UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter Of	)	
	)	
EXELON GENERATION COMPANY, LLC,	)	**Docket No. 50-352-LR**
	)	**Docket No. 50-353-LR**
(Limerick Generating Station)	)	

(License Renewal Application)

DECLARATION OF THOMAS B. COCHRAN, Ph.D., MATTHEW G. MCKINZIE, Ph.D. AND CHRISTOPHER J. WEAVER, Ph.D., ON BEHALF OF THE NATURAL RESOURCES DEFENSE COUNCIL

INTRODUCTION

We, Thomas B. Cochran (TBC), Matthew G. McKinzie (MGM), and Christopher J. Weaver (CJW), declare that the following statements are true and correct to the best of our knowledge.[1]

1. (TBC) My name is Thomas B. Cochran. I received my Ph.D. in Physics from Vanderbilt University in 1967. I am currently a consultant to the Natural Resources Defense Council (NRDC) at its Washington, D.C. office. Prior to retiring from NRDC in 2011, I was a senior scientist and held the Wade Greene Chair for Nuclear Policy at NRDC, and was director of its Nuclear Program until 2007. My curriculum vitae is provided in Attachment A.

2. (MGM) My name is Matthew G. McKinzie. I received my Ph.D. in Physics from the University of Pennsylvania in 1995. I am a Senior Scientist in the Nuclear Program and

[1] This Declaration is presented jointly by all three of us but in some instances discrete points are offered by only one or two of us. Each paragraph is preceded by the initials of the Declarant(s) who are offering the information contained in that paragraph.

the Lands and Wildlife Program at NRDC at its Washington, D.C. office. My curriculum vitae is provided in Attachment B.

3. (CJW) My name is Christopher J. Weaver. I received my Ph.D. in Nuclear Engineering from the University of Texas at Austin in May 2011. I am a Project Scientist in the Nuclear Program and Science Center Fellow at NRDC at its Washington, D.C. office. My curriculum vitae is provided in Attachment C.

4. (TBC, MGM, CJW) On June 22, 2011, the Nuclear Regulatory Commission (NRC) received a License Renewal Application (Exelon, 2011a) for Limerick Generating Station (LGS or "Limerick") Unit 1 and Unit 2 from the licensee, Exelon Generation Company, LLC ("Exelon"). The operating license for Unit 1 currently expires on October 26, 2024, and the operating license for Unit 2 currently expires on June 22, 2029 (Exelon, 2011a). The two nuclear power plant units at Limerick are General Electric Type 4 Boiling Water Reactors (BWR) with Mark II containment structures (Exelon, 2011a). Exelon seeks to extend the operating license of Unit 1 until the year 2044, and Unit 2 until the year 2049 (Exelon, 2011a).

5. (TBC, MGM, CJW) Exelon has submitted an Environmental Report (Exelon, 2011b) in conjunction with its License Renewal Application that does not include a Severe Accident Mitigation Alternatives (SAMA) analysis for Limerick. Exelon, citing 10 CFR 51.53(c)(3)(ii)(L) (Exelon, 2011b), claims that it is not required to prepare a SAMA analysis for License Renewal because the NRC staff had previously considered a Severe Accident Mitigation Design Alternatives (SAMDA) analysis in a Supplement (NRC, 1989) to the Limerick Final Environmental Statement (NRC, 1984). The Limerick Final Environmental Statement (FES) is dated April, 1984, and the Supplement to the Limerick

FES (FES Supplement) is dated August 1989. Exelon adopts the 1989 SAMDA analysis as its SAMA analysis. Nonetheless, in its Environmental Report Exelon does recognize that at least four items of new information bear directly on the validity of the previous SAMDA analysis and offers their view as to why this new information is not significant – i.e. why it does not warrant modifying the 1989 SAMDA analysis results (Exelon, 2011b).

6. (TBC, MGM, CJW) In the context of the environmental review for License Renewal conducted consistent with the National Environmental Policy Act (NEPA), the NRC considers new information significant if it presents a seriously different picture of the environmental impact of the proposed project from what was previously envisioned. We have found that new information in seven areas is plausibly significant: 1) additional SAMA candidates analyzed for BWRs; 2) additional accident scenarios analyzed for BWRs; 3) real world information regarding reactor core damage frequency; 4) population within 50 miles Limerick; 5) economic consequences from accident scenarios at Limerick; 6) evacuation speed assumed during accident scenarios at Limerick; and 7) meteorology at Limerick. Taken individually and especially in combination, this new information would plausibly cause a materially different result in the SAMA analysis for Limerick and render the SAMDA analysis upon which Exelon relies incomplete.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT DO NOT CONSIDER A REASONABLY SUFFICIENT SET OF SAMA CANDIDATES

7. (MGM) In 1989, in Limerick Ecology Action v. NRC, the 3rd Circuit ruled that in the absence of an NRC finding that severe accidents are remote and speculative, the cost-

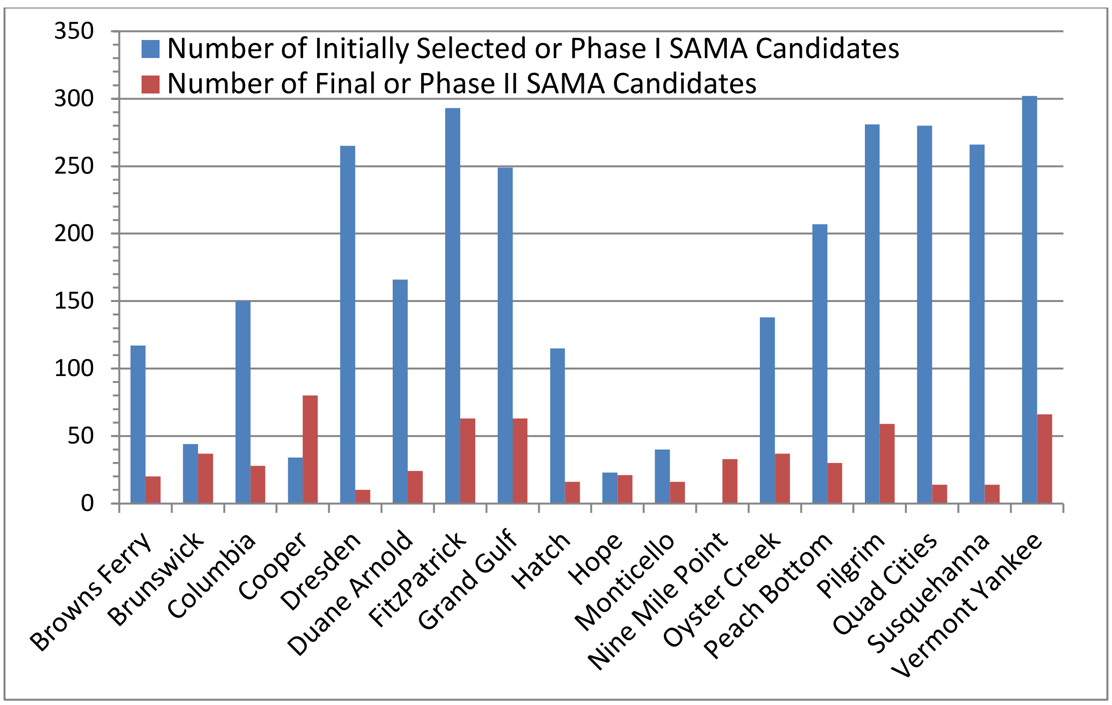
benefits of severe accident mitigation design alternatives (SAMDAs, currently termed SAMAs) should be considered as part of the NEPA analysis. As a direct consequence of this ruling, eight SAMDA candidates were initially considered in the Limerick FES Supplement, and seven final SAMDA candidates given a cost-benefit analysis with respect to person-rem averted (NRC, 1989). However two of these SAMDA candidates had already been implemented at Limerick at that time – the "Decay Heat Sized Vent Without Filter" and the "Low Pressure Reactor Makeup Capability" – and therefore in the FES Supplement the NRC noted that its staff "has not quantified the effectiveness of these SAMDAs in reducing risk." (NRC, 1989). Therefore the Limerick FES Supplement in effect considered only five SAMDA candidates.

8. (MGM) In the Limerick FES Supplement, the NRC staff determined that "while the screening cost/benefit analysis performed above indicates that several candidate SAMDAs might be cost effective, based on a criterion of $1000 per person-rem averted a more recent utility PRA presents lower risk estimates which indicate that SAMDAs are not justified. While the staff has not verified the utility estimates, the staff is convinced that risk is now lower for Limerick than the estimates used in our cost/benefit study." (NRC, 1989). In making this determination, the NRC staff in effect disregarded the SAMDA analysis in the FES Supplement due to forthcoming new and significant information: information which the NRC had not verified, and information for which the impacts on NRC's calculations were not precisely determined.

9. (MGM) Subsequent to the 1989 Limerick FES Supplement, industry lessons learned and NRC studies have produced a large set of SAMA candidates that have been analyzed for License Renewal applications in accordance with NEPA. In contrast to the Limerick FES

Supplement, the cohort of 27 U.S. BWR units at 18 sites undergoing license renewal reviews, or that have recently been granted license renewal, have on average considered 175 Phase I SAMA candidates and 35 Phase II SAMA candidates (Constellation Energy, 2004; Energy Northwest, 2010; Entergy 2006a; Entergy 2006b; Entergy 2006c; Entergy, 2011; Exelon, 2001; Exelon, 2003a; Exelon, 2003b; Exelon, 2005; Florida Power and Light, 2008; Nebraska Public Power District, 2008; Progress Energy, 2004; PSEG Nuclear, 2009; Southern Nuclear Operating Company, 2000; Susquehanna, 2006; Tennessee Valley Authority. 2003; Xcel Energy Corporation, 2005). This data is displayed graphically in Figure 1 for these BWR SAMA analyses.

10. Figure 1: A chart of the numbers of Initially-Selected or Phase I, and Final or Phase II SAMA candidates analyzed with respect to License Renewal for U.S. BWRs .



11. (MGM) In my review of these 18 SAMA analyses conducted for BWR License Renewal Applications, the list of initial or Phase I SAMA candidates were developed by applicants both through examining industry documents and by considering plant-specific

enhancements. These industry documents were a product of industry lessons learned covering the time period subsequent to the 1989 Limerick FES, and in addition include SAMA candidates from the Individual Plant Examination (IPE) and Individual Plant Examination of External Events (IPEEE) processes. These resources constitute new and significant information post-dating the Limerick FES Supplement.

12. (MGM) The 18 SAMA analyses conducted for BWR License Renewal Applications which I reviewed include numerous examples of SAMA candidates for BWR technology that have been determined to be cost-beneficial or potentially cost-beneficial in Phase II of the SAMA candidate evaluations. Table 1 lists cost-beneficial or potentially cost-beneficial SAMA candidates from my review. Examples of or cost-beneficial SAMA candidates for Susquehanna, a GE Type 4 BWR with Mark II containment similar to Limerick Unit 1 and Unit 2, include: "Improve Cross-Tie Capability Between 4kV AC Emergency Buses (A-D, B-C)" and "Procure Spare 480V AC Portable Station Generator" (Susquehanna, 2006). These SAMA candidates were not considered in the Limerick FES Supplement (NRC, 1989). Of the SAMA analyses I surveyed for BWRs, on average four cost-beneficial or potentially cost-beneficial SAMAs were found for each site, with a maximum of 11 cost-beneficial or potentially cost-beneficial SAMAs. Browns Ferry, Nine Mile Point and Peach Bottom had no cost-beneficial or potentially cost-beneficial SAMA candidates identified.

13. (MGM) Table 1: SAMA candidates that were found to be cost- beneficial or potentially cost-beneficial in BWR applications for license renewal. (Constellation Energy, 2004; Energy Northwest, 2010; Entergy 2006a; Entergy 2006b; Entergy 2006c; Entergy, 2011; Exelon, 2001; Exelon, 2003a; Exelon, 2003b; Exelon, 2005; Florida Power and Light,

2008; Nebraska Public Power District, 2008; Progress Energy, 2004; PSEG Nuclear, 2009; Southern Nuclear Operating Company, 2000; Susquehanna, 2006; Tennessee Valley Authority. 2003; Xcel Energy Corporation, 2005).

Nuclear Power Plant	**Number of Cost-Beneficial or Potentially Cost-Beneficial SAMAs and List of Titles of SAMAs Found to be Cost-Beneficial or Potentially Cost-Beneficial**	
Brunswick	7	Portable DC generator; Diverse EDG HVAC logic; Provide alternate feeds to panels supplied only by DC bus 2A-1; Provide an alternate means of supplying the instrument air header; Proceduralize battery charger high voltage shutdown circuit inhibit; Portable EDG fuel oil transfer pump; Use fire water as a backup for containment spray
Columbia	3	Reduce CCFs between EDG-3 and EDG1/2; Improve the fire resistance of cables to the containment vent valve; Improve the fire resistance of cables to transformer E-TR-S
Cooper	11	Portable generator for DC power to supply the individual panels; Revise procedure to allow bypass of RCIC turbine exhaust pressure trip; Improve training on alternate injection via FPS; Revise procedures to allow manual alignment of the fire water system to RHR heat exchangers; Proceduralize the ability to crossconnect the circulating water pumps and the service water going to the TEC heat exchangers; Create ability for emergency connection of existing or new water sources to feedwater and condensate systems; Operator procedure revisions to provide additional space cooling to the EDG room via the use of portable equipment; Provide an alternate means of supplying the instrument air header; Proceduralize the use of a fire pumper truck to pressurize the fire water system; Generation Risk Assessment implementation into plant activities; Modify procedures to allow use of the RHRSW system without a SWBP
Duane Arnold	2	Provide an alternate source of water for the RHRSW/ESW pit; Increase the reliability of the low pressure ECCS RPV low pressure permissive circuitry. Install manual bypass of low pressure permissive
Grand Gulf	3	Procedural change to cross-tie open cycle cooling system to enhance containment spray system; Enhance procedures to refill CST from demineralized water or service wather system; Increase operator training for alternating operation of the low pressure ECCS pumps (LPCI and LPCS) for loss of SSW scenarios.
Monticello	6	Enhanced DC Power Availability (provide cables from DG-13, the security diesel, or another source to directly power division II 250V battery chargers or other required loads); Enhance Alternate Injection Reliability (include the RHRSW and FSW valves in the maintenance testing program); Additional Diesel Fire Pump for FSW system (proceduralize the use of a fire truck to pressurize and provide flow to the fire main for RPV injection); Refill CST (develop emergency procedures and ensure viability of refilling the CSTs with FSW); Divert Water from Turbine Building 931-foot elevation; Manual RCIC Operation
Oyster Creek	7	Allow 4160 VAC bus IC and ID crosstie; Provide an alternate method for IC shell level determination; Portable DC battery charger to preserve IC and EMRV operability along with adequate instrumentation; Reduce fire impact in dominant fire areas; Operator Training; Protect Combustion Turbines; Upgrade Fire Pump House structural integrity

Nuclear Power Plant	Number of Cost-Beneficial or Potentially Cost-Beneficial SAMAs and List of Titles of SAMAs Found to be Cost-Beneficial or Potentially Cost-Beneficial	
Pilgrim	5	Enhance procedures to make use of AC bus cross-ties; Enhance procedures to make use of DC bus cross-ties; Provide redundant DC power supplies to DTV valves; Proceduralize use of the diesel fire pump hydro turbine in the event of EDG A failure or unavailability; Proceduralize the operator action t feed B1 loads via B3 When A5 is unavailable posttrip Similarly, feed B2 loads via B4 when A6 is unavailable post trip
Susquehanna	2	Improve Cross-Tie Capability Between 4kV AC Emergency Buses (A-D, B-C); Procure Spare 480V AC Portable Station Generator
Vermont Yankee	3	Shield injection system electrical equipment from potential water spray; Improve operator action: Defeat low reactor pressure interlocks to open LPCI or core spray injection valves during transients with stuck open SRVs or LOCAs in which random failures prevent all low pressure injection valves from opening; Install a bypass switch to bypass the low reactor pressure interlocks of LPCI or core spray injection valve

14. (CJW) In addition to these currently-documented SAMAs, there are technological options that should plausibly be reviewed as SAMA candidates due to the fact that they address issues related to prolonged station blackout (SBO) and improvement to safety-related systems. One possible SAMA candidate is to replace the emergency DC-powered valve actuators and speed controls for the steam-driven Safety-Related Turbines with a self-powered digital speed control and electrically-actuated valve-control system. This SAMA candidate would allow critical emergency core cooling pumps to run for days under SBO conditions. Another plausible SAMA candidate for Limerick relates to a concern raised in a recent Government Accountability Office report, that industry has limited ability to measure changes in safety-related pipe wall thickness caused by corrosion and located underground without costly excavation (GAO, 2011). To address this issue, nuclear plant operators could employ the use of non-destructive inspection techniques such as robotic crawlers that can navigate complex geometries to perform in-line pipe inspection. This SAMA candidate can potentially provide quantitative analysis without the need for expensive surface preparations.

15. (MGM) The Limerick Environmental Report for its License Renewal Application does not remedy the absence of SAMA candidates analyzed in the FES Supplement. Foremost this is because a new SAMA analysis for Limerick was not performed in support of license renewal using a set of SAMA candidates derived from new and significant information acquired by industry and by the NRC since 1989.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT DO NOT CONSIDER ADDITIONAL ACCIDENT SCENARIOS FOR BWRS THAT COULD ALTER PREVIOUSLY ASSUMED ACCIDENT CONSEQUENCES

16. (CJW) The Limerick FES Supplement does not consider accident scenarios involving: prolonged SBO events, multiunit events, seismically-induced fire events, or seismically-induced flooding events. In *The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*, the NRC staff noted that "prolonged SBO and multiunit events present new challenges to EP facilities that were not considered when the NRC issued NUREG-0696. The accident at Fukushima has clearly shown that these events are a reality." (NRC, 2011a) With respect to seismically-induced fire and flooding events, the NRC Generic Safety Issue 172 (GSI-172) was closed in 2002 based on IPEEE results, and as a result the NRC established no new requirements to prevent or mitigate seismically induced fires or floods (NRC, 2002). However the NRC Near-Term Task Force concludes that the NRC should re-evaluate the closure of GSI-172 in light of plant experience in Japan and the potential for common-mode failures of plant safety equipment as the result of seismically induced fires and floods (NRC, 2011a).

17. (TBC, MGM, CJW) The Limerick Environmental Report for License Renewal Application does not remedy the absence of additional accident scenarios for BWRs that could plausibly alter previously assumed accident consequences. The Limerick Environmental Report fails to consider extended SBO events, multiunit events, seismically-induced fire events, or seismically-induced flooding events.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT DO NOT INCLUDE OR ASSESS REAL WORLD INFORMATION REGARDING CORE DAMAGE FREQUENCY, WHICH INDICATES THAT THE CORE DAMAGE FREQUENCY USED IN THE SAMDA ANALYSIS IS LIKELY IN ERROR AND NOT CONSERVATIVE

18. (TBC) The Limerick SAMDA analysis relies on a Core Damage Frequency (CDF) of 4.2×10^{-5} per year (NRC, 1989) and the Environmental Report submitted by the applicant cites an estimate of CDF, which only includes internal events, for Limerick Units 1 and 2 of 3.2×10^{-6} per year based on a Probabilistic Risk Assessment (PRA) (Exelon, 2011b). In a recent update to the licensee’s IPEEE model to include internal fire risks as well as internal events in its PRA, the license calculated a total CDF of 1.8×10^{-5} per year for these hazard groups (NRC, 2011b). Because the PRA is based on modeling assumptions that contain a large number approximations, large uncertainties and omissions, the absolute value of a CDF calculated using PRA is not a reliable predictor of the actual CDF value.
19. (TBC) Worldwide, I calculate that there have been approximately 429 light water reactors (LWR) that have operated approximately 11,500 reactor-years, and that five of these LWRs (Three Mile Island Unit 2, Greifswald Unit 5, Fukushima Daiichi Units 1, 2,

and 3) have experienced core damage as CDF is defined in NUREG-1150 Vol. 1, pg 2-3. Thus, for this class of nuclear power reactors, LWRs, the CDF is approximately 4.3×10^{-4} per reactor-year based on the historical record. I calculate that in the United States there have been approximately 116 LWRs that have operated approximately 4,100 reactor years. One of these LWRs (Three Mile Island Unit 2) experienced core damage as defined by NUREG-1150. Thus, for this class of nuclear power reactors the CDF is approximately 2.4×10^{-4} per reactor-year based on the historical record. The Limerick reactors, BWRs with Mark 2 containments, are similar in many respects to Fukushima Daiichi Units 1, 2 and 3, BWRs with Mark 1 containments. While no U.S. BWRs have experienced core damage as defined by NUREG-1150, I calculate that worldwide there have been approximately 117 BWRs that have operated approximately 3,300 reactor-years. Three of these BWRs (Fukushima Daiichi Units 1, 2, and 3) have experienced core damage as defined by NUREG-1150. Thus, for this class of nuclear power reactors worldwide the CDF is approximately 9×10^{-4} per reactor-year based on the historical record.

20. (TBC) In sum, the global CDFs for all LWRs and the subset of BWRs based on historical data are much greater than the theoretical value calculated by the applicant for Limerick Units 1 and 2, as is the U.S. historical CDF for LWRs. If a larger CDF is assumed in a PRA, then the calculated cost of severe accidents within a SAMA analysis would be increased proportionally, and thus it would be more likely that the economic viability of the measures to mitigate such accidents would be cost-beneficial.

21. (TBC, MGM, CJW) We do not argue that any of the above CDF estimates based on the historical evidence represent the most accurate CDFs for Limerick Units 1 and 2. In our

judgment the most accurate values of CDF probably lie somewhere between the theoretical values calculated by the applicant and one or more of the U.S. or global values based on the historical record. However, the CDFs used in a Limerick SAMA analysis should be evidence based. The applicant's estimates of CDF are non-conservative and a Limerick SAMA analysis would benefit from a sensitivity analysis in which higher core damage frequencies are assumed. Given the historical operating record of similar reactors, we assert that it is simply not credible to assume the CDF for older BWR reactors in the United States, such as Limerick Units 1 and 2, to be as low as 1.8×10^{-5} per reactor year, i.e., about one core damage event per 55,000 reactor-years of operation. A range of CDF values including values close to those estimated from the global historical evidence should be used in the SAMA analyses for Limerick Units 1 and 2. This issue should be analyzed and discussed in the Limerick environmental report and the final environmental impact statement.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT RELY ON INCORRECT DEMOGRAPHIC DATA

22. (MGM) The cost- benefit ratios calculated in the 1989 SAMDA analysis rely on population data for the 50-mile zone around Limerick derived from 1980 census data (Exelon, 2011b). The 1984 FES stated that the area within 10 miles of Limerick experienced a decrease in population of 4.2% from 1970 to 1980, and the area with within 50 miles experienced a decrease in population of less than 0.2% between 1970 and 1980. Noting this trend, the NRC staff remarked that "…the area has not experienced—nor is it likely to experience—the growth anticipated." (NRC, 1984).

23. (MGM) By contrast, data from the 1990 Census, the 2000 Census, and the 2010 Census does show a substantial growth in population in the 10-mile and in the 50-mile zones around Limerick over the last thirty years. Census data for 1990, 2000 and 2010 were analyzed using ESRI ArcGIS 10 Geographic Information Systems (GIS) software, summing the total population in each census tract intersecting the 10-mile or 50-mile zones around Limerick (Census Bureau, 1990; Census Bureau, 2000; Census Bureau, 2011). The results of this GIS analysis can be seen in Table 2. By 1990, the Census population within the 10-mile zone already exceeded the year 2000 projection in the Limerick Final Environmental Statement by 40 percent. The 2010 Census population within the 10-mile zone is more than 200 percent of the 1980 value used in the Limerick SAMDA study. The 2010 Census population within the 50-mile zone around Limerick is 21 percent larger than the 1980 population used in the Limerick SAMDA analysis.

24. (MGM) Table 2: Census population data for 1990, 2000 and 2010 analyzed for the 10-mile and 50-mile zones around Limerick (Census Bureau, 1990; Census Bureau, 2000; Census Bureau, 2011) and projected to the years 2030 and 2049, and population data used in the 1984 Final Environmental Impact Statement (NRC, 1984).

	10-Mile Zone around Limerick	**50-Mile Zone around Limerick**
1980 Population (1984 Limerick FES)	156,354 People	6,863,983 People
2000 Population (1984 Limerick FES)	158,607 People	7,253,880 People
1990 Population (U.S. Census)	221,701 People	7,334,214 People
2000 Population (U.S. Census)	251,287 People	7,751,181 People
2010 Population (U.S. Census)	318,582 People	8,300,122 People
Calculated Average Annual Population Growth Rate (1990-2010)	*4,844 People per Year*	*48,295 People per Year*
2030 Projected Population	415,463 People	9,266,030 People
2049 Projected Population	507,500 People	10,183,643 People

25. (MGM) This large discrepancy between the population data used for the 1989 SAMDA analysis and the subsequent Census data represents new information. This new information could plausibly cause materially different results in the assessment of impacts of an accident at Limerick, and materially different benefit/cost results in a new SAMA analysis for Limerick. Radiation doses resulting from an accident at Limerick have not been calculated for over 1.4 million people now living within 50 miles of these reactors.

26. (MGM) The Limerick Environmental Report for its License Renewal Application does not remedy the population errors in the 1989 Limerick SAMDA analysis. Foremost this is because a new SAMA analysis for Limerick was not performed in support of license renewal with revised population data. But in addition, Exelon commits errors in the 2011 Environmental Report in an effort to claim that the population data is not significant new information.

27. (MGM) First, the licensee states that the 50-mile zone population in 2030 is projected to be 9,499,925, and 2030 was the latest year out in time considered because: "this was the farthest future year to which population data for most counties within the 50-mile radius were projected." (Exelon, 2011b). By contrast, SAMA analyses for nearly all other BWR license extensions relied on projected populations out to the end of the extended license, for example: Browns Ferry cited population projections to the year 2036 (Tennessee Valley Authority, 2003), Brunswick to 2036 (Progress Energy, 2004), Columbia to 2040 (Energy Northwest, 2010), Cooper to 2034 (Nebraska Public Power District, 2008), Dresden to 2031 (Exelon, 2003a), Fitzpatrick to 2034 (Entergy, 2006a), Grand Gulf to 2044 (Entergy, 2011), Hope Creek to 2046 (PSEG Nuclear, 2009), Monticello to 2030

(Xcel Energy Corporation, 2005), Oyster Creek to 2029 (Exelon, 2005), Peach Bottom to 2034 (Exelon, 2001), Quad Cities to 2032 (Exelon, 2003b), Susquehanna to 2044 (Susquehanna, 2006), and Vermont Yankee to 2032 (Entergy, 2006c). Populations were extrapolated out to the end of the renewed license terms in these SAMA studies in order to calculate person-rem of radiation exposure with respect to the maximum potential population within the 50-mile zones around the units during the re-licensing period. As shown in Table 2, the year 2030 population within the Limerick 10-mile zone is projected to be 415,463, and the year 2049 projected population in the 10-mile zone is projected to be 507,500. As also shown in Table 2, the year 2030 population within the Limerick 50-mile zone is projected to be 9,266,030, and the year 2049 population in the 50-mile zone is projected to be 10,183643. Under Exelon's current License Renewal Application, Limerick Unit 2 would be operating in the year 2049 while relying on a SAMDA analysis performed with population data obtained 69 years earlier.

28. (MGM) Second, the licensee states that the "relationship between the population surrounding a nuclear plant and the estimated dose following a severe accident is approximately linear" and therefore "increase in population within 50 miles of the LGS site would yield an approximate 39% increase in dose values over those calculated in the LGS June 1989 Update." (Exelon, 2011b). My examination of SAMA analyses performed for other BWR license renewals shows that the relationship between population surrounding a reactor and the estimated dose from a severe accident is not necessarily linear. For example, the Oyster Creek BWR (619 MWe) has a 50-mile population of 5.4 million, and the SAMA frequency-weighted total dose risk is 36 person-rem per year (Exelon, 2005). The Pilgrim BWR (685 MWe) has a greater 50-mile

population of 7.5 million, but the SAMA frequency-weighted total dose risk is calculated to be three times less: 13.6 person-rem per year (Entergy, 2006b). The estimated dose from a severe accident depends not just on the total population but also through prevailing winds on the geographic distribution of the population, which can change with time.

29. (MGM) Third, the licensee argues that "none of the SAMDAs in the LGS June 1989 Update would become cost beneficial if 2030 population numbers were assumed, the new information concerning population increase is not judged to be significant." (Exelon, 2011b). This statement is incorrect as it relies on an assumed linear relationship between total 50-mile population and estimated dose. But more importantly, the 1989 Limerick SAMDA analysis stated in conclusion that "…while the screening cost/benefit analysis performed above indicates that several candidate SAMDAs might be cost effective, based on a criterion of $1000 per person-rem averted, a more recent utility PRA presents lower risk estimates which indicate that SAMDAs are not justified." (NRC, 1989). Therefore contrary to the claim of the licensee in the License Renewal Application Environmental Report, the Limerick 1989 Supplement did find some of the eight initial SAMDA candidates to be potentially cost effective in that analysis. Those findings were subsequently questioned by the NRC staff due to uncertainties in averted dose and cost for the SAMDA candidates – uncertainties created by the 1989 owner's PRA analysis that NRC Staff had not yet evaluated.

30. (MGM) I also note that the 1984 FES, the 1989 FES Supplement, the 2011 License Renewal Application and its Environmental Report do not discuss or analyze uncertainty in offsite dose calculations for Limerick related to census undercount or to transient

populations. Beginning in the 1990s, demographers have commonly understood that the U.S. Census is subject to a systematic undercount of minority populations (Census Monitoring Board, 2001), a trend which has greater significance in urban areas like Philadelphia. In addition, the Census undercounts tourist and commuter populations. If an accident at Limerick occurred during a weekday, the population at risk may have a very different geographic distribution than if the accident occurred at night or on the weekend.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT FAIL TO CONSIDER OFF-SITE ECONOMIC COST RISKS

31. (MGM) Exelon confirms in the Limerick Environmental Report that the SAMDA analysis in the 1989 FES Supplement did not compute cost- benefit values for SAMDA candidates with respect to their reduction in land contamination subject to long-term interdiction, or the reduction in associated economic cost, from a severe accident (Exelon, 2011b). Economic cost risk calculations are now a codified component of SAMA cost- benefit assessments and have been performed as an integral part of other License Renewal Applications submitted to the NRC. New information pertaining to economic risk could plausibly cause materially different results in the assessment of impacts of an accident at Limerick, and materially different cost- benefit results in a new SAMA analysis for Limerick. The proximity of Limerick to the city of Philadelphia, with substantial economic activities and assets, reinforces this conclusion.

32. (MGM) The Limerick Environmental Report for its License Renewal Application does not remedy the lack of economic risk assessment in the 1989 SAMDA study. Principally this is because a new SAMA analysis for Limerick was not performed in support of

license renewal including economic cost risk. But in addition, the licensee commits errors in the 2011 Environmental Report in an effort to claim that economic risk is not significant new information.

33. (MGM) In its 2011 Environmental Report, the licensee claims that the economic cost of a severe accident at Limerick "can be estimated using information from other license renewal applications." The example of Three Mile Island Nuclear (TMI) Station Unit 1 Environmental Report for License Renewal is cited, and the licensee argues that the Three Mile Island finding that economic cost risk is 70% larger than the off-site exposure cost risk is representative (Exelon, 2011b). This argument is incorrect: an examination of 18 SAMA analyses performed in support of License Renewal Applications for BWR shows that the ratio of economic cost risk to exposure cost risk exhibits a wide variation, as shown by example in Table 3. Claiming that economic cost risk simply scales with the exposure cost risk assumes that economic productivity and assets scale with population density, which may not true when considering low-income communities, for example North Philadelphia. TMI is also an inappropriate example to use in estimating the economic risk for Limerick because TMI is a Pressurized Water Reactor (PWR) rather than a BWR, with correspondingly different accident scenario source terms, and Harrisburg near TMI is smaller and less urban economic center than Philadelphia near Limerick.

34. (MGM) Table 3: A comparison of dose risk cost and economic risk cost for selected SAMA performed for BWR License Renewal Applications (Exelon, 2003a; Entergy, 2011; PSEG Nuclear, 2009; Constellation Energy, 2004; Exelon, 2005; Entergy, 2006b; Exelon, 2003b; AmerGen, 2008).

Nuclear Plant	Weighted Population Dose Risk (person-rem/year)	Weighted Population Dose Risk Cost ($/year)	Offsite Economic Risk Cost ($/year)	Percentage Change in Off-Site Economic Cost over Off-Site Economic Exposure Cost
Dresden	10.23	$20,460.00	$18,408.00	-10.0%
Grand Gulf	0.486	$972.00	$1,240.00	+27.6%
Hope Creek	22.9	$45,800.00	$155,000.00	+238.4%
Nine Mile Point Unit 1	22.5	$45,000.00	$86,000.00	+91.1%
Nine Mile Point Unit 2	50.9	$101,800.00	$125,000.00	+22.8%
Oyster Creek	36	$72,000.00	$118,000.00	+63.9%
Pilgrim	13.6	$27,200.00	$45,900.00	+68.8%
Quad Cities	1.67	$3,340.00	$2,806.87	-16.0%
Three Mile Island Unit 1	32.61	$65,220.00	$112,259.00	+72.1%

35. (MGM) Economic risk to the east of Limerick is dominated by the economic productivity of the city of Philadelphia and its surrounding region. The 2010 gross domestic product for all industries in the Philadelphia-Camden-Wilmington Metropolitan Statistical Area which lies within the Limerick 50-mile zone was computed to be $347 billion, or more precisely $346,932,000,000.00 (Bureau of Economic Analysis, 2011). Personal income summaries for the 23 counties in Delaware, Maryland, New Jersey and Pennsylvania which substantially overlap the 50-mile zone around Limerick is given in Table 4 (Bureau of Economic Analysis, 2011). The sum of 2009 personal income in the three Pennsylvania counties that overlap the 10-mile EPZ is approximately $93 billion, and the sum of 2009 personal income in all of the counties that substantially overlap the 50-mile zone around Limerick is approximately $497 billion.

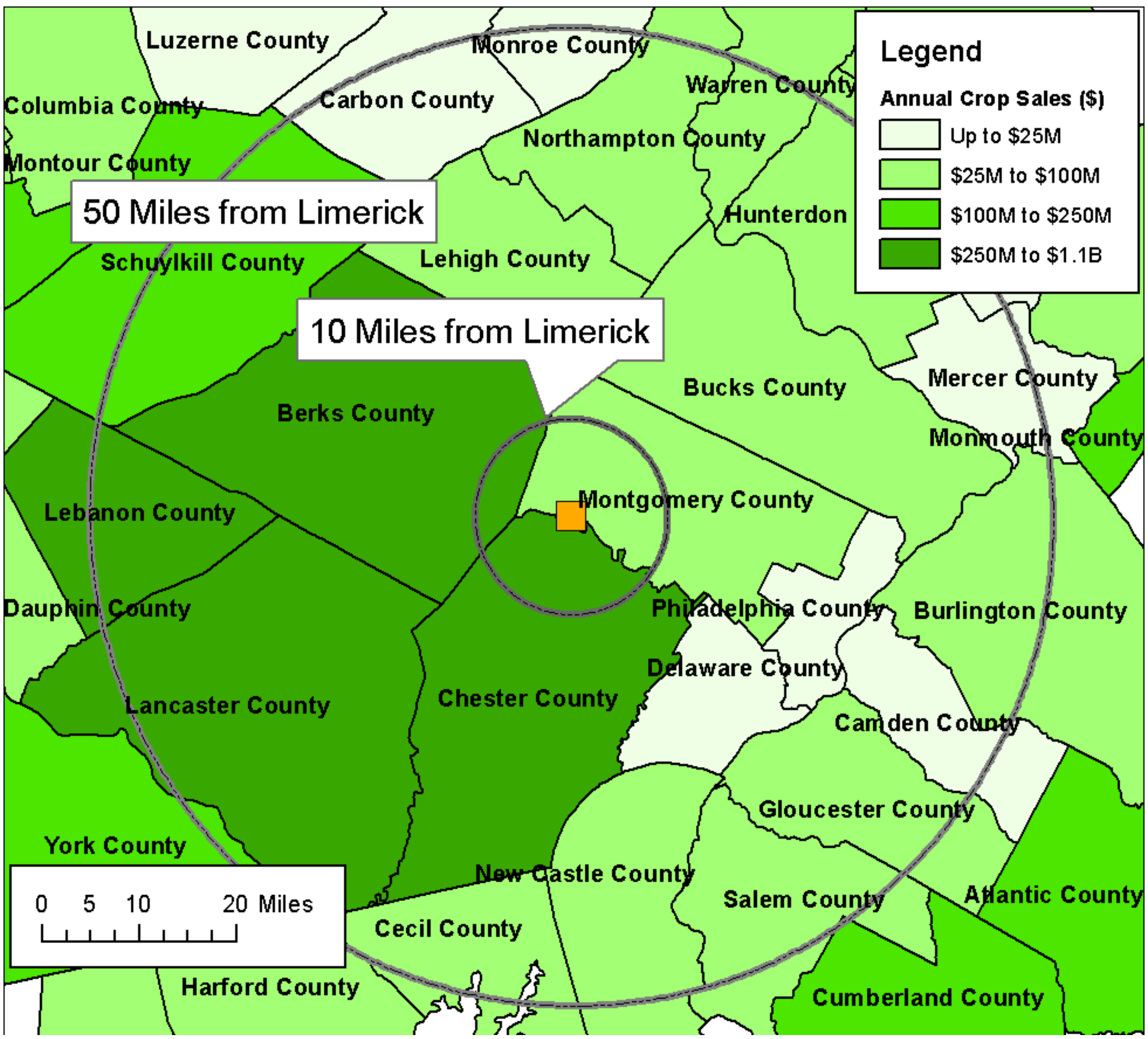
36. (MGM) Table 4: Personal income in dollars for the year 2009 summed for the indicated county (Bureau of Economic Analysis, 2011).

County Name, State	2009 Personal Income Summed by County
Counties Overlapping the Limerick 10-mile EPZ	
Berks County, PA	$14,793,423,000.00
Chester County, PA	$28,453,609,000.00
Montgomery County , PA	$49,654,050,000.00
Total in Counties Overlapping 10-mile EPZ	***$92,901,082,000.00***
Counties Outside the Limerick 10-mile EPZ and Overlapping the 50-mile zone	
Bucks County, PA	$31,862,647,000.00
Carbon County, PA	$2,007,062,000.00
Delaware County, PA	$27,524,171,000.00
Lancaster County, PA	$18,450,403,000.00
Lebanon County, PA	$4,809,208,000.00
Lehigh County, PA	$13,586,500,000.00
Monroe County, PA	$5,298,681,000.00
Northampton County, PA	$11,152,782,000.00
Philadelphia County, PA	$54,125,507,000.00
Schuylkill County, PA	$4,569,375,000.00
Total Pennsylvania	***$359,188,500,000.00***
New Castle County, DE	$23,500,800,000.00
Total Delaware	***$23,500,800,000.00***
Cecil County, MD	$3,715,479,000.00
Total Maryland	***$3,715,479,000.00***
Burlington County, NJ	$20,751,126,000.00
Camden County, NJ	$21,379,186,000.00
Gloucester County, NJ	$11,478,111,000.00
Hunterdon County, NJ	$8,497,001,000.00
Mercer County, NJ	$19,024,257,000.00
Salem County, NJ	$2,541,629,000.00
Somerset County, NJ	$22,679,780,000.00
Warren County, NJ	$4,673,941,000.00
Total New Jersey	***$111,025,031,000.00***
Total	***$497,429,810,000.00***

37. (MGM) Agriculture is an important component to the economic risk to the west of Limerick has. As an example of data pertinent to determining economic risk that is absent from the Limerick FES Supplement but found universally in SAMA analyses conducted

for other BWR License Renewal Applications, I have displayed U.S. Bureau of Agriculture statistics on crop sales by county within the 50-mile zone around Limerick in Figure 2 (USDA, 2011). As can be seen in this figure, Lancaster County to the southwest of Limerick had over $1 billion in crop sales in 2007, Chester Counties had about one-half billion dollars in crop sales in 2007, and Berks County had bout $400 million in crops sales in 2007 (USDA, 2011).

38. (MGM) Figure 2: US Bureau of Agriculture data on annual crop sales in the area surrounding Limerick in 2007 (USDA, 2011).



39. (CJW) As documented in a number of studies on considerations for decontamination costs (Chanin, 1996; Luna, 2008), the cost to cleanup fission products in a densely populated and developed region, such as the Philadelphia metropolitan area, could be significantly larger on a per capita basis than previously estimated. The reports state that input parameters used in analyses for less densely populated areas are inappropriate for highly populated urban areas. Without considerable modifications to the input values used by accident consequence codes such as MELCOR Accident Consequences Code System (MACCS2), the analysis could result in large underestimations of the decontamination costs associated with the off-site economic costs of a severe accident.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT USE FLAWED EVACUATION SPEED ASSUMPTIONS

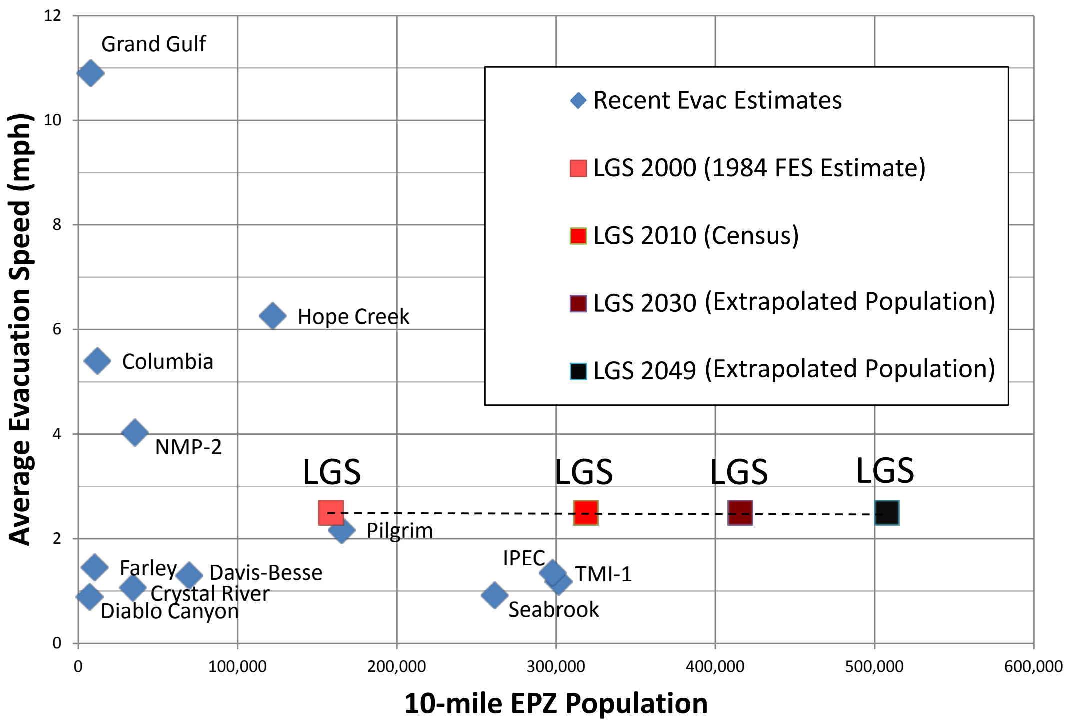
40. (CJW) An important step in calculating the offsite exposures for a SAMA analysis is to accurately model the evacuation within the 10-mile Emergency Planning Zone (EPZ). A typical nuclear accident evacuation assumption is a 95% response, i.e. 5% of the population does not evacuate during an accident. Other site-specific parameters needed for accurate evacuation modeling are the evacuation start time delay, and the radial evacuation speed. These input parameters can be obtained from the emergency action plans for the site in question, and studies on the evacuation dynamics which incorporates information such as the road network, traffic congestion, and other external effects (KLD, 2003).

41. (CJW) The 2005 Nuclear Energy Institute SAMA Guidance Document, which the NRC staff recommends using during license renewal, states: “Population dose may be significantly affected by radial evacuation speed, and uncertainties may be introduced

during derivation of a single evacuation speed from emergency plan information… Therefore, perform sensitivity analysis to show that variations in this parameter would not impact the results of the analysis." (NEI, 2005). The evacuation modeling performed in the 1984 FES appears to overestimate the evacuation speed based on comparisons with SAMA analyses in support of other reactor re-licensing, and does not include an uncertainty analysis.

42. (CJW) The only evacuation speed that was assumed in the 1984 Limerick evacuation modeling was 2.5 miles per hour (mph). The Indian Point Energy Center (IPEC) estimated that the evacuation of their entire EPZ, containing about 297,000 permanent residents, would take 9.25 hours, including a 2-hour delay, or mobilization time, for the start of evacuation (KLD, 2003). Factoring in this mobilization time would result in an actual evacuation duration for IPEC of 7.42 hours, resulting in an average evacuation speed of 1.35 mph. Both the year 2010 and projected year 2049 population within the Limerick EPZ are greater than that for IPEC, and suggest that an updated analysis of the evacuation scenarios needs to be performed for Limerick to account for the likely reduction in evacuation speeds. A reduced evacuation speed would likely increase the offsite exposure following a release because the complete dose is dependent on the exposure time. The evacuating population could remain in the plume pathway for extended periods in turn increasing their dose, which could plausibly cause materially different results in the assessment of impacts of an accident at Limerick, and materially different benefit/cost results in a new SAMA analysis for Limerick. Figure 3 plots evacuation speeds assumed in selected SAMA analyses against the total population within the 10-mile EPZ.

43. (CJW) Figure 3: A chart of base case evacuation speeds plotted against EPZ populations from License Renewal Application SAMA analyses for selected nuclear power plants (blue diamond symbols). The populations for the Limerick EPZ is given for the FES Supplement (light red square symbol), the 2010 Census (red square symbol), and population extrapolations to the year 2030 (dark red square symbol) and to the year 2049 (black square symbol).



44. (CJW) Finally, the FES Supplement for Limerick does not contain a sensitivity analysis with regard to evacuation speeds as described in the NRC SAMA guidance document. SAMA analyses for other nuclear power plants have provided the results of a sensitivity analysis, exploring the offsite exposure doses as a percentage change from the base speed result. I find that doses are characteristically determined for a 50% reduction in the evacuation speed, for which the resulting collective dose ranges anywhere from a few percent difference to as much as 15 percent higher. Therefore the sensitivity analysis

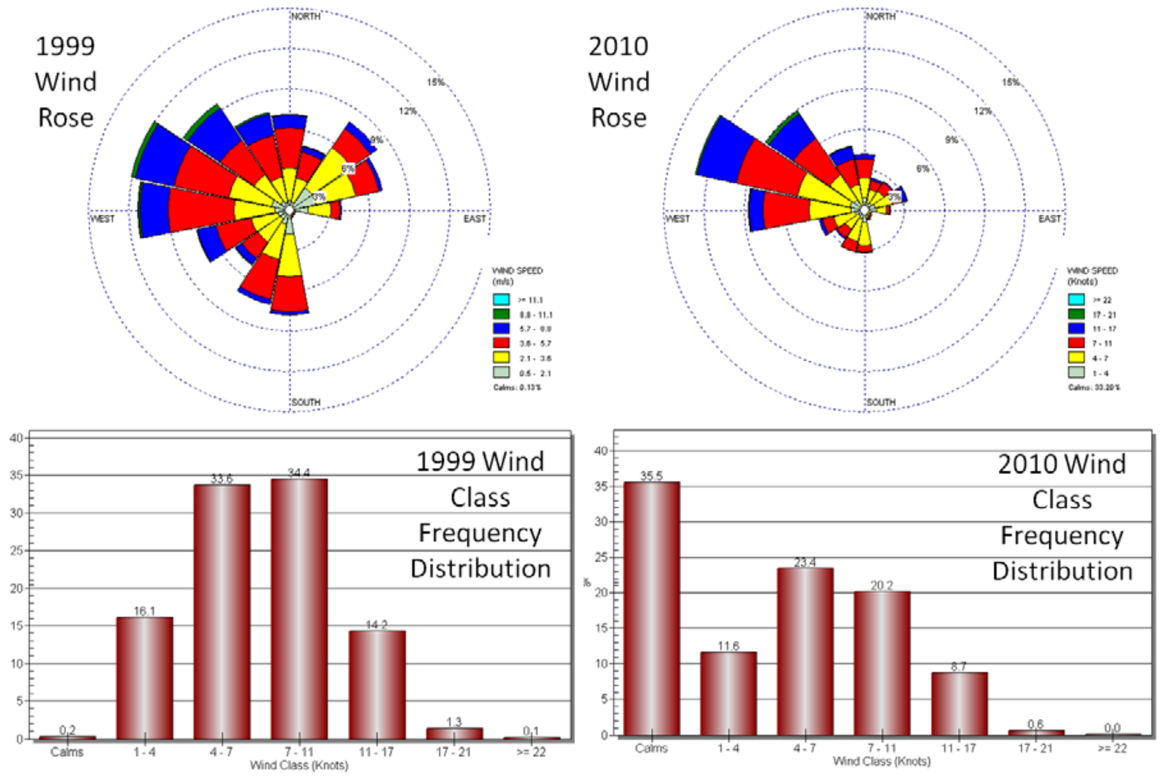
performed for SAMA analysis at other nuclear power plants reinforces that a reduction in evacuation speed from an updated SAMA analysis for Limerick could materially alter the assessment of impacts of a severe accident and the cost- benefit results of certain mitigation alternatives.

THE LIMERICK FES SUPPLEMENT AND LICENSE RENEWAL APPLICATION ENVIRONMENTAL REPORT RELY ON 1976 METEOROLOGY

45. (MGM) The Limerick FES Supplement relies on hourly wind data measurements for the single year 1976 (NRC, 1984). A review of other SAMA analyses submitted for License Renewal demonstrates that applicants used information current to the relicensing period, and screened wind data to determine whether this meteorology was characteristic of the site or represented atypical weather patterns. The SAMDA analysis in the Limerick FES Supplement is deficient in that the averaged wind speed along 16 compass directions used in the cost-benefit calculations would predate the end of the license renewal period by as much as 73 years. Nor has Exelon demonstrated that it determined the wind data for 1976 is characteristic of the site. Meteorological data, in particular prevailing wind directions and speeds, is a significant component in establishment of the baseline consequences of a severe accident, particularly when the population is clustered in an urban center along several compass directions downwind from the nuclear power plant.
46. (MGM) I have reviewed and analyzed hourly historical weather data from the Pottstown, Pennsylvania weather station, named KPTW, maintained by the Federal Aviation Administration. This weather station is located at latitude 40.240 North, longitude 75.550 West, which is approximately two miles northeast of Limerick. I downloaded hourly wind data at this station for the available years beginning in 1999 (Penn State, 2011), and

created wind rose and wind class frequency distribution charts using the software WRPLOT View by Lakes Environmental. Yearly-averaged wind roses and wind class frequency distributions at Pottstown are shown for the year 1990 and the year 2010 in Figure 4. I have found that the 1999 meteorology differs significantly from the 2010 meteorology for Pottstown. In 1999, northerly, northeasterly and southerly winds are a significant component to the wind rose, whereas in 2010 the winds are dominated by north-northwesterly, northwesterly and westerly winds, which is a pattern more like the 1976 data used for the Limerick SAMDA analysis (NRC, 1984). I have found that the wind class frequency distributions for 1999 and 2010 are also very different: 1999 was a much windier year in Pottstown, the most probable wind class for 2010 in Pottstown being calm. With respect to the Limerick SAMDA, wind data needs to be analyzed for representative patterns for direction and speed to properly estimate the off-site dose to surrounding populations.

(MGM) Figure 4: Yearly-averaged wind rose data from the Federal Aviation Administration's KPTW station located in Pottstown, Pennsylvania, approximately two miles northeast of Limerick. Shown at left are the 1999 wind rose and wind class frequency distribution, and shown at right are the 2010 wind rose and wind class frequency distribution.



47. (MGM) In addition, a 2008 study by Pennsylvania State University projects a warmer, wetter Pennsylvania, with a longer growing season and significantly less snow by the middle of the current century (Shortle, 2009). These predicted changes in the Pennsylvania climate could plausibly case a materially different result in analyzing the baseline consequences of a severe accident as winds and atmospheric stability depend strongly on ambient temperature.

SUMMARY: NEW AND SIGNIFICANT INFORMATION COULD MATERIALLY ALTER THE ASSESSMENT OF IMPACTS OF A SEVERE ACCIDENT AND THE COST-BENEFIT RESULTS OF MITIGATION ALTERNATIVES AT LIMERICK, INCLUDING NEW SAMA CANDIDATES

48. (TBC, MGM, CJW) A SAMA analysis entails five main steps: (1) the establishment of the baseline consequences of a severe accident, including off-site exposure costs and off-site economic costs; (2) the identification of SAMA candidates; (3) preliminary or Phase I screening of SAMA candidates; (4) final or Phase II Screening and cost-benefit evaluation of SAMA candidates; and (5) sensitivity analysis. We find that the Limerick FES Supplement is inadequate regarding all five steps of the SAMA analysis process. Building on industry lessons learned and NRC studies, hundreds of SAMA candidates have been identified for BWRs since the Limerick FES Supplement was published in 1989, and numerous SAMA candidates for BWRs have been analyzed to be cost-beneficial or potentially cost-beneficial in reducing risk. The Limerick FES Supplement relies on outdated and inappropriate population data, evacuation speeds and meteorology, neglects to calculate economic costs entirely, and uses $1000 per person-rem for dose risk costs, rather than $2000 per person-rem. A sensitivity analysis was not performed in the FES Supplement. These problems are not remedied in the 2011 Limerick Environmental Report.

49. (TBC, MGM, CJW) Our review of 18 SAMA analyses prepared by other BWR License Renewal applicants demonstrate that accurate site-specific data leads to results pertinent to individual cases. For example, the SAMA analysis for Hatch concluded that: "The area surrounding HNP is predominantly agricultural and forested land with sparse population. As a result, the baseline risk of the plant is low both for population doses and economic risk. This limits the potential averted risk from any severe accident modifications."

(Southern Nuclear Operating Company, 2000). Limerick represents an opposite extreme case from Hatch, as Limerick is located in an area of high population density and high economic productivity. We have found that new information in seven areas – 1) additional SAMA candidates analyzed for BWRs; 2) additional accident scenarios analyzed for BWRs; 3) real world information regarding reactor core damage frequency; 4) population within 50 miles Limerick; 5) economic consequences from accident scenarios at Limerick; 6) evacuation speed assumed during accident scenarios at Limerick; and 7) meteorology at Limerick – are plausibly significant. Taken individually and in combination, this new information would plausibly cause a materially different result in the SAMA analysis for Limerick. Given that applicants are required by law to perform a SAMA analysis for License Renewal as a component of assessing environmental impacts under NEPA, Exelon's License Renewal Application would therefore be incomplete.

Pursuant to 28 U.S.C. § 1746, we declare that the foregoing is true and correct to the best of our knowledge, information and belief, and that this declaration was executed in Washington, DC on November 22, 2011.

/s/ Dr. Thomas B Cochran (electronic signature approved)

/s/ Dr. Matthew G. McKinzie (electronic signature approved)

/s/ Dr. Christopher J. Weaver (electronic signature approved)

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Attachment A: Curriculum Vitae for Thomas B. Cochran

Dr. Thomas B. Cochran is a consultant to the Natural Resources Defense Council (NRDC) where he began working in 1973. Prior to retiring in 2011, he was a senior scientist and held the Wade Greene Chair for Nuclear Policy at NRDC, and was director of its Nuclear Program until 2007. He has served as a consultant to numerous government and non-government agencies on energy, nuclear nonproliferation, nuclear reactor and nuclear waste matters. He is a member of the Department of Energy's Nuclear Energy Advisory Committee (NEAC) and three of its subcommittees: the NEAC Nuclear Reactor Technology Subcommittee, the NEAC Infrastructure/Facilities Subcommittee and the NEAC International Subcommittee. Previously he served as a member of DOE's Environmental Management Advisory Board, Fusion Energy Sciences Advisory Board and Energy Research Advisory Board, the Nuclear Regulatory Commission's Advisory Committee on the Cleanup of Three Mile Island and the TMI Public Health Advisory Board.

Dr. Cochran initiated NRDC's Nuclear Weapons Databook Project. He also initiated a series of joint nuclear weapons verification projects with the Soviet Academy of Sciences. These include the Nuclear Test Ban Verification Project, which demonstrated the feasibility of utilizing seismic monitoring to verify a low-threshold test ban, and the Black Sea Experiment, which examined the utility of passive radiation detectors for verifying limits on sea-launched cruise missiles.

Dr. Cochran is the author of *The Liquid Metal Fast Breeder Reactor: An Environmental and Economic Critique* (Washington, DC: Resources for the Future, 1974); and co-editor/author of the *Nuclear Weapons Databook, Volume I: U.S. Nuclear Forces and Capabilities* (Cambridge, MA: Ballinger Press, 1984); *Volume II: U.S. Nuclear Warhead Production* (1987); *Volume III: U.S. Nuclear Warhead Facility Profiles* (1987); *Volume IV: Soviet Nuclear Weapons* (1989); and *Making the Russian Bomb: From Stalin to Yeltsin* (Boulder, CO: Westview Press, 1995). In addition, he has published numerous articles and working papers, including those in *SIPRI Yearbook* chapters, *Arms Control Today*, and the *Bulletin of the Atomic Scientists*. He has co-authored (with Dr. Robert S. Norris) the article on "Nuclear Weapons" and in the 1990 printing of *The New Encyclopedia Britannica* (15th edition), revised and updated in the *Encyclopedia Britannica*, 2011 Ultimate DVD (Copyright 2010, Encyclopedia Britannica**).**

Dr. Cochran's publications can be found at http://www.nrdc.org/nuclear/cochran/cochranpubs.asp One of his most recent publications (with Christopher E. Paine) is "Nuclear Islands: International Leasing of Nuclear Fuel Cycle Sites to Provide Enduring Assurance of Peaceful Use," *The Nonproliferation Review*, Vol. 17, No. 3, November 2010, pp. 441-474.

Dr. Cochran received his Ph.D. in Physics from Vanderbilt University in 1967. He was assistant Professor of Physics at the Naval Postgraduate School, Monterey, California, from 1967 to 1969, Modeling and Simulation Group Supervisor of the Litton Mellonics Division, Scientific Support

Laboratory, Fort Ord, California, from 1969 to 1971, and from 1971 to 1973, he was a Senior Research Associate at Resources for the Future.

Dr. Cochran is the recipient of the American Physical Society's Szilard Award and the Federation of American Scientists' Public Service Award, both in 1987. As a consequence of his work, NRDC received the 1989 Scientific Freedom and Responsibility Award by the American Association for the Advancement of Science (AAAS). Dr. Cochran is a Fellow of the American Physical Society and the AAAS and a member of the American Nuclear Society, the Health Physics Society and Sigma Xi.

Attachment B: Curriculum Vitae for Matthew G. McKinzie

EDUCATION

Ph.D. (experimental nuclear physics): 1995; University of Pennsylvania, Philadelphia, PA; Dissertation Advisor: Prof. H. T. Fortune; Dissertation Title: "Inelastic Scattering and Single and Double Charge Exchange Reactions within the A=27 Isobaric Multiplet"

B.A. (physics): 1988; Bard College, Annandale-on-Hudson, NY

EMPLOYMENT HISTORY

July 2007- present: Senior Scientist, Nuclear Program and Lands and Wildlife Program, **Natural Resources Defense Council**, 1200 New York Ave., N.W., Suite 400, Washington, DC

June 1997 - June 2003: Project Scientist, Nuclear Program, **Natural Resources Defense Council**, 1200 New York Ave., N.W., Suite 400, Washington, DC

September 1995 **–** May 1997: Postdoctoral Associate, Peace Studies Program, Mario Einaudi Center for International Studies, **Cornell University**, Ithaca, NY

June 1988 **–** July 1995: Graduate Research Assistant, Department of Physics, **University of Pennsylvania**, Philadelphia, PA

Summers 1988-1992: Summer Graduate Research Student, **Los Alamos National Laboratory**, Los Alamos, NM

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David Hawk, “The Hidden Gulag: Exposing North Korea’s Prison Camps – Prisoners’ Testimonies and Satellite Photographs,” U.S. Committee for Human Rights in North Korea (2003).

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M. G. McKinzie, H. T. Fortune, P. Hui, R. Ivie, C. Laymon, X. Li, S. Loe, D. A. Smith, A. L. Williams, J. M. O'Donnell, S. Blanchard, G. R. Burleson, and B. Lail, "Interference effects in non-analog pion double charge exchange," *Physical Review C (Nuclear Physics)* **49**, pg. 2054 (1994).

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Attachment C: Curriculum Vitae for Christopher J. Weaver

EDUCATION

Ph.D., Mechanical Engineering – Nuclear & Radiation Engineering Program, May 2011
University of Texas at Austin

Master of Science, Mechanical Engineering – Nuclear & Radiation Engineering Program, May 2008
University of Texas at Austin

Bachelor of Science, Physics, December 2005
Louisiana State University (Baton Rouge, LA)

PROFESSIONAL EXPERIENCE

- **Natural Resources Defense Council (NRDC), Washington, D.C. (July 2011 – Present)**
  - Project Scientist – Nuclear Program
  - Science Center Fellow
- **University of Texas at Austin, Austin, TX (Sept 2006 – May 2011)**
  - Graduate Research Assistant

RESEARCH EXPERIENCE

- **Nuclear Engineering Teaching Laboratory (NETL), UT Austin (Sept 2006 – May 2011)**
  - Developed PYRAMDS (Python for Radioisotope Analysis and Multi-Detector Suppression) code for the analysis of List Mode gamma detector data with a focus on fission product detection limit improvements through the use of a multi-detector system (Dissertation Research).
  - Developed an aerosol sampler to improve detection in nuclear explosion monitoring through the use of cascade impactors. Including design, manufacture, and performance characterization of said aerosol sampler as deliverables (Thesis Research).
  - Provided operational support during field tests for Signature Science, LLC (Austin, TX) to develop atmospheric aerosol samplers. Personal focus on the applicability of radioactive sample collection and analysis.
  - Co-developed research project proposing a hypothetical advanced fuel cycle partnership in Southeast Asia for presentation at GLOBAL 2009 (Paris, France).

Focus on fuel cycle simulation and economic analysis during steady-state environment.

  - Conducted initial dissertation research at Argonne National Laboratory in Chicago, IL as part of a 10-week fellowship practicum. ORIGEN modeling of various reactor operational schemes for forensic signatures.
  - Conducted environmental sample analysis via neutron activation analysis (NAA) on local fishes. Focus on heavy metal uptake in the liver and flesh of samples.
  - Summer Student Laboratory - Taught/conducted various lab classes about radiation statistics and radioanalytical processes (spectroscopy, activation analysis).
  - TA for various classes - Presented lectures, administered tests, and grading.
- **ALLEGRO Gravitational Wave Group, LSU (Jan 2003 – Dec 2005)**
  - Assisted with redesign and maintenance of vacuum and cryogenics systems (liquid helium, nitrogen).
  - Designed/built noise- and vibration-proof vacuum pump enclosures to reduce interference with the acoustically and seismically sensitive experiment apparatus.
  - Redesigned and coded research group website front end.
- **Experimental Condensed Matter and Superconductivity Group, LSU (Jan 2002 – Jan 2003)**
  - Repaired cryostat units for quantum phase transition measurements of silicon-based magnetic semiconductors.
  - Performed research duties such as sample preparation, including smelting, annealing, EDM sample cutting, polishing, and liquid helium & nitrogen transfers.

CONFERENCE PRESENTATIONS

- "A Regional Advanced Fuel Cycle Partnership in Southeast Asia" – GLOBAL 2009 Paris, France. — Sept 6 – 11, 2009
- "Assessment of non-traditional isotopic ratios by mass spectrometry for analysis of nuclear activities" – MARC VIII Kona, Hawaii — April 4 – 11, 2009
- "Evaluation of Heavy Metal Uptake in Micropterus Salmoides (Largemouth Bass) of Lake Austin, TX by Neutron Activation Analysis" – MARC VIII Kona, Hawaii — April 4 – 11, 2009
- "Design of Aerosol Sampler to Remove Radon and Thoron Progeny — April 4 – 11, 2009

Interference from Aerosol Samples for Nuclear Explosion Monitoring" – MARC VIII Kona, Hawaii

- "Testing of Aerosol Sampler to Remove Radon and Thoron Progeny Interference from Aerosol Samples for Nuclear Explosion Monitoring," 29th Monitoring Research Review (MRR 2007) — Sept 26 – 28, 2007

PUBLICATIONS

- B. Buchholz, S. Bieglaski, S. Whitney, S. Tumey, J. Weaver "Basis for developing samarium AMS for fuel cycle analysis," *Nucl. Instr. Meth. Phys. B* (2010) 268 p. 773-775 — April 2010
- J. Weaver, S. R. F. Biegalski, B. A. Buchholz "Assessment of non-traditional isotopic ratios by mass spectrometry for analysis of nuclear activities," *J Radioanal Nucl Chem.* (2009) 282 p. 709-713. — Dec 2009
- J. Weaver, S. R. F. Biegalski, A. Brand, E. J. Artnak "Design of aerosol sampler to remove radon and thoron progeny interference from aerosol samples for nuclear explosion monitoring," *J Radioanal Nucl Chem*. (2009) 282 p. 687-692. — Dec 2009
- J. Weaver, W. H. Wilson, S. R. F. Biegalski, D. J. O'Kelly "Evaluation of heavy metal uptake in micropterus salmoides (Largemouth Bass) of Lake Austin, TX by neutron activation analysis," *J Radioanal Nucl Chem*. (2009) 282 p. 443-447. — Nov 2009
- S. Biegalski, J. Weaver, S. Waye, O. Ezekoye, and P. Hopke "Testing of Aerosol Sampler to Remove Radon and Thoron Progeny Interference from Aerosol Samples for Nuclear Explosion Monitoring," *29th Monitoring Research Review (MRR 2007) Proceedings*, Denver, CO, p. 719-728. — Sept 26 – 28, 2007
- M. McHugh, W. Johnson, W. Hamilton, J. Hanson, I. Heng, D. McNeese, P. Miller, D. Nettles, J. Weaver, P. Zhang "Calibration of the ALLEGRO resonant detector," *Class. Quantum Grav.* (2005) 22 p. S965-S973 — Aug 2005

ACTIVITIES & HONORS

- Nuclear Forensics Graduate Fellowship Recipient – U.S. Dept of Homeland Security Domestic Nuclear Detection Office (DNDO) — Sept 2008 - Dec 2010
- President, American Nuclear Society – UT Austin Chapter — June 2008 – July 2009
- George A. Heuer, Jr. Ph.D. Endowed Graduate Fellowship Recipient – UT Austin — Fall/Spring 2007
- Victor L. Hand Endowed Scholarship Recipient – UT Austin — Fall/Spring 2006