UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In re: License Renewal Application Submitted By Entergy Indian Point 2, LLC, Entergy Indian Point 3, LLC, and Entergy Nuclear Operations, Inc.	Docket Nos. 50-247LR and 50-286LR ASLB No. 07-858-03-LR-BD01 DPR-26, DPR-64

DECLARATION OF BRUCE A. EGAN, SC.D.

1. I am president of Egan Environmental Inc., an environmental consulting firm in Beverly, Massachusetts. My education and professional experience are summarized in the attached curriculum vitae (Exhibit 1) and are described in detail below, with an emphasis on my experience that is directly relevant to the air dispersion modeling of a radioactive release from the Indian Point Power Station.

2. As I explain in this declaration, there is no material dispute in the scientific community or within the NRC itself that ATMOS cannot accurately predict the dispersion and concentration of a release of radionuclides from the complex terrain in which the Indian Point Power Station is located.

CURRICULUM VITAE

3. I earned an A.B. degree from Harvard College in 1961 and an S.M. degree in Engineering and Applied Physics from the Harvard Graduate School of

Arts and Sciences in 1962 where I specialized in Fluid Dynamics and Thermodynamics. After completing that degree in 1962, I became the Engineer-in-Charge of the Mechanical Engineering Undergraduate Instructional Laboratory at the Harvard University Division of Engineering and Applied Physics. My primary focus was designing and supervising the construction of new experiments and apparatus in fluid dynamics and thermodynamics for student use.

4. In 1964, my former advisor, Professor Arthur Bryson, hired me as Staff Engineer and then Associate Director of the National Committee for Fluid Mechanics Films (NCFMF). The NCFMF was producing 30-minute feature educational films with sponsorship from the National Science Foundation at the Education Development Corporation. At the NCFMF, I worked with several world renowned fluid dynamicists, the Film Principals, to design and develop experiments and methods for visualizing a variety of complex fluid flow phenomena. I became very interested in air pollution transport issues while working on films entitled 'Stratified Flows' and 'Turbulence'. Utilizing my fluid dynamics background, I also taught a course entitled 'Applied Aerodynamics' at Boston University for two semesters in 1966 and 1967.

5. When the NCFMF project ended in 1968, I enrolled at the Division of Environmental Health Sciences at the Harvard School of Public Health (HSPH) to further my education in air pollution. At the HSPH, I took courses including Physiology, Biostatistics, Epidemiology, Air Pollution Control, Air Pollution Meteorology, and Operations Research.

6. I earned a second Masters of Science degree (S.M. in Industrial Hygiene) in 1969 and earned a Doctorate of Science (Sc.D. 1972) in Environmental Health Sciences. My thesis was entitled Numerical Modeling of Urban Air Pollution Transport Phenomena. To support this thesis topic, I cross registered with the Meteorology Department at the Massachusetts Institute of Technology upon the advice of my thesis advisor, Dr. James R. Mahoney, where I took additional courses in Air Pollution Meteorology and Dynamical Meteorology.

7. For my thesis, I developed an innovative way to solve the advection and diffusion transport equations over an Eulerian grid which dramatically reduced the unwanted pseudo diffusion which was numerically introduced by finite difference methods. The method, known as the 'second moment method' was published in the AMS Journal of Applied Meteorology. (Egan and Mahoney, 1972a, 1972b) The moment method was used, improved upon, and extended to other applications by researchers internationally (Pedersen and Prahm, 1974; Nordo, 1974; Sykes and Henn, 1992; Kerr and Blumberg, 1992; Ghods et al., 2000).and has been extended to other fluid dynamics applications including oceanographic transport (Chu and Altai, 2001).

8. Upon passing my doctoral dissertation exam, I joined the environmental consulting company, Environmental Research and Technology Inc. that Dr. Mahoney had co-founded. As the company grew and changed names to ERT and then ENSR, over a period of 22 years, I advanced to the position of Senior Vice President and Chief Scientist.

9. Some of my early industrial work at ERT was associated with dispersion modeling of air pollution associated with smelters, paper mills and power plants located in complex, mountainous terrain. That work led the American Meteorological Society (AMS) to invite me to write a state of the art position paper on this subject for a workshop the AMS was holding on air pollution and environmental impact analyses (Egan, 1975).

10. I also managed a project to develop a site specific dispersion model for the Luke Mill, a large paper mill located in a river valley in complex terrain. The model development and validation effort required by this effort relied upon an extensive air quality monitoring program involving measurements of air pollution concentrations at various locations in high terrain together with meteorological data from towers based in the valley bottom and at a high point in the surrounding terrain. The study results illustrated the importance of appropriate meteorological measurements and appropriate model formulations to understand the impact of releases from sources in complex terrain. The project included an extensive model verification effort (Hanna, et al., 1984). The Luke Mill Model was used to establish emission limits on the paper mill for an EPA-required revision to the State of Maryland Clean Air Act State Implementation Plan. It was a predecessor to the RTDM model (Egan and Paine, 1986) which was later recommended by EPA for certain screening model applications (EPA, 2000).

11. As a result of controversies associated with dispersion modeling methods for energy development projects located in the western United States, the

United States Environmental Protection Agency (USEPA) requested proposals for the development and verification of a dispersion modeling method for use in the permitting of sources of air pollution located in complex terrain settings. ERT was awarded that project and I became the Project Director of the Complex Terrain Model Development project (CTMD) (Schiermeier, et al., 1983). The model was developed for use in stable atmospheric conditions (Venkatram et al., 1982) and required field studies to be performed during nighttime hours when the atmosphere is generally most stable.

12. Field experiments were performed at three different locations with different terrain geometries: an isolated hill, Cinder Cone Butte (Lavery et al., 1982), in south east Idaho, a long ridge (The Hogback) in the Four Corners area of New Mexico and a Full Scale Plume Study at the Tracy power plant in the Truckee River Valley east of Reno, Nevada (Lavery et al., 1983, NASA, 2005). Scale model laboratory experiments were also conducted by the EPA's fluid modeling facilities to provide data to verify the model trajectory parameters utilized (Snyder et al., 1985). The CTMD project study resulted in the development and verification of the Complex Terrain Dispersion Model (CTDM) (EPA, 1987; Paine et al., 1987) and later the CTDM PLUS model (Perry, et al. 1992). These models are based upon algorithms that calculate the detailed deformation, trajectories, and ground level concentrations of plumes that pass close to and around or above terrain features (Perry et al., 1992). The statistical performances of CTDM and CTDM PLUS were extensively validated with field data from several complex terrain sites. (Paumier et

al., 1990) and these models became the preferred refined EPA Guideline models for complex terrain settings (EPA, 2003). These models were recently replaced by AERMOD (described below). As a result of the CTMD model development and validation efforts, I was asked to write another review of the science of modeling in complex terrain for an international conference. (Egan, 1984)

13. I formed my own consulting company in 1998 and have continued with a specialty of modeling in complex terrain (Egan and Snyder, 2002; Egan and Murphy, 2007). In 2000, I performed an analysis for the PG&E National Energy Group of the effects of down slope winds from mountains near the Palo Verde Nuclear Generating Station (Palo Verde) near Tonopah, Arizona. The purpose of the analysis was to determine under what meteorological conditions the high terrain of a mountain between the meteorological tower at the Palo Verde site and the site of a proposed conventional power plant would interfere with the reliability of the meteorological data from the Palo Verde tower compared to data from a lower tower which was closer to the proposed plant. I provided recommendations based upon a review of several years of meteorological data. I have also worked more generally in complicated topographic and meteorological settings such as near building complexes using AERMOD and other advanced models. (Hanna, et al., 2000)

14. In 2002, for the Massachusetts Department of Public Health, I led a project and collaborated with other scientists and meteorologists from Pennsylvania State University, to develop a dispersion modeling capability for calculating the impact of releases from sources that may be affected by sea breeze circulations.

(Egan et al., 2002). That effort was based upon the application of a mesoscale meteorological model, MM5, that uses fundamental dynamical equations and parameterizations to develop complex and evolving meteorological predictions. (Seaman et al., 2002). The wind fields and dispersion parameters calculated with MM5 are used in conjunction with appropriate dispersion models, including CALPUFF and SCI PUFF to calculate time and spatially varying ambient air concentration values over a computational grid. I co-authored another review of dispersion modeling in complex terrain in 2001. (Egan and Snyder, 2001)

15. I have also performed accident and consequence analyses for risk management plans and modeling for both hypothetical and actual accidental release scenarios. I am the co-author of a book about compliance with USEPA's Risk Management Program under the Clean Air Act. (Egan and Heinold, 1997)

16. I have been an active member of the American Meteorological Society (AMS) for over thirty-five years and have served on its committees relating to air pollution and meteorology. I am a Certified Consulting Meteorologist. I am an elected Fellow of the AMS.

17. I have been a member of the Air and Waste Management Association for over 30 years, have continuously served on their meteorology committee and chaired a joint conference for the AMS and the AWMA on Meteorological Aspects of Air Pollution.

THE SCIENCE OF ATMOSPHERIC DISPERSION MODELING

18. Atmospheric dispersion modeling is the field of predicting the fate and the consequences of releases of contaminants into the atmosphere. Dispersion models are routinely used for determining compliance with ambient air quality regulations by state and federal environmental agencies, including assessing the incremental changes in air quality levels associated with the permitting of new facilities and for health risk assessments for nuclear energy facilities. Dispersion models use meteorological and emission rate information as inputs to mathematical algorithms that simulate the transport and dispersion of air pollutants. Dispersion models can estimate the ambient air concentrations, deposition rates of particles to ground surfaces at all places of interest and for different averaging times. Models can include chemical or nuclear atmospheric transformation algorithms to estimate dosages to exposed populations.

19. It is critical that the meteorological input data be representative of the air flow conditions between the source area and the locations of interest where air pollutant concentrations are being calculated. For example, if the purpose of the modeling is to predict the locations of higher pollutant concentrations, as in health risk assessment applications, the reliability of the model for that purpose is very sensitive to the wind directions input. If inaccurate wind direction data is put into the model, it may inaccurately predict high concentrations in the wrong locations, and far away from the actual locations of the populations at risk. The model's

reliability is thus crucial to decision-makers in environmental or public health and safety positions.

20. Another important factor in modeling is the presence or absence of high terrain in the study area. The presence of high terrain introduces several complicating factors into dispersion analyses. First, the presence of high terrain distorts and changes the directions of approaching winds because the flow cannot pass through the terrain. The distortion of the flow direction materially changes the downwind destination of pollutants emitted into the airflow and, for elevated stack emissions, reduces the distance of plume material to the ground surface generally increasing the ground level concentrations.

21. As described further below, the presence of valley sidewalls together with radiational cooling will cause drainage flows that further distort air flow directions.

22. The reasons that the straight line Gaussian model does not accurately predict air dispersion in complex terrain are fundamentally related to these multiple effects that the presence of high terrain has on altering the air flow dynamics.

23. The presence of high terrain may also degrade the ability of a single meteorological station to accurately represent the transport wind speed and direction that must be put in the model, especially for longer distance transport calculations. This is because wind directions measured near the surface will vary with location. The effect is most pronounced during the lighter wind and stable

atmospheric conditions that occur at night. This can be remedied by placing anemometers at higher elevations and by the use of multiple sources of meteorological data to provide information of the spatial variations of the wind.

24. Different models can be used depending upon the application and regulatory requirements. For example, EPA recommends simple screening models (EPA, SCREEN3, or CTSCREEN) that are structured to provide conservative concentration estimates for simple pass or fail determinations. If the estimates fail the test, i.e., if the concentrations are too high for regulatory compliance, the modeler would have an option of using a more refined model and more appropriate meteorological input data in further analyses. But even these screening models must be appropriate for the terrain in which the source is located. SCREEN3 is appropriate for sources located in flat terrain. CTSCREEN is appropriate for complex terrain. Where the goal is to ascertain the total amount of a pollutant to which a population would be exposed in the event of a release and the population density varies depending upon the direction and distance the plume takes following the release, screening technologies would be inappropriate because they could not provide a reliable upper limit exposure value without artificially assuming that all the released pollution reached the areas of highest population.

25. Where the purpose of the air dispersion model is to predict the actual exposure of individuals in the path of the pollutant plume in order to assign a monetary cost to the full extent of the potential health risk, and then to quantify in monetary terms the cost savings that can be achieved by mitigating that exposure,

the air dispersion model must have a high degree of accuracy to avoid either understating or overstating the economic costs and benefits involved.

26. The need for accuracy in the predictive model is particularly important where the number of individuals who could be exposed to the pollutant, and the level and duration of the exposure is greatly affected by the actual path of the pollutant plume once it is released from the source.

27. The need for accuracy in the predictive model is also particularly important where the economic costs of mitigation measures and the economic benefits of mitigation measures are fairly close, such as within a factor of 2 of each other.

28. Generally, the selection of a dispersion model depends critically upon the complexity of the meteorology and terrain influencing a release from a source and at what downwind distances reliable concentration projections are needed. In flat terrain settings with homogeneous surface characteristics (e.g., surface roughness, albedo and Bowen ratio) and relatively evenly distributed populations of interest, the simple straight-line Gaussian plume model algorithm is often appropriate. The Industrial Source Complex (ISC3ST) model (a Gaussian plume model) was used for such permitting applications by EPA until it was replaced by AERMOD (EPA, 2005). However, even ISC3ST was not deemed suitable for calculating concentrations on terrain elevations above the height of the source. This limitation was the reason that EPA sought the development of models appropriate for complex terrain settings. After the CTMD project, for sources located in complex

terrain (defined by EPA as in terrain that exceeded the height of release (EPA, 2003, p18452)), EPA's Guideline recommended the use of complex terrain screening models or the preferred refined model CTDM-PLUS (EPA, 2003, p18453). The adoption of AERMOD as a refined model (EPA, 2005) (70 F.R. 68218 (November 9, 2005) and now codified in 40 C.F.R. Part 51, Appendix W) for both simple (flat) and complex terrain settings obviated the need for separate refined dispersion models.

29. AERMOD was developed for applications within 50 Km (about 31 Miles) of a source. (Cimorelli, et al., 2005). AERMOD was developed after more than a decade of efforts of many researchers to incorporate the greatly advanced understanding of boundary layer meteorology into the dispersion algorithms that were available when the Gaussian plume model was parameterized by Pasquill and Gifford. (Pasquill, 1961; Gifford, 1961). *See* ¶¶ 22 – 26 of my November 27, 2007 Declaration, annexed to this declaration as Exhibit 2, for a fuller discussion of boundary layer meteorology. Further, the AERMOD model was subjected to extensive statistical model evaluations in a variety of terrain settings. (Perry et al., 2005). These efforts showed that AERMOD represented a major improvement over the ISC3ST and other models.

30. The CALPUFF model is appropriate for simulating transport and dispersion in wind fields that change with space and time. Scire, et al., 2000a. It is often coupled to CALMET (Scire, et al., 2000b), a model that computes the needed wind and dispersion fields from meteorological data. CALPUFF may also be coupled to a full mesoscale meteorological flow model such as MM5. CALPUFF also

has benefited from advances in the parameterization of wind fields and turbulent dispersion over the past four decades. CALPUFF is routinely used in both simple and complex terrain settings to estimate ambient air concentrations at distances beyond the recommended 50 kilometer upper limit of AERMOD (EPA, 2005). The air flow fields used by CALPUFF generally use data from more than one meteorological station in order to estimate concentrations at large distances from a source. Straight line Gaussian plume models, like ATMOS, do not have the capability to simultaneously use meteorological data from several different sources.

THE TERRAIN WITHIN WHICH THE INDIAN POINT POWER STATION IS LOCATED AND ITS VARYING POPULATION DENSITY

31. The Indian Point Nuclear Power Station (the "Indian Point Station") is located in the Village of Buchanan in the northwest corner of Westchester County on the eastern bank of the Hudson River. The Indian Point reactors and spent fuel pools are approximately 24 miles north of the New York City line, and approximately 37 miles north of Wall Street, in lower Manhattan. *Draft Supplemental Environmental Impact Statement,* Draft NUREG-1437, Supplement 38 ("DSEIS") at page 2-1. The station is approximately 3 miles southwest of Peekskill, with a population of 22,441, 5 miles northeast of Haverstraw, with a population of 33,811, 16 miles southeast of Newburgh, with a population of 31,400, and 17 miles northwest of White Plains, with a population of 52,802. It is also 23 miles northwest of Greenwich, Connecticut, 37 miles west of Bridgeport, Connecticut and 37-39 miles north northeast of Jersey City and Newark, New Jersey. Portions of four counties – Westchester, Rockland, Orange, and Putnam –

fall within the inner 10-mile Emergency Planning Zone, and significant population centers in New York, Connecticut, and New Jersey lie within the 50 mile Emergency Planning Zone. DSEIS at 2-1. The U.S. Census Bureau estimated that New York City, located approximately 24 miles south of plant, had a population of 8,214,426 in 2006. DSEIS at 2-1. The total estimated population within a 50 mile radius of the Indian Point Station is more than 17 million. DSEIS at 2-3, Figure 2-1.

32. The Indian Point Station is on a point of land in the Hudson River valley that protrudes into the Hudson River as the river bends west. The region surrounding the Indian Point site has many peaks and valleys. DSEIS at 2-2. On the west side of the Hudson River, one mile north of the station, is Dunderberg Mountain. This mountain rises to a height of 1086 feet above sea level at a distance of approximately 2.5 miles from the station. North of the Indian Point Station, the eastern bank of the river is formed by high grounds reaching an elevation of 800 feet; to the west across the river, the Timp Mountains reach an elevation of 844 feet. DSEIS at 2-2.

33. For purposes of categorizing appropriate air dispersion models for regulatory applications, EPA defines complex terrain as "terrain exceeding the height of the stack being modeled." (EPA, 2003, pages 18452-18453) The Indian Point Station is located in a complex terrain. Releases from the station may come from near ground level sources or from stack vents with heights up to 334 feet and within 1-2 miles of high terrain features on the opposite side of the Hudson River,

such as Dunderberg and the Timp Mountains, that rise to heights greater than 800 feet and are well above the facility and well above the top of the 122 meter (400 feet) meteorological tower located onsite.

34. Attached as Exhibit 3 are two quadrangle maps prepared by the United States Department of the Interior Geological Survey for the Peekskill and Haverstraw quadrangles. These quadrangle maps contain topographic information and depict the complex terrain in the vicinity of the Indian Point Station, and enable a better visualization of the features that affect the dispersion of a release from the Station. Note that the Indian Point Station is located in a turning part of the Hudson River. The high terrain of Dunderberg Mountain to the west will distort and turn winds which might be measured to be from the east at the anemometer at the primary tower location. Even though the Hudson is still tidal at this location, under overall light wind conditions the net average downstream movement of the river water and the effects of drainage induced airflows will favor the downriver movement of air above and near the river surface (UFSAR Indian Point Unit 3 at Paragraph 2.5, p. 68). The presence of the moving river water surface adds an additional complexity to the air flows near the Indian Point Station. Also attached as Exhibit 3 is a less detailed map included in the DSEIS at Figure 2-9; this DSEIS map does not fully reflect the surrounding topography or the turns in the river.

The ATMOS Air Dispersion Model is Scientifically Unreliable for Use at the Terrain in Which Indian Point Is Located

35. ATMOS is a steady-state straight line Gaussian plume model which assumes that any emissions from the Indian Point Station are imbedded in an air mass having a single wind speed that flows for each period of simulation in a single straight line direction. The atmospheric stability classification is also assumed to be constant over that time period. Thus each simulation will predict that the pollutants will theoretically travel in a straight line to infinity or to the limits of the computational domain, regardless of topographical features that might render such a trajectory impossible.

36. The concentrations of contaminants within the plume are assumed to have a maximum value along the plume centerline and to fall off in a bell shaped, Gaussian distribution curve with distance away from the plume centerline.

37. The simplicity of the ATMOS model's assumptions are scientifically unreliable for use in the terrain in which Indian Point is embedded and the model therefore cannot accurately predict the geographic dispersion and concentration of a radionuclide release from that site.

38. From a meteorological air flow perspective, the presence of the river, nearby terrain features and non-homogeneous ground surface features all affect the overall air flow patterns, which in turn affect the rates of vertical and horizontal mixing of any pollutants released from the plant. Because there are nearby mountains that are higher than the meteorological tower at the Indian Point Plant, ATMOS, which can only use one meteorological source at a time, cannot predict the

wind speed and direction accurately from the meteorological data measured by that tower because wind speeds and directions in the valley are unlikely to be representative of the larger scale flow patterns that carry contaminants from the plant to the surrounding areas. It is important that atmospheric dispersion modeling of the effluents from the plant consider these factors in order to provide a reliable basis for estimating ground level concentrations and corresponding estimates of potential exposures to the surrounding population.

39. There are several effects of the terrain at Indian Point on air flow patterns, which cannot be accounted for by the ATMOS model. First is the deflection of the flow by the high terrain features. In the case of high terrain features across the river from Indian Point, air flow from the east will either turn and pass along the side of the mountain or rise over the mountain, depending upon atmospheric stability conditions. (Snyder, et al., 1985). Therefore, air pollution released from Indian Point and embedded in the air flow will not take the straight line trajectory across the river valley that would be predicted by the ATMOS model using data from the Indian Point meteorological tower. Under the more stable atmospheric conditions associated with greater ground level impacts, the plume is likely to be turned down the overall river valley as it cannot pass through the terrain.

40. A second effect of mountainous terrain on sources located in river valleys, such as Indian Point, is the creation of drainage flows by the presence of the valley side walls. For example, at night when the earth's surface cools by radiating

its heat upward, the air in contact with the surface cools. Because it is heavier than other air at that elevation, it flows under the forces of gravity down the valley slopes toward the base of the valley. In the absence of other influences, the pooling of the heavier air at the low point of the valley cross section causes that air to tend to flow downriver following the valley contours.

41. Meteorological models that incorporate effects of topography will simulate the phenomenon of valley sidewalls tending to channel air within the confines of the valley flows to follow the valley contours. Nighttime drainage flows in river valleys will tend to stay within the valley and flow in the same direction as the river itself.

42. A straight line Gaussian plume model cannot account for these phenomena, which could cause a night time radionuclide release to travel downriver towards the most populous areas in the fifty mile radius around Indian Point, including New York City and its surrounding suburbs – an area including approximately 17,000,000 people.

THE NRC, OTHER GOVERNMENT AGENCIES AND THE AIR DISPERSION MODELING COMMUNITY AGREE THAT STRAIGHT LINE GAUSSIAN PLUME MODELS CANNOT ACCOUNT FOR THE EFFECTS OF COMPLEX TERRAIN ON THE DISPERSION OF POLLUTANTS FROM A SOURCE

43. The NRC, in a 2009 Presentation to the National Radiological Emergency Planning Conference (NRC 2009 Presentation) concluded that straight-line Gaussian plume models cannot accurately predict dispersion in a complex terrain such as the Indian Point site and are therefore scientifically defective for that purpose. In fact, the NRC 2009 Presentation supports the criticisms I set forth

here and in my previous declaration. The relevant portion of this presentation is annexed to this declaration at Exhibit 4; the full presentation is available at ML091050226, ML091050257, and ML091050269 (page references used here refer to the portion attached, Part 2, ML091050257).

44. The NRC, in its 2009 Presentation, states that the "most limiting aspect" of the basic Gaussian Model, is its "inability to evaluate spatial and temporal differences in model inputs." Slide 28. Because ATMOS is non-spatial, it cannot account for the effect of terrain on the trajectory of the plume – that is, the plume is assumed to travel in a straight line regardless of the surrounding terrain. Therefore, it cannot, for example, "'curve' a plume around mountains or follow a river valley." NRC 2009 Presentation, Slide 33. However, Indian Point is located in the Hudson River Valley, and if meteorological conditions caused the plume to follow the valley downriver, radionuclides from the release would approach and perhaps reach, the most populated areas in the fifty mile radius around the plant.

45. The NRC 2009 Presentation also acknowledges the "gravity drainage" phenomenon I described above that could cause the plume to travel downriver towards New York City from a valley site such as Indian Point. As Slide 46 explains, the air in a valley is not heated directly by the sun but by heat convection from the earth. At night the earth cools and because higher elevations cool faster, cool air flows toward warmer air in the valley. This flow is described by the NRC as "gravity drainage," and in the absence of other meteorological influences (such as high wind speeds), the drainage will tend to flow downriver. Slide 46.

46. In its introduction to a discussion of advanced air dispersion models, the NRC 2009 Presentation summed up the Gaussian model's inability to project dispersion in a complex terrain:

> In many Gaussian models, terrain height is addressed only in determining the effective plume height.
>
> The impact of terrain on plume transport is not addressed.
>
> Straight-line models can not "curve" a plume around mountains or follow a river valley.
>
> NRC 2009 Presentation, Slide 33.

All of the above limitations apply to the ATMOS model. Significantly, the NRC 2009 Presentation then discussed the methods of more advanced models that *can* address terrain impact on plume transport, including models in which emissions from a source are released as a series of puffs, each of which can be carried separately by the wind, (NRC 2009 Presentation Slides 35, 36). This modeling method is similar to CALPUFF, which I describe above and in my earlier declaration (paragraphs 46, 47) as a model that could accurately predict the dispersion of radionuclides from a site such as Indian Point.

47. Puff type models simulate steady emissions rates as a series of separate "puffs" released over a time period so that the total quantity of the emissions is the same as if the release were steady. The individual puffs are then advected horizontally and diffuse across the modeling domain with the wind field. The concentration dosage received at any specific location is calculated by the sum of the exposures to each of the individual puffs. If a terrain feature causes the wind

to turn, then the puffs will follow that change in wind direction, and the model will thereby provide a much more realistic simulation of the actual trajectories of the contamination.

48. Indeed, even in an NRC research paper that shows small differences in outcome between a Gaussian, a two-dimensional and a three-dimensional model, a strong caveat is added about the use of simple straight line Gaussian models in complex terrain. This paper was prepared for the NRC in 2004 by the Lawrence Livermore Laboratory "to determine if the average ATD [Air Transport Dispersion] resulting from these codes are sufficiently close that more complex models are not required . . . or different enough that one or both of the NRC codes should be modified to provide more rigorous ATD." *Comparison of Average Transport and Dispersion Among a Gaussian, A Two- Dimensional and a Three-Dimensional Model*, Lawrence Livermore National Laboratory, October, 2004 at 2. ("Livermore Report") [1] (Ex. 5).

49. The site chosen for the study was the Department of Energy's Atmospheric Radiation Measurement Program Southern Great Plains Site in central Oklahoma and Kansas. The topography of Oklahoma and Kansas is relatively smooth, has minimal affect on the wind field, and the surface is fairly uniform and therefore produces relatively little thermal forcing." Livermore Report at 3. Although the authors "would have preferred a site with greater topographical and diurnal heterogeneity," the central Oklahoma and Kansas site was chosen as

[1] The study authors did not reach a judgment on this question but left it to the NRC to decide what to do with the study results. Livermore Report.

the only area with multiple wind and temperature measurements over a one year period." Livermore Report, Executive Summary at xi.

50. A significant caveat was added to the Report's summary about the scientific reliability of the use of ATMOS in complex terrains:

> . . .[T]his study was performed in an area with smooth or favorable terrain and persistent winds although with structure in the form of low-level nocturnal jets and severe storms. In regions with *complex terrain*, particularly if the surface wind direction changes with height, *caution should be used.* Livermore Report at 72. (emphasis added)

Thus, the Livermore Laboratory study supports the NRC 2009 Presentation and New York State's position that more advanced models than ATMOS should be used to accurately predict dispersion in complex terrains. [2]

51. As early as 1977 NRC began to question the feasibility of using straight line Gaussian plume models for complex terrain. *See* U.S.NRC, 1977, Draft for Comment Reg. Guide 1.111 at 1c (pages 1.111-9 to 1.111-10)(Ex. 6).

52. More recently, the NRC revised their Regulatory Guide 1.23, Meteorological Monitoring Programs for Nuclear Power Plants (US NRC, 2007). This document is attached as Exhibit 13. Regulatory Guide 1.23 recognizes the important relationship between meteorological measurements and atmospheric

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[2] It should be noted that a number of features of the Lawrence Livermore study make it inappropriate as a test of the reliability of the ATMOS model use at the Indian Point site for purposes of the SAMA analysis. First, the terrain used for the study is not complex, a feature which is the critical difference between Indian Point and other sites and is the critical feature that ATMOS is unable to address. Second, the study produced only annual averages which tends to smooth out the variations that occur during more discrete 24 hour events, which are the focus of the SAMA analysis. Third, while the report does not reject or endorse the ATMOS model for any particular NRC use, it does note that the variation between ATMOS and more sophisticated models was close to, or in excess of a factor of two, a difference that could be critically important in deciding whether to implement a particular mitigation measure.

dispersion modeling by stating in the Introduction on page 3, "Thus, each nuclear power plant has multiple needs for an onsite program to measure and document basic meteorological information. These data may be used to develop atmospheric transport and diffusion parameters that with *appropriate* (emphasis added) atmospheric dispersion models, may be used to estimate potential radiation doses to the public resulting from actual routine or accidental releases of radioactive materials to the atmosphere or to evaluate the potential dose to the public and control room as a result of hypothetical reactor accidents....This regulatory guide describes a suitable onsite program to provide meteorological data to estimate these impacts."

53. On pages 4 and 5, Regulatory Guide 1.23 states that the program should be capable of providing the meteorological information needed to make several assessments including: "a realistic assessment by both the applicant and the regulatory staff of the potential dispersion of radioactive materials from, and the radiological consequences of, a spectrum of accidents to aid in evaluating the environmental risk posed by a nuclear power plant in accordance with Subpart A to 10 CFR Part 51." On page 11, the section entitled *Special Considerations for Complex Terrain Sites* states that the program "should provide an adequate basis for atmospheric transport and diffusion estimates ... [within 8 kilometers (5 miles) in each downwind sector]" (brackets in original) and mentions special "complex flow patterns in nonuniform terrain" and "circulation for a hill-valley complex or a site near a large body of water." Regulatory Guide 1.23, Ex. 13, at 11. The Regulatory

Guide also states that "The plant's operational meteorological monitoring program should provide an adequate basis for atmospheric transport *estimates* [emphasis added] within the plume exposure emergency planning zone [i.e., within approximately 16 kilometers (10 miles)]." Regulatory Guide 1.23, at 11. These excerpts from Regulatory Guide 1.23 demonstrate that the NRC recognizes there are certain sites, such as Indian Point, where multiple meteorological data input sources are needed for appropriate air dispersion modeling. Since, for the reasons discussed above, ATMOS is incapable of handling complex flow patterns and meteorological data input from multiple locations, Regulatory Guide 1.23 is an NRC recognition that it should not be used at a complex terrain site like Indian Point.

54. There are numerous other acknowledgments from the NRC and the U.S. Department of Energy about the inability of a straight line Gaussian plume model to account for the effects of complex terrain on the dispersion of a pollutant release. In 1996, the NRC acknowledged the inadequacy of simple straight-line Gaussian plume models to predict air transport and dispersion of a pollutant released from a source in a complex terrain when it issued RTM-96, *Response Technical Manual,* which contains simple methods for estimating possible consequences of various radiological accidents. In the glossary of that document, the NRC's definition of "Gaussian plume dispersion model" states that such models have important limitations, including the inability to "deal well with complex terrain." NUREG/BR-0150, Vol.1 Rev.4, Section Q; ADAMS Accession Number ML062560259, attached as Exhibit 7.

55. In December, 2005, as part of a cooperative program between the governments of the United States and Russia to improve the safety of nuclear power plants designed and built by the former Soviet Union, the NRC issued a Procedures Guide for a Probabilistic Risk Assessment, related to a Russian Nuclear Power Station. The Guide, prepared by the Brookhaven National Laboratory and NRC staff, explained that atmospheric transport of released material is carried out assuming Gaussian plume dispersion, which is "generally valid for flat terrain." However, the Guide contained the caveat that in "specific cases of plant location, such as, for example, a mountainous area or a valley, more detailed dispersion models may have to be considered." *Kalinin VVER-1000 Nuclear power Station Unit 1 PRA, Procedures Guide for a Probabilistic Risk Assessment,* NUREG/CR-6572, Rev. 1 at 3-114; excerpt attached as Exhibit 8, full report available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6572.

56. The U.S. Department of Energy ("USDOE") has also acknowledged problems with the ATMOS simple straight line Gaussian plume model in the MACCS2 Code when used in complex terrain. For example, the Radiation Safety Information Computational Center ("RSICC") of DOE's Oak Ridge National Laboratory has a summary description of the MACCS2 Code in its Code Package CCC-652. Under the heading, Restrictions or Limitations, the RSICC unequivocally states that "the atmospheric model included in the code does not model the impact of terrain effects on atmospheric dispersion." Exhibit 9.

57. In June 2004, the U.S. Department of Energy's Office of Environment, Safety and Health issued a final report entitled *MACCS2 Computer Code, Application Guidance for Documented Safety Analysis.* DOE-EH-4.2.1.4 – MACCS2 Code – Code Guidance (excerpt attached as Ex. 10; full document available at www.hss.energy.gov/nuclearsafety/qa/sqa/central_registry/maccs2/final_maccs2_guidance_report_june_1_2004old.pdf). In Table 2-1, *Summary Description of MACCS2 Code Software*, under the heading Restrictions or Limitations, the Guidance also states that "the atmospheric model included in the Code does not model the impact of terrain effects on atmospheric dispersion nor can it accept more than one weather spatial location." Page 2-5. A separate table 6-1 entitled "Limitations of Gaussian Plume Model in MACCS2 and MACCS," describes the "terrain sensitivity" of the Gaussian plume model as "flat earth to 'gently rolling'" and instructs that "complicated terrain over the region of transport may require Lagrangian particle or other models." Page 6-1. (Exhibit 10).

58. The inability of a simple Gaussian plume model to accurately predict air transport and dispersion in complex terrains is such a basic flaw that it is discussed in a textbook for a college-level introductory course in environmental science and engineering. In listing the assumptions that are made to develop a simple straight line Gaussian plume model, the textbook warns that:

> The equation is to be used over relatively flat, homogeneous terrain. It should not be used routinely in coastal or mountainous areas, in any area where building profiles are highly irregular, or where the plume travels over warm bare soil and then over colder snow or ice-covered surfaces.

Environmental Science and Engineering, J. Glynn Henry & Gary W. Heinke, (Prentice-Hall 1989) at 528 (Chapter 13 authored by William J. Moroz).

59. For over three decades atmospheric scientists and meteorologists have been identifying problems in the use of models similar to ATMOS for complex terrain settings like Indian Point. *See* Hanna et al., 1982 (attached as Ex. 11); Randerson, 1984, section 13-10. Also for several decades, meteorologists have been working to improve the methods and models which would provide much more reliable impact analyses for complex terrain than straight line Gaussian models. I have identified some of those efforts in this declaration.

CONCLUSION

60. In sum, there is a consensus in the scientific community of meteorologists that create and use air dispersion models, and government agencies that rely on them, that a simple straight-line Gaussian plume model, such as ATMOS, is scientifically unreliable when applied to the complex terrain in which the Indian Point power station is located and cannot accurately predict the dispersion and concentrations of radionuclides in a 50 mile radius of the Station. Because of these deficiencies, and because of the wide variations in population density within the 50 mile radius, the DSEIS's SAMA analysis could have grossly underestimated the number of people who would be exposed in a severe accident and the concentration of the doses they would receive. This would, in turn,

underestimate the "cost" of a severe accident and thus the "benefit" of a proposed mitigation measure that would reduce the magnitude of the initial release of radiation from the plant or reduce the probability of the release occurring, or both.

59. Pursuant to 28 U.S.C. § 1746. I declare under penalty of perjury that the foregoing is true and correct.

Executed on

August 28, 2009
Beverly, Massachusetts

Bruce A. Egan
8/28/09

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