May 31, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY	)	Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN	)	50-401 OL
MUNICIPAL POWER AGENCY	)	
	)	
(Shearon Harris Nuclear Power	)	
Plant, Units 1 and 2)	)	

APPLICANTS' TESTIMONY OF JOHN J. MAURO AND STEPHEN F. MARSCHKE ON JOINT CONTENTION II(c) (RADIOLOGICAL DOSE CALCULATIONS)

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I. Introduction

My name is John J. Mauro. I am the Director of the Radiological Assessment and Health Physics Department of Envirosphere Company, a division of Ebasco Services, Inc. Ebasco is the architect-engineeer for the Shearon Harris Nuclear Power Plant. As indicated in Attachment 1A to this testimony, I have a doctorate in biology and radiological health and am a certified health physicist. I have worked for the last twelve years in the field of radiological assessment, and have written a number of publications in this field.

My name is Stephen F. Marschke. I am Principal Radiological Assessment Engineer at Envirosphere Company. As indicated in Attachment 1B, I have a bachelors degree in nuclear engineerirg. I have worked for ten years in the field of radiological assessment.

We have assisted Carolina Power & Light Company (CP&L) in the preparation of the radiological assessments contained in the Harris Plant Environmental Report (ER). We also have reviewed the Draft and Final Environmental Statements (DES and FES) prepared by the NRC Staff which assess the environmental impacts of operation of the Harris Plant. The radiological dose calculations that are included in the ER, the DES and the FES rely on the methodology specified in Reg. Guide 1.109.

The purpose of this testimony is to respond to the issues raised by the Joint Intervenors' Contention II(c) which remain in controversy.

Contention II(c) states:

> The long term somatic and genetic health effects of radiation releases from the facility during normal operations, even where such releases are within existing guidelines, have been seriously underestimated for the following reasons . . . c) the work of Gofman and Caldicott shows that the NRC has erroneously estimated the health effects of low-level radiation by examining effects over an arbitrarily short period of time compared to the length of time the radionuclides will be causing health and genetic damage.

In its Memorandum and Order dated January 27, 1984, as supplemented by its Memorandum and Order dated March 15, 1984, the Licensing Board partially denied Applicants' motion for summary disposition on Joint Contention II(c). In doing so, the Board limited the issues to be litigated to "whether the NRC staff should confine itself, as it has done in this case, to computations of annual doses and effects," and "whether it would be more appropriate to disclose the total risk represented by the life of the plant." The Board also ruled that the time period over which doses should be calculated should not include geologic time periods.

This testimony, prepared in response to the Board's January 27 and March 15 Orders, is designed to accomplish three objectives:

1) to briefly describe the method used in the FES and the ER for calculating radiological doses and risks, and to explain the reasons for characterizing the offsite impacts of these doses on an annual basis;

2) to quantify the impacts in terms of the life of the plant; and

3) to demonstrate that the impact of radiation released from the Harris Plant on the population and the maximally exposed individual over the life of the plant are vanishingly small relative to background radiation.

In evaluating doses from Harris Plant radiological releases, consideration must be given both to the population dose, i.e., the sum of the individual doses, and to the dose to the hypothetical maximally exposed individual. These two different ways of assessing dose are used in order to insure that (1) regulatory limits, which are designed to protect the individual, are met; and (2) the risk to the population as a whole is understood. In response to the Board's Order, this testimony is based on the calculation of doses to the population from 40 years of plant operation. The calculation includes consideration of any residual exposures from releases during the life of the plant (40 years) for a period of 100 years after plant operation ceases. The highly speculative doses accrued over geologic time periods are excluded. Doses to the maximally exposed individual are expressed in terms of lifetime dose from the 40-year operating life of the plant. As with population doses, the maximum individual doses are calculated on the basis of exposure to radionuclides released over a 40-year plant life, and the individual's exposure to residual radioactivity in the environment after the plant ceases operation.

This testimony is divided into two sections. The first section addresses the doses and risks to the 50-mile and U.S. populations; the second section addresses the doses and risks to the maximally exposed individual.

II. Population Doses and Risks

A. Current Values in the FES

Table D-7 of the FES, which is included as Attachment 2A to this testimony, presents the whole body and thyroid population doses within 50 miles (80 km) of the Harris Plant on an annualized basis. Separate values are provided for doses from liquid effluents, and from noble gases radioiodines and particulates in the gaseous effluents. Table D-9 of the FES, which is included as Attachment 2B, summarizes annual U.S. population doses from the Harris Plant and from natural background radiation.

The doses from the liquid effluents are from the ingestion of sport and commercial fish harvested from the main reservoir and from the Cape Fear River. The values are calculated by assuming the annual source term, presented in Table D-1 of the FES, is diluted in the reservoir. The calculation also assumes that the reservoir water overflows to the Cape Fear River, where it is mixed in the river flow. Fish in the reservoir and the Cape Fear River are assumed to reconcentrate the radionuclides to varying degrees, depending on the element; the fish then are harvested and consumed.

The doses from the gaseous effluent include external exposure from air submersion and deposited radioactivity, and internal exposure from inhalation and the ingestion of contaminated vegetables, milk and beef. These exposures are presented in Table D-7 for an 80 km radius from the plant, and in Table D-9 for the U.S. population.

The annual population doses from operation of the Harris Plant are compared to the annual doses from background radiation in Tables D-7 and D-9. This comparison also could have been presented on the basis of plant life. Since the annual doses represent the average annual dose over the life of the plant, the annual dose may be multiplied by 40 to estimate the cumulative dose from the operating life of the plant. There are no regulatory or other limits established for population doses; consequently, in order to evaluate their significance, population doses from nuclear power plants are compared with annual natural background population doses. It is also convenient to annualize doses from the Harris Plant because, for the purpose of NEPA assessment, the impacts from the nuclear fuel cycle are generically expressed on an annual basis (see Tables S-3 and S-4 of 10 CFR 51), and are compared to the benefits of the facility, which also are annualized. In sum, annualizing doses from the Harris Plant facilitates the assessment of the significance of those doses and provides a reasonable representation of the radiological impacts of plant operation.

B. Population Doses and Risk for the Life of the Plant

Life-of-the-plant population doses can be obtained by multiplying the values in Tables D-7 and D-9 by the assumed 40-year plant life and adding in the residual dose to the population due to radionuclides which reside in the environment after plant operation terminates. The annual doses contained in the FES would change to reflect the population doses for the life of the plant as follows:

Table 1 */

Pathway	Annual Whole Body Person-rems 80 km	U.S.	40-Year Whole Body Person-rems 80 km	U.S.
Liquid	1.7	1.7	68	68
Gaseous	13.7	24	556	1670
Total	15.4	25.7	624	1738
Natural Bkgd	180,000	26,000,000	7,200,000	1,040,000,000

*/ The number of significant digits is not intended to indicate the degree of calculational accuracy, but is provided to facilitate independent verification of the tabulated values.

Attachment 3 to this testimony demonstrates that the total additional dose to the population within 50 miles of the plant and to the U.S. population due to residual radioactivity in the environment is about 8 person-rems and 706 person-rems, respectively, over a 100-year period following plant shutdown. Considering that this residual dose is relatively small and in light of the numerous conservatisms inherent in the calculation

of annual dose during operation (see Attachment 4), the residual doses following plant operation are not significant. Accordingly, the 50-mile and U.S. population doses due to the operating life of the plant may be estimated by multiplying the annual doses presented in the FES by 40.

Similarly, the U.S. population health risk of 0.008 cancer deaths per year, referred to on page 5-35 of the FES, is multiplied by a factor of 40 to yield the risks due to the operating life of the facility. The result is 0.32 cancer deaths associated with the operating life of a two-unit plant, which means 0.16 cancer deaths for the single unit Harris Plant.

C. Comparison of Population Doses and Risks for the Operating Life of the Plant to Doses and Risks from Natural Background Radiation

As indicated in Table 2, the risk to the population as a whole due to the cumulative exposures associated with 40 years of operation is many thousands of times smaller than the risks due to natural background radiation over the same period of time.

Table 2 - Doses & Risks (Fatalities)

Source of Exposure	Population Dose (Person-Rems)	Population Risk	Average Individual Dose (Rems)	Average Individual Risk
40 yr operation				
50-mile*	624	0.10	3.5×10^{-4}	5.0×10^{-8}
U.S.**	1738	0.25	7.0×10^{-6}	1.0×10^{-9}
Natural Bkgd over 40 year				
50-mile	7,200,000	1,000	4	6.0×10^{-4}
U.S.	1,040,000,000	150,000	4	6.0×10^{-4}

* For 50-mile radius, the exposed population is assumed to be 1.8 million people.

** For U.S., the exposed population is assumed to be 260 million people.

Table 2 also reveals that the cumulative risk to the 50-mile population (0.10) and the U.S. population (0.25) due to 40-years of plant operation is less than one cancer fatality. In fact, the above results reveal that the best estimate of the number of cancer fatalities due to plant operation for 40 years is zero. This number can be compared to both the expected number of cancer fatalities over 40 years in the U.S., which is over 10 million,1/ and the expected number of cancer fatalities

1/ There are approximately 190 cancer fatalities per year per 100,000 people in the United States (Cancer Facts and Figures, 1984), and there are approximately 260 million people in the U.S.

within a 50-mile radius of the facility over 40 years, which is over 100,000.2/

III. Exposure of the Maximum Individual

A. Current Values in the FES

Table D-6 of the FES (provided in Attachment 5 of this testimony) presents the annual dose commitment to the hypothetical maximally exposed individual. Prior to the performance of the dose calculations, a land use survey was performed to identify the locations of residents and food ingestion pathways near the Harris Plant site. The result of this survey is the identification of the limiting exposure pathways and their locations, i.e., the locations with the potential for the highest exposure. As for most sites, the important radiation exposure pathways are inhalation, direct exposure, and the ingestion of vegetables, milk and beef. The limiting locations typically are farms or gardens closest to the plant. The limiting locations for each pathway are those presented in Table D-6.

Table D-6 presents doses for 4 locations.

(1) The first location is the nearest site boundary (2.1 km north of the plant). This is the offsite location with the greatest potential for exposure from routine gaseous effluent, and although no one resides there, doses are provided for two

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2/ There will be approximately 1.8 million people in the 50-mile plant vicinity at the year 2000.

reasons. First, Appendix I to 10 CFR Part 50 sets a limit on the annual air dose offsite. Second, should a person reside at that location some time in the future, it is desirable to determine annual exposures which may be expected. Thus, this location establishes the limiting benchmark for calculated annual offsite doses.

(2) The second location is the residence that is actually nearest to the plant site (2.7 km NNE).3/ At this location, individuals may be expected to receive exposure from inhalation and ground deposition. In addition, it is likely that the resident will have a backyard garden. Accordingly, the exposure from vegetable consumption is considered.

(3) The third location (2.9 km N) is the closest farm on which milk cows and beef cattle are exposed by consuming grass contaminated by deposited radionuclides.

(4) At the fourth location (7.4 km NNW), the closest milk goat pathway is considered.

At each location, and for each pathway at that location, doses are calculated for four age groups (adult, teen, child and infant) and for eight organs (bone, liver, total body, thyroid, kidney, lung, GI tract, and skin). The doses are presented in this way because the dose limits in Appendix I to 10 CFR 50 are expressed in terms of total body and organ doses.

3/ There is a typograhical error in Table D-6. As noted in Table D-2 of the FES and Table 5.2.2-1 of the ER, the nearest residence and garden is located 2.7 km NNE.

In Table D-6, the highest doses from these calculations are tabulated.

Table D-6 is useful in determining the maximum dose to the critical organs via each pathway for the critical age groups. In order to determine the maximum dose to an individual, the doses in Table D-6 must be summed. Thus, for example, the highest dose to any organ for any age group is to the infant thyroid gland due to the consumption of milk at the nearest cow milk location. In order to determine the infant's total thyroid dose, which is the maximum and, hence, limiting organ dose, the exposure to the thyroid from inhalation (0.22 mrem/yr), ground deposition (0.20 mrem/yr) and milk consumption (4.19 mrem/yr), must be combined, yielding 4.6 mrem/yr. This is the value reported in Table D-7 of the FES as the limiting "dose to any organ from all pathways." Table D-7 compares the calculated annual commitments for the maximally exposed individual to the Appendix I design objectives.

The doses from the liquid effluent pathways are determined in very much the same manner as those for the gaseous pathway. However, the analysis is simpler because all exposures, except for drinking water, are conservatively assumed to occur at the plant liquid effluent discharge area. This location is selected because it is possible that people will fish there. Since drinking water is not taken from the reservoir, the closest source of drinking water, which is at Lillington, is assumed in the dose calculations.

B. Maximum Individual Doses for the Life of the Plant

The previous discussion reveals that the annual doses in the FES are for selected organs and age groups at selected locations. Accordingly, the maximum dose to an individual over the operating life of the plant cannot be obtained by directly multiplying the values in Table D-6 by 40. Doing so would be unrealistically conservative because it would mean, for example, that an infant remains an infant for 40 years. Instead, a calculation was performed to determine the doses to an individual who receives the maximum lifetime exposure because he is initially exposed at birth and lives his entire life in the vicinity of the plant. The calculation takes into consideration changes in internal dosimetry and feeding habits as the individual grows to an adult. In order to simplify this calculation, it is conservatively assumed that a family resides at the nearest site boundary and obtains its beef, milk and vegetables at that location, drinks water from Lillington and fishes near the discharge area. It is also assumed that the individual remains at this location for a period of 70 years, which is taken as his life expectancy. The results of the analysis, presented in Attachment 6, are stated in terms of the annual dose to each organ and age group for each pathway.

As indicated in Attachment 6, the maximum lifetime whole body radiation dose to an individual from the 40-year operation of the Harris Plant is 130 mrem. This figure was obtained by

multiplying the annual doses for each age group by the number of years the individual is in that age group while the plant is operating,4/ and then summing these values. To this number is added the residual dose after plant shutdown (from 41 to 70 years). The calculated risk of cancer mortality from this exposure is estimated to be about 2×10^{-5} (0.00002). This risk was calculated using the age specific cancer risk coefficients and the methodology presented in BEIR I. Attachment 6 briefly describes this calculational method.

C. Comparison of Doses and Risks for the Operating Life of the Plant to the Maximally Exposed Individual Relative to Background Radiation

The above section indicates that the lifetime dose to the maximally exposed individual due to a 40-year operating life of the facility is 130 mrem. This dose appropriately is compared to that individual's 40-year and lifetime doses from natural background radiation, which is 4,000 and 7,000 mrem, respectively.

The maximum individual's calculated lifetime risk of dying of cancer from radiation released from the plant and from natural background radiation is about 2×10^{-5} (0.00002) and 1×10^{-3} (0.001), respectively. The risk posed by operation of the Harris Plant also can be compared to the average risk of dying of cancer from other causes of about 2×10^{-1} (0.2).

4/ Infant 0-1 year
Child 1-11 years
Teen 11-17 years
Adult 17-40 years

IV. Conclusions

The calculated cumulative radiation exposures to the 50-mile population and U.S. population due to operation of the Harris Plant is demonstrated to be less than one ten-thousandth of the doses to these populations due to background radiation over the plant lifetime. The calculated lifetime whole body dose to the individual maximally exposed to the Harris Plant's operation, assuming a 40-year plant operating life, is 130 mrem, which is about two one-hundredths of the lifetime dose from natural background radiation.

Based on these calculations, it is reasonable to conclude that even using extremely conservative calculation assumptions, the offsite radiation doses and associated health risks to individuals and the population from normal operation of Shearon Harris are vanishingly small and are, in our opinion, totally insignificant.

ATTACHMENT 1A

Resume

JOHN J MAURO

Education:

BS - Long Island University 1963
MS - New York University 1970
PhD - New York University Medical Center - Institute of Environmental Medicine 1973

Awards:

- Alvin Gruder Memorial Award for Excellence in Biological Sciences
- Member of the Optimates Society for Academic Achievement
- Founder's Day Award for Doctoral Dissertation

Societies:

- Health Physics Society
- American National Standards Committee on Emergency Planning

Certifications:

Certified by the American Board of Health Physics

Consultancies:

- Radiological Health Bureau of the California Office of Emergency Services
- Battelle Memorial Institute
- Louisiana Power and Light Company
- Shaw Pittman, Potts and Trowbridge
- EG&G Idaho
- Union Carbide Corporation - Nuclear Division

Current Position:

Director of the Radiological Assessment and Health Physics Department of Envirosphere Company in New York City.

Summary of Professional Experience:

While a graduate student at the Institute of Environmental Medicine of New York University, I was also a full-time Research Assistant from 1970 to 1973. In this position I assisted Principal Investigators on numerous research projects on the ecology and radioecology of the lower Hudson River Estuary. These activities included the collection of aquatic organisms from the estuary to determine species abundance and diversity, the life history of white perch and the concentration of radionuclides in aquatic organisms, water and sediment. These activities also included experimentation into the ability of microorganisms collected from the Hudson River sediment to organify inorganic mercury.

In addition to my responsibilities as Research Assistant, I was a full-time graduate student, studying environmental health, health physics and radioecology. My doctoral research was on the radioecological behavior of Cs-137 in the lower Hudson River Estuary. Research for my thesis covered a three-year period which included extensive field studies and laboratory experimentation to identify and mathematically model the uptake and elimination of Cs-137 by aquatic organisms.

After receiving my doctoral degree in 1973, I joined Ebasco Services as a Radiological Assessment Engineer. Ebasco Services is a major architect-engineer-constructor for power generating facilities. My initial responsibilities at Ebasco were to evaluate the radionuclide release rates from proposed and operating nuclear power facilities under normal plant operation and following postulated accidents, and to determine the radiation exposures and health risks to workers and members of the nearby general population. In this capacity I developed several models for performing radiological impact assessment, and have prepared the radiological impact assessment sections of license applications.

Since joining Ebasco I have held positions of increasing responsibility, and am currently Director of the Radiological Assessment and Health Physics Department in Envirosphere Company, the Nuclear Licensing and Environmental Health Division of Ebasco Services. In this position, I report directly to the Vice President of Nuclear Operations and, I am responsible for all radiological health and emergency planning services provided by Envirosphere Company. I manage a technical staff of 10 senior level consultants with advanced degrees in nuclear and biological sciences, with a combined 150 years of professional experience in technological risk management.

My responsibilities as Director of the department are divided into radiological health consulting (40%), project management (30%), marketing and business development (20%), and department administration (10%). A brief description of each of these areas of responsibilities follows.

Though my management responsibilities have increased considerably since joining Ebasco, I continue to personally provide consulting services to our clients. These services include the analysis of radiological source terms, environmental transport, radio-ecology, internal and external dosimetry, health risk assessment, radiological surveillance, emergency planning, regulatory analysis and the preparation and defense of expert testimony on these subjects. Recently I have also become involved in the evaluation of toxic chemical hazards at industrial sites and low-level radioactive waste management. These services have been provided for a large number of clients representing the nuclear power industry and federal and state agencies and their subcontractors.

I have also managed several consulting contracts in the areas of radiological and chemical toxicology, health physics, and emergency planning. A detailed description of these projects will be provided upon request. Most of these projects have been of a multidisciplined nature and included participation of specialists in the areas of toxicology, nuclear engineering, mathematical modelling, meteorology, hydrology and computer sciences. On these projects I had overall responsibility for budget, schedule and technical quality of deliverables.

As director of the Radiological Assessment and Health Physics Department, I am also responsible for developing and meeting an annual budget. The budget includes staff and non-staff salaries and out-of-pocket expenses for client billable work, department overhead and business development. My effectiveness as Director is judged by my ability to achieve or exceed the budget for billable work and to effectively control non-billable expenses. Non-billable expenses include business development, training and publications, presentations, participation on standards committees and other professional practices. I have responsibility for hiring new staff and for staff performance review, promotions and merit increases. In this capacity I am assisted by 2 department managers who report directly to me.

Publications and Presentations:

Mauro, J J and M E Wrenn 1972. A Review of Radiocesium in Aquatic Biota. Presented at the Health Physics Society Annual Meeting, Las Vegas, Nevada, June 12-16, 1972.

Mauro, J J and M E Wrenn 1973. Reasons for the Absence of a Trophic Level Effect for Radiocesium in the Hudson River Estuary. Presented at the IRPA meeting held in Washington, D C in October. Published in the proceedings of that meeting.

Mauro, J J and J Porrovecchio 1976. Numerical Criteria for In-plant As Low as is Reasonably Achievable. In "Operational Health Physics". Proceedings of the 9th Mid-Year Topical Symposium of the Health Physics Society.

Mauro, J J, D Michlewicz and A Letizia 1977. Evaluation of Environmental Dosimetry Models for Applicability to Possible Radioactive Waste Repository Discharges, Y/OWI/SUB-77/45705.

Mauro, J J 1978. Comparison of Gaseous Effluent Standards for Nuclear and Fossile Fuel Power Production Facilities. Proceedings of the December 1979 Annual Meeting of the American Nuclear Society.

J Thomas, J J Mauro, J Ryniker and R Fellman 1979. Airborne Uranium, Its Concentration and Toxicity in Uranium Enrichment Facilities, K/PO/SUB -79/31057/1, February.

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Mauro, J J 1980. A Real Time Computer Program for Offsite Radiological Impact Assessment. Presented at the 1980 Annual Meeting of the American Nuclear Society. TANSAO 34 1-899.

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Marschke S, and Mauro, J J 1980. Radiocesium Transport Into Reservoir Bottom Sediments - A Licensing Approach. Presented at the 1980 Annual Meeting of the ANS. TANSAO 34 1-899.

Mauro, J J and D Michlewicz 1981. Deployment Concepts for Real Time Environmental Dosimetry Systems. Presented at the 1981 Annual Meeting of the Health Physics Society.

Mauro, J J and E P O'Donnell 1982. The Role of the Architect/Engineer in the Emergency Planning Process. Presented at the Annual Meeting of the American Nuclear Society. June 6-10, 1982.

Mauro, J J and W R Rish 1982. Dealing with Uncertainties in Examining Safety Goals for Nuclear Power Plants. In NUREG-CP-0027. Proceedings of the International Meeting on Thermal Reactor Safety.

Mauro, J J, S Schaffer, J Ryniker, and J Roetzer. Survey of Chemical and Radiological Indices Evaluating Toxicity. National Low-Level Radioactive Waste Management Program. DOE/LLW-17T. March, 1983.

Vold E, J J Mauro and D Michlewicz 1984. Dose Projection for Nuclear Emergency Response on a Microcomputer. Published in "Computer Applications in Health Physics." Proceedings of the Health Physics Midyear Topical Meeting, Pasco, Washington. February 5-9, 1984.

Mauro, J J, S Schaffer, W Rish and J Parry. Application of Probabilistic Techniques to Dose and Risk Assessment Performed by EPA in Support of 40 CFR 191. Submitted for Publication.

ATTACHMENT 1B

STEPHEN F. MARSCHKE
Principal Engineer

SUMMARY OF EXPERIENCE (Since 1973)

Total experience - Ten years in the area of radiological impact assessment and nuclear engineering.

Professional Affiliations - American Nuclear Society
Health Physics Society
Ecological Society of America

Education - B.S., State University of New York at Buffalo, 1973 - Nuclear Engineering
Harvard School of Public Health, 1980 - Planning for Nuclear Emergencies

REPRESENTATIVE ENVIROSPHERE PROJECT EXPERIENCE (1977-1978, Since 1979)

Radiological Assessment Engineer

Lead radiological assessment engineer on the development team for Envirosphere's real time dose assessment computer program, CEPADAS. As such, responsibilities include:

- development of specifications,
- review of input from other disciplines,
- performing quality assurance,
- writing user's manuals, and
- training utility operators.

One of the principal authors of the report "Decommissioning Requirements for Nuclear Waste Repository Licensing" for the Office of Nuclear Waste Isolation. Prepared the alternative waste disposal concepts, radiological impact sections of the Environmental Impact Statement - DOE/EIS-0046F.

Other responsibilities include performing the analyses and preparation of the radiological impact sections of Safety Analysis Report Chapters 11 and 15 and Environmental Impact Report Chapters 5 and 7. Performs cost-benefit analyses to determine the most advantageous mode of radwaste system design, calculating both the in-plant and offsite radiological impacts.

Responds to questions from the various regulatory agencies concerning the radiological safety of LWR's, both domestic and foreign. Performs studies to determine the environmental and radiological consequences of decommissioning nuclear facilities. Developed Emergency Plans and Implementing Procedures for nuclear plants. Determine the effect on reservoir radionuclide concentration of the transfer of radionuclides to sediment.

PRIOR EXPERIENCE

Ralph M. Parsons Company
Nuclear Engineer (1 year)

Assigned to the design of a nuclear fuels reprocessing facility. Duties included the determination of individual component and area gamma shielding requirements. Performed analyses to determine the proper design for shield wall piping, instrumentation and HVAC penetrations. Was responsible for developing acceptable designs for access labyrinths. Determined the dose rate above a spent fuel storage pool from the spent fuel, the contaminated water and "skyshine".

United Engineers and Constructors, Inc.
Nuclear Engineer (4 years)

Responsible for performing the radiological analyses of various postulated accidents in both PWR and HTGR systems. These analyses included the determination of the radiological impact at the site boundary and to control room personnel. Determined inplant shielding requirements. Performed site radiological evaluation studies to determine which of a number of alternative sites was the preferred site and for a given site which of the NSSS would be the preferred system. Performed studies for the HTGR to determine the offsite effects of various modes of operation of the containment ventilation system and the waste gas management system. Responsible for the determination of fuel cycle costs for a number of nuclear fuel bid evaluations. From June 1975 to the termination of the project, was the Coordinating Engineer between the Nuclear Staff and HTGR project. As such, directed the flow of all work between the project and the staff.

Publications

Kang, C.S., R.L. Simard, S.F. Marschke and J.W. Trost 1976. Fuel bid evaluation, UEC-NSR-003-0, Proprietary report, August.

Marschke, S.F., J.J. Mauro 1980. Radiocesium transport into reservoir bottom sediments - a licensing approach. Presented at the 1980 Annual Meeting of the American Nuclear Society, June.

Table D-7 Calculated Appendix I dose commitments to a maximally exposed individual and to the population from operation of the Harris nuclear plant

	Annual Dose per Reactor Unit	
	Individual	
	Appendix I Design Objectives*	Calculated Doses**
Liquid effluents		
Dose to total body from all pathways	3 mrems	1.6 mrems
Dose to any organ from all pathways	10 mrems	2.1 mrems (liver)
Noble gas effluents (at site boundary)		
Gamma dose in air	10 mrads	0.3 mrads
Beta dose in air	20 mrads	0.8 mrads
Dose to total body of an individual	5 mrems	0.2 mrems
Dose to skin of an individual	15 mrems	0.6 mrems
Radioiodines and particulates***		
Dose to any organ from all pathways	15 mrems	4.6 mrems (thyroid)

	Population Within 80 km	
	Total Body (person-rems)	Thyroid (person-rems)
Natural background radiation†	180,000	
Liquid effluents	1.7	0.04
Noble gas effluents	1.7	1.7
Radioiodine and particulates	12	22

*Design Objectives from Sections II.A, II.B, II.C, and II.D of Appendix I, 10 CFR 50 consider doses to maximally exposed individual and to population per reactor unit.

**Numerical values in this column were obtained by summing appropriate values in Table D-6. Locations resulting in maximum doses are represented here.

***Carbon-14 and tritium have been added to this category.

†"Natural Radiation Exposure in the United States," U.S. Environmental Protection Agency, ORP-SID-72-1, June 1972; using the average background dose for North Carolina of 100 mrems/yr, and year 2000 projected population of 1,750,000.

Table D-9 Annual total-body population dose commitments, year 2000 (both units)

Category	U.S. population dose commitment, person-rems/yr
Natural background radiation*	26,000,000*
Radiation from Harris Units 1 and 2 (combined) operation	
Plant workers	1000
General public:	
Liquid effluents**	3.5***
Gaseous effluents	48
Transportation of fuel and waste	6

*Using the average U.S. background dose (100 mrem/yr) and year 2000 projected U.S. population from "Population Estimates and Projections," Series II, U.S. Department of Commerce, Bureau of the Census, Series P-25, No. 704, July 1977.

**80-km (50-mile) population dose

***See Errata to FES dated January 12, 1984

Attachment 3

Exposures from Residual Radioactivity Following Plant Shutdown

In the main text of this testimony, the population dose from 40 years of plant operation is presented. The dose was obtained by multiplying the annual dose in the FES by 40 and adding in the residual dose due to radionuclides which remain in the environment after the plant terminates operation. In this attachment, an estimate is made of the integrated population dose due to these radionuclides over a 100-year period following plant shutdown (after 40 years of operation).

Liquid Effluents

The population doses in the FES for the liquid pathway are presented in Appendix D and discussed in Appendix B of the FES. The methods and assumptions used by the NRC Staff to calculate population doses are as follows. The annual radionuclide releases in the liquid effluent listed in Table D-4 of the FES are assumed to be mixed in the circulating water discharge. The discharge water is assumed to mix in the reservoir and flow into the Cape Fear River where it mixes and is transported downstream. Commercial fishing, as estimated in Appendix I of the FES, is assumed to be taking place. The total commercial and sports fishing harvest in the reservoir and Cape Fear River

is conservatively estimated by the NRC Staff to be about 46,000 kg/yr.

The harvested fish are assumed to reconcentrate the radionuclides in the water in accordance with the reconcentration factors listed in Table A-1 of Regulatory Guide 1.109, and are assumed to be ingested and the population doses calculated using the dose conversion factors listed in Tables E-11 to E-14 of Regulatory Guide 1.109. As indicated in Table D-7 of the FES, the results of this calculation yields a 50-mile population dose of 1.7 person-rems/year to the whole body and 0.04 person-rems/year to the thyroid gland.

Assuming a 40-year plant operating life, the population dose integrated over the life of the plant may be simply estimated by multiplying the annual dose by 40. This approach, however, neglects the population dose which may be delivered by radionuclides which remain in the environment after the plant terminates operation. The radionuclides which could contribute to this residual dose are those with a half life that is relatively long, i.e., comparable to the operating life of the plant. There are several radionuclides that fall into this category, including Cs-137 (T1/2 = 30 yr), Cs-134 (T1/2 = 3.4 yrs), Co-60 (T1/2 = 5 yrs); H-3 (T1/2 = 12.6 yrs), and Sr-90 (T1/2 = 27.7 yrs). However, except for tritium (H-3), these radionuclides will be bound to the sediments in the reservoir and Cape Fear River, after termination of operation, where they will decay away. Thus, it is only tritium that remains in

solution and delivers a dose to the population. This tritium will mix uniformly in the world oceans and become part of the water cycle. The global dose commitment from tritium is 10^{-3} person-rems/Ci released (Benison; NUREG-0597). The dose to the population in the 50-mile vicinity of the plant is obtained by calculating the individual dose and then multiplying that figure by the 50-mile population size. Assuming a 40-year operating life and 370 Ci/yr released (see Table D-4 of the FES), the additional dose is less than 0.01 person-rems to the population within 50 miles of the plant. Similarly, the residual dose is less than 1 person-rems to the U.S. population.

Gaseous Effluents

The 50-mile population doses from the gaseous effluents are estimated in Table D-7 of the FES to be 13.7 person-rems/year. In these calculations, the gaseous effluents in Table D-1 of the FES are assumed to disperse in the atmosphere. As the radionuclides are transported they decay, deposit onto the ground and are further diluted in the atmosphere. Individuals located in the vicinity of the plant can receive external exposure from the passing airborne activity or from deposited activity on the ground. The population also can receive internal exposure from inhalation and the ingestion of foods contaminated from deposited radionuclides.

Assuming a 40-year plant operating life, the population dose integrated over the life of the plant may be estimated by multiplying the annual dose by 40. This approach, however, neglects the population dose which may be delivered by long-lived radionuclides which will remain in the environment after plant operation ceases, which includes Kr-85 (10 yr T1/2), H-3 (12.6 yr T1/2), C-14 (T1/2 = 5730 yrs) and several particulate radionuclides.

Krypton 85 is a noble gas which may be assumed to mix uniformly in the global atmosphere and deliver an external dose until it decays away within about 100 years. The 50-mile and U.S. population doses due to this residual activity are about 2×10^{-4} (0.0002) person-rems and 3×10^{-2} (0.03) person-rems, respectively (Benison, NUREG-0597).

The residual population dose from tritium in the gaseous effluent may be calculated in the same manner as that in the liquid effluent since it will also become part of the global water cycle. The 50-mile and U.S. population doses from this source of tritium are about 0.01 and 1 person-rems, respectively.

Particulate radionuclides include Cesium-137, Cesium-134 Strontium-90 and Cobalt-60. Within 50 miles of the plant, these radionuclides will all deposit onto the land and decay away within 100 years following plant shutdown. During this time, these radionuclides will reside in the soil and contribute to external exposure from direct radiation, and internal

exposure due to ingestion of foods contaminated via root uptake. Table A presents the residual population doses for these radionuclides via these pathways. In summary, from plant shutdown to 100 years after plant shutdown, there is a residual particulate dose of 4.2 person-rems.

TABLE A

Population Dose (person-rems)

	External Exposure	Internal Exposure			
		Vegetables	Milk	Beef	Total
Cs-137	3	1.5×10^{-2}	3.3×10^{-2}	7.0×10^{-3}	3.1
Cs-134	1.0×10^{-1}	2.9×10^{-4}	6.5×10^{-4}	1.3×10^{-4}	1.0×10^{-1}
Co-60	1	1.2×10^{-4}	2.6×10^{-5}	1.5×10^{-4}	1.0
Sr-90	-	6.2×10^{-3}	1.0×10^{-3}	3.7×10^{-4}	7.6×10^{-3}
Total	4.1	2.2×10^{-2}	3.5×10^{-2}	7.7×10^{-3}	4.2

Carbon 14 has a 5,820 year half life and, thus, will reside in the environment for a long period of time after plant operation ceases. In order to calculate the residual dose from Carbon-14, it may be assumed that the Carbon-14 uniformly mixes in the troposphere and slightly changes the specific activity of the carbon cycle. The 100-year dose to the population within 50 miles of the plant and to the U.S. population from Carbon-14 is estimated to be about 4 person-rems and 700 person-rems, respectively. (Killough, NUREG-0597).

Summary

As indicated in Table B, the total residual radiation doses accumulated for 100 years after the Harris Plant has ceased operating both by the populace living within 50 miles of the plant and by the entire U.S. population are 8 person-rems and 706 person-rems, respectively.

Table B

Residual (100 year post-operation) dose
(person-rems)

Isotope	50 Mile	U.S. Population
H-3	0.2	2
Kr-85	0.0002	0.03
Particulates	4.2	4.2
C-14	4	700
Total	8	706

Attachment 4

Conservatism in the Dose Calculations

In the main text of this testimony, it is stated that the population dose due to residual radioactivity in the environment following plant shutdown is relatively small compared to the dose during operation, and that this residual dose may be ignored because it is more than accounted for by the conservatism in the calculation of dose during operation. This attachment describes some of the more important conservatisms.

The calculation of the doses in the FES and the ER consist of a three-step process, each with varying degrees of inherent conservatism. The following presents a brief description of some of the more important conservative assumptions in each step.

Source Terms

The first step in the calculation of individual and population doses is to estimate the liquid and gaseous radionuclide release rate (i.e., source term). The source term, as estimated using the standard methods described in Regulatory Guide 1.112, is based on 0.12% failed fuel. However, operating experience over the four-year period 1978-1981 reveals a percentage of failed fuel of about 0.01% (NUREG-0633, NUREG/CR-1818, NUREG/CR-2410, NUREG/CR-3001). As a result, the radionuclide

concentrations in primary coolant are much lower than assumed, resulting in much lower radionuclide release rates. Tables 4-1 and 4-2 compare the measured radioiodine release rates in gaseous and liquid effluents at operating PWRs with the estimated values. Actual measured releases are many times smaller than those predicted using standard methods.

Dispersion

The second step in the calculation of individual and population doses is to determine the concentration of the released radionuclides in the environment. For gaseous releases, dispersion is calculated using the methods described in Regulatory Guide 1.111 which have been demonstrated to be conservative (Gogolak, et al; Miller and Hoffman). For aquatic releases, dispersion is calculated using the methods described in Regulatory Guide 1.113. Those methods take no credit for removal of radionuclides by sedimentation, resulting in an overestimate of the concentration of many radionuclides in water (Marschke and Mauro).

Dose Calculation

In calculating the dose to the individual and population, numerous assumptions are made which tend to overestimate the dose. Some of these assumptions are: (1) no reduction in dose is taken for removal of radionuclides from foods during preparation; (2) no reduction of dose is taken for removal of

radionuclides from drinking water due to treatment; and (3) no reduction of dose is taken for the weathering of radionuclides from the soil.

Table 4-1

AIRBORNE RADIOIODINE SOURCE TERMS

UNIT	PREDICTED[1,3] (Ci/Yr - unit)	MEASURED (Ci/Yr)[2] Average	Range
Arkansas 1	.048	.14	.003-.74
Arkansas 2	.17	.0047	.0047
Beaver Valley	.014	.021	.0001-.072
Calvert Cliffs (2 units)	.25	.27	.035-1.0
Crystal River	.12	.0071	.0025-.019
Davis-Besse	.12	.0021	.00026-.0057
D.C. Cook (2 units)	.10	.028	.005-.055
Ft. Calhoun	.065	.011	.0016-.02
Haddam Neck	.04	.019	.0017-.05
H.B. Robinson	-	.063	.0004-.3
Indian Point 1 & 2	.36	.22	.005-.81
Indian Point 3	-	.0084	.0039-.013
J.M. Farley	.049	.032	.022-.041
Kewaunee	.081	.12	.00062-.66
Maine Yankee	-	.14	.0021-.94
Millstone 2	.105	.0059	.0-.013
North Anna 1	.095	.045	.032-.057
Oconee (3 units)	.10	.062	.0033-.18
Palisades	.79	.1	.01-.38
Point Beach (2 units)	-	.049	.0025-.28
Prairie Island	.137	.0093	.0009-.021
Rancho Seco	-	.013	.005-.032
R.F. Ginna	.11	.039	.01-.17
Salem	.21	.016	.0-.04
San Onofre	-	.17	.00014-1.6
St. Lucie 1	1.0	.22	.01-.52
Surry	2.1	.097	.0076-.35
TMI 1	-	.035	.01-.14
Trojan	.24	.028	.01-.051
Turkey Point (2 units)	.80	.44	.03-1.8
Yankee Rowe	-	.077	.0-.53
Zion (2 units)	.20	.033	.005-.07
Average (Ci/Yr-unit)	.34 ci/yr-unit	.065 ci/yr-unit	

FOOTNOTES

(1) The predicted values were obtained from the FES for each plant and are based on calculations performed by the NRC using industry wide standard methods. The values are for I-131 except where indicated.

(2) The average and range are inclusive over the years of operation from 1970 to 1979. The values are a slight overestimate because they include I-131 and particulates with half lives greater than 8 days.

(3) Value not available is denoted by "-".

Table 4-2

I-131 RELEASES IN LIQUID EFFLUENTS IN 1979

PLANT	PREDICTED(1,3) (Ci/Yr-Unit)	MEASURED(2) (Ci/Yr)
Arkansas 1	9.2	.28
Arkansas 2	.26	.24
Beaver Valley 1	.34	.0008
Calvert Cliffs 1 & 2 (2 units)	.27	.65
D.C. Cook 1 & 2 (2 units)	.47	.012
Crystal River 3	2.0	.06
Davis-Besse 1	2.37	.0035
J.M. Farley 1	.48	.0013
Ft. Calhoun 1	1.8	.019
R.E. Ginna 1	.27	.0093
Haddam Neck 1	.36	.067
Indian Point 1 & 2 (2 units)	2.06	.079
Indian Point 3	-	.059
Kewaunee	.51	.00059
Maine Yankee 1	-	.41
Millstone 2	.9	.12
North Anna 1	1.2	.16
Oconée 1, 2 & 3 (2 units)(?)	.2	.14
Palisades 1	-	.00038
Point Beach 1 & 2 (2 units)	-	.088
Prarie Is. 1 & 2 (2 units)	3.8	.00076
Rancho Seco 1	0	.0
H.B. Robinson 2	-	.0037
Salem 1	1.43	.019
San Onofre 1	-	.025
St. Lucie 1	.17	.048
Surry 1 & 2 (2 units)	12.15	.064
TMI 1	-	.14
Trojan 1	.21	.012
Turkey Pt. 3 & 4 (2 units)	10.2	.020
Yankee Rowe 1	-	.0041
Zion 1 & 2 (2 units)	.81	.011
Average (Ci/Yr-unit)	2.1	.065

(1) From the Final Environmental Statement

(2) From NUREG/CR-2227

(3) Value not available is denoted by "-".

Table D-6 Annual dose commitments to a maximally exposed individual near the Harris plant

Location	Pathway	Doses (mrems/yr per unit, except as noted)			
		Noble Gases in Gaseous Effluents			
		Total Body	Skin	Gamma Air Dose (mrads/yr/unit)	Beta Air Dose (mrads/yr/unit)
Nearest site boundary* (2.1 km, N)	Direct radiation from plume	0.20	0.57	0.33	0.81
		Iodine and Particulates in Gaseous Effluents**			
		Total Body		Organ	
Nearest*** site boundary (2.1 km, N)	Ground deposition	0.44 (T)		0.44 (C) (thyroid)	
	Inhalation	0.24 (T)		0.56 (C) (thyroid)	
Nearest residence and garden (2.3 km, NNW)	Ground deposition	0.26 (C)		0.26 (C) (bone)	
	Inhalation	0.13 (C)		0.003 (C) (bone)	
	Vegetable consumption	0.49 (C)		1.13 (C) (bone)	
Nearest milk cow and meat animal (2.9 km, N)	Ground deposition	0.20 (C)		0.20 (I) (thyroid)	
	Inhalation	0.11 (C)		0.22 (I) (thyroid)	
	Vegetable consumption	0.41 (C)		N/A	
	Cow milk consumption	0.18 (C)		4.19 (I) (thyroid)	
	Meat consumption	0.04 (C)		N/A	
Nearest milk goat (7.4 km, NNW)	Ground deposition	0.016 (C)		0.016 (I) (thyroid)	
	Inhalation	0.014 (C)		0.027 (I) (thyroid)	
	Vegetable consumption	0.052 (C)		- (I) (thyroid)	
	Goat milk consumption	0.035 (C)		0.43 (I) (thyroid)	
		Liquid Effluents**			
		Total Body		Organ	
Nearest drinking water at Lillington	Water ingestion	0.007 (A)		0.01 (C) (liver)	
Nearest fish at plant discharge area	Fish consumption	1.7 (A)		2.3 (A) (liver)	
Nearest shore access near plant discharge area	Shoreline recreation	0.002 (A)		0.002 (A) (liver)	

*"Nearest" refers to that site boundary location where the highest radiation doses as a result of gaseous effluents have been estimated to occur.

**Doses are for age group and organ that result in the highest cumulative dose for the location: A=adult, T=teen, C=child, I=infant. Calculations were made for these age groups and for the following organs: gastrointestinal tract, bone, liver, kidney, thyroid, lung, and skin.

***"Nearest" refers to the location where the highest radiation dose to an individual from all applicable pathways has been estimated.

Attachment 6

Estimate of Individual Doses and Risks

In the main text of this testimony, the lifetime doses and risks to the maximally exposed individual are presented. The values include doses due to the releases from the plant during the 40-year life of the plant and doses due to residual radioactivity in the environment following plant shutdown. This Attachment presents the bases for these values.

In order to derive the maximum lifetime doses to an individual, it is assumed that at the time of plant start-up, a family with a newborne infant resides at the site boundary at the location of the highest average annual atmospheric dispersion factor. It is also assumed that the family has a backyard garden and milk and beef cows grazing on their property.

Table 6-1 presents the annual doses during plant operation for the maximum individual during infancy, childhood, teens and adulthood. The doses are presented for each organ. The lifetime dose due to annual plant operation is obtained by multiplying the dose by the number of years the individual is in each age category and then summing the doses. This covers the 40-year period of plant operations. To this is added the additional dose from residual radioactivity in the environment following shutdown. This residual exposure is assumed to continue until the individual is 70 years old. Using this calculation method, the maximum lifetime whole body dose is estimated to be

about 130 mrem. The lifetime risk of death to the individual due to this lifetime exposure is calculated to be about $2x10^{-5}$ (0.00002). This value is obtained by summing the lifetime risk associated with each year of exposure. These, in turn, were obtained by multiplying the age specific annual dose (described above) by the age specific risk coefficients. The age specific risk coefficients, presented in Table 6-2, were derived using the methods described in BEIR I for a linear dose response model.

Table 6-1

ANNUAL ADULT DOSES (MREM/YEAR)

GASEOUS PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
PLUME	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.66E-01	6.64E-01
GROUND	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	8.28E-02
VEGET	7.40E-01	7.23E-01	1.63E+00	7.46E-01	7.25E-01	9.13E-01	7.17E-01	7.13E-01
MEAT	1.89E-01	1.89E-01	6.33E-01	1.89E-01	1.87E-01	2.16E-01	1.86E-01	1.86E-01
MILK	2.99E-01	2.80E-01	7.05E-01	3.07E-01	2.91E-01	1.11E+00	2.81E-01	2.79E-01
INHAL	2.34E-01	2.33E-01	3.76E-03	2.35E-01	2.34E-01	4.94E-01	2.48E-01	2.31E-01
TOTAL	1.79E+00	1.75E+00	3.30E+00	1.81E+00	1.77E+00	3.06E+00	1.77E+00	2.16E+00

LIQUID PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
DRINK	6.48E-03	6.21E-03	2.23E-04	6.59E-03	6.33E-03	6.87E-03	6.24E-03	0.
FISH	1.61E+00	5.74E-02	1.22E+00	2.17E+00	7.28E-01	4.45E-02	2.52E-01	0.
SHORE	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.16E-03	1.35E-03
TOTAL	1.62E+00	6.48E-02	1.22E+00	2.18E+00	7.35E-01	5.25E-02	2.59E-01	1.35E-03

TOTAL PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
TOTAL	3.41E+00	1.82E+00	4.52E+00	3.98E+00	2.50E+00	3.11E+00	2.03E+00	2.16E+00

ANNUAL TEENAGER DOSES (MREM/YEAR)

GASEOUS PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
PLUME	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.66E-01	6.64E-01
GROUND	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	8.28E-02
VEGET	1.02E+00	1.00E+00	2.71E+00	1.05E+00	1.01E+00	1.16E+00	1.00E+00	9.94E-01
MEAT	1.44E-01	1.44E-01	5.34E-01	1.45E-01	1.43E-01	1.64E-01	1.43E-01	1.42E-01
MILK	4.58E-01	4.40E-01	1.30E+00	4.86E-01	4.60E-01	1.76E+00	4.43E-01	4.37E-01
INHAL	2.35E-01	2.34E-01	4.77E-03	2.38E-01	2.36E-01	5.61E-01	2.57E-01	2.33E-01
TOTAL	2.19E+00	2.15E+00	4.89E+00	2.25E+00	2.18E+00	3.97E+00	2.18E+00	2.55E+00

LIQUID PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
DRINK	4.52E-03	4.38E-03	2.15E-04	4.74E-03	4.49E-03	4.95E-03	4.42E-03	0.
FISH	9.14E-01	4.29E-02	1.29E+00	2.22E+00	7.38E-01	3.90E-02	2.91E-01	0.
SHORE	6.47E-03	6.47E-03	6.47E-03	6.47E-03	6.47E-03	6.47E-03	6.47E-03	7.55E-03
TOTAL	9.25E-01	5.38E-02	1.30E+00	2.23E+00	7.49E-01	5.04E-02	3.02E-01	7.55E-03

TOTAL PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
TOTAL	9.25E-01	2.20E+00	6.17E+00	4.48E+00	2.93E+00	4.02E+00	2.48E+00	2.56E+00

ANNUAL CHILD DOSES (MREM/YEAR)

GASEOUS PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
PLUME	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.66E-01	6.64E-01
GROUND	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	8.28E-02
VEGET	2.04E+00	2.02E+00	6.56E+00	2.10E+00	2.04E+00	2.27E+00	2.02E+00	2.01E+00
MEAT	2.45E-01	2.44E-01	1.00E+00	2.47E-01	2.45E-01	2.76E-01	2.44E-01	2.44E-01
MILK	9.32E-01	9.16E-01	3.19E+00	9.96E-01	9.51E-01	3.53E+00	9.23E-01	9.14E-01
INHAL	2.07E-01	2.06E-01	5.73E-03	2.10E-01	2.09E-01	5.83E-01	2.26E-01	2.06E-01
TOTAL	3.75E+00	3.71E+00	1.11E+01	3.88E+00	3.77E+00	6.99E+00	3.75E+00	4.12E+00

LIQUID PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
DRINK	8.50E-03	8.38E-03	6.18E-04	9.11E-03	8.61E-03	9.75E-03	8.45E-03	0.
FISH	3.55E-01	2.16E-02	1.59E+00	1.93E+00	6.22E-01	3.79E-02	2.30E-01	0.
SHORE	1.35E-03	1.35E-03	1.35E-03	1.35E-03	1.35E-03	1.35E-03	1.35E-03	1.58E-03
TOTAL	3.65E-01	3.13E-02	1.59E+00	1.94E+00	6.32E-01	4.90E-02	2.40E-01	1.58E-03

TOTAL PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
TOTAL	4.12E+00	3.75E+00	1.27E+01	5.83E+00	4.41E+00	7.04E+00	3.99E+00	4.12E+00

ANNUAL INFANT DOSES (MREM/YEAR)

GASEOUS PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
PLUME	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.58E-01	2.56E-01	2.66E-01	6.64E-01
GROUND	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	7.07E-02	8.28E-02
MILK	1.77E+00	1.75E+00	6.23E+00	1.91E+00	1.80E+00	8.09E+00	1.76E+00	1.74E+00
INHAL	1.19E-01	1.19E-01	3.40E-03	1.22E-01	1.20E-01	4.64E-01	1.31E-01	1.18E-01
TOTAL	2.22E+00	2.20E+00	6.56E+00	2.36E+00	2.25E+00	8.88E+00	2.23E+00	2.60E+00

LIQUID PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
DRINK	1.28E-02	1.27E-02	9.92E-04	1.42E-02	1.31E-02	1.60E-02	1.28E-02	0.
TOTAL	1.28E-02	1.27E-02	9.92E-04	1.42E-02	1.31E-02	1.60E-02	1.28E-02	0.

TOTAL PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
TOTAL	2.23E+00	2.21E+00	6.56E+00	2.37E+00	2.26E+00	8.90E+00	2.24E+00	2.60E+00

Table 6-2

Age Specific Fatal Cancer Risk Coefficients

Age	Risk of Fatal Cancer/Person-Rem*
0	0.5 x 10-3
0-4	1.0 x 10-4
5-9	1.0 x 10-4
10-14	2.4 x 10-4
15-19	2.4 x 10-4
20-24	1.9 x 10-4
25-29	1.6 x 10-4
30-34	1.4 x 10-4
35-39	1.1 x 10-4
40-44	0.9 x 10-4
45-49	0.6 x 10-4
50-54	2.8 x 10-5
55-59	1.0 x 10-5
60	0.5 x 10-5

* Values derived from Table 3-2 of the BEIR I Report. The time of risk, or plateau, was assumed to last the duration of life following the specified latent period which was assumed to begin at the midpoint of each age interval. Lifetime was assumed to be 70 years. For those age groups in Table 3-2 which were given a specific plateau duration, the specified value was used or that portion of it which did not exceed the 70 year age cutoff point.

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May 31, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY	)	Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN	)	50-401 OL
MUNICIPAL POWER AGENCY	)	
	)	
(Shearon Harris Nuclear Power	)	
Plant, Units 1 and 2)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of Applicants' letter to the Appeal Board and "Applicants' Testimony of Leonard D. Hamilton on Wells Eddleman's Contention 8F(1) (Table S-3 Coal Particulates)," "Applicants' Testimony of John J. Mauro and Steven A. Schaffer on Joint Contention II(e) (Fly Ash)" and "Applicants' Testimony of John J. Mauro and Stephen F. Marschke on Joint Contention II(c) (Radiological Dose Calculations)" were served this 31st day of May, 1984, by deposit in the U.S. mail, first class, postage prepaid, to the parties on the attached Service List and by hand delivery on June 1 to the parties identified by one asterisk.

Deborah B. Bauser

Deborah B. Bauser

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY and NORTH CAROLINA EASTERN MUNICIPAL POWER AGENCY	)	Docket Nos. 50-400 OL 50-401 OL
	)	
	)	
(Shearon Harris Nuclear Power Plant, Units 1 and 2)	)	

SERVICE LIST

James L. Kelley, Esquire
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Glenn O. Bright
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dr. James H. Carpenter
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Charles A. Barth, Esquire
Janice E. Moore, Esquire
Office of Executive Legal Director
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Docketing and Service Section
Office of the Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Daniel F. Read, President
CHANGE/ELP
5707 Waycross Street
Raleigh, North Carolina 27606

John D. Runkle, Esquire
Conservation Council of North Carolina
307 Granville Road
Chapel Hill, North Carolina 27514

M. Travis Payne, Esquire
Edelstein and Payne
P.O. Box 12607
Raleigh, North Carolina 27605

Dr. Richard D. Wilson
729 Hunter Street
Apex, North Carolina 27502

* Mr. Wells Eddleman
718-A Iredell Street
Durham, North Carolina 27705

Richard E. Jones, Esquire
Vice President and Senior Counsel
Carolina Power & Light Company
P.O. Box 1551
Raleigh, North Carolina 27602

Dr. Linda W. Little
Governor's Waste Management Board
513 Albemarle Building
325 North Salisbury Street
Raleigh, North Carolina 27611

Bradley W. Jones, Esquire
U.S. Nuclear Regulatory Commission
Region II
101 Marrietta Street
Atlanta, Georgia 30303

Steven F. Crockett, Esquire
Atomic Safety and Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Robert P. Gruber
Executive Director
Public Staff - NCUC
P.O. Box 991
Raleigh, North Carolina 27602