Review of Conservatism in the Seabrook Consequence Analysis

Technical Review April 25, 2014

1.0 Introduction

A Settlement Agreement among Friends of the Coast and the New England Coalition (FOTC/NEC), NextEra, and the NRC has been reached related to Contention 4D regarding the reasonableness of the atmospheric dispersion model used in the NextEra SAMA analysis. As part of the settlement agreement, NRC Staff has agreed to include an evaluation of the CALMET sensitivity in the FSEIS and to identify the SAMAs that might be considered potentially cost beneficial if the CALMET sensitivity were added to NextEra's uncertainty factor. NRC Staff also agreed to analyze conservatisms in NextEra's SAMA analysis and the extent to which such conservatisms may offset the uncertainty factor, in accordance with *Title 10 Code of Federal Regulations Part 51*. In support of the NRC activities, Sandia National Laboratories has conducted a review of CALMET and of the conservatisms in NextEra's SAMA analysis. The approach to this analysis, methods used, and the conclusions are presented in this technical report.

Sandia first reviewed the Seabrook submittals including the SAMA analysis and the inputs and assumptions used to calculate offsite consequences for Seabrook Station. Sandia reviewed revisions to the SAMA analysis and clarifications provided by NextEra in response to NRC Staff requests for additional information (RAIs). Sandia also reviewed portions of the Second Draft Report for Comment of NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 46 Regarding Seabrook Station (April 2013), specifically Section 5.3 and Appendix F concerning the SAMA analysis. Sandia reviewed relevant pleadings of the parties, including the October 20, 2010 "Friends of the Coast and New England Coalition Petition for Leave to Intervene, Request for Hearing, and Admission of Contentions." Sandia also reviewed NextEra's Motion for Summary Disposition of Friends of the Coast/New England Coalition Contention 4D (SAMA analysis atmospheric modeling) including Attachment 1, "Statement of Material Facts;" Attachment 2, Joint Declaration of Steven R. Hanna and Kevin R. O'Kula in Support of NEXTERA's Motion for Summary Disposition of Contention 4D (SAMA analysis atmospheric Modeling); Attachment 3, "Analysis of Annual Wind Roses within about 50 Miles of the Seabrook Station, and use of CALMET to Calculate the Annual Distribution of Trajectories from the Seabrook Station;" and Attachment 4, "Exposure Index Study Using MACCS2 and CALMET: A sensitivity Study Supporting the Seabrook Station SAMA Analysis."

2.0 Review of CALMET

Sandia reviewed CALMET documentation and the method in which NextEra applied CALMET in their analysis. CALMET is the meteorological model used with the CALPUFF Modeling System [Scire, 2000]. As an air dispersion and air quality model, CALPUFF includes a model of contaminant dispersion and deposition that produce contaminant concentrations at various receptor locations as functions of time. CALPUFF is one of the models preferred and recommended by the U.S. Environmental Protection Agency (EPA) for modeling air dispersion and air quality. NextEra applied the CALMET model in their analysis. CALMET is a weather preprocessor code to CALPUFF. One of the functions of CALMET is to calculate trajectories of puffs. CALMET does not calculate dispersion of puffs or air concentrations; it simply tracks where the center of a puff would travel.

MACCS2 is an NRC model used for estimating dispersion and deposition of a radioactive plume released from a nuclear power plant, and includes models of radioactive decay and ingrowth, ground contamination, dose consequences to the public for defined emergency response, and

economic impacts of the release. MACCS2 consists of three modules, ATMOS, EARLY, and CHRONC, which analyze given inputs to evaluate the consequences resulting from different potential accident scenarios. ATMOS calculates the dispersion and deposition of material released to the atmosphere as a function of downwind distance and uses a Gaussian plume model with Pasquill-Gifford dispersion parameters. ATMOS treats the following phenomena: building wake effects, buoyant plume rise, plume dispersion during transport, wet and dry deposition, and radioactive decay and ingrowth [NRC, 1998]. MACCS2 was specifically designed to treat radioactive air pollutants and treats radioactive decay and daughter ingrowth for decay chains up to a length of six[1].

CALMET contains a trajectory model that was applied by NextEra and the results used in an Exposure Index (EI) calculation. It does not treat radioactive decay and daughter ingrowth, calculate air concentrations accounting for dispersion, or calculate ground concentrations accounting for deposition. Radioactive decay and deposition are mechanisms that deplete the plume as it travels. Not accounting for these mechanisms results in a conservative result when using CALMET to perform an EI calculation. This is because the EI calculation is structured to treat exposure to individuals at short distances the same as exposure to individuals at long distances. This ignores the fact that the plume is depleted by the time it reaches longer distances, both because of radioactive decay of the shorter lived isotopes and because some of the contents have already deposited onto the ground. For example, using the assumptions made by NextEra, ATMOS calculates that deposition depletes the plume by 70% (70% of the original content of the plume deposits and is no longer airborne) by the time it reaches a distance of 40 to 50 miles. These effects are exacerbated by the fact that the plume may follow a curved or meandering trajectory in the CALMET analysis, which results in more time for radioactive decay to occur and a longer path length for deposition to occur than if the plume had followed a straight line, as it is assumed to do in the MACCS2 analysis. Finally, the EI calculation does not account for the fact that the plume is more disperse and therefore doses are lower at longer distances than they are at shorter distances. For example, ATMOS calculates the plume is about 50 times more dilute at 45 miles than it is at 5 miles. This is important for the application of an EI calculation at Seabrook because the largest population centers (e.g., Boston) are in the outer portion of the grid. Thus, putting together the two facts that (1) doses diminish with distance from the plant, both by dispersion and by depletion of the plume, and (2) the majority of the population lives towards the outer portion of the 50-mile region, the EI analysis conducted by NextEra tends to overestimate the increase in consequences using the CALMET trajectory rose. Quantifying the magnitude of this overestimation is not possible without doing further analyses, but we note here that the 32% increase calculated by NextEra is likely to be larger than the increase that would have been observed had it been possible to have done a full analysis with CALPUFF.

Properly accounting for radioactive decay is very important for the isotopes with short half-lives, i.e., half-lives that are less than or comparable to the length of the emergency phase, which is typically 1 week. Because they disappear relatively quickly, not accounting for the decay of those isotopes leads to an overestimate of the consequences they produce. Because NextEra included 99 isotopes in their analysis, it is not practicable to estimate the overall depletion of the plume by radioactive decay during the transport of the plume through the 50-mile region.

2.1 NextEra CALMET Application

In their motion for summary disposition for Contention 4D, NextEra included an "Analysis of Annual Wind Roses within about 50 Miles of the Seabrook Station, and use of CALMET to

[1] This reflects the parent plus 5 daughter products.

Calculate the Annual Distribution of Trajectories from the Seabrook Station," and an "Exposure Index Study Using MACCS2 and CALMET: A sensitivity Study Supporting the Seabrook Station SAMA Analysis." Sandia reviewed the CALMET calculation and Exposure Index (NextEra Attachment 3 and 4) in detail to understand the approach used to calculate the exposure index (EI) and determine whether the analysis correctly accounted for the effect on the estimated benefits of the SAMA candidates. The NextEra description of how to get from the EI calculation to the result is cryptic, but after review, it appears correct. NextEra calculated the increase in the EI (the 35% increase) and the fraction of the overall costs that are from the offsite portion of the costs (91%) and putting these two factors together, they identify that benefits should be escalated by 32%. The following is an explanation of the Sandia review.

The offsite component of the benefit of a SAMA candidate is the difference between the baseline cost and the cost after accounting for the effect of a SAMA, which is:

> Offsite Benefit per Year = Offsite Cost Risk(baseline) - Offsite Cost Risk(SAMA candidate)

Here Offsite Cost Risk has two components, which are:

> Offsite Cost Risk = OECR + PDR x $2000/person-rem

Where OECR = Offsite Economic Cost Risk ($/yr)
PDR = Population Dose Risk (person-rem/yr)

Setting aside the conservatisms introduced in the EI analysis because of depletion and dilution of the plume with distance, as noted above, both OECR and PDR should approximately scale with the EI, especially if only a small fraction of the costs are from farmland within the 50-mile region. Farmland costs scale with area while nonfarm costs scale with population. The EI is based on population, not area. However, the fact that farm area does not scale with population is relatively unimportant for two reasons: (1) only about 6% of the land area around Seabrook is used for farming and (2) less than 1% of the offsite economic costs are associated with farmland. Sandia believes NextEra's EI study correctly implements the EI methodology (costs increase proportionally to the increase in the EI that they calculate) because escalating both the baseline cost and cost after implementing a SAMA candidate by a factor (in this case the EI Factor) leads to the Offsite Benefit being increased by that same factor:

> Offsite Benefit per Year = EI Factor x Cost(baseline) - EI Factor x Cost(SAMA candidate)
>
> = EI Factor x [Cost(baseline) - Cost(SAMA candidate)]
> = EI Factor x [Original Offsite Benefit per Year based on Wind Rose]

In other words, the Offsite Benefit per Year increases by the EI Factor (1.35 in this case) when both the baseline cost and the cost after implementing the SAMA candidate are escalated by the EI Factor. This relationship does not hold if the study had simply multiplied one of the terms in the equation by the EI Factor. Thus, the discussion in NextEra's EI report of the effect of the increased EI on the SAMA benefit is consistent with the equations used to estimate the benefit of a SAMA candidate.

Finally, the Total Benefit per Year is:

Total Benefit per Year = Onsite Benefit per Year + Offsite Benefit per Year

Sandia confirmed that the Offsite Benefit per Year is 91% of the total, which means the increase in the Total Benefit per Year is 0.91 times the increase in the Offsite Benefit per Year since there is no change to the Onsite Benefit per Year. The NextEra calculation accounts for this factor when they assert that the total benefit increases by 32% (0.35 x 0.91 = 0.32). Sandia also verified the 35% increase reported by NextEra for their EI analysis.

The application of a more complex model such as CALMET can reduce some uncertainty in the system, but as shown by the 32% difference, even to a distance of 50 miles, the overall impact was not large. However, it did bring additional SAMAs into consideration if both the 32% increase and the uncertainty factor are applied to the baseline results of NextEra's SAMA analysis. As noted above in Section 2.0, the EI analysis using the CALMET trajectory rose is a conservative result because it counts exposure to all of the population equally and ignores plume depletion and dispersion. If it had been possible to perform a full CALPUFF analysis, Sandia expects the increase in estimated offsite cost risk to be lower than estimated with the EI. Quantification of the conservatism in the EI analysis would require that a CALPUFF or other analogous calculation be performed, but there is currently no capability to perform a complete SAMA analysis with CALPUFF.

3.0 Review of Conservatisms in NextEra's SAMA Analysis

3.1 Approach

Sandia applied a systematic approach to analyze additional conservatisms that might be present in the NextEra SAMA analysis. The review started with the MACCS2 input files to identify candidates which could be conservative. Sandia investigated the CALMET calculation used by NextEra. Sandia conducted an independent MACCS2 analysis using parameters more representative of the site. Finally, Sandia compared the independent analysis with the NextEra SAMA analysis to quantify the conservatism.

Appendix E of the Environmental Report, Attachment F, "Severe Accident Mitigation Alternatives," describes sensitivity analyses performed by NextEra to investigate effects on risk. The parameters analyzed in the sensitivity analyses and their effect are identified and summarized in Table 1.

Table 1. Summary of NextEra Sensitivity Analyses Included in the Environmental Report.

Parameter	Affect
Annual Meteorological Data	Data from other years resulted in decreases to dose and economic risk when compared to the 2005 baseline case. NextEra's choice for meteorological data was conservative because they chose the worst year out of the five years that were evaluated.
Release Height	Risks are a minimum at ground level and increase as release height increases to the top of containment. Baseline was at top of containment. NextEra's choice for release height was conservative, but it is difficult to quantify the conservatism because estimated release heights are not presented in the ER.
Release Heat	Increasing heat results in less ground level consequences near the release. Risk from some accident categories is relatively

	more important near the release point. Adequate data are not presented in the ER to quantify realistic release heats for the set of source term categories evaluated in the SAMA analysis.
Wake Effects	Risk is not sensitive to building wake effects. Baseline values used by NextEra are considered best estimate values.
Evacuation Speed	Dose increases as evacuation speed decreases. Change in dose risk is not significant. Baseline values used by NextEra are considered reasonable for the site.
Evacuation Preparation Time	Changing the preparation time had a minor effect on most accident category risks with a slightly larger effect noted on late containment release categories with risk concentrated near the release. Baseline values chosen by NextEra are considered reasonable for the site.
Evacuation Warning Time	Similar behavior as evacuation preparation time. Baseline values chosen by NextEra are considered reasonable for the site.
Fraction of Population Evacuating	Assuming no evacuation for release category SE-3 (a risk dominant category) results in a small increase to the overall total population dose risk. No change to economic risk. Baseline values chosen by NextEra are considered reasonable for the site.
Meteorology in Last Spatial Ring Segment	Decrease in offsite economic risk due to removing the assumed perpetual rainfall and its resulting wet deposition. Baseline values chosen by NextEra are conservative since perpetual rainfall is not realistic.

From review of the above documentation, Sandia identified some of the approaches used as conservative. In addition to those identified in Table 1, NextEra made additional changes to its SAMA analysis that varied from other SAMA analyses reviewed by the staff and Sandia. As part of reviewing NextEra's SAMA analysis for conservatisms, Sandia also investigated these additional changes described below.

- NextEra used 4 plume segments while most SAMA analyses only include one or two plume segments;
- NextEra developed a site specific Dose Coefficient file that used 99 isotopes instead of the standard 60 isotopes; and
- NextEra applied the older MACCS food chain model instead of the newer and more widely used COMIDA2 food chain model.

3.2 MACCS2 Review

Following the review of the SAMA documentation, Sandia conducted a review of the MACCS2 parameters to identify additional parameters to investigate. Parameters in the ATMOS, EARLY, and CHRONC modules of the MACCS2 code were reviewed and discussed among the Sandia team. More than 250 parameters were reviewed, and 20 parameters shown in Table 2 were identified as candidates for further investigation. These parameters include those identified during the review of the SAMA documentation.

Table 2. Systematic Review of MACCS2 Parameters

MACCS Module	Parameter	Description
ATMOS	BNDRAN	Boundary Weather Rain Rate
	BNDWND	Boundary Wind Speed
	NUMREL	Number of Released Plume Segments
	PLHEAT	Plume Heat Contents
	PLHITE	Plume Release Height
	VDEPOS	Dry Deposition Velocities
	ZSCALE	Scale Factor for Vertical Dispersion
EARLY	CSFACT[S]	Cloudshine Shielding Factor for Shelter
	CSFACT[E]	Cloudshine Shielding Factor for Evacuees
	CSFACT[N]	Cloudshine Shielding Factor for Normal Conditions
	DOSHOT	Hot Spot Relocation Dose Threshold
	DOSNRM	Normal Relocation Dose Threshold
	GSHFAC [E]	Groundshine Shielding Factor Table - Evacuating
	GSHFAC [N]	Groundshine Shielding Factor Table - Normal Activity
	GSHFAC [S]	Groundshine Shielding Factor Table - Sheltering
	PROTIN [E]	Inhalation Protection Factor - evacuation
	PROTIN [N]	Inhalation Protection Factor - normal activity
	PROTIN [S]	Inhalation Protection Factor - sheltering
	TIMHOT	Hot Spot Relocation Time
	TIMNRM	Normal Relocation Time

For each of the parameters identified in Table 2, Sandia reviewed the inputs used by NextEra in the SAMA analysis. Where appropriate, Sandia identified more realistic values for use in a comparative analysis. A discussion of each parameter is presented below.

The following parameters are used in the ATMOS module:

Boundary Weather Rain Rate (BNDRAN) – This parameter represents the rain rate that is used for the boundary weather conditions, which NextEra imposed in the last ring (40 to 50 miles) in the SAMA analysis. NextEra assumed perpetual rainfall in the last ring, which has the effect of washing out most of the plume contents before the plume can exit from this ring. This choice is artificial and conservative. The best estimate approach is to use measured weather data from the meteorological data file to represent the weather in the last ring of the analysis.

NextEra Value: 1.78 mm/hr
Recommended Value: 0 mm/hr

Boundary Wind Speed (BNDWND) – This parameter represents the wind speed that is used for the boundary weather conditions. NextEra used 3.03 m/s, which is the average wind speed for the 2005 weather year used in the SAMA analysis. While using the average wind speed for the outer ring is a reasonable choice, a better choice is to use hourly weather data from the meteorological data file to represent the weather conditions in the outer ring. This can be accomplished by changing the MACCS parameter, LIMSPA, from 9 to 10. This change also eliminates boundary rain, which is discussed in the previous paragraph.

NextEra Value: 3.03 m/s
No change recommended for BNDWND.

Recommend Value for LIMSPA: 10.

Number of Released Plume Segments (NUMREL) – This parameter defines the number of plume segments that are released. A constant rate of release is assumed over each plume segment. NextEra used the maximum number of plume segments allowed by the version of MACCS2 used in the analysis (Version 1.13.1), which is a larger number of plume segments than is typical. In principle, the number of plume segment should not have a significant impact on the results. However, the overall duration of the release was chosen to be longer than standard, as discussed subsequently. Longer release duration is expected to add conservatism to the SAMA analysis.

NextEra Value: 4
No change recommended.

Plume Heat Content (PLHEAT) – This parameter specifies the rate of release of sensible heat in each plume segment. NextEra assumed zero heat content in all plume segments. NextEra also performed a sensitivity analysis of the effect of plume heat content on the SAMA results and found that there could be a reduction in the OCR of up to 12%. However, NextEra provides no information on heat contents for the plume segments that could be used to quantify the magnitude of this conservatism.

NextEra Value: 0 W
No change recommended.

Plume Release Height (PLHITE) – This parameter specifies the height above ground level at which each plume segment is released. NextEra conservatively chose the release height to be top of containment. NextEra also performed a sensitivity study and showed that the OCR could be up to 4% lower. However, NextEra does not provide adequate information to assess realistic release heights to quantify the magnitude of this conservatism.

NextEra Value: 54.64 m
No change recommended.

Dry Deposition Velocities (VDEPOS) – This parameter contains the set of dry-deposition velocities corresponding to the particle-size groups. In the SAMA analysis conducted by NextEra, one aerosol size was selected to represent the released aerosols and therefore only a single deposition velocity was used.

NextEra chose a dry deposition velocity of 1 cm/s, which corresponds to an aerosol with a 6 micrometer hydrodynamic diameter. In the State of the Art Reactor Consequence Analysis (SOARCA) study [NRC, 2012], a higher level of fidelity was used than is typically employed in a SAMA analysis: 10 aerosol sizes were used to capture the distribution of sizes predicted using a state-of-the-art model for source term and each aerosol size used its own deposition velocity. It was noted at the time of the SOARCA study that the behavior of the aerosols corresponded to a 0.3 cm/s mean deposition velocity. Further discussion of the 0.3 cm/s deposition velocity is provided in the next section. The effect of a lower deposition velocity is to reduce ground concentrations (as shown in Figure 1) and reduce the amount of land that needs to be interdicted and decontaminated. The effect of using a more realistic deposition velocity is considered in the next section.

NextEra Value: 1 cm/s
Recommended Value: 0.3 cm/s

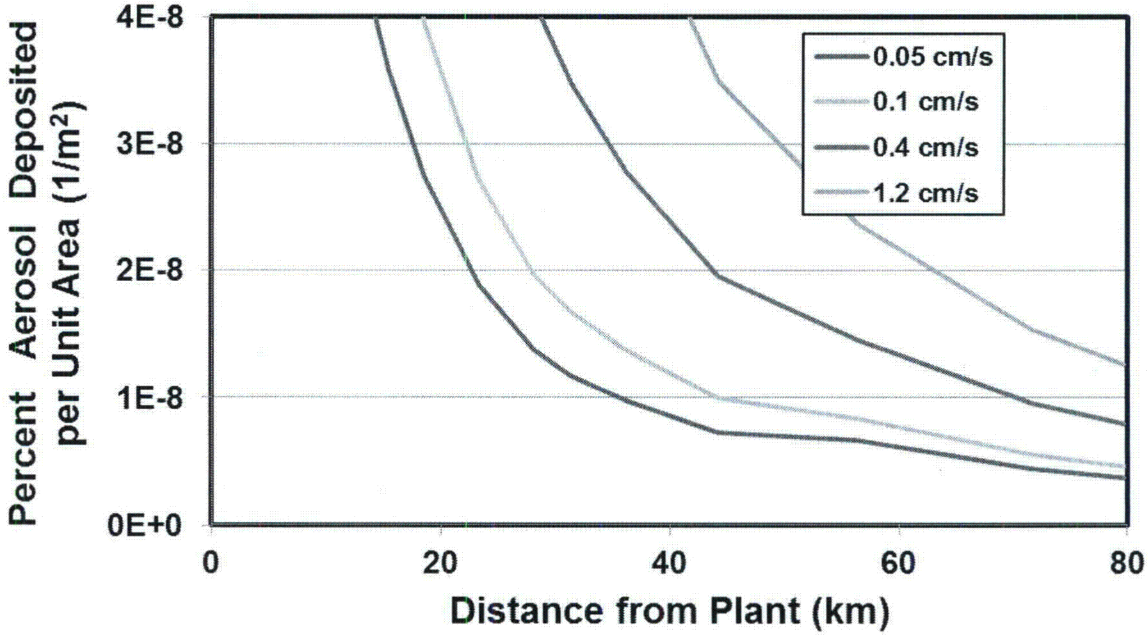

Figure 1. Effect of deposition velocity on deposition at distances up to 80 km from the release location.

Surface Roughness
The SOARCA project [NRC, 2013a], included a sensitivity analysis for surface roughness and showed that health effects risk is affected by surface roughness. This parameter was therefore reviewed for Seabrook. NextEra selected a surface roughness value of 10 cm. The area around Seabrook consists largely of forest intermixed with suburban housing, farmland, and of course ocean. Near the southern limit of the SAMA analysis, the land use becomes more urban while the rest of the outer limits of the SAMA area are largely forested and suburban. It is the inland area that is of interest in the SAMA analysis, because this is the area within which costs are accounted; therefore, the surface roughness does not need to include consideration of the ocean. As indicated in Figure 2, the inland mixture of land use better corresponds to a surface roughness value between 20 and 100 cm, making the value of 10 cm selected by NextEra conservative. To estimate the conservatism in surface roughness, Sandia chose a value of 50 cm to better represent this diverse land area.

Surface roughness is not an input parameter to MACCS2, but influences two parameters that are used as input. The first is the scale factor for vertical dispersion (ZSCALE, which is discussed in the next paragraph) and the second is the deposition velocity, which was discussed in the previous paragraphs. The effect of increasing surface roughness in NUREG/CR-7110 Vol. 1 [NRC, 2013a] is that health effect risk is decreased. It should have a similar effect on OCR in a SAMA analysis.

NextEra Value: 10 cm
Recommended Value: 50 cm

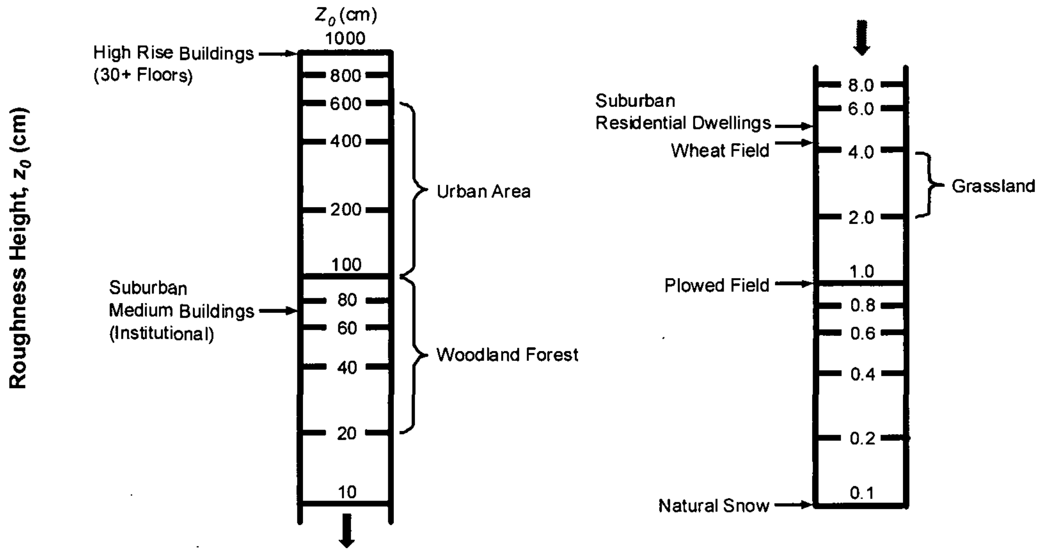

Figure 2. Approximate surface roughness lengths (z_0) for various surfaces [DOE, 1987].

Scale Factor for Vertical Dispersion (ZSCALE) – This parameter is a linear scaling factor that is applied to the formula for sigma-z. It is used to account for surface roughness. This factor modifies all of the sigma-z values by a constant multiplicative factor for both power-law and lookup-table options. NextEra used a value of 1.27 for this scale factor, which corresponds to a surface roughness of 10 cm. Sandia believes that a value of 1.76 is more representative of the land area surrounding Seabrook, which corresponds to a surface roughness of 50 cm. The larger value is representative of a region that is mainly forested with some suburban areas, as discussed in the previous paragraphs on surface roughness.

NextEra Value: 1.27
Recommended Value: 1.76

The following parameters are used in the EARLY module:

Cloudshine Shielding Factor for Sheltering (CSFACT[S]) – This parameter is the cloudshine shielding factor during sheltering. A value of 0 indicates complete shielding, and a value of 1 indicates no shielding. Shielding values for MACCS2 analyses may be obtained from NUREG-1150, which provides values for Grand Gulf, Peach Bottom, Sequoyah, Surry, and Zion (NRC, 1990a). The shelter-related values were based on regional characteristics related to type of housing construction and percent of homes with basements, as described in NUREG/CR-4551 (NRC, 1990b). NextEra chose the shielding values for sheltering that correspond to the Surry plant, which are provided with Sample Problem A. Sandia reviewed US Census data related to housing construction, and determined the Surry shielding values are reasonable for this analysis of the Seabrook site.

NextEra Value: 0.6
No change recommended.

Cloudshine Shielding Factor for Evacuees (CSFACT[E]) – This parameter is the cloudshine shielding factor for the public while they are evacuating. The value used is consistent with the recommended value in NUREG/CR-4551 (NRC, 1990b). There is no change recommended for this shielding factor.

NextEra Value: 1.0
No change recommended.

Cloudshine Shielding Factor for Normal Activity (CSFACT[N]) - This parameter is the cloudshine shielding factor for the public during normal activity. The value used is consistent with the recommended value in NUREG/CR-4551(NRC, 1990b). There is no change recommended for this shielding factor.

NextEra Value: 0.75
No change recommended.

Hot Spot Relocation Dose Threshold (DOSHOT) – This parameter defines the hot spot relocation dose threshold. If the total dose commitment to individuals for the entire emergency-phase period would exceed DOSHOT, those people are relocated at the hot-spot relocation time (TIMHOT) following plume arrival. The Sample Problem A value for DOSHOT was 50 rem and that is the value used in the NextEra SAMA analysis. A more reasonable value is 5 rem, which is the upper bound given in the Environmental Protection Agency (EPA) Protective Action Guide (PAG) listed in the EPA Manual of Protective Action Guides (EPA, 1992).

NextEra Value: 50 rem
Recommended Value: 5 rem

Normal Relocation Dose Threshold (DOSNRM) – This parameter defines the normal relocation dose threshold. If the total dose commitment to individuals for the entire emergency phase period exceeds DOSNRM, those people are relocated at the normal relocation time (TIMNRM) following plume arrival. The Sample Problem A value for DOSNRM was 25 rem and that is the value used in the NextEra SAMA analysis. A more reasonable value is 1 rem, which is the lower bound of the EPA PAG (EPA, 1992).

NextEra Value: 25 rem
Recommended Value: 1 rem

Groundshine Shielding Factor – Evacuating (GSHFAC [E]) - This parameter is the groundshine shielding factor for the public while they are evacuating. The value used is consistent with the recommended value in NUREG/CR-4551 (NRC, 1990b). There is no change recommended for this shielding factor.

NextEra Value: 0.5
No change recommended.

Groundshine Shielding Factor - Normal Activity (GSHFAC [N]) - This parameter is the groundshine shielding factor for the public during normal activity. The value used in the SAMA analysis is slightly lower than the recommended value of 0.4 in NUREG/CR-4551(NRC, 1990b). This very minor difference would not be expected to significantly change the results of the SAMA analysis. There is no change recommended for this shielding factor.

NextEra Value: 0.33
No change recommended.

Groundshine Shielding Factor – Sheltering (GSHFAC [S]) - This parameter is the groundshine shielding factor for the public during the shelter period. As described above, sheltering values are based on regional housing characteristics. A range from 0.1 to 0.25 is provided in NUREG/CR-4551 (NRC, 1990b). Based on this range, the value used in the SAMA analysis appears reasonable. There is no change recommended for this shielding factor.

NextEra Value: 0.2
No change recommended.

Inhalation Protection Factor – evacuation (PROTIN [E]) – This parameter is the inhalation protection factor for the public during evacuation. The value used is consistent with the recommended value in NUREG/CR-4551 (NRC, 1990b). There is no change recommended for this shielding factor.

NextEra Value: 1.0
No change recommended.

Inhalation Protection Factor - normal activity (PROTIN [N]) - This parameter is the inhalation protection factor for the public during normal activity. A range from 0.15 to 1.0 is provided in NUREG/CR-4551 (NRC, 1990b). Based on this range, the value used in the SAMA analysis appears reasonable. There is no change recommended for this shielding factor.

NextEra Value: 0.41
No change recommended.

Inhalation Protection Factor – sheltering (PROTIN [S]) - This parameter is the inhalation protection factor for the public during the shelter period. A range from 0.1 to 0.4 is provided in NUREG/CR-4551 (NRC, 1990b). Based on this range, the value used in the SAMA analysis appears reasonable. This minor difference would not be expected to significantly change the results of the SAMA analysis. There is no change recommended for this shielding factor.

NextEra Value: 0.33
No change recommended.

The following parameters are used in the CHRONC module:

Hot Spot Relocation Time (TIMHOT) – This parameter defines the hot-spot relocation action time after plume arrival. Hot-spot relocation only occurs for individuals residing outside the emergency-planning zone (EPZ) and for non-evacuees within the EPZ. TIMHOT must be less than or equal to TIMNRM and less than or equal to ENDEMP. NextEra chose a hot spot relocation time of 12 hours, which Sandia considers to be a reasonable estimate.

NextEra Value: 12 hours
No change recommended.

Normal Relocation Time (TIMNRM) - This parameter defines the normal relocation action time after plume arrival. Normal relocation only occurs for individuals residing outside the emergency-planning zone (EPZ) and for non-evacuees within the EPZ. TIMNRM must be greater than or equal to TIMHOT and less than or equal to ENDEMP. NextEra chose a normal relocation time of 24 hours, which Sandia considers to be a reasonable estimate.

NextEra Value: 24 hours
No change recommended.

4.0 Conduct Independent Analysis

Sandia conducted an independent analysis using MACCS2 to evaluate the conservatisms introduced in the SAMA analysis by NextEra. The source terms and frequencies generated by the Level 1 and Level 2 portions of the PRA used in the SAMA analysis were used to evaluate the consequences within the 50-mile radius surrounding the plant. Offsite PDR and OECR were evaluated for each conservatism considered to get a percentage change to the Offsite Cost Risk (OCR, which is the sum of PDR and OECR) and Total Cost Risk (TCR, which is the sum of onsite and offsite cost risks) resulting from the conservatism. At the end of this section, all of the conservatisms are considered together to estimate the overall conservatism introduced by NextEra in their SAMA analysis.

The following conservatisms are considered in this section:

- Deposition velocity
- Food pathway model
- Set of isotopes used in the analysis
- Relocation criteria for normal and hotspot relocation
- Weather year selected for the analysis
- Surface roughness

The effect of each of these conservatisms is reported individually. The integrated effect of all of them, and also including one of the conservatisms investigated by NextEra, i.e., boundary rain, is considered in a final analysis to estimate the overall magnitude of conservatism.

Typically, SAMA analyses include one single plume segment or two plume segments and assume that the release ends at about 48 hours after accident initiation. NextEra chose to use 4 plume segments and a release duration extending to 72 hours after accident initiation. No quantitative analysis of the effect of longer release duration is presented in this report; however, it is clearly more conservative than the usual choice of 48 hours. The SOARCA project demonstrated that 48 hours was a reasonable time to implement mitigative strategies at the Peach Bottom and Surry plants, taking into account site specific and region specific capabilities [NRC, 2012]. Additionally, NUREG-1150 used a strategy of terminating releases 24 hours after the release began, which means that releases ended less than 48 hours after accident initiation [NRC, 1990a].

Deposition Velocity – The deposition velocity used by NextEra in their SAMA analysis is a standard value that was used in NUREG-1150 and in previous SAMA analyses, which is 1 cm/s. By comparison, SOARCA used 10 aerosol sizes, each with its own deposition velocity ranging from 0.05 to 1.7 cm/s. This range of deposition velocities more accurately characterizes plume depletion and deposition from a realistic accident source term. A weighted average deposition velocity from SOARCA [NRC, 2013a] is about 0.27 cm/s, which is currently considered to be a better, more representative deposition velocity than 1 cm/s.

The Seabrook SAMA analysis was rerun using a deposition velocity of 0.3 cm/s (0.27 cm/s rounded to a single significant digit) to provide an estimate of the conservatism introduced by NextEra when they performed their SAMA analysis. The percent reduction in risk is shown in the following table:

Table 3. Reduction in Risks by Introducing a Best-Estimate Deposition Velocity in the NextEra SAMA Analysis (1 cm/s Replaced by 0.3 cm/s)

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
4.3%	3.1%	3.5%	3.2%

Food-Chain Model – One of the significant improvements in MACCS2, as compared with the original MACCS code, is a newer food-chain model for calculating doses from ingestion of food. The new model is based on COMIDA2. The COMIDA2 food-chain model has achieved widespread usage and has mostly replaced the older MACCS food-chain model used in NUREG-1150. NextEra chose to use the older MACCS food-chain model in their SAMA analysis rather than the newer one. Sandia evaluated whether using this older model introduced any conservatism into their results and found that this choice did introduce a very modest amount of conservatism, as shown in the following table:

Table 4. Reduction in Risks by Introducing a Best-Estimate Food-Chain Model in the NextEra SAMA Analysis (MACCS Model Replaced by the COMIDA2 Model)

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
0.1%	0.5%	0.4%	0.3%

Set of Isotopes – NextEra chose to use a set of 99 isotopes in their analysis. To do this, they modified the standard dose conversion factor file (DOSDATA.INP) that is commonly used with MACCS2 to include additional isotopes. The standard set of 60 isotopes (including 9 additional isotopes that are captured as implicit daughters) were chosen to account for very nearly the entire dose that might be created by a severe accident source term. Sandia compared the NextEra results with the results that would have been obtained by using the standard set of 60 isotopes and found that doses were only increased by about 0.1%. Since the analysis performed by NextEra is arguably slightly more accurate than using the standard set of isotopes, this is not considered a source of conservatism. Also, the difference between including 60 or 99 isotopes is so small that it can be ignored.

Relocation Criteria – NextEra used the standard values from NUREG-1150 for dose that would trigger normal and hotspot relocations. These doses are 25 rem for normal relocation and 50 rem for hotspot relocation. These dose levels follow older EPA PAGs, but current PAGs are consistent with doses of 1 rem for normal relocation and 5 rem for hotspot relocation [EPA, 1992]. These doses are projected over the entire emergency phase, which is a 7-day exposure period. To evaluate whether some conservatism was introduced by NextEra when they chose the older PAG levels, Sandia reran the SAMA analysis with 25 rem replaced by 1 rem for normal relocation, and 50 rem replaced by 5 rem for hotspot relocation. The following table shows the reduction in the risks attained, which represents a level of conservatism in the NextEra SAMA analysis:

Table 5. Reduction in Risks by Introducing Relocation Doses Based on Current EPA PAGs in the NextEra SAMA Analysis (25 rem Replaced by 1 rem for Normal Relocation and 50 rem Replaced by 5 rem for Hotspot Relocation)

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
15.8%	-0.4%	4.3%	3.9%

For this change, the results show that population dose risk (PDR) is reduced because more people are relocated during the emergency phase; however, offsite economic cost risk (OECR) is increased slightly because there is a cost associated with relocating more people. The overall effect is a reduction in the OCR and TCR.

Weather Year – NextEra conservatively chose to use the weather year that gives the largest value of OCR (2005). They could have chosen to use the median year from their set of five years, which is 2006. The choice to use the median year (in terms of the value of OCR) would have been acceptable according to NEI guidance [NEI, 2005]. To evaluate the conservatism introduced by choosing the worst weather year, Sandia repeated the SAMA calculation using 2006 instead of 2005 as the basis year for weather data. The percentage reduction shown in the following table indicates the conservatism introduced by NextEra when they chose to use 2005 as the basis for weather data.

Table 6. Reduction in Risks by Introducing Median Instead of Worst Case Weather Data in the NextEra SAMA Analysis (Weather Data for 2005 Replaced by Weather Data for 2006)

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
10.2%	14.5%	13.2%	12.0%

Surface Roughness – NextEra used 10 cm for the surface roughness of the area surrounding Seabrook. Based on the above discussion, Sandia believes the surface roughness is larger, about 50 cm. Surface roughness has an effect on both deposition velocity, which Sandia estimated to increase from 0.3 cm/s to 0.35 cm/s based on the equations in NUREG/CR-7161 [NRC, 2013b], and on the value of the scaling factor on vertical dispersion (ZSCALE), which increases from 1.27 to 1.76 according to the equation provided in NUREG/CR-4691 [NRC, 1990c]. This latter factor effectively causes vertical dispersion to occur more rapidly and thereby decreases ground-level concentrations. The overall effect of surface roughness on the Seabrook SAMA results is shown in Table 7.

Table 7. Reduction in Risks by a Best Estimate of Surface Roughness (10-cm Surface Roughness Replaced by a 50-cm Surface Roughness)

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
5.0%	4.1%	4.3%	3.9%

Overall Conservatism – Putting together the sources of conservatism evaluated by NextEra with the additional ones considered in this section produces an overall estimate of conservatism in the NextEra analysis. This analysis of conservatism does not consider some of the sensitivities investigated by NextEra when the baseline values are arguably the best estimates. Specifically, this analysis uses the following input values, which are modified from NextEra's baseline values:

Table 8. Best-Estimate Models and Parameters Used to Quantify Overall Conservatism in NextEra SAMA Analysis.

Description	MACCS2 Variable	Value
Best Estimate Deposition Velocity	VDEPOS	0.35 cm/s
Best Estimate Vertical Dispersion Scale Factor	ZSCALE	1.76

Currently Used Food-Chain Model	FDPATH	NEW (Invokes COMIDA2 model)
Normal Relocation Dose Criterion from EPA PAG	DOSNRM	0.01 Sv (1 rem)
Hotspot Relocation Dose Criterion from EPA PAG	DOSHOT	0.05 Sv (5 rem)
Median Weather Year	SEABRK06.met	2006 weather data
Boundary Weather not Used	LIMSPA	10
Boundary Rain Rate Set to Zero	BNDRAN	0 mm/hr
Standard Set of Isotopes	NUMISO	60

Table 9. Reduction in Risks by Combining the Best-Estimate Models and Parameters Shown in Table 8.

Population Dose Risk	Offsite Economic Cost Risk	Offsite Cost Risk	Total Cost Risk
44.8%	34.6%	37.6%	34.1%

Summary

As part of the settlement agreement, a review of the CALMET and EI sensitivity performed by NextEra has been conducted. In addition, conservatisms in NextEra's SAMA analysis and the extent to which such conservatisms may offset the uncertainty factor were investigated.

NextEra's CALMET analysis of the trajectory rose around Seabrook combined with their exposure index (EI) calculation estimated that the offsite cost risk (OCR, a combination of population dose risk and offsite economic cost risk) for Seabrook could increase by about 35% and that the total cost risk (TCR, which includes both offsite and onsite cost risks) could increase by about 32%. While it would be difficult to quantify the conservatism in NextEra's EI results, arguments presented in this report support that the 35% estimate is conservative (too high). Quantification of the conservatism would require that a CALPUFF or other analogous calculation be performed, but there is currently no capability to perform a complete SAMA analysis with CALPUFF.

NextEra's revised SAMA analysis also incorporated a number of conservative assumptions, leading to a conservative estimate of OCR that is estimated to be about 38% too high, which corresponds to a value of TCR that is 34% too high. The leading sources of conservatism in their SAMA analysis are perpetual rain in the last ring (the area from 40 to 50 miles from the plant), the choice of weather year, underestimation of surface roughness near Seabrook, and using older EPA values for hot spot and normal relocation doses. These conservatisms approximately offset the higher OCR that NextEra estimated when it performed its EI analysis.

References

Appendix A to Appendix W of Part 51 – Summaries of Preferred Air Quality Models, Federal Register, Vol. 70, No. 216, Nov. 9, 2005.

Department of Energy (DOE). DOE/RL/87-09. "The Remedial Action Priority System (RAPS): Mathematical Formulations." Washington DC.: DOE. 1987.

Environmental Protection Agency (EPA). EPA-400-R-92-001. "Manual of Protective Action Guides and Protection Actions for Nuclear Incidents." 1992.

Nuclear Energy Institute (NEI). "Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document." NEI: Washington, D.C. November, 2005.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-7110 Volume 1, Rev. 1, "State-of-the-Art Reactor Consequence Analyses Project. Volume 1: Peach Bottom Integrated Analysis." Washington DC.: NRC. 2013a.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-7161, "Synthesis of Distributions Representing Important Non-Site-Specific Parameters in Off-Site Consequence Analyses." Washington DC.: NRC. 2013b.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG 1935, "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report." Washington DC.: NRC. 2012.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-6613, "Code Manual for MACCS2: Volume 1, User's Guide". NRC: Washington, D.C. May, 1998.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, Final Summary Report." Washington DC.: NRC. 1990a.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-4551, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters. MACCS Input." Washington DC.: NRC. 1990b.

Nuclear Regulatory Commission (U.S.) (NRC). NUREG/CR-4691, "MELCOR Accident Consequence Code System (MACCS): Model Description." NRC: Washington, D.C. 1990c.

Scire, Joseph, S., et al. "A User's Guide for the CALMET Meteorological Model (Version 5). Earth Tech, Inc. Concord, MA. January, 2000.