UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
ENTERGY NUCLEAR OPERATIONS, INC.	)	Docket Nos. 50-247/286-LR
	)	
(Indian Point Nuclear Generating	)	
Units 2 and 3)	)	

NRC STAFF TESTIMONY OF NATHAN E. BIXLER, S. TINA GHOSH, JOSEPH A. JONES, AND DONALD G. HARRISON CONCERNING NYS' CONTENTIONS NYS 12/16

Q1. Please state your name, occupation, and by whom you are employed.

A1a. [NEB] My name is Nathan E. Bixler. I am a Principal Member of the Technical Staff employed by Sandia National Laboratories ("Sandia"), which is operated by Lockheed-Martin for the US Department of Energy. I have been employed by Sandia for more than 28 years as an engineer and computer software researcher in the areas of accident analysis and fluid mechanics. My statement of qualifications is attached as Exhibit ("Ex.") NRC000042.

A1b. [STG] My name is S. Tina Ghosh. I am a senior program manager employed by the U.S. Nuclear Regulatory Commission (NRC). I have been employed by the NRC for over seven years. My statement of qualifications is attached as Ex. NRC000043.

A1c. [JJ] My name is Joseph A. Jones. I am a registered professional engineer and a Distinguished Member of the Technical Staff employed by Sandia, which is operated by Lockheed-Martin for the US Department of Energy. I have over 28 years experience in engineering and analysis, 23 years of which was at Sandia. I have been primarily involved in radiological emergency preparedness, consequence management, and radioactive materials cleanup activities both nationally and internationally. I perform emergency plan reviews and evacuation time estimate reviews for the NRC Staff in support of new reactor license applications. I have actively managed project teams in the decontamination and decommissioning of radioactively contaminated facilities at Sandia and have managed development of advanced decontamination techniques for radioactive materials. I am a holder of US Patent 7,514,493 B1, “Strippable Containment and Decontamination Coating Composition and Method of Use,” April 7, 2009. My statement of qualifications is attached as Ex. NRC000044.

A1d. [DGH] My name is Donald G. Harrison. I have been employed by the U.S. Nuclear Regulatory Commission (NRC) for over twelve years, with the majority of that time employed as a senior reliability and risk analyst in the Probabilistic Risk Assessment Licensing Branch (APLA) of the Division of Risk Assessment (DRA) within the Office of Nuclear Reactor Regulation (NRR). I became the branch chief APLA, which had responsibility for the license renewal severe accident mitigation alternatives (SAMA) reviews and associated development of this aspect of the environmental impact statement (EIS) at the time of the Indian Point license renewal application, as well as most risk-informed rulemaking and license application reviews that involve the use of probabilistic risk assessments (PRAs). My statement of qualifications is attached as Ex. NRC000045.

Q2. Please describe your current responsibilities.

A2a. [NEB] My current responsibilities for Sandia are fairly broad. They include (1) the lead role for development and application of the MACCS2 code for the Nuclear Regulatory Commission (“NRC”); (2) acting as the lead consequence analyst for the State of the Art Reactor Consequence Analysis (“SOARCA”) Project for the NRC; (3) supporting the NRC in its work in the license extension process for the Pilgrim Nuclear Generating Station (“Pilgrim”) and Indian Point Nuclear Generating Units 1 & 2; (4) teaching a class annually at the NRC’s Professional Development Center on Level-3 PRA (Course No. P-301); (5) developing a source term analysis capability to support the license application process for nuclear fuel recycling facilities for the NRC; (6) supporting the licensing process for a nuclear reactor under construction for Argentina's Nuclear Regulatory Authority (ARN); and (7) serving as the lead consequence analyst to support the launch approval process for upcoming NASA missions involving nuclear materials for the DOE.

A2b. [STG] My current primary responsibility is to be the NRC lead for the State of the Art Reactor Consequence Analysis's ("SOARCA") uncertainty analysis. In my previous position as a reactor engineer in the Office of Nuclear Reactor Regulation's (NRR) Division of Risk Assessment, one of my primary responsibilities was to review Severe Accident Mitigation Alternatives ("SAMA") analyses submitted in support of nuclear power plant license renewal applications, and write the corresponding portions of the NRC's supplemental environmental impact statements. I also reviewed risk-informed licensing applications that used level 2 and level 3 PRA results (i.e., analyses of accidents that involve potential radioactive releases outside the reactor containment). In my first position at the NRC in the Division of High-Level Waste Repository Safety in the Office of Nuclear Material Safety and Safeguards, my primary responsibility was to review different aspects of the Department of Energy's total-system performance assessment (TSPA) and pre-closure safety analysis (PCSA) for the Yucca Mountain repository license application. The TSPA is analogous to a level 3 PRA applied to a geologic waste disposal system, and the PCSA is analogous to a PRA for the waste-handling facilities in the operational phase in the Yucca Mountain license application. For my doctoral thesis at the Massachusetts Institute of Technology, I developed a sensitivity analysis method to generate risk information that would be useful for making decisions about high-level nuclear waste repositories given the uncertainty in the risk analyses. I demonstrated the application of the method using the proposed Yucca Mountain repository as an example, and subsequently published a paper on the method in the journal, Nuclear Technology.

A2c. [JJ] My current responsibilities for Sandia are broad. I am the project manager for the State of the Art Reactor Consequence Analyses (SOARCA) project. I am the project leader for review of emergency plans submitted with new reactor licenses. I was the lead author for the guidance document NUREG/CR-7002, "Criteria for Development of Evacuation Time Estimate Studies," and NUREG/CR-6953, "Review of NUREG-0654 Supplement 3, 'Criteria for Protective Action Recommendations for Severe Accidents," Volumes 1, 2, and 3. I am the project manager for the Pilgrim Nuclear Generating Station ("Pilgrim") and Indian Point Nuclear Generating Units 1 & 2. I was previously the project manager for Department of Homeland Security (DHS) and the Defense Advanced Research Projects Agency (DARPA) projects to develop decontamination and containment coatings for use in cleanup of radiological contamination. I was the project manager and technical lead for the decommissioning of Sandia radiological facilities including the Radiochemistry Laboratory, Toxic Machine Shop, and other facilities. I was the Sandia principle investigator and project manager for the Low Level Radioactive Waste Volume Reduction project which involved design and construction of radioactive waste processing facilities at two naval shipyards in Russia for which I authored the decommissioning plan for the radiological facilities at both of the naval shipyards.

A2d. [DGH] I continue as the branch chief of the Probabilistic Risk Assessment Licensing Branch (APLA) with responsibility for most risk-informed rulemaking and license application review activities that involve the use of PRAs. Due to an internal reallocation of review responsibilities and associated staff resources within the Division of Risk Assessment, the license renewal severe accident mitigation alternatives (SAMA) reviews were recently reassigned to another branch, the Accident Dose Branch (AADB). However, I have retained the responsibility for those SAMA reviews that were performed under APLA, including the Indian Point SAMA analysis review.

Q3. Please explain your duties in connection with the Staff's review of the License Renewal Application ("LRA") submitted by Entergy Nuclear Operations, Inc. ("Entergy," "Applicant" or "Licensee") for the renewal of Indian Point's License Nos. 50-247-LR and 50-286-LR.

A3a. [NEB] I was not directly involved in the Staff's review of the LRA. I was contracted by the NRC to review NYC contention 12 on Entergy's Environmental Report and NRC's DSEIS. In the course of my review, I discovered a potential error in the wind rose used in the MACCS2 portion of the analysis which resulted in an NRC staff request for additional information to Entergy. The Staff also relied on my review of contention 12 in their evaluation of the issues related to contention 12 in the FSEIS, Appendix G.

A3b. [STG] I was not involved in the review of the SAMA analysis in the LRA. I provided some input for the Final Supplemental Environmental Impact Statement ("FSEIS") in the form of responses to public comments on the postulated accidents and SAMA portions of the Draft Supplemental Environmental Impact Statement ("DSEIS").

A3c. [JJ] I was not directly involved in the Staff's review of the LRA. The NRC staff relied on my review of contentions 12 and 16 in their evaluation of the issues related to those contentions in the FSEIS, Appendix G.

A3d. [DH] I was Branch Chief for the APLA, which had the responsibility for performing the review of the Indian Point's SAMA analysis.

Q4. Why are you testifying here today?

A4a. [NEB] I am testifying as an expert witness on the use of the MACCS2 computer code in the Indian Point Severe Accident Mitigation Alternatives ("SAMA") analysis. I have been asked by the NRC staff to testify concerning the use of the MACCS2 code in the Indian Point SAMA analysis. Specifically, I am addressing how the MACCS2 code is used to predict consequences for a SAMA analysis and the selection of various inputs used in the SAMA analysis.

A4b. [STG] I am testifying regarding the staff's review of the Indian Point SAMA analysis, the use of PRA in SAMA analyses, and the handling of uncertainty in the SAMA analysis. Specifically, I am addressing portions on how plants identify mitigation measures and their associated costs and the evaluation of risk and benefits for SAMA analyses, generally.

A4c. [JJ] I am testifying as an expert witness in the area of radiological decontamination. Specifically I am addressing the cost estimating, decontamination techniques, and technologies for decontamination after a nuclear power plant accident. I am also testifying in regards to the population differences regarding the potential for a U.S. Census undercount and commuters within the SAMA area.

A4d. [DGH] I am testifying regarding the staff’s use of PRA-related information in SAMA analyses and specifically, the staff's perspective on the historical consideration of the time period associated with the relocation of populations while decontamination activities are performed as used in past NRC PRA-related dose consequence analysis activities and in the Indian Point SAMA analysis.

Q5. What did you review in order to prepare your testimony?

A5a. [NEB] I reviewed the Board’s orders setting the scope for the contentions and reviewed the contentions filed by NYS. I reviewed a portion of applicant’s information provided in the Environmental Report, IP2 and IP3 Cost-Benefit Analysis of Severe Accident Mitigation Alternatives engineering reports, Volume I, “Site Specific MACCS2 Input Data for Indian Point Energy Center,” and applicant responses to requests for additional information. I also reviewed Answer of Entergy Nuclear Operations, Inc. Opposing New York State Notice of Intention to Participate and Petition to Intervene. January 22, 2008; State of New York New Contention 12-

C Concerning NRC Staff's December 2010 Final Environmental Impact Statement and the Underestimation of Decontamination and Clean Up Costs Associated with a Severe Reactor Accident In the New York Metropolitan Area.

Applicant information, technical documentation and supporting documentation that I reviewed in developing my testimony includes: Nuclear Energy Institute (NEI). Severe Accident Mitigation Alternatives (SAMA) Analysis. Guidance Document. November 2005; Site Specific MACCS2 Input Data for Indian Point Energy Center, Volume II. ENERCON Services, Inc. April 7, 2006; Entergy LRA Appendix E, Applicant's Environmental Report Operating License Renewal Stage Indian Point Energy Center; Volume I, Site Specific MACCS2 Input Data for Indian Point Energy Center, (4/7/2006); Volume II, Site Specific MACCS2 Input Data for Indian Point Energy Center, (4/7/2006); IP2 Cost-Benefit Analysis of Severe Accident Mitigation Alternatives. Engineering Report No. IP-RPT-07-00007. IP3 Cost-Benefit Analysis of Severe Accident Mitigation Alternatives. Engineering Report No. IP-RPT-07-00008; NUREG/CR-6613, SAND97-0594. "SECPOP2000: Sector Population Land Fraction, and Economic Estimation Program." 2003; NUREG/CR-6613, "Code Manual for MACCS2: Volume 1, User's Guide." May, 1998; NUREG/CR-6853, "Comparison of Average Transport and Dispersion Among a Gaussian, a Two-Dimensional and a Three-Dimensional Model". 2004; Title 10 Code of Federal Regulations (CFR) 835, Appendix D, *Surface Contamination Values*.

Intervener information that I reviewed includes "Review of Indian Point Severe Accident Off Site Consequence Analysis," ISR Report 13014-01-01, 21 December, 2011; "Pre-Filed Written Testimony of Dr. Francois J. LeMay Regarding Consolidated NYS-12-C," 21 December, 2011; Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents. (Ex. NYS000249).

Other literature that I reviewed includes "State-of-the-Art Reactor Consequence Analyses (SOARCA) Report," NUREG-1935, January 2012; "State-or-the-Art Reactor

Consequence Analyses Project, Vol. 1: Peach Bottom Integrated Analysis, and Vol. 2: Surry Integrated Analysis, NUREG/CR-7110, January 2012.

A5b. [STG] I reviewed the Board's orders setting the scope for the contentions. I reviewed the contentions, pre-filed expert testimony, and supporting references filed by NYS. I reviewed the applicant's SAMA information provided in the Environmental Report and responses to requests for additional information. I reviewed the NRC's SAMA review in the FSEIS for Indian Point.

A5c. [JJ] I reviewed the Board's orders setting the scope for the contentions and reviewed the contentions filed by NYS. I reviewed the Applicant's information provided in the Environmental Report, and applicant responses to requests for additional information. Documents I have reviewed include: New York State Notice of Intention to Participate and Petition to Intervene, November 30, 2007; State of New York Contentions Concerning NRC Staff's Draft Supplemental Environmental Impact Statement, ASLBP No. 07-858-03-LR-BD01. February, 27, 2008; NRC Staff's Response to Petitions for Leave to Intervene Filed by (1) Connecticut Attorney General Richard Blumenthal, (2) Connecticut Residents Opposed to Relicensing of Indian Point, and Nancy Burton, (3) Hudson River Sloop Clearwater, Inc., (4) The State of New York, (5) Riverkeeper, Inc., (6) The Town of Cortlandt, and (7) Westchester County, January 22, 2008; Reply to Request for Additional Information Regarding License Renewal Application – Severe Accident Mitigation Alternatives Analysis, Indian Point Units 2&3 Docket Nos. 50-247 and 50-286, February 5, 2008; New York State Reply in Support of Petition to Intervene. February 22, 2008; Applicant's Reply to Request for Additional Information Regarding License Renewal Application - Severe Accident Mitigation Alternatives Analysis, February 05, 2008; Supporting Exhibits To The Declaration of Bruce A. Egan, Sc.D.; State of New York Contentions Concerning NRC Staff's Draft Supplemental Environmental Impact Statement, February 27, 2008; Applicant's Supplemental Reply to Request for Additional

Information Regarding License Renewal Application - Severe Accident Mitigation Alternatives Analysis May 22, 2008; Answer of Entergy Nuclear Operations, Inc. Opposing New York State Notice of Intention to Participate and Petition to Intervene. January 22, 2008; Supplemental Declaration of Stephen C. Sheppard, February 2009; Statement of Material Facts Not in Dispute, August 28, 2009; State of New York's Motion for Leave to File New and Amended Contentions Concerning the December 2009 Reanalysis of Severe Accident Mitigation Alternatives, March 11, 2010; Statement of David Chanin, March 11, 2010; State of New York New Contention 12-C Concerning NRC Staff's December 2010 Final Environmental Impact Statement and the Underestimation of Decontamination and Clean Up Costs Associated with a Severe Reactor Accident In the New York Metropolitan Area, February 3, 2011; State of New York Initial Statement of Position, Contention NYS-16/16A/16B, (Ex. NYS000206); Report of Dr. Steven C. Sheppard (Ex. NYS000209).

Applicant information, technical documentation and supporting documentation that I reviewed in developing my testimony included the Nuclear Energy Institute (NEI 05-01), Severe Accident Mitigation Alternatives (SAMA) Analysis. Guidance Document (Ex. NYS000287); Entergy LRA Appendix E, Applicant’s Environmental Report Operating License Renewal Stage Indian Point Energy Center, Volume I, Site Specific MACCS2 Input Data for Indian Point Energy Center, (4/7/2006); Volume II, Site Specific MACCS2 Input Data for Indian Point Energy Center, (4/7/2006); IP2 Cost-Benefit Analysis of Severe Accident Mitigation Alternatives, Engineering Report No. IP-RPT-07-00007; IP3 Cost-Benefit Analysis of Severe Accident Mitigation Alternatives, Engineering Report No. IP-RPT-07-00008; “MACCS2 Computer Code Application Guidance for Documented Safety Analysis” (Ex. NYS000244); Environmental Protection Agency "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," [NYS000245A]; Revised 1991; EPA “Empire Abrasive Blast N’Vac for Radiological Decontamination,” EPA 600/R-11/014, May 2011 (Ex. NRC0000046); NUREG/CR-6613, “Code

Manual for MACCS2," Volumes 1 (Ex. NYS000243); NUREG-0654/FEMA-REP-1, Rev. 1, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," 1980; NUREG-1150, “Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants,” (Ex. NYS000252A); NUREG/CR-6225, Rev. 1, “SECPOP2000: Sector Population Land Fraction, and Economic Estimation Program,” (Ex. NYS000271); 10 C.F.R. § 835, Appendix D, *Surface Contamination Values*. Luna, et al, “Survey of Costs Arising from Potential Radionuclide Scattering Events,” (Ex. NYS000255); County-To-County Worker Flow, U.S. Census (Ex. NYS000215); Innovative Technology Summary Report for ALARA™ 1146 Strippable Coating, Department of Energy, 1999 (Ex. NRC000047).

Demmer, Rick, “Large-Scale Urban Decontamination; Developments, Historical Examples, and Lessons Learned.” Idaho National Laboratory (Ex. NRC000048). February, 2007; Beyea, Lyman, and von Hippel, “Damages from a Major Release of ^{137}Cs into the Atmosphere of the United States,” (Ex. NRC0000049); Lyman, Edwin. “Chernobyl on the Hudson? The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant,” (Ex. NRC000050); Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents (Ex. NYS000249); Technical/Regulatory Guidance: Decontamination and Decommissioning of Radiologically Contaminated Facilities. The Interstate Technology & Regulatory Council Radionuclides Team, January, 2008; Economic Costs from a Radiological Transportation Accident D. Osborne, R. Weiner, M. Dennis, and T. Heames. Sandia National Laboratories (Ex. NRC0000051); Economic Consequences of a Rad/Nuc Attack: Cleanup Standards Significantly Affect Cost, Reichmuth, et al (Ex. NYS000256); Practical Means for Decontamination 9 Years after a Nuclear Accident (RISO) (Ex. NYS000251); G.J. Edgington, M.P. O’Neill, and K. Holt-Larese “Decontamination of Cs-137, Pu-239, and Am-241 from Hard Surfaces using a Peelable Polymer-based Hydrogel.”

Health Physics Society Annual Meeting. Pittsburgh, PA. 2008 (Ex. NRC000052)]; Testing for Radiological Decontamination Strippable Coating for Cellular Bioengineering, Inc., Sandia National Laboratories, 2007 (Ex. NYS000259); CONDO: Software for Estimating the Consequences of Decontamination Options (Ex. NYS000250);Generic Environmental Impact Statement for License Renewal of Nuclear Plants Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3. NUREG-1437, Supplement 38, Vol. 3 (Ex. NYS00133H); US Environmental Protection Agency website, Radiation Protection; Plutonium; US EPA website, Radiation Protection Plutonium (http://www.epa.gov/radiation/radionuclides/plutonium.html#affecthealth) (NRC000053); US EPA website, Radiation Protection Cesium (http://www.epa.gov/radiation/radionuclides/cesium.html) (Ex. NRC000054); Brookhaven National Laboratory, Urban Remediation and Response Project, (Ex. NYS000284); NUREG/CR-4551, Vol. 2, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters," (Ex. NYS000248); U.S. Census Monitoring Board, Final Report to Congress (Ex. NYS000213); ESCAP II: Demographic Analysis Results (Ex. NYS000214); The Bureau's Plans for Reducing the Undercount Show Promise, but Key Uncertainties Remain, US Government Accountability Office, 2008 (Ex. NRC000055).

A5d. [DGH] I reviewed the Board's orders setting the scope for the contentions. I reviewed the contentions, pre-filed expert testimony, and supporting references filed by NYS. I reviewed the NRC's SAMA review in the FSEIS for Indian Point. I reviewed historical documents related to the use of various decontamination activities related to nuclear power plant accident scenarios and the time period for relocation during these decontamination activities; specifically NUREG-75/014 (WASH-1400), "Reactor Safety Study – An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," published in 1975 (Ex. NRC000056); Environmental Protection Agency (EPA) 400-R-92-001, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents," NUREG/CR-4551, Volume 2, Part 7, "Evaluation of Severe

Accident Risks: Quantification of Major Input Parameters – MACCS Input" (Ex. NRC000057), and NUREG/CR-3673, "Economic Risks of Nuclear Power Reactor Accidents," (Ex. NRC000058).

Q6. Based on your review, what is your expert opinion regarding New York State's Contention 12C ("NYS-12")?

A6a. [NEB] New York State's Contention 12C ("NYS-12C") contains several assumptions that if New York had properly accounted for would alter New York's conclusions. I do not believe that NYS-12C raises valid issues that would materially impact the Indian Point Units 2 and 3 SAMA analysis. First, the contention claims that the SAMA analysis assumed unrealistically large aerosol particles and that accounting for smaller particle sizes would have resulted in greater cleanup costs. This claim is not correct and represents a fundamental misunderstanding of the SAMA analysis because New York concentrates on only one aspect of particle size, clean-up costs. However, particle size impacts the deposition rates, deposition locations, among others issues affecting potential clean-up costs. Ignoring the impact of changing particle size on these other issues results in a fundamental mistake in NYS' evaluation of the SAMA analysis. Assuming that NYS' claims regarding smaller particle sizes were true, it is not clear that additional clean-up costs would be experienced. Smaller particles tend to stay aloft for significantly greater distances and therefore are more unlikely to be deposited in the modeled zone, a circular area with a 50-mile radius from the Indian Point site. Smaller particles are likely to result in decreased deposition of contamination and, thus, decreased clean-up costs and exposure to the population.

Secondly, Contention 12 asserts that the cleanup costs would have been more realistically treated by using the methods discussed in SAND96-0957[1] (Ex. NYS000249), which are for cleanup of plutonium dispersal accidents. However, there are significant differences between cleanup of plutonium dispersal accidents and the isotopes resulting from a severe nuclear reactor accident. These differences make the use of SAND96-0957 inappropriate for modeling the clean-up costs from a reactor accident than the EARLY and CHRONC modules contained in MACCS2, as used by Entergy in its SAMA analysis. As discussed by my colleague, the development of the cost model for the Site Restoration Study (Ex. NYS000249) was not rigorous due to the study's purpose and scope.

I also disagree with the assertion that the SAMA analysis fails to recognize that particles released during a severe accident would differ from particles released during a nuclear weapons accident. Firstly, most of the radiation from plutonium is from alpha particles; most of the radiation from a severe nuclear reactor accident is from gamma radiation. Also, the two are different from a chemical perspective. The weapons accident produces plutonium aerosols; the nuclear reactor accident produces aerosol composed of a number of chemical elements, with cesium being the most important. Finally, the two are different in physical size. These differences make the use of SAND96-0957 inappropriate for evaluating cleanup costs from a nuclear reactor accident. In fact, the ISR Report demonstrates this point: the cleanup costs derived from the Site Restoration Study are a factor of four or more higher than the costs derived using any of the other methods considered in this report (*c.f.*, Ex. NYS000242 at Table

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[1] SAND96-0957, which is Ex. NYS000249, is commonly referred to as the Site Restoration Study.

11). Contrary to this assertion by NYS, Entergy based its methods and input values on documents that are specifically for nuclear reactor accidents.

Aerosol particles from a nuclear weapons accident are primarily created by physical processes (e.g., mechanical crushing); whereas, aerosol particles from a nuclear reactor accident are primarily created by thermal processes (e.g., vaporization followed by nucleation and growth). The physical processes in a nuclear weapons accident generate larger aerosols that tend to deposit in a local area and create high contamination levels. The thermal processes in a nuclear reactor accident generate smaller aerosols that produce lower contamination levels over a larger area. The treatment of aerosols used by Entergy in its SAMA analysis is appropriate for the aerosols that would be created in a nuclear reactor accident. The sources of input parameters that Entergy used to model aerosol deposition and cleanup costs were developed specifically for a nuclear reactor accident. The Site Restoration Study was developed specifically for nuclear weapons accidents and is inappropriate for nuclear reactor accidents.

I disagree with the assertion that the MACCS2 code relies on inputs that are not specific to Indian Point and uses inaccurate information. There are many inputs to the MACCS2 Code, some of which are generic (such as the Breathing Rate for an exposed individual) and these are applicable to any site. Some parameters are more specific to the site, such as source term and Entergy used the site-specific source term values. Entergy also used site-specific values for population, land fractions, and other economic inputs that are contained in the site file used by MACCS2. As a whole, the large majority of the economic inputs used by Entergy are specific to the Indian Point site.

A6b. [STG] I do not believe that NYS-12C raises valid issues that would materially impact the Indian Point Units 2 and 3 SAMA analysis, because of the reasons explained by my colleagues, and because of the existing margin in the SAMA analysis to account for uncertainties.

A6c. [JJ] Like my colleagues, I disagree with several of the underlying premises in NYS-12C. I disagree with the testimony of Dr. Lemay (Ex. NYS000241) and the ISR report (Ex. NYS000242), upon which NYS relies, which assert that Entergy's analysis does not account for the unique characteristics of the New York City area and fails to recognize that particles released during a severe accident would differ from particles released during a nuclear weapons accident. Entergy's SAMA analysis accounted for the unique characteristics of New York City through the application of population-based cost parameters which allows full consideration of the population density and corresponding building density unique to New York City. Entergy's SAMA analysis was based on cost values developed specifically for a nuclear power plant accident, from which the primary contaminant of concern for cleanup would be cesium. This differentiates from particles released during a nuclear weapons accident where the contaminant of concern would be plutonium. Plutonium and cesium have very different characteristics with regard to health risk and cleanup, which is why the cleanup criteria in 10 C.F.R § 835, Appendix D, *Surface Contamination Values*, identify more stringent requirements for Plutonium than for cesium. Surface contamination levels above which areas need to be posted for removable contamination are 20 dpm (disintegrations per minute) for transuranics (plutonium is transuranic) and 1,000 dpm for beta-gamma emitters, including mixed fission products (cesium is a gamma emitter). The contamination limits are 50 times higher for a beta-gamma emitter, like cesium, than for a transuranic like plutonium.

I also disagree with the assertion that the MACCS2 code does not provide a reasonable analytical framework to compute the economic analysis for the SAMA and the New York State assertion that the analytical framework of the 1996 "Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents" study should be used instead. The MACCS2 analytical framework for estimating the consequences of an accident provides a reasonable and consistent approach for estimating the cost of an accident. Many of the equations and algorithms that are applied in the model are described in NUREG/CR-4551. (Ex. NRC000057). I reviewed the Site Restoration Study and found that it describes decontamination and associated cost elements for a plutonium weapons dispersal, but the analytical framework in the study was based on generic residential and commercial areas. (Ex. NYS000249 at F-11). After review of the Site Restoration Study's framework, I concluded that the analytical framework was not based on a referenceable technical foundation but was created in a somewhat ad hoc fashion to support the needs of that particular project. As such, the framework is neither particularly relevant to SAMA application for severe accidents nor subject to reasonable extension into unrelated accident scenarios.

A6d. [DH] Like my colleagues, I also disagree with the conclusions drawn by Dr. Lemay and NYS. Dr. Lemay asserts that decontamination times used by Entergy in its SAMA analysis are not reasonable but, Dr. Lemay concentrates his analysis on the worst accidents under the worst conditions. The key to understanding the proper selection of decontamination times is that the they must represent a time that appropriately quantifies the decontamination time for all accidents including ones with very little contamination or clean-up requirements. For MACCS2 to be able to provide a reliable and reasonable analysis, the decontamination times must represent all the modeled severe accidents including ones that require little decontamination. Entergy's use of two decontamination times to model the clean-up was reasonable. Dr. Lemay's assertion would represent a worst case scenario not required under NEPA or the NRC regulations.

Q7. Based on your review, what is your expert opinion regarding New York State's Contention 16?

A7. [JJ] My review with regard to NYS-16B focused on the population estimates. NYS asserts that Entergy's projections of the 2035 population are underestimated because it does not address the U.S. Census undercount and does not address commuters. NYS asserts that Entergy did not include a census undercount of 230,000 persons and that Entergy did not consider 1 million persons living outside the SAMA area and commuting to work locations inside the SAMA area. (Ex.NYS000216 at 15).

Dr. Sheppard explains that Entergy did not address an undercount of the population of the US Census, estimated at about 231,000 people. (Ex. NYS000207 at 13). Dr. Sheppard develops this estimate by averaging values of 0.52% and 4.49% from Ex. NYS000213 (average is 3%) which is applied to the non-white population resulting in an increase of 1.11% for the SAMA population. In my opinion, a 1% change in population, largely located within the outer distances of the SAMA area where potential doses would be lower than near the plant, would not materially change the results of Entergy's SAMA analysis. Furthermore, Entergy's population estimate did not include other types of population adjustments that can reduce the SAMA population. For instance, Entergy did not take credit for the percent of people that are on vacation at a given time. Also, Entergy did not take credit for the 170,000 residents who commute from the north down to New York City. The current SAMA analysis estimates a higher dose, and correspondingly higher cost, for these residents because it calculates dose as though they were at home, closer to the plant. The occurrence of these types of fluctuations in population make Dr. Sheppard's 1.11% difference in population due to undercount immaterial in the overall analysis. I disagree with the assertion that the Entergy analysis does not consider commuters. Although Entergy did not specifically describe commuters, the regional commuting patterns are indirectly considered in the analysis. I evaluated commuters entering the SAMA area from locations outside the modeled area and agree with Dr. Sheppard (Ex. NYS000207 at 16) that about 1,000,000 commuters enter the SAMA area for a work shift and then return home. Business travelers that arrive on multi-day business trips are considered in the transient population, and are not a part of the commuter population. In this respect, commuters arrive, work a shift, and return home. Indian Point is about 24 to 40 miles from New York City from the north to the south. Assuming a wind speed of 5 miles per hour, it would take about 5 to 8 hours to travel 24 to 40 miles plus we must add the time from the start of the accident to the release to the environment, because during this time, the media will be reporting on the event. Considering that 8 hours is a typical workday, this leaves a very small window of opportunity for commuters to actually remain in the area while a plume is passing over. In fact, the meteorology of the area shows that wind patterns would generally be upstream, or northerly along the Hudson River Valley during the day, and downstream or southerly during the evening. For commuters to be most affected, a radioactive release would likely need to occur in the early evening, such that a plume has time to travel 8 hours to the New York City area by the following morning when commuters would be arriving to work. If such an accident were communicated to the public, along with the wind direction, it is reasonable to expect that commuters to New York City would likely be informed through the media not go to work until instructed to do so. If the accident were to occur during the workday, commuters would have left work and taken their normal mode of transportation home, before the plume would travel the distance to New York City. Treating commuters identically to the permanent population would result in a significant overcount of the off-site economic consequences from temporary and permanent relocation costs that would not be required and an excess dose from calculating exposure even after the commuters has left their workplace.

Based on the above evaluations, I concluded that the Entergy population values are reasonable for the SAMA analysis and that changing these values to include a US Census undercount or commuters would not affect the results of the SAMA analysis.

Overview of Severe Accident Mitigation Alternatives Analysis

Q8. What is a SAMA analysis?

A8. [STG] [NEB] A SAMA analysis is a systematic search for potentially cost beneficial enhancements to further reduce nuclear power plant accident risk. In particular, a SAMA analysis allows for the comparison of benefits derived from particular mitigation measures with their cost to implement. The SAMA analysis for Indian Point uses probabilistic risk assessment ("PRA") to consider improvements and evaluate the change in economic risk that would result from those improvements.

Q9. Please describe how a SAMA analysis is performed?

A9. [STG] [NEB] The first step of a SAMA evaluation is to identify and characterize the leading contributors to core damage frequency (CDF) and offsite risk based on a plant-specific risk study or applicable studies for other plants. The next step in the process is to identify candidate SAMAs to mitigate these risk contributors. Once candidate SAMAs have been identified, an initial screening is performed to determine which SAMAs cannot be cost-beneficial. For example, if the cost of implementing a SAMA is higher than the elimination of all risk from operating the plant (called the "Maximum Achievable Benefit"), that SAMA is screened out since it cannot be cost effective. For each SAMA that survives this initial screening, a benefit assessment is performed to address how the change would affect relevant risk measures (i.e., the reduction gained in core damage frequency, offsite population dose in person-rem, and offsite economic cost risk). A cost assessment is also performed for each SAMA. To identify SAMAs that may be cost-beneficial, the net value of each SAMA is estimated.

Q10. How are the potential mitigation measures identified?

A10. [STG] Based on the dominant risk contributors, potential SAMAs are identified that could mitigate the associated risks of the particular plant, in this case Indian Point 2 and 3. The contribution of external events is considered to the extent that it can be supported by available risk methods, because external events can affect whether or not a SAMA is cost-beneficial (greater reduction of risk). In some cases, a candidate SAMA may be identified to specifically mitigate risk from external events.[2] In other cases, a SAMA that may have been identified based on internal event considerations (e.g., use of portable generators to power equipment in a station blackout ("SBO")) may also reduce the risk for external events (e.g., a seismically induced SBO). In addition to this search for SAMAs that mitigate plant-specific dominant risk contributors, the SAMA analyses for other plants are typically also consulted for ideas about potential candidate SAMAs and evaluated when applicable.

Q11. How are the costs to implement a mitigating measure calculated?

A11. [STG] Cost estimates for hardware modifications can be taken from past studies performed for a similar plant, or developed on a plant-specific basis. Procedure and training cost estimates are typically estimated based on plant experience. Cost estimates are generally conservative in that they neglect certain cost factors (e.g., surveillance/maintenance, the cost of replacement power during implementation), therefore tending to increase the number of potentially cost beneficial SAMAs. Typically screening estimates are used for initial assessments and refined as appropriate if a SAMA is potentially cost-beneficial.

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[2] For example, the risk from an external event might be minimized by improving the characteristics of hardware only capable of being damaged in a seismic event.

Q12. Can you explain what a baseline PRA is?

A12. [STG] [NEB] A PRA assesses the risk from operating nuclear power plants by answering three basic questions: (1) what can go wrong, (2) how likely is it, and (3) what are the consequences. The baseline PRA for a plant evaluates the risk of operating the plant based on its current state, i.e., without implementing any of the proposed improvements or procedures. The PRA for a commercial power reactor has traditionally been divided into three levels: level 1 is the evaluation of the combinations of plant failures that can lead to core damage; level 2 is the evaluation of core damage progression and possible containment failure resulting in an environmental release for each core-damage sequence identified in level 1; and level 3 is the evaluation of the consequences that would result from the set of environmental releases identified in level 2. All three levels of the PRA are required to perform a SAMA analysis. The MACCS2 code is used to perform the consequence analysis in the level-3 portion of the PRA. Typically, the baseline PRA for a SAMA analysis starts with the existing most current version of the Level-1 and -2 PRA that is available for the plant at the time of the SAMA analysis. Since most plants do not have a level 3 PRA, typically the level 3 portion is developed using the MACCS2 code for the purpose of supporting the SAMA analysis. For the SAMA analysis, all potential consequences are converted into dollar amounts. Thus, the existing level 1 and 2 analysis with the new level 3 analysis typically form the baseline PRA that represents operating the plant in its current state and the corresponding economic risk. The baseline PRA also enables the calculation of the plant's "Maximum Achievable Benefit," which is the dollar amount that corresponds to all risk posed by the plant.

Q13. How is the benefit for each SAMA evaluated?

A13. [STG] [NEB] The benefit is evaluated by modifying the PRA to account for the effect of the plant improvement being evaluated, and then comparing the risk results of the baseline and modified PRAs. A single plant improvement is evaluated at a time. The effect of the plant improvement might be to decrease the likelihood of an accident or group of accidents calculated in level 1 of the PRA. Other plant improvements would have no effect on the frequency of accidents, but would diminish the outcome of some of the accidents, leading to smaller consequences. These would affect the magnitude of the source term predicted in level 2 of the PRA and result in lower consequences in level 3 of the PRA. Some plant improvements would reduce both accident frequencies and consequences. All consequences are translated to dollar amounts. The economic risk (in dollars) is reevaluated, assuming that one of the SAMAs was implemented. The benefit is the reduction in economic risk (in dollars) after implementing the SAMA compared with the baseline. This process is repeated to evaluate the benefit for each SAMA. The benefit calculated for an individual SAMA will be a fraction of the "Maximum Achievable Benefit," since an individual SAMA is unlikely to eliminate all possible accident initiators or mitigate all kinds of possible accidents.

Q14. How are external events and uncertainty accounted for in the SAMA benefit evaluation?

A14. [STG] The SAMA analysis uses a simplified approach to account for external events and analysis uncertainties. Benefits are typically quantified using the internal events PRA model that is available, and then multiplied by a ratio of the total CDF (representing both the internal and external events) to the internal event CDF. Impacts of uncertainties on the results of the SAMA analysis are addressed through an additional multiplier. This additional multiplier is typically based on the ratio of the 95th percentile CDF to the mean or point estimate CDF. Any SAMAs that become cost beneficial after the use of these multipliers are included as potentially cost-beneficial.

Q15. How is the cost effectiveness of a SAMA evaluated?

A15. [STG] [NEB] The cost effectiveness is evaluated by comparing the benefit of the SAMA with the cost of the SAMA. The decrease in economic risk from implementing a SAMA, calculated by comparing the result of the baseline and modified PRAs (as explained in A11), is evaluated in units of dollars per year of reactor operation. For Indian Point, the time period for the benefit is 20 years. The benefit over the 20-year period is evaluated by using a standard formula and discount rate to evaluate the present value of the benefit (according to guidance in NUREG/BR-0058 (Ex. ENT000013) and NUREG/BR-0184 (Ex. ENT000010)). Elements of the benefit calculation include: averted public exposure costs, averted offsite property damage costs, averted occupational exposure costs, and averted onsite costs which include both averted cleanup and decontamination costs and averted replacement power cost. The present value of the benefit is compared with the cost of implementing the mitigation measure. The SAMA is cost effective if the benefit is greater than the cost; it is not cost effective if the benefit is less than the cost.

<u>Composition of the Source Term and Its Impact on Clean-up</u>

Q16. Are you familiar with the term “source term” as it is used regarding SAMAs?

A16. [NEB] Yes.

Q17. What is a source term?

A17. [NEB] A source term describes the physical, chemical, and radiological composition of an atmospheric release. The information in the source term description includes the quantity of each important radionuclide released into the atmosphere, the initial time of the release relative to the start of the accident, the duration of the release, the elevation of the release, the buoyancy of the plume released, and the particle size of the released material.

Q18. How are the source terms determined for SAMAs?

A18. [NEB] Evaluation of source terms for a SAMA analysis requires a relatively detailed model that includes a multitude of physical process models accounting for timing of safety actions taken automatically by the installed systems and any human actions affecting accident progression and containment conditions. Any radionuclide releases outside of containment are sequentially modeled from their release from the reactor core through any release or breach in containment. Source term calculations are usually based on the Methods for Estimation of Leakages and Consequences of Releases ("MELCOR") or Modular Accident Analysis Program ("MAAP") computer code. The Indian Point SAMA analysis used the MAAP code as the basis for its source term analysis. Source terms generally depend on how rapidly the accident progresses, the path by which the radionuclides escape from the reactor into containment, the path through containment (or possibly bypassing containment altogether), and the effectiveness of both passive and active safety features, especially pools and sprays, that are intended to mitigate releases by, e.g., "scrubbing" the radionuclides and/or reducing containment internal pressure driving the release.

A large number of source terms were calculated in the Indian Point SAMA analysis, each corresponding to a specific accident sequence. Each source term was characterized as a set of release fractions corresponding to groups of radionuclides with potential for detrimental health effects. The Indian Point SAMA used eight source term groups ("STGs") to characterize consequences based on the timing of release and the magnitude of release. A representative set of release fractions was assigned to each STG by calculating a frequency-weighted mean of the radionuclide release fraction for each accident within the STG. These representative STGs were used to perform the consequence analysis.

Q19. How is the source term used by the MACCS2 code?

A19. [NEB] The source term is defined in the level-2 portion and used in the level-3 portion of the PRA analysis. It is used to determine the off-site economic and human health consequences for that particular source term group. Consequence analysis is the primary element of the level-3 PRA analysis. The consequence analysis, which is performed by MACCS2, uses the source terms and frequencies generated by the Level-1 and -2 portions of the PRA analysis to define the source of contamination that will spread over a portion of the 50-mi. radius surrounding the plant.

MACCS2 consists of three modules that analyze given inputs to evaluate the consequences resulting from different potential accident scenarios. The three modules are known as ATMOS, EARLY, and CHRONC. Each module uses input data provided in multiple input text files in order to complete the calculations. The modules operate sequentially: (1) ATMOS, (2) EARLY, and (3) CHRONC.

The ATMOS module uses an atmospheric transport model that uses the source terms and various other input data, including a full year of hourly meteorological measurements (wind direction, wind velocity, precipitation rate, and stability class), surface roughness, and a spatial grid of the 50-mile region surrounding the plant, in this case Indian Point. The ATMOS module assembles these data and treats a statistically significant number of weather trials to adequately analyze the likely weather conditions that might be present during a severe accident. In Indian Point's SAMA analysis, 155 weather trials were selected; that is 155 discrete times were selected as the point in time for the beginning of release of radioactive contamination into the environment. The wind in each of these 155 weather trials was forced to blow in all 16 compass directions based on the annual likelihood that wind would blow in each direction according to binned weather data with similar conditions.[3] For each accident scenario, 2480 meteorological conditions[4] were modeled. The ATMOS module determines the transport and deposition of contamination within the 50-mile area surrounding Indian Point. It calculates the location of the plume and concentration of each released isotope for each spatial grid cell and further determines how much contamination falls out of the plume to be finally deposited into each spatial grid cell. Finally, these calculations are repeated for each accident scenario. Indian Point's SAMA analysis used 8 different representative accident scenarios (different source terms with distinct release characteristics) to represent the variety of accidents that could occur.[5] This information for each model run is passed from the ATMOS module to the EARLY and CHRONC modules for determination of the dose to population and the costs, like clean-up of the contamination, evacuation, and relocation, for each meteorological condition (i.e., 2480 meteorological conditions passed to EARLY and CHRONC for each accident scenario).

Q20. Does the composition of the source term impact the costs from decontamination?

A20. [NEB] The isotopic composition of the source term significantly impacts the costs that would be needed to decontaminate. Some isotopes require no decontamination at all while others might require extensive decontamination.

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[3] Annual weather data is binned into separate files based on similar meteorological conditions including precipitation, stability, velocity and other characterizing properties.

[4] The 2480 meteorological conditions modeled for each accident scenario is the result of modeling 155 weather trials and forcing the conditions through the 16 compass directions or 155*16.

[5] Modeling the 8 different accident scenarios results in 19,840 (8*2480) models for the transport and deposition of contamination within the surrounding 50-mile area.

Q21. How does the composition of the source term impact the costs for decontamination?

A21. [NEB] The composition of the source term affects the costs for decontamination through deposition rates, half-life, and the types of radiation that would be emitted. For example, the noble gases, primarily xenon and krypton, are responsible for a significant amount of the released radioactivity that could result from a severe accident. However, these gases do not deposit and do not contribute significantly to doses to humans because they are very inert (i.e., they are nonreactive and do not absorb onto surfaces). They do not contribute to inhalation doses because they do not absorb onto the surfaces of the lungs and thus are immediately exhaled. As a result of these attributes, the noble gases contribute little to population doses and do not contribute at all to decontamination costs.

The other isotopes can deposit onto surfaces and cause contamination, but most of them have short half-lives and only remain in the environment for days or weeks. For example, iodine-131 has an eight-day half-life. Thus, in 80 days (10 half-lives) its concentration is diminished to $2^{-10} \approx 0.001$ of its initial radioactivity. As a result, it contributes to short-term doses but does not require decontamination because it disappears on its own. Only a few of the isotopes that could potentially be released from a nuclear reactor are radiologically important and require effort to decontaminate. Among these are Cs-134 and Cs-137, which have half-lives of 2 years and 30 years, respectively. These are the most important isotopes that could be released during a nuclear accident in terms of decontamination costs.

When significant quantities of plutonium isotopes are released into the atmosphere, they are very important for land contamination and for decontamination costs. This stems from the fact that several of these isotopes have long half-lives and present a health risk for thousands of years. For example, Pu-239, the most important isotope for nuclear weapons, has a half-life of about 24,000 years. This isotope is the major concern for a weapons accident, but is unimportant for a nuclear reactor accident.

In terms of the type of the radiation that would be emitted, the most important cesium isotope, Cs-137, decays to Ba-137m, which rapidly decays and emits gamma radiation. Most of the doses are from deposition onto the ground and onto buildings; inhalation and ingestion are relatively unimportant because cesium is rapidly excreted from the body. Buildings and other structures can provide significant shielding from these gamma doses. The purpose of decontamination is to remove enough of the cesium to reduce the level of radiation from ground and building surfaces to acceptable levels.

Plutonium decontamination is very different. Plutonium is an emitter of alpha radiation. The important dose pathways for plutonium are inhalation and ingestion. Doses are received from inhalation while a plume is passing through an area. They are also received after plume passage via inhalation of resuspended aerosols, which are aerosols that deposit then are subsequently kicked back up into the air. Resuspension can occur because of the influence of wind, from automobile traffic, from pedestrian traffic, and from other mechanical disturbances such as mowing lawns. Ingestion can also occur if plutonium gets into food and water supplies. In all of these cases, the inhaled or ingested plutonium is captured by the human body and retained for tens of years. The plutonium then produces doses to the organs where it is retained, primarily the lungs, bone, and liver, for the remainder of a person’s lifetime. Because of its potential for inhalation and ingestion for thousands of years, it is important that plutonium be decontaminated to a high standard.

Q22. How is the SAMA analysis completed once the MACCS2 code completes its calculations?

A22. [NEB] Separately from the MACCS2 code, a spreadsheet or other similar application calculates the "mean consequence value" by summing the on-site economic costs and the MACCS2 code outputs, including the mean of the offsite economic costs and value of the mean population dose. Once the costs for each accident scenario and weather condition are calculated by MACCS2, the "mean consequence value" for each accident scenario is determined by calculating the statistical mean of the range of consequences calculated (summation of the consequences associated with the 2480 meteorological conditions weighted by the probability of each). Further, the likelihood of the accident occurring is accounted for by multiplying the probability that the accident would occur with the costs of the particular accident if it did occur. The net present value of the consequence is determined by using discount rates of, alternatively, 3% and 7%, to account for potential variations in the discount rate. Each of the other accident scenarios' "mean consequence value" is determined similarly. In Indian Point's case, 8 different accident scenarios and their representative source terms were used.

Q23. How does the "mean consequence value" compare with the distribution of consequence values calculated by Entergy for the SAMA analysis?

A23. [NEB] The distribution of consequence results is roughly a lognormal distribution. For this type of distribution, the mean value is well above the median of the distribution. The median is defined as the value for which the outcome is lower half the time and for which it is greater half the time. The mean is simply the arithmetic average of all the outcomes. I evaluated the MACCS2 results calculated by Entergy in its SAMA analysis and estimated that the mean results were generally between the 66th and 72nd percentiles. A 70th percentile result is one for which 70% of the outcomes are lower and 30% of the outcomes are higher.

Q24. How should the costs for decontamination be balanced across the multiple accident scenarios under unknown environmental conditions?

A24. [NEB] The standard SAMA procedure provides a means of balancing the costs of decontamination over multiple accident scenarios and over a wide range of potential weather conditions. For each accident scenario, a source term is developed to represent this scenario. A frequency is also developed to determine the likelihood that an accident might occur that would create such a source term. Risk is the weighted sum of the products of the frequency and the consequence over the set of accidents that could occur.

An added layer of complexity is that the consequences of an accident depend on the type of weather that may happen to occur at the time of the accident. The type of weather that may occur is evaluated by gathering historical weather data over several years and making the very reasonable assumption that future weather should be statistically similar to historical data from recent years. The reasonableness of this assumption is established by showing that weather data from a number of years, usually five or more, are statistically similar.

To evaluate the range of consequences that could result from variations in weather, MACCS2 is run in a mode that performs weather sampling. A statistically significant set of weather samples are used to determine the effect of realistic weather patterns on the consequences. The mean consequences over weather are used for each accident sequence in a SAMA analysis.

In this way, the SAMA analysis methodology creates the mathematical value known as the expectation value to represent risk. This methodology accounts for the fact that some accidents are more likely to occur than others; at the same time, some weather patterns are more likely to occur than others. However, all combinations of accidents and weather are combined statistically to evaluate the risk of operating the plant.

Q25. Does Dr. Lemay's methodology adequately balance the decontamination costs over multiple accident scenarios under unknown environmental conditions?

A25. [NEB] No, the decontamination costs used by Dr. Lemay tend to be biased toward the worst accident scenarios and for the worst environmental conditions.

Dr. Lemay's estimated cleanup costs were based on a simple area-weighted approach. Without examination, this might seem reasonable but the approach is flawed. His approach begins with decontamination costs on a cost per area ($\$/km^2$) basis. He evaluates the cost per area for all of the land outside New York City (NYC) based on the assumption that all of this area is suburban or urban; he separately evaluates the cost to decontaminate NYC based on the assumption that all of the area is urban or hyper urban. There are two significant flaws to this approach.

The first flaw is that Dr. Lemay assumes that all of the surface area, which is actually comprised of urban areas, rivers and lakes, woodlands, and farms, require the same level of decontamination. This is not true, as discussed below, and biases all of Dr. Lemay's results toward higher costs.

The second flaw is that Dr. Lemay assumes that land far from the plant is equally likely to be contaminated as land close to the plant. This second flaw is implicit in the fact that Dr. Lemay's methodology weights land areas farther from the source, such as NYC, equally with land areas closer to the source. The assumption of equal weighting is more justified for larger source terms and for weather conditions that produce higher levels of contamination at greater distances; this assumption is less justified for smaller source terms and for weather conditions that produce lower levels of contamination at greater distances. Even for cases with high contamination levels, Dr. Lemay's assumptions create some bias in the costs to decontaminate because land close to the site would always be contaminated to a higher level than land far from the site.

NYS-12C – Challenges to the Costs to Decontaminate

Q26. Did NYS provide information that was based on the source terms?

A26. [NEB] Yes. In the ISR report, a process was described to evaluate the sensitivity of each CHRONC input parameter. (Ex. NYS000242 at 9.) ISR performed a MACCS2 simulation run for Indian Point Unit 2 using the Entergy input files. The ISR report states that since only the source terms contained in the ATMOS module vary between Indian Point Units 2 and 3, ISR assumed that the general conclusions resulting from the sensitivity analysis are applicable to both stations. (Ex. NYS000242 at 9.)

Q27. Do you agree with the ISR conclusion that its sensitivity study is applicable to both Indian Point Units 2 and 3?

A27. [NEB] Not entirely. The ISR report does not appear to appreciate the importance of the contribution from the source term when it states that "only the source terms" contained in the ATMOS module vary between IP2 and IP3. The ISR report selected IP2 for all of the analyses, and upon further investigation, I found that IP2 has a source term[6] about 35% larger than IP3 in terms of the cesium release, which is the most important element for long-term consequences. By only focusing on Indian Point Unit 2, ISR exaggerates the importance of the cost of decontamination for the overall results of the SAMA analysis presented in Entergy's ER.

Q28. How much impact would Dr. Lemay's assumption have on his conclusions regarding the SAMA analysis performed for Indian Point?

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[6] The source term discussed here is ST2, which accounts for more than 60% of the offsite economic cost risks for both Indian Point Unit 2 and 3.

A28. [NEB] The effect of Dr. Lemay's assumption would clearly result in less costs for Indian Point Unit 3 than for Unit 2 because smaller source terms generally require less decontamination and therefore lower costs for decontamination. Dr. Lemay assumed that light decontamination costs are somewhere between $19,000 and $272,000 per person, compared with $5,184 per person for Entergy. Thus, Dr. Lemay's values are between 3.7 and 52 times the value used by Entergy. Dr. Lemay assumed that heavy decontamination costs are somewhere between $90,000 and $898,000 per person, compared with $13,824 per person for Entergy. So Dr. Lemay's values are between 6.5 and 65 times the value used by Entergy. Clearly, the increase in cost assumed by Dr. Lemay is less for lightly contaminated land that only requires light decontamination than it is for heavily contaminated land that requires heavy decontamination. Less land would be highly contaminated for an accident at Indian Point Unit 3, which has smaller source terms, than it would be for an accident at Unit 2, which has larger source terms. Thus it is clear that the increase in offsite economic cost risk (OECD) would have been lower had Dr. Lemay studied Unit 3 rather than Unit 2.

Q29. How are the source terms evaluated and used in a SAMA analysis?

A29. [NEB] A primary result of the level-1 and -2 portions of the PRA is the estimation of a set of source terms, each corresponding to a specific accident sequence. The number of source terms is usually too large to perform a consequence analyses on each one. To reduce the computational effort for the consequence analysis, the source terms are sorted into a set of bins, often referred to as source term groups ("STGs"). The sorting into bins is generally based on the magnitude of the release and the timing of the release. Earlier releases result in greater consequences because there may not be adequate time to evacuate the public within the Emergency Planning Zone ("EPZ"), the area within about 10 miles of the plant, before the release begins. Larger releases lead to larger doses to members of the public and greater environmental contamination to deal with in the aftermath of the accident. The set of source terms in each STG is expected to result in relatively similar consequences. In a SAMA analysis, a single source term is usually chosen to represent each STG. The representative source term may be a best estimate or a bounding source term. In the Indian Point SAMA analysis, a weighted average source term was chosen to represent each STG. Source term groups are referred to as Release Categories and the source terms corresponding to the Release Categories are referred to as Release Category Source Terms in the Indian Point Environmental Report. The frequency associated with each source term is the sum of the frequencies of all sequences that fall into the STG. The Indian Point Environmental Report considers nine Release Categories; however, one of the Release Categories had an associated frequency of zero, which means that none of the sequences that were evaluated contributed to that category, so eight Release Categories with associated source terms are evaluated for consequences in the Indian Point ER.

Q30. How is the consequence for each accident represented by a source term calculated?

A30. [NEB] A consequence analysis is performed for each STG identified in the Level-2 portion of the PRA. The consequences are evaluated assuming that the accident occurs. The likelihood of the accident occurring during one year of plant operation is the frequency associated with the STG. The risk is the expected value of the consequences. Multiplying the frequency of a STG by the mean consequences that would result if an accident were to occur gives the risk per year of reactor operation for that STG. The total risk of operating the plant per year of operation is the sum of the risks for the set of STGs. Neglecting the time value of money, the risk over the remaining years of plant operation is the risk per year times the number of years the plant is expected to operate. The time value of money is included in a SAMA analysis by using a standard formula to estimate the present value of the benefit.

Q31. What consequences are evaluated for a SAMA analysis?

A31. [NEB] Five types of consequences are considered in a SAMA analysis. The first three of these are onsite costs and include (1) the monetary value of occupational doses to decontamination workers; (2) onsite decontamination costs; and (3) the cost to replace lost power. Estimation of these costs is independent of atmospheric transport and deposition modeling performed by MACCS2. The remaining two categories are offsite costs: (4) offsite economic costs associated with evacuation and relocation of the population, decontamination of property, loss of use of property, and condemnation of property and (5) a monetary value associated with doses to members of the public. These five types of costs are added together to get the total cost that would result if an accident occurred. For each type of cost, there is a standard method to evaluate that cost. MACCS2 is the standard tool used to evaluate off-site costs (4 and 5), as described in NUREG/BR-0184. Offsite economic cost (4) is a direct output from the MACCS2 code. The cost associated with doses to the public (5) is calculated by multiplying the population dose reported in the MACCS2 output by $2000/person-rem.

The benefit associated with a SAMA is calculated by accounting for reductions in accident frequencies and reductions in accident consequences. The reduction in the economic cost risk assuming the SAMA was implemented compared with the baseline risk is the benefit of the SAMA.

Q32. How are the consequences for each accident calculated by the MACCS2 code?

A32. [NEB] EARLY and CHRONC use the information calculated by ATMOS along with additional input data to determine the doses and other consequences for separate portions of the response. EARLY models the doses and costs of the accident related to the initial response through the first seven (7) days. During this period of time, the plume passes through the grid and emergency response is implemented. CHRONC models the doses and costs of the accident related to its long-term responses and clean-up from seven days through 30 years.

The EARLY module uses transport and deposition results from the ATMOS module and input data regarding human population in the area to model estimated doses during the plume passage and from deposition for the first seven (7) days of an accident. EARLY also uses input data describing dose conversion factors, land use, economic inputs (costs for emergency response, including evacuation), a spatial grid refinement factor, relocation information, re-suspension factors, cohort definitions, evacuation data, and shielding data.

Entergy performed a sensitivity analysis on evacuation speed following the SAMA Guidance Document and modeled a 'no evacuation' scenario. In the applicant's Reply to Request for Additional Information, Entergy confirmed the no evacuation scenario was used to estimate population dose and economic impact. A no evacuation scenario provides conservative results because the Emergency Planning Zone ("EPZ") population is subjected to dose during the emergency phase unless they are relocated under the hotspot or normal relocation criterion during the emergency phase. This scenario is conservative because the population dose is greater and the costs associated with evacuation still apply to relocated individuals after they have been removed from the EPZ. The assumption of no evacuation does not influence the results for the long-term phase calculated by CHRONC.

Using these input data, EARLY calculates the consequences of the accident for the first seven days. After seven days, the consequences are determined by the CHRONC module. The CHRONC module uses the transport and deposition calculations from the ATMOS module, some of the input data for the EARLY module, and additional input data regarding per diem costs for the displaced population, decontamination costs, long-term protective action values (habitability criteria), interdiction, weathering factors, regional land value, and food-chain dose conversion factors.

Based on these inputs, CHRONC calculates the costs or economic consequences of the accident. As part of the CHRONC module, the decision to decontaminate or condemn is made based on whether the habitability criterion could be met following decontamination. This decision process is described in more detail under A34. The effect of decontamination or condemnation is accounted for in the long-term consequences of the doses received by decontamination workers, doses received by members of the public, and in the economic costs for the accident.

Once CHRONC completes its calculations for one accident scenario, the MACCS2 code assembles an output file with a statistical description of the consequences, including the mean population dose and the mean offsite economic costs. These are the two output values used in the SAMA analysis. These two output values are used to determine the offsite consequences.

Q33. What cost categories are included in the offsite economic costs calculated by MACCS2?

A33. [NEB] The costs calculated by MACCS include the following six categories for offsite economic costs:

1. Per-diem costs associated with the population that is temporarily relocated. These costs are calculated by adding up the number of displaced people times the number of days they are displaced from their homes.
2. Costs associated with decontaminating property. These costs include labor and materials for performing the decontamination. They depend on the population and size of the area that needs to be decontaminated as well as the level of decontamination that needs to be performed. They can include the cost to dispose of contaminated material.

3. Costs associated with loss of use of property. These costs include an expected rate of return on property and depreciation caused by lack of routine maintenance during the period of interdiction, the time when the property cannot be used.
4. Disposal of crops and dairy products that cannot be consumed.
5. Costs of condemning property that cannot be restored to meet the habitability criterion. The habitability criterion used in the Indian Point ER is consistent with EPA guidance, which is that an area is habitable in the long-term if an occupant would receive less than 2 rem in the first year and less than 0.5 rem per year in subsequent years.
6. A one-time moving expense for the population displaced from their homes because of decontamination, interdiction, or condemnation.

All of the costs for the six cost categories are summed over the entire offsite area affected by the assumed atmospheric release to get the total offsite economic costs.

Q34. How are the costs associated with decontamination modeled by MACCS2?

A34. [NEB] Decontamination is modeled through a decision process. After the emergency phase, which extends one week from the beginning of atmospheric release, the first decision is whether an area is too contaminated to meet the habitability criterion. If it is not, then it is immediately habitable and no decontamination is needed. No economic cost is tallied after the population returns to their homes, but that population receives a dose that is tallied in the population dose calculated by MACCS2. The population dose is later converted to an offsite cost as explained in A31.

If an area is too heavily contaminated for the population to return immediately, then decontamination is considered. In the Indian Point ER, two decontamination factors (DF) were considered. The lower level of decontamination reduces the initial contamination by a factor of 3 (i.e., 66.7% of the contamination is removed and 33.3% remains); the higher level of decontamination reduces the initial contamination by a factor of 15 (i.e., 93.3% of the contamination is removed and 6.7% remains). Each of these levels has an associated cost to perform. The higher level of decontamination corresponds to a higher cost to implement. If the lower level of decontamination is sufficient to restore habitability, then it is selected and the cost to perform the decontamination is tallied. If it is not sufficient to restore habitability, then the higher level of decontamination is performed and its cost is tallied.

If habitability is restored immediately following the decontamination, then the population who live in that area return to their homes and no further economic costs are assessed; however, the returning population receives a dose that contributes to the population dose. If the land is still not habitable following the higher level of decontamination, then the land is interdicted for an additional period of time to allow further radioactive decay and weathering, which work to reduce the level of contamination. When habitability is eventually restored, the population return and no further economic costs are accrued, but doses are received and accounted for in the population dose.

Decontamination is not performed under three circumstances: (1) it is not needed because the land is immediately habitable; (2) decontamination plus additional interdiction are not sufficient to restore habitability, in which case the property is condemned; and (3) decontamination plus additional interdiction are more costly than the value of the property, in which case the property is condemned.

In the case that property is condemned, the value of the property is declared as a loss. In this case, the population is permanently relocated and a one-time expense to account for moving and loss of income is also included as a loss. Since this population does not return to their homes, no further population dose is tallied for them.

The period of interdiction includes the period during which land is decontaminated and any subsequent period of interdiction needed to restore habitability. Loss of use of the land, including both a lost return on investment and depreciation, are tallied for this entire period of time. A one-time cost to account for moving and lost income is also included as a loss.

Q35. Can you describe the decontamination factor (DF)?

A35. [JJ, NEB] The MACCS2 model determines the level of contamination that occurs and determines where decontamination may be required. The DF is a parameter in MACCS2 that is intended to represent an amount of decontamination achieved. MACCS2 allows for the use of 3 DFs. Two DFs were used in the Indian Point analysis including a DF of 3 and a DF of 15. DFs will be discussed throughout our testimony, therefore, we are providing a table of DFs and the relationship to percent contamination removed.

Table 1: Decontamination Factors

Decontamination Factor	**Percent Contamination Removed**
2	50%
3	66.7%
5	80%
10	90%
15	93.3%
20	95%
50	98%
100	99%

The DF is intended to represent the physical removal of radioactive material. For example, sandblasting walls has been shown to achieve a DF up to 100. (Ex. NYS000263 at 75). This would mean that in the referenced exhibit, use of sandblasting on walls was found to remove 99% of the contamination.

The DF is calculated with the following equation:

$$DF = C_i/C_f$$

Where DF is the decontamination factor and C_i and C_f are the surface contamination levels before and after the decontamination step, respectively. (Ex. NUREG/CR-4551 at 5-2).

The model evaluates the DF of 3 first. If the application of this factor reduces the dose to below the habitability criteria, then a DF of 3 is used by the model. When a DF of 3 does not reduce the dose to the habitability level, then the model evaluates the DF of 15. If the contamination is reduced to an acceptable level using the DF of 15, then this part of the calculation is complete. If the DF of 15 does not reduce the dose below the habitability criteria, then the land is interdicted for an additional period of time in the model and the decay and weathering reductions apply. It is noted that decay and weathering apply throughout the entire calculation, including during the decontamination phases.

The cost of achieving the DF is input in terms of dollars per person ($/person). By using a per-person basis, this approach takes into account the site-specific high population density of New York City and the correspondingly high density of buildings. The decontamination cost MACCS2 input values used in Entergy's analysis are a DF of 3 = $5,184 per person and a DF of 15 = $13,824 per person. Entergy's approach, which uses only 2 DFs in a high population density area, such as New York City, is conservative.

Q36. Why does the use of 2 DFs provide a conservative estimate?

A36. [JJ, NEB] By using only 2 DFs, the Entergy analysis provides a level of conservatism, because for any area where a DF of 3 is not sufficient, the model jumps to a much higher DF of 15, which costs much more to implement than a DF of 3. Where the model actually calculates the need for a DF of 3.1, the full cost of $13,824 per person is applied for implementing a DF of 15. In reality, an area requiring a DF of 3.1 would not need to be decontaminated to a DF of 15. An intermediate decontamination factor would cost less to implement, (something between $5,184 and $13,824/per person) therefore, applying a DF of 15 to these areas where less costly approaches would likely be used, produces conservatism in the estimate.

Q37. Do you agree with the assertion by NYS that the decontamination factors used by Entergy were not rationally related to Indian Point?

A37. [JJ, NEB] No. The DF is simply a parameter in MACCS2 that represents an amount of decontamination achieved. It is specific to the technique used and the substrate being cleaned. The ability to achieve a DF is not a function of where the decontamination is being performed, so it is certainly rational for Indian Point. Two DFs were used in the Indian Point analysis, a DF of 3 and a DF of 15, which correspond to a removal of 67% and 93% of contamination, respectively. These two DFs are often used in MACCS2 analyses because they represent a reasonable level of decontamination that may be achieved with current technologies and applications. In Table A7, “Decontamination Factors,” of the CONDO document], which is a reference provided by the intervener, DFs are based on the technique used for decontamination, surface of material to be decontaminated, the contaminant (e.g., cesium), and time. (Ex. NYS000250 at 45-47.) There is no discussion regarding the geographical location of where the DFs may be achieved because the DF is not a function of location.

Q38. Do you agree with Dr. Lemay's testimony regarding decontamination factors?

A38. [JJ] While I agree with Dr. Lemay’s definition of effectiveness for a DF of 3 and 15, I disagree with many of the assumptions and conclusions he makes regarding the implementation of these DFs. For example, Dr. Lemay makes a number of assumptions regarding the requirements for achieving different levels of decontamination that do not fully account for our current understanding of the decontamination process.

I do not entirely agree with his definitions of light, moderate, and heavy decontamination. First, he states that light decontamination includes activities such as prompt vacuuming. (Ex. NYS000241 at 28.) There is no requirement that light decontamination be prompt, and assuming that a prompt response is necessary may have limited the selection of a cost effective decontamination technique in his cost estimates. I agree with Dr. Lemay's description that light decontamination typically corresponds to a DF range of 2 to 5, or removal of 50% to 80% of the contamination. The range is reasonable and I agree with the term 'typically', because DFs vary depending on the contaminant, type of substrate, decontamination method, and other factors. The criterion for the DF is the percent of contamination removed. Time may affect the DF, but other factors, such as the type of substrate influence whether time is important.

Dr. Lemay also describes moderate decontamination to include DFs from 5 to 10 or 80% to 90% removal of contamination, and he describes heavy decontamination to include DF of greater than 10. (Ex. NYS000241 at 29). Dr. Lemay states that a level greater than 10 may not be possible without complete demolition. I disagree with Dr. Lemay's statement that a DF greater than 10 may not be possible without complete demolition. The assumption is simply not correct because there are many commercially available technologies that can achieve a DF greater than 10 on many surfaces without requiring demolition. Both the ISR report (Ex. NYS000242 at 12) and the Site Restoration Study (Ex. NYS000249 at 5-10) state that a DF greater than 10 is not considered achievable without demolition. In the course of preparing my testimony, I identified many DF's for cesium that are greater than 10 and do not require destruction. Table 2 identifies just a few such technologies, many of which are identified in exhibits provided by NYS. Beginning a decontamination cost estimate with the assumption that complete demolition is needed if a DF of 10 is required can lead to an excessively high cost estimate because demolition and replacement of a building is much more expensive than applying decontamination techniques that can achieve a DF of greater than 10. Demolition remains a method of last resort for circumstances when other more cost effective methods cannot be used.

Table 2: Achievable Decontamination Factors

Reference	Technology/Technique	Achievable DF	Comment
Brookhaven National Laboratory (Ex. NYS000284 at 36)	Chemical	>100	Non-porous surfaces
Brookhaven National Laboratory (Ex. NYS000284 at 11)	ANL chemical	Up to 33.3	Cesium on concrete (97% removal)
Brookhaven National Laboratory (Ex. NYS000284 at 11)	INL chemical	Up to 33.3	Cesium on marble (97% removal)
Brookhaven National Laboratory (Ex. NYS000284 at 20)	Pressure washing	Up to 50	Good for irregular surfaces
EPA (Empire) (Ex. NRC000046 at 14]	Blast N'Vac	Average 58	Cesium on concrete
Idaho National Laboratory (Ex. NRC000048at 6]	Sandblasting	100	Sandblast buildings
Sandia (Ex. NYS000259)	Peelable Coating	Up to 100	Cesium on carbon steel, stainless steel, Plexiglas
Sandia (Ex. NYS000259)	Peelable Coating	Up to 100	Plutonium on carbon steel
RISO (Ex. NYS000251)	Vacuum, razors, manual scraper, brush	>100	Removal of wall paper
RISO (Ex. NYS000251)	Detached polymer paste	Up to 30	Smooth metal painted surfaces

Q39. Is the analytical framework suggested by NYS for estimating the cost more appropriate for the SAMA analysis?

A39. [JJ, NEB] No. NYS suggested that the analytical framework of the 1996 "Site Restoration: Estimation of Attributable Costs from Plutonium-Dispersal Accidents" study should be used. This would not be appropriate because the Site Restoration Study was specifically developed to support an understanding of costs for the cleanup of a nuclear weapons plutonium accident which would have very different and more costly issues than reactor accident cleanup. Furthermore, the Site Restoration Study's framework was created in a somewhat ad hoc fashion to support the needs of that particular project. For instance, the Site Restoration study developed personal possession costs by assuming that for a family, each man and woman own one suit and each child owns one pair of pajamas. (Ex. NYS000249 at G-9.)

The Site Restoration Study is based on a less rigorous analytical framework. The Site Restoration Study did not employ statistical techniques to develop its economic model. Rather, it was developed subjectively based on visits to several areas "in and near Albuquerque, NM." (Ex. NYS000249 at F-11.) Based apparently on those several visits, the Site Restoration Study assumed a residential setting has 16 houses on each block. No information regarding details of the housing or land was provided, but a specific assumption of 4 trees per house was provided. To estimate personal allowances, a hypothetical family was assumed rather than using US Census-based family statistics. (Ex. NYS000249 at F-12-14.) Pricing for family allowances, such as the suits and pajamas described above, was obtained from the 1995 Summer Edition of the JC Penney Catalog. (Ex. NYS000249 at G-9). This arbitrary and statistically unsupportable model detail introduces uncertainty and unreliability into the cost estimate results. To introduce the conclusions from unreliable and unsupportable portions of the Site Restoration Study to a reactor accident impacting portions of New York City would introduce a lack of rigor and a lack of statistical reliability into the SAMA analysis.

Similar to unsupported development of the residential model, the Site Restoration Study used hypothetical commercial and industrial areas and developed more assumptions to estimate costs to decontaminate plutonium. The study assumes for instance, "The contents of the warehouses were assumed to be equal to the value of the warehouse…." (Ex. NYS000249 at F-12.) Such an assumption has the potential to produce very conservative results, particularly in an area of high property value, such as New York City. There is no technical basis referenced for these assumptions and no suggested confidence level for the data. Had technically defensible data been used to support the Site Restoration Study cost estimates, it may have been possible to extrapolate the data for other applications. However, the compounded assumptions without statistical basis renders the Site Restoration Study's model inappropriate for application to a new, unrelated, hypothetical landscape introducing too much uncertainty to be credible.

In contrast to the analytical framework developed for the Site Restoration Study, the parameters used in the MACCS2 economic model are described in NUREG/CR-4551, Vol. 2, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters," which was developed to support NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants." (Ex. NRC000059.) NUREG-1150 included an economic analysis and was subjected to an extensive peer review and public comment. (Ex. NRC000059 at iii.) Two peer reviews were conducted on the second version of NUREG-1150, one of which was NRC sponsored, and the second was sponsored by the American Nuclear Society.

Q40. Does the difference in contaminants between a weapons accident and a nuclear power plant accident affect the decontamination cost?

A40. [JJ, NEB] Yes. The Site Restoration Study, understandably, is based on the dominant contaminants being plutonium isotopes. Conversely, the dominant contaminants for a reactor accident are cesium isotopes. As the Site Restoration Study explains, "because of the radiological and chemical characteristics of weapons grade plutonium (over 99% by mass alpha-emitting $^{239+240}$PU), inhalation dominates over other exposure pathways considered in other types of radiological assessments such as those for nuclear power plant accidents." (Ex.

NYS000249 at 2-3).The Site Restoration Study's author basically explains that the conclusions in this study are not appropriate for application to nuclear power plant accidents due to the material difference in the type of source terms created by a nuclear weapon plutonium accident and a nuclear power reactor accident. The author explains that in a nuclear power plant accident, external exposure from the cesium would dominate the health risk, whereas inhalation dominates the health risk in a plutonium cleanup. It is the difference in toxicity of the contaminant and the exposure pathway that makes plutonium accidents more expensive to clean-up than otherwise similar accidents involving cesium. Plutonium, due to its toxicity and type of radioactive decay, requires a more stringent clean-up criterion than cesium, and the Site Restoration Study addressed this difference by establishing strict criteria regarding decontamination factors up to and including when demolition may be needed.

Plutonium (^{239}Pu) is primarily an inhalation risk, and it has a half life of 24,000 years. Ex. NRC000053). This means that if 1 curie of ^{239}Pu contamination was present today, in 24,000 years 0.5 curies of Pu-239 contamination would still be present. Because it is an inhalation risk, many elements of decontamination are more difficult, and nearly complete removal of the contaminant is required. As described by the US EPA, "External exposure to plutonium poses very little health risk, since plutonium isotopes emit alpha radiation, and almost no beta or gamma radiation. *Id.* In contrast, internal exposure to plutonium is an extremely serious health hazard. It generally stays in the body for decades, exposing organs and tissues to radiation, and increasing the risk of cancer. Plutonium is also a toxic metal, and may cause damage to the kidneys." *Id.* As a result, workers cleaning up plutonium contamination must take additional precautions not required for cesium.

To further illustrate the risk, I reviewed the cleanup criteria in 10 C.F.R § 835, Appendix D, *Surface Contamination Values*, which identifies more restrictive cleanup limits for plutonium than for cesium. Surface contamination levels above which areas need to be posted for removable contamination are 20 dpm (disintegrations per minute) for transuranics (Pu is a transuranic) and 1,000 dpm for beta-gamma emitters, including mixed fission products (cesium is a gamma emitter). The contamination limits are 50 times higher for a beta-gamma emitter like cesium, than for a transuranic like plutonium. Following this criterion would require 50 times the level of effort to clean plutonium than required to clean the same amount of cesium.

For cesium, which is the primary contaminant from a nuclear power plant accident, the external dose is the primary contributor to the health risk. Cesium-137 has a half-life of about 30 years. (Ex. NRC000054.) If 1 curie of cesium-137 were dispersed as contamination today, in about 30 years, there would be 0.5 curies of cesium-137 remaining. However, for cesium-137, the quantity is not necessarily the concern because the dose that it delivers is the primary contributor to health risk. If the 1 curie were dispersed over a large area, the initial dose might be low enough that there is negligible risk and no decontamination would be required. As described by the US EPA, "If cesium-137 enters the body, it is distributed fairly uniformly throughout the body's soft tissues, resulting in exposure of those tissues." *Id.* EPA explains that "Compared to some other radionuclides, cesium-137 remains in the body for a relatively short time. It is eliminated through the urine." *Id.* This is not the case with plutonium which is why nearly all of the plutonium would need to be removed during decontamination.

Q41. Is there any expectation that particles released during a severe accident would be different than the particles modeled by MACCS2 or the particles asserted by NYS?

A41. [NEB] The deposition velocity used by the licensee corresponds to about a 6 micrometer aerodynamic diameter or to about a 3 micrometer physical diameter, as explained below. This is a very reasonable size for aerosols that would be released during a nuclear accident. As stated in A48, a smaller aerosol size would have reduced the amount of deposition throughout the 50-mile region of the SAMA analysis, including New York City. This would have reduced the cost of cleanup, all other things being equal. During a reactor accident, the mass median aerodynamic diameter of aerosols released to the atmosphere generally are within the range of 1 to 3 micrometers. Mass median indicates that half of the mass of aerosols is in smaller aerosols and half is in larger aerosols than the mass median diameter. Each aerosol particle contains a mixture of different elements and isotopes, e.g., cesium, iodine, tellurium, barium, and strontium. Some of the elements tend to be released earlier because they take more volatile forms, e.g., cesium iodide, and others tend to be released later because they are less volatile during the early stages of core degradation, e.g., barium and strontium. Even with the variations in release rate and elemental composition during a nuclear reactor accident, the aerosol sizes tend to stay within the ranges described above. The reason is that the smaller aerosol particles tend to coalesce with other particles to create larger ones, a process called agglomeration. The larger aerosol particles are heavy and tend to deposit by gravitational settling, impaction onto surfaces, or by other processes before they can be released into the environment. These physical processes govern the aerosol sizes that are released to the environment and keep them within a reasonably narrow range, regardless of the elemental composition of the aerosol.

The aerosol sizes assumed by Entergy are at the larger end of the size spectrum that would be expected during a reactor accident. However, that assumption results in more deposition within the 50-mile region modeled by Entergy, as explained in my testimony. Thus the treatment of deposition used in the Entergy SAMA analyses is conservative. Furthermore, there is no demonstrable difference in the cost of decontamination for particle sizes within the range of 1 to 10 micrometers, so the assertion by NYS that Entergy underestimated the cost of decontamination because their costs are based on larger aerosol sizes is incorrect.

Q42. What is the difference between the particles that would be released during a severe accident and the particles modeled by MACCS2 or suggested by NYS?

A42. [NEB] It is likely that the aerosols released during a nuclear reactor accident would have a mass median aerodynamic diameter of 1 to 2 micrometers instead of the 6 micrometers assumed by license's selection of deposition velocity. However, Entergy assumption is conservative in that it produces more deposition and thus requires more decontamination to be performed.

There is no evidence that decontamination costs depend on aerosol sizes when they are in the range of 1 to 10 micrometers. Thus, overall, the assumption on particle size made by Entergy is conservative.

Q43. How would these changes in the particle characteristics alter the SAMA analysis?

A43. [NEB] Our most current analyses (SOARCA) show that a realistic treatment of aerosol sizes corresponds to a deposition velocity of about 0.3 cm per second as opposed to the 1 cm/s deposition velocity assumed by Entergy. Entergy's larger deposition velocity results in about 3 times more deposition than it would have gotten using a more realistic deposition velocity. Thus Entergy predicts too much deposition throughout the 50-mile region, which results in an overprediction of decontamination costs.

Q44. Why do you make that conclusion regarding the impact of the various particle sizes?

A44. [NEB] We would expect less deposition throughout the 50-mile region had smaller particles been assumed.

Q45. How were you able to determine the impact of varying the particle size on the SAMA conclusion?

A45. [NEB] I ran MACCS2 for a set of deposition velocities corresponding to a set of aerosol diameters. I did this for a site in Oklahoma, but I am confident that the results were about the same as they would have been at other locations and specifically at the Indian Point Site. The results are presented in Figure 1. This figure demonstrates the effect of aerosol size on the quantity of deposition as a function of distance from a site. The major conclusion is that reducing the aerosol size from the value assumed by Entergy would have reduced the amount of deposition and, as a result, reduced the cost of decontamination. This is contrary to the position of NYS.

Q46. What other references were proposed by NYS for evaluating the offsite economic costs?

A46. [JJ] In addition to the Site Restoration Study, NYS also suggested that two other reports be used to determine the present and future value of decontamination for the area within 50-miles of the plant. The suggested reports are "Damages from a Major Release of Cs137 into the Atmosphere of the United States" (Ex. NRC000049) and "Chernobyl on the Hudson? The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Power Plant" (Ex. NRC000050). Beyae states that the decontamination cost estimates are based primarily on the results of a Sandia study, referring to the Site Restoration Study. (Ex. NRC000049 at 125.) The Lyman report also states that the model utilizes the results of a 1996 Sandia National Laboratories report which is referenced as the Site Restoration Study. (Ex. NRC000050 at 50).Thus, the additional documents NYS suggests be used to support development of the cost estimate are based on the results of the Site Restoration study, which, as described earlier, is not defensible for developing cost estimates for nuclear power plant accident. The Site

Restoration Study specifically discounts the use of its methodology for urban areas stating in the simplifying assumptions that “The cost estimates for mixed-use urban land do not include downtown business and commercial districts, heavy industrial areas, or high-rise apartment buildings.” (Ex. NYS000249 at 6-2.) New York City, which is located 24 to 40 miles from Indian Point, consists of precisely these conditions including downtown business, commercial districts, heavy industrial areas, and high-rise apartment buildings.

Q47. In NYS’ contention 12, the intervener raised the issue of particle size effect on the decontamination clean-up costs – do you have an opinion on how particle size would impact the analysis at Indian Point Units 2 and 3?

A47. [NEB] Yes.

Q48. How does particle size impact the decontamination costs?

A48. [NEB] The size of the aerosols released during an accident has two distinct effects on the cost of decontamination. These two effects are treated independently in the MACCS2 code. The first effect is on the quantity of deposition as a function of distance from the point of release. The second effect is on the cost to decontaminate for a specified decontamination factor. The first effect, the effect on deposition, is important, as explained below. The second effect, on the cost of decontamination, may be of minor significance. This is also explained below.

As explained below, the aerosol deposition velocity used in the Indian Point SAMA analysis corresponds to an aerodynamic aerosol diameter of about 6 micrometers and to a physical aerosol diameter of about 3 micrometers, depending on the relative abundance of the chemical species contained in the aerosol particles.

If a smaller diameter had been assumed in the Indian Point SAMA analysis, say an aerodynamic diameter of only 1 micrometer, the amount of deposition over New York City would have been lower, by about a factor of three. This change on its own would significantly reduce the overall cost of decontamination in the SAMA analysis. The effect of aerosol size on the amount of deposition is shown in Figure 1, which I created by running MACCS2 for a site in Oklahoma with a set of deposition velocities corresponding to the aerodynamic aerosol diameters shown in the figure. The trends at Indian Point would be expected to parallel those shown in this figure with some minor differences due to differences in weather data. For reference, New York City lies from 24 to 40 miles from the Indian Point site. The figure shows that deposition in New York City would have been about a factor of 2 or 3 lower if an aerodynamic aerosol diameter of 1 micrometer had been assumed in the IP SAMA analysis.

Notice that Figure 1 shows that aerosols with an aerodynamic diameter of 0.3 micrometers results in the smallest amount of deposition. This corresponds to the minimum in the deposition velocity curves shown in Figure 2. In other words, aerosols with aerodynamic diameters of 0.1 and 1 micrometers both have higher deposition velocities than particles with 0.3 micrometer aerodynamic diameters. As a result, the 0.1 and 1 micrometer particles deposit faster and generate higher ground concentrations than 0.3 micrometer particles (the reasons for this are explained in A49).

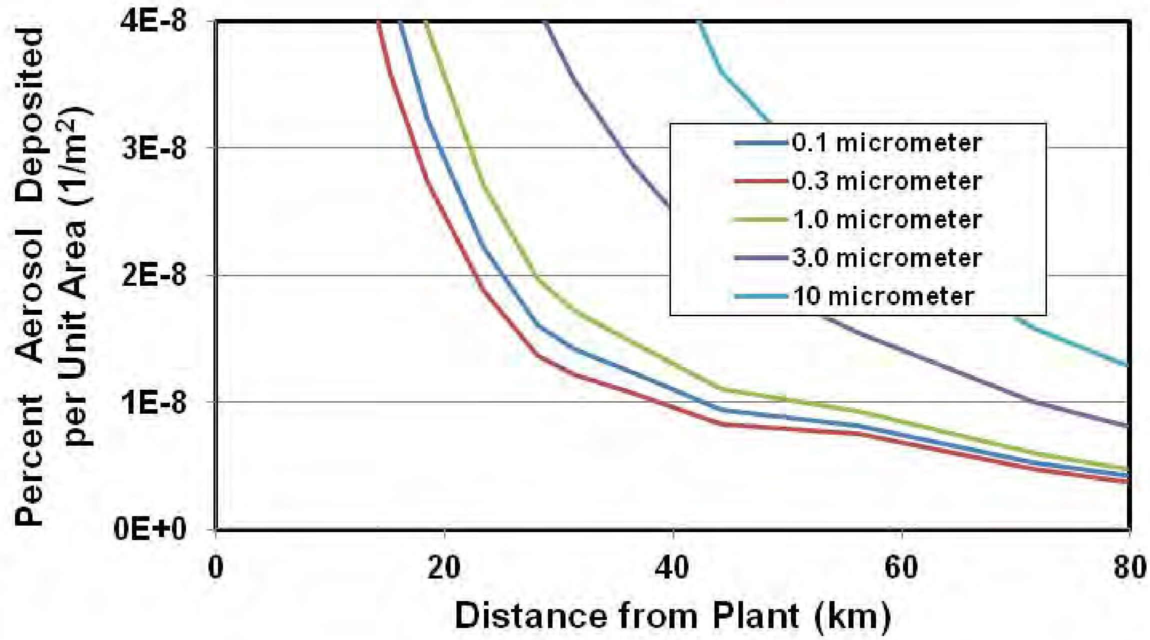

Figure 1. Effect of aerodynamic aerosol diameter on deposition at distances up to 80 km from the release location.

NYS asserts that MACCS2 decontamination and cleanup costs are based on large-sized radionuclide particles. NYS provided a definition of large-sized radionuclide particles as "particles ranging in size from tens to hundreds of microns" and references the Site Restoration Study as the source of this definition. Because our calculation shows that a particle size of less than 6 micrometers was used in the analysis, it is clear that the particle size does not meet the definition of large particle size provided by NYS. Furthermore, Figure 1 shows that the amount of deposition would have been less if a smaller aerosol size had been assumed.

Q49. Can you explain why a decreased particle size in the Entergy analysis would have resulted in decreased decontamination costs?

A49. [NEB] The actual particle size was not specifically identified in the Entergy analysis, but the deposition velocity, which is a function of particle size, used in the analysis allows us to estimate the particle size. In the Entergy MACCS2 input files *(*atmbi2NS.inp and atmbi3NS.inp), a deposition velocity of 1 cm/s (0.01 m/s) was used to represent the aerosol particles in the Indian Point SAMA analysis for both Units 2 and 3. The corresponding aerodynamic diameter can be estimated from Figure 2.

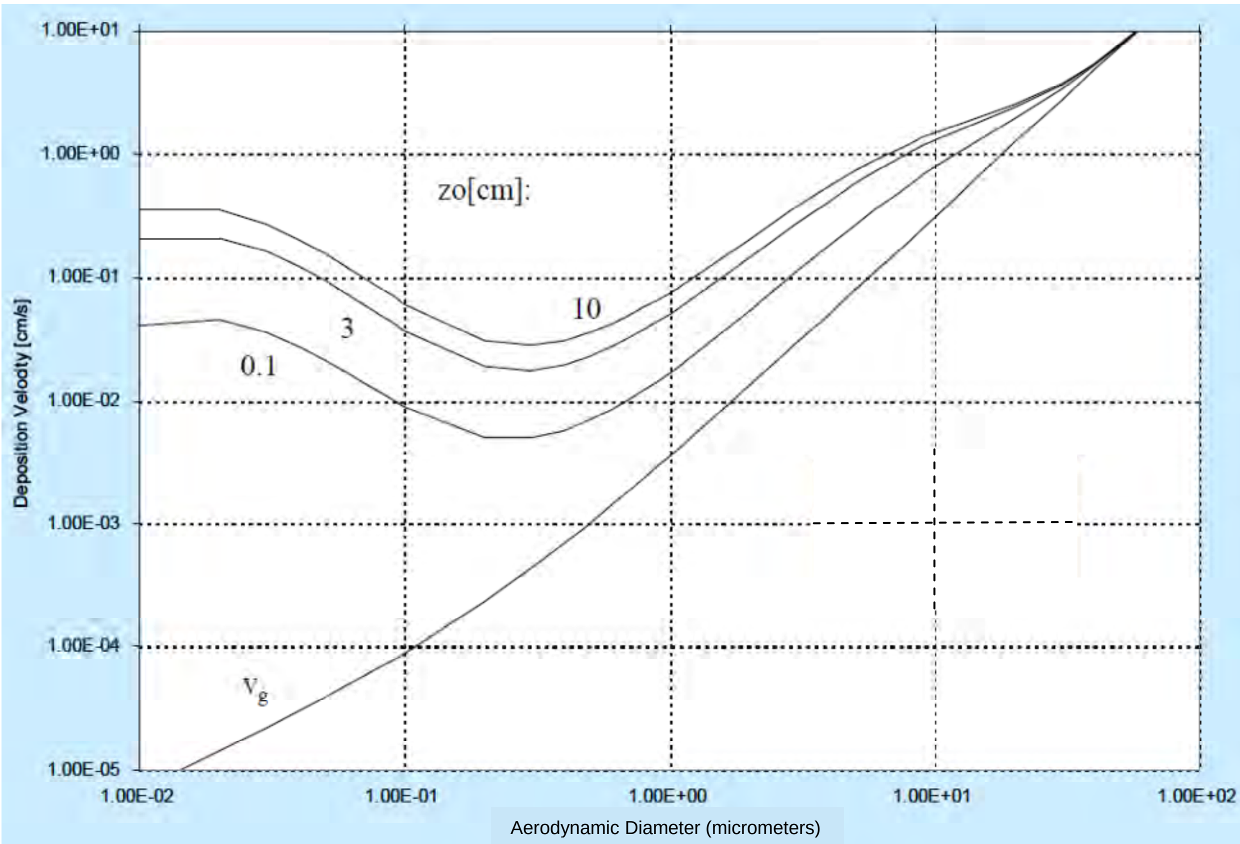

Figure 2. Effect of aerodynamic particle diameter on deposition velocity for selected values of surface roughness.

Figure 2 shows the dependence of deposition velocity in cm/s on aerodynamic particle diameter in micrometers. Three of the four curves in the figure show deposition velocity for discrete values of surface roughness, z_0 (cm), which are for 0.1, 3, and 10 cm. Surface roughness is a measure of surface height variations in the terrain, including bushes, trees, and manmade structures. Entergy chose a surface roughness of 10 cm in its SAMA analysis. The fourth curve in Figure 1 (labeled V_g) shows gravitational settling velocity. The other curves include gravitational settling and other deposition mechanisms, e.g., Brownian motion of the aerosol particles and impaction onto irregular surfaces, depending on the amount of surface roughness. The relevant curve for this discussion is the one for a surface roughness of 10 cm, since that is the value used in the Indian Point SAMA analysis. Notice that, aside from the curve showing gravitational settling velocity, the curves have a minimum deposition velocity. At the larger end of the size range, gravitational settling is the dominant mechanism for deposition. At the smaller end of the size range, Brownian motion is the dominant mechanism for deposition. In the middle, both mechanisms contribute. Also, notice that larger values of surface roughness correspond to larger values of deposition velocity. This is because aerosol particles impact and stick to rough surfaces more readily than they do to smooth, flat surfaces.

For a 10-cm surface roughness, Figure 2 shows that a 1 cm/s deposition velocity corresponds to approximately a 6 micrometer aerodynamic diameter (keeping in mind that the plot uses a logarithmic rather than a linear scale). The corresponding physical diameter of such an aerosol depends on its mass density, but it would be less than 6 micrometers for a nuclear reactor accident. The connection between physical diameter (d) and aerodynamic diameter (d_a) of a spherical aerosol particle is described by the following equation:

$$d_a = \sqrt{\rho}d$$

Here, ρ is the specific mass density of the aerosol particle. Specific mass density is the ratio of the particle mass density to that of a reference, which is taken to be water. Most aerosols that would be created during a reactor accident have a density greater than water. For example, cesium iodide, one of the more important chemical species that would be released during a nuclear reactor accident, has a specific density of 4.5. Cesium molybdate, also an important chemical species for nuclear reactor accidents, has a specific density of 4.0. If the specific density of an aerosol particle released during a nuclear reactor accident were 4.0, then a physical diameter of 3 micrometers would correspond to an aerodynamic diameter of 6 micrometers. A physical diameter of 3 micrometers, which is consistent with the deposition velocity used in the Indian Point SAMA analysis, is very representative of the aerosols that would be released into the atmosphere during a reactor accident. This conclusion is in contradiction to the statement by NYS that "Entergy also failed to take the properties of the large- and small-sized particles released during a nuclear reactor accident into account in many of its input parameters" (EX. NYS000240 at 37).

Q50. What other factors besides particle size can impact decontamination costs?

A50. [JJ] Particle size is only one of many factors that influence decontamination cost. Other factors include the amount of contamination, the dose to the decontamination worker at the beginning of the effort, the surface of the substrate being decontaminated, the type of technology selected for decontamination, and the achievable DF. Additional factors that can contribute to decontamination costs include the length of time that contamination has been in place.

Decontamination of small particles is not necessarily more difficult or more costly than large particles. For instance, the ISR report describes a Sandia project testing a peelable coating where identical experiments were conducted to remove cesium and plutonium from 4 different material types. (Ex. NYS000242 at 17.) The resulting data showed that for 3 of 4 material types, the smaller particles were equal to or easier to decontaminate than large particles.

Q51. Can you describe the Sandia project related to peelable coatings that was provided by NYS as Ex. NYS000259?

A51. [JJ] Yes, the Sandia project related to peelable coatings was proprietary work performed for a company called Cellular Bioengineering. The Ex. NYS000259 is found on the

Internet and additional data related to this work was made publicly available at the 2008 Health Physics Society (HPS) conference. (Ex. NRC000052). This work was performed in my current department at Sandia National Laboratories and was performed in the same radiochemistry laboratory where I managed decontamination technology development projects from 2000 through 2006. I am also knowledgeable of the technician, Ms. Holt, because she worked for me performing very similar activities in development of strippable coatings for removal of cesium-137. The Sandia project for Cellular Bioengineering included performing controlled tests of proprietary peelable coating to determine the decontamination effectiveness on concrete, carbon steel, stainless steel, and Plexiglas. The tests included decontamination of americium-241, plutonium-239, and cesium-137 from each material type.

My department has extensive experience with decontamination coatings through previous work sponsored by the Defense Advanced Research Projects Agency ("DARPA") and the Department of Homeland Security ("DHS"). I, together with Dr. Bob Moore and Dr. Mark Tucker obtained US Patent 7,514,493 B1, "Strippable Containment and Decontamination Coating Composition and Method of Use," as a result of the DARPA effort.

Q52. Can you describe what you mean by a strippable coating?

A52. [JJ] A strippable coating, also called a removable or peelable coating, is a decontamination application. The coating material is fairly viscous, similar to a thick household paint, and it comes in 5 gallon buckets. The coating is typically applied using application methods similar to painting including: paint sprayers, brushes, or rollers. The material is then allowed to dry. Once dry, the coating is stripped or peeled off (removed), and the contamination is stuck to the coating. The material typically strips off in large sheets, depending on the type of surface from which it is removed. At this point, it is bagged and discarded as radioactive waste.

Strippable coatings have been around for decades and were one of the applications used in the cleanup efforts at Chernobyl. I have had field experience in the use of these coatings when I managed radioactive decontamination activities in several buildings at Sandia. I have also been involved in the development of advanced coatings as I have discussed earlier. The coatings can be applied over large areas and do not require extensive labor or unique resources. There are no surface preparation requirements for most coatings on most surfaces.

The concept of these coatings is relatively simple. The radioactive contamination sticks to the coating, and when it is dry, the coating is removed. In the last decade, there has been a considerable effort to improve those coatings. Some areas where improvements have been made include reducing the drying time, increasing the elasticity, and increasing the decontamination effectiveness. When I used these coatings beginning in 1996, the drying time was 24 hours. If we attempted to remove the coating too soon, it would come up in small pieces, which then became labor intensive. It would also peel off in smaller pieces if the surface was rough, like the face of a brick. Advancements, in these coatings have reduced the drying time to a few hours and have increased the elasticity such that removal from rough surfaces like brick is no longer an issue. Successful advancements have also been achieved in adding binders, chelators, and other substances to the coating products such that they now have improved decontamination efficiency. The use of carefully selected binders and chelators improves the efficacy of the contaminant removal by chemically binding the contaminants to the coating along with the mechanical binding associated with the coating. These advancements have demonstrated that a DF of 100 or more can be achieved on some surface types with selected strippable coatings. [Ex. NYS000259 at 3 - 4]. This is an improvement of about a factor of 20 over strippable coatings using only mechanical binding as found in a Department of Energy ("DOE") study published in 1999. The DOE study, an Innovative Technology Summary Report for ALARA™ 1146 Strippable Coating described key results of a controlled demonstration where ALARA™ "was successfully demonstrated" and an average DF of 5.55 was achieved for removal of beta contamination. (Ex. NRC000047 at 3.) The ALARA™ coating mechanically locks the contaminant into the material whereas the more advanced coatings described above also include chemical binding characteristics, which vastly improve performance. *Id.* at 5.

The Sandia project tested 4 different types of materials and results of one test on concrete referenced in the ISR report showed a DF for cesium-137 of 1.2 and a second test showed a DF for plutonium of 5.8. (Ex. NYS000242 at 17.) There are 24 sets of test data in NYS exhibit, and review of the full set of data shows many examples where a much greater DF was achieved. (*See* Ex. NYS000259 at 3 – 4.) For Sample #7, #19 and #20 a DF of 100 was achieved (99% removal) for cesium-137 on carbon steel and Plexiglas. Sample #8 and #14 show a DF of 50 (98% removal) for cesium-137 on carbon steel and stainless steel. As we have discussed earlier, cesium represents smaller particles; therefore, these test results show that a DF of up to 100 can be achieved for small particles. For this particular set of tests, the results were not favorable for removal of cesium from concrete. As shown in Figure 3, only a 25% removal of cesium from concrete was achieved.

For larger size particles, Sample #11 showed a DF of 100 for plutonium (99% removal) from carbon steel. Multiple samples showed a DF of 50 (98% removal) for plutonium and americium. (Ex. NYS000259].) Note that for sample #19 and #20, the DF for cesium-137 is 100 (99% removal) and the DF for plutonium on Plexiglas is about 2 (about 50% removal) in samples #23 and #24. These data clearly show that a DF for cesium can be greater than for plutonium. This is contrary to the ISR report which states that the DF for cesium is never greater than the DF for plutonium. (Ex. NYS000242 at 17.) Furthermore, the data shows that a DF of 100 can be achieved for cesium and that a DF of greater than 10 is achievable on multiple material types for multiple contaminants.

Figure 3 shows the results of similar tests that were completed for this project and presented at the Health Physics Society Annual Meeting in 2008. (Ex. NRC000052.)

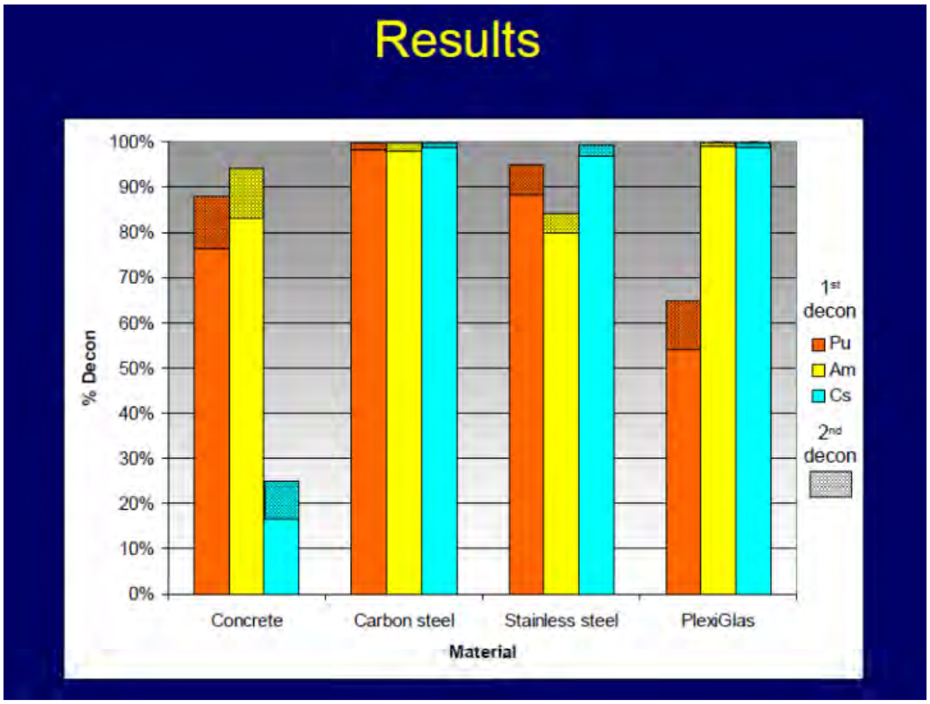

Figure 3. "Decontamination of Cs-137, Pu-239, and Am-241 from Hard Surfaces using a Peelable Polymer-based Hydrogel," presented at the Health Physics Society Annual Meeting in 2008.

It is clearly evident in Figure 3 that the percent decontamination of cesium was equal to or better than plutonium for 3 of the 4 material types. This again shows that a DF for cesium can be greater than a DF for plutonium.

Q53. Why is it important that the DF for cesium can be greater than the DF for plutonium?

A53. [JJ] This is important because the ISR report determined precisely the opposite, that the DF for cesium may be less than or equal to plutonium, but never greater. (Ex. NYS000242 at 17). The ISR report cites the Sandia project, where the results of one test showed a DF for cesium-137 of 1.2 and a DF for plutonium of 5.8. *Id.* at 17. Based on these two data points and on the DF values listed in the CONDO document (Ex. NYS000250 at 45 – 47), the ISR report determined that the DF for cesium is never greater than the DF for plutonium (Ex. NYS000242 at 17). Using these two low value DF data points from a single Sandia test together with the CONDO document does not provide a defensible basis for the ISR determination. It is clear from the information above as well as the DFs identified in Table 2 earlier, that DFs larger than 10 are achievable using multiple techniques on multiple surface types, without having to resort to demolition.

Q54. Do you agree with the conclusion that the DF for cesium is never greater than the DF for plutonium?

A54. [JJ] I disagree with this conclusion. Having managed multiple decontamination projects, I understand that there are too many contributing factors in the decontamination process to make such a conclusion. Furthermore, the technical basis identified in the ISR report for making this conclusion is based entirely on 2 Sandia data points and the CONDO document. The full set of information from the Sandia Report relied on in the ISR report contradicts this conclusion. It is also important to note that although I have discussed strippable coatings in detail, there are dozens of decontamination techniques and many different technologies available for use in decontamination. Current decontamination methods generally fall under three categories: Low Impact Mechanical, High Impact Mechanical, and Chemical. Available technologies for surface decontamination include acids, chelants, CO_2 blasting, sand-blasting, foams, HEPA vacuuming, light ablation, manual wiping, power brushing, pressure washing, scabbling, sponge-jet blasting, and many more. Most of these techniques and technologies, and many others, would be applied in a large scale decontamination effort.

Q55. Do you believe the ISR determination that the DF for cesium is never greater than the DF for plutonium affected the cost estimating in the ISR report?

A55. [JJ] Yes. Immediately following this conclusion in the ISR report, ISR considered two cases (Ex. NYS000242 at 17): (1) that cost of cesium decontamination equals that of plutonium; and (2) that the cost of cesium decontamination is twice that of plutonium. ISR starts with the premise that the cost of decontaminating cesium is at least as expensive as decontamination of plutonium, which is proven incorrect using the supporting Sandia data provided by ISR (Ex. NYS000242 at 17), which shows that for 3 of 4 material types, the cesium is in fact equal to or easier to decontaminate than plutonium. As we discussed previously, Pu-239 represents unique challenges to the safety of the decontamination workers and the allowable material that may remain in place that further elevate the costs for cleaning a site with the primary contaminant being Pu-239 instead of a Cs isotope.

Q56. Can the data in the Sandia project results be considered typical for decontamination factors for cesium and plutonium?

A56. [JJ] I would not say typical for all DFs, because an achievable DF depends upon the decontamination technique, the substrate being cleaned, and the contaminant. The DFs achieved in the Sandia project are achievable for advanced strippable coatings. It is significant to note that the application of the contamination in the Sandia project was wet deposition. Ex. NYS000259 at 1). Wet deposition is considered to be more difficult to decontaminate because the liquid contamination can absorb quickly into the material substrate. This represents more of a worst case scenario for cleanup. With dry deposition, there may be some surface binding on the substrate, such as concrete, but the contamination remains near the surface and there are many techniques available to clean this. With wet conditions, the contaminant can be drawn into a substrate, such as concrete, to a depth that would be more difficult to remove. Even with the challenge of wet deposition, the data showed that for 3 of 4 material types, the smaller cesium particles were equal to or easier to decontaminate than larger plutonium particles. It is clear from the information above and Table 2 (*supra* A37) that there can be quite a range of DFs.

Q57. Do you agree with Dr. Lemay and the ISR report that Cs from a nuclear reactor accident would always be at least as expensive or more expensive than Pu from a weapons accident?

A57. [JJ] I do not agree. The question regarding whether particles from a severe accident are more difficult to clean up than from a nuclear weapons accident is only one factor to consider. A weapons accident would disperse plutonium which releases alpha particles that are an inhalation hazard. Even if they are easier to remove, which is not always the case, the concern with plutonium is toxicity and its half-life of 24,000 years. The contaminant of concern from a nuclear power plant accident is cesium, which is a dose or exposure health issue. The cesium must be decontaminated to the point where the dose meets the habitability criterion. This means that even if cesium were harder to remove, which is not always the case, not all of the cesium needs to be removed, but just enough to get below the habitability criterion.

To further illustrate this issue, the cleanup criteria in 10 C.F.R. § 835, Appendix D, *Surface Contamination Values*, identifies more restrictive criteria for plutonium than cesium. Surface contamination levels above which areas need to be posted for removable contamination are 20 dpm (disintegrations per minute) for transuranics (Pu is transuranic) and 1,000 dpm for beta-gamma emitters, including mixed fission products (cesium is a gamma emitter). The contamination limits are 50 times higher for a beta-gamma emitter, like cesium, than for a transuranic like plutonium. Following this criterion would require that for the same amount of contamination of plutonium and cesium, the plutonium would need to be cleaned up by a factor of 50 more than the cesium. So, even if the large size plutonium particles were easier to clean up, which is not always the case, it must be cleaned to a factor of 50 times that of cesium to achieve the same posting level as cesium. In other words, if Cs only required a DF of 3, then Pu would require a DF of 150.

It is important not to simply focus on the techniques for removal of contamination, but to focus on the objective of the SAMA analysis, which is to determine the cost necessary to return the area to habitable use by taking advantage of all available techniques and methods. This requires decontaminating the area to a dose threshold. The characteristics of small particles can work to an advantage when the higher value real property is located long distances away from the release point. The dispersion of small particles at great distances from the plant would result in a dispersed, less concentrated contaminant deposition, which results in lower doses. The lower concentration of contaminants and correspondingly lower dose rates mean that less decontamination would be needed to return the area to a set habitability criteria.

Q58. Can you describe the CONDO model?

A58. [JJ] CONDO is a cost estimating tool developed in England to provide cost estimates for radiological decontamination projects. CONDO is structured to allow the analyst to input detail regarding the types of equipment and processes to be used in a decontamination project. However, the CONDO report appears to have used a simplistic approach to estimate costs rather than a realistic approach. This is apparent because there are more than 60 decontamination techniques identified in the CONDO report and the authors used the same DFs for both contaminants for all of these - except for high pressure hosing where the report identifies a greater DF for plutonium than for cesium. (Ex. NYS000250 at 45 - 47). For high pressure hosing of plutonium, the author added a footnote which states “No experimental data found for these time windows.” (Ex. NYS000250 at 47.) Figure 3 shown earlier, "Decontamination of Cs-137, Pu-239, and Am-241 from Hard Surfaces using a Peelable Polymer-based Hydrogel," clearly shows different amounts of contamination are removed depending on the contaminant and the substrate. This is also clear when comparing the DFs identified in Table 2 also shown earlier, "Achievable Decontamination Factors," where DFs are provided for the same techniques identified in the CONDO document. Table 2 shows a DF up to 100 for sandblasting surfaces contaminated with cesium (Ex. [NRC000048 at 6) while CONDO shows a DF of 10 for sandblasting surfaces contaminated with both cesium and plutonium (Ex. NYS000250 at 45). Similarly, Table 2 shows vacuuming can achieve a DF up to 100 while the CONDO document shows a DF of 2 for both cesium and plutonium for outdoor vacuuming and 5 for both cesium and plutonium for indoor vacuuming. In my opinion, applying a single, low value DF to both cesium and plutonium in the CONDO document shows that either the data were old, when less was known in the industry regarding decontamination, or that an overly simplistic approach was implemented.

Q59. Are there any conclusions you can make from the CONDO document?

A59. [JJ] Yes, I concluded that the CONDO document attempted to simplify the cost estimating by applying general values for DFs. Because the same DFs are identified for both cesium and plutonium, I could conclude based on just the CONDO report, that decontamination of small particles, like cesium, is not any more difficult than decontamination of large particles such as plutonium. This is precisely what these DF values indicate, but I would not draw such a conclusion from one individual document. Having managed many decontamination projects and being one of the named inventors for a patented strippable coating decontamination technology, the use of identical DFs for cesium and plutonium for such a wide range of techniques and surfaces is not a normal practice. The fact that virtually all of the DFs for cesium and plutonium are the same leads one to question the basis for the values.

It is possible that the DFs are the same for cesium and plutonium because CONDO used older data in establishing the DFs for cesium and newer data for establishing DFs for plutonium. CONDO references Brown, 1996, for cesium and Brown and Jones, 2000, for plutonium. (Ex. NYS000250 at 43). Thus their DFs, particularly for cesium would not be based on current technology or lessons learned through the DOE programs and would add additional conservatism in cost estimates for decontaminating cesium.

Q60. Can you briefly describe how clean-up costs are calculated using the MACCS2 code?

A60. [NEB] [JJ] MACCS2 accounts for three types of cost during a period of decontamination and possible subsequent interdiction. These are:

- Costs to decontaminate property, including labor and materials needed to perform the decontamination and disposal of contaminated materials generated during the decontamination,
- Loss of return on investment for the entire interdiction period, including the time needed to decontaminate, for property that cannot be used, and
- Depreciation on the improvements to property (excluding the value of the land itself) that cannot be maintained during decontamination and possible subsequent interdiction.

Two decontamination levels are specified in the Indian Point analyses. Each decontamination level carries with it a decontamination factor, a cost, and the time needed to decontaminate. The decontamination factor is used to reduce the level of contamination on property that is decontaminated. Subsequently, further reductions in contamination levels are based on radioactive decay and weathering, (e.g., washing away of aerosols by means of precipitation).

The decision process to determine what decontamination is performed in MACCS2 begins by asking whether the land is immediately habitable following the emergency phase for each land area considered in the analysis. In the Indian Point SAMA analysis, habitability is defined using EPA guidance to be a maximum dose of 2 rem in the first year and 0.5 rem in any subsequent year for people returning to their homes. If land is habitable, the population returns to their land immediately; if not, decontamination is considered. The lowest level of decontamination is performed that would restore the land area to habitability and the associated cost for that level of decontamination is accrued. Furthermore, one-time relocation costs are accrued during this period. If the highest level of decontamination is insufficient to restore habitability, an additional period of interdiction is administered. For nonfarm land, the period can extend up to 30 years. In the Indian Point SAMA analysis, DFs of 3 and 15 were used to define the two decontamination levels. A DF of 3 means that the activity of deposited aerosols is reduced to one-third of its original level; likewise, a decontamination factor of 15 means that the activity of deposited aerosols is reduced to one-fifteenth of its original level. The values used by Entergy for non-farm decontamination cost were $5,184/person for a DF of 3 and $13,824/person for a DF of 15. During the period of interdiction, contamination is also reduced by radioactive decay and weathering. Additional costs for loss of use, depreciation, and relocation are accrued during this period. If habitability cannot be achieved by 30 years, then the land is declared condemned. It is also declared condemned if the total costs of remediation exceed the value of the land plus the cost to permanently relocate the population. Decontamination is not performed if land is condemned.

Q61. How did Entergy develop the non-farm decontamination cost used in the analysis?

A61. [JJ] The values used by Entergy for the non-farm decontamination (CDNFRM) cost were $5,184/person for a DF of 3 and $13,824/person for a DF of 15. Entergy developed these values by escalating the values from Sample Problem A using the CPI change from 1986 to

2005. The recommended values for non-farm economic parameters are described in NUREG/CR-4551 and most of the data used to develop the parameters were taken from the Statistical Abstract of the United States (Ex. NYS0000248 at OAGI0000919 00155). As described earlier, MACCS2 applies the CDNFRM values on a per person basis. Thus, the high-population within the SAMA area is multiplied by the CDNFRM values, when appropriate, making the cost site-specific to the New York metropolitan area. The detailed methodology described in NUREG/CR-4551 and applied at the per-person level provides a reasonable and tested approach for use in the SAMA analysis. As I will describe in greater detail later, the MACCS2 values of $5,184 per person for light decontamination and $13,824 per person for heavy decontamination are substantially similar to the corrected cost values we estimate using the ISR report Approach C and D once we account for the extra conservatism applied by ISR with regard to the amount of area decontaminated.

Q62. Did you review the alternative non-farm decontamination cost values provided by NYS?

A62. [JJ] Yes.

Q63. Do you agree with these alternative non-farm decontamination cost values?

A63. [JJ, NEB] No. The alternative non-farm decontamination cost values developed in the ISR report [NYS000242 at 13] provide ultra-conservative values, some of which are grossly misleading. For instance, ISR shows an estimate from Approach A that is about $898,000 per person for heavy decontamination. (Ex. NYS000242 at 18). Such an estimate is misleading because it arbitrarily assumes the cost of cesium is 2 times the cost of plutonium. Dr. Lemay argues, in my opinion incorrectly, that plutonium is more costly to decontaminate than cesium, but he never quantifies that the cost is double. There is no sound basis provided for this arbitrary doubling of costs, and it is simply incorrect because as demonstrated earlier, typically cesium is cheaper to decontaminate than plutonium.

The ISR report acknowledges that estimating the cost of decontamination is very complex but then attempts to maintain simplicity and accuracy in developing cost estimates using 4 different approaches. Simplicity in approach is inappropriate for this important element of the SAMA analysis. The ISR report's Approaches A through D are described below. (Ex. NYS000242 at 13).

- Approach A used the Site Restoration Study modified by the Survey of Costs Study to develop a CDNFRM for a DF of 3 and a DF of 15. (Ex. NYS000255).
- Approach B used costs developed by Reichmuth to develop a CDNFRM for a DF of 15.
- Approach C developed a CDNFRM for a DF of 3 and a DF of 15 using the CONDO cost estimating tool.
- Approach D again used the CONDO cost estimating tool but used cost values for decontamination techniques obtained from a RISO study for a DF of 3.

Q64. Have you evaluated each of the 4 approaches described in the ISR report?

A64. [JJ] Yes. The Site Restoration Study was described in detail earlier as an estimate of the cost to cleanup a plutonium weapons accident. (Ex. NYS000249). The Reichmuth study was an estimate developed for the DHS based on a large cesium radiological dispersal device exploding in downtown Manhattan. (Ex. NYS000256). The CONDO model (Ex. NYS000250) is an estimating tool developed in the United Kingdom to support radiological decontamination, and the RISO study (Ex. NYS000251) was a decontamination estimate based on actual methods employed in the decontamination after Chernobyl. I will discuss each of these in greater detail and explain why each of the approaches used was not appropriate for estimating cleanup from a nuclear power plant accident.

To maintain simplicity, the ISR report made some assumptions that result in an overestimate of decontamination costs. We have identified three fundamental issues with this approach and many other issues that invalidate the ISR results for comparison with Entergy's values. First, the SAMA area is not made up of 100% urban and semi-urban areas. There are parklands, waterways, and other non-urban areas for which the ISR report assigned a cost value related to urban or semi-urban. The second issue is that ISR used the source term for Unit 2 in all of the analyses. (Ex. NYS000242 at 9). The Unit 2 source term is about 35% larger than the Unit 3 source term for Cs, therefore, all of the estimates are artificially high with no consideration for accidents from the smaller Unit 3 source term. Lastly, the third fundamental issue is that the ISR estimates do not consider that contamination is heaviest near the plant and lightest at the outer boundary of the 50-mile region. These are fundamental issues that establish the foundation for overestimating the decontamination costs in each of the 4 approaches.

Q65. What is the effect of only considering urban and semi-urban areas in the analyses.

A65. [JJ] Prior to implementing the four cost estimating approaches (A through D), the ISR report divides the 50-mile SAMA area into 2 areas, including the New York City metropolitan area (urban) and areas outside the New York City metropolitan area (semi-urban). (Ex. NYS000242 at 13, 23). The decontamination cost was then calculated for each of these areas for light and/or heavy decontamination for 100% of the SAMA. (Ex. NYS000242 at 24).

This part of the calculation is demonstrated in Tables 3, 4, 7, 8, 9 and 10 of the ISR report when calculating the CDNFRM for comparison to Entergy's values. Land use categories define the way that land is used. For example, the US Geological Survey (USGS) defines the following categories: urban or built-up land, agricultural land, rangeland, forest land, water, wetland, barren land, tundra, and perennial snow or ice. ISR considered 100% of the land within the 50-mile region surrounding Indian Point to be urban or built-up land when in fact, approximately 12% of the land area is made up of surface water in the Entergy file, and the farm area as used in the Entergy file is 9%. (Ex. NRC000060). In addition, within the SAMA area are many large open space parks including the Clarence Fahnestock Memorial State Park, Bear Mountain State Park, the Harriman State Park, and many others that total about 1,600 km^2, or 8% of the SAMA area. *Id.* Some of these areas are shown in Figure 4 provided by NYS a edited to identify the Indian Point plant location. The ISR report treats these areas, which total 29% of the SAMA area, as urban and semi-urban or urban and hyper-urban. (Ex. NYS000242 at 20). This flawed assumption leads to an overestimated cost because the SAMA area consists of 29% uninhabited area, which the ISR report designates as urban or semi-urban. Therefore, when the ISR report multiplies the decontamination cost per km^2 times the land area, it is overestimating this part of the calculation by 29% in each of the approaches A through D.

Figure 4. US Department of the Interior Geological Survey Map: Peekskill Quadrangle – graphically displays large forested and surface water areas.

Q66. What is the effect of only considering the Unit 2 source term in the analysis.

A66. [NEB, JJ] ISR used the source term for Unit 2 in all of the analyses. (Ex. NYS000242 at 9). The Unit 2 source term is about 35% larger than the Unit 3 source term in terms of the cesium release, which is the most important element for long-term consequences. Using the larger source term for all of the analyses artificially inflates the cost estimate. Less land would be highly contaminated for an accident at Indian Point Unit 3, which has smaller source terms, than it would be for an accident at Unit 2, which has larger source terms. A cost estimate that included the Unit 3 source term would have been less than the estimates provided in the ISR report.

Q67. Why is the assumption of uniformity of contamination level for the purpose of estimating decontamination costs incorrect?

A67. [JJ, NEB] The problem with this assumption is illustrated in Figure 1 of the ISR Report. (Ex. NYS0000242 at 6). Contamination levels generally decrease with distance because a plume would become more dispersed as it travels away from the source. Depending on the size of the source term, areas might require decontamination at a DF of 15 plus additional interdiction near the plant, decontamination at a DF of 15 with no additional interdiction in the next zone away from the plant, decontamination at a DF of 3 with no additional interdiction in the next zone from the plant, and no decontamination at the outer edges of the region, as illustrated in Figure 1 of the ISR Report. The problem with the ISR cost estimates arises because ISR includes the cost to decontaminate New York City in all cases, even if New York City does not require decontamination. Under relatively few circumstances would a DF of 3 be needed at distances as far from Indian Point as NYC; this is even truer for a DF of 15. Thus, the assumptions made by ISR lead to an overestimation of the cost of decontamination for a DF of 3 and especially for a DF of 15 in its analysis.

Q68. Have you reviewed the alternative cost estimates described as approaches A through D in Dr. Lemay's testimony?

A68. [JJ] Yes. I reviewed Dr. Lemay's testimony and the ISR report which describes each approach in greater detail.

Q69. Was the approach used in the ISR report more reasonable than the methodology applied by Entergy in MACCS2?

A69. [JJ] Not in my opinion. As described above, the initial framework established by ISR for these calculations has 3 fundamental flaws, each of which increase the cost estimate for each approach. In addition to the fundamental issues discussed above, there are errors and inconsistencies with each approach that cause the results of these analyses to be overestimated. I will discuss each of the specific calculations.

Approach A was based upon the results of the Site Restoration Study, which as described earlier is not appropriate for use because it was developed for plutonium decontamination, and the study specifically states that the cost estimates within the document, for mixed-use urban land, do not include downtown business and commercial districts, heavy industrial areas, or high-rise apartment buildings. (Ex. NYS000249 at 6-2). For Approach A, ISR used the Site Restoration Study as modified by the Survey of Costs study developed by Luna. (Ex. NYS000255). The ISR report explains that Luna used the Site Restoration Study as a basis for calculating the cost of cleanup. (Ex. NYS000242 at 16). Luna applied a population density factor to his values that was proportional to building density. The ISR report explains that instead of assuming building density is proportional to population density, ISR used the actual building densities for New York City. *Id.* As a result, the ISR report develops an increased value for decontamination on a cost per person basis. *Id.* This simplistic application of a building density proportional to population density is not appropriate for cost estimating purposes. The Site Restoration Study recognized the difficulties with estimating decontamination of urban areas and rather than developing a simplistic assumption, chose not to include downtown business and commercial districts, heavy industrial areas, or high-rise apartment buildings.

The approach is not reasonable because applying a building density factor, and assuming that the entire building needs to be decontaminated to the same level, implies an assumption that contamination would be uniform across a building of any size. This is simply not correct and effectively increases the area of decontamination above what is reasonable. In areas where decontamination is required, it would be confined to only those areas that presented a health risk. For example, the ground floor of a building provides the primary entry points for contamination. The ventilation systems provide additional pathways into the interior of the building. However, the ventilation systems do provide some scrubbing (capturing some of the contamination) of the air, which reduces the level of contamination entering the buildings at these points. I would expect contamination to settle around the exterior perimeter of the building and enter the building through personnel doorways, loading doors, windows and access points. Because of the personnel traffic in and out of buildings, I would generally expect the ground floor of a building to have higher contamination levels, and I would expect the levels to decrease on the upper floors of a typical building. Assuming every building requires complete decontamination is very conservative. My conclusion with regard to Approach A, based on the above discussion, is the approach does not provide a more reasonable estimate than the MACCS2 economic model employed by Entergy.

The cost estimate developed in the ISR report for Approach B used data from a study by Reichmuth. (Ex. NYS000242 at 18). Reichmuth developed cost estimates for cleanup of a cesium radiological dispersion device (RDD) and two high impact nuclear weapons detonated in New York City. (Ex. NYS000256 at 5). The cesium RDD is of interest in the Reichmuth report because cesium is the contaminant of primary concern from a nuclear power plant accident.

The study explains that cleanup cost data came from the RADTRAN 5 computer program and from cleanup of a World Trade Center (“WTC”) study "Measuring the effects of the September 11 attack on New York City,” (“FBRNY”) Reichmuth. (Ex. NYS000256 at 5 – 6). Reichmuth explains that the RADTRAN economic model was initially developed to estimate the consequences of a plutonium dispersal and once again we see reference to the Site Restoration Study. This is the same Site Restoration Study used in Approach A which I have explained is not appropriate because it was developed for a plutonium weapons accident and does not directly address the urban areas of interest to this SAMA analysis.

Reichmuth appears to agree that the Site Restoration Study is not appropriate explaining that unit costs from RADTRAN 5 were not considered to be a good estimate for high population density areas because it was developed based on a population density of 1,344 people/km^2 and that New York City has an average population density of over 20,000 people/km^2. Reichmuth then explains that the FBRNY costs were developed for the WTC site, and this is not representative of New York City in general or any other major population center in the US because unique and very high value buildings stood on this site. (Ex. NYS000256 at 6). Reichmuth explains the FBRNY costs were used for high and very high density urban areas. Reichmuth then states that the WTC data were used to derive the unit costs for cleanup. (Ex. NYS000256 at 6). However, there is no algorithm provided to demonstrate how the WTC data were used to derive costs, no process explaining how the WTC data were used, and no technical discussion of the approach to extend the WTC cleanup costs to represent a cesium decontamination. The FBRNY study was used to develop the cost estimates even though Reichmuth states twice that the WTC site for which the study was based is not representative of New York City and in fact may be overly expensive as a representation for New York City on whole. (Ex. NYS000256 at 6, 7). My review found that the approach and bases for the cost estimating are unsupported even by the author.

I then looked closely at the framework Reichmuth established for developing the cost estimates. Reichmuth developed the cost estimates based on detonation of a cesium radiological dispersion device ("RDD") in New York City. The chosen location in New York City of the RDD detonation would result in the highest levels of contamination remaining in the immediate city area. The cost estimate therefore includes decontaminating the highest value property from the highest contamination levels. This is not representative of an accident at a nuclear power plant 24 to 40 miles away.

Given Reichmuth's own statements questioning the validity of using RADTRAN and FBRNY cost estimates, and the fact that the RDD is detonated in an area where the highest costs would be incurred, I concluded that the Reichmuth does not present a reasonable estimate for a credible severe accident and does not provide a better economic estimate than the MACCS2 model employed by Entergy.

The ISR report next describes Approaches C and D which used the CONDO cost estimating tool to establish a decontamination cost. (Ex. NYS000242 at 19). CONDO provides unit cost estimates for different technologies and types of applications which could be used to provide a reasonable cost estimate, but the estimate developed in the ISR report did not apply these appropriately. Specifically, the ISR report did not consider the method in which the MACCS2 model calculates the level of contamination and subsequent level of DF needed to return an area to habitability and as a result did not account for mass balance of contamination that the MACCS2 model estimates. Mass balance is important because MACCS2 calculates an amount of contamination per unit area as though it is on a flat plane, such as a perfectly horizontal surface. Applying additional multipliers which effectively increase the base areas used in MACCS2 without equally reducing the amount of contamination in this area results in artificially high cost estimates.

Q70. Can you explain why it is important to consider the method in which the MACCS2 model calculates the level of contamination?

A70. [JJ] Yes. The MACCS2 model calculates contamination as though it is on a flat plane as described above. The MACCS2 model determines if decontamination of the surface requires a DF of 3, a DF of 15, a DF of 15 plus additional interdiction, or condemnation.

CONDO facilitates more detail in the cost estimating by allowing the user to calculate the cost for all surface types that are to be decontaminated. (Ex. NYS000250 at 8). This allows a user to separate costs of say grass, sidewalks, and streets rather than just apply a decontamination cost per acre. Similarly, CONDO allows the user to include building walls, building roofs, and indoor surfaces in the analysis. (Ex. NYS000250 at 29 – 31). This is where the incompatibility with MACCS2 occurs.

Q71. How can the additional detail in CONDO be incompatible with MACCS2?

A71. [JJ] I'll explain with an example. Let's assume MACCS2 estimates contamination for a 1 acre plot of land. A one acre plot is about 209 feet x 209 feet. If we assume that a 20-story building is 209 feet tall (about 10 feet per story is reasonable), we have a building with 4 sides, each of which are 209 feet wide and 209 feet tall. The roof would also be 209 feet x 209 feet. Therefore we have 4 exterior walls plus the roof that are each equal to 1 acre in area. This is a total of 5 acres of exterior surface area that the ISR report treats as though it were contaminated to the same level that MACCS2 estimated for the single 1 acre plot of land. The approach does not consider that the contamination MACCS2 estimated for the 1 acre plot of land is a fixed amount.

Annex C of the ISR report [NYS000242 at 46 through 56] supports the CONDO approach and provides an analysis to develop building fractions for external walls, roofs, and internal walls that were then used in the ISR cost estimating. Table 3 summarizes the ISR values which are described as "Additional fraction to separate surface fraction."

Table 3: Total Weighted Area Building Fractions (from NYS000242 at 47)

Surface	Semi-urban areas	Urban areas	Hyper-urban areas
External Walls	2.19	2.97	4.725

Roofs	1	1	1
Internal Walls	11.551	15.329	23.8295

The ISR report multiplied the Table 3 values times the unit cost values in the CONDO document to come up with a final cost per km^2 for each surface type. By applying the multipliers in Table 3 for a one (1) acre parcel of hyper-urban area, where MACCS2 would calculate a DF of 3 is required, the ISR report estimated the cost of decontaminating 1 acre but added factors for internal and external walls as high as 23.8295 as shown above. These factors were applied to a fraction of the area and effectively increase the area to be decontaminated. This is a misapplication of the extra detail in the CONDO model and results in an overestimate of the decontamination costs. Approach D used the same methodology to develop costs using the RISO study based on values from the RISO National Laboratory report, “Practical Means for Decontamination 9 Years after a Nuclear Accident. (Ex. NYS000251). Furthermore, by applying the same DF to areas that are increased by these building fractions again infers a uniform distribution of contamination throughout the buildings. This is not realistic or reasonable.

The above discussion describes how the ISR report added a multiplier to increase decontamination costs which were established in dollars per km^2. ISR then took the dollars per km^2 values and multiplied these times the total land area of 20,342 km^2 in Tables 3, 4, 7, 8, 9, and 10 as shown below in Figure 4 which is Table 3 of the ISR report with notes that I added to illustrate this point. (Ex. NYS000242 at 18).

Table 3: Suggested values of CDNFRM assuming cost (cesium) = cost (plutonium) (costs in 2005 USD)

Note only 2 area types: NYC metro and Area Outside NYC Metro Area

	Light Decontamination (DF=3)		Heavy Decontamination (DF=15)	
	NYC metro	Area Outside NYC Metro Area	NYC metro	Area Outside NYC Metro Area
Cost per km² ($) from *Site Restoration/Survey of Costs*	5.39E+08	1.21E+08	2.18E+09	3.93E+08
Total area within 50-mi radius (km²)	356	19986	356	19986
Total cost for the area ($)	1.92E+11	2.42E+12	7.77E+11	7.85E+12
Total cost over 50-mi radius ($)	2.61E+12		8.63E+12	
Population over 50-mi radius	19,228,712		19,228,712	
CDNFRM Per capita cost ($ 2005)	135,927		448,889	

356 km2 + 19986 km2 = 20,342 km2 which equals the total 81 km (50-mile) radius SAMA

Figure 4: Table 3 from the ISR report shows only two land area types used in the cost estimating for which urban and semi-urban decontamination costs were applied.

The value of 20,342 km^2 includes waterways, parklands, forests, and farmland and is not the correct value for use in this part of the cost estimating. I have shown earlier that approximately 29% of the land area is not urban or semi-urban. By using the full SAMA land area, the ISR estimate adds an additional 29% to the cost.

Q72. Does MACCS2 use a building density factor?

A72. [JJ, NEB] No. MACCS2 implements a cost per person value for decontamination, which accounts for high building densities through population densities. This approach ensures the MACCS2 analysis is site specific. For example, assume we have a single story building, and there are 200 people in the building. Then consider another building, with the same building footprint, but with 20 floors and 200 people living on each floor. Now we have 4,000 people in the same land area. Because the MACCS2 analysis applies a decontamination cost on a per person basis, the cost to decontaminate a building with 4,000 people will be 20 times the cost to decontaminate a single-story building with 200 people.

Q73. Are you able to make a direct comparison of the ISR cost estimates to the Entergy estimate?

A73. [JJ] No, I could not make a direct comparison. To account for mass balance of the MACCS2 estimate of contamination, I redid the calculation provided in Annex C of the ISR report for heavy decontamination where NYC metro is considered urban and the area outside the NYC metro area is considered semi-urban. The ISR values for this estimate are shown in Table 7 of the ISR report. (Ex. NYS000242 at 21). My only interest in the calculation was the effect of the multipliers used by ISR and I focused on the 2 largest multipliers which are for building walls and building interiors. For my approach, I divided the building walls Final Fragmented and Final Continuous costs by the 2.19 factor identified in Table 21 for semi-urban areas. (Ex. NYS000242 at 49). I then divided the building interiors Final Fragmented and Final Continuous costs by the 11.55 factor used by ISR. Removing these 2 factors reduced the total from $\$8.4 \times 10^7$ to $\$2.24 \times 10^7$. I performed the same calculation for Table 23 which is for urban areas. I divided the building walls Final Fragmented and Final Continuous costs by the 2.97 factor identified in Table 21 for semi-urban areas. (Ex. NYS000242 at 49). I then divided the building interiors Final Fragmented and Final Continuous costs by the 15.33 factor used by ISR. Removing these 2 factors reduced the total from $\$1.31 \times 10^8$ to $\$2.46 \times 10^7$. I input my adjusted values into Table 7 of the ISR report and the result was $23,631 per person for heavy decontamination (DF = 15) compared to ISRs original value of $89,734. I then factored in that 29% of the land area is not urban or semi-urban and therefore reduced the total by 29%. This results in $16,778 per person using the CONDO model with consideration of mass balance of the contamination. The results are reasonably close to the Entergy value of $13,824 per person for heavy decontamination.

Q74. Is it appropriate to assume uniform distribution of contamination on the inside of a building?

A74. [JJ] No. We have enough knowledge in the decontamination of facilities and in plume modeling to fully understand that uniform distribution of contamination within a building will not occur. By applying the same DF for all building surface areas, the ISR report infers a uniform distribution throughout the buildings. This is not an appropriate assumption because contamination cannot enter the building and deposit uniformly. The ground floor of a building provides the primary entry points for contamination. The ventilation systems also provide a pathway to the interior but roof-mounted and window-mounted ventilation units will provide some scrubbing (capturing some of the contamination) of the air reducing the level of contamination entering the buildings at these points. Contamination may be expected to settle around the external perimeter of the building and enter the building through personnel doorways, loading doors, windows and access points. Because of the personnel traffic in and out of buildings, I would generally expect the ground floor of a building to have more contamination than upper floors. I generally would expect the interior contamination to decrease on the upper floors of a building.

Surface contamination of buildings is also affected by the relative direction of the wind at the time that deposition occurs. Surface contamination will typically be greater on the windward sides of buildings and less on the downwind sides of the buildings and on all surfaces of buildings shielded from the wind by other structures and buildings. However, eddies on the downwind side of the buildings (building wakes) can contribute to localized contamination of portions of the downwind surfaces. Thus, the complex flow of the wind through groups of urban buildings creates a very non-uniform distribution of contamination onto the building surfaces.

Q75. Is it appropriate to assume uniform distribution of contamination on a building exterior?

A75. [JJ] No. Gravitational settling will cause much of the contamination to fall to the ground. Some contamination will adhere to the sides of buildings, and this will vary depending on the external surface material of the building. If the exterior building surface is glass, contamination that initially clings to the surface may largely be washed down from weathering and rain before decontamination would begin. If the surface of the building is concrete or porous type material, the contamination may adhere to the surface and would not readily weather away. For the situation in which contamination does adhere to the outside surface, we need to consider the location of this contamination and the risk, if any, that it may pose to the public.

The requirement for decontamination is based on whether the dose exceeds the habitability criterion. The public is not exposed to the exterior face of the upper floors of a building, however they may be exposed if they are inside the building. To estimate dose to the public from contamination that has adhered to the outside of a building, the shielding benefit from the building material would be a factor. Given the distance of New York from Indian Point and considering gravitational settling of the contamination, I believe dose to the public from contamination clinging to the exterior surface of a building would seldom exceed the habitability threshold and would seldom require decontamination. This is because only small amounts of contamination travel 24 to 40 miles from Indian Point, only a portion of this would cling to the upper levels of a building, and there is a shielding benefit from the concrete type exterior wall surfaces.

Q76. What other particle characteristics did you consider?

A76. [NEB] I also considered the radioactive decay characteristics. These characteristics do not affect the transport or deposition of the aerosol particles. They do affect the dose pathways that can lead to a dose and the period of time that the contaminant remains in the environment. The primary contaminant of importance for a nuclear reactor accident, especially for long-term contamination issues, is cesium. In particular, cesium-137 has a half-life of about 30 years. It decays to Ba-137m, which decays within a few minutes to Ba-137, a stable isotope. As Ba-137m decays, it emits gamma radiation. Most of the long-term doses are from the Cs-137 that deposits onto land and building surfaces. Because it is an external dose, i.e., the source is outside the human body, it is shielded by buildings and other structures.

Q77. How does the type of radioactive decay vary between the MACCS2 model employed by Entergy, NYS' asserted reference, and the actual expectations for a severe accident?

A77. [NEB] MACCS2 is extremely general and allows consideration of a large set of radionuclides. It includes ones that produce alpha, beta, gamma radiation and combinations of these types of radiation. The reference provided by the intervener is for isotopes of plutonium, which primarily emit alpha radiation. Another characteristic of the plutonium isotopes considered in that reference is that they have very long half-lives. For example, Pu-239 has a half-life of about 24,000 years. Thus, the radiation produced by these isotopes would likely outlast any physical barriers that could be created and the plutonium would have to be physically removed from contaminated areas to a high standard. In other words, cleaning up an accident producing Pu contamination cannot utilize radioactive decay as a method for restoring habitability. In a severe nuclear accident, on the other hand, the primary isotopes of concern for decontamination are Cs-134 and Cs-137. Cs-137, the more important of the two isotopes in terms of long-term contamination, decays to Ba-137m, which rapidly decays and produces gamma radiation. Cs-137 has a half-life of about 30 years. Cs-134 may produce more radiation in the short term than Cs-137, but with a half-life of about 2 years it decays more rapidly than Cs-137 and is less important for long-term habitability. Unlike plutonium, the important isotopes from a nuclear reactor accident do not have to be completely removed because their half lives are much shorter. Furthermore, these isotopes do not pose an inhalation or ingestion risk like plutonium does. The lower inhalation and ingestion risk for the cesium isotopes results from their rapid elimination from the body through urine; by contrast, inhaled or ingested plutonium remains in the body for decades.

The decontamination costs used in NUREG-1150 were $3000/person and $8000/person to achieve DFs of 3 and 15, respectively. Entergy used $5,184 and $13,824 for these same decontamination factors. Comparing the two numbers shows that they increased both costs by a factor of 1.728 to adjust for inflation.

Q78. How would the use of intervenor’s proposed decontamination factor alter the SAMA analysis?

A78. [JJ] The intervener didn’t actually propose a DF. As described above, the ISR report concluded that the DF for cesium may be less than or equal to plutonium. (Ex. NYS000242 at 17). Based upon my experience in developing decontamination technologies and conducting decontamination in actual facilities, I must disagree with the ISR conclusion. Implementing the ISR conclusion would increase decontamination costs because it potentially eliminates the consideration of cost effective technologies than can achieve high DFs.

The intent of DFs is to provide a means to categorize, by efficiency, different decontamination techniques and technologies. DFs are only useful as a guide and are often misinterpreted, particularly by analysts, rather than practitioners of decontamination projects. Conclusions such as a DF of greater than 10 or 15 is not achievable without demolition (Ex. NYS000249 at 5-8; Ex. NYS000242 at 12), are inappropriate as general conclusion regarding the effort necessary to perform varying levels of decontamination.

Q79. Can you explain what you mean by saying the DF is based on many different factors?

A79. [JJ] A DF depends upon the type of contaminant, the substrate, the quantity of deposition, environmental factors, and of course the selected method for decontamination. Time can also influence the DF. The DF can change if any one of these factors changes. If dry deposition of cesium occurs on dry glass, it may be cleaned up using commercially available wipes and a high DF would be achieved. If the same dry deposition of cesium occurs on concrete, which is a porous material, decontamination using the same wipes would result in less removal of the contaminant. This is a simple example, where all conditions are held constant except the substrate, shows how different DFs can be achieved using the same technique. The example shows a DF for a method is not universal and should not be assumed to apply under all conditions.

Another example, using actual data can be seen in Figure 3. Note that for stainless steel, the percent decontamination (which represents the DF) is different for each contaminant when decontaminated with a peelable coating. This was a controlled experiment and all factors were held constant, except the contaminant. The DF is different for plutonium, americium, and cesium. This again shows that changing a single condition (the contaminant) influences the DF and one cannot claim that the DF for a technique is universal. This understanding is important when reviewing how cost estimates are developed. For instance, the ISR report (NYS000242 at 17) concludes that a DF for cesium will never be greater than that for plutonium and based this on the Sandia data together with the CONDO document. Figure 3, “Decontamination of Cs-137, Pu-239, and Am-241 from Hard Surfaces using a Peelable Polymer-based Hydrogel,” presented earlier, clearly shows that for 3 of the 4 material types, the DF for cesium is equal to or greater than plutonium.

The CONDO report identifies the same DF for cesium and plutonium for all but one decontamination technique. For example, the CONDO document (NYS000250 at 45) lists a DF of 5 for peelable coatings for cesium and plutonium. For the peelable coatings shown in Figure 3, a DF of greater than 15 was achieved for plutonium in 2 of the 4 materials, and a DF of greater than 20 was achieved for cesium in 3 of the 4 materials. The DF was different for each contaminant in almost every case, yet the CONDO document applied an equal and low value for cesium and plutonium. The RISO report also identifies DFs considerably higher than those identified in the CONDO model. (Ex. NYS000251 at 24 - 25). The RISO report provides a catalog of feasible techniques for reduction of dose 9 years after the Chernobyl accident. The report was based on experimental work that was followed by field trials in contaminated areas of Russia, Belarus and the Ukraine and lists strippable (peelable) coatings with a DF up to 30. (Ex. NYS000251 at 25).

Comparison of the RISO and Sandia data show that DFs vary by contaminant, yet the CONDO document identifies the same DFs for cesium and plutonium. In my opinion, the CONDO values cannot be technically substantiated. This is important because the ISR report used the CONDO estimating approach for 2 of the 4 alternate cost estimates.

Q80. Did you review the decontamination times used by Entergy?

A80. [DH, TG, JJ] Yes. Entergy used decontamination times, which are identified by the TIMDEC parameter in MACCS2, of 60 days when a DF of 3 is applied and 120 days when a DF of 15 is applied.

Q81. Are these decontamination times appropriate for the SAMA analysis at Indian Point?

A81. [DH, TG] The 60- and 120-day decontamination time selected by Entergy was appropriate based on the need of the MACCS2 code to develop a decontamination time representative of all possible severe accident scenarios and not simply the worst case scenarios. The NRC has been examining the decontamination times for over 37 years. Beginning in 1975, the Reactor Safety Study provided discussions regarding decontamination activities that are capable of restoring areas to habitability quickly given sufficient resources. (Ex. NRC000056, WASH-1400 (NUREG-75/014) in Appendix VI, Chapters 11 and 12 and sub-Appendix K). Some of these simple decontamination techniques include grading open land areas or pressure washing hard surfaces and result in decontamination factors greater than 3 and 15. (*Id.* at K-16.) As my colleague discussed previously, more modern decontamination techniques have been developed that are capable of significantly better decontamination performance.[7] More recently, the Staff published a report reviewing the MACCS2 code input parameters. (Ex. NRC000057, NUREG/CR-4551, Volume 2, Part 7, “Evaluation of Severe Accident Risks: Quantification of Major Input Parameters – MACCS Input”). The report reviewed the input parameters selected in the NUREG-1150, which performed an off-site consequence analysis for selected reactors located in the United States. (Ex. NRC000059,

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[7] *See supra* A38, A51.

NUREG-1150, “Severe Accident Risks: An Assessment of Five U.S. Nuclear Power Plants”). From NUREG/CR-4551, I can conclude that the decontamination times selected, namely 60 days for a DF 3 and 120 days for a DF of 15 were reasonable. *See* Ex. NRC000057, NUREG/CR-4551. NUREG/CR-4551 based its analysis on an additional NRC study of economic risks of a nuclear accident. (Ex. NRC000058, NUREG/CR-3673, “Economic Risks of Nuclear Power Reactor Accident”). That additional report identified an average effort required to restore habitability to an area after the most severe type of reactor accident. The report states an average clean-up was expected to take 90 days with approximately 46,000 workers (11,000 person-years of effort) for this most severe type of reactor accident. The key is that this report cites this as an average time to complete decontamination efforts following the most severe type of reactor accident. Less severe accidents, including ones that may result in little clean-up being required, might take less time or involve fewer resources and take about the same amount of time. In either situation, the average time to complete decontamination efforts would be about 90 days or less for severe reactor accidents. (*Id.* at 6-24 – 6-25.) For MACCS2 to be able to provide a reliable and reasonable analysis, the decontamination times must represent all the modeled severe accidents including ones that require little decontamination. Entergy’s use of two decontamination times to model the clean-up was reasonable. Dr. Lemay’s suggested clean-up times are skewed to the worst case severe accident scenarios under some of the worst case conditions for implementing a clean-up and cannot represent the multitude of clean-up scenarios modeled in a SAMA analysis. As with any modeling effort, it is likely that an actual decontamination effort would depart from the modeled inputs based on the extent of the accident, environmental conditions during the clean-up, and actual resources expended during the clean-up.

Q82. Did you review the discussion regarding decontamination times in the ISR report?

A82. Yes. The ISR report discussed using a range of decontamination times from 4 to 30 years for heavy contamination and 2 to 15 years for light decontamination. (Ex. NYS000242 at 24, 25).

Q83. Do you agree with the ISR report?

A83. [JJ] Not entirely. I agree that the decontamination times used by Entergy are probably not reflective of the specific time that would be required from the occurrence of particular worst-case accident at Indian Point. My colleague explains in A80 that the decontamination times need to be reflective of the full range of severe accidents and their decontamination requirements and not simply reflective of the worst case scenarios.

The ISR suggested ranges for decontamination time are not substantiated. The ISR report describes estimating the decontamination costs over a range of time periods of 2 to 15 years for light contamination and 4 to 50 years for heavy contamination. (Ex. NYS000242 at 24). The ISR report concludes that for this range of decontamination times, the OECR is 3.0 to 5.7 times greater than the OECR calculated by Entergy. (Ex. NYS000242 at 25). The ranges of 2 to 15 years and 4 to 30 years are based on decontamination efforts at Chernobyl and Fukushima. (Ex. NYS000242 at 24). This wide range of decontamination times is too broad to be meaningful. I will first discuss why use of Chernobyl and Fukushima as a basis for decontamination times is not appropriate, and then I will discuss the selection of the time values by ISR.

Let's first look at Chernobyl, which was a nuclear power plant accident that occurred on April 26, 1986, in the former Soviet Union country of Ukraine. Cleanup technologies for large scale applications were not mature at that time, and the capabilities of the Ukraine would not have been considered advanced with regard to environmental cleanup. As explained in the

IAEA report cited by NYS large scale cleanup was performed by the military. This untrained response would likely not have been optimal. (Ex. NYS000263 at 73).

Many decontamination techniques were implemented in response to Chernobyl and these are described in the RISO report. (Ex. NYS000251). However, one must remember that this was the first large scale nuclear reactor accident. As such, it was also the first time decontamination at such a large scale was attempted. This is another indication the response was likely not optimal. Additionally, we cannot discuss Chernobyl without recognizing that the source term was tremendously larger than any source term considered in this SAMA analysis. Thus, the levels of contamination would likely also be considerably greater.

One example of the sub-optimal approach is the effectiveness of the strippable coatings used after Chernobyl which according to the RISO report varied with a DF ranging from 4 to 30. (Ex. NYS000251 at 25). As discussed earlier, an advanced commercially available strippable coating was tested by Sandia and achieved a DF as high as 100 for cesium. It is advancements such as this that have been developed long after Chernobyl, many of which have been successfully used in decontamination of DOE nuclear facilities together with the nuclear cleanup expertise gained in the last 25 years that make Chernobyl a poor example for use in determining how long a decontamination effort may take.

With regard to Fukushima, the earthquake and tsunami caused extensive local and regional damage that stretched the limits of the response agencies. Japan has advanced response capabilities and advanced understanding of decontamination requirements. Japan also has advanced decontamination technologies and has shown a willingness to identify improved technologies available from other countries and partner with owners of technologies that will benefit in the cleanup effort. This has allowed Japan to decontaminate and release areas for public use just a few months after the accident. Successful decontamination and return of property to the public has occurred and is ongoing in Japan in spite of having to concurrently address significantly damaged infrastructure issues resulting from the tsunami and not the reactor accidents. The ability for Japan to successfully reestablish areas through decontamination demonstrates that areas can be returned to habitability in a timely manner. There are areas where decontamination has not begun, but it is difficult at this time to determine whether this is because Japan's national resources are largely engaged in cleaning up debris and rebuilding coastal cities and infrastructure that were destroyed by the tsunami. Without such an understanding, it is difficult to determine if this has affected the decontamination times. The unique and severe circumstances surrounding Fukushima, especially the damage to infrastructure as a result of the earthquake and tsunami, make Fukushima a poor example for use in establishing decontamination times.

There are only 2 significant nuclear power plant accidents for which we can compare the modeled decontamination time to the observed decontamination time. However, as described above, these 2 accidents are very unique and are not appropriate comparison for postulated accident decontamination timelines at Indian Point. ISR established a decontamination time of 4 to 30 years for heavy decontamination and then assumed half this time for light decontamination. There is a discussion of Chernobyl and Fukushima, but no basis to establish 4 to 30 years for heavy decontamination. Cleanup at Fukushima began in areas last summer and continues at this time but is complicated by the correspondingly greater accident and damage resulting from the tsunami.

Q84. Does the SAMA analysis account for potential uncertainties like the time necessary to complete the clean-up and decontamination?

A84. [STG] As explained previously in A14, SAMA analyses typically use two multipliers on the internal benefit quantification in order to account for external events and analysis uncertainties. Though the analysis uncertainties multiplier is typically estimated as the ratio of the 95th percentile CDF to the mean or point estimate CDF, this multiplier is meant to account for analysis uncertainties generally, not just uncertainties in the level 1 PRA. In the Indian Point SAMA analysis, a total multiplier of 8 was used for IP2 and IP3. As explained in the FSEIS, this was a slight overestimate of the product of the external events multiplier by the "analysis uncertainties" multiplier, which was (3.8 x 2.1) for IP2 and (5.5 x 1.4) for IP3. Furthermore, these multipliers are applied to the total benefit, which includes all the averted cost terms (as laid out in A14). Hence the margin for error that could be handled for any one or subset of terms is higher.

In addition to the margin afforded by the external events and analysis uncertainties multiplier, there are some conservatisms in the SAMA analysis that are likely to make the true margin for error larger. Examples include the following: (a) the FSEIS notes that the external events CDF and hence the multiplier is likely overestimated; (b) as noted in A32, the assumption of no evacuation results in an overestimate of doses incurred in the early phase of potential accidents; (c) for the reasons noted in A36, the use of only 2 decontamination factors is conservative.

NYS-16B – NYS' Challenge to the Population Estimate

Q85. What issues did you examine for NYS-16?

A85. [JJ] I examined the population estimates with regard to the total population, commuters, and the US Census undercount.

Q86. What did you conclude about the applicant's population estimate?

A86. [JJ] I concluded that the Entergy approach to using State information to project population growth provides conservative population values for the SAMA analysis. This is because the total (permanent + transient) population is larger, and therefore more conservative, than a projection based solely on US Census data. Entergy projected total permanent populations to the year 2035 for 25 of the 28 counties that are within or encroach upon the limit of 50 miles from Indian Point using linear extrapolation. Entergy used areal weighting, which assumes a constant population distribution over the area assessed (i.e., in each of the 160 cells within the 16 sectors and radial rings representing the 50-mile radius surrounding the IP site), to establish fractional population within 50 miles of Indian Point. Entergy then adjusted this permanent population projection upward to account for the presence of the transient (tourist) population as estimated from available tourist information [Entergy, Volume 1 Site Specific Input 2006].

Entergy then used polynomial regression for projecting the population for the remaining 3 counties including New York (Manhattan), Rockland, and Westchester counties. The New York State data shows a decrease in the population of these counties as indicated in Volume 1, “Site Specific MACCS2 Input Data for Indian Point Energy Center,” Table 2.1 “Population Projections (2035 Calculated from Table).” (Ex. NRC000061 at IPEC00019458 - IPEC00019459). The population was projected by the State to increase for New York County from 2000 to 2020 and then decrease from 2020 to 2030 resulting in a peak in population at 2020. Because there is a peak within the projection period, use of a polynomial projection to the year 2035 is a more appropriate approach than a linear projection for these counties.

Q87. Did you perform your own estimate of the population surrounding Indian Point during the license renewal period?

A87. [JJ] Yes. I performed two separate evaluations of population growth to project from the 2000 data to the year 2035.

Q88. How did you perform your population estimate?

A88. [JJ] I used two different approaches to estimate the population. First we used SECPOP2000 to estimate the population based on 2000 US Census Bureau data. The population for the year 2000 estimated by SECPOP2000 is 16,800,272. This compares very closely with Entergy's year 2000 estimate of the permanent population within the 50-mile radius, which is 16,914,178. Entergy projected the permanent population out to 2035 to be 18,879,657, an increase of 12.43%. The population Entergy used in its SAMA analysis was 19,228,714, which accounts for the transient (tourist) population, as described above.

We evaluated the population growth to project from 2000 to the year 2035 by first using the U.S. Census Bureau's projected growth from 2000 to 2008 for the Northeast region of the US. During these 8 years, the projected growth is 2.344%; based on this number, the annualized growth rate for the Northeast region of the country is 0.2900%. Assuming a constant growth rate between the years 2000 and 2035 results in an estimated growth for the Northeastern region of the US of 10.67%. This estimate is lower than the Entergy value of 12.43%.

We then performed a second evaluation using the same data for the 28 counties surrounding Indian Point as used by Entergy, but using a simpler method than Entergy for extrapolating out to 2035. The annualized growth rate was calculated starting from the 2000 census values to the final year projected by each of the states. Then assuming this growth rate to continue through 2035, the estimated growth for the 28 counties is 15.98%. This value is slightly larger than Entergy's projected growth of 12.43%.

In addition, we performed a separate evaluation of the population data for New York City using the same method of extrapolation described above to project populations to the year 2035. For New York, Queens, and Richmond Counties, our estimate projected slightly higher populations than Entergy. For Bronx and Kings Counties, Entergy projected higher populations. The difference between the Sandia and Entergy population projections for all 5 counties was only 0.39%. Based on our independent analysis of population, I concluded that Entergy's projection is reasonable.

Q89. Did you compare Entergy's projected population with the current 2010 US Census data?

A89. [JJ] Yes. The comparison showed that Entergy's projected population values were greater than the 2010 US Census values. This is shown in the Table 4 below, where the total population in the 28 counties within or partially within the 50-mile radius surrounding IPEC had a 2010 population of 20,570,079 while Entergy projected in its 2006 license renewal application 20,974,307, a difference of 404,228 people [IPEC00019458 and IPEC00019459]. When apportioning the census values by percent of county that is within the SAMA area (for the counties that straddle the 50 mile boundary), the Entergy value still exceeds the US Census value by 326,878 people.

Table 4: 2010 Census Comparison

County in SAMA	Entergy 2010 Projection	2010 census**	% Difference
Fairfield	857,870	916,829	6%
Litchfield	192,290	189,927	-1%
New Haven	838,340	862,477	3%
Bergen	949,100	905,116	-5%
Essex	816,400	783,969	-4%
Hudson	635,100	634,266	0%
Middlesex	858,600	809,858	-6%
Morris	532,700	492,276	-8%
Passaic	515,500	501,226	-3%
Somerset	357,800	323,444	-11%
Sussex	167,500	149,265	-12%
Union	545,400	536,499	-2%
Warren	121,400	108,692	-12%
Bronx	1,425,170	1385108	-3%
Dutchess	293,520	297,488	1%
Kings	2,531,424	2504700	-1%
Nassau	1,312,166	1,339,532	2%
New York	1,587,098	1,585,873	0%
Orange	370,521	372,813	1%
Putnam	103,786	99,710	-4%
Queens	2,452,109	2,230,722	-10%
Richmond	505,844	468,730	-8%
Rockland	291,706	311,687	6%
Suffolk	1,456,195	1,493,350	2%
Sullivan	79,522	77,547	-3%
Ulster	190,389	182,493	-4%
Westchester	926,798	949,113	2%
Pike	60,059	57,369	-5%
Total	20,974,307	20,570,079	-2%

**http://2010.census.gov/2010census/popmap/ipmtext.php?fl=36 (link to Bronx County), Accessed Feb. 6, 2012.

Q90. Are you familiar with Dr. Sheppard's assertion that the U.S. Census systemically undercounts certain portions of the population?

A90. [JJ] Yes. With every census, questions arise with regard to the percent of the population that has been accounted for in the total population. The undercount is the term used to describe a part of the population that may not have been fully represented in the total. Dr.

Lemay states that factoring census undercount into population estimates is uncontroversial, and an additional 230,000 persons should have been added to the Entergy population estimate to address the undercount [NYS000206 at 15]. The census undercount is far from uncontroversial not only in terms of how to determine the undercount, but what to do with an undercount if it can be agreed upon. The U.S. Census Monitoring Board, Final Report to Congress, regarding the 2000 census explains that statistical estimation to adjust the census *has been a controversial issue*. [NYS000213 at OAGI0001265_00031]. Furthermore, the Government Accounting Office, (GAO) noted that for the first time in its history, the Bureau reported a slight net overcount of approximately 0.5 percent or about 1.3 million people in the 2000 census. (Ex. NRC000055 at 3).

Efforts to estimate the census undercount are conducted with each census. The U.S. Census Bureau Executive Steering Committee published ESCAP II: Demographic Analysis Results in September 2001 regarding the 2000 census which compares two methods of estimating the census undercount including a Demographic Analysis (DA) and the Accuracy and Coverage Evaluation (A.C.E). The ESCAP II report provides an example of the extent of controversy by stating that the Census Bureau decided that redistricting data not be adjusted based on data from the A.C.E due to concern that the DA and A.C.E estimates of the population were inconsistent. (Ex. NYS000214 at OAGI00012266_00004). Similarly, the U.S. Census Monitoring Board, Final Report to Congress states that DA is a useful benchmark from which to evaluate census results but should not be used as a determining factor in the debate over adjustment. (Ex. NYS000213 at OAGI0001265_00015). The Census Bureau and many other agencies and organizations continue to grapple with estimating an undercount. The one thing is fairly certain regarding the census undercount is that it is most definitely a controversial issue.

Q91. Did Entergy consider a potential for U.S. Census undercount as part of the population within the SAMA area?

A91. [JJ] No. It does not appear that Entergy explicitly included the undercount in its analysis. However, it did model the population growth through 2035 using some conservative assumptions that adequately account for any potential undercount that may have been present in the 2000 Census.

Q92. What impact would there be on the analysis if a U.S. Census undercount were included?

A92. [JJ] Directly adding 230,000 residents, which intervenor suggests, to compensate for an undercount would increase the base population by the number of residents added. If Entergy were to add 230,000 people and run the SAMA analysis again, the cost would be expected to increase a small amount. In my opinion, the increase in cost from the addition of 230,000 people located in the outer limits of the SAMA area would not materially affect the conclusions of the SAMA analysis. Furthermore, we have shown above that Entergy's current population estimate exceeded the 2010 population estimate by 326,878 people. If population adjustments are to be made, the net difference between Entergy's overcount and the intervener's undercount is an overestimate of the 2010 census by about 100,000 people. Therefore, the actual results of considering these population differences would reduce the Entergy estimate.

Q93. Did Entergy consider commuters as part of the population within the SAMA area?

A93. [JJ] No. Entergy did not consider commuters in the population estimate.

Q94. Was it reasonable for Entergy to not consider the commuters explicitly in its population estimates?

A94. [JJ] Yes. Entergy captured the important population segments for a SAMA analysis including the permanent population and tourists in their estimate and as described in Volume 1, "Site Specific MACCS2 Input Data for Indian Point Energy Center," (Ex. NRC000061 at IPEC00019451). Tourists including business travelers who stay overnight are included in the permanent population because they are in the modeled SAMA area for an extended time and could potentially accumulate dose as the result of an accident at Indian Point. Commuters, on the other hand, are only in the SAMA area about a third of day (8 hours plus commuting time). This incorporates some additional conservatism because it ignores the affects of holidays, vacations, sick days, telecommuting, or other types of absences, which would lower the percentage of time in the modeled area further. Fundamentally, however, counting commuters as though they were permanent residents of the modeled area results in a significant overestimation of the economic costs of the dose to population since MACCS2 estimates their dose based on returning to the area permanently. The increase in population from commuters would be better represented as a fraction of the permanent population. In my opinion, and further discussed below, an increase of less than 1% in the permanent population would account for the commuter population in the analysis. I found that Entergy's population estimate for 2010 already exceeded the 2010 Census by 326,878 people, which more than adequately encompasses the effective commuter population.

Q95. What effect would it have on the Entergy analysis if commuters are included in the population estimate?

A95. [JJ] After reviewing the commuter patterns in the area, in my opinion the effect would not change the conclusions of the SAMA analysis. I first looked at the commuters from within the SAMA area and found that approximately 170,000 people travel from the northern towns and counties around Indian Point, down to the New York City area. I identified about

55,000 residents who commute from New York City to the north more near the Indian Point nuclear power plant. Under the simulated accident conditions, the MACCS2 model will calculate a dose to the 170,000 commuters from the north as though they were at home and closer to the plant. MACCS2 would predict a higher dose than is actually received by these residents because they would be farther away at work. This provides some conservatism in the Entergy analysis.

I then looked at commuters who enter into the SAMA area from areas beyond the SAMA boundary. I reviewed the commuters column of Table 1, prepared by Dr. Sheppard (Ex. NYS000209 at 8) and reviewed his process of using county-to-county commuter flows and apportioning these by percent of commuters and percent of county within the SAMA area. This was necessary because some counties straddle the SAMA perimeter. I agreed with Dr. Sheppard's process using the county-to-county data to establish a baseline value of total people who enter the SAMA area, but I do not agree that these would all be defined as commuters for use in the consequence model. Dr. Sheppard did not acknowledge that the county-to-county data includes both commuters and business travelers. This is evident because the data shows commuters from as far away as California, Hawaii, and Alaska, and these 'commuters' would have to overnight in SAMA area. In the Entergy analysis, these would be considered business travelers and this population is already considered in the SAMA analysis. Therefore, only a portion of Dr. Sheppard's total value in his Table 1 should actually be considered commuters. Sheppard's Table 1 shows a total of 995,778 commuters enter the SAMA area to work and lists the county within the SAMA area in which they work (Ex. NYS000209 at 8).

I then considered the potential for an impact on commuters from an accident at Indian Point. This required some review because commuters are only in the SAMA area for about one-third of a day and most work a typical Monday through Friday workweek. I initially looked at the New York City area which is the location of the largest number of the commuters identified in Table 1. The northern edge of New York City is located a radial distance of about 24 miles from Indian Point and the southern tip of Manhattan is located a radial distance of about 40 miles from Indian Point.

Assuming a wind speed of 5 miles per hour, it would take up to 5 hours to reach parts of New York City and about 8 hours before it would have passed over the city. Considering that eight hours is a typical work day, this leaves a small time window for commuters to actually remain in the area while a plume is passing over.

Under a worst case scenario, which is not the intent of this analysis, commuters would remain in the city for the work day. By definition, these commuters are workers, so we would assume they are indoors for most of the workday. Therefore, if they were to arrive at work precisely when the plume is passing over and remain at work throughout the day, the largest effect would be the dose they may receive while working in a building. The level of shielding the building provides would be expected to reduce the dose to these commuters.

It is much more likely that in the event of an accident at Indian Point, and news that a plume is travelling down the Hudson River Valley, the commuters would not go to work or that they would go home directly after work prior to arrival of any contamination in the area. It is important to note that most of the Entergy source terms included in the SAMA analysis do not result in contamination in the New York City area.

I also considered the location of commuters within the SAMA area to determine whether it would be reasonable for them to go home in a timely manner. Using Table 1 provided by Dr. Sheppard, I developed a list of counties that lie within approximately 20 miles of the SAMA boundary. The 20-mile distance is arbitrary but is only intended to help quantify the number of commuters with a relatively short commute out of the SAMA area.

Table 4: Number of commuters within about 20 miles of the SAMA boundary.

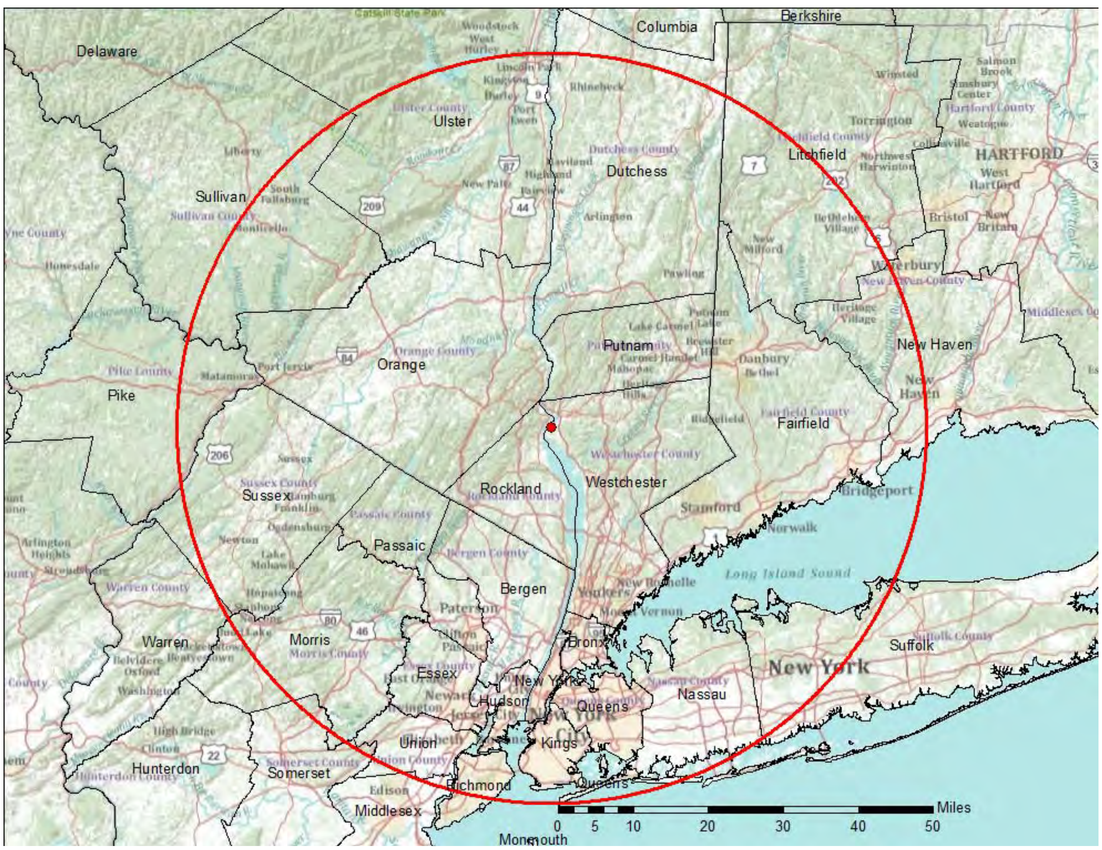
County	Commuters

Litchfield	20,633
New Haven	85,165
Essex	62,809
Hudson	30,913
Middlesex	7,739
Morris	83,176
Somerset	9,169
Sussex	9,762
Union	69,446
Kings	34,740
Nassau	78,710
New York	154,793
Queens	47,269
Richmond	37,816
Suffolk	87,491
Sullivan	6,724
Pike	2,503
Total	828,858

As indicated in Table 4, there are more than 800,000 commuters that work within about 20 miles of the SAMA boundary (many of which are business travelers for which Dr. Sheppard did not separately account). It is reasonable to expect these daily commuters would either not come into work, or go home at the end of the work day with little potential for exposure. If we assume that Dr. Sheppard's values are inflated by 25% for business travelers, we can use a value of about 600,000 for commuters that work within about 20 miles of the SAMA boundary.

The counties identified in italics in Table 4 are located in areas away from the Hudson River Valley and have a commuter population of 371,661 developed from the initial values provided by Dr. Sheppard which include business travelers. Reducing this by the assumed 25% business travelers results in 278,746 commuters not located within the dominant plume exposure pathway. This is of interest because the wind directions identified in Figure 2 of NYS Initial Statement of Position, which was a graphic prepared by Sandia, show the prevailing wind traveling northerly or southerly generally following the Hudson River Valley. (Ex. NYS000206). For those commuters not located in the plume areas, the likelihood of receiving any measurable dose is further reduced and thus would not affect the conclusions of the SAMA analysis. I concluded that of the 1 million commuters that the NYS contends were not addressed, the the vast majority of are located outside of the dominant plume exposure pathway or are located near the SAMA boundary and could very reasonably just go home prior to plume arrival if they happen to be at work when a plume began releasing from Indian Point. The locations of the counties identified above are depicted in Figure 5 below, typically along the periphery of the SAMA boundary.

Figure 5. Region within 50 miles of IPEC (From the report of Dr. Stephen C. Sheppard (NYS000209 at 3))



I then considered what cost might be incurred if commuters did receive some dose. As explained earlier by Dr. Bixler, five types of consequences are considered in a SAMA analysis including: (1) the monetary value of occupational doses to decontamination workers; (2) onsite decontamination costs; (3) the cost to replace lost power; (4) offsite economic costs associated with evacuation and relocation of the population, decontamination of property, loss of use of property, and condemnation of property; and (5) a monetary value associated with doses to members of the public. These five types of costs are added together to get the total cost that would result if an accident occurred. The only one of these five cost elements that would apply to commuters is the monetary value associated with doses to members of the public. This cost element would not be applied to the full 1 million persons, because as I described earlier, some of this population are business travelers double counted by Dr. Sheppard, and it is very likely actual commuters will either stay home, will have returned home at the end of the workday prior to plume arrival, or are not located along the plume path, reducing the potential for receiving dose. For the small percent of these commuters who must be at work, possibly due to job responsibilities, in my opinion, the amount of dose received, and corresponding cost of that dose would not materially affect the results of the SAMA analysis.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
ENTERGY NUCLEAR OPERATIONS, INC.	)	Docket Nos. 50-247/286-LR
	)	
(Indian Point Nuclear Generating	)	
Units 2 and 3)	)	

AFFIDAVIT OF NATHAN E. BIXLER

I, Nathan E. Bixler, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Executed in Accord with 10 CFR 2.304(d).
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Dated at Rockville, Maryland
this 29th day of March 2012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
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(Indian Point Nuclear Generating	)	
Units 2 and 3)	)	

AFFIDAVIT OF S. TINA GHOSH

I, S. Tina Ghosh, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

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Dated at Rockville, Maryland
this 29th day of March 2012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
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	)	
(Indian Point Nuclear Generating Units 2 and 3)	)	

AFFIDAVIT OF JOSEPH A. JONES

I, Joseph A. Jones, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Executed in Accord with 10 CFR 2.304(d).
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this 29th day of March 2012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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Units 2 and 3)	)	

AFFIDAVIT OF DONALD G. HARRISON

I, Donald G. Harrison, do hereby declare under penalty of perjury that my statements in the foregoing testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Executed in Accord with 10 CFR 2.304(d).
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Dated at Rockville, Maryland
this 29th day of March 2012