2 reflecting the higher vertical dispersion values calculated from the crediting site-specific surface roughness. Option 2 and 3 results are obtained with DOE Central Registry computer software reflect default parameters in Option 2, and more site-specific input with Option 3. An averaging time of two hours leads to dose results that are lower than those obtained with an averaging time of three minutes by a factor of 2.5 due to the higher crosswind dispersion parameter values. This effect is due to the larger crosswind dimension of the plume with increasing averaging time using the Gifford meander model. A sensitivity case study indicates appreciable differences are observed between results obtained with the NRC Regulatory Guide 1.145 temperature difference (ΔT) method and those with U.S. Environmental Protection Agency (EPA) EPA-454/R-99-005 methodology for stability class categorization. A second sensitivity case suggests that crediting deposition, hold-up or other retention of tritium may be difficult to defend from a regulatory perspective, recognizing region of transport characteristics and accounting for reemission phenomenon. In terms of recommending one of the three options for modeling tritium releases in Documented Safety Analysis (DSA) applications, the Option 2 approach (Application of a DOE-approved toolbox code and conservative input parameters - without crediting tritium deposition) is the simplest model for source to receptor distances of 500 m or greater. Option 3 requires additional resource commitment and DOE authority approval, but may provide regulatory relief for certain accident scenarios. These recommendations apply to deterministic DSA dispersion analysis but are not extended to best estimate, realistic analyses such as those supporting probabilistic safety analyses.

I. INTRODUCTION

U.S. Department of Energy (DOE) nuclear facilities, including those nonreactor nuclear facilities storing, processing, and handling tritium, must meet the applicable Code of Federal Regulation (i.e., 10 C.F.R. Part 830) requirements for the preparation of documented safety analyses (DSAs).[1] The safe harbor primary methodology for performing this function, DOE Standard DOE-STD-3009-2014 (*Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*), was revised in late 2014 and contains three options for performing the atmospheric dispersion and consequence analysis.[2] The dispersion analysis and the initial step of quantifying the source term support the estimation of DSA radiological dose estimates. The dose estimates are applied as part of a process for determining whether structure, system, component (SSC) need to be identified to prevent or mitigate radiological exposures from postulated accident events in the analyzed facility. This paper assumes a unit source term of tritium oxide and compares the three dispersion modeling options. Specifically, the primary focus is on the atmospheric transport and dispersion (ATD) differences among the three options rather than subsequent pathway or biokinetic considerations.

Each of the DOE-STD-3009-2014 options is characterized by differing sets of assumptions and inputs that allow incorporating greater user flexibility and realism into the modeling and subsequent analysis. In this paper, radiological exposure results for the three DOE-STD-3009-2014 options are compared for a hypothetical unit tritium oxide release for an eastern U.S. DOE site. The DOE Central Registry code, MACCS2, Version 1.13.1, is applied for Options 2 and 3, and the three sets of results are compared to those obtained with the tritium radiological dispersion code, UFOTRI.

Key objectives of the analysis are to compare the three options and to identify sources of the differences in the radiological dose consequence to the maximally exposed offsite individual (MOI). The MOI is a hypothetical individual defined to allow dose or dosage comparison with numerical criteria for the public. This individual is an adult typically located at the point of maximum exposure on the DOE site boundary nearest to the facility in question (ground level release), or may be located at some farther distance where an elevated or buoyant radioactive plume is expected to cause the highest exposure (airborne release).[a] In practice, the energetics, or transport and dispersion characteristics of the source term may influence the maximum exposure location, and this distance may be different from the closest location relative to the point of release, but not under the control of the site or facility.

II. METHODOLOGY

The two main steps in the DOE accident radiological dose calculation are: (1) the determination of the *source term,* which is the amount of respirable radioactive material that is released as a result of the postulated accident scenario, and (2) the *radiological dose calculation,* which includes the evaluation of the downwind air concentration from the point of release and quantification of the radiological concentration at the receptor location, and the associated Total Effective Dose (TED) based on the integrated committed dose to all target organs, accounting for a fifty-year commitment from direct exposures. With respect to the tritium oxide source term, the chief radiological concern is the airborne pathway, and inhalation and skin absorption of tritium. In particular, results are calculated and compared for the three options presented in DOE-STD-3009-2014 for calculating the individual dose to the MOI.

The three options presented in DOE-STD-3009-2014 for the radiological dose calculation are based on different methods for determining the atmospheric relative concentration or χ/Q values that represents the normalized dilution of the radioactive material in the plume as it travels from the source location to the downwind location of the MOI. During transport, dilution occurs through various mechanisms that include effects for dispersion through atmospheric turbulence and depletion through deposition. The three methods for determining the χ/Q value are summarized as follows:

- Option 1: Manual calculation consistent with the methodology described in the Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*.[3]
- Option 2: Calculation using a DOE-approved toolbox code and applying a specified set of conservative parameters.
- Option 3: Calculation using site-specific methods and parameters as defined in a site/facility specific DOE-approved modeling protocol.

II.A Dispersion Software

In addition to what is largely a spreadsheet exercise to implement Option 1, two Gaussian computer models are applied to support the objectives of the methodology comparison. The first is DOE Central Registry model, MACCS2, a general purpose ATD code capable of modeling several hundred radionuclides, and in a limited way, tritium. The second is the tritium-specific model, UFOTRI. This section briefly summarizes the two computer models.

II.A. 1 MACCS2 – Department of Energy Central Registry Version 1.13.1

The DOE Office of Environment, Health, Safety and Security maintains a list of software in that has been evaluated against the department's Safety Software Quality Assurance (SSQA) requirements and related safety software guidance. The software is deemed Central Registry, or "toolbox" software, or codes. These codes are used by DOE contractors to perform calculations and to develop data used to establish the safety basis for DOE nuclear facilities and their operation, and to support the variety of safety analyses and safety evaluations developed for these facilities. Included in the set of toolbox codes is MELCOR Accident Consequence Code System, Version 2, or MACCS2, a Gaussian plume segment model for calculation of radiological atmospheric dispersion and consequences due to postulated atmospheric releases of radionuclides from nuclear facilities.[4,5]

MACCS2 is maintained by Sandia National Laboratories (SNL) and has been updated since its release in 1998. It is the chief consequence code used in probabilistic safety analysis for numerous commercial nuclear power plants throughout the world. In the DOE Complex, it is the most applied software tool for deterministic consequence analysis. Specifically, use of MACCS2 in the DOE applications is primarily to support decision-making on control selection mostly in the identification of safety structures, systems, and components (SSCs). The Central Registry-recognized version is 1.13.1 from 2004,[b] and is the version applied for modeling tritium oxide releases using Options 2 and 3 as described above.[6]

For most DSA applications, MACCS2 use follows stratified random sampling of qualified, site meteorological data, where each hour of the year's data is analyzed. Also, of importance in the present application, the deposition velocity of tritium oxide is user-specified as an explicit input parameter.

II.A.2 UFOTRI Version 4.0

The second computer software applied in this analysis is Unfallfolgen-modell für Tritiumfreisetzungen, or UFOTRI.[7,8] UFOTRI is a Gaussian trajectory model tritium especially developed to treat the unique phenomena associated with the atmospheric transport and dispersion of tritium species. The software treats relevant phenomena with respect to tritium oxide (HTO) and tritium gas (HT) atmospheric releases. It allows for reemission after HT/HTO deposition and models all relevant transfer processes in the environment (soil, plant, and animal) after the hypothetical release event (during which atmospheric transport plays the dominant role) during plume passage and post-plume passage phases. It is coupled to a first order compartment module, which describes dynamically the longer-term behavior of the two different chemical forms of tritium in the food chain.[9]

UFOTRI has been used in the BIOMOVS II (Biological Model Validation Study) with the aim to test and validate environmental tritium models, and has been a major software tool for tritium safety applications with respect to ITER and other international projects.[10] Although meteorology can be analyzed probabilistically equivalent to one of the sampling modes in the MACCS2 software, in this study the UFOTRI model is executed with persistent, user-prescribed meteorology as a limited sensitivity case. In contrast to MACCS2, the deposition velocity and re-emission of tritium oxide are evaluated implicitly by the UFOTRI code as part of its dynamic model.

II.B Interpretation of DOE-STD-3009-2014 Options

As noted previously, there are three ATD dispersion options listed in the DOE-STD-3009-2014 dispersion modeling protocol. An important initial step in dispersion modeling is the collection and processing of meteorological data. In Option 1, the analyst is directed to follow the meteorological data guidance within NRC's Regulatory Guide 1.23, *Meteorological Monitoring Programs for Nuclear Power Plants*.[11] For Options 2 and 3, the guidance in both Regulatory Guide 1.23 and in Environmental Protection Agency (EPA)-454/R-99-005, *Meteorological Monitoring Guidance for Regulatory Modeling Applications,*[12] are acceptable means of generating the meteorological data with the caveat that these two guidance documents should be evaluated for their applicability to the site or facility being evaluated. For Option 3, the impact of local surface roughness on the data may be considered.

Regulatory guidance in DOE-STD-3009-2014 states that appropriate χ/Q values at the general public receptor shall be determined using a method consistent with application of Regulatory Guide 1.145, using either the directionally independent or directionally dependent method. For directionally independent assessments, this calculation represents the 95th percentile conditions, as described in Regulatory Guide 1.145, Section C.3, Regulatory Position 3 (Determination of 5 Percent Overall Site χ/Q Value). For directionally-dependent calculations this calculation represents the 99.5th percentile, as described in Regulatory Guide 1.145, Section C.2, Regulatory Position 2 (Determination of the Maximum Sector Values).

Although a toolbox code is not required with Option 3, most, if not all, DOE sites use one of the three toolbox codes available for radiological consequence analysis. Option 3 provides analysts with wider latitude in input and modeling options, but requires DOE Safety Basis Approval Authority prior to use. In the tritium oxide application discussed here, the baseline Option 3 calculation will only deviate slightly from the Option 2 calculation and use the following set of input parameters and modeling specifications that are required with Option 2, including:

- Non-buoyant, ground level, point source release;
- Plume centerline concentrations for calculation of dose consequences;
- Rural dispersion coefficients;
- A deposition velocity of 0 cm/sec for tritium (including tritium oxide) or noble gases (for particulate releases, 0.1 cm/s for unfiltered release of particles in the respirable range of 1 to 10 μm Aerodynamic Equivalent Diameter (AED) or 0.01 cm/sec for filtered particles);

- A minimum wind speed of 1 m/s (0.5 m/s is used in the present analysis given this is the default minimum wind speed MACCS2 uses for wind speeds less than 0.5 m/s);
- Plume meander may be used, consistent with the accident release duration and the appropriate code guidance; and
- Building wake factors are not credited in the plume dispersion.

An additional requirement for Option 2 is that the vertical dispersion coefficients (σ_z) are based on a surface roughness of 3 cm. In this paper, Option 3 applies a surface roughness length (z_o) of 160 cm to adjust the reference vertical dispersion coefficients ($\sigma_{z,ref}$) with 3 cm as the reference surface roughness ($z_{o,ref}$). The following correlation from the American Meteorological Society (AMS) is used:[13]

$$\sigma_z = \sigma_{z,ref} \times (z_o/z_{o,ref})^{0.2}. \tag{1}$$

The 160-cm surface roughness specification is used in dispersion analysis for the Savannah River Site (SRS), as this region is mostly a forested site interspersed with nuclear facility operating areas.

II.C Meander Models

The NRC plume meander model adjusts the horizontal dispersion coefficients (σ_y) by the factor shown in Figure 3 of NRC Regulatory Guide 1.145. The adjustment factor is a function of wind speed and stability class and is only applied to augment σ_y for plume travel distances up to 800 m from the release location. The σ_y values reflect the enhanced spreading up to 800 m and less effective spreading in the crosswind direction beyond 800 m.

The other plume meander model is based on increased apparent dispersion with increasing averaging time.[14] The averaging time typically represents the plume exposure time and generally is assumed to equal the duration over which the release occurs from the source (t_{rel}). The horizontal dispersion coefficients are adjusted based on the reference time (t_{ref}) representing the averaging time for the reference horizontal dispersion coefficients ($\sigma_{y,ref}$) and the following correlation,

$$\sigma_y = \sigma_{y,ref} \times (t_{rel}/t_{,ref})^n; \quad \text{where } n = 0.2\ (t_{ref} \leq 60 \text{ minutes}) \text{ or } 0.25\ (t_{ref} > 60 \text{ minutes}). \qquad (2)$$

The reference time for commonly applied sets of dispersion coefficients is three minutes.

II.D Overall Comparison of Methods

The meteorological data applied for Options 1 through 3 are from the collocated Vogtle Electric Generating Plant (Plant Vogtle) database. Plant Vogtle is a commercial nuclear power plant (Figure 1), located in close proximity (16 km to 32 km) to the Savannah River Site. Given that there are no significant topographical or other influential land-use differences, or singular features that would cause weather data from Plant Vogtle to be unrepresentative of weather obtained for SRS, the Plant Vogtle data are assumed to be applicable to the postulated tritium source term from SRS discussed in this paper.

The primary reason for choosing the Plant Vogtle meteorological data is that it incorporates stability class typing that is determined from measurements of temperatures at two different heights, or temperature difference method (ΔT method) as specified under Regulatory Guide 1.23, Revision 1, for Option 1. In contrast, meteorological data collected at SRS determines the stability class from the EPA method that uses measurements of the turbulent fluctuations of the azimuth and elevation angles of the wind vector using bi-directional vanes, or bivanes.

The surface roughness specification is the only difference between Option 2 case and the baseline Option 3 case. Additional Option 3 sensitivity cases were executed that included: (1) utilizing EPA methodology-based meteorological file input; and (2) UFOTRI code results using persistent meteorological input of F stability class and a wind speed of 1 m/s. TABLE 1 summarizes the modeling differences between Option 1 and those of Options 2 and 3 as implemented in the analysis described here.

The following list of inputs and assumptions are applied in all protocol options considered here, including MACCS2 Options (2 and 3) and UFOTRI (sensitivity case 2) cases:

- Ground-level release of 3.7E+10 Bq (one curie).
- Plume passage up to a week (168 hours) post-release is modeled;
- Precipitation effects on the plume are not considered (Options 2 and 3);
- The acute or early phase is evaluated, but not the long-term phase (i.e., food and water ingestion pathways are not modeled);
- Inhalation is the predominant pathway;
- Skin absorption pathway is modeled as 50% of the inhalation dose;[15]
- The overall dose conversion factor for the MOI receptor, accounting for inhalation and skin absorption is 2.7E-11 Sv/Bq;[16]
- The Option 3 case with MACCS2 and the sensitivity case with UFOTRI apply characteristics (surface roughness) of the Savannah River Site; and
- Meteorological data when applied for Options 1 through 3 uses meteorological data from Plant Vogtle.

III. RESULTS

Two sets of dose consequence results are reported from application of the three DOE-STD-3009-2014 dispersion modeling protocol options with respect to a postulated unit activity release of tritium oxide. Figure 2 shows the baseline set of dose results from the three modeling results for distances between 1,000 m (1 km) and 10,000 m (10 km). The TED dose results are presented in units of 10^{-18} sievert per becquerel (equivalent to one attosievert/becquerel, or one aSv/Bq). Differences between the sets of results largely reflect differences in the quantification of the crosswind and vertical dispersion parameters, σ_y and σ_z, respectively. The relative air concentration (χ/Q) and dose results are each inversely proportional to the σ_y, σ_z and wind speed.

The following observations are drawn from the results in Figure 2:

- The Option 1 dose results are the lowest of the three set of results at 1,000 m, but are the highest results at distances of 3,000 m or larger. At 1,000 m, the low Option 1 results reflect the diminishing effects of the NRC plume meander factor. This effect becomes less pronounced for distances beyond 800 m.
- At larger distances, the Option 1 doses are the highest due to the use of a lower minimum wind speed and consideration of G stability (Table 1).
- The Option 3 dose results are consistently lower than the Option 2 results by a factor of 2.2 reflecting the higher σ_z values calculated from Equation 1 based on site-specific surface roughness length.

Figure 3 shows additional results together with the baseline set of dose results shown in Figure 2. In this figure, the distance spanned is 100 m to 10,000 m. The following can be concluded:

- The Option 1 results using the 99.5th directionally-dependent approach produced results (shown for 100 m, 1,000 m and 10,000 m) that are approximately 10% lower than the 95th directionally-independent results.
- The Option 2 and 3 results with an averaging time of two hours are lower than the Option 2 and 3 results with an averaging time of three minutes by a factor of 2.5 reflecting the higher σ_y values calculated from Equation 2.

- The first sensitivity case is an SRS Option 3 case that uses the same input parameters and modeling specifications as those for the base case Option 3, except that a different meteorological data file is applied. As noted earlier, meteorological data collected at SRS is used in which stability class is determined from the EPA method that uses measurements of the turbulent fluctuations of the elevation angle of the wind vector using bivanes. The SRS results are shown for distances that correspond to distances from various processing facilities to the site boundary. Relative to the EPA method, the ΔT method tends to overestimate the occurrence of E, F, and G stability classes leading to more conservative χ/Q and dose results.[17] The results in Figure 3 suggest evidence of this difference when comparing Plant Vogtle and Savannah River Site meteorological data.[18]
- The second sensitivity case applies UFOTRI and uses persistent F-stability and 1 m/s wind speed, Pasquill-Gifford dispersion parameters, and an one-hour averaging time. It is about the same or somewhat less dose consequence than the MACCS2 results under Option 2 for distances ranging from 2,000 m to 10,000 m. Although this is a ground-level release, the wind direction is persistent over a 144-hour period of time, and the dose maximum occurs at approximately 320 m from the source. This is due to the effect of re-emission of the tritium oxide as an area source from vegetation and other surfaces that persist long after the passage of the plume. As modeled by UFOTRI, re-emission comprises less than 0.1% of the dose at 100 m, but about 11% of the dose at 1,000 m and about 26% of the dose at 10,000 m. The combination of the two factors, i.e., the wind direction being persistent, and the effect of re-emission of the tritium oxide seem to compensate for most tritium plume depletion by natural processes.

IV. CONCLUSIONS

A comparison of three DOE-STD-3009-2014 dispersion modeling protocol options has been performed assuming a ground-level release of tritium oxide source term. The options are characterized by differing sets of assumptions and inputs that reflect approaches with increasing degrees of flexibility that allow more realism to be incorporated into the modeling. The three options used to evaluate atmospheric dispersion include: Option 1 - Use of NRC Regulatory Guide 1.145; Option 2 - Application of a DOE-approved toolbox code and application of conservative input parameters; and Option 3 - Use of site-specific methods and parameters as defined in a site/facility specific DOE-approved modeling protocol.

Baseline results indicate that Option 1 dose results are the lowest of the three sets of results at close-in distances ($\leq$ 1000 m), but are the highest results at distances beyond approximately 4,000 m. However, by 1,000 m, the low Option 1 results reflect the diminishing influence of the NRC plume meander model. At larger distances, the Option 1 doses are the highest due to the use of a lower minimum wind speed and consideration of G stability. Option 3 dose results are consistently lower than the Option 2 results by a factor of 2.2 reflecting the higher vertical dispersion values calculated from the crediting of site-specific surface roughness.

In addition, Option 1 using the 99.5^{th} percentile, directionally-dependent approach yielded results that are approximately 10% lower than the Option 1, 95^{th} directionally-independent results. Differences of small magnitude such as 10% are expected given that these two statistical algorithms, developed for NRC Regulatory Guide 1.145, were designed to provide equivalent sets of results. The Option 1 trends and results obtained here are dependent on the specific meteorological data alone applied in this example, and do not incorporate site characteristics.

Results for other U.S. locations would likely differ as was shown in the technical basis document supporting Regulatory Guide 1.145 (Ref. 19).

The Option 2 and 3 results with an averaging time of two hours are lower than the Option 2 and 3 results with an averaging time of three minutes by a factor of 2.5 reflecting the higher crosswind dispersion parameter values in the two-hour case. This is due to the larger effect of meander with increasing averaging time as incorporated in the MACCS2 software's Gifford model. The SRS Option 3 case used the same input parameters and modeling specifications as those for the baseline case Option 3 except that meteorological data collected at SRS is used in which stability class is determined from the EPA method. The ΔT method is known to have a bias that overestimates the occurrence of the more stable categories (E, F, and G).

The UFOTRI sensitivity case indicates about the same or somewhat less dose consequence than the MACCS2 result under Option 2 (not crediting deposition velocity) for distances ranging from 2,000 m to 10,000 m. This result is a combination of the wind direction being persistent, and the effect of reemission of a portion of the tritium oxide as an area source. Taken together, these factors compensate for most of the initial plume depletion by natural processes. Therefore, consideration of short-term, postulated accident releases of tritium oxide that credit deposition, hold-up or other retention of tritium within vegetation, soil, and other media may be difficult to defend from a regulatory perspective for DSA purposes. This is because reemission mechanisms will ultimately release most of the initially retained tritium. Thus, one simplifying, overarching recommendation would be to not credit deposition phenomenon and subsequent reemission.

In terms of recommending one of the three options for modeling tritium releases in DSA applications, the Option 2 approach (Application of a DOE-approved toolbox code and conservative input parameters) is simplest to model for source to receptor distances of 500 m or greater, yields appropriately conservative results and is easiest to defend. Option 3 (Use of site-specific methods and parameters defined in a site/facility specific DOE-approved modeling protocol) can be beneficial in cases where the source term is large and the dose results challenge the dose criteria when evaluated under Option 2. Option 3 requires additional resource commitment and DOE authority approval, but may provide regulatory relief for certain accident scenarios. However, in neither option is it suggested that a non-zero tritium deposition velocity be implemented or modeled implicitly.

Special case, close-in evaluations of MOI receptor locations in the 100 m – 500 m range, or other extenuating circumstances, may wish to consider use of software such as UFOTRI. For these situations, the time-dependent integration of deposition velocity and reemission modeling should be performed with conservative inputs and supporting assumptions.

These recommendations would apply to design basis, conservative dispersion analysis but are not extended to best estimate, realistic analyses where time-dependent behavior could be credited, such as that supporting environmental assessments or probabilistic safety applications.

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TABLE I. Summary of Key Option Characteristics as Modeled for Tritium Oxide

Model Attribute	Option 1 (RG 1.145)	Option 2/3 (MACCS2)	Comment
Stability Classes	A through G	A through F	MACCS2 treats G stability as F stability
Set of Dispersion Coefficients	Eimutis-Konicek (E-K)	Tadmor-Gur (T-G)	E-K supports G stability class; T-G is default set for MACCS2. Both the E-K and T-G set of dispersion coefficients are based on 3-cm surface roughness and 3-minute averaging time.
Source Roughness Length	3 cm	Option 2: 3 cm Option 3: 160 cm Option 3 (UFOTRI): 100 cm	NRC RG 1.145 methodology does not use an algorithm for adjusting σ_z to the area of transport surface roughness length.
Plume Meander Model	NRC Model (Regulatory Guide 1.145)	Averaging Time Model Gifford (1975)	3 minutes used as averaging time for Option 2 and 3 baseline cases; a sensitivity case for Option 3 uses 2 hours
Deposition Velocity	Not Applicable	0 cm/s for Tritium Oxide	Options 2 and 3 allow for plume depletion from deposition for particulate releases
Minimum Wind Speed	0.1 m/s	0.5 m/s	The wind speed in the meteorological data file has a minimum wind speed of 0.1 m/s.

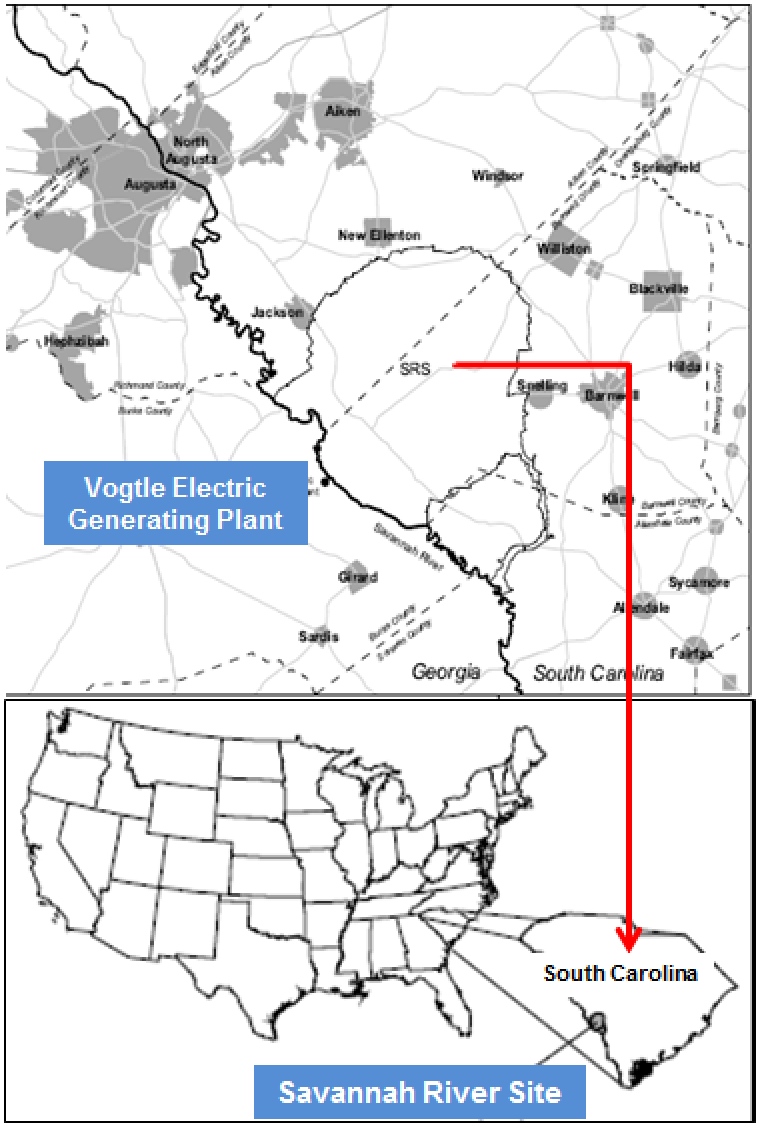

Fig. 1. Meteorological data is from Plant Vogtle located southwest and across the Savannah River from the Savannah River Site.

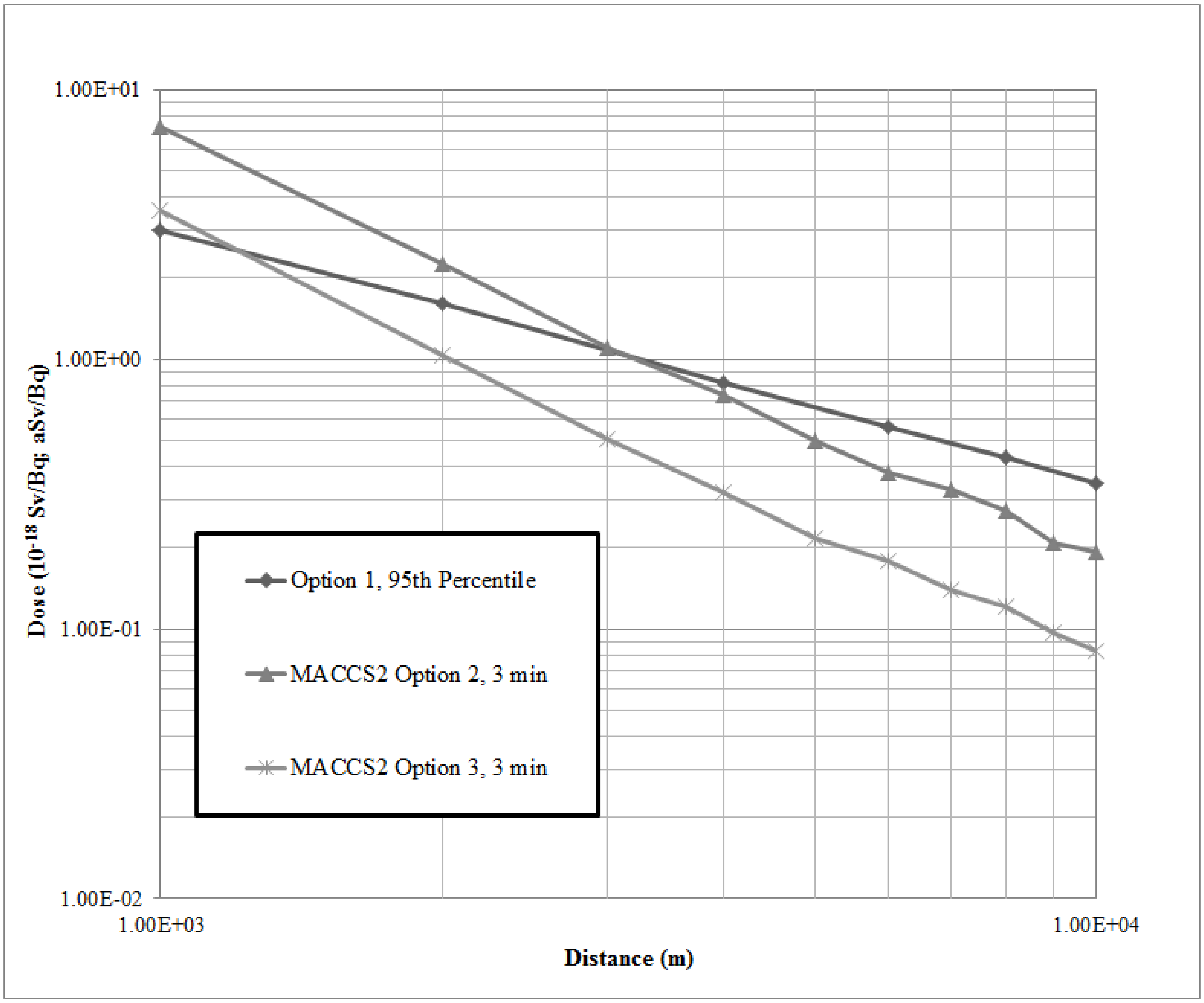

Fig. 2. Baseline Set of Total Effective Dose Results as a Function of Distance for Three Modeling Options of DOE-STD-3009-2014

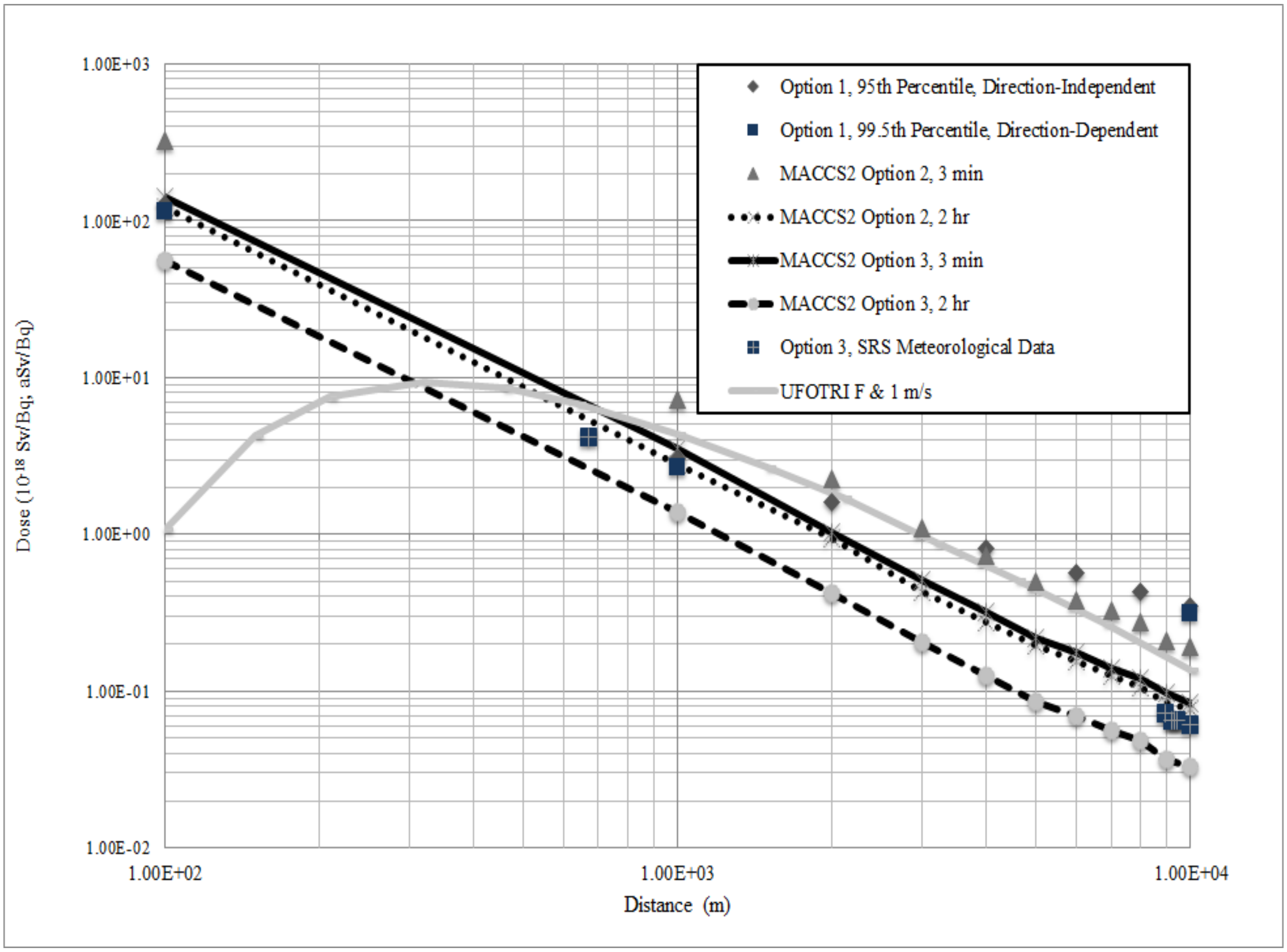

Fig. 3. TED Dose Results with Distance for Four Modeling Options of DOE-STD-3009-2014 with SRS Meteorological Data, and three-minute and two-hour averaging times applied for MACCS2 Option 2 and 3.

Table:

TABLE I. Summary of Key Option Characteristics as Modeled for Tritium Oxide

Figures:

Fig. 1. Meteorological data is from Plant Vogtle located southwest and across the Savannah River from the Savannah River Site.

Fig. 2. Baseline Set of Total Effective Dose Results as a Function of Distance for Three Modeling Options of DOE-STD-3009-2014

Fig. 3. TED Dose Results with Distance for Four Modeling Options of DOE-STD-3009-2014 with SRS Meteorological Data, and three-minute and two-hour averaging times applied for MACCS2 Option 2 and 3.

Footnotes:

a. Ref. 2, page 9.

b. The current version of MACCS2 is 3.9 (http://maccs.sandia.gov/events.aspx), released in 2014.