May 16, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
Entergy Nuclear Generation Company and	)	Docket No. 50-293-LR
Entergy Nuclear Operations, Inc.	)	ASLBP No. 06-848-02-LR
	)	
(Pilgrim Nuclear Power Station)	)	

DECLARATION OF KEVIN R. O'KULA

Kevin R. O'Kula states as follows under penalties of perjury:

I. INTRODUCTION

1. I am a Senior Fellow Advisor with Washington Safety Management Solutions ("WSMS") LLC. My professional and educational experience is summarized in the Curriculum Vitae attached as Exhibit 1 to this Declaration.

2. I have over 24 years of experience as a manager and technical professional in the areas of safety analysis standard and guidance development, computer code evaluation and verification, probabilistic risk assessment, accident and consequence analysis, source term evaluation, risk management, reactor materials dosimetry, shielding, and tritium safety applications. I obtained my BS in Applied and Engineering Physics from Cornell University in 1975; my MS in Nuclear Engineering from the University of Wisconsin in 1977; and my Ph.D. in Nuclear Engineering from the University of Wisconsin in 1984.

3. I have extensive experience (nearly 18 years) in using the MELCOR Accident Consequence Code System (MACCS) and the MACCS2 Computer Codes and have taught

MACCS2 training courses for the Department of Energy ("DOE") at Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Idaho National Laboratory and at DOE Safety Analysis Workshops. I was the lead author of a DOE guidance document on the use of MACCS2.[1] Additionally, I am a member of the MACCS2 Review Panel, which has provided recommendations on applying MACCS2 for severe accident consequence analysis to Sandia National Laboratories and the Nuclear Regulatory Commission regarding the 3-year State of the Art Reactor Consequence Analysis (SOARCA) Program.

4. I am the principal author and was responsible for the preparation of the WSMS Report entitled "Radiological Dispersion and Consequence Analysis Supporting Pilgrim Nuclear Power Station Severe Accident Mitigation Alternative Analysis" Revision 1 ("SAMA") (May 2007) ("WSMS Report") (attached as Exhibit 2 to this Declaration).[2] WSMS prepared the Report in response to a request from Entergy Nuclear Operations for technical assistance for the Pilgrim Nuclear Power Station ("PNPS") license renewal proceeding to address the claims raised in Pilgrim Watch Contention 3. WSMS Report at ix. The statements and conclusions in the Report are true and correct to the best of my information and belief.

5. I am familiar with Pilgrim Watch Contention 3, which, as admitted by the Licensing Board, asserts that "Applicant's SAMA analysis for the Pilgrim plant is deficient in that the input data concerning (1) evacuation times, (2) economic consequences, and (3)

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[1] *MACCS2 Computer Code Application Guidance for Documented Safety Analysis*, DOE-EH-4.2.1.3-Final MACCS2 Code Guidance, Final Report, U.S. Department of Energy, Washington, DC, June 2004.

[2] Washington Safety Management Solutions, "Radiological Dispersion and Consequence Analysis Supporting Pilgrim Nuclear Power Station Severe Accident Mitigation Alternative Analysis" Revision 1 (May 2007).

meteorological patterns are incorrect, resulting in incorrect conclusions about the costs versus benefits of possible mitigation alternatives, such that further analysis is called for."

6. This Declaration will summarize the evaluation and results of the WSMS Report as it addresses the claims raised in Pilgrim Watch Contention 3 concerning the adequacy of the MACCS2 code modeling performed for the PNPS license renewal SAMA analysis. The WSMS Report answers claims raised in Contention 3 regarding the adequacy of the MACCS2 meteorological, evacuation, and economic modeling for the PNPS SAMA analysis. As I will demonstrate below, PNPS properly used the MACCS2 code in these respects to perform the PNPS SAMA analysis. Also, the WSMS Report reports on a series of additional MACCS2 sensitivity analyses that were performed to evaluate potential uncertainties in the meteorological, evacuation, and economic input parameters used in the PNPS SAMA analysis. As I discuss below, these additional sensitivity analyses show that significant changes in the input parameters do not result in the identification of any additional potentially cost-effective SAMAs. The sensitivity runs show at most a 4% increase in benefit, whereas, before any additional SAMAs would be identified as potentially cost-effective, the increase in benefit would need to be on the order of 100%, or a factor of twenty-five times greater. These sensitivity analyses conclusively demonstrate that Pilgrim Watch Contention 3 is without factual basis.

II. OVERVIEW OF MACCS2 AND ITS USE IN THE PNPS SAMA ANALYSIS

7. Entergy used the MELCOR Accident Consequence Code System 2("MACCS2") to perform the SAMA analyses contained in the PNPS Environmental Report. MACCS2 is a state-of-the-art computer model, well-suited for SAMA analysis determination of consequences and risks. WSMS Report at ix. The Nuclear Regulatory Commission sponsored the development of the MACCS2 code and it has been used by nearly all nuclear power plants in the

United States, for performing SAMA analyses for nuclear power plant operating license renewals. WSMS Report at 4.

8. As detailed in the WSMS Report, MACCS2 employs a Gaussian plume model for the calculation of radiological atmospheric dispersion and consequences. WSMS Report at 4. MACCS2 executes in three sequential steps: (1) ATMOS calculates air and ground concentrations, plume size, and timing information for all plume segments as a function of downwind distance; (2) EARLY calculates consequences due to radiation exposure in the emergency phase (first seven days) from the time of release; and (3) CHRONC calculates long-term consequences due to exposure after the emergency phase, and for determining decontamination and other economic impacts from the hypothetical accident. WSMS Report at 4. Figure 1 on page 5 of the WSMS Report depicts the execution of the three steps.

9. In support of PNPS license renewal, MACCS2 was used to analyze the consequences from a set of release conditions over a 50-mile radius region around the PNPS site. For each of the postulated accident release conditions, a statistically significant number of simulations (well over 100) were run in order to evaluate the consequences of postulated releases under different weather conditions. This enables the analysis to account for the direction of the plume, the turbulence, mixing and dispersion of the plume under different weather conditions, and so on. The key measurements of interest are population dose (person-sievert), population dose risk ("PDR") (person-rem per year), off-site economic cost (dollars), and off-site economic cost risk ("OECR") (dollars per year). WSMS Report at 5, 7 and Table 1 at 9. The mean values of the consequence distributions for each postulated release category are used in the analysis and the mean population dose and the mean offsite economic costs are multiplied by the frequency of occurrence for the postulated release condition to determine mean PDR and OECR values for

each release condition. The risk estimates for the postulated release conditions are summed to determine overall PDR and OECR estimates. WSMS Report at 5 and Table 1 at 9.

10. MACCS2 models three phases of consequence analysis: (1) an emergency phase, which is the seven day period after the postulated accident; (2) an interdiction phase, which is the five year period after the postulated accident; and (3) a long-term phase, which is a 30 year period after the postulated accident. WSMS Report at 6. Mitigation plans incorporating evacuation and sheltering are modeled only during the emergency phase, and usually are applied only to residents within the emergency planning zone ("EPZ"). WSMS Report at 6.

11. A review of the results of the PNPS SAMA analysis shows that most of the population dose – on the order of 83% – is due to the interdiction and long-term phase after the accident. WSMS Report at 8 and Table 3 at 10. This implies that emergency actions, such as evacuation and sheltering or timing of these and other dose mitigation strategies will have only small impacts to the overall population dose. Further review of the results of the PNPS SAMA analysis shows that the majors factors controlling population dose and off-site economic costs are the size of the source term (i.e., amount of radioactivity released), the parameters controlling the interdiction and long term phases after the accident, and the large population impacted in the 20-mile to 50-mile spatial region surrounding the plant. WSMS Report at 11 and Appendix A. This again shows that changes in the assumptions and input parameter values for the early or emergency phase effects for the close-in population (within 20 miles of the PNPS) should have little impact on the overall PDR and OECR.

12. As discussed in Sections IV and VI below, changes in the assumptions and input parameter values for the early or emergency phase effects for the close-in population in fact have

little impact on the overall PDR and OECR. Major changes in the input assumptions for the evacuation delay time and evacuation speed for the population within the 10-mile emergency planning zone ("EPZ") have negligible effect on the SAMA results and would cause no additional SAMAs to be identified as potentially cost-effective.

III. GAUSSIAN PLUME MODELING ISSUES

13. Pilgrim Watch contends that the MACCS2 model used by PNPS has "a number of limitations" because it employs a Gaussian plume model to estimate the atmospheric dispersion of radionuclides. According to Pilgrim Watch, the Gaussian plume model is significantly flawed because it fails to (1) take into account changes in wind speed or direction, either in time or space or (2) take into account terrain effects. Pilgrim Watch Pet. at 35.

14. Contrary to Pilgrim Watch's claims, the Gaussian plume model employed in the PNPS MACCS2 analysis is the standard atmospheric plume model used for nuclear safety and environmental evaluations for numerous regulatory applications. It is the underlying radiological dispersion and consequence model underpinning NRC Regulatory Guide 1.194, Regulatory Guide 1.145 (NUREG/CR-2260), and DOE-STD-3009-94, Appendix A for NRC and DOE nuclear safety analyses. Indeed, the MACCS2 code has been widely used within the 50-mile (80-km) basis distance of nuclear facilities, *e.g.*, for many Environmental Impact Statement and Ingestion Planning Zone ("IPZ") applications, including SAMA studies. The code is referenced extensively in the NRC-approved industry guidance for SAMA analysis. WSMS Report at 14.

15. Importantly for SAMA analyses, the MACCS2 code uses a flat-earth Gaussian plume model that can meet the computational demands of calculating many kinds of consequence results, with the appropriate level of statistical sampling. In a SAMA analysis, each

postulated release is simulated in well over a hundred simulations to achieve meaningful statistical results under different weather conditions. Taking into account the multiple postulated release conditions that are evaluated in SAMA analyses (19 for the PNPS SAMA analysis), literally hundreds of runs must be analyzed using different weather conditions to calculate statistically meaningful results. Computer codes that can accommodate multiple-station data so as to be able to model spatial and variation of wind speed and direction are simply impracticable to use for analyzing the large number of weather sequences needed for SAMA analyses. WSMS Report at 13-14.

16. Furthermore, contrary to Pilgrim Watch's claim, MACCS2 does account for time dependent weather conditions by analyzing multiple plumes under different weather conditions. Each plume that is "emitted" in the atmospheric release simulation is modeled with the meteorological data read for the date and the hour randomly selected by the code. A statistically significant number of plume release simulations are performed by MACCS2 with weather conditions randomly chosen from the site meteorological file. Data read from the file include wind speed, stability class, and precipitation rate, all of which are available on an hour-by-hour basis in the MACCS2 meteorological data file. Thus, by simulating multiple plumes for each postulated release condition, the MACCS2 code, as used for the Pilgrim SAMA analysis, does take into account changes in atmospheric stability, wind speed and direction as a function of time. WSMS Report at 13.

17. Also, as set forth in the WSMS Report at 14-17, the MACCS2 Gaussian plume model has been shown to provide results that are in good agreement, and generally conservative, when compared with more sophisticated models that address variable meteorological and terrain effects. For example, one study performed by the Idaho National Laboratory released a tracer

and then measured the air concentrations of the tracer. The results were compared with three different atmospheric transport models – two versions of the Gaussian model and a more sophisticated wind field and terrain sensitive Atmospheric Release Advisory Capability ("ARAC") code developed at Lawrence Livermore National Laboratory. WSMS Report at 14. The comparison showed that the Gaussian model provided significantly more conservative results than the actual dose measured by the field equipment as well as the maximum dose predicted by the more sophisticated wind and terrain sensitive ARAC code. WSMS Report at 14-15. Another study compared the MACCS2 code to a fully three dimensional code that accounted for terrain changes and the spatial variability of weather. The comparison showed that the results from the MACCS2 code were in reasonably good agreement with those obtained from the three dimensional model. WSMS Report at 16.

18. Furthermore, the MACCS2 code was conservatively applied to the Pilgrim SAMA analysis so as to produce overall conservative results. The choice of the input parameter for the surface roughness length used in the Pilgrim SAMA analysis was particularly conservative. The surface roughness length is a measure of the amount of mechanical mixing of the plume introduced by the roughness of the surface due to, for example, human-built structures, trees and other vegetation, and surface features. The greater the surface roughness length, the greater the mechanical mixing and dispersion of the plume and the smaller the doses. This feature was modeled conservatively in the Pilgrim SAMA analysis by using a 10 cm value surface roughness length whereas a value of 100 cm could have reasonably been used for this parameter. WSMS Report at 16-18.

19. Additionally, two sensitivity cases were run which showed minimal effect on the PDR and OECR from varying the weather or terrain from that used in the SAMA analysis base

case. WSMS Report 15-16, 18. Sensitivity Case 2 was run to estimate the effects of changing wind direction trajectory in the MACCS2 consequence analysis by choosing different meteorological input data for release categories that last longer than an hour. Case 2 was conservative because it used conditions at the beginning of a plume release, when the release has larger dose potential (because less decay has occurred), rather than using the conditions for dispersion an hour or more later into the release. The results from Case 2 show a negligible 3% increase in both PDR and OECR as compared to the base case. WSMS Report at 15-16. MACCS2 Sensitivity Case 3 was run to show the effects of a reduced plume release height – from thirty meters in the original SAMA analysis to zero meters in Case 4. This case approximates a terrain change by releasing the plume at the ground level. For a ground level release, the Case 3 results showed a 1% increase in PDR and a 4% increase in OECR. WSMS Report at 18. As discussed in Section VI below, far greater increases in the PDR and OECR, by a factor substantially greater than 25, would be required before any additional SAMAs would be identified as potentially cost-effective

20. Pilgrim Watch Contention 3 incorrectly claims that the Gaussian plume model employed by PNPS inappropriately fails to account for the sea breeze effect and the coastal topography near PNPS. Pilgrim Watch Pet. at 35-36. The meteorological data gathered at the Pilgrim site and used in the SAMA analysis would reflect the occurrence of sea breeze conditions in terms of both wind speed and direction at the Pilgrim site. Moreover, as explained in the WSMS Report (at 19-22) sea breeze conditions are (1) most often localized within 10 miles of the coast, and (2) generally beneficial in dispersing the plume and decreasing doses. Sea breeze is generally a highly beneficial phenomenon that disperses and dilutes the plume concentration and thereby <u>lowers</u> projected doses downwind from the release point. WSMS

Report at 20-21. Furthermore, the extent of the sea breeze influence would generally be less than the EPZ region (within ten miles of the Pilgrim Station), and not a factor towards the heavily populated areas in the Pilgrim 50-mile region. WSMS Report at 19. As discussed above, it is the impact in the populated zones that dominates population dose and off-site economic cost consequences. Similarly, while sea breeze may be variable along various coastal locations, local sea breeze variations will be insignificant factors to population dose at tens of miles away and will have negligible impact in the calculation of regional population doses. WSMS Report at 20.

21. The other claims raised by Pilgrim Watch also lack merit:

- Pilgrim Watch's claim that the MACCS2 model cannot be used to estimate atmospheric dispersion less than 100 meters from the source, Pilgrim Watch Pet. at 35, is irrelevant. The PNPS SAMA analysis followed NRC guidance for on-site exposure and economic costs, which were accounted for separately, and so did not use the MACCS2 code to estimate dispersion within several hundred meters (in the "near field") of the release point. Thus, any limitation of the MACCS2 model for this range has no relevance to the SAMA analysis. Furthermore, the near field is within the exclusion area boundary controlled by PNPS and, thus, has no permanent residents that could incur radiological exposure. WSMS Report at 18-19.

- Pilgrim Watch disputes the adequacy of using meteorological data for a single year for the PNPS SAMA analysis. Pilgrim Watch Pet. at 36-38. However, use of data for a single representative year is typical of other SAMA analyses. WSMS Report at 22. Furthermore, the year chosen provides the most complete set of meteorological data available for the PNPS site and, as discussed in the declaration of Fred Mogolesko, is representative of meteorological conditions at the plant.

- Pilgrim Watch erroneously claims that a proper analysis would require multiple years of data from multiple sources in order to take into account the specific characteristics of the Plymouth area. Pilgrim Watch Pet. at 37-38. However, meteorological instrumentation close to, or at the point of release, is the most critical placement for identifying the atmospheric turbulence conditions governing initial plume travel. At PNPS, instrumentation used for the upper and lower towers are properly positioned to account for the turbulence structure of the atmosphere. Furthermore, standard practice for MACCS2 PRA analysis, of which the SAMA analysis runs are one application, is to apply Tadmor and Gur dispersion parameterization to account for atmospheric turbulence, which was used in the PNPS SAMA studies. WSMS Report at 22.

- Pilgrim Watch also claims that an accurate analysis would require installation of continuous recording meteorological instruments along the coast and at additional inland sites. Pilgrim Watch Pet. at 37-38. While continuous recording instruments would relate to the ability to track a <u>specific</u> plume, such instrumentation would have no bearing for SAMA analyses where the focus is determining mean consequence levels to support cost-benefit decision-making on potential plant modifications. Furthermore, as previously discussed, it is impractical to employ multiple weather station data for SAMA cost-benefit analyses given the large number of weather trials that are needed to provide statistically valid consequence results. WSMS Report at 23.

IV. EMERGENCY EVACUATION MODELING ISSUES.

22. The MACCS2 modeling assumptions used to model emergency response evacuation in the PNPS SAMA analysis are based on evacuation time estimates prepared as part of the Emergency Plan for PNPS. The details of the basis for the evacuation time estimates, including supporting assumptions regarding population, alarm criteria, delay times, speed, distance, areas and routes, are provided in "Pilgrim Station Evacuation Time Estimates and Traffic Management Plan Update, KLD Report TR-203A-5" (November 1998) ("KLD, 1998"). These values were updated in 2004 in the report entitled "Pilgrim Nuclear Power Station, Development of Evacuation Time Estimates, KLD Report TR-382" (December 2004) ("KLD, 2004"). WSMS Report at 25.

23. The MACCS2 base case applied in the SAMA analysis is a simple radial evacuation model. The base case considered a forty-minute evacuation delay time, which is the time between notifying the public of an evacuation and the beginning of the evacuation of persons within the 10-mile EPZ. A constant evacuation speed of 2.17 mph derived from the evacuation time estimates prepared for the PNPS was used in the base case as the speed at which persons evacuate from the EPZ. The base case model assumes that the entire EPZ is evacuated. Once the EPZ residents reach a 20-mile radius, they are assumed to have reached shelters and are no longer radiologically exposed during the emergency phase. Residents in the area from 10-mile to 50-mile region receive radiological exposure if they are within the plume passage region. The EPZ residents as well as residents within the 10-mile to 50-mile region will receive

radiological exposures during the 30-year long-term phase following the accident, assuming that their point of origin within the EPZ is habitable. WSMS Report at 25.

24. An analysis of the base case results demonstrates that most (approximately 83%) of the population dose is received during the long term phase after the accident. This suggests that emergency actions, such as evacuation and sheltering or timing of these and other dose mitigation strategies, will have only small impacts on the overall population dose. WSMS Report at 11

25. The original PNPS SAMA analysis also considered two sensitivity cases to evaluate the consequences of potential uncertainties in the evacuation delay time and evacuation speed. Case 1.a assumed a two-hour delay before evacuees in the EPZ begin evacuation to evaluate the sensitivity of the consequence results to uncertainties in the delay time. WSMS Report at 7, 24. Case 1.b maintained the base case 40-minute delay time before evacuation begins, but assumed a lower effective evacuation speed of 1.54 mph to evaluate consequence sensitivities due to uncertainties in the evacuation speed, *e.g.*, road conditions and traffic congestion. WSMS Report at 7, 24. The results of the two sensitivity cases compared to the base case showed a maximum change in the population dose estimates of less than 2%, for one release category (CAPB-8), and about a 1% change to the PDR. PNPS License Renewal Environmental Report at E.1-68.

26. Pilgrim Watch raises a series of claims to challenge the adequacy of the input parameters for the evacuation delay time and evacuation speed used in the PNPS SAMA analysis. To test whether these claims, if true, would affect the results of the SAMA analysis, a series of sensitivity cases were run to evaluate the consequences of longer delay times and

slower evacuation speeds. These sensitivity cases considered evacuation delay times as long as six hours and evacuation speeds as slow as 0.76 mph. Another sensitivity case assumed that no evacuation of the EPZ was undertaken and that everyone within the EPZ carried on with their normal activities. The maximum change to the PDR resulting from any of these sensitivity cases was 6%. WSMS Report at 25-28. As discussed in Section VI of this Declaration, a 6% increase in PDR would increase the total cost risk of the postulated release events evaluated in the SAMA analysis by only 2% (because the PDR accounts for approximately only 33% of the total cost risk in the SAMA analysis). A 2% increase in total cost risk is far less than that which would be required before any additional SAMA would be identified as potentially cost-effective. As discussed in Section VI, the total cost risk would need to increase by more than 100% before any additional SAMAs would be identified as potentially cost-effective. Thus, it is readily apparent that the claims made by Pilgrim Watch concerning the adequacy of the evacuation delay and evacuation speed input parameters used in the PNPS SAMA analysis would have no impact on the results of the PNPS SAMA analysis.

27. Focusing on Pilgrim Watch's specific claims and the specific sensitivity cases considered in the WSMS Report, Pilgrim Watch claims that the MACCS2 model improperly assumes that radiation danger will not extend beyond 10 miles and that the EPZ population is out of danger upon crossing the 10-mile EPZ boundary. Pilgrim Watch Pet. at 39, 42. Pilgrim Watch is incorrect. MACCS2 does model consequences beyond the 10-mile EPZ boundary, out to 50 miles, and thus accounts for potential doses beyond 10 miles from the plant. Residents in the 10-mile to 50-mile region receive radiological exposure during the emergency phase if they are within the plume passage region. Also, they will receive doses during the long term phase, which in fact accounts for most of the population dose as previously discussed. MACCS2 will

calculate the population dose from cloudshine, groundshine, and inhalation of material directly from the plume. Inhalation doses from resuspended material are also accounted for in the dose calculation. WSMS Report at 25.

28. In the current base and sensitivity MACCS2 cases, once the evacuating population from the EPZ has moved beyond the 20-mile distance, they no longer incur radiological exposure for the remainder of the 7-day emergency phase. This is a standard assumption made in using the MACCS2 code based on emergency planning to evacuate away from the plume direction and resulting radiological footprint. However, the evacuees may receive future dose during the long-term phase if their point of origin within the EPZ remains inhabitable. In addition, MACCS2 Sensitivity Case 4 was run to model evacuees as moving to a 40-mile radius before assuming that they have reached centers established for the evacuees. Because these centers are in fact located at a distance that is closer than 40 miles to PNPS, Case 4 is conservative in that evacuees are traveling a greater distance than would be expected in an actual evacuation procedure. WSMS Report at 25. The summary for Case 4 is shown in Appendix D to the WSMS Report. There is less than 1% difference for PDR and OECR between the Base Case and Case 4. Thus, assuming increased travel distance for evacuees does not produce any noticeable increase to population dose or the risk indices of PDR and OECR. The dose mitigation strategies for the EPZ during the emergency phase have little impact on the overall dose results, which are dominated by effects in the 20-mile to 50-mile regions and late-phase portions of the consequence modeling. WSMS Report at 25.

29. Pilgrim Watch incorrectly claims that the MACCS2 model fails to consider those who cannot evacuate and must shelter. Pilgrim Watch Pet. at 39. The PNPS SAMA analyses assumed that persons who could not evacuate on their own would be provided assistance to

evacuate. Current emergency planning by the State of Massachusetts provides for such assistance. WSMS Report at 26. In addition, MACCS2 Sensitivity Case 6 was run wherein the evacuation model was turned off altogether. In other words, everyone within the EPZ is assumed to carry on with their normal activities. The results under these assumptions are shown in Appendix E to the WSMS Report. The results indicate an increase in population dose risk of about 6%. As already discussed, such an increase would have no impact on the results of the PNPS SAMA analysis.

30. Pilgrim Watch erroneously asserts that the PNPS SAMA analysis used faulty evacuation time estimate assumptions, and that "voluntary evacuation from within the EPZ was estimated to be 50% within a 2-5 mile ring around the reactor, excluding the "key-hole;" and 25% in the annular ring between the 5-mile boundary of the circle and the 10-mile EPZ boundary". Pilgrim Watch Pet. at 40. However, the SAMA analyses were not based on voluntary evacuation, but assumed that the entire 10-mile EPZ would be evacuated in accordance with the Emergency Plans providing for such evacuation in appropriate circumstances. WSMS Report at 27.

31. Pilgrim Watch claims that the evacuation delay time estimates of 40 minutes and 2 hours used in the SAMA analysis are inappropriate because it could take longer to notify the population. Pilgrim Watch Pet. at 41. Pilgrim Watch's claims are wrong, as discussed in the Declaration of Thomas Sowdon. Furthermore, Sensitivity Case 6, which assumes no evacuation and results in an increase in the PDR of only 6%, demonstrates that any uncertainty in the evacuation delay estimate is inconsequential. WSMS Report at 27. In addition, MACCS2 Sensitivity Analysis Case 7a was performed, employed a 6 hour evacuation delay time as compared to the base case of 40 minutes for the evacuation delay time. The results for Case 7a

are provided in Appendix F to the WSMS Report. The PDR for Case 7a is 5% higher than the base case. This case is bounded by the no-evacuation model in Case 6, for which the change was 6% to the PDR. WSMS Report at 28.

32. Pilgrim Watch claims that the evacuation speed estimates are wrong. Pilgrim Watch Pet. at 41-43. Pilgrim Watch's claims are wrong, as discussed in the Declaration of Thomas Sowdon. Again, Sensitivity Case 6, which assumes no evacuation and results in an increase in the PDR of only 6%, demonstrates that any uncertainty in the evacuation speed estimate is inconsequential. WSMS Report at 27. In addition, MACCS2 Sensitivity Analysis Case 7b was performed, which employed an extremely slow evacuation speed of 0.76 mph as compared to 2.17 mph in the base case. The results for Case 7a are provided in Appendix F to the WSMS Report. The PDR for Case 7b is 3% higher than the base case. This case is bounded by the no-evacuation model in Case 6 in which the change was 6% to the PDR. WSMS Report at 28.

V. ECONOMIC COST MODELING ISSUES

33. The third area Pilgrim Watch challenges is the adequacy the Pilgrim MACCS2 economic consequence model, claiming that it only includes the economic costs of "mitigative actions" and does not model the loss of economic activity, such as loss of tourism or other business activity. Pilgrim Watch Pet. at 43-45. Pilgrim Watch notes that travel and tourism accounted for over $11 billion in spending for calendar year 2003 in Massachusetts and claims that a severe accident at PNPS would severely impact travel in four counties for which it provides 2003 travel expenditures. Pilgrim Watch Pet. at 43-45.

34. Pilgrim Watch's challenges to the adequacy of the economic analysis performed in the PNPS SAMAs are without merit. First, Pilgrim Watch's claim that the MACCS2 and the PNPS SAMA only considered the economic costs of mitigative actions, such as evacuation and decontamination, is wrong. A wide range of economic costs are accounted for by the MACCS2 model in accordance with the SAMA cost-benefit analysis guidance from NEI[3]. The economic costs calculated by MACCS2 account for region-specific and county-specific costs, and include (1) cost of evacuation; (2) cost for temporary relocation (food, lodging, and lost income); (3) cost of decontaminating land and buildings; (4) <u>loss of building/land use and any corresponding lost return on investment and depreciation associated with decontamination and interdiction</u>; (5) cost of repairing temporarily interdicted property; (6) <u>value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated through root uptake</u>; and (6) value of farmland and of individual, public, and non-farm commercial property that is condemned. WSMS Report at 29.

35. Thus, contrary to the Contention's broad assertions, the MACCS2 code provides for the modeling of a wide range of economic losses. As reflected in items 4 and 6 underlined in paragraph 34 above, these include losses associated with economic activity, such as loss of income, loss of value of crops not grown, and loss of use and return on property, including commercial and business property. WSMS Report at 30. In terms of loss of use and return on property, as part of interdiction costs the MACCS2 code provides for (1) a depreciation rate on property improvements to account for loss of value of buildings and other structures, and (2) an expected rate of return from land, buildings, equipment, etc. The Pilgrim SAMA analysis used

[3] ("NEI 05-01, Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document, and Revision A" (Nov. 2005) ("NEI 2006").

an annual depreciation rate of 20% and an annual rate of return of 12%. WSMS Report at 31. The provision for these losses in the SAMA analysis and the specific input parameters used for the PNPS SAMA analysis are in accordance with the SAMA cost-benefit analysis guidance from NEI 2006, which has been recommended by the NRC Staff for use in SAMA analyses.

36. The value for non-farm property used in the MACCS2 base case for the PNPS SAMA analysis was based on the latest data at the time the analysis was performed of non-farm fixed reproducible tangible wealth – a measure of the non-farm land and durable goods (things that people own). These goods may be business and commercial buildings, related equipment and inventory, residential houses, cars, washing machines, etc. The values for non-farm property used in the SAMA analysis were based on equalized valuations of all property so as to equate to the actual fair market value of all property within the region. WSMS Report at 32.

37. Thus, the MACCS2 SAMA analysis for PNPS allows for a return of 12% on the actual fair market value of all business property, including land, buildings, equipment and inventory and, as such, does account for loss of economic activity during the interdiction phase. Additionally, the full value of any non-farm property that would be condemned would also be accounted as an economic cost in the SAMA analysis.

38. The economic analysis performed by the MACCS2 code as described above and as applied in the PNPS SAMA analysis is the state of the art for SAMA analysis studies. It follows the NEI 2006 guidance on SAMA analyses, which the NRC Staff has recommended for performing SAMA analyses. No other code exists that performs similar analyses for severe accidents at nuclear power plants.

39. Nonetheless additional analysis has been performed to assess Pilgrim Watch's claims regarding business and tourism loss risks. Specifically, a sensitivity case was performed in which the input parameters for the value of non-farm property have been modified to include data that specifically account for county and metropolitan area gross domestic product. Such data would directly account for tourism, business activity, wages, etc. WSMS Report at 31-32.

40. Under this revised approach, the gross domestic product has been determined on a county basis for the counties included in the SAMA analysis. The county-specific gross county product ("GCP") for each county was then added to the non-farm property value used in the original analysis for the county, and the new, higher value for non-farm property for each county was used in the sensitivity analysis. WSMS Report at 31-32. The addition of gross county product to the non-farm property value in the analysis directly accounts for the total value of goods and services produced in an area. The revised value therefore measures the non-farm wealth (tangible wealth owned) in the individual counties as well as their direct economic output. WSMS Report at 32.

41. Substituting the new value for non-farm property for the various counties in the analysis and holding the other parameters of the analysis constant (Sensitivity case 8.b) resulted in no change to the PDR and an increase of the OECR of 2%. WSMS Report at 34 and Table G.2.[4] Thus, augmenting the non-farm wealth economic indices with county- and region-specific business and tourism data has negligible impact on the results of the SAMA analysis.

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[4] As discussed in the WSMS Report, the original SAMA analysis utilized a highly conservative value for the average regional value of non-farm property, which is used in making determinations in the analysis of whether property is interdicted or condemned. WSMS Report at 29-30, 33-34. Retaining the same highly conservative value for non-farm property used in the original analysis while using the new, augmented county values for non-farm property (Sensitivity case 8.b) results in the 2% increase in

42. As discussed in Section VI below, this 2% increase in the OECR would not result in identifying any additional potentially cost effective SAMAs. In fact, the OECR would need to increase by roughly 200% (assuming no increase in the PDR) before any additionally SAMAs would be identified as being potentially cost effective. This is two orders of magnitude more than the increase calculated for Sensitivity case 8.b and provides high confidence in the validity of the PNPS SAMA analysis results.

VI. SAMA COST BENEFIT INCORPORATING NEW SENSITIVITY ANALYSES

43. The results of the new sensitivity analyses do not make any of the SAMAs being considered cost beneficial. The maximum increase to the PDR for any of the new sensitivity studies discussed above was 6% and the maximum increase to the OECR for any of the sensitivity studies discussed above was 4%. Using these maximum increases for the PDR and the OECR values would increase the total cost for each of the 59 SAMAs by about 4%. This is because the off-site population exposure cost contributes about 32% of the total cost resulting from the postulated accident evaluated as part of the SAMA analysis, and the off-site economic cost contributes about 54% of the total. WSMS Report at 39.[5]

44. For the SAMA that is closest to becoming potentially cost effective, SAMA #8, the baseline benefit for this SAMA ($2,405,508) is less than half of the estimated cost of implementing the SAMA (>$5,000,000). Accordingly, the baseline benefit, or the total cost avoided, would have to increase by more than 100% before SAMA #8 would become cost

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the OECR discussed above. If the average regional value of non-farm property were recalculated based on the new, augmented county values for non-farm property in accordance with the applicable SAMA guidance (Sensitivity case 8.a), the OECR would decrease by 13%. WSMS Report at 34 and Table G.1.

[5] The remaining costs are attributable to on-site exposure costs and on-site economic costs (defined as on-site clean-up and decontamination cost, and replacement power cost). WSMS Report at 39.

beneficial. WSMS Report at 39. This is a factor of 25 times greater than the maximum increases seen from any of the additional sensitivity analyses evaluated in the WSMS Report.

45. The baseline risk is the sum of the mean PDRs and the mean OECRs for the 19 different release categories evaluated in the PNPS SAMA analysis (as well as the other costs included in the SAMA analysis referenced in note 5 above). The baseline case, or the mean, is used to determine whether a SAMA is potentially cost effective. NEI 2006 at 15. The baseline or mean value is used in making this determination in order to ensure that the costs and benefits are appropriately balanced and not biased in one direction or another in determining whether a particular mitigating action is cost-effective. Thus, the increase in total cost would need to be on the order of 25 times greater than the maximum increases for the PDR and OECR shown by any of the sensitivity analyses before any additional SAMAs would become potentially cost effective.

46. The large margins and conservatisms retained in the SAMA analysis before additional SAMAs would be cost beneficial can be further demonstrated by reviewing two bounding analyses that were conducted as part of the original SAMA analysis. The first was the baseline case with uncertainty and the second was a sensitivity case that assumed a lower discount rate (3% versus the 7% originally assumed). Comparing the estimated cost to implement the SAMA that is closest to becoming potentially cost effective, SAMA #8, the benefits for the baseline with uncertainty case and the 3% discount rate sensitivity case are still far below the cost to implement this SAMA. This difference between the benefit for these two bounding analyses and the cost to implement SAMA #8 is approximately an order of magnitude larger than the calculated increase in benefit for the maximum increases in PDR and OECR shown for any of the sensitivity analyses in the WSMS Report. In other words, the benefit

increase derived from the maximum increases for the PDR and OECR shown by any of the sensitivity analyses would need to be approximately an order of magnitude larger before any additional SAMAs would become potentially cost-effective even under the baseline with uncertainty and the 3% discount rate bounding sensitivity analyses. WSMS Report at 40.

47. In summary, the maximum benefit increase of 4% calculated from the MACCS2 sensitivity analyses in this Report would not change the existing set of potentially cost-effective SAMAs identified by the PNPS SAMA analysis. Before any additional SAMAs would be identified as potentially cost-effective, the increase in benefit would need to be on the order of 100%. Even under the baseline with uncertainty and the 3% discount rate sensitivity analyses, the increase in benefit would need to be approximately an order of magnitude larger before these bounding sensitivity analyses would be affected. WSMS Report at 40.

VII. CONCLUSION

48. The PNPS SAMA analysis performed in support of license renewal was properly performed and used appropriate methodology and input data. Additional sensitivity analyses that have been subsequently performed demonstrate with high confidence the validity of the PNPS SAMA analysis. Consequently, Pilgrim Watch Contention 3 lacks any factual basis.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on May 16, 2007

Kevin R. O'Kula

Kevin R. O'Kula

WASHINGTON SAFETY MANAGEMENT SOLUTIONS

KEVIN R. O'KULA

KEY AREAS:

Computer Model Verification and Validation
Accident Analysis Computer Code Evaluation
Regulatory Standard & Guidance Development
Accident and Consequence Analysis
Software Quality Assurance
Probabilistic Risk Assessment
MACCS2 Code Applications
Level 3 PRA Standards

PROFESSIONAL SUMMARY:

Dr. O'Kula has 24 years experience as a manager and technical professional in the areas of safety analysis standard and guidance development, computer code evaluation and verification, probabilistic risk assessment (PRA), accident and consequence analysis, source term evaluation, risk management, reactor materials dosimetry, shielding, and tritium safety applications. He was part of the Department of Energy (DOE) team writing DOE G 414.1-4, *Safety Software Guide*, is a member of the American Nuclear Society Standard working group on Level 3 Probabilistic Safety Assessment, and is on the MELCOR Accident Consequence Code System, Version 2 (MACCS2) Review Committee for the NRC's State-of-the-Art Reactor Consequence Analysis (SOARCA) Program. He coordinated technical support for the DOE Office of Environment, Safety, and Health (EH) in addressing Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2002-1 on Software Quality Assurance (SQA), and is a consultant to DOE/EH-31 Office of Quality Assurance for disposition of SQA issues. He is a past chair for Energy Facility Contractors Group (EFCOG) Accident Analysis Subgroup.

Dr. O'Kula led a successful effort demonstrating Savannah River Site (SRS) K-Reactor siting compliance to 10 CFR 100, and tritium facility compliance with SEN-35-91. He was the project leader for independent Verification and Validation (V&V) of urban dispersion software for the Defense Threat Reduction Agency (DTRA) and is currently the V&V project leader for several types of simulation software for Dugway Proving Ground's Chemical-Biological Program.

EDUCATION:

Ph.D., Nuclear Engineering, University of Wisconsin, 1984
MS, Nuclear Engineering, University of Wisconsin, 1977
BS, Applied and Engineering Physics, Cornell University, 1975

TRAINING:

Conduct of Operations (CONOPS), 1994
Atomic, Science, and Radioactivity Releases, 1995
Consequence Assessment, 1995
U.S. DOE Risk Assessment Workshop, 1996
MELCOR Accident Computer Code System (MACCS) 2 Computer Code, 1997, 2005
MCNPX Training Class at ANS Meeting, 1999

CLEARANCE:

Active DOE "Q"

PROFESSIONAL EXPERIENCE:

Washington Safety Management Solutions — **1997 to Present**
Senior Fellow Advisor

Dr. O'Kula provides ongoing support to DOE/EH-31 for addressing SQA issues for safety analysis software. He co-wrote DOE G 414.1-4, *Safety Software Guide* on SQA practices, procedures, and programs. As a member of the MACCS2 Review Panel, he recommends practices to Sandia National Laboratories (SNL) and the NRC regarding the 3-year State-of-the-Art Reactor Consequence Analysis (SOARCA) Program. Dr. O'Kula is also part of the Level 3 PRA Standard working group charged with developing an ANSI/ANS standard for Level 3 PRA analysis. He participated in a team that conducted an SQA gap analysis on the bioassay code [Integrated Modules for Bioassay Analysis (IMBA)] based on DOE G 414.1-4 requirements. He identified safety analysis codes that were designated as DOE "toolbox" codes, and oversaw production of the first documents (QA criteria and application plan, code guidance reports, and gap analysis) for 6 accident analysis codes designated for the DOE Safety Software Toolbox.

Dr. O'Kula developed the outline, coordinated contributors, and assembled the first draft of the DOE *Accident Analysis Guidebook*, a reference guide for hazard, accident, and risk analysis of nuclear and chemical facilities operated in the DOE Complex. He is also the primary author and coordinator for the *Accident Analysis Application Guide* for the Oak Ridge contractor. Dr. O'Kula also developed a one-day course and exam for the guide, which he later presented to the Oak Ridge, Paducah, and Portsmouth staff.

Dr. O'Kula also led an independent V&V review for the DTRA of the U.K.-developed Urban Dispersion Model (UDM) software for predicting chemical and biological plume dispersion in city environments, and is leading projects to verify several software applications for the Dugway Proving Ground (Utah), and the Edgewood Chemical Biological Center (ECBC) in Maryland.

Managing Member, Consequence Analysis

Dr. O'Kula was responsible for the consequence analysis associated with accident analysis sections of Documented Safety Analysis (DSA) reports and other safety basis documents for SRS, Oak Ridge, and other DOE nuclear facilities. He also developed the methodology and identified appropriate computer models for this purpose. Additionally, Dr. O'Kula developed training to enhance consistency and standardize analyses in the consequence analysis area.

Dr. O'Kula coordinated development of a DOE Accident Analysis Guidebook involving over 10 sites and organizations. He also led the effort to produce Computer Model Recommendations for source term (fire, spill, and explosion), in-facility transport, and dispersion/consequence (radiological and chemical) areas.

Westinghouse Savannah River Company **1989 to 1997**
Group Manager

Dr. O'Kula managed consequence analyses associated with accident analysis sections of DSA reports and other safety basis documents. He also developed the associated methodologies and identified appropriate computer models. He was a member of the management team supporting Criticality Safety Evaluation preparation in assistance of Safe Sites of Colorado plutonium dispositioning facilities at the Rocky Flats Environmental Technology Site.

Dr. O'Kula managed the completion of the SRS K Reactor PRA program. He developed the K Reactor Source Term Predictor Model and assisted with the core technology lay-up program to preserve competencies in reactor safety. He coordinated a 25-person group responsible for K Reactor probabilistic and deterministic dose analyses, and led the examination of reduced power cases at project termination. He developed risk and dose management applications to cost-effectively prioritize facility modifications.

Dr. O'Kula interfaced with DOE Independent and Senior Review teams to finalize study acceptance, and transitioned the risk assessment team to risk management functions for nuclear and waste processing facilities. In addition, he successfully prepared a 10 CFR 100 Siting white paper to resolve issues raised by the DNFSB, and teamed with DOE/HQ legal support to document resolutions. He led the development of a position paper demonstrating SRS Replacement Tritium Facility compliance with DOE Safety Policy (SEN-35-91).

Staff Engineer

Dr. O'Kula led an analytical team quantifying the tritium source term during a Loss of River Water design basis accident. He evaluated airborne tritium levels with multi-cell CONTAIN model, interfaced with a multidisciplinary team to resolve Operational Readiness Review concerns, developed an SRS-specific methodology for applying MACCS as a tool for Level 3 PRA Applications, and applied CONTAIN code for K Reactor source term analysis.

E.I. duPont de Nemours & Company **1982 to 1989**
Principal Engineer, Research Engineer

Dr. O'Kula performed risk analysis duties for the Savannah River Laboratory (SRL) Risk Analysis Group, and research activities for the Reactor Materials and Reactor Physics Groups.

Westinghouse Electric Corporation **1975**
Summer Student, Reactor Licensing

American Electric Power Corporation **1973 to 1974**
Co-op Student, Reactor Physics and Reactor Licensing

PUBLICATIONS (2000-2006):

K. R. O'Kula and D. C. Thoman, *Analytical Evaluation of Surface Roughness Length at a Large DOE Site (U)*, American Nuclear Society Winter Meeting, November 12-16, 2006 (Albuquerque, NM).

K. R. O'Kula and D. Sparkman, *Safety Software Guide Perspectives for the Design of New Nuclear Facilities (U),* Winter Meeting of the American Nuclear Society, November 13 – 17, 2005 (Washington, D.C.).

K. R. O'Kula and R. Lagdon, *Progress in Addressing DNFSB Recommendation 2002-1 Issues: Improving Accident Analysis Software Applications*, Fifteenth Annual Energy Facility Contractors Group Safety Analysis Workshop, April 30 – May 5, 2005, Los Alamos, NM (2005).

K. R. O'Kula and Tony Eng, *A "Toolbox" Equivalent Process for Safety Analysis Software*, Fourteenth Annual Energy Facility Contractors Group Safety Analysis Workshop, May 1-6, 2004, Pleasanton, CA (2004).

K. R. O'Kula, D. C. Thoman, J. A. Spear, R. L. Geddes, *Assessing Consequences Due to Hypothetical Accident Releases from New Plutonium Facilities (U)*, American Nuclear Society Embedded Topical Meeting on Operating Nuclear Facility Safety, November 14 – 18, 2004 (Washington, D.C.).

Kevin O'Kula and Jerry Hansen, *Implementation of Methodology for Final Hazard Categorization of a DOE Nuclear Facility (U)*, Annual Meeting of the American Nuclear Society, June 13-17, 2004, (Pittsburgh, PA).

K. R. O'Kula and Tony Eng, *A "Toolbox" Equivalent Process for Safety Analysis Software*, Fourteenth Annual Energy Facility Contractors Group Safety Analysis Workshop, May 1-6, 2004, Pleasanton, CA (2004).

K. R. O'Kula, et al., *Evaluation of Current Computer Models Applied in the DOE Complex for SAR Analysis of Radiological Dispersion & Consequences*, WSRC-TR-96-0126, Westinghouse Savannah River Company (2003).

K. R. O'Kula, et al., *Evaluation of Current Computer Models Applied in the DOE Complex for SAR Analysis of Radiological Dispersion & Consequences*, WSRC-TR-96-0126, Rev. 3, Westinghouse Savannah River Company (2002).

K. R. O'Kula, *A DOE Computer Code Toolbox: Issues and Opportunities*, Eleventh Annual EFCOG Workshop, also 2001 Annual Meeting of the American Nuclear Society, Milwaukee, WI (2001).

EXHIBIT 2

Washington Group International

Integrated Engineering, Construction, and Management Solutions

WSMS-TR-07-0005
Revision 1

Radiological Dispersion and Consequence Analysis Supporting Pilgrim Nuclear Power Station Severe Accident Mitigation Alternative Analysis

Submitted to:

Entergy Nuclear Operations
Plymouth, Massachusetts

by:

Washington Safety Management Solutions LLC

Contract No. 4500555019

May 2007

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Key words:

Radiological Dispersion
Consequence Assessment
Computer Modeling of Severe Accidents
Consequence Mitigation
Economic Costs
Emergency Planning

Radiological Dispersion and Consequence Analysis Supporting Pilgrim Nuclear Power Station Severe Accident Mitigation Alternative Analysis

May 2007

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Radiological Dispersion and Consequence Analysis Supporting Pilgrim Nuclear Power Station Severe Accident Mitigation Alternative Analysis

Executive Summary

Entergy Nuclear Operations requested the technical assistance of Washington Safety Management Solutions LLC (WSMS) to address a contention admitted as part of the license renewal process for the Pilgrim Nuclear Power Station in Plymouth, Massachusetts. This contention, Contention 3, was submitted by the Pilgrim Watch organization, and raises issues on the applicability of the MACCS2 computer code to support the Pilgrim Severe Accident Mitigation Alternatives (SAMA) analysis, and consequently, the ability to draw conclusions about the economic impacts relative to benefits of possible mitigation alternatives.

Three areas of issues raised in Contention 3 have been admitted into the license renewal proceeding:

- The validity of the MACCS2 meteorological model and data used in the economic SAMA analysis, including the ability of the model to treat terrain effects and sea breeze phenomena. Also spatial and temporal data resolution requirements were questioned.
- The adequacy of the input data and assumptions influencing the evacuation and sheltering model in MACCS2, and the capabilities of the code itself to model actual and worst case scenarios.
- The adequacy of the model for economic losses, especially those characterizing tourism and business costs.

This report supports the technical resolution of the main contention areas. It provides technical information to answer questions about the original SAMA analysis relating to use of the MACCS2 code, especially on meteorological, evacuation, and economic modeling. Also, additional MACCS2 code runs to support sensitivity analysis of the consequences of uncertainties in specific input data and parameter values were performed. The insights gained from these additional analyses are used to address the related contention issues.

The analysis provided here reaffirms the use of the MACCS2 computer model to guide the identification of SAMAs for the Pilgrim plant based on postulated accident conditions. In particular, MACCS2 is a state-of-the-art computer model, well-suited for SAMA analysis determination of consequences, including the population dose risk (PDR) and off-site economic cost risk (OECR). MACCS2 consequences are calculated using the Gaussian plume methodology that is well-understood and is applied using conservative modeling assumptions and input data that is compliant with Nuclear Regulatory Commission guidance and nuclear industry practices.

Use of the MACCS2 code and application to the Pilgrim Station set of postulated accident conditions provided the following insights:

- The Gaussian plume model is appropriate for the fifty-mile region of interest surrounding the Pilgrim site. The Gaussian plume model is found to be in good agreement with more sophisticated and complex models that are considerably more data-intensive and has been applied using conservative modeling assumptions to produce conservative results.
- Most of the PDR and OECR estimates are primarily due to radiological exposures and subsequent economic effects in the 20-mile to 50-mile region areas and sea breeze effects and variability are rarely important at these distances.
- The dose mitigation models implemented in the MACCS2 code used authoritative, evacuation time estimate (ETE) data and a conservative model of evacuation of residents from the EPZ. In addition, these contributions are not significant to the overall PDR and OECR estimates.
- Sensitivity analyses demonstrated that while evacuation timing and speed can affect the population dose incurred in the initial phase following an accident condition, the influence to the overall population dose is small.
- Population dose is mostly due to groundshine effects occurring in the long-term phase of the analysis, or approximately the first 30 years following the accidental release. Other contributors are decontamination dose and ingestion dose.
- An updated accountability of business and tourism losses in the 50-mile region around Pilgrim indicated small, incremental increase to the OECR. However the increase was insufficient to justify additional severe accident mitigation alternatives.
- Similar to the population dose component, economic costs are incurred mostly in the long-term phase. During the long-term phase, the major contributors to cost are, in order of descending importance, population interdiction, decontamination, and condemnation costs.
- Agricultural losses are insignificant compared to non-farm, business loss and tangible property losses.

MACCS2 sensitivity cases explored trajectory effects, terrain impacts, distance to travel for evacuees, no-evacuation, evacuation delay time and evacuation speed, and the addition of non-farm wealth data to account more fully for economic costs. The increase in PDR ranged from 0% to 6%, and on average, was about 3%. The increase in OECR ranged from 0% to 4%, and averaged about 1%.

Using the maximum increase in the results of the MACCS2-based sensitivity studies for PDR and OECR of 6% and 4%, respectively, would increase the total cost by about 4%. However, before any additional SAMAs would be identified as potentially cost-effective, the increase in benefit would need to be on the order of 100%, or a factor of twenty-five times greater than shown by any of the sensitivity analyses in this report. Even under bounding sensitivity analyses previously performed for the SAMA analysis, including 95th percentile uncertainty and three percent discount rate cases, the increase in benefit would need to be approximately an order of magnitude larger before these analyses would be affected.

Accordingly, the maximum benefit increase of 4% calculated from the MACCS2 sensitivity analyses in this report would not change the existing set of potentially cost-effective SAMAs identified by the PNPS SAMA analysis. Much larger increases in benefit would need to occur before any new SAMAs would be identified as potentially cost effective.

Introduction

Entergy Nuclear Generation Company and Entergy Nuclear Operations, Inc. (Entergy Nuclear) are requesting renewal of the operating license for the Pilgrim Nuclear Power Station (PNPS or Pilgrim) through the process established by the U.S. Nuclear Regulatory Commission (NRC) and other federal entities. The current license for the Pilgrim Nuclear Plant, located in Plymouth, Massachusetts, extends into 2012.

In May 2006, requests for a hearing and petitions to intervene were filed by the petitioners Pilgrim Watch and the Attorney General of the State of Massachusetts (Pilgrim Watch, 2006). The Pilgrim Watch's Petition contained five contentions, and included one that questioned the Severe Accident Mitigation Alternatives (SAMA) analysis prepared for PNPS. Specifically, Pilgrim Watch Contention 3 (PW3) contends:

> The Environmental Report inadequately accounts for off-site health exposure and economic costs in its SAMA analysis of severe accidents. By using probabilistic modeling and incorrectly inputting certain parameters into the modeling software, Entergy has downplayed the consequences of a severe accident at Pilgrim and this has caused it to draw incorrect conclusions about the costs versus benefits of possible mitigation alternatives.

This contention was subsequently admitted in part into the license renewal proceedings by the Atomic Safety and Licensing Board (ASLB) of the Nuclear Regulatory Commission. At least in part, Contention 3 centers on the sufficiency of the MACCS2 computer code (SNL, 1998a, 1998b), the data input to the code to support the Pilgrim SAMA analysis, and the capability of the MACCS2 model to provide a basis upon which to draw conclusions in the Pilgrim SAMA analysis (PNPS, 2006; LRA, 2006a, 2006b).

The main areas at issue that are addressed in this report are the following:

- The validity of the MACCS2 meteorological model and data used in the economic SAMA analysis, including the ability of the model to treat terrain effects and sea breeze phenomena. Also spatial and temporal data resolution requirements were questioned.
- The adequacy of the input data and assumptions influencing the evacuation and sheltering model in MACCS2, and the capabilities of the code itself to model actual and worst case scenarios.
- The adequacy of the model for economic losses, especially those characterizing tourism and business costs.

This document provides technical information that addresses each of the three PW3 issues listed above. It includes aspects of the radiological dispersion and consequence analysis prepared to support the original SAMA analysis and also contains the new sensitivity cases that were run to address issues and important phenomena questions raised in the contention.

Contention Issues, Use of the MACCS2 Code and Applications to Pilgrim SAMA Analysis

In this section, the admitted contention is described along with statements concerning the contention, as given by the ASLB. The MACCS2 computer model is then discussed followed by characteristics of the base case consequences. Finally, a discussion on each of the three issues relative to the MACCS2 computer model is given before reviewing the outcome of the sensitivity analyses.

A. Contention as Admitted by the Licensing Board

1. Contention as Formally Admitted by Board: "Applicant's SAMA analysis for the Pilgrim plant is deficient in that the input data concerning (1) evacuation times, (2) economic consequences, and (3) meteorological patterns are incorrect, resulting in incorrect conclusions about the costs versus benefits of possible mitigation alternatives, such that further analysis is called for."

2. Board Statements Concerning the Contention:

a. "[W]e find their contention, that use of more accurate input data in these three areas could materially impact the computed outcome, to be reasonable and the possibility intuitively obvious in the absence of actual computations definitively demonstrating otherwise."

b. "[T]he evacuation and economic information provided by Pilgrim Watch would seem reasonably to indicate that different results might have been reached in the SAMA analysis, and the same applies, to an extent, to the meteorological data."

B. PW Challenges to the MACCS2 Model and the Input Parameters

This section restates the pertinent parts of the Pilgrim Watch Contention #3 as they relate to the MACCS2 code and its application in the SAMA analysis.

1. PW CHALLENGES TO THE METEOROLOGICAL MODEL AND DATA USED IN THE SAMA ANALYSES:

a. The MACCS2 Code uses a Gaussian plume model to estimate atmospheric dispersion of point release of radionuclides. Such a model has the following inherent limitations.
   (1) Model does not take into account changes in wind speed or direction, either in time or space.
   (2) Model does not take into account terrain effects.
   (3) Model cannot be used to estimate dispersion less than 100 meters.

b. Sea breeze would have an important impact on dose exposure. The sea breeze effect is described in 1988 Spengler and Keeler report.

c. Coastal topography also plays an important part in dose exposure.

d. Data from only two sources for a single year were used.

e. Proper analysis requires multiple years of data from multiple sources in order to take into account the specific characteristics of the Plymouth area. For example, under sea breeze conditions, turbulence structure of the atmosphere will not be accurately determined by meteorological sensors at the Pilgrim plant.
f. Accurate analysis would require installation of continuous recording meteorological instruments along the coast and at additional inland sites.

2. <u>PW CHALLENGES TO THE EVACUATION TIME ESTIMATES USED IN THE SAMA ANALYSES</u>:

a. MACCS2 model improperly assumes that the population is out of danger upon crossing the 10-mile boundary.
b. MACCS2 model does not consider those who cannot evacuate and must shelter.
c. The SAMA analysis did not use the most recent evacuation time estimates.
d. Many of the assumptions and estimates of the evacuation time estimates used in the Pilgrim SAMA analysis are faulty.
e. The evacuation delay time estimates of 40 minutes and 2 hours are incorrect because "notice of evacuation could take longer than 2 hours to reach people."
f. The evacuation speed estimates are incorrect.

3. <u>PW CHALLENGES TO THE MACCS2 ECONOMIC ANALYSIS</u>:

a. The MACCS2 Code models only the economic costs of mitigative actions.
    (1) Economic costs include the cost of decontamination, condemnation and temporary or permanent relocation.
    (2) The valuations include only the assessed value of the property, ignoring the business value of the property.
    (3) Nowhere does the model account for the loss of economic activity, such as loss of tourism.
b. Tourism is an important business in the area surrounding the Pilgrim plant.
    (1) 2003 report shows $11.2 billion spent in Massachusetts annually on transportation, lodging, food, entertainment, recreation, and incidentals.
    (2) A severe accident at Pilgrim would severely impact travel in at least four counties, Plymouth, Barnstable, Dukes and Nantucket. In 2003, travel expenditures for these counties were as follows:
    (a) Plymouth – $353.14 million.
    (b) Barnstable – $684.27 million.
    (c) Dukes – $91.86 million.
    (d) Nantucket – $139.93 million.
(3) Plymouth Plantation, less than five miles from plant, brings in almost $10 million annually.

Response for Pilgrim Watch #3 Issue Resolution

As discussed in the Introduction section, PW#3 primarily raises questions on: (1) the adequacy of the single-point Gaussian model for a fifty-mile radius region surrounding Pilgrim; and (2) the choice of input parameters in the MACCS2 SAMA analysis. The central themes in the contention relate to the Gaussian model, emergency evacuation and economic costs.

Prior to discussing the three key issues in the contention, an overall review of the MACCS2 code is required. The base case modeled in the SAMA analysis is described next, followed by observations drawn from the initial base case MACCS2 results.

MACCS2 Consequence Model

The code used for the previous and updated SAMA analyses is MACCS2. Version 1.12 of MACCS2 was used in the original SAMA analysis documented in the Appendix E Environmental Report (PNPS, 2006). Version 1.13.1 of the code from Sandia National Laboratories (SNL) was applied in response to the NRC's Request for Additional Information (RAI) (LRA, 2006a. 2006b). MACCS2 is an update to MACCS, and the CRAC line of radiological dispersion and consequence codes (SNL, 1998a and SNL, 1998b).[1] MACCS2 is a Gaussian plume model for calculation of radiological atmospheric dispersion and consequences that has been used by nearly all nuclear power plants in the U.S. to support Probabilistic Safety Assessments (PSAs) and more recently, SAMA analysis as part of nuclear power license extension. It has been used worldwide for nuclear facility safety analysis, chiefly to support PSAs, but also deterministic safety analysis and cost-benefit studies.

In general, MACCS2 is setup to execute in three sequential steps: (1) ATMOS calculates air and ground concentrations, plume size, and timing information for all plume segments as a function of downwind distance; (2) EARLY calculates consequences due to radiation exposure in the emergency phase (first seven days) from the time of release; and (3) CHRONC calculates long-term consequences due to exposure after the emergency phase, and for determining decontamination and other economic impacts from the hypothetical accident. Additional input files include site, meteorological data, dose conversion factors (DCFs), and site/population data to support overall execution. The complete three-step execution of MACCS2, including input and output files, is shown in Figure 1 for a general analysis.

[1] The United States Nuclear Regulatory Commission (NRC) sponsored the development of the MACCS code (Chanin, 1990; Jow, 1990; Rollstin, 1990; and Chanin, 1993) as a successor to the CRAC2 code for the performance of commercial nuclear industry probabilistic safety assessments (PSAs). The MACCS code was used in the NUREG-1150 PSA study (NRC, 1990a) in the early 1990's. Prior to being released to the public, MACCS was independently verified by Idaho National Engineering and Environmental Laboratory (Dobbe, 1990). After verification, the NRC released MACCS, Version 1.5.11 for unrestricted use. Examples of MACCS applied in this period include commercial reactor PSAs (both U.S. and international), as well as non-reactor nuclear facilities (primarily U.S.). Although MACCS2 was originally released in 1997, it was not until 2004 that Version 1.13.1 was released. MACCS2 1.13.1 dispositioned known errors and addressed a number of user interface issues.

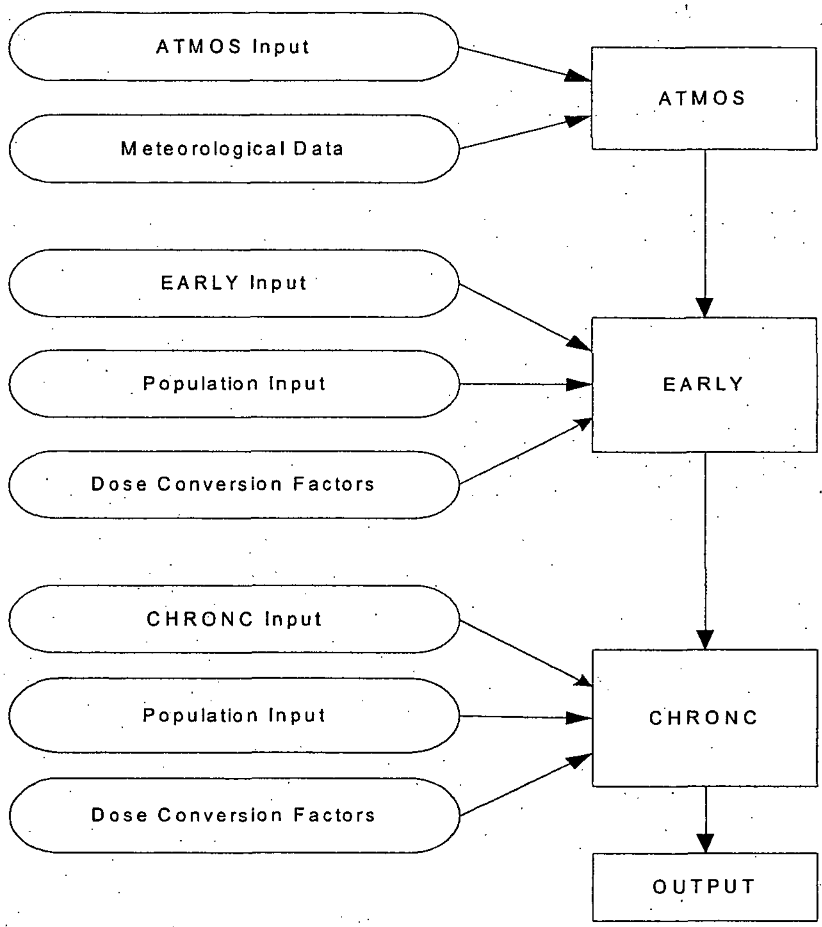

Figure 1. MACCS2 Three-step Execution for a postulated release condition.

Base Case and Original Sensitivity Cases

MACCS2 was used to analyze consequences from a set of release conditions over a 50-mile, or 80-km, radius region around the Pilgrim site. The key consequences of interest were population dose (person-sievert), population dose risk (PDR, in units of person-rem/year), and total off-site economic cost ($) and off-site economic cost risk (OECR, in units of $/year). The mean values of consequence distributions were used in the analysis and the mean population dose and off-site economic costs are multiplied by the frequency of occurrence to determine risk values for each release condition. These are summed to determine overall PDR and OECR estimates.

The base case in the SAMA analysis is based on a Pilgrim plant-specific Level 3 Probabilistic Risk Assessment (PRA) and Individual Plant Examination (IPE) model results to measure the changes in consequences with potential plant modifications as described in PNPS (2002). The set of source terms applied in the base analysis are representative of accident sequences evaluated in the PRA and IPE analyses for the Pilgrim Station and described in Section E.1.2.2.6 of the Environmental Report (PNPS, 2006). Characteristics and frequency of the nineteen release categories or source terms were also documented in PNPS (2006).

The Pilgrim SAMA results are based on a 2028 MW_{th} core inventory with an adjustment of a 25% increase for long-lived radionuclides, ^{90}Sr, ^{134}Cs, and ^{137}Cs (Table E1-14 of LRA, 2006b). MACCS2 considers the source term in nine groups based on their physical/chemical behavior and characteristics once the group of radionuclides is released from the fuel and enters the environment as part of a plume.

For the MACCS2 cases, the 2000 Census Bureau data, along with projected growth for the 50-mile region was used to estimate permanent resident population levels to the year 2032 on a county-specific basis (PNPS, 2002). A transient/permanent resident ratio was estimated for each of the counties within the 50-mile grid and is conservatively set at the 2000 level. The total population for a given spatial element in the MACCS2 grid is conservatively projected at the 2032 permanent resident level for the county making up most of the spatial element added to the peak transient level (using the ratio of transient to permanent as determined for 2000). Details of the analysis are documented in PNPS (2002).

Hourly meteorological data for the MACCS2 code was obtained from the PNPS meteorological monitoring system and the Plymouth airport (precipitation). The PNPS data was based on calendar year 2001 observations from the upper tower, and was processed into hourly wind speed, wind direction, atmospheric stability, precipitation input for MACCS2. Data was evaluated from PNPS to provide the mixing layer height on a seasonal basis (PNPS, 2002; PNPS, 2006).

In general, most economic data for farm and non-farm activities, including decontamination, interdiction, and condemnation data sets and individual parameter values are based on the best available cost information current at the time of the analysis. Later sections of this report discuss individual point values for key parameters in more detail.

Several phases of consequence analysis are usually modeled in MACCS2: a.) an emergency phase; b.) an interdiction phase; and c.) a long-term phase. MACCS2 has been configured in the PNPS SAMA analysis to model a seven-day emergency phase after the postulated accident, followed by a five year interdiction period, and then a thirty-year long-term consequence analysis period. Mitigation plans incorporating evacuation and sheltering are modeled only during the emergency phase, and applied only to residents within the EPZ. During the second period, or interdiction phase, protective actions such as decontamination, or decontamination followed by interdiction are evaluated to determine if the exposure of an individual can be reduced to an allowable dose level (typically, 4 rem over 5 years). If it is not possible to reduce doses to the defined dose level in a cost-effective manner, the property is condemned, and the resident population is permanently relocated. During the long-term phase (set for 30 years in this analysis) exposure pathways include

- Groundshine
- Inhalation of resuspended radioactivity
- Food ingestion
- Water ingestion.

The SAMA analysis (Pilgrim, 2006) considered three MACCS2 cases. The three cases are:

- Base case MACCS2 (Case 1): This case considered a forty-minute delay between the site siren alert and the beginning of evacuation of persons within the 10-mile Emergency Planning Zone (EPZ). A constant evacuation speed of 2.17 miles/h (0.97 m/s) was used in the base case. The MACCS2 dose mitigation model evaluates inhabitants within the EPZ as beginning evacuation at a specified time and moving outward from the PNPS until they reach a distance of 20 miles. Once the evacuees reach the specified distance of 20 miles, they receive no additional exposure until the emergency phase is over (7 days).
- Delayed effective evacuation time (Case 1.a): The first sensitivity case assumed a two-hour delay before evacuees in the EPZ begin evacuation. This case was run to check the sensitivity of the consequence results to uncertainties in the delay time.
- Delayed evacuation speed (Case 1.b). The second sensitivity case maintains the 40-minute delay time before evacuation begins, but assumes a lower effective evacuation speed of 0.69 m/s to evaluate consequence sensitivities due to uncertainties in the evacuation speed.

In this report, new MACCS2 sensitivity cases were developed that help resolve part or parts of the PW #3 issues, and they are run using the same set of release conditions as were applied in the original Appendix E SAMA study. These are run using the revised input data and assumptions. The results are compared to the base case results and thus used to evaluate whether any new SAMAs would potentially be cost beneficial.

Characteristics of Pilgrim Population Dose and Off-site Economic Cost Risks

As introduced earlier, nineteen source term sets or bins, with an appropriate frequency of occurrence, were analyzed for the Pilgrim SAMA analysis. Each accident bin represents a postulated accident sequence and the source term characteristics governing the release. Included in this information is the amount and the fission and activation products released, the timing, duration, height, sensible energy, whether collocated buildings are influencing the release, and other parameters. Table 1 is a revision to the original SAMA analysis documented in the PNPS Environmental Report (Table E.1-15) as revised in response to Requests for Additional Information (LRA, 2006b). Table 1 shows the base case (Case 1) mean population dose and off-site economic cost results for each of the 19 Collapsed Accident Progression Bins (CAPBs), and after weighting by their respective frequency, the PDR and OECR results. Table 2 contains atmospheric release characteristics information for each of the CAPBs evaluated in the SAMA analysis.

Table 1 indicates that almost 98% of the PDR and the OECR values are due to contributions from CAPB-15, -14, -10, and -11, in descending order of importance. Approximately 94% of the PDR and the OECR is based on CAPB-15 and CAPB-14 alone. These two CAPBs dominate because their high respective frequencies are coupled to relatively large consequence results for both population dose and off-site economic cost. Table 2 indicates that these four CAPBs may be characterized as elevated releases (30 m), several hours in length, and with sensible heat release rate in the emitted plume of 7 MW – 8 MW.

The Case 1 MACCS2 results were broken down into finer spatial and temporal segments to identify spatial and temporal dependencies, and thereby help identify the key factors controlling the subsequent PDR and OECR results. Once the trends were understood for the base case, the major factors controlling the consequence results were recognized. As a prefacing first step, understanding the base case results was important to anticipating the results of additional MACCS2 sensitivity analyses to a large degree.

Table 3 shows the early (seven-day) phase and the late phase of population dose at the mean level of consequence for each of the nineteen CAPBs. The late phase includes population doses due to activities including decontamination, interdiction, ingestion of contaminated foodstuffs and water.[2] The average contribution from the long-term doses to the total population dose is approximately 83%.

A similar examination can be made of the spatial dependence of the population dose. Appendix A shows the population dose contributions at the mean level from ring 1 through ring 15 of the Pilgrim 50 –mile grid. Most of the population dose is contributed by dose in the following four rings in decreasing order of population dose importance: 1.) 30 miles – 40 miles; 2.) 20 miles – 30 miles; 3.) 40 miles – 50 miles; and 4.) 10 miles – 20 miles. The order is based on MACCS2 base case results that show the dose-dominant conditions arise in the simulation with the intersection of high exposure conditions and high population levels.

While off-site economic costs are numerically different, the same trend can be shown for early phase and long-term phase contributions to the total economic costs. Higher doses to population will drive the interdiction costs, decontamination costs, relocation costs, and finally condemnation costs, so this similarity is not surprising.

[2] Food ingestion dose to a population from a postulated release in the MACCS2 analysis is based on agricultural productivity, and the land area that is contaminated.

Table 1. Mean Consequence and Risk Values for Base Case Population Dose and Off-site Economic Cost – (Numerically Equivalent to Table E.1-15 of LRA (2006b)

Release Mode	Frequency (per year)	Population Dose (person-Sv)*	Off-site Economic Cost ($)	Population Dose Risk,** (person-rem)/year)	Off-site Economic Cost Risk** Risk,($/year)
CAPB-1	9.51E-08	5.77E-01	3.82E+06	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	7.18E+06	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.28E+02	7.31E+06	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.50E+04	4.93E+09	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.92E+04	6.15E+09	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.60E+04	4.35E+09	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.78E+04	5.25E+09	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.42E+04	1.68E+10	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.54E+04	9.26E+09	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.74E+04	1.72E+10	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.72E+04	1.29E+10	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.18E+02	4.85E+06	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.48E+03	8.36E+08	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.69E+04	4.96E+09	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.65E+04	1.80E+10	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.93E+04	6.28E+09	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.12E+04	1.98E+10	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.58E+04	8.43E+09	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.72E+04	2.11E+10	1.39E-01	5.12E+02
TOTALS				1.46E+01	5.26E+04

* 1 person-Sv = 100 person-rem
** Calculated as follows:
PDR (person-rem/year) = Release mode frequency (per year) X Population Dose (person-Sv) X 100 rem/Sv;
OECR ($/year) = Release mode frequency (per year) X Off-site Economic Cost ($)

Table 2. Release Characteristics of PNPS Releases for SAMA Collapsed Accident Progression Bins

Release Mode	Frequency (per year)	Time of Release After Shutdown, (seconds)	Release Duration, (seconds)	Release Height, (m)	Sensible Heat Release Rate in Plume, (W)
CAPB-1	9.51E-08	2.20E+04	9.00E+03	30.	2.61E+05
CAPB-2	1.27E-08	2.20E+04	9.00E+03	30.	2.50E+05
CAPB-3	2.39E-09	2.20E+04	9.00E+03	30.	2.50E+05
CAPB-4	3.29E-09	1.83E+04	3.56E+03	30.	1.10E+07
CAPB-5	2.73E-09	2.53E+04	7.93E+03	30.	8.34E+06
CAPB-6	7.95E-09	2.56E+04	8.11E+03	30.	8.23E+06
CAPB-7	7.93E-09	2.61E+04	8.46E+03	30.	8.03E+06
CAPB-8	2.06E-08	2.00E+04	4.59E+03	30.	1.04E+07
CAPB-9	9.25E-09	2.44E+04	8.87E+03	30.	4.18E+06

Release Mode	Frequency (per year)	Time of Release After Shutdown, (seconds)	Release Duration, (seconds)	Release Height, (m)	Sensible Heat Release Rate in Plume, (W)
CAPB-10	8.53E-08	2.60E+04	8.40E+03	30.	8.06E+06
CAPB-11	4.35E-08	2.60E+04	8.40E+03	30.	8.06E+06
CAPB-12	1.70E-06	4.64E+04	9.00E+03	30.	7.59E+06
CAPB-13	2.30E-09	2.71E+04	9.00E+03	30.	1.80E+06
CAPB-14	2.26E-06	4.46E+04	9.00E+03	30.	7.08E+06
CAPB-15	2.12E-06	4.62E+04	9.00E+03	30.	7.60E+06
CAPB-16	1.18E-09	2.12E+04	9.00E+03	30.	2.50E+05
CAPB-17	6.91E-09	2.14E+04	9.00E+03	30.	2.50E+05
CAPB-18	4.61E-10	2.12E+04	9.00E+03	30.	2.50E+05
CAPB-19	2.43E-08	2.18E+04	9.00E+03	30.	2.50E+05

Table 3. Comparison of Early and Long-Term Population Dose for Case 1 CAPBs

Release Mode	Frequency	Population Dose	Early	Long-term	Long-term/Total
	(per year)	(person-Sv)	(person-Sv)	(person-Sv)	
CAPB-1	9.51E-08	5.77E-01	9.25E-03	5.68E-01	9.84E-01
CAPB-2	1.27E-08	1.21E+02	2.58E+00	1.18E+02	9.75E-01
CAPB-3	2.39E-09	1.28E+02	2.91E+00	1.25E+02	9.77E-01
CAPB-4	3.29E-09	1.50E+04	2.02E+03	1.30E+04	8.67E-01
CAPB-5	2.73E-09	1.93E+04	2.84E+03	1.64E+04	8.50E-01
CAPB-6	7.95E-09	1.60E+04	1.71E+03	1.43E+04	8.94E-01
CAPB-7	7.93E-09	1.78E+04	2.37E+03	1.54E+04	8.65E-01
CAPB-8	2.06E-08	4.46E+04	1.38E+04	3.04E+04	6.82E-01
CAPB-9	9.25E-09	2.55E+04	4.94E+03	2.05E+04	8.04E-01
CAPB-10	8.53E-08	4.76E+04	1.30E+04	3.44E+04	7.23E-01
CAPB-11	4.35E-08	3.73E+04	1.02E+04	2.70E+04	7.24E-01
CAPB-12	1.70E-06	1.18E+02	9.14E+00	1.09E+02	9.24E-01
CAPB-13	2.30E-09	8.48E+03	4.39E+02	8.04E+03	9.48E-01
CAPB-14	2.26E-06	1.69E+04	1.59E+03	1.53E+04	9.05E-01
CAPB-15	2.12E-06	4.69E+04	1.27E+04	3.38E+04	7.21E-01
CAPB-16	1.18E-09	1.94E+04	4.02E+03	1.53E+04	7.89E-01
CAPB-17	6.91E-09	5.15E+04	1.41E+04	3.71E+04	7.20E-01
CAPB-18	4.61E-10	2.59E+04	6.56E+03	1.93E+04	7.45E-01
CAPB-19	2.43E-08	5.78E+04	1.80E+04	3.92E+04	6.78E-01

Trends from Base Case Results

Characteristics of the original base case provide useful insights to the SAMA analysis studies for Pilgrim. Before exploring sensitivity calculations to determine the impact of changes to input data and parameters, several conclusions can be drawn from the original base case:

- The population dose includes an early, or emergency phase of the accident (7 days duration), and a long-term phase (~35 years duration). Most of the population dose, on the order of 83%, is due to the long-term phase after the accident. The dose pathways included over this period are: groundshine, inhalation of resuspended radionuclides, ingestion of contaminated food and ingestion of contaminated water. Groundshine tends to dominate followed by food and water ingestion as lesser contributors. This implies that emergency actions, such as evacuation and sheltering or timing of these and other dose mitigation strategies will have only small impacts to the overall population dose.
- The CAPBs that dominate risk are CAPB-15 and CAPB-14. This is mostly due to the high frequency and large release associated with these two bins.
- Off-site economic costs include population-dependent habitability, and agricultural activity-dependent production costs. Farming costs are found to be virtually negligible in these analyses. Of the costs for late phase higher source term bins, population interdiction, decontamination, and condemnation costs are typically the largest in descending order of importance. Costs for the emergency phase CAPBs are driven by emergency phase actions and by interdiction activities.
- Similar to the population dose risk, CAPB-15 and CAPB-14 are dominant bins for the off-site economic cost risk, which again follow from high frequency and large release associated with these two bins.
- For population dose and off-site economic costs, the majors factors are the size of the source term (i.e., amount of radioactivity released), the parameters controlling the long-term phase after the accident, and the population levels impacted in the 20 mile to 50 miles spatial region. Early or emergency phase effects and effects to the close-in population (within 20 miles of the PNPS) can be changed by assumptions and parameter values in the early phase but their contribution to the overall PDR and OECR is likely to be small.

For most of the sensitivity runs that are described in the next three sections, most of the results can be anticipated based on the insights gained from the original base case result characteristics.

The remainder of this report discusses the three contention areas, or challenges as follows:

- Meteorological model and application to the Pilgrim regional environment
- Evacuation modeling and other aspects of the consequence mitigation model
- Economic model.

The commentary and analysis provided herein also includes the results of new MACCS2 sensitivity analysis cases. The specific cases shall be discussed at the end of the appropriate section for the sensitivity case study was performed. Section 4 will summarize the results and compare the overall PDR and OECR to the base case values. Section 5 will integrate the sensitivity analysis into the SAMA analysis framework and evaluate whether any new SAMAs are identified. Section 6 will provide conclusions.

1. Meteorological Model

This section describes the meteorological input data and modeling approaches used in the MACCS2 code for the PNPS SAMA analysis.

a. Meteorological Model Overview

The first challenge is primarily a claim that the Gaussian model underpinning MACCS2 is inappropriate to the Pilgrim plant physical environment, and that the meteorological model cannot adequately treat dispersion and the subsequent consequences of postulated severe accidents. As introduced earlier in this report, the computer code MACCS2 is used to model off-site consequences of postulated severe accidents for PNPS. The MACCS2 meteorological model is a Gaussian plume model, with each postulated release occurring over a single time interval, or plume segment. Each plume segment in the release travels in the direction that the wind is blowing at the time that the plume leaves the facility. Several hundred weather trials are run and the results for a particular trial weighted by the probability of the specific weather trial's occurrence.

b. PW#3 Meteorological Model Challenge by Subpart

(1) Model does not take into account changes in wind speed or direction, either in time or space.

For a given plume, the MACCS2 model assumes that wind speed, wind direction, stability category, precipitation rates, persist, or are spatially invariant. Specifically, MACCS2 uses a single-point source for weather data and approximates weather data as spatially uniform.

While MACCS2 does not model spatial variation in weather conditions, it does model time dependence by simulating the same plume release under different weather conditions based on hourly changes reflected in the site meteorological data file. Each plume that is "emitted" in the atmospheric release simulation is modeled with the meteorological data read for the date and the hour randomly selected by the code. A statistically significant number of plume release simulations are performed by MACCS2 with weather conditions randomly chosen from the site meteorological file. Data read from the file include wind speed, stability class, and precipitation rate can change on an hour-by-hour basis. Thus the MACCS2 code, as used for the Pilgrim SAMA analyses, does take into account changes in wind speed and direction as a function of time for each sampled weather condition, but not as a function of space.

Nuclear safety SAMA regional analyses require running well over a hundred different weather trials to obtain robust statistical results (NEI, 2006). The MACCS2 code is a flat-earth Gaussian plume models that can meet the computational demands of calculating many kinds of consequence results, with the appropriate level of statistical sampling. In contrast, computer codes that can accommodate multiple-station data so as to be able to model spatial variation of wind speed and direction (e.g., mesoscale Lagrangian puff models) and thus provide regional consequences would be impractical for analyzing the large number of weather sequences needed for SAMA analyses. The computer code for SAMA analysis must analyze several hundred weather records at minimum to calculate statistically meaningful results, and thereby provide plant insights with respect to many different site-specific weather sequences, rather than time-intensive modeling of only a few sequences. Use of other codes for this purpose is not practical given statistical requirements and the amount of input data necessary to fully account for off-site exposure and economic costs.

Mean levels of consequence are required in SAMA analysis to provide an adequate basis for cost-benefit decision-making on potential plant modifications (NEI, 2006). Decisions made on 95th quantile (exceeded only 5% of the time) or worst-case results could potentially lead to high cost, time intensive plant modifications without commensurate improvements to plant safety.

The Gaussian model is the basis for major regulatory guidance of the U.S. Nuclear Regulatory Commission for reactor licensing and safety applications (NUS, 1981; NRC, 1983; NRC, 2003), and the Department of Energy for nuclear facility consequence analysis (DOE, 2006). While many experimental data – computer code comparisons have been performed, very often a single-site weather data capability such as that used in MACCS2 can demonstrate good agreement in recent analytical comparisons with more complex models [Molenkamp et al., 2004] to a range of 100 miles. The MACCS2 code has been widely used within the 50-mile (80-km) basis distance of nuclear facilities, e.g., for many Environmental Impact Statement and Ingestion Planning Zone (IPZ) applications, including SAMA studies. The code is referenced extensively in the NRC-approved industry guidance for SAMA analysis (NEI, 2006).

The choice of a particular computer model for consequence analysis often presents a decision to the analyst in terms required resources and data uncertainty, and appropriate level of information that is required. In other words, a sophisticated model, in principle, can provide a more accurate answer, but the data input requirements are usually high, and these may not always be known with certainty. An example of this choice is illustrated in Figure 2, which compares the predictions of various models to actual plume behavior. Figure 2 shows the results from a test conducted in 1981 at the Idaho National Laboratory [Lewellen, 1985], in which a non-radioactive tracer (SF_6) was released and the resulting air concentrations were measured and compared with the predictions of three different atmospheric transport models. The plots in Figure 2 depict the air concentration patterns (the plots display concentration contours, or isopleths of air concentrations on the site grid), as well as the estimated maximum dose (assuming radioactive material was released) for (a) a simple straight-line Gaussian plume model, (b) a Gaussian-puff trajectory model with wind-shift, (c) a more sophisticated wind field/terrain sensitive model, Atmospheric Release Advisory Capability (ARAC), developed at Lawrence Livermore National Laboratory, and (d) actual measured air concentrations.

In the case of the Gaussian plume model (a) such as the MACCS2 code, it is terrain-insensitive and cannot follow changes in wind direction *once a plume has been released.* In this comparison, the Gaussian puff model (b) is also terrain insensitive but models a plume in individual puffs and so can more accurately truncate a specified, time-varying release than can a plume model. The wind field and terrain sensitive ARAC model (c) is most accurate portrayal of the actual release conditions in terms of both the spatial and temporal variations.

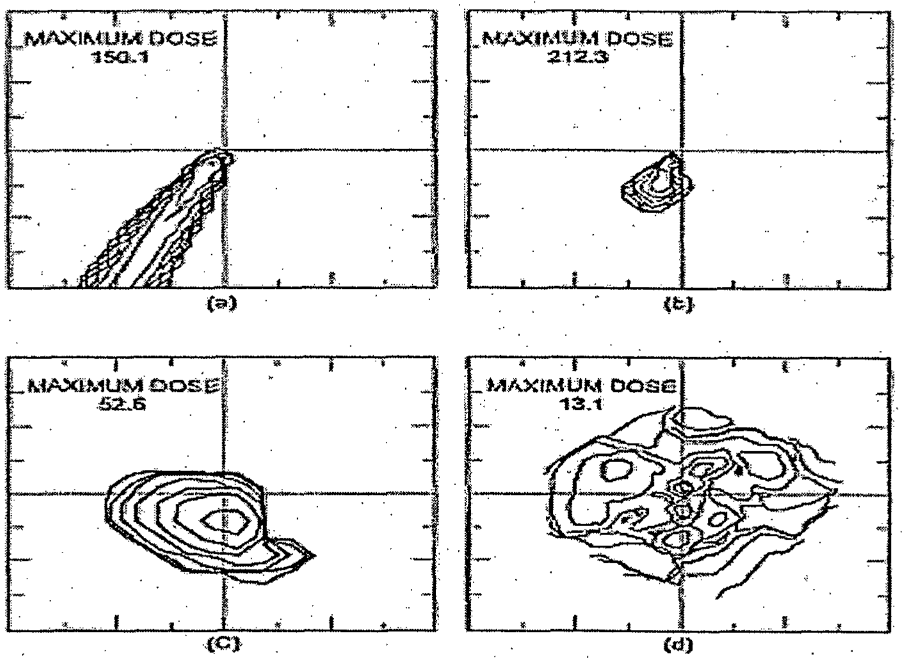

Figure 2. Comparison of Gaussian Plume Model to Other Models and Actual Test Data. Illustration of: (a) Gaussian plume model (b) Gaussian puff model and (c) LLNL ARAC wind field/terrain sensitive model. Measured isopleths are shown in (d) (Gregory and Harper, 1999; originally Lewellen, 1985).

This comparison is not precise, but shows the conservative nature of the Gaussian model for the SF_6 release field test, in the prediction of concentration isopleths (Gaussian plume model) and in the maximum dose predicted (Gaussian puff model). The Gaussian model is significantly more conservative than (1) the actual maximum dose and isopleths as measured by field equipment, and (2) the maximum dose isopleths predicted by the more complex wind field/terrain sensitive code.

MACCS2 Sensitivity Case 2:
The MACCS2 code was rerun to show the effect of using different weather sampled from the Pilgrim meteorological data set than that used in the base case. Most of the release categories listed in Table 2 (from the Pilgrim SAMA analysis) last longer than an hour. A sensitivity analysis was run to estimate the effects of a changing wind direction trajectory in the MACCS2 consequence analysis by choosing different meteorological input data for release categories that last longer than an hour. (The multiple-hour release cases can be identified from Table 2 which lists characteristics of the set of nineteen CAPBs.) The sensitivity case used the weather conditions at the beginning of the plume release rather than at a point an hour or more later into the release as was done in the base case. Because MACCS2 "reads" different weather on an hourly basis, the sensitivity run modifies the weather sequence relative to the base case. Also, the sensitivity is conservative because the plume's radioactivity is released earlier in time than is the case from base case (set from the plant PRA), and is therefore a larger quantity in that less decay has taken place.

Appendix B shows the results by CAPB source term, and summed over the nineteen CAPBs. This set of sensitivity cases shows a negligible 3% increase in both the mean PDR and OECR values for this sensitivity relative to the base case. Thus, this change to the sampled weather used in the MACCS2 runs produced no significant impact to the results caused by the time variation in wind or other meteorological conditions.

(2) Model does not take into account terrain effects.

This issue is one on the ability of the MACCS2 model to account for variations in terrain between the point of release and downwind populations. The discussion that follows indicates that the code generally is in good agreement with more complex models especially over the relatively flat terrain within the 50-mile region of the Pilgrim Station. Furthermore, the MACCS2 input parameters used for the PNPS SAMA analysis were conservatively chosen so as to produce conservative results in the analysis.

The terrain surrounding the Pilgrim site is characterized by elevation changes of up to 400 feet, that take place within roughly two kilometers (1.2 miles) of the Pilgrim Plant (PNPS, 1992 and internet topographical maps). While these changes in elevation could certainly influence the path of a single plume, the kinds of calculations being done by the MACCS2 code are for several hundreds of projected plumes (depending on user selected options for executing the code).

Molenkamp et al. (2004) compared several codes for recorded data in a terrain changing location in the Midwest. This study compared MACCS2 to a fully three-dimensional (3-D) code (which possesses the ability to take into account terrain changes and spatial variability of weather), at a series of one-mile wide arcs at various distances downwind over a distance of 100 miles. The results showed reasonably good agreement obtained with MACCS2 compared to the three-dimensional (LODI) model with the MACCS2 code varying by 40% higher to about 20% lower as a function of distance as shown in Table 4.

For a study of a 50-mile grid region as used in the Pilgrim SAMA analysis, the three distances at 50 miles or less are of particular interest. An assessment of the Table 4 results indicates MACCS2 agreement is within 10% of the 3-D model if the three sets of results are averaged, or 9% above and 2% below for exposure-dependent and ground deposition-dependent results, respectively.

Table 4. Results Comparing MACCS2 to a 3-Dimensional Code (based on (Molenkamp et al., 2004))

Depositing Species Arc Average Exposure (Bq-s/m^3) & Ratio to 3-Dimensional Model				
Model	10 miles	20 miles	50 miles	100 miles
MACCS2	5.18E+07/1.41	1.40E+07/1.05	2.49E+06/0.81	7.86E+05/0.89
3-D model/ (LODI)	3.68E+07/1.00	1.34+07/1.00	3.07E+06/1.00	8.86E+06/1.00
Arc Average Deposition (Bq/m^2) & Ratio to 3-Dimensional Model				
Model	10 miles	20 miles	50 miles	100 miles
MACCS2	5.57E+05/1.21	1.53E+05/0.96	2.87E+04/0.78	8.96E+03/0.89
3-D model//(LODI)	4.62E+05/1.00	1.60+05/1.00	3.67E+04/1.00	1.08E+04/1.00

Hence, it is concluded that MACCS2 will produce results that are in reasonably good agreement with more sophisticated, data intensive code that can follow terrain features as well as time-varying weather patterns. Furthermore, the MACCS2 code was applied to the Pilgrim SAMA analysis in a conservative manner so as to produce overall conservative results in the analysis.

An illustration of the conservative input selection is the surface roughness length, z_0. As applied in the SAMA analysis, the 50-mile regional average surface roughness length was set at 10 cm. The surface roughness length is a measure of the amount of mechanical mixing introduced by the surface roughness elements over a region of transport (Hanna and Britter, 2002). Roughness elements include, but are not limited to, human-built structures, trees and other vegetation, and other surface features. As a general rule, z_0 is approximately 0.1 times the average height of roughness elements located on the transport region of interest, between the point of release and the downwind population. In the MACCS2 code, smaller values of the surface roughness length will decrease vertical dispersion, or σ_z. The vertical dispersion is a measure of the spread of a plume in the vertical direction (Figure 3).

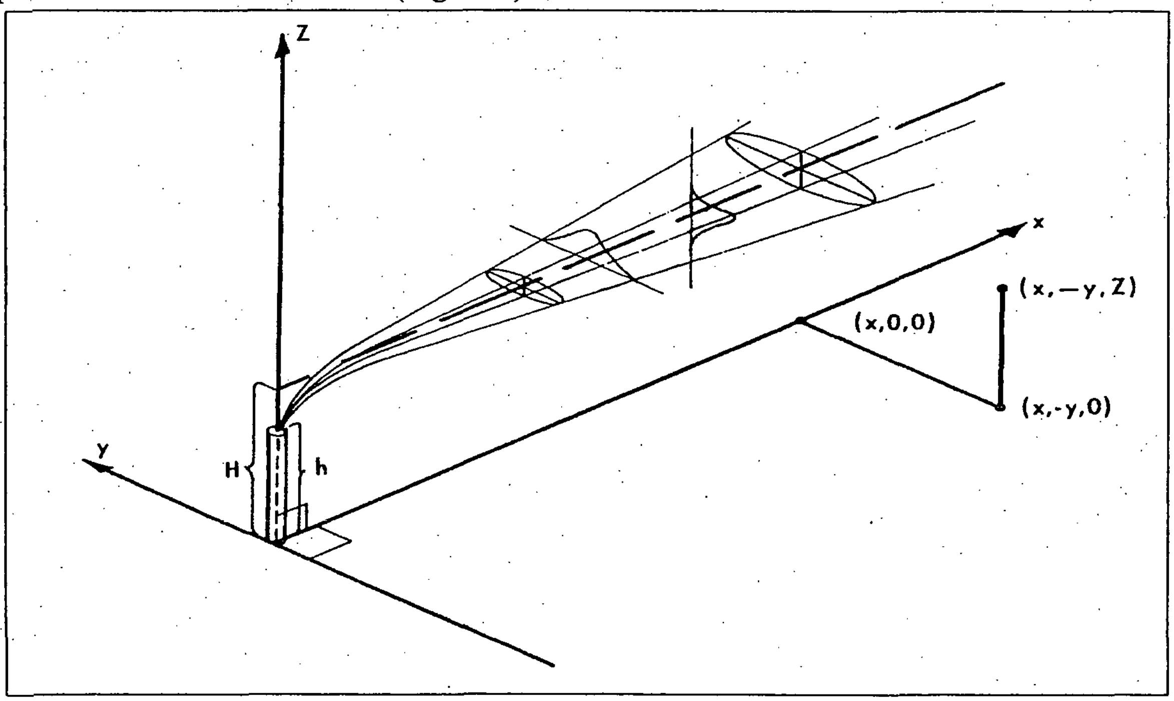

Figure 3. Gaussian plume growth in horizontal (y) and vertical directions (z). (from Turner (1970)).

Because the dilution factor[3] (χ/Q) is inversely proportional to vertical dispersion of the plume, larger surface roughness length values will decrease the dilution factor and subsequently, lead to smaller calculated doses. The Pilgrim SAMA calculations use a 10-cm surface roughness length, characteristic of tall grasses. Larger values of the surface roughness length (~100 cm) could be justified for the 50-mile region around Pilgrim, especially in areas 20 to 40 miles downwind,

[3] χ/Q is a normalized air concentration, with units of s/m^3.

characterized by forested regions, and the suburban/urban features of the populated areas. Table 5 shows the surface roughness length (z_o) for various surfaces, the increase in vertical dispersion if the new value was applied relative to the z_o value used in the Pilgrim SAMA analysis, and an estimate of the dose decrease because χ/Q, and therefore the dose, scale inversely proportional to σ_Z.

Table 5. Representative Surface Roughness Lengths based on Surface Type (Based on Table 2.3 in Jow (1990))

Surface Type	Surface Roughness Length, (cm)	$\sigma_{z,new}/\sigma_z(z_o=10\text{ cm})$*	Reduction in Dose, relative to z_o=10 cm
Lawns	1	-	-
Tall grass, crops	10-15	1.00 – 1.08	0% - 8%
Countryside	30	1.25	20%
Suburbs	100	1.58	37%
Forests	20 – 200	1.15 – 1.82	13% - 45%
Urban	100 - 300	1.58 – 1.97	37% - 49%

* Surface roughness length correction $[(z(\text{cm})/z(=10\text{ cm})]^{0.2}$

In summary, while the MACCS2 plume model can be shown to be in good agreement with more sophisticated models that address variable terrain and topography effects, it was applied in the Pilgrim SAMA analysis with conservative choices of input parameter values. One example of this is the surface roughness length. This feature has been modeled conservatively in the Pilgrim study with a 10-cm value when a reasonable argument could be made to apply a value on the order of 100 cm, with a resulting reduction in the PDR consequence.

<u>MACCS2 Sensitivity Case 3</u>:
A MACCS2 sensitivity case has been run with a reduced plume release height (30 m in the original SAMA analysis to 0 m in this analysis). This set of results approximates terrain changes relative to the source of release and dose receptors downwind. In effect, the sensitivity case approximates a terrain change by releasing at ground level, and shows the effects of a modified source-to-receptor height difference to consequences integrated over a fifty-mile radius.

It was noted above that any changes to the early phase and exposure effects to the population within about 20 miles of the point of release will have little impact to the overall SAMA PDR and OECR results. The sensitivity case 3 supports this characteristic. The change as shown in the summary table in Appendix C indicates a negligible increase with a ground-level (0 m) release for both population dose (1%) and off-site economic cost (4%) risks as compared to the base case release height of 30 m.

(c) Model cannot be used to estimate dispersion less than 100 meters

The Pilgrim SAMA analysis followed NRC-approved guidance in calculating on-site exposure and economic costs, and so did not use the MACCS2 code to estimate dispersion in the near-field (< several hundred meters of the release point) (NEI, 2006). Therefore, limitations of the

MACCS2 Gaussian model in this range have no bearing on the SAMA studies. In addition, on-site property damage and exposure costs are accounted for separately, using an NRC-approved methodology.[4]

In addition, the near-field region is encompassed by the Exclusion Area Boundary (EAB), therefore controlled by the Pilgrim plant, and has no permanent residents that potentially could incur radiological exposure. In these analyses, the MACCS2 code is applied from the EAB out to a fifty-mile radius, as is recommended in guidelines for SAMA analysis (NEI, 2006).

(d) Sea breeze would have an important impact on dose exposure.

The central concepts of the response to this issue are that (1) while sea breeze effects can be important to dispersion conditions at coastal sites, such as Pilgrim, the effects are most often localized within 5 to 10 miles, of the coast, and (2) the sea breeze phenomenon is not a concentrating one (increasing the plume concentration) but a dispersive one (diluting the plume concentration and thereby lowering projected doses). Thus, the sea breeze phenomenon generally has the beneficial effect of decreasing doses rather than increasing them.

Contention 3 cites a report by Spengler and Keeler (1988) to correctly assert that sea breeze effects can be important to dose exposure. However, the authors indicate that depending on topography, intensity of heating by the sun (solar heating), and pressure gradients, sea breeze effects can penetrate from 1 to 15 km (9.3 miles). Thus, the extent of the sea breeze influence would generally be less than the 10-mile EPZ, and not a factor towards the heavily populated areas in the Pilgrim 50-mile region that impacts population dose and off-site economic costs. Secondly, the Spengler and Keeler study itself notes that "among the meteorological variables that determine exposure are wind direction, wind speed and turbulence or stability conditions," and that the greater the distance away from the source, the longer the time over which turbulence can act on the plume to disperse the concentration. Thus, even in weather conditions where sea breeze effects persist to 30 to 40 miles from the Pilgrim Plant, the populations in these areas would experience substantially less radiological exposure than without the sea breeze effects.

An additional phenomenon, fumigation, is sometimes observed that can interact with sea breeze conditions to influence local plume concentrations. Fumigation is a dispersion process that can lead to relatively high ground-level concentrations and can occur when an elevated plume traveling in a stable (or neutral) sea breeze onshore flow is restricted vertically by an inversion (Hanna, 1982). The plume becomes "caught" or is entrained and undergoes rapid vertical mixing due to convective motions generated within the layer of air close to the surface, typically described as the mixing zone or the internal boundary layer. While fumigation effects can occur with concurrent sea breeze condition, Spengler and Keeler (1988) note that this is likely to occur within five miles of the Pilgrim Plant. As the plume travels inland, addition dispersion would become important due to convective mixing of the air within the mixing zone.

[4] Refer to (NRC, 2006), Proposed License Renewal Interim Staff Guidance LR-ISG-2006-03: Staff Guidance for Preparing Severe Accident Mitigation Alternatives (SAMA) Analyses, (August 10, 2006).

The Pilgrim UFSAR points out that the sea breeze question was investigated using a special smoke release field study in the summer of 1969. The results are summarized on page 2.3-6 of the UFSAR:

1. Greatest frequency was wind from north through east.
2. Only 0.1 to 1 percent of the time did ground locations experience fumigation from the site Exclusion Area Boundary (EAB) to 500 m beyond site boundary.
3. Maximum frequency of fumigation ranged from 600 to 1000 m from the stack.

In terms of application with respect to plume behavior away from the Pilgrim plant, the mixing to the surface took place quite quickly and thus the plume was uniformly mixed as it traveled and dispersed laterally toward the higher population areas. Thus, sea breeze - fumigation conditions are only likely to affect populations that are relatively close to the plant (within about a mile), and are relatively infrequent, and would not be able to extend to the 30 to 40 mile distance to affect the major population centers of Boston and Providence. In contrast, as previously discussed, the off-site consequences modeled by MACCS2 for the SAMA analysis are affected most by the population dose especially in the 20-mile to 50-mile region. Thus the close-in effects within five to ten miles of the point of release will have little bearing on the SAMA PDR and OECR results.

The Spengler and Keeler (1988) study recommended a better network of sampling sites for weather data collection near the Pilgrim Plant. Greater accuracy through close-in meteorological monitoring would be the result. Nevertheless, such a network would not have any bearing on the exposure conditions to the far-field population, the key factor that is important in the Pilgrim SAMA analysis.

The contention also mentions sea breeze is variable along various coastal locations. However, local sea breeze variations will be insignificant factors to population dose at tens of miles away and will have negligible impact in the calculation of regional population doses. In addition, sea breeze conditions should be properly weighted by frequency of occurrence based on site conditions, time of day, effective release elevation, and other factors. The MACCS2 Gaussian plume model has been applied in many safety analysis studies where the plant site, or the point of the hypothetical release, was very similar to Pilgrim's coastal environment, and thus subject to sea breeze phenomena. A partial list of SAMA analyses applied to coastal zone plants using MACCS2 includes Oyster Creek, Brunswick SEP, Point Beach, and Surry, as well as coastal plants overseas. Using MACCS2 in a probabilistic sampling mode and applying site-specific meteorology will ensure that representative weather sequences are accounted for and weighted by their likelihood, including sea breeze effects, and those combinations of wind conditions that lead to consequences to sensitive economic zones in the fifty-mile region.

Furthermore, as noted, sea breeze effects are generally highly beneficial and are commonly observed to reduce air pollution and thereby improve air quality. Among the factors that improve air quality (by lowering airborne concentrations of pollutants) and help mitigate the effects of potential atmospheric releases are those that increase dilution at the source, such as increased volume of air moving over the release point, and those that help mix and spread the plume as it moves downwind. The concentration of pollutants emitted by the source is inversely related to the wind speed, i.e., the greater the wind speed, the lower the concentration and vice versa. The sea breeze is extremely important in this regard since it provides both enhanced dilution and mixing at the release location on the coast. The sea breeze also aids dispersion well away from a release location with increased dilution due to enhanced turbulence within a windborne plume. Enhanced turbulence generates additional eddy currents in a moving stream of air. These eddy currents entrain or capture clean air from areas outside a contaminated plume and mix this clean air with plume air resulting in lower pollutant concentration.

Normally, the sea breeze is expected to develop during the mid-day hours on clear days during the spring through summer seasons as the land surfaces warm up and the temperature of coastal waters becomes cooler than the adjoining land surfaces. The strength of the sea breeze is directly related to the land-sea temperature difference (Simpson, 1994). If the sea breeze encounters an opposing wind due to an opposing pressure gradient, it might not be able to overcome the opposing force unless the land-sea temperature difference exceeds a certain value based on the location being examined (Simpson, 1994). Increased stack/source dilution from sea breezes is due to higher than normal wind speeds over that which would be expected in the absence of the land-sea temperature difference.

While sea breezes are sometimes recognized to be able to penetrate long distances inland, it should be recognized that this also means that these conditions of increased turbulence will also accompany the sea breeze conditions. Simpson (1994) shows evidence of sea breeze penetrations up to 300 km inland over a period of about 15 hrs in Australia. Although not all coastal locations will experience such a large inland penetration, Simpson (1994) noted penetrations on the south coast of England up to 100 km inland from 10 to approximately 80 days per year depending on location. Buckley and Kurzeja (1997a, b) found evidence that a sea breeze front penetrated over 100 km over a period of a few hours from the South Carolina coast. These same authors also found evidence that increased turbulence remained well into the night for a distance of 100 km inland after the sea breeze front had moved through the area. This increased turbulence was in excess of that predicted by a sophisticated, three-dimensional transport and dispersion model.

Meteorological data collected on towers at the Pilgrim site do reflect the occurrence of sea breeze conditions in both the wind speed and direction. As stated above, whenever sea breeze conditions prevail, the increased dilution of effluent plumes due to the increased wind speed would produce a beneficial effect from the standpoint of dose to downwind exposed individuals. The other beneficial effect as noted in both sea breeze model simulations and measurements by Buckley and Kurzeja (1997a, 1997b) is increased turbulence. This enhanced turbulence further increases the dilution of plume material as it moves downwind over what would be expected in otherwise steady wind conditions. This enhanced turbulence is reflected in the measurements of wind direction fluctuations made at the Pilgrim meteorological tower.

The Pilgrim site has an additional advantage from the point of view of enhanced dispersion and accident mitigation. This is due to the coastal location and the southeast-northwest orientation of the shoreline at the Pilgrim site. This particular combination results in a wind direction distribution with more frequent offshore than onshore winds (e.g., Figure 2.31 of the PNPS-FSAR, 1992).

(e) Coastal topography also plays an important part in dose exposure

There are no significant topography differences relative to the Pilgrim region in contrast to other coastal nuclear power plant sites that suggests it cannot be analyzed with MACCS2. Moreover, as discussed above, (1) topography and terrain features are conservatively accounted for in the Gaussian model; (2) the effect that topography may have on a specific plume is not critical in risk type studies where mean consequence or risk output is the end product; and (3) sensitivity case 3 demonstrates that topography and terrain effects have negligible effects on both population dose and off-site economic cost risks of the SAMA analysis.

(f) Data from only two sources for a single year were used.

From reviewing a number of similar SAMA analyses, a single, representative year of data is typically used in a SAMA analysis. Two sources of meteorological data for the same year were used in the PNPS SAMA analysis, the Pilgrim site upper tower and the nearby airport. The 2001 year selected is representative of weather patterns near the plant, and leads to the correct conclusions regarding SAMA identification (Mogolesko, 2007). The SAMA approach taken by Entergy is consistent with SAMA analysis industry guidelines (NEI, 2006) that have been reviewed and recommended by the NRC.[5]

(g) Proper analysis requires multiple years of data from multiple sources in order to take into account the specific characteristics of the Plymouth area. For example, under sea breeze conditions, turbulence structure of the atmosphere will not be accurately determined by meteorological sensors at the Pilgrim plant

Instrumentation used for the upper and lower towers at the Pilgrim site are properly positioned to account for turbulence structure of the atmosphere. Meteorological instrumentation close to, or at the point of release is the most critical placement for identifying the atmospheric turbulence conditions governing initial plume travel. Given the coastal siting for PNPS any sea breeze influence at the point of release will be very influential towards decreasing concentrations in the plume.

Standard practice for MACCS2 SAMA analysis is to apply Tadmor and Gur dispersion parameterization to account for atmospheric turbulence (Dobbins, 1979; SNL, 1990). This, in fact, is the set of dispersion parameters used for the Pilgrim SAMA studies. Coupled with use of archived, representative meteorological data collected at the Pilgrim site, it is concluded that statistically-accurate results were obtained for consequences in the far field for hypothetical releases from the Pilgrim plant.

[5] Refer to (NRC, 2006), Proposed License Renewal Interim Staff Guidance LR-ISG-2006-03: Staff Guidance for Preparing Severe Accident Mitigation Alternatives (SAMA) Analyses, (August 10, 2006).

(h) Accurate analysis would require installation of continuous recording meteorological instruments along the coast and at additional inland sites.

The issue raised by this claim relates to the ability to track a specific plume to support mitigative actions in the EPZ and has no bearing for SAMA analyses where the focus is determining mean consequence levels to support cost-benefit decision-making on potential plant modifications. Furthermore, it is impractical to employ multiple weather station data for SAMA cost-benefit analyses, as previously discussed, where hundreds of weather trials are needed to provide statistically valid consequence results.

2. Evacuation Time Estimates and Other Aspects of the Emergency Response Model

This section describes evacuation consequence mitigation assumptions, input data and modeling approaches used in the MACCS2 code for the PNPS SAMA analysis. It also addresses the emergency response issues raised as part of PW#3.

a. Evacuation Time Estimates and Emergency Response Model Overview

The second challenge questions timing, participation, and effective speed of the evacuating population from the EPZ used in the emergency phase countermeasure model in the MACCS2 analysis. The MACCS2 base case applied in the SAMA analysis is a simple radial evacuation model. In this approach, the ten-mile EPZ population is modeled to move radially outward at a constant collective speed, after a specified delay time following accident conditions. Different shielding factors and breathing rates can be used while evacuating, performing normal activities, and sheltering.

The MACCS2 plume transport model assigns the plume a finite length calculated by using the assumed release duration and wind speed during the release. The length of the radioactive cloud is assumed to remain constant following the release and the concentration of radioactive material is assumed to be uniform over the length of the cloud. The radial position of evacuating persons, while stationary, and while in transit, is compared with the positions of the front and back of the plume as a function of time to determine the period of exposure to airborne radionuclides.

The base case model assumes that all EPZ residents evacuate without exception. Once the evacuees reach a 20-mile radius, and are assumed to be sheltered, they are no longer exposed during the emergency phase to a radiological environment. Residents in the area from 10-mile to 50-mile region receive radiological exposure if they are within the plume passage region. Both groups incur dose during the 30-year long-term phase following the accident.

The original sensitivity cases explored changes in the delay time and the evacuation speed:

- Delay time to evacuate: The base case (case 1) for beginning evacuation, or the elapsed time between siren alert and the beginning of evacuation is forty (40) minutes. A sensitivity case was run (case 1.a). The sensitivity case assumed a 2-hour delay for evacuees to begin evacuation in order to quantify the consequence sensitivities due to delay time uncertainty.
- Evacuation speed: The evacuation speed for the population in a MACCS2 simulation is usually specified at a very low speed to compensate for road conditions, traffic congestion, etc. Using EPZ evacuation time estimates developed for PNPS, an average speed of 2.17 miles/hour, or 0.97 m/s was determined and used for the base case analysis (PNPS, 2006). A sensitivity case (case 1.b) was run in the original SAMA analysis to evaluate consequence uncertainties due to evacuation speed uncertainty in which the average speed of evacuation was set at the worst case evacuation speed for the PNPS EPZ of 1.54 miles per hour, or 0.69 m/s.

b. PW#3 Evacuation Model Challenge by Subpart

(a) MACCS2 model improperly assumes that the population is out of danger upon crossing the 10-mile boundary.

The MACCS2 modeling assumptions used to model emergency response evacuation are based on the Pilgrim evacuation time estimate analysis. The details of the basis for the evacuation time estimates including supporting assumptions regarding population, alarm criteria, delay times, speed, distance, areas and routes are provided in PNPS (1998) and updated in PNPS (2004).

During the emergency phase, populations incur dose from inhalation (both plume passage and inhalation of resuspended activity), groundshine, and cloudshine. In the long-term phase, exposure is calculated for 30 years, based on EPA Superfund guidance (EPA, 1991). In the current base and sensitivity MACCS2 cases, once the evacuating population from the EPZ has moved beyond the 20-mile distance, it is assumed that they no longer incur radiological exposure for the remainder of the 7-day emergency phase. This is a standard assumption made in MACCS2 applications based on emergency planning to evacuate away from the plume direction and resulting radiological footprint. The evacuees may receive future dose during the long-term phase if their point of origin in the EPZ is habitable. Also, residents in the 10-mile to 50-mile region receive radiological exposure during the emergency phase if they are within the plume passage region and during the long term phase. MACCS2 will calculate a population dose from cloudshine, groundshine, and inhalation of material directly from the plume as well as resuspended material.

<u>MACCS2 Sensitivity Case 4</u>:
The base case assumed that EPZ evacuees were removed from further exposure during the emergency phase of analysis once they reached 20 miles. A MACCS2 sensitivity case was run to conservatively treat this movement by modeling evacuees as moving to a 40-mile radius before assuming they've reached the evacuation centers. Because the actual evacuation centers are located at 35 miles away, the Pilgrim MACCS2 sensitivity model is conservative in that evacuees are traveling a greater distance than would be expected in an actual evacuation procedure.

The summary for this case is shown in Appendix D. There is some variability among the CAPB mean values, but the differences in total plant risks are less than one percent for the PDR and OECR relative to the base case. As stated earlier in this report, the dose mitigation strategies for the EPZ during the emergency phase have little impact on the overall dose results since these are dominated by effects in the 20-mile to 50-mile regions and late-phase portions of the consequence modeling. A short-term modeling assumption such as increasing the travel distance for evacuees, does not produce any noticeable increase to population dose and subsequently, to plant risk indices such as the PDR and OECR.

(b) MACCS2 model does not consider those who cannot evacuate and must shelter.

Pilgrim's SAMA analyses assumed that persons who could not evacuate on their own would be provided assistance to evacuate. Current emergency planning by the State of Massachusetts provides for such assistance. Also, sensitivity analyses discussed below will assess how large the impact is to population dose if everyone is not able to evacuate as assumed in the analysis.

<u>MACCS2 Sensitivity Case 5</u>:
A Case 5 is defined that assumes sheltering within the EPZ without evacuation, but will be bounded by the next sensitivity case (Case 6), which assumes no evacuation or emergency sheltering action at all by anyone within the EPZ.

(c) The SAMA analysis did not use the most recent evacuation time estimates.

The emergency response team at Pilgrim verified that the SAMA analysis did use the most recent evacuation time estimates at the time the SAMA analysis was performed, and pointed out that the evacuation delay times for both the 1998 and 2004 ETEs are identical. Also, the evacuation speeds for the 1998 ETEs, on which the SAMA analyses are based, are virtually identical to the evacuation speeds of the 2004 ETE (KLD, 1998; KLD, 2004).

<u>MACCS2 Sensitivity Case 6</u>:
A no-evacuation case has been run whereby the evacuation model is turned off altogether. Everyone within the EPZ is assumed to carry on with their normal activities. The results under these assumptions are shown in Appendix E. The results indicate an increase in population dose risk of about 6%, and no change in economic cost risk.

Thus, the issue on use of the most appropriate ETEs is viewed as relatively unimportant to the overall population dose incurred to the inhabitants in the 50 mile zone because: (1) the dominant portion of the population dose arises to the population not affected by the specific evacuation model used, and (2) emergency phase dose mitigation plans, such as evacuation, do not impact the dose impacts from the long-term phase of exposure. As was calculated previously, on average for the nineteen CAPBs analyzed, the latter is 83% of the overall dose incurred by the 50-mile population.

Normal activity assumes that some of the activity is indoors and therefore provides better shielding compared to the probable exposure of evacuees who are not protected as they move outdoors. Table 6 compares the shielding or protection factors used in the Pilgrim model for evacuating, normal, and sheltering persons. A protection factor decreases the dose from the

Table 6. Protection Factor Input Values Used in the MACCS2 Code for Pilgrim SAMA

Protection Factor	Evacuating	Normal Activity	Sheltering
Cloudshine	1.00	0.75	0.60
Inhalation	1.00	0.41	0.33
Skin Protection	1.00	0.41	0.33
Groundshine	0.50	0.40	0.20

pathway in question, e.g., cloudshine protection factor of 0.75 means that 25% less dose is incurred. All values shown in the table are technically defensible default values used in the NUREG-1150 PSA study of commercial U.S. plants, or have been specified by NRC staff. A comparison of the shielding factors shows that that a no-evacuation sensitivity case (Case 6) would bound the sensitivity Case 5 which assumes sheltering in the EPZ.

(d) Many of the assumptions and estimates of the evacuation time estimates used in the Pilgrim SAMA analysis are faulty.

Appropriate assumptions were used for voluntary evacuations in the EPZ for postulated accident conditions in the SAMA MACCS2 analysis. Many of these are covered in the applicable PNPS reports. Page 40 of the PW Petition claims that "voluntary evacuation from within the EPZ was estimated to be 50% within a 2-5 mile ring around the reactor, excluding the "key-hole;" and 25% in the annular ring between the 5-mile boundary of the circle and the 10-mile EPZ boundary". This is erroneous, since the SAMA analyses was not based on voluntary evacuation, but assumed that the entire 10 mile EPZ would be evacuated in accordance with the Emergency Plans providing for such evacuation in appropriate circumstances.

There are many conservative assumptions and modeling choices already included in the estimates developed for emergency response as applied to the MACCS2 runs. Some of the primary ones include, but are not limited to, the values applied for evacuation speed and delay time. However, it is inappropriate for SAMA analysis to assume a "worst case scenario." The basic approach recommended in the SAMA NEI (2006) guidance and applied to the Pilgrim studies is to use the Individual Plant Examination and Level 3 PRA information where it is available and focus on the mean or average values. This is the standard approach for the performance of SAMA analyses for National Environmental Policy Act (NEPA) purposes. In summary, the SAMA prescriptive guidance for analysis of severe accidents does not require using worst case scenario assumptions.

(e) The evacuation delay time estimates of 40 minutes and 2 hours are incorrect because "notice of evacuation could take longer than 2 hours to reach people."

Evacuation time estimate (ETE) information and inputs to the MACCS2 SAMA consequence were based on studies performed in 1998 and updated in 2004 by KLD (1998, 2004). Details on the ETE analysis can be obtained directly from the KLD source documents.

Because the basis for the evacuation delay time estimates is the central issue here, the analysis presented in the no-evacuation case adequately bounds any question on perceived non-conservatisms regarding the delay time before evacuating people in the EPZ are assumed to start moving away from the Pilgrim plant.

MACCS2 Sensitivity Case 7:

The previous Case 6 applied a no-evacuation assumption in the plant risk modeling and will bound the effect of sensitivity of results to evacuation delay time or speed uncertainty assumption changes. Nonetheless, sensitivity cases were run for a delay in evacuation time (6 hours compared to the base case of 40 minutes) and an extremely slow evacuation speed (0.34 m/s compared to the base case of 0.97 m/s). These two sensitivity cases are designated as Case 7.a and 7.b, respectively.

The summary tables for Cases 7.a and 7.b are shown in Appendix F. The PDRs for the delayed evacuation and slow evacuation speed cases are 5% and 3% larger than the base case model and assumptions (40 minutes delay time and 2.17 MPH (0.97 m/s) evacuation speed, respectively. There is no increase to the OECRs for the two sensitivities. Thus, the two cases are bounded by the no-evacuation case in which the change was 6% to the PDR.

Both of these cases illustrate that while slight variation can be achieved in the population dose outcome with more conservative modeling assumptions, the impacts are minimal to the overall SAMA PDR and OECR indices.

(f) The <u>evacuation speed estimates</u> are incorrect.

Evacuation time estimate (ETE) information and evacuation speed inputs to the MACCS2 SAMA consequence were based on studies performed in 1998 and updated in 2004 by KLD (1998, 2004).

<u>MACCS2 Sensitivity Case 7</u>: Case 7b, as discussed above, addresses this point.

3. Economic Consequences

This section describes economic consequence assumptions, input data and modeling approaches used in the MACCS2 code for the PNPS SAMA analysis. It also addresses economic issues raised as part of PW#3.

a. Economic Model Overview

The third challenge questions the adequacy of the Pilgrim MACCS2 economic consequence model, suggesting that it is confined to mitigative actions alone. The challenge also argues that loss of tourism economic activity due to an accident event at Pilgrim needs to be specifically addressed. It is further noted that travel/tourism accounted for over $11 billion in spending for calendar year 2003 in Massachusetts alone. Travel expenditures in four affected counties as well and the economic benefit of Plymouth Plantation were identified in the challenge.

Economic costs are accounted for by the MACCS2 model in accordance with the SAMA cost-benefit analysis guidance from NEI (2006). The nominal costs calculated by MACCS2, account for region-specific and county-specific costs, and include:

- Cost of evacuation
- Cost for temporary relocation (food, lodging, and lost income)
- Cost of decontamination land and buildings
- Lost return on investments from properties that are temporarily interdicted to allow contamination to be decreased by radionuclide decay
- Cost of repairing temporarily interdicted property
- Value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated by root uptake
- Value of farmland and of individual, public, and non-farm commercial property that is condemned.

The SAMA guidance indicates that the economic data used in the analysis should be expressed in dollars for the year in which the SAMA analysis is being performed (NEI, 2006). This enables SAMA economic costs to be compared to SAMA mitigation costs in current day dollars. To scale available economic data from a past census or survey to current conditions, the ratio of consumer price indices can be applied.

Consistent with this guidance, the PNPS SAMA analysis used economic data expressed in 2002 dollars (except for the regional value of non-farm wealth in the region discussed further below). The economic values were evaluated either on the basis of MACCS2 code recommended values, or from 2002 site characteristics and the analysis performed for the original SAMA analysis (PNPS, 2002). Older values were scaled to be consistent with calendar year 2002 using the consumer price and other cost of living indices, as recommended in the NEI (2006) guidance. Most of these calculations are described in S&SA-170.

Of particular note in calculating economic costs employing the MACCS2 code is the use of regional parameters to assess whether a land element should be condemned or not. MACCS2 evaluates potential mitigative actions for both farm land use and population habitability in order to determine if it is possible to satisfy the applicable criteria for radiological exposures. If either of the criteria, for farming or habitability, cannot be satisfied after the maximum duration interdiction, then that land use is permanently interdicted, or condemned. A second manner in which land for farming or supporting a population can also be condemned is if the total cost involved in restoring it to use would exceed the user-specified value of the property. If this is done, the use of land for either farming or population habitability or both can be condemned. When a land use is condemned for either reason, (i.e., the dose criteria cannot be satisfied, or the cost of reclamation exceeds the property's value), MACCS2 calculates the corresponding long-term food and population exposures as zero, and assesses an economic cost for the condemnation of the property.

The decision on whether to condemn farm or non-farm property is based on the average regional values of farm property (VALWF) and of non-farm property (VALWNF). However, once the decision to condemn is made, condemnation costs are incurred on a per capita basis using county-specific data.

b. PW#3 Economic Challenge by Subpart

(a) The MACCS2 Code models only the economic costs of mitigative actions.

1. ***Economic costs include the cost of decontamination, condemnation and temporary or permanent relocation.***
2. ***The valuations include only the assessed value of the property, ignoring the business value of the property.***
3. ***Nowhere does the model account for the loss of economic activity, such as loss of tourism.***

The MACCS2 model, although not all-inclusive of all costs that could be hypothesized, nonetheless allows a rather complete assessment of economic impacts from hypothetical reactor accident releases. Economic costs calculated by MACCS2 include:

- Food, lodging, lost income associated with evacuation and relocation (including those incurred in early, or plume-passage phase)
- Losses associated with crop and property destruction, and value of crops not grown because they would be contaminated by root uptake
- Decontamination labor and materials for decontaminating and repairing land and buildings
- Loss of building/land/produce use and any corresponding lost return on investment and depreciation associated with decontamination/interdiction
- Value of condemned land and improvements.

All these specific costs were included in the Pilgrim SAMA analyses. The MACCS2 code will invoke user-specified condemnation if dose criteria are not met following decontamination/interdiction efforts.

Thus, contrary to the contention issue, the MACCS2 code provides for the modeling of a wide range of economic losses. These include losses associated with economic activity, such as loss of income, loss of value of crops not grown, and loss of use and return on property, including commercial and business property. In terms of loss of use and return on property, as part of interdiction costs the MACCS2 code provides for (1) a depreciation rate on property improvements to account for loss of value of buildings and other structures, and (2) an expected rate of return from land, building, equipment, etc. The Pilgrim SAMA analysis used an annual depreciation rate of 20% and an annual rate of return of 12%.

Furthermore, the MACCS2 user is free to substitute different data of interest to account for other costs that may not otherwise be fully or routinely examined in the typical SAMA analysis specified in NEI (2006). While recognition of additional types of economic consequences may offer some further insight into the economic risks associated with a postulated accident, this type of analysis is above and beyond that typically done in a SAMA analysis. Nevertheless, a sensitivity case is outlined under (b.) below to assess claims made in Pilgrim Watch Contention #3 regarding business and tourism loss risks.

(b) Tourism is an important business in the area surrounding the Pilgrim plant.

2003 report shows $11.2 billion spent in Massachusetts annually on transportation, lodging, food, entertainment, recreation, and incidentals.

A severe accident at Pilgrim would severely impact travel in at least four counties, Plymouth, Barnstable, Dukes and Nantucket. In 2003, travel expenditures for these counties were as follows:

Plymouth – $353.14 million.

Barnstable – $684.27 million.

Dukes – $91.86 million.

Nantucket – $139.93 million.

Plymouth Plantation, less than five miles from plant, brings in almost $10 million annually.

As stated above, the MACCS2 computer code was designed to assess a wide range of consequence types, and the computer code contains a variety of assumptions and input data with respect to economic costs of severe accidents. However, to address the business and tourism loss challenge with greater insight, an economic loss analysis has been prepared as a reasonable approach to better understand economic impacts due to postulated accident conditions within the context of a SAMA analysis. The revised approach has augmented the MACCS2 model assumptions for VNFRM and VALNFW by supplementing the types of data normally considered to develop those values for the SAMA analysis (Enercon, 2007). The modified VNFRM and VALNFW input parameters for the value of non-farm property include data that specifically account for county and metropolitan area gross domestic product, and indicators of tourism, business loss, lost wages, etc.

The original MACCS2 set of VNFRM inputs was developed using the latest data at the time (2002) on a county-specific basis and was based on the non-farm fixed reproducible tangible wealth - a measure of the durable goods (things that people own). These goods may be business and commercial buildings, related equipment and inventory, residential houses, cars, washing machines, etc. These VNFRM input values for the original MACCS2 base case were based on equalized valuations of all property so as to equate to the actual fair market value of all property within the region (PNPS, 2002).

In accordance with the NEI guidance, the VNFRM county input values for the original base case SAMA analysis were expressed in 2002 dollars. However, the original SAMA analysis projected the regional value of non-farm wealth in the region, the VALWNF parameter, to the year 2032 (last year of license extension), and calculated a value of $189,041 per person for this parameter. A VALWNF parameter of $189,041 per person is a significant conservatism in the original SAMA analysis that is retained in the second of the two sensitivity analyses discussed below.

The revised approach includes as part of the VNFRM input value the county-specific gross ~~county product (GCP). The addition of GCP/person values account for~~ the total value of goods and services produced in an area for the basis year, 2004 (Enercon, 2007). This is essentially all the items that were manufactured or produced in a county in 2004, plus "services" that produce economic activity in that year. The revised VNFRM results therefore measure the non-farm wealth (tangible wealth owned) of the individual counties as well as their economic output (Table 7).

Table 7. New Values of VNFRM for MACCS2 at the Pilgrim Site (Table 4 from Enercon (2007)

VNFRM Values
Pilgrim Economic Regions

State	County	GCP (in billions)	2004 Estimated Population**	GCP / person	Original VNFRM*	Final VNFRM
MA	Barnstable	9.1	227,984	39,915	149,460	189,375
MA	Bristol	20.4	547,278	37,275	55,486	92,761
MA	Dukes	0.8	15,574	51,368	416,486	467,854
MA	Essex	30.2	737,447	40,952	78,987	119,939
MA	Middlesex	80.9	1,462,822	55,304	97,491	152,795
MA	Nantucket	0.6	10,113	59,330	815,028	874,358
MA	Norfolk	32.4	653,621	49,570	97,711	147,281
MA	Plymouth	17.6	489,979	35,920	74,035	109,955
MA	Suffolk	57.2	864,263	66,110	80,103	166,213
MA	Worcester	32.5	778,606	41,741	54,603	96,344
RI	Bristol	1.4	52,899	26,466	76,995	103,461
RI	Kent	7.5	171,703	43,680	67,988	111,668
RI	Newport	3.6	84,846	42,430	87,055	129,485
RI	Providence	26.6	641,874	41,441	52,637	94,078
RI	Washington	4.5	128,594	34,994	97,569	132,563

* VNFRM reported in PNPS calculation S&SA-170.
** [U.S. Census Bureau, 2007]

County-specific gross county product (GCP)/normalized to the population in the county indices have been tallied by Enercon, then added to the original value of VNFRM to obtain a final VNFRM per person for counties in the 50-mile zone surrounding Pilgrim. In the sensitivity cases described below, the MACCS2 set of runs for the nineteen CAPBs incorporated this revised economic data. Two sensitivity analysis cases are conducted using these new county NVFRM values. These new values are used in calculating both interdiction and condemnation costs. The first sensitivity analysis uses a regional value of non-farm wealth parameter, VALWNF (used by the code to decide whether interdiction is feasible relative to condemnation) of $135,188, which is the VALWNF value calculated to the same basis year as the new VNFRM values. The second sensitivity analysis uses the same conservative value of VALWNF that was used in the original study of $189,041 per person.

<u>MACCS2 Sensitivity Case 8</u>:
This is a set of sensitivity cases to account for the economic costs associated with business and tourism losses by augmenting the non-farm wealth economic indices with county- and region-specific business and tourism value data. Two cases were run to show the impacts of updating the economic indices relative to the base case given in the previous SAMA analysis, with overall PDR and OECR results summarized in Appendix G.

Each of the two cases incorporate the Enercon (2007) data to update the county non-farm wealth VNFRM indices, but use different regional non-farm wealth values as follows:

- $135,188, the value calculated by Enercon (2007) based on the updated VNFRM indices for the counties in the 50-mile region around Pilgrim, and referenced to data for the year 2004
- $189,041 per person, the conservative value used in the original SAMA analysis.

The first set of results (Table G.1) for VALWNF=$135,188 based on the new, higher VNFRM values shows no change in the PDR and a decrease in the OECR of 13%. This decrease in the OECR occurs because of the very conservative value of VALWNF of $189,041 used in the original SAMA analysis, which directly impacts and increases the calculated interdiction costs as previously discussed. Because of the high degree of conservatism of the original VALWNF value, the sensitivity run using the new, higher VNFRM values and the VALWNF based on the new VNFRM values results in a decrease of the OECR. In order to avoid this anomalous result and to identify the impact of using an increased VNFRM value, a second sensitivity case was performed using the original, highly conservative VALWNF value of $189,041 and the new VNFRM values. This second sensitivity case (Table G.2) shows no change in the PDR and an incremental increase in the OECR of 2%.

The source of these differences can be explained in part by examining the mean values to economic cost in the dominant source term, CAPB-15. Table 8 shows the results for economic costs and lists the individual components that make up the total off-site economic costs for three cases: (1) the base case value of $189,041 (VALWNF) and original economic indices; (2) VALWNF=$135,188 and the new VNFRM county economic indices; and (3) VALWNF=$189,041 and the new county economic indices (VNFRM). The original economic indices do not include the GCP-based measure of business and tourism loss reflected in the new Enercon report.

Several features are obvious from inspection of the table. Firstly, agriculture based economic costs are small relative to population and property-based costs. Secondly, emergency phase costs, incurred during the 7-day early phase after the postulated accident release, is also relatively insignificant compared to the long-term costs. Thirdly, of the long-term costs, the population-dependent interdiction, decontamination, and property condemnation costs rank first, second, and third in importance to economic costs. While these specific results are from CAPB-15, these economic cost trends are found in the other risk-dominant source terms identified earlier (CAPB-14, CAPB-10, and CAPB-11).

Other information on the calculation of costs to be included in the SAMA analysis is needed to draw conclusions on whether any further SAMAs might be considered cost beneficial, and is found in Section 5 of this report. It will be shown through the Case 8 sensitivity analysis that no additional cost effective SAMAs are identified based on incorporation of the new and more complete Enercon business and tourism economic indices.

Table 8. Economic Costs from Source Term CAPB-15

Cost Type	Base Case	Ref. Table G.1	Ref. Table G.2
VALWNF Sensitivity Parameter	$189,041	$135,188	$189,041
Basis for VALWNF Wealth Parameter	2032	2004	2032
County-Specific Non-farm Wealth Indices	Old VNFRM	New VNFRM	New VNFRM
TOTAL ECONOMIC COSTS ($)	1.80E+10	1.57E+10	1.85E+10
POPULATION-DEPENDENT COSTS ($)	1.79E+10	1.57E+10	1.84E+10
FARM-DEPENDENT COSTS ($)	6.33E+07	6.33E+07	6.33E+07
POPOPULATION-DEPENDENT DECONTAMINATION COST ($)	4.06E+09	4.05E+09	4.06E+09
FARM-DEPENDENT DECONTAMINATION COST ($)	6.87E+06	6.87E+06	6.87E+06
POPULATION.-DEPENDENT INTERDICTION COST ($)	1.29E+10	1.01E+10	1.29E+10
FARM-DEPENDENT INTERDICTION COST ($)	3.08E+07	3.08E+07	3.08E+07
POP.-DEPENDENT CONDEMNATION COST ($)	9.47E+08	1.49E+09	1.42E+09
FARM-DEPENDENT CONDEMNATION COST ($)	3.10E+06	3.10E+06	3.10E+06
EMERGENCY PHASE COST ($)	8.45E+06	8.45E+06	8.45E+06
INTERMEDIATE PHASE COST ($)	0.00E+00	0.00E+00	0.00E+00
MILK DISPOSAL COST ($)	3.16E+04	3.16E+04	3.16E+04
CROP DISPOSAL COST ($)	2.25E+07	2.25E+07	2.25E+07

4. MACCS2 Sensitivity Case Results

This section provides a summary of the results from the revised MACCS2 cases discussed by contention issue earlier in this report. The cases were run to develop insights into the sensitivity of results with respect to assumptions and input parameter values.

Table 9 lists characteristics of the MACCS2 cases from the revised SAMA analysis, and also those executed to support the sensitivity studies discussed earlier in this report. Case 1 is the base case analysis, and is a base line for the sensitivity cases. As discussed in the introductory section of this report, mitigation alternatives may be appropriate if a sensitivity analysis shows a large increase in population dose risk and/or economic cost risk relative to the base case. Cases 1.a and 1.b are the sensitivity cases that were run as part of the original revised SAMA analysis for exploring uncertainties in the evacuation delay time (40 minutes to 2 hours), and evacuation speed (2.17 miles/hour to 1.54 miles/hour). Cases 2 through 8 represent the revised sensitivity analyses that were discussed earlier in this report. These cases were run to specifically evaluate and address issues from the Pilgrim Watch Content #3.

Table 9. MACCS2 Sensitivity Cases

Case	Description	Evacuation delay time (min.)	Release Height/Building Wake Effects;	Evacuation speed (MPH)	Fraction of people in EPZ evacuating	Evacuees move to distance (miles)	Population & Economic Data. Base Case = 2032 permanent population data/ 2000 transient population site data
1.	Base case analysis	40	30 m; YES	2.17	1.0	20	Base case
1.a	Sensitivity case - Delayed Evacuation	120	30 m; YES	2.17	1.0	20	Base case
1.b.	Sensitivity case – Reduced Evacuation	40	30 m; YES	1.54	1.0	20	Base case
2.	Approximate plume trajectory effect	40	30 m; YES	2.17	1.0	20	Base case
3.	Terrain sensitivity	40	0 m; NO	2.17	1.0	20	Base case
4.	EPZ Evacuees move to relocation centers	40	30 m; YES	2.17	1.0	Relocation center distance; Assumed to be 40 miles	Base case
5.	Shelter only/No evacuation	immediately	30 m; YES	0.0	0.0	n/a	Base case
6.	No Evacuation	n/a	30 m; YES	n/a	0.0	20	Base case
7.a	Delayed evacuation time	6 h delay for evacuation	30 m; YES	2.17	1.0	20	Base case
7.b	Significantly reduced evacuation speed	40	30 m; YES	0.76	1.0	20	Base case
8.a	Modified values of VNFRM to account for business and tourism losses	40	30 m; YES	2.17	1.0	20	Base case VALWNF=$135,188; 2004 basis calculated by Enercon (2007) & new values of VNFRM
8.b	Modified values of VNFRM to account for business and tourism losses	40	30 m; YES	2.17	1.0	20	Base case VALWNF=$189,041; Original SAMA basis; New values of VNFRM

Table 10 shows the outcome of the MACCS2 sensitivity analysis cases. The PDR changes average about a 3% increase, with the largest being for a no-evacuation sensitivity (Case 6). The OECR cases average about a one percent increase, with the largest result shown for the terrain effect case. All increases are insufficient to justify additional SAMAs.

Table 10. Comparison of MACCS2 Sensitivity Cases for PDR and OECR with Base Case

Case	Description	PDR, Population Dose Risk, (person-rem/year)	OECR, Offsite Economic Cost Risk, ($/year)	PDR Ratio	OECR Ratio
1	Base Case	1.46E+01	5.26E+04	1.00	1.00
1.a	Exended delay time	1.46E+01	5.26E+04	1.00	1.00
1.b	Slower evacuation speed	1.47E+01	5.26E+04	1.01	1.00
2	Trajectory Approx.	1.51E+01	5.41E+04	1.03	1.03
3	Terrain Effect	1.48E+01	5.48E+04	1.01	1.04
4	Distance to evacuate	1.47E+01	5.26E+04	1.01	1.00
5	Shelter w/o evacuation	Bounded by no-evacuation/Case 6		1.06	1.00
6	No Evacuation	1.54E+01	5.26E+04	1.06	1.00
7.a	Change in evac. delay	1.54E+01	5.26E+04	1.05	1.00
7.b	Change in evac. Speed	1.50E+01	5.26E+04	1.03	1.00
8.a	Economic Impacts - VALWNF=$135,188	1.45E+01	4.58E+04	1.00	0.87
8.b	Economic Impacts - VALWNF=$189,041	1.46E+01	5.37E+04	1.00	1.02

5. SAMA Analysis Incorporating MACCS2 Sensitivity Results

The objective of this section is to evaluate the impact of the new MACCS2 sensitivity results with respect to Pilgrim's current SAMA analysis and to determine whether the new sensitivity analyses would result in any additional SAMAs being considered cost beneficial.

The Pilgrim SAMA analysis follows the recommendations of NUREG/BR-0184, where total costs includes off-site exposure cost, off-site economic cost, on-site exposure cost, and on-site economic cost (defined as on-site clean-up and decontamination cost, and replacement power cost) (NRC, 1997). In the original analysis (PNPS, 2006), equivalent present dollar values for the calculated PDR and OECR were estimated assuming a discount rate of 7%. The off-site population exposure cost contributes about 32% of the total cost resulting from the postulated accident evaluated as part of the SAMA analysis, and the off-site economic cost contributes about 54% of the total.

Even though the maximum increases to the PDR and OECR for any of the sensitivity cases discussed above result from different MACCS2 sensitivity cases, the maximum increase for each risk is used to adjust the base case total cost results for the 59 PNPS SAMAs in order to determine whether any additional SAMAs would be considered cost beneficial. The maximum increase to the PDR for any of the sensitivity studies was 6% and the maximum increase to the OECR for any of the sensitivity studies was 4%. Using these maximum increases for the PDR and the OECR values would increase the total cost for each of the 59 SAMAs by about (6% x 0.32 + 4% x 0.54), or 4%.

Looking at the next SAMA that is closest to becoming potentially cost effective, SAMA #8, it can be seen that the baseline benefit for this SAMA (of $2,405,508) is less than half of the estimated cost of implementing the SAMA (>$5,000,000). Accordingly, the baseline benefit, or the total cost avoided, would have to increase by more than 100% before SAMA #8 would become cost beneficial. This is a factor of 25 times greater than the maximum increases seen from any of the additional sensitivity analyses evaluated in this report.

The baseline benefit case in the Pilgrim SAMA analysis assumes a discount rate of 7% and is based on the mean benefit, or total cost avoided, as shown by the SAMA analysis. As part of the SAMA study, several bounding analyses were also studied. The first, a baseline case with uncertainty was considered, based on the 95th percentile level (PNPS, 2006; LRA, 2006a). For the baseline case with uncertainty (shown as the sixth column in Table 11), the benefit for each SAMA is 60% higher than for the baseline case. Additionally, a sensitivity case was also performed to investigate the impact on each SAMA when a lower discount rate of 3% is assumed (PNPS, 2006; LRA, 2006a). Table 11 shows the result from the 3% discount rate sensitivity case (seventh or last column). A comparison of the benefit costs shows that the benefit for the 3% discount rate case is at least 30% higher than the base case for each SAMA under consideration except for SAMA 52, which is 12% higher. As seen in Table 11, no additional SAMAs become cost-beneficial under either the baseline with uncertainty case or the 3% discount rate sensitivity case even with their much higher benefits. Thus, the sensitivity analyses performed in this report showing a maximum benefit increase of 4% are amply bounded by these pre-existing sensitivity analyses.

The large margins and conservatisms retained in the SAMA analysis before additional SAMAs would be cost beneficial is further demonstrated by comparing the estimated cost of implementing the next SAMA that is closest to becoming potentially cost effective, SAMA #8 to the benefits for the baseline with uncertainty case and the 3% discount rate sensitivity case. This comparison is as follows:

Benefits	Costs	Difference	
$3,361,353	>$5,000,000	>$1,638,647	(3% discount rate case)
$3,848,813	>$5,000,000	>$1,151,187	(baseline with uncertainty)

Accordingly, the benefits, or total cost risk avoided, for SAMA #8 would need to increase almost 50% for the 3% discount rate case and almost 30% for the baseline case with uncertainty before this SAMA would become potentially cost effective under these bounding sensitivity analyses. These percentages are approximately an order of magnitude greater than the less than 4% maximum benefit increase shown for any of the sensitivity analyses performed in this report.

In summary, the maximum benefit increase of 4% calculated from the MACCS2 sensitivity analyses in this report would not change the existing set of potentially cost-effective SAMAs identified by the PNPS SAMA analysis. Before any additional SAMAs would be identified as potentially cost-effective, the increase in benefit would need to be on the order of 100%, or a factor of 25 times greater than shown by any of the sensitivity analyses in this report. Even under the bounding sensitivity analyses performed for the SAMA analysis, the increase in benefit would need to be approximately an order of magnitude larger before these bounding analyses would be affected.

Table 11. Summary of Phase II SAMA Analysis
(Based on Table RAI.3-2 Revised Summary of Phase II SAMA Analysis[6])

Phase II SAMA ID	SAMA	Baseline Benefit Case	Estimated Cost	Conclusion	Baseline With Uncertainty Case	3% Discount Rate Alternate Case
1	Install an independent method of suppression pool cooling.	$234,337	$5,800,000	Not cost effective	$374,940	$319,334
2	Install a filtered containment vent to provide fission product scrubbing. Option 1: Gravel Bed Filter Option 2: Multiple Venturi Scrubber	$871,795[1]	$3,000,000	Not cost effective	$1,394,872	$1,218,209
3	Install a containment vent large enough to remove ATWS decay heat.	$56,799	>$2,000,000	Not cost effective	$90,878	$78,556
4	Create a large concrete crucible with heat removal potential under the basemat to contain molten core debris.	$2,405,508	>$100 million	Not cost effective	$3,848,813	$3,361,353
5	Create a water-cooled rubble bed on the pedestal.	$2,405,508	$19,000,000	Not cost effective	$3,848,813	$3,361,353
6	Provide modification for flooding the drywell head	$0	>$1,000,000	Not cost effective	$0	$0
7	Enhance fire protection system and/or SGTS hardware and procedures.	$59,196	>$2,500,000	Not cost effective	$94,714	$82,718
8	Create a core melt source reduction system.	$2,405,508	>$5,000,000	Not cost effective	$3,848,813	$3,361,353
9	Install a passive containment spray system.	$236,327	$5,800,000	Not cost effective	$378,123	$321,572

[6] Table 11 is Table RAI 3-2 of the "Revised Summary of Phase II SAMA Analysis" (footnotes omitted) that was provided in LRA (2006a) which replaced the results of the original SAMA analysis provided with the license renewal application.

Table 11. Summary of Phase II SAMA Analysis
(Based on Table RAI.3-2 Revised Summary of Phase II SAMA Analysis[6])

Phase II SAMA ID	SAMA	Baseline Benefit Case	Estimated Cost	Conclusion	Baseline With Uncertainty Case	3% Discount Rate Alternate Case
10	Strengthen primary/ secondary containment.	$1,151,630	$12,000,000	Not cost effective	$1,842,609	$1,609,238
11	Increase the depth of the concrete basemat or use an alternative concrete material to ensure melt-through does not occur	$26,907	>$5,000,000	Not cost effective	$43,052	$37,599
12	Provide a reactor vessel exterior cooling system	$5,381	$2,500,000	Not cost effective	$8,610	$7,520
13	Construct a building to be connected to primary/ secondary containment that is maintained at a vacuum	$59,196	>$2,000,000	Not cost effective	$94,714	$82,718
14	Dedicated Suppression Pool Cooling	$234,337	$5,800,000	Not cost effective	$374,940	$319,334
15	Create a larger volume in containment.	$1,151,630	$8,000,000	Not cost effective	$1,842,609	$1,609,238
16	Increase containment pressure capability (sufficient pressure to withstand severe accidents).	$1,151,630	$12,000,000	Not cost effective	$1,842,609	$1,609,238
17	Install improved vacuum breakers (redundant valves in each line).	$0	>$1,000,000	Not cost effective	$0	$0
18	Increase the temperature margin for seals.	$0	$12,000,000	Not cost effective	$0	$0
19	Install a filtered vent	$871,795[1]	$3,000,000	Not cost effective	$1,394,872	$1,218,209
20	Provide a method of drywell head flooding.	$0	>$1,000,000	Not cost effective	$0	$0
21	Use alternate method of reactor building spray.	$59,196	>$2,500,000	Not cost effective	$94,714	$82,718

Table 11. Summary of Phase II SAMA Analysis
(Based on Table RAI.3-2 Revised Summary of Phase II SAMA Analysis[6])

Phase II SAMA ID	SAMA	Baseline Benefit Case	Estimated Cost	Conclusion	Baseline With Uncertainty Case	3% Discount Rate Alternate Case
22	Provide a means of flooding the rubble bed.	$1,124,723	$2,500,000	Not cost effective	$1,799,557	$1,571,639
23	Install a reactor cavity flooding system.	$2,405,508	$8,750,000	Not cost effective	$3,848,813	$3,361,353
24	Add ribbing to the containment shell.	$1,151,630	$12,000,000	Not cost effective	$1,842,609	$1,609,238
25	Provide additional DC battery capacity.	$132,726	$500,000	Not cost effective	$212,362	$183,030
26	Use fuel cells instead of lead-acid batteries.	$132,726	>$1,000,000	Not cost effective	$212,362	$183,030
27	Modification for Improving DC Bus Reliability	$838,625	$1,953,682	Not cost effective	1,341,800	$1,129,635
28	Provide 16-hour SBO injection.	$132,726	$500,000	Not cost effective	$212,362	$183,030
29	Provide an alternate pump power source.	$248,313	>$1,000,000	Not cost effective	$397,301	$342,381
30	AC Bus Cross-Ties	$426,797	$146,120	Potentially cost effective	$682,876	$576,901
31	Add a dedicated DC power supply.	$833,243	$3,000,000	Not cost effective	$1,333,189	$1,122,116
32	Install additional batteries or divisions.	$833,243	$3,000,000	Not cost effective	$1,333,189	$1,122,116
33	Install fuel cells.	$132,726	>$1,000,000	Not cost effective	$212,362	$183,030
34	DC Cross-Ties	$109,569	$13,000	Potentially cost effective	$175,311	$145,259
35	Extended SBO provisions.	$132,726	$500,000	Not cost effective	$212,362	$183,030
36	Locate RHR inside containment.	$8,366	>$500,000	Not cost effective	$13,385	$10,878

Table 11. Summary of Phase II SAMA Analysis
(Based on Table RAI.3-2 Revised Summary of Phase II SAMA Analysis[6])

Phase II SAMA ID	SAMA	Baseline Benefit Case	Estimated Cost	Conclusion	Baseline With Uncertainty Case	3% Discount Rate Alternate Case
37	Increase frequency of valve leak testing.	$25,505	$100,000	Not cost effective	$40,808	$34,557
38	Improve MSIV design.	$0	n/a	Not cost effective	$0	$0
39	Install an independent diesel for the CST makeup pumps.	$0	$135,000	Not cost effective	$0	$0
40	Provide an additional high pressure injection pump with independent diesel.	$102,606	>$1,000,000	Not cost effective	$164,170	$137,423
41	Install independent AC high pressure injection system.	$102,606	>$1,000,000	Not cost effective	$164,170	$137,423
42	Install a passive high pressure system.	$102,606	>$1,000,000	Not cost effective	$164,170	$137,423
43	Improved high pressure systems	$68,736	>$1,000,000	Not cost effective	$109,977	$91,989
44	Install an additional active high pressure system.	$102,606	>$1,000,000	Not cost effective	$164,170	$137,423
45	Add a diverse injection system.	$102,606	>$1,000,000	Not cost effective	$164,170	$137,423
46	Increase SRV reseat reliability.	$47,618	$1,800,000	Not cost effective	$76,188	$63,832
47	Install an ATWS sized vent.	$56,799	>$2,000,000	Not cost effective	$90,878	$78,556
48	Diversify explosive valve operation.	$0	>$200,000	Not cost effective	$0	$0
49	Increase the reliability of SRVs by adding signals to open them automatically.	$31,881	>$1,500,000	Not cost effective	$51,010	$43,196
50	Improve SRV design.	$172,744	$1,500,000	Not cost effective	$276,391	$232,454
51	Provide self-cooled ECCS pump seals.	$29,891	>$200,000	Not cost effective	$47,826	$40,957

Table 11. Summary of Phase II SAMA Analysis
(Based on Table RAI.3-2 Revised Summary of Phase II SAMA Analysis[6])

Phase II SAMA ID	SAMA	Baseline Benefit Case	Estimated Cost	Conclusion	Baseline With Uncertainty Case	3% Discount Rate Alternate Case
52	Provide digital large break LOCA protection.	$995	>$100,000	Not cost effective	$1,592	$1,119
53	Control containment venting within a narrow band of pressure	$114,364	$300,000	Not cost effective	$182,982	$153,582
54	Install a bypass switch to bypass the low reactor pressure interlocks of LPCI or core spray injection valves.	$23,515	$1,000,000	Not cost effective	$37,624	$32,318
55	Improve SSW System and RBCCW pump recovery.	$334,596	>$5,000,000	Not cost effective	$535,353	$459,971
56	Provide redundant DC power supplies to DTV valves.	$200,010	$112,400	Potentially cost effective	$320,016	$264,600
57	Proceduralize the use of diesel fire pump hydroturbine in the event of EDG A failure or unavailability.	$156,828	$26,000	Potentially cost effective	$250,925	$214,544
58	Proceduralize the operator action to feed B1 loads via B3 when A5 is unavailable post-trip.	$175,142	$50,000	Potentially cost effective	$280,226	$236,616
59	Provide redundant path from fire protection pump discharge to LPCI loops A and B cross-tie.	$845,784	$1,956,000	Not cost effective	$1,353,255	$1,166,976

6. Conclusions

A technical study has been completed to address issues raised by Pilgrim Watch Contention # 3 on use of the MACCS2 code to support severe accident mitigation alternative (SAMA) analysis as part of the license extension process for the Pilgrim Nuclear Power Station. Specifically, the contention challenged

- The validity of the MACCS2 meteorological model and data used in the economic SAMA analysis, including the ability of the model to treat terrain effects, sea breeze phenomena
- The adequacy of the input data and assumptions influencing the evacuation and sheltering model in MACCS2, and the capabilities of the code itself to model actual and worst case scenarios.
- The adequacy of the modeling of economic losses, especially those characterizing tourism and business costs.

The study as documented in this report reaffirms the use of the MACCS2 computer model to guide the identification of SAMAs for the Pilgrim plant based on site and regional input data, and postulated accident conditions. In particular, MACCS2 is the best available methodology for sampling a sufficient number of Pilgrim site-specific weather sequences to generate the appropriate statistical basis for determining mean consequence estimates needed for SAMA analysis. These include the off-site population dose risk (PDR) and off-site economic cost risk (OECR). MACCS2 results are calculated using Gaussian plume methodology that is well-understood and is applied using conservative modeling assumptions and input data that is compliant with Nuclear Regulatory Commission guidance and nuclear industry practices.

Use of the MACCS2 code and application to the Pilgrim plant set of postulated accident conditions provided the following insights:

- The Gaussian plume is in good agreement with more sophisticated and complex models that are considerably more data-intensive. The model has been conservatively applied to produce conservative results in the fifty-mile region of interest surrounding the Pilgrim site.
- Most of the PDR and OECR levels are due to radiological exposures and subsequent economic effects in the 20-mile to 50-mile region areas, and especially in high population density areas between 30 to 40 miles distant from the plant.
- The effect of sea breeze on plumes released from Pilgrim will be to disperse rather than concentrate radioactivity in a plume. This effect, while obviously important to local prediction of plumes within the first five to ten miles from Pilgrim, would decrease the plume concentrations and therefore the population dose in the important 20-mile to 50-mile region. Since the 20-mile to 50-mile effects dominate the consequences, sea breeze effects are not significant to the Pilgrim SAMA analysis. In addition, variability of wind direction and wind speed in the coastal region near Pilgrim, while measurable, is not

important to the SAMA analysis and is compensated for in the MACCS2 modeling by selection of appropriately conservative input parameters and data.

- The dose mitigation models implemented in the MACCS2 code used region-specific, evacuation time estimate (ETE) data and a conservative model of evacuation of residents from the EPZ. Because the analysis followed SAMA methodology and used NRC and industry guidelines, mean or average consequences and risk values were calculated. Worst case calculations are not appropriate for risk-informed, cost-benefit SAMA analysis studies.
- Sensitivity analyses demonstrated that while evacuation timing and speed can affect the population dose incurred in the initial phase following an accident condition, the influence to the overall population dose is small. On average, the initial seven-day period following the accident contributed on average about 17% of the overall dose. Thus, effects are largely limited to lowering a small dose component. The largest component of dose is not influenced by the emergency phase assumptions or model and so is unaffected by changes in emergency planning.
- Emergency phase actions have at best a minor influence to the SAMA consequence analyses because of the dominant effect of the 30-to-40 mile zone on the results of the SAMA analyses. In other words, the contention challenge on evacuation and other dose avoidance plans is negligible in its applicability to impact the outcome of the SAMA analysis.
- Population dose is mostly due to groundshine effects occurring over the long-term phase of the analysis. Other contributors are decontamination dose and ingestion dose.
- The economic impact model in MACCS2, with an expanded accountability of business and tourism losses indexed on county business activity, indicated small, incremental increase to the OECR. However the increase was insufficient to justify additional severe accident mitigation alternatives.
- Economic costs are based mostly on interdiction, decontamination, and condemnation costs in that order. Agricultural losses are insignificant compared to non-farm, business loss and tangible property losses.

MACCS2 sensitivity analysis cases supported the judgment that long-term and mid- to far field consequences dominate the determination of consequences of interest in the PNPS SAMA analysis, and that the Gaussian plume model is a reasonable tool that provides a unique combination of meteorological data analysis, representative statistics on consequence results, and versatility. The sensitivity cases explored trajectory effects, terrain impacts, distance to travel for evacuees, no-evacuation, evacuation delay time and evacuation speed, and the addition of non-farm wealth data to account more fully for economic costs. The increase in PDR ranged from 0% to 6%. The increase in OECR ranged from 0% to 4%.

Using the maximum increase in results of the MACCS2-based sensitivity studies for PDR and OECR of 6% and 4%, respectively, would increase the total cost by about 4% (6% x 0.32 + 4% x 0.54). However, before any additional SAMAs would be identified as potentially cost-effective, the increase in benefit would need to be on the order of 100%, or a factor of 25 times greater than shown by any of the sensitivity analyses in this report. Even under the bounding sensitivity analyses previously performed for the SAMA analysis, the increase in benefit would need to be approximately an order of magnitude larger before these bounding analyses would be affected.

Accordingly, the maximum benefit increase of 4% calculated from the MACCS2 sensitivity analyses in this report would not change the existing set of potentially cost-effective SAMAs identified by the PNPS SAMA analysis. Much larger increases in benefit cost would need to occur before any new SAMAs could be determined to be potentially cost effective.

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Acronyms

ASLB	Atomic Safety Licensing Board
CAPB	Collapsed Accident Progression Bin
DOE	U.S. Department of Energy
EAB	Exclusion Area Boundary
EPZ	Emergency Planning Zone
ER	Environmental Report
GCP	Gross County Product ($)
LPZ	Low Population Zone
MACCS2	MELCOR Accident Consequence Code System 2
MW_{th}	Megawatt thermal (10^6 Watts)
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
OECR	Off-site Economic Cost Risk ($/year)
PDR	Population Dose Risk, (person-Sv/year) or (person-rem/year)
PNPS	Pilgrim Nuclear Power Station
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment (or Analysis)
RAI	Request for Additional Information
SAMA	Severe Accident Mitigation Alternatives
WSMS	Washington Safety Management Solutions LLC

Appendix A. Base Case for Pilgrim SAMA Analysis – Population Dose (person-Sv) by Spatial Ring for Each Source Term/Collapse Accident Progression Bin (1-14)

Grid Ring Number	Grid Interval	CAPB-1	CAPB-2	CAPB-3	CAPB-4	CAPB-5	CAPB-6	CAPB-7
1	(0-0.53 mile)	4.83E-02	1.92E+00	1.93E+00	9.58E+00	1.46E+01	9.82E+00	1.21E+01
2	(0.53-1.0 mi	5.65E-02	4.52E+00	4.70E+00	3.00E+01	4.22E+01	3.44E+01	4.06E+01
3	(1-2 miles)	4.09E-02	6.82E+00	7.19E+00	2.96E+01	3.90E+01	3.41E+01	3.90E+01
4	(2-3 miles)	2.48E-02	5.70E+00	6.05E+00	4.42E+01	3.35E+01	4.01E+01	4.07E+01
5	(3-4 miles)	2.15E-02	5.19E+00	5.52E+00	6.70E+01	5.72E+01	6.69E+01	6.08E+01
6	(4-5 miles)	1.97E-02	4.80E+00	5.09E+00	7.73E+01	8.91E+01	8.82E+01	9.74E+01
7	(5-6 miles)	1.65E-02	4.09E+00	4.35E+00	8.57E+01	1.07E+02	9.13E+01	1.05E+02
8	(6-7 miles)	1.40E-02	3.48E+00	3.70E+00	8.91E+01	1.18E+02	1.09E+02	1.10E+02
9	(7-8 miles)	1.27E-02	3.18E+00	3.38E+00	1.06E+02	1.39E+02	1.15E+02	1.31E+02
10	(8-9 miles)	1.27E-02	3.19E+00	3.40E+00	1.17E+02	1.56E+02	1.22E+02	1.42E+02
11	(9-10 miles)	1.19E-02	3.00E+00	3.20E+00	1.70E+02	2.43E+02	1.91E+02	2.20E+02
12	(10-20 miles	7.73E-02	1.95E+01	2.08E+01	1.73E+03	2.64E+03	1.89E+03	2.33E+03
13	(20-30 miles	8.67E-02	2.18E+01	2.33E+01	3.56E+03	4.68E+03	3.90E+03	4.43E+03
14	(30-40 miles	9.96E-02	2.51E+01	2.67E+01	5.73E+03	7.05E+03	6.11E+03	6.40E+03
15	(40-50 miles	3.36E-02	8.45E+00	9.01E+00	3.15E+03	3.82E+03	3.22E+03	3.65E+03
	TOTAL	5.77E-01	1.21E+02	1.28E+02	1.50E+04	1.92E+04	1.60E+04	1.78E+04

Grid Ring Number	Grid Interval	CAPB-8	CAPB-9	CAPB-10	CAPB-11	CAPB-12	CAPB-13	CAPB14
1	(0-0.53 mile)	9.15E+01	3.77E+01	8.83E+01	5.18E+01	1.27E+00	6.47E+00	1.22E+01
2	(0.53-1.0 mi	1.96E+02	8.57E+01	1.86E+02	1.11E+02	2.25E+00	2.11E+01	4.28E+01
3	(1-2 miles)	1.06E+02	6.35E+01	8.62E+01	7.56E+01	3.78E+00	3.70E+01	3.42E+01
4	(2-3 miles)	1.19E+02	6.07E+01	1.16E+02	9.06E+01	3.04E+00	4.58E+01	4.30E+01
5	(3-4 miles)	1.39E+02	5.87E+01	1.28E+02	1.01E+02	2.97E+00	5.23E+01	6.04E+01
6	(4-5 miles)	1.88E+02	7.79E+01	1.65E+02	1.19E+02	3.17E+00	6.48E+01	9.05E+01
7	(5-6 miles)	1.94E+02	1.04E+02	1.70E+02	1.17E+02	3.00E+00	5.95E+01	9.84E+01
8	(6-7 miles)	1.91E+02	1.28E+02	1.62E+02	1.26E+02	2.71E+00	5.36E+01	1.01E+02
9	(7-8 miles)	1.95E+02	1.53E+02	1.49E+02	1.61E+02	2.62E+00	5.38E+01	1.16E+02
10	(8-9 miles)	2.08E+02	1.82E+02	1.45E+02	1.88E+02	2.69E+00	6.30E+01	1.32E+02
11	(9-10 miles)	4.69E+02	3.31E+02	4.70E+02	4.07E+02	2.77E+00	8.28E+01	1.89E+02
12	(10-20 miles	6.09E+03	3.82E+03	6.00E+03	5.93E+03	1.93E+01	1.10E+03	1.97E+03
13	(20-30 miles	1.21E+04	6.55E+03	1.35E+04	9.61E+03	2.23E+01	2.44E+03	3.84E+03
14	(30-40 miles	1.64E+04	9.44E+03	1.82E+04	1.38E+04	3.57E+01	3.16E+03	6.79E+03
15	(40-50 miles	7.61E+03	4.31E+03	7.81E+03	6.36E+03	1.05E+01	1.23E+03	3.34E+03
	TOTAL	4.43E+04	2.54E+04	4.74E+04	3.72E+04	1.18E+02	8.47E+03	1.69E+04

Appendix A. Base Case for Pilgrim SAMA Analysis – Population Dose (person-Sv) by Spatial Ring for Each Source Term/Collapse Accident Progression Bin (15-19)

Grid Ring Number	Grid Interva	CAPB-15	CAPB-16	CAPB-17	CAPB-18	CAPB-19
1	(0-0.53 mile	1.06E+02	2.79E+01	2.79E+02	5.64E+01	3.18E+02
2	(0.53-1.0 mi	2.32E+02	8.18E+01	6.04E+02	1.31E+02	6.90E+02
3	(1-2 miles)	8.76E+01	5.82E+01	1.21E+02	8.13E+01	1.38E+02
4	(2-3 miles)	1.15E+02	5.02E+01	1.51E+02	7.45E+01	1.64E+02
5	(3-4 miles)	1.19E+02	6.30E+01	1.64E+02	7.04E+01	1.74E+02
6	(4-5 miles)	1.37E+02	1.12E+02	1.89E+02	8.90E+01	2.01E+02
7	(5-6 miles)	1.34E+02	1.34E+02	1.87E+02	1.11E+02	1.95E+02
8	(6-7 miles)	1.28E+02	1.42E+02	1.69E+02	1.57E+02	1.83E+02
9	(7-8 miles)	1.22E+02	1.48E+02	1.51E+02	1.83E+02	1.60E+02
10	(8-9 miles)	1.23E+02	1.77E+02	1.60E+02	2.11E+02	1.65E+02
11	(9-10 miles)	4.13E+02	3.20E+02	5.12E+02	3.96E+02	6.26E+02
12	(10-20 miles	5.86E+03	3.18E+03	7.28E+03	4.17E+03	8.02E+03
13	(20-30 miles	1.36E+04	4.81E+03	1.43E+04	6.54E+03	1.58E+04
14	(30-40 miles	1.72E+04	6.66E+03	1.85E+04	9.29E+03	2.12E+04
15	(40-50 miles	8.20E+03	3.35E+03	8.32E+03	4.27E+03	9.20E+03
	TOTAL	4.66E+04	1.93E+04	5.11E+04	2.58E+04	5.72E+04

Appendix B. Case 2 – Approximate Trajectory Effect

Case 2	Trajectory Approximation - Different Weather is Sampled by Plume Than in Base Case						
						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.60E-01	3.85E+06	5.33E-06	3.66E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.17E+02	7.19E+06	1.49E-04	9.13E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.24E+02	7.46E+06	2.96E-05	1.78E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.50E+04	4.93E+09	4.94E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.92E+04	6.15E+09	5.24E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.60E+04	4.35E+09	1.27E-02	3.46E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.78E+04	5.25E+09	1.41E-02	4.16E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.42E+04	1.68E+10	9.11E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.54E+04	9.26E+09	2.35E-02	8.57E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.74E+04	1.72E+10	4.04E-01	1.47E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.72E+04	1.29E+10	1.62E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.16E+02	4.84E+06	1.97E-02	8.23E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.36E+03	8.67E+08	1.92E-03	1.99E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.69E+04	5.04E+09	3.82E+00	1.14E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.88E+04	1.86E+10	1.03E+01	3.94E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.93E+04	6.28E+09	2.28E-03	7.41E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.12E+04	1.98E+10	3.54E-02	1.37E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.58E+04	8.43E+09	1.19E-03	3.89E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.72E+04	2.11E+10	1.39E-01	5.13E+02	1.39E-01	5.12E+02
				1.51E+01	5.41E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				**1.03E+00**	**1.03E+00**		

Appendix C. Case 3 Terrain Model Effect

Case 3 - 0.0 m Release height and no building wake							
						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	6.00E-01	3.81E+06	5.71E-06	3.62E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	6.69E+06	1.54E-04	8.50E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.29E+02	6.92E+06	3.08E-05	1.65E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.45E+04	4.99E+09	4.77E-03	1.64E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.91E+04	6.09E+09	5.21E-03	1.66E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.64E+04	4.18E+09	1.30E-02	3.32E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.75E+04	5.30E+09	1.39E-02	4.20E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.37E+04	1.68E+10	9.00E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.63E+04	9.06E+09	2.43E-02	8.38E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.73E+04	1.80E+10	4.03E-01	1.54E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.82E+04	1.29E+10	1.66E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.17E+02	4.11E+06	1.99E-02	6.99E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.41E+03	8.88E+08	1.93E-03	2.04E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.71E+04	4.94E+09	3.86E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.72E+04	1.90E+10	1.00E+01	4.03E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.94E+04	6.33E+09	2.29E-03	7.47E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.18E+04	1.99E+10	3.58E-02	1.38E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.58E+04	8.50E+09	1.19E-03	3.92E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.83E+04	2.14E+10	1.42E-01	5.20E+02	1.39E-01	5.12E+02
				1.48E+01	5.48E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				1.01E+00	1.04E+00		

Appendix D. EPZ Evacuees Moving to 40 miles Away

Case 4	Evacuees end at 40 miles					Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.77E-01	3.82E+06	5.49E-06	3.63E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	7.18E+06	1.54E-04	9.12E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.28E+02	7.31E+06	3.06E-05	1.75E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.50E+04	4.93E+09	4.94E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.93E+04	6.15E+09	5.27E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.61E+04	4.35E+09	1.28E-02	3.46E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.79E+04	5.25E+09	1.42E-02	4.16E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.46E+04	1.68E+10	9.19E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.55E+04	9.26E+09	2.36E-02	8.57E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.77E+04	1.72E+10	4.07E-01	1.47E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.74E+04	1.29E+10	1.63E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.19E+02	4.85E+06	2.02E-02	8.25E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.49E+03	8.36E+08	1.95E-03	1.92E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.69E+04	4.96E+09	3.82E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.68E+04	1.80E+10	9.92E+00	3.82E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.94E+04	6.28E+09	2.29E-03	7.41E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.15E+04	1.98E+10	3.56E-02	1.37E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.60E+04	8.43E+09	1.20E-03	3.89E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.77E+04	2.11E+10	1.40E-01	5.13E+02	1.39E-01	5.12E+02
				1.47E+01	5.26E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				**1.00E+00**	**1.00E+00**		

Appendix E. No Evacuation Case

Case 6. No Evaculation from EPZ						Base Case	
Release Mode	Frequency (y⁻¹)	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.86E-01	6.91E+00	5.57E-06	6.57E-07	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.23E+02	3.36E+06	1.56E-04	4.27E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.31E+02	3.49E+06	3.13E-05	8.34E-03	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.53E+04	4.92E+09	5.03E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.99E+04	6.15E+09	5.43E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.65E+04	4.35E+09	1.31E-02	3.46E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.84E+04	5.24E+09	1.46E-02	4.16E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.67E+04	1.68E+10	9.62E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.68E+04	9.26E+09	2.48E-02	8.57E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	5.03E+04	1.72E+10	4.29E-01	1.47E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.93E+04	1.29E+10	1.71E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.21E+02	1.03E+06	2.06E-02	1.75E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.68E+03	8.32E+08	2.00E-03	1.91E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.73E+04	4.96E+09	3.91E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.97E+04	1.80E+10	1.05E+01	3.82E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	2.18E+04	6.28E+09	2.57E-03	7.41E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.93E+04	1.98E+10	4.10E-02	1.37E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.95E+04	8.42E+09	1.36E-03	3.88E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	6.76E+04	2.11E+10	1.64E-01	5.13E+02	1.39E-01	5.12E+02
				1.54E+01	5.26E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				**1.06E+00**	**1.00E+00**		

Appendix F. Evacuation Delay Time and Speed Sensitivity Studies

Case 7.a	Six-hour Delayed Evacuation from EPZ (Base Case assumes 40 minute delay)						
						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.63E-01	3.85E+06	5.35E-06	3.66E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.22E+02	7.18E+06	1.55E-04	9.12E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.29E+02	7.31E+06	3.08E-05	1.75E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.54E+04	4.93E+09	5.07E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	2.01E+04	6.15E+09	5.49E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.65E+04	4.35E+09	1.31E-02	3.46E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.85E+04	5.25E+09	1.47E-02	4.16E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.77E+04	1.68E+10	9.83E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.70E+04	9.26E+09	2.50E-02	8.57E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	5.14E+04	1.72E+10	4.38E-01	1.47E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	4.01E+04	1.29E+10	1.74E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.22E+02	4.85E+06	2.07E-02	8.25E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.62E+03	8.36E+08	1.98E-03	1.92E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.72E+04	4.96E+09	3.89E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.96E+04	1.80E+10	1.05E+01	3.82E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	2.15E+04	6.28E+09	2.54E-03	7.41E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.78E+04	1.98E+10	3.99E-02	1.37E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.91E+04	8.43E+09	1.34E-03	3.89E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	6.53E+04	2.11E+10	1.59E-01	5.13E+02	1.39E-01	5.12E+02
				1.54E+01	5.26E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				1.05E+00	1.00E+00		

Case 7.b	Evacuation speed is 0.34 m/s from EPZ (Base Case uses 0.97 m/s)						
						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.61E-01	3.85E+06	5.34E-06	3.66E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	7.18E+06	1.54E-04	9.12E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.29E+02	7.31E+06	3.08E-05	1.75E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.55E+04	4.93E+09	5.10E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.97E+04	6.15E+09	5.38E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.63E+04	4.35E+09	1.30E-02	3.46E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.82E+04	5.25E+09	1.44E-02	4.16E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.73E+04	1.68E+10	9.74E-02	3.46E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.61E+04	9.26E+09	2.41E-02	8.57E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.95E+04	1.72E+10	4.22E-01	1.47E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.88E+04	1.29E+10	1.69E-01	5.61E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.20E+02	4.85E+06	2.04E-02	8.25E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.54E+03	8.36E+08	1.96E-03	1.92E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.70E+04	4.96E+09	3.84E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.80E+04	1.80E+10	1.02E+01	3.82E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	2.00E+04	6.28E+09	2.36E-03	7.41E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.33E+04	1.98E+10	3.68E-02	1.37E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.69E+04	8.43E+09	1.24E-03	3.89E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.99E+04	2.11E+10	1.46E-01	5.13E+02	1.39E-01	5.12E+02
				1.50E+01	5.26E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				**1.03E+00**	**1.00E+00**		

Appendix G. Economic Index Sensitivity Study

Table G.1 Case 8.a with change to VALWNF ($135,188)						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.77E-01	3.82E+06	5.49E-06	3.63E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	6.78E+06	1.54E-04	8.61E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.28E+02	6.89E+06	3.06E-05	1.65E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.50E+04	4.29E+09	4.94E-03	1.41E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.92E+04	5.37E+09	5.24E-03	1.47E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.60E+04	3.80E+09	1.27E-02	3.02E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.78E+04	4.58E+09	1.41E-02	3.63E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.40E+04	1.43E+10	9.06E-02	2.95E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.54E+04	8.06E+09	2.35E-02	7.46E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.71E+04	1.47E+10	4.02E-01	1.25E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.71E+04	1.11E+10	1.61E-01	4.83E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.18E+02	4.74E+06	2.01E-02	8.06E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.47E+03	7.30E+08	1.95E-03	1.68E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.68E+04	4.33E+09	3.80E+00	9.79E+03	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.64E+04	1.57E+10	9.84E+00	3.33E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.93E+04	5.49E+09	2.28E-03	6.48E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.09E+04	1.69E+10	3.52E-02	1.17E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.58E+04	7.36E+09	1.19E-03	3.39E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.70E+04	1.80E+10	1.39E-01	4.37E+02	1.39E-01	5.12E+02
				1.45E+01	4.58E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				9.96E-01	8.72E-01		

Table G.2 Case 8.b with change to VALWNF to 2004 basis ($189,041)						Base Case	
Release Mode	Frequency (y^{-1})	Population Dose (person-Sv)*	Offsite Economic Cost ($)	Population Dose Risk (person-rem)/y*	Offsite Economic Cost Risk ($/y)	Population Dose Risk (person-rem/y)	Offsite Economic Cost Risk ($/y)
CAPB-1	9.51E-08	5.77E-01	3.82E+06	5.49E-06	3.63E-01	5.49E-06	3.63E-01
CAPB-2	1.27E-08	1.21E+02	7.18E+06	1.54E-04	9.12E-02	1.53E-04	9.08E-02
CAPB-3	2.39E-09	1.28E+02	7.31E+06	3.06E-05	1.75E-02	3.06E-05	1.75E-02
CAPB-4	3.29E-09	1.50E+04	4.93E+09	4.94E-03	1.62E+01	4.94E-03	1.62E+01
CAPB-5	2.73E-09	1.92E+04	6.17E+09	5.24E-03	1.68E+01	5.24E-03	1.68E+01
CAPB-6	7.95E-09	1.60E+04	4.36E+09	1.27E-02	3.47E+01	1.27E-02	3.46E+01
CAPB-7	7.93E-09	1.78E+04	5.26E+09	1.41E-02	4.17E+01	1.41E-02	4.16E+01
CAPB-8	2.06E-08	4.42E+04	1.71E+10	9.11E-02	3.52E+02	9.10E-02	3.46E+02
CAPB-9	9.25E-09	2.54E+04	9.32E+09	2.35E-02	8.62E+01	2.35E-02	8.56E+01
CAPB-10	8.53E-08	4.74E+04	1.75E+10	4.04E-01	1.49E+03	4.05E-01	1.47E+03
CAPB-11	4.35E-08	3.72E+04	1.30E+10	1.62E-01	5.66E+02	1.62E-01	5.61E+02
CAPB-12	1.70E-06	1.18E+02	4.85E+06	2.01E-02	8.25E+00	2.01E-02	8.25E+00
CAPB-13	2.30E-09	8.48E+03	8.38E+08	1.95E-03	1.93E+00	1.95E-03	1.93E+00
CAPB-14	2.26E-06	1.69E+04	4.97E+09	3.82E+00	1.12E+04	3.82E+00	1.12E+04
CAPB-15	2.12E-06	4.65E+04	1.85E+10	9.86E+00	3.92E+04	9.86E+00	3.82E+04
CAPB-16	1.18E-09	1.93E+04	6.31E+09	2.28E-03	7.45E+00	2.27E-03	7.40E+00
CAPB-17	6.91E-09	5.12E+04	2.01E+10	3.54E-02	1.39E+02	3.54E-02	1.37E+02
CAPB-18	4.61E-10	2.58E+04	8.48E+09	1.19E-03	3.91E+00	1.19E-03	3.88E+00
CAPB-19	2.43E-08	5.72E+04	2.15E+10	1.39E-01	5.22E+02	1.39E-01	5.12E+02
				1.46E+01	5.37E+04	1.46E+01	5.26E+04
Ratio of Sensitivity Case to Base Case				1.00E+00	1.02E+00		

From: "Gaukler, Paul A." <paul.gaukler@pillsburylaw.com>
To: "HearingDocket" <HearingDocket@nrc.gov>
Date: Tue, Jun 5, 2007 12:11 PM
Subject: Confirmation that O'Kula Resume is publicly available

This is to confirm that Dr. O'Kula's resume (Exhibit 1 to his declaration filed in support of Entergy's Motion for Summary Disposition of Pilgrim Watch Contention 3 in Entergy Nuclear Generation Company and Entergy Nuclear Operations, Inc. (Pilgrim Nuclear Power Station), Docket No. 50-293-LR) is publicly available. Please call or e-mail me if you need any further information.

DOCKETED
USNRC

June 5, 2007 (12:11pm)

OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF
Docket No. 50-293-LR

Paul Gaukler | Pillsbury Winthrop Shaw Pittman LLP

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From: Rebecca Giitter [mailto:RLL@nrc.gov]
Sent: Tuesday, June 05, 2007 11:22 AM
To: Gaukler, Paul A.
Cc: Emile Julian
Subject: Kevin R. O'Kula

Mr. Gaukler,

Thank you for getting back to me so quickly with the information. If possible, can you please send hearingdocket@nrc.gov an email confirming that Mr. O'Kula's resume (Exhibit 1) is publicly available? I appreciate your help.

Rebecca Giitter
Litigation Analyst
Rulemakings & Adjudications Staff
Office of the Secretary
U.S. Nuclear Regulatory Commission

(301) 415-1679

Mail Envelope Properties (46658B31.ADC : 1 : 10972)

Subject:	Confirmation that O'Kula Resume is publicly available
Creation Date	Tue, Jun 5, 2007 12:11 PM
From:	"Gaukler, Paul A." <paul.gaukler@pillsburylaw.com>
Created By:	paul.gaukler@pillsburylaw.com

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Junk Mail handling disabled by User
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Block List is not enabled