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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before Administrative Judges
Ivan W. Smith, Chairperson
Gustave A. Linenberger, Jr.
Dr. Jerry Harbour

In the Matter of PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, ET AL. (Seabrook Station, Units 1 and 2)	Docket Nos. 50-443-444-OL (Off-site EP) June 30, 1988

REBUTTAL
TESTIMONY OF DR. GORDON THOMPSON,
DR. ROBERT L. GOBLE, AND DR. JAN BEYEA
ON BEHALF OF THE ATTORNEY GENERAL FOR THE
COMMONWEALTH OF MASSACHUSETTS ON SHELTERING CONTENTIONS

I. IDENTIFICATION OF WITNESSES

Q. Please state your names, positions, and business addresses.

A. (Thompson) My name is Dr. Gordon Thompson. I am Executive Director of the Institute for Resource and Security Studies in Cambridge, Massachusetts.

A. (Goble) My name is Dr. Robert Goble. I am a Research Associate Professor at Clark University in Worcester, Massachusetts.

A. (Beyea) My name is Dr. Jan Beyea. I am the Senior Energy Scientist for the National Audubon Society in New York City.

Q. Briefly summarize your experience and professional qualifications.

(Thompson) I received a Ph.D in applied mathematics from Oxford University in 1973. Since then I have worked as a consulting scientist on a variety of energy, environment, and international security issues. My experience has included technical analysis and presentation of expert testimony on issues related to the safety of nuclear power facilities.

In 1977, I presented testimony before the Windscale Public Inquiry in Britain, addressing safety aspects of nuclear fuel reprocessing. During 1978 and 1979, I participated in an international scientific review of the proposed Gorleben nuclear fuel center in West Germany, a review sponsored by the government of Lower Saxony.

Between 1982 and 1984, I coordinated an investigation of safety issues relevant to the proposed nuclear plant at Sizewell, England. This plant will have many similarities to the Seabrook plant. The investigation was sponsored by a group of local governments in Britain, under the aegis of the Town and Country Planning Association. This investigation formed the basis for testimony before the Sizewell Public Inquiry by myself and two other witnesses.

From 1980 to 1985, first as a staff scientist and later as a consultant, I was associated with the Union of Concerned Scientists (UCS), at their head office in Cambridge, MA. On behalf of UCS, I presented testimony in 1983 before a licensing board of the US Nuclear Regulatory Commission (NRC), concerning the merits of a system of filtered venting at the Indian Point nuclear plants. Also, I undertook an extensive review of NRC research on the reactor accident "source term" issue, and was co-author of a major report published by UCS on this subject in 1986.

Currently, I am one of the principal investigators for an emergency planning study based at Clark University, Worcester, MA. The object of the study is to develop a model emergency plan for the Three Mile Island nuclear plant. Within this effort, my primary responsibilities are to address the characteristics of severe reactor accidents.

My other research interests include: the efficient use of energy; the supply of energy from renewable sources; radioactive waste management; the restraint of nuclear weapons proliferation; and nuclear arms control. I have written and made public presentations in each of these areas.

At present, I am Executive Director of the Institute for Resource and Security Studies, Cambridge, MA. This organization is devoted to research and public education on the efficient use of natural resources, protection of the environment, and the furtherance of international peace and security.

A detailed resume is included in the attachments to this testimony.

A. (Goble) I received a Ph.D. in physics from the University of Wisconsin in 1967, specializing in high energy elementary particle physics. Since then I have held combined research and teaching posts at Yale University, the University of Minnesota, the University of Utah, Montana State University, and Clark University. My present position at Clark is Research Associate Professor of Physics where I am a member of the program on Environment, Technology, and Society, and part of the Hazards Assessment Group of the Center for Technology, Environment, and Development [CENTED].

I have taught a wide range of physics courses at both the undergraduate and graduate level and a number of courses dealing with the relationship between technologies and society. My current research interests are: (1) emergency planning for nuclear reactor accidents (I am one of the principal researchers in a two year Clark project to write an emergency response plan for the TMI nuclear reactor); (2) risk assessment (I am conducting research on risks from radon exposures in indoor air, and am working with other CENTED group members on reviewing risk assessments for a potential radioactive waste repository in Nevada); (3) air pollution dispersal (I am continuing work on both short and long range pollutant dispersal, including applications to the acid rain problem, as well as the transport of radionuclides from nuclear accidents). A complete resume is included in the attachments to this testimony.

(Beyea) I received my doctorate in nuclear physics from Columbia University in 1968. Since then I have served as an Assistant Professor of physics at Holy Cross College in Worcester, MA; as a member for four years of the research staff of the Center for Energy and Environmental Studies at Princeton University; and, as of May 1980, as the Senior Energy Scientist for the National Audubon Society.

While at Princeton University, I worked with Dr. Frank von Hippel to prepare a critical quantitative analysis of attempts to model reactor accident sequences. The lessons learned from this general study of nuclear accidents and the computer codes written to model radioactivity releases I then applied to specific problems at the request of governmental and non-governmental bodies around the world. I have written major reports on the safety of specific nuclear facilities for the President's Council on Environmental Quality (TMI reactor), for the New York State Attorney General's Office (Indian Point), for the Swedish Energy Commission (Barsebeck reactor), and the state of Lower Saxony (Gorleben Waste Disposal Site). I have also examined safety aspects of specific sites for the California Energy and Resources Commission, the Massachusetts Attorney General's Office and the New York City Council. Also while at Princeton, I wrote a computer program, useful for reactor emergency planning, for the New Jersey Department of Environmental Protection.

After joining the National Audubon Society, I continued to work as an independent consultant on nuclear safety issues. I participated in a study, directed by the Union of Concerned Scientists (UCS) at the request of the Governor of Pennsylvania, concerning the proposed venting of krypton gas at Three Mile Island. The UCS study, for which I made the radiation dose calculations, was the major reason the Governor gave for approving the venting.

I participated in the international exercise on consequence modeling (Benchmark Study) coordinated by the Organization for Economic Cooperation & Development (O.E.C.D.). Scientists and engineers from fourteen countries around the world used their own consequence models to calculate radiation doses following hypothetical "benchmark" releases. Other participants from the United States included groups from Sandia Laboratories, Lawrence Livermore Laboratory, Batelle Pacific-Northwest, and Pickard, Lowe and Garrick, Inc. I also served as a consultant from the environmental community to the N.R.C. in connection with their development of "Safety Goals for Nuclear Power Plants."

At the request of the Three Mile Island Public Health Fund, I supervised a major review of radiation doses from the Three Mile Island accident. This report, "A Review of Dose Assessments at Three Mile Island and Recommendations for Future Research," was released in August of 1984. Subsequently, I organized a workshop on TMI Dosimetry, the proceedings of which were published in early 1986.

In 1986, I developed new dose models for the Epidemiology Department of Columbia University. These models are being used to assess whether or not the TMI accident is correlated with excess health effects in the local population. The new computer models account for complex terrain, as well as time varying meteorology (including changes in wind direction).

In addition to reports written about specific nuclear facilities, an article of mine on resolving conflict at the Indian Point reactor site, an article on emergency planning for reactor accidents, and a joint paper with Frank von Hippel of Princeton University on failure modes of reactor containment systems have appeared in The Bulletin of the Atomic Scientists.

I have also prepared risk studies covering sulfur emissions from coal-burning energy facilities, and I have managed a project that analyzed the side effects of renewable energy sources.

I regularly testify before congressional committees on energy issues and have served on several advisory boards set up by the Congressional Office of Technology Assessment.

I currently participate in a number of ongoing efforts aimed at promoting dialogue between environmental organizations and industry.

A complete resume is included in the attachments to this testimony.

II. OVERVIEW OF TESTIMONY

Q. To what testimony does your rebuttal testimony refer?

A. (All) Our testimony addresses the "Amended Testimony of William R. Cumming and Joseph H. Keller on Behalf of the Federal Emergency Management Agency on Sheltering/Beach Population Issues" ["FEMA Testimony"], dated June 10, 1988. Specifically, our testimony addresses the conclusion of that testimony that, "if the dose reduction strategy is sheltering first followed by an evacuation after plume passage, the total dose reduction would not be as great as that for the immediate evacuation strategy." FEMA Testimony at p. 9. As FEMA's technical witness, Joseph Keller, testified on cross-examination, FEMA's conclusion, that evacuation would in almost all cases be the preferred dose reduction strategy for the beach population, is premised on a generic analysis (including a generic dose consequence analysis) that did not take into account any factors or problems of emergency planning specific to the Seabrook site. See Tr. at 14192-14193; 14230; 142[illegible]3; 14250. Our testimony demonstrates that this generic analysis is not applicable to the Seabrook site.

In addition, our testimony addresses certain matters raised in cross-examination of the Applicants' Panel No. 6 on Sheltering. Specifically, our testimony rebuts that Panel's conclusion, as developed on cross-examination, that immediate evacuation would always be the preferred dose reduction strategy in the event of a severe accident. See, e.g., Tr. at 10556; 10426; 10428; 10591-10592. Our testimony also addresses the appropriateness of that Panel's use, as developed on cross-examination, of a "maximum dose reduction" standard, and the Panel's reliance on precautionary measures, i.e. early beach closing, as providing sufficient time to protect the summer beach population.

Q. Please summarize your testimony.

A. (All) Our testimony addresses the relative effectiveness of a range of emergency response strategies for protection of the beach population near the Seabrook Plant. These strategies encompass a spectrum of potential actions in regard to sheltering and evacuation. The relative effectiveness of the strategies is assessed for a range of potential reactor accident conditions.

Through this testimony, we demonstrate three major deficiencies of the NHRERP. First, the NHRERP will not be significantly more effective than strategies involving unplanned emergency response. Second, New Hampshire does not have an adequate basis for rejecting sheltering as a planned emergency response measure for the general beach population, especially in severe accident situations. Third, the NHRERP will be significantly less effective than generic emergency responses to nuclear plant accidents. As a result of these deficiencies, the NHRERP cannot be said to provide adequate protection to the beach population.

Q. Does your testimony cover the same ground as the rejected April 25, 1988 Commonwealth of Massachusetts Testimony of Sholly, Beyea, and Thompson?

A. (All) No. Our present testimony does not contain estimates of radiation doses and does not assume any particular accident scenario. Instead, the testimony addresses the relative effectiveness of emergency response strategies across a range of potential accident conditions. The same issue has been addressed in the June 10, 1988 FEMA Testimony of Keller and Cumming, although in that case without supporting analysis.

III. ANALYTIC APPROACH

Q. Please explain your analytic approach.

A. (All) We follow in the footsteps of the authors of NUREG-0396, which provides the planning basis for current emergency planning. Appendix I of NUREG-0396, which provides the rationale for that planning basis, includes a discussion of the emergency planning implications of the Reactor Safety Study (WASH-1400). Within that discussion, the results of technical analyses are presented, partly without attribution and partly with attribution to the report NUREG/CR-1131.[1/] Where attribution to NUREG/CR-1131 is made, the analytic results drawn from that document pertain in part to the relative effectiveness of various emergency response strategies. NUREG/CR-1131 itself contains a more elaborate treatment of the relative effectiveness issue.

Our approach is similar in principle to that of NUREG/CR-1131, except that we do not present estimates of actual radiation doses or the number of people suffering adverse health effects. Thus, our analysis is strictly confined to the issue of relative effectiveness. In addition, some details of our analytic approach differ from those of NUREG/CR-1131, as explained later in this testimony.

Q. What are the major elements of your analysis?

1/ Reference (6) in Appendix I of NUREG-0396 is currently available as: D.C. Aldrich et al., Examination of Offsite Radiological Emergency Protective Measures for Nuclear Reactor Accidents Involving Core Melt, NUREG/CR-1131, October 1979.

A. (All) First, we identify a set of emergency response strategies which collectively represent the spectrum of sheltering and evacuation actions potentially available to the beach population. Second, we select parameters which represent the potential application of these strategies. T..rd, we select, following NUREG/CR-1131, a set of parameter combinations to represent the spectrum of potential accidents at the Seabrook plant. Fourth, we estimate, in part using the MACCS computer program, the relative effectiveness of each emergency response strategy.

IV. EMERGENCY RESPONSE STRATEGIES

Q. Please outline the set of emergency response strategies which you have identified.

A. (All) We have identified four evacuation strategies and four sheltering strategies. Collectively, these represent the spectrum of sheltering and evacuation actions which might in principle be available to protect the general beach population.

Of the four evacuation strategies, the first (E1) represents evacuation performed without be.iefit of prior planning. The second (E2) corresponds to the evacuation currently envisioned in the NHRERP. The third (E3) respresents evacuation conducted with a rapidity typical of that anticipated at a generic plant site. Tne :ourth (E4) represents evacuation situations in which plume arrivai overlaps evacuation but there is no entrapment of the population. These strategies are hereafter referred to as "unplanned evacuation," "NHRERP evacuation," "generic evacuation" and "generic evacuation with difficulties", respectively.

The NHRERP contemplates the possibility of sheltering the general beach population in certain limited, unspecified circumstances. (See Applicants' Direct Testimony No. 6 (Sheltering), dated April 15, 1988, at p. 19.) However, the NHRERP contains no plans for implementing that strategy. (See generally, Comm. of Mass. Testimony of Goble, Renn, Eckert and Evdokimoff, dated April 25, 1988; See also, Tr. at 10180, 10182, 10153, 10165, 10578). Thus, our first sheltering strategy (S1) represents sheltering carried out without benefit of prior planning; we hereafter refer to this as "ad hoc shelter." Our second sheltering strategy (S2) represents a type of sheltering which might be contemplated if the NHRERP were modified to provide for implementing this kind of response. Since much of the currently available shelter space is in wood-frame buildings without basements, we hereafter refer to this strategy as "shelter equivalent to wood frame buildings without basements." It is important to remember tha many of the buildings in the beach area are so insubstantial that they do not meet the specifications we have assumed for this strategy. Our third and fourth sheltering strategies may be considered the "generic" sheltering strategies. The third strategy (S3) represents the degree of sheltering which is achievable in the basements of typical houses in the Northeast region.

Hereafter, we refer to this as our "shelter equivalent to wood frame buildings with basements" strategy. Our fourth strategy (S4) represents a better quality of shelter, achievable in medium-sized office or industrial buildings of masonry construction. This strategy is hereafter referred to as the "good shelter" case.

Q. Are all these options available to the beach population?

A. (All) Clearly, the E1 and E2 strategies are readily available. Also, existing structures would allow the S1 and S2 strategies to be available to part of the general beach population, although execution of the S2 strategy would require considerably more planning than is currently evidenced in the NHRERP, Rev. 2. The remaining strategies would only be available if additional preparations were made.

Preparation for implementing strategies equivalent to E3 and E4 would involve measures which increase the mobility of the beach population. Increased mobility could be achieved through measures such as the building of new roads, or by limiting the number of people who are permitted to visit the beaches. It is not our purpose here to propose or to assess the merits of any particular measure for achieving faster evacuation but simply to compare the relative effectiveness of various potential strategies.

The S3 and S4 strategies could be made available by the construction of special-purpose shelters or the improvement of existing structures. Alternatively, access to the beach could be limited so that the beach population never exceeded the capacity of existing shelter space in the relevant category.

Q. Why did you include in your analysis protective strategies not readily available to the beach population?

A. We included these strategies in response to FEMA's analysis of the adequacy of the NHRERP's provisions for the beach population. FEMA's conclusion that the NHRERP's provisions for the beach population are "adequate in concept" (FEMA Testimony at p. 8) is based on a generic assessment of the relative dose savings to be achieved from evacuation and sheltering in the event of a serious accident, and not on any site-specific analysis of the situation at the Seabrook site.2/ One of the purposes of our testimony is to demonstrate that this generic analysis is not applicable to the Seabrook site. By introducing the E3 and E4 cases, we are able to show how generic evacuations differ from evacuations at the Seabrook site. The E4 case, although it accounts for difficulties which might be experienced during evacuation, nevertheless represents a faster rate of evacuation than is envisioned for the Seabrook beach population.

Similarly, the S3 strategy represents sheltering of a type which could readily be achieved at a "generic" site in this Northeast region where, according to 1970 U.S. census data, 87%

2/ Tr. at 14192-14193; 14230; 14233; 14250.

of the year-round housing units have basements.[3/] By contrast, the S1 and S2 strategies, which employ shelters of a type currently available in the New Hampshire beach area near Seabrook, provide the sheltered population even less shielding from radiation than Aldrich et al. have assumed would be provided to populations at other nuclear power plant sites even if no protective actions were recommended.[4/]

Q. Please describe how you have selected parameters to describe the four evacuation strategies.

A. (All) The most important parameter here is the evacuation time. For the E2 case, we use times estimated by Dr. Thomas Adler, using methods described by him in separate testimony in this case. (See Testimony of Adler, dated April 25, 1988) Adler's calculations indicate that 4000 to 5000 vehicles will leave the beach area in an initial relatively rapid movement, before traffic jams become established. We assume that half of these vehicles belong to residents, while the remaining half belong to members of the beach population.

3/ D.C. Aldrich et al., Public Protection Strategies for Potential Nuclear Reactor Accidents: Sheltering Concepts with Existing Public and Private Structures, Sandia National Laboratory, SAND 77-1725, February 1978 [hereinafter "Aldrich et al., SAND 77-1725"].

4/ D.C. Aldrich et al., SAND 77-1725 at 14.

The characterization of an "unplanned evacuation" (strategy E1) is necessarily speculative. Two considerations are noteworthy for the case of Seabrook. The first concerns the efficiency of notification. Because the evacuation network in the beach areas freezes into traffic jams very quickly (see Adler Testimony), delays in notifying even a substantial portion of the beach population will have negligible effect on the evacuation times. The second consideration is planning for enhancing traffic flow. Here the major proposal in the NHRERP is a capacity-enhancing traffic control point (TCP) at the junction of I-95 and Route 51. [Adler, April 25 Testimony]. We have based our estimated times on two runs by Adler [April 25 Testimony] using the Applicants' "updated beach population figures"; one run with staffing for the TCP; the other without. We assume the same increases in times will hold for our assumed populations.

The E3 case represents evacuation with a rapidity typical of a generic nuclear plant site. As indicated above, such a site would have a very small population within 2-3 miles. Thus, the evacuation time will reflect only the time required to notify people, and the time required for vehicles to leave the affected area.

In some instances, evacuation times will be prolonged by factors such as a high population density. Our E4 case represents evacuation where such factors are operative -- hence our use of the designation "generic evacuation with difficulties." In selecting an evacuation time for strategy

E4, we were guided by evacuation time estimates made for some nuclear plant sites with a high density surrounding population. We employed, in part, a recent survey by Dr. Michael Black of evacuation time estimates for fourteen densely populated sites. This survey indicates that the population within 2 miles could be completely evacuated out to ten miles, under adverse conditions, in times ranging from 1 hour to 6 hours. For nine of the sites, it is estimated that this population could be evacuated within 2 hours.[5/] Of these fourteen sites, the San Onofre site provides a pertinent comparison with Seabrook, in that people frequent the beach near the San Onofre plant on summer weekends. Evacuation time estimates by Wilbur Smith and Associates indicate that the summer weekend population within 2 miles of San Onofre can be completely evacuated in 2.25 hours, while the population within 5 miles can be completely evacuated in 3.50 hours, assuming a balanced North-South routing of evacuees.[6/] Presumably it would take less time for an evacuation just to three miles.

An important point to note about our E4 case is that it reflects an overlap of evacuation with plume passage, but

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5/ Michael Black, Comparing Emergency Response Potential at Seabrook With That of Other US Nuclear Plant Sites, April 12, 1988.

6/ Wilbur Smith and Associates, Analysis of Time Required to Evacuate Transient and Permanent Population From Various Areas Within the Plume Exposure Pathway Emergency Planning Zone: San Onofre Nuclear Generating Station, November 1985.

without entrapment of the evacuating population. Such a situation could easily arise at a typical site where factors hindering evacuation are operative. We have chosen evacuation times which illustrate the resulting effects.

Q. What are the conventions associated with your selection of evacuation times?

A. (All) First, we selected evacuation times both for the 50th percentile and for the 90th percentile members of the beach population. In this instance, the 50th percentile member is that person who, when successfully evacuated, has been preceded by 50 percent of the initial beach population. Likewise, the 90th percentile member is that person who, when successfully evacuated, has been preceded by 90 percent of the initial beach population.

Second, we have defined "successful evacuation" as departure from the beach area or, more precisely, as moving beyond a 3-mile radius from the Seabrook plant. We chose a 3-mile radius because for most accident sequences that encompasses the area wherein people are at greatest risk of receiving doses that could result in early fatalities and severe health effects. (See, e.g., NUREG-1210, Vol. 4, at pp. 12-14, 28, 41). In fact, the generic protective action strategy that is advocated in NUREG-1210 (within 3 miles of the plant: early evacuation; beyond 3 miles: sheltering and selective expeditious evacuation after monitoring to locate hotspots) is based on their conclusion that "even for the worst possible accident, virtually all early fatalities can be prevented if the area near the plant (2 to 3 miles) is evacuated before or shortly after a release . . . ."[7/]

Third, our selected evacuation times begin at the time when plant conditions yield a signal that a release is imminent. This point precedes the commencement of the release by a time interval hereafter designated as the "warning time." With this convention, the term "evacuation time" actually covers a number of sequential actions. It includes sequential time intervals during which utility officials notify state authorities, those authorities make the decision to evacuate, notification of the beach population occurs, and that population moves to its vehicles. Throughout this testimony, for both evacuation and sheltering cases, a composite notification time of 0.5 hours is assumed. That is, the sequence of emergency response actions taken by a member of the public is assumed to begin at a point 0.5 hours after the release is known to be imminent.

Q. What evacuation times do you use?

A. (All) For the E2 ("NHRERP evacuation") case, we use evacuation times of 4.25 hours and 7.0 hours for the 50th percentile and 90th percentile population members, respectively. In the E1 ("unplanned evacuation") case, we use evacuation times of 4.75 hours and 8.0 hours for these two population members. For the E3 ("generic evacuation") case we use evacuation times of 0.9 and 1.4 hours, while for the E4

7/ NUREG-1210, Vol. 4, at 41.

("generic evacuation with difficulties") case, we use evacuation times of 1.5 and 2.5 hours, based on an assumed clearance time of 2 hours after notification.

Q. What assumptions do you make about radiation exposure during evacuation?

A. (All) We assume that people are located inside cars with the windows open. (We assume windows are open because on a hot summer beach day it is highly unlikely that people could stay in their cars for any reasonable length of time with the windows closed and the use of air-conditioning systems under the evacuation conditions expected in the Seabrook beach area may cause cars to overheat.) A shielding factor of 1.0 is assumed for exposure to the radioactive cloud and 0.7 is assumed for exposure to contaminated ground. In addition, we account for deposition of radioactivity on the outer and inner surfaces of each car and on the people inside each car. This is done by increasing the effective shielding factor for exposure to contaminated ground from 0.7 to 1.0. Appendix A provides a technical justification for these factors.

Q. Please describe how you have selected parameters to describe the four sheltering strategies.

A. (All) For our illustrative analysis, four parameters are important: the time it takes people to get into shelters; the quality of the shelter; the time during which sheltering occurs; and the time required for successful subsequent evacuation.

As our testimony evaluating the NHRERP's provisions for sheltering indicates, without any plans in place for implementing a shelter strategy in the beach area the task of getting people into shelter could be a considerable problem at the Seabrook site.[8/] Thus, our S1 ("ad hoc shelter") case assumes that people are still in the open, seeking shelter, at times when the radioactive plume may have arrived. In our remaining three sheltering cases, it is assumed that the relevant population is sheltered prior to plume arrival. It will be noted that careful planning would be necessary to achieve that result, and we do not imply that such planning would be successful.

Earlier in this testimony we have outlined the types of shelter which would characterize each sheltering strategy. Our choice of specific parameters to describe those shelter types is described later.

For all four sheltering cases, we assume that a portion of the population who are instructed to shelter will instead choose to evacuate. These evacuees, who do not shelter, are assumed to account for 50 percent of the resident and employee population within the EPZ, together with 25 percent of the beach population. We further assume that people who do shelter will be instructed to leave shelter only after the roads have cleared of the initial evacuees. Based on Adler's testimony,

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8/ See Testimony of Goble, Renn, Eckert and Evdokimoff, dated April 25, 1988.

we assume that the roads will be cleared of the initial evacuees within 3.75 hours. Allowing 0.5 hours for this information to be communicated to the sheltering population, this means that everyone in shelter (from the remaining resident population in the beach area and the remaining beach population) is assumed to leave shelter at a point 4.25 hours after a release is known to be imminent.

We assume that post-sheltering evacuation will be qualitatively similar to a direct evacuation, except that the evacuating population will be smaller (since an initial group is assumed to evacuate instead of seeking shelter). In selecting post-sheltering evacuation times, we employ Adler's calculations, adjusted for the smaller population. This approach ignores any special behavioral effects which might arise as populations evacuate areas known to be contaminated.

In introducing the S3 and S4 strategies, we pointed out that sheltering of this quality might be obtainable at Seabrock if access to the beach were limited so that the beach population never exceeded the capacity of existing space in the relevant category. If such an approach were taken, the post-sheltering evacuation times would be smaller than assumed here. This point could be pursued through further analysis if appropriate.

Q. What conventions do you employ in describing the sheltering strategies?

A. (All) As with the evacuation strategies, we selected sheltering and evacuation times for the 50th percentile and

90th percentile members of the initial beach population, as previously defined. Here also, "successful evacuation" is defined as moving beyond a 3-mile radius from the Seabrook plant.

As mentioned above, our sheltering cases assume that 25 percent of the beach population will evacuate immediately, without seeking shelter. In some instances, people in this group will accrue greater radiation doses than many in the sheltering population. The capturing of this effect would require a more elaborate analysis than we have conducted so far, and would involve ranking the beach population by dose rather than by precedence in achieving successful evacuation. We do not expect that such an analysis would lead to change in our overall conclusions.

As for evacuation, the time at which sheltering sequences commence is defined here as the point when plant conditions signal that a release is imminent, a point which precedes commencement of the release by a time interval known as "warning time." However, unlike evacuation strategies, sheltering strategies involve three phases: the time interval during which shelter is sought; the sheltering interval; and the subsequent evacuation interval.

Q. What time intervals did you select?

A. (All). As mentioned earlier, we assumed that, in the S2, S3 and S4 cases, people reach shelter before the plume arrives. In these cases, the pre-sheltering interval is thus effectively zero.

For the S1 case, we assume that the 50th percentile person will enter shelters after 1.4 hours, while the 90th percentile person enters shelter after 3.1 hours. These times are derived by adding a 0.5 hour notification interval to time estimates made by Ortwin Renn in testimony before this Board.[9/]

As mentioned above, for each sheltering strategy we assume that people begin post-sheltering evacuation at a point 4.25 hours after a release is known to be imminent. For the S2, S3, and S4 cases, we select post-sheltering evacuation times of 2.5 hours and 5.0 hours for the 50th percentile and 90th percentile person, respectively. In the S1 case, we are interested in the average post-sheltering evacuation time, which we assume to be 3.0 hours. The 50th percentile and 90th percentile persons are distinguished under the S1 strategy by the difference in their pre-sheltering intervals.

Q. What shielding factors did you select to represent shelter quality?

A. (All) For sheltering in the S1 and S2 cases, we were guided by the NHRERP, whose decision criteria for sheltering assume a shielding factor of 0.9 for cloud shielding, and 2 air changes per hour. For a structure of this kind, an appropriate shielding factor for radionuclides deposited on the ground is

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9/ See Testimony of Goble, Renn, Eckert and Evdokimoff, dated April 25, 1988. At page 78, a median estimate of 2.6 hours is shown for the pre-shelter interval for the 90th percentile person.

Under cross-examination on May 9, 1988 (see Transcript, page 11108), Renn estimated the pre-shelter interval for the 50th percentile person at 55-60 minutes. We assume an interval of 0.9 hours for this person.

0.5.[10/] In the S1 case, it is also necessary to account for deposition of radioactive material on people who are exposed to the plume prior to entering shelter. We account for this by increasing the ground shielding factor in proportion to the fraction of the duration of plume passage during which the person is exposed prior to sheltering, up to a maximum ground shielding factor of 0.8. Appendix A provides supporting information.

As mentioned above, the S3 strategy is equivalent to sheltering in the basements of typical New England houses. For this type of shelter, cloud and ground shielding factors of 0.5 and 0.08, respectively, are appropriate.[11/] We assume 1 air change per hour.

The S4 strategy is equivalent to sheltering in a medium-sized office or industrial building. Here, cloud and ground shielding factors of 0.2 and 0.02, respectively, are typical.[12/] We assume 0.5 air changes per hour.

Q. What assumptions do you make about radiation exposure prior to sheltering and during post-shelter evacuation?

10/ Aldrich *et al*., SAND 77-1725, Tables 1 and 2. We use values from the upper end of the range reported in Table 2.

11/ Aldrich *et al*, SAND 77-175, Tables 1 and 2.

12/ Aldrich *et al*, SAND 77-175, Tables 1 and 2.

A. (All) The S1 case is the only one in which pre-sheltering radiation exposure must be considered. Here, we assume a cloud shielding factor of 1.0 and a ground shielding factor of 1.0. The latter factor reflects the deposition of radioactivity on exposed people. For post-sheltering evacuation under case S1, we also assume a cloud shielding factor of 1.0, but assume a variable ground shielding factor. To account for deposition both on cars and on people, we assume that the ground shielding factor ranges from 0.9 to 1.2, in proportion to the fraction of the duration of plume passage during which the person is exposed prior to sheltering. For post-sheltering evacuation in the S2, S3 and S4 cases, we assume a shielding factor of 1.0 for exposure to the radioactive cloud. However, we employ an effective shielding factor for exposure to contaminated ground of 0.9, instead of the factor of 1.0 used in the direct evacuation case. The difference is based on our expectation that less radioactivity will be deposited on the skin. Appendix A provides a justification for this assumption.

Q. Please summarize the parameters selected for each strategy.

A. (All) Table 1 shows the exposure times selected for each strategy, while Table 2 shows the shielding factors. Together with the statements made immediately above about the rates of air change in various shelters, these two tables completely characterize the six emergency response strategies.

V. POTENTIAL REACTOR ACCIDENTS

Q. How did you select parameters to represent a range of accident conditions?

A. (All) In the spirit of NUREG/CR-1131, we selected the parameters estimated in WASH-1400 for the accident release categories PWR 1 through PWR 9. These release categories encompass the spectrum of potential accidents. WASH-1400, Appendix VI, Table VI 2-1 [Attachment 2 to this testimony] provides a complete characterization of these release categories, including their estimated probabilities of occurrence.

We actually go beyond NUREG/CR-1131, in that the more limited set of release categories PWR1 through PWR5 was used in NUREG/CR-1131 as a basis for comparative analysis of the effectiveness of emergency response strategies. Through its reference to that analysis, and through presentation of results from related analyses, NUREG-0396 clearly regards these five release categories as playing an important role in defining the emergency planning basis. However, our points are made even more forcefully by considering the entire spectrum of potential accidents.

Q. Do you endorse the WASH-1400 estimates of the probability and other characteristics of severe core damage accidents?

A. (All) Not necessarily. Our purpose here is to create an analogue to the analytic procedure which underlies

NUREG/CR-1131 and, through its reference to that document, NUREG-0396.

Q. Please explain the relationship between accident release characteristics and the effectiveness of precautionary emergency responses.

A. (All) The "warning time", as defined above, provides a time interval during which emergency responses can be initiated. If the warning time is long enough, it may be possible to evacuate people before they are exposed to the radioactive plume, with an obvious public health advantage.

The State of New Hampshire apparently believes that warning times at Seabrook will be long enough to allow such successful precautionary evacuation. In the State's Letter of February 11, 1988 to FEMA, it is stated (at p.4) that "the addition of these precautionary measures alleviates most concerns about sheltering the beach population."

Q. Has New Hampshire demonstrated any basis for this assumption?

A. (All) No. In order to demonstrate such a basis, New Hampshire or the applicants would need to address the potential characteristics of accidents specific to the Seabrook plant. There is no testimony on that subject before this Board.

Q. How have you handled the issue of warning time?

A. (All) Following the planning basis in NUREG-0396, we have analyzed the relative effectiveness of emergency response strategies across the range of release categories PWR1 through PWR9. The warning times for these release categories are provided by WASH-1400. [See Attachment 2].

VI. ESTIMATING THE RELATIVE EFFECTIVENESS OF THE EMERGENCY RESPONSE STRATEGIES

Q. Please outline the analytic procedure you employ to assess the relative effectiveness of emergency response strategies.

A. (All) We use three measures of relative effectiveness. First, we use the total exposure of a relevant individual over the time interval until successful evacuation is completed, relative to the exposure of the 50th percentile individual in the "unplanned evacuation" (S1) case. Here, "exposure" is physically equivalent to the collective dose to the red bone marrow of the exposed population, which is in turn similar to the collective whole body dose.

Second, we use the probability of an individual suffering early death, again relative to the 50th percentile individual in the "unplanned evacuation" (S1) case. Finally, we use the probability of an individual suffering prodromal vomiting, relative to the same 50th percentile individual.

A single measure of effectiveness such as "dose savings" (see Applicants Testimony p. 4) is not adequate to characterize emergency preparedness. That is because the goals of emergency planning include the avoidance of early death and injuries (see NUREG-0654, p. 6) as well as dose reduction, and those early health effects have thresholds. A protective response strategy that is primarily directed toward reducing the aggregate dose to a large population (such as the ordering of a prompt evacuation over a large region) might be quite ineffective at preventing injuries and deaths to a population close to the plant. We, therefore, consider dose reduction, reduction in the number of deaths, and reduction in one representative early injury to be three independent measures for judging the effectiveness of a response.

For each of the release categories PWR 1 through PWR 9, we estimate the radiation exposure and the probabilities of early health effects for each emergency response strategy, both for the 50th percentile and 90th percentile individuals. We use the MACCS computer code for this purpose, assuming a wind-speed of 12 miles per hour (20 km/hr) and Class C (moderately unstable) stability. These meteorological conditions are intended as representative fair weather conditions. They are not favorable conditions for emergency response, nor are they "worst case" conditions.

These results are combined over the release categories PWR 1 through PWR 9 by weighted averaging, where the weights correspond to the probabilities of occurrence of each release category, as estimated in WASH-1400. In this respect, we employ a more sophisticated procedure than NUREG/CR-1131, which merely combines the release categories into one composite category.

Q. How do you analyze the relationship between air change in buildings and inhalation exposure?

A. (Goble) We have assumed continuous exchange of indoor air with air outside and have compared the average concentration indoors with the concentration outdoors assuming the outdoor concentration is constant for the duration of the release (as specified for each accident category in WASH-1400, Table VI 2-1). The indoor average is calculated only for the period of plume passage except that, in agreement with the NHRERP, we use the 1-hour average for releases of less than an hour duration. We do not assume that the building provides any filtering. The values we have used for various durations of release and air exchange rates are shown in Table 3.

Q. Please summarize your results.

A. (All) Tables 4 through 6 and Figures 1 through 3 summarize the results of our assessment.

Our interpretation of the summarized results depends on two sets of observations: one is the relative magnitude of the entries in the tables; the second is the sensitivity of these entries to particular assumptions in the modeling.

The magnitudes in the tables and figures show: 1) The "NHRERP evacuation" (E2) case is only marginally more effective than is the "unplanned evacuation" (E1) case according to all three measures of effectiveness; 2) The "generic evacuation" (E3) and the S3 and S4 sheltering cases are substantially more effective than either the E1 or the E2 cases. Thus, protective responses which are available at most nuclear power plant sites provide significant reduction in exposure to radiation and in early deaths and injuries as compared with emergency responses envisioned for Seabrook; 3) The E4 and S2 (shelter equivalent to wood frame buildings without basements) cases appear to have some potential effectiveness, with E4 appearing generally better according to these measures; 4) The "ad hoc shelter" (S1) case is not an effective response.

The quoted results are potentially sensitive to a wide range of uncertainties in the modeling, including details of accident characteristics and meteorological conditions. Of most interest in interpreting the results are the effects of possible variation in warning times and duration of release. The results for the E1 and E2 cases are quite insensitive to moderate changes in warning time and duration of release. The three sheltering cases, S2, S3 and S4 are insensitive to warning time, until it becomes short enough that a significant fraction of the population remains outdoors at the time of plume arrival. The effectiveness of sheltering, especially poor sheltering, decreases moderately with increased duration of release, because large inhalation exposures may be anticipated. The E4 case is most sensitive to changes in warning times and duration of release (since it represents an evacuation which overlaps with plume passage, but does not have a trapped population). Increases in warning time and release duration provide substantial increases in effectiveness, a decrease in warning time reduces the effectiveness.

To conclude: the results of our analysis show with reasonable robustness that: 1) As a response to the spectrum of potential accidents, including those used in the NRC planning basis, the NHRERP appears to be only marginally more effective in reducing exposures and early health effects for the transient beach population than an unplanned evacuation. The situation would be characterized by "entrapment" of the population, exposing them potentially to the major portion of the release while they are immobile and without shelter; 2) The relative effectiveness of the NHRERP is much poorer for the spectrum of accidents than the effectiveness expected for emergency response at most nuclear power plant sites where sheltering and more rapid evacuation are provided; 3) Our analysis is not adequate to quantify the benefits of a sheltering strategy as S2, nor do we address its feasibility. The analysis does indicate that there are potential benefits to be derived from such a planned sheltering response, but that no such benefit would be derived from an ad hoc sheltering response. In view of the ineffectiveness of the proposed plan and the absence of a detailed analysis of the feasibility of a sheltering strategy based on existing or improved buildings, New Hampshire has no basis for rejecting sheltering as a planned emergency response.

APPENDIX A

SHIELDING FACTORS DURING EVACUATION BY AUTOMOBILE: TECHNICAL DISCUSSION

Due to the relatively lightweight structure in the upper part of an automobile, and the presence of windows, the shielding factor for exposure of a vehicle occupant to a radioactive cloud is effectively 1.0. That is, a person inside an automobile gains no protection against cloudshine.

For exposure to contaminated ground, neglecting deposition of radioactivity on the automobile or on the exposed person, the shielding factor for a vehicle occupant can be calculated to have a range of 0.53-0.78. This range represents an updating of the 0.4-0.7 shielding factor range used in the Reactor Safety Study (WASH-1400). Cars are lighter today (and will be more so in the future) compared to the 1975 vehicles analyzed in the Reactor Safety Study. Assuming that vehicles involved in an evacuation will be 30% lighter than 1975 vehicles,[1/] the appropriate shielding factor range turns

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1/ Due especially to the decrease in the amount of steel used in U.S.-built cars, the material weight of U.S. cars dropped 15% between 1975 and 1981 and was projected to drop another 15% by 1985. (Table 4.3, p. 122, Transportation Energy Data Book, edition 6, G. Kulp, M.C. Holcomb, ORNL-5883 (special), Noyes Data Corporation.)

out to be 0.53-0.78.[2/] Now, the relative contributions of doses from deposited material, accounting for deposition on the ground, on or in the automobile, or on people, can be obtained as follows:

Dose per unit time (Relative to dose from a flat, contaminated plane):[3/]

A) to person standing on contaminated beach, parking lot, road, etc: 1.0 x Sg [4/]

B) Dose inside car from contaminated ground: 1.0 x Sc [5/]

2/ Shielding varies exponentially with mass per unit area. Thus $(.4)^{.7} = 0.53$; $(.7)^{.7} = 0.78$

3/ In the absence of detailed calculations, we assume that absorption effects in air can be handled by neglecting all absorption at distances less than 100 meters and by treating absorption beyond 100 meters as total. Thus, we replace the exact problem of a contaminated plane of infinite extent by a finite circular surface of radius 100 meters. Since the integral over the disk turns out to be logarithmic with radial distance, the total dose is insensitive to the cutoff distance chosen. These calculations are conservative since they ignore ground scattering effects which increase relative doses from deposition close to the receptor.

Deposition is assumed to proceed uniformly on any external surface regardless of the surface's orientation. Thus, a square centimeter of ground is assumed to receive the same contamination as a square centimeter of skin.

4/ Shielding factor, Sg = 0.47-0.85. See WASH-1400, Appendix VI.

5/ Shielding factor, Sc = 0.53-0.78. See WASH-1400, Appendix VI.

C) Dose inside car from radioactivity deposited on outside of vehicle: .22 x Sc 6/

D) Dose inside car from radioactivity deposited on inside of vehicle with open windows: .04 -.2 7/

E) Dose from skin contaminated while outside vehicles: .35 8/

6/ Based on numerical integration over an idealized automobile, deposition is assumed to take place on the underside of the vehicle as well as on the top surface.

7/ This case would occur: (1) if windows had been left open, or (2) if evacuees reached their vehicles and opened windows before plume passage were complete.

The low number corresponds to low wind speeds; the high number corresponds to high wind speeds.

8/ An estimate of the relative contribution of skin contamination to the total dose can be obtained by replacing the complex shape of the human body with a set of bounding geometric surfaces:

1) sphere: the dose rate at the center of a sphere contaminated with N curies of radioactivity per square centimeter is 43% of the dose rate 1 meter above a circle of 100 meter radius that has also been contaminated with N curies per unit area.

   Although a cylindrical model would be more accurate, the results will not differ by a large amount, as shown below.

2) right circular cylinder: numerical integration in the case of a cylinder with radius 1/10th of the length indicates that the average centerline dose is approximately 17% greater than the sphere center dose discussed previously. For a cylinder with radius 1/5th of the length, the average centerline dose is slightly less than the sphere case.

The results of these rough calculations suggest that direct contamination of people must make a significant contribution to the total dose. We take the numerical relationship to be 35%, that is, the skin contribution is assumed to be 35% of the dose from contaminated ground.

F) Dose from skin contaminated while inside vehicles with open windows. .17 9/

For our illustrative analysis, we assume that the basic shielding factor without deposition on the car or on people -- that is, the factor Sc -- is 0.7.

During direct evacuation, we assume that car windows will be open during passage of the radioactive plume. Thus, people inside cars will be exposed to dose elements B, C and D from the above list. This yields an effective ground shielding factor in the range 0.89-1.05.

In addition, people will be exposed to doses from radioactive material deposited on their skin or clothes -- that is, to dose elements E or F from the above list.

Considering all these dose contributions, we assume an overall effective ground shielding factor of 1.0 for the direct evacuation case.

For post-sheltering evacuation, it is likely that many cars will have been left with their windows closed, and will not have been internally contaminated during plume passage. In addition, people will have been protected from deposition of radioactive material on their bodies, to an extent dependent on the rate of shelter. However, people will be at risk of being contaminated after leaving shelter, through brushing against

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9/ We take this dose to be half of the value for a person standing in the open, assuming that half of a person's surface area is pressed against a seat and, therefore, not subject to deposition.

contaminated buildings or vehicles or from passage through clouds of resuspended material. We account for all these considerations by assuming an overall effective ground shielding factor of 0.9 for the post-shelter evacuation case.

TABLE 1

POTENTIAL EXPOSURE TIMES FOR EACH STRATEGY

STRATEGY	TIME IN THE OPEN BEFORE SHELTERING (hours)	TIME IN SHELTER (hours)	TIME ON THE ROAD (hours)
(A) Evacuation Strategies			
E1. Unplanned Evacuation	0, 0	0, 0	4.75, 8.0
E2. NHRERP Evacuation	0, 0	0, 0	4.25, 7.0
E3. Generic Evacuation	0, 0	0, 0	0.9 , 1.4
E4. Generic Evacuation with Difficulties	0, 0	0, 0	1.5 , 2.5
(B) Sheltering Strategies			
S1. Ad Hoc Shelter	1.4, 3.1	2.95, 1.55	3.0 , 3.0
S2. Shelter Equivalent to Wood Frame Buildings Without Basements	0, 0	4.25, 4.25	2.5 , 5.0
S3. Shelter Equivalent to Wood Frame Buildings With Basements	0, 0	4.25, 4.25	2.5 , 5.0
S4. Good Shelter	0, 0	4.25, 4.25	2.5 , 5.0

NOTES:

1. The entries x, y indicate times for the 50th percentile and 90th percentile population members, respectively.

2. Sequences of protective action begin when plant conditions signal that a release is imminent. The three time periods shown across each row are consecutive.

3. "Time on the road" terminates when people move beyond a 3-mile radius from the Seabrook Plant.

TABLE 2

SHIELDING FACTORS FOR EACH STRATEGY

STRATEGY	CLOUD SHIELDING FACTOR			GROUND SHIELDING FACTOR		
	BEFORE SHELTER	IN SHELTER	IN CAR	BEFORE SHELTER	IN SHELTER	IN CAR
(A) Evacuation Strategies						
E1. Unplanned Evacuation	NA	NA	1.0	NA	NA	1.0
E2. NHRERP Evacuation	NA	NA	1.0	NA	NA	1.0
E3. Generic Evacuation	NA	NA	1.0	NA	NA	1.0
E4. Generic Evacuation with Difficulties	NA	NA	1.0	NA	NA	1.0
(B) Sheltering Strategies						
S1. Ad Hoc Shelter	1.0	0.9	1.0	1.0	0.5 to 0.8 [2]	0.9 to 1.2 [2]
S2. Shelter Equiv. to Wood Frame Building Without Basements	NA	0.9	1.0	NA	0.5	0.9
S3. Shelter Equiv. to Wood Frame Buildings With Basements	NA	0.5	1.0	NA	0.08	0.9
S4. Good Shelter	NA	0.2	1.0	NA	0.02	0.9

NOTES:

1. "NA" means "Not Applicable".
2. Across this range, the factor is proportional to the fraction of the duration of plume passage during which the person is exposed prior to sheltering.

TABLE 3

FRACTION OF EXTERNAL INHALATION
EXPOSURE THAT WOULD OCCUR INDOORS

Number Of Air Changes Per Hour

Duration of Release	2	1	.5
.5 hour	.5	.35	.22
1.5 hours	.65	.45	.29
3.0 hours	.85	.65	.45
4.0 hours	.9	.75	.55

TABLE 4

RELATIVE EXPOSURE FOR EACH STRATEGY

STRATEGY	50th PERCENTILE PERSON	90th PERCENTILE PERSON
(A) Evacuation Strategies		
E1. Unplanned Evacuation	1.0	1.24
E2. NHRERP Evacuation	0.95	1.16
E3. Generic Evacuation	0	0.33
E4. Generic Evacuation With Difficulties	0.46	0.70
(B) Sheltering Strategies		
S1. Ad Hoc Shelter	0.97	1.43
S2. Shelter Equivalent to Wood Frame Buildings Without Basements	0.71	0.88
S3. Shelter Equivalent to Wood Frame Buildings With Basements	0.49	0.66
S4. Good Shelter	0.38	0.55

NOTES:

1. The entry for the 50th percentile person for the "Unplanned Evacuation" strategy is arbitrarily set at unity.
2. Here, "exposure" is physically equivalent to red marrow dose.

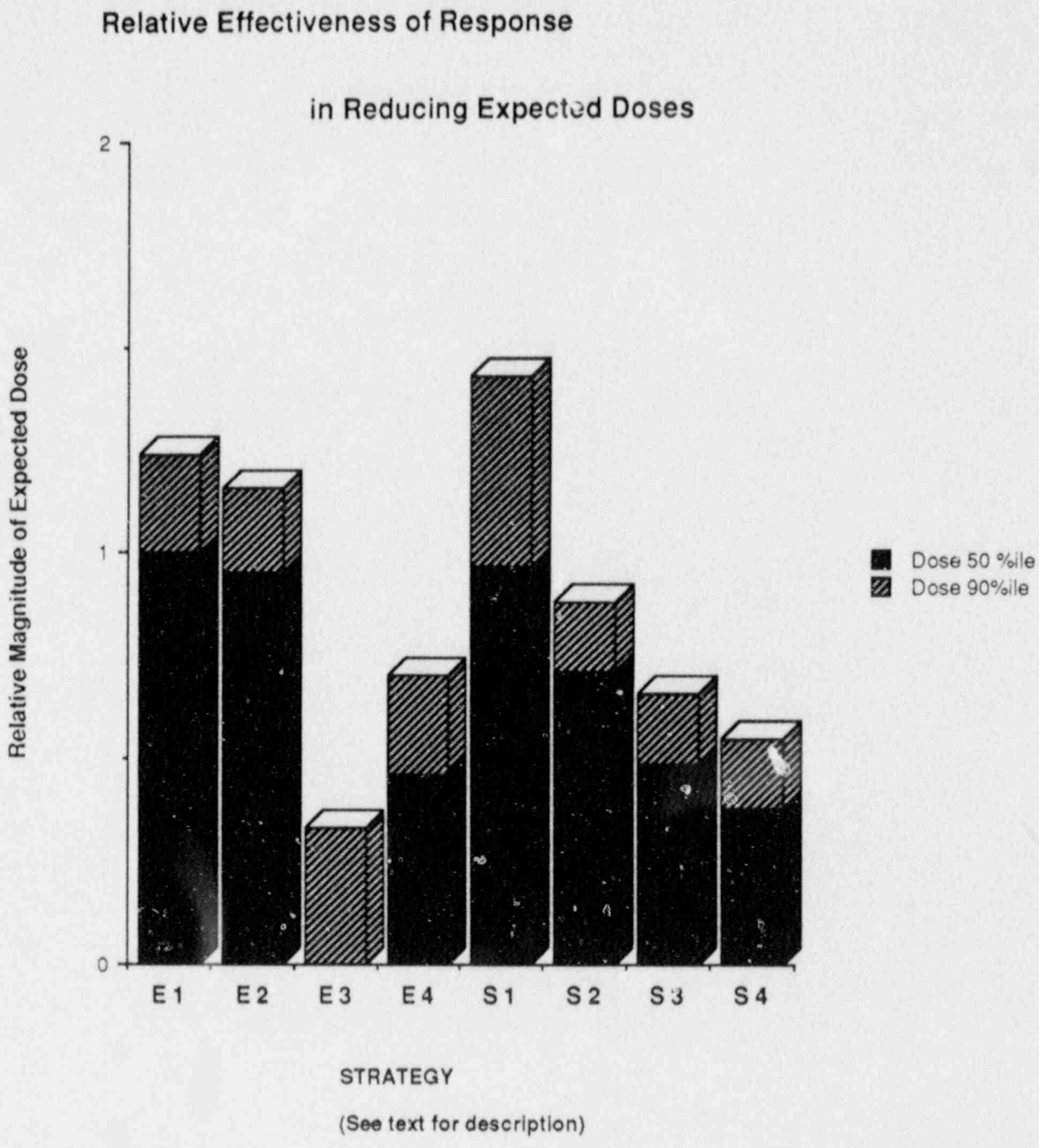

Relative Effectiveness of Response
in Reducing Expected Doses
2
1
0
Relative Magnitude of Expected Dose
Dose 50 %ile
Dose 90%ile
E1
E2
E3
E4
S1
S2
S3
S4
STRATEGY
(See text for description)

FIGURE 1

TABLE 5

RELATIVE PROBABILITY OF
EARLY DEATH FOR EACH STRATEGY

STRATEGY	50th PERCENTILE PERSON	90th PERCENTILE PERSON
(A) Evacuation Strategies		
E1. Unplanned Evacuation	1.0	6.55
E2. NHRERP Evacuation	0.84	3.45
E3. Generic Evacuation	0	0.0005
E4. Generic Evacuation With Difficulties	0.004	0.27
(B) Sheltering Strategies		
S1. Ad Hoc Shelter	1.26	47.1
S2. Shelter Equivalent to Wood Frame Buildings Without Basements	0.09	1.76
S3. Shelter Equivalent to Wood Frame Buildings With Basements	0	0.042
S4. Good Shelter	0	0.013

NOTE:

The entry for the 50th percentile person for the "Unplanned Evacuation" strategy is arbitrarily set at unity.

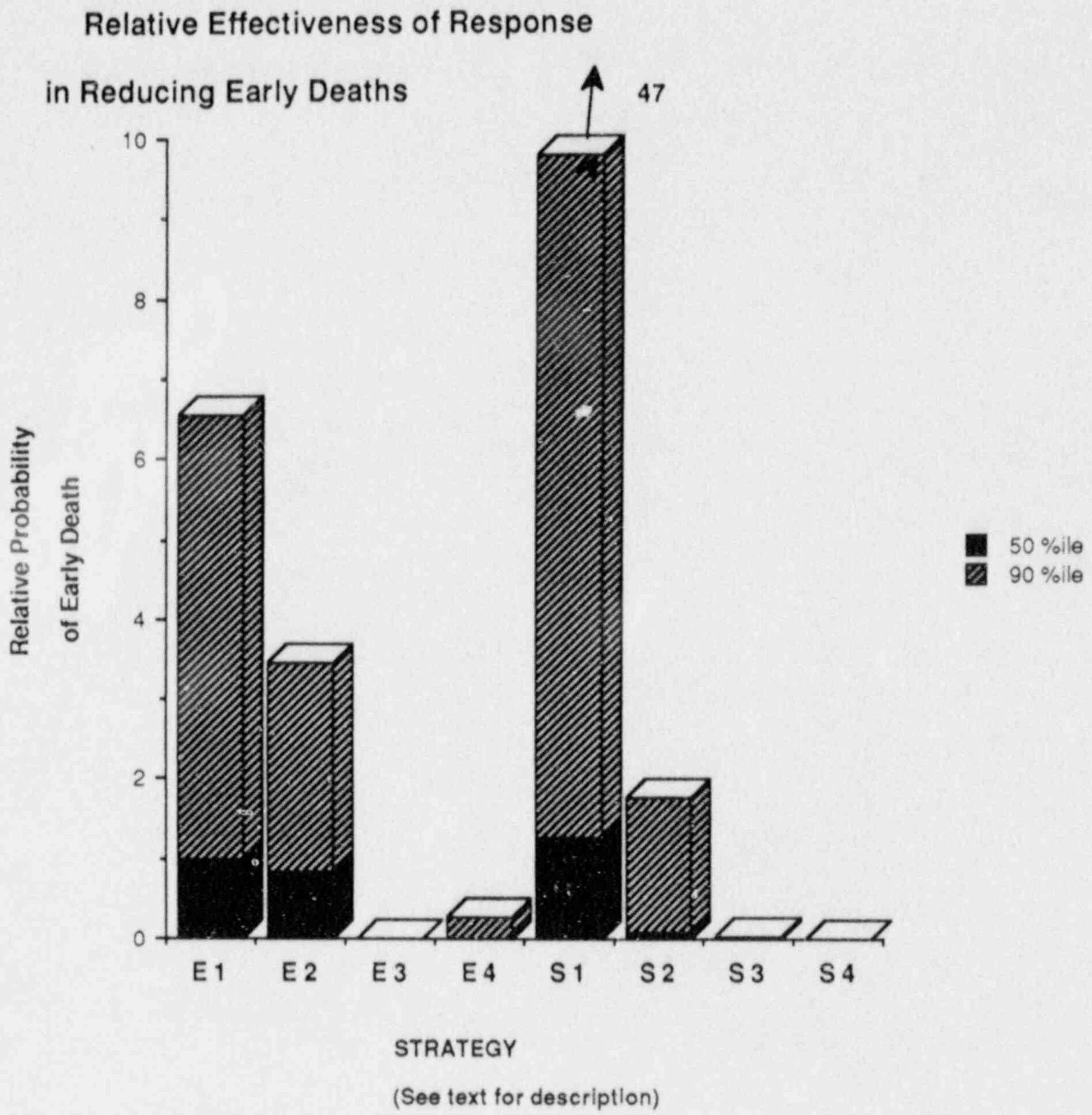

Relative Effectiveness of Response
in Reducing Early Deaths
47
10
8
6
4
2
0
Relative Probability
of Early Death
50 %ile
90 %ile
E 1
E 2
E 3
E 4
S 1
S 2
S 3
S 4
STRATEGY
(See text for description)

FIGURE 2

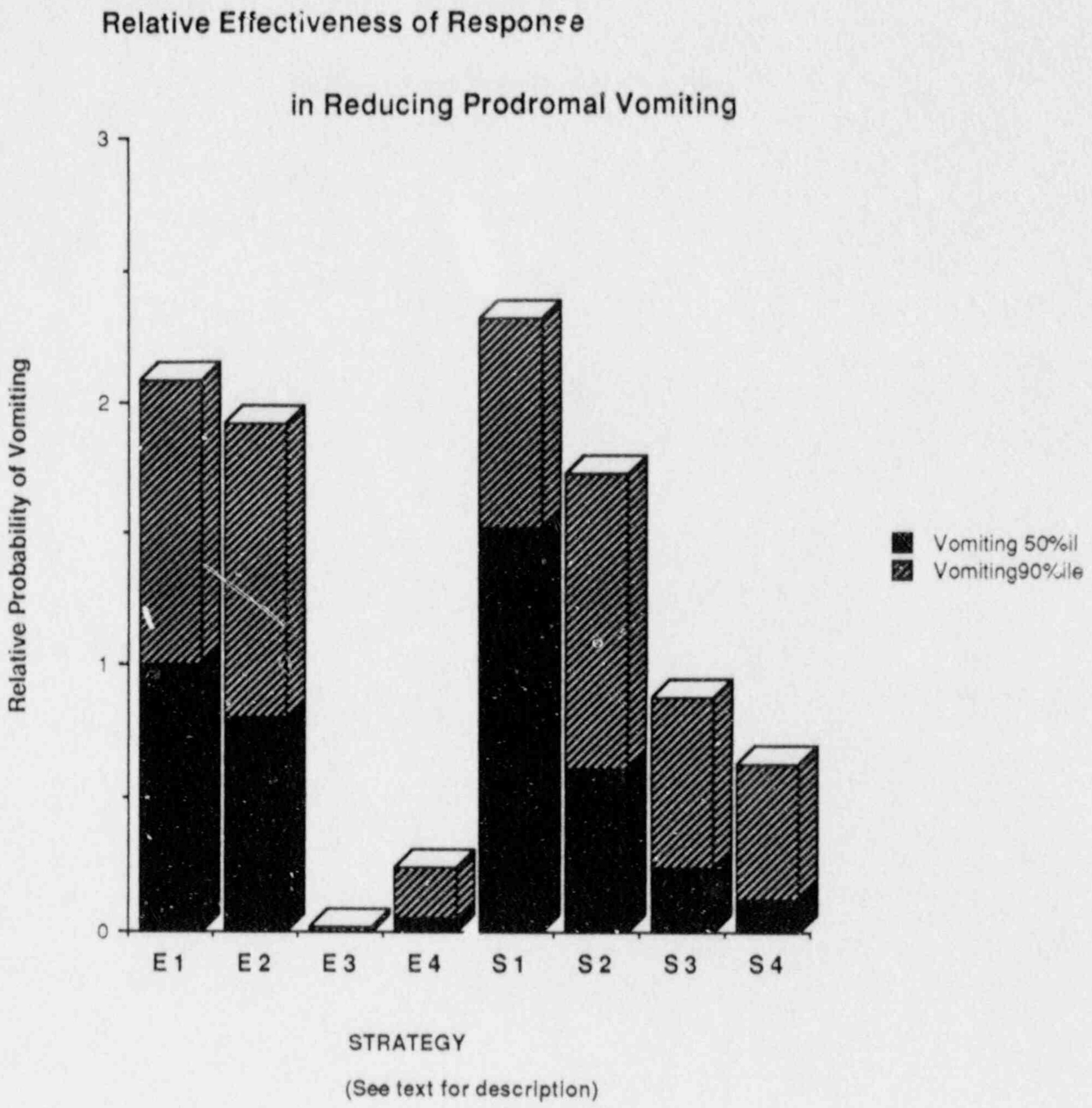
TABLE 6

RELATIVE PROBABILITY OF
PRODROMAL VOMITING FOR EACH STRATEGY

STRATEGY	50th PERCENTILE PERSON	90th PERCENTILE PERSON
(A) Evacuation Strategies		
E1. Unplanned Evacuation	1.0	2.08
E2. NHRERP Evacuation	0.80	1.92
E3. Generic Evacuation	0	0.016
E4. Generic Evacuation With Difficulties	0.056	0.24
(B) Sheltering Strategies		
S1. Ad Hoc Shelter	1.52	2.32
S2. Shelter Equivalent to Wood Frame Buildings Without Basements	0.81	1.73
S3. Shelter Equivalent to Wood Frame Buildings With Basements	0.24	0.88
S4. Good Shelter	0.12	0.63

NOTE:

The entry for the 50th percentile person for the "Unplanned Evacuation" strategy is arbitrarily set at unity.



Relative Effectiveness of Respon?e
in Reducing Prodromal Vomiting
3
2
1
0
Relative Probability of Vomiting
Vomiting 50%il
Vomiting90%ile
E1
E2
E3
E4
S1
S2
S3
S4
STRATEGY
(See text for description)

FIGURE 3

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before Administrative Judges:
Ivan W. Smith, Chairperson
Gustave A. Linenberger, Jr.
Dr. Jerry Harbour

In the Matter of PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, ET AL. (Seabrook Station, Units 1 and 2)	Docket Nos. 50-443-444-OL (Off-site EP) June 30, 1988

ATTACHMENTS TO

REBUTTAL
TESTIMONY OF DR. GORDON THOMPSON,
DR. ROBERT L. GOBLE, AND DR. JAN BEYEA
ON BEHALF OF THE ATTORNEY GENERAL FOR THE
COMMONWEALTH OF MASSACHUSETTS ON SHELTERING CONTENTIONS

Carol Sneider
Assistant Attorney General
Nuclear Safety Unit
Department of the Attorney General
Commonwealth of Massachusetts
One Ashburton Place
Boston, MA 02108-1698
(617) 727-2200

ATTACHMENTS

Attachment 1	Professional Qualifications of Dr. Gordon Thompson
	Professional Qualifications of Dr. Robert L. Goble
	Professional Qualifications of Dr. Jan Beyea
Attachment 2	WASH-1400, Appendix VI, Table VI 2-1

ATTACHMENT 1

PROFESSIONAL QUALIFICATIONS OF

DR. GORDON THOMPSON

I

Resume
for
Gordon Thompson

January 1987

Professional Expertise

Consulting scientist on energy, environment, and international security issues.

Education

* PhD in Applied Mathematics, Oxford University, 1973.
* BE in Mechanical Engineering, University of New South Wales, Sydney, Australia, 1967.
* BS in Mathematics and Physics, University of New South Wales, 1966.

Current Appointments

* Executive Director, Institute for Resource & Security Studies (IRSS), Cambridge, MA.
* Coordinator, Proliferation Reform Project (an IRSS project).
* Treasurer, Center for Atomic Radiation Studies, Acton, MA.
* Member, Board of Directors, Political Ecology Research Group, Oxford, UK.
* Member, Advisory Board, Gruppe Okologie, Hannover, FRG.

Consulting Experience (selected)

* Natural Resources Defense Council, Washington, DC, 1986-1987 : preparation of testimony on hazards of the Savannah River Plant.
* Lakes Environmental Association, Bridgton, ME, 1986 : analysis of federal regulations for disposal of radioactive waste.
* Greenpeace, Hamburg, FRG, 1986 : participation in an international study on the hazards of nuclear power plants.
* Three Mile Island Public Health Fund, Philadelphia, PA, 1983-present : studies related to the Three Mile Island nuclear plant.
* Attorney General, Commonwealth of Massachusetts, Boston, MA, 1984-present : analyses of the safety of the Seabrook nuclear plant.
* Union of Concerned Scientists, Cambridge, MA, 1980-1985 : studies on energy demand and supply, nuclear arms control, and the safety of nuclear installations.

* Conservation Law Foundation of New England, Boston, MA, 1985 : preparation of testimony on cogeneration potential at the Maine facilities of Great Northern Paper Company.
* Town & Country Planning Association, London, UK, 1982-1984 : coordination and conduct of a study on safety and radioactive waste implications of the proposed Sizewell nuclear plant.
* US Environmental Protection Agency, Washington, DC, 1980-1981 : assessment of the cleanup of Three Mile Island Unit 2 nuclear plant.
* Center for Energy & Environmental Studies, Princeton University, Princeton, NJ, 1979-1980 : studies on the potentials of various renewable energy sources.
* Government of Lower Saxony, Hannover, FRG, 1978-1979 : coordination and conduct of studies on safety aspects of the proposed Gorleben nuclear fuel center.

Other Experience (selected)

* Co-leadership (with Paul Walker) of a study group on nuclear weapons proliferation, Institute of Politics, Harvard University, 1981.
* Foundation (with others) of an ecological political movement in Oxford, UK, which contested the 1979 Parliamentary election.
* Conduct of cross-examination and presentation of evidence, on behalf of the Political Ecology Research Group, at the 1977 Public Inquiry into proposed expansion of the reprocessing plant at Windscale, UK.
* Conduct of research on plasma theory (while a PhD candidate), as an associate staff member, Culham Laboratory, UK Atomic Energy Authority, 1969-1973.
* Service as a design engineer on coal plants, New South Wales Electricity Commission, Sydney, Australia, 1968.

Publications (selected)

* The Nuclear Freeze Revisited (written with Andrew Haines), November 1986, Nuclear Freeze and Arms Control Research Project, Bristol, UK.
* Nuclear-Weapon-Free Zones : A Survey of Treaties and Proposals (edited with David Pitt), Croom Helm Ltd, Beckenham, UK, forthcoming.
* International Nuclear Reactor Hazard Study (written with fifteen other authors), September 1986, Greenpeace, Hamburg, FRG (2 volumes).
* "What happened at Reactor Four" (the Chernobyl reactor accident), Bulletin of the Atomic Scientists, August/September 1986, pp 26-31.

PROFESSIONAL QUALIFICATIONS OF

DR. ROBERT L. GOBLE

May 1988

ROBERT L. GOBLE

Center for Technology,
Environment, and Development
and Department of Physics
Clark University
Worcester, MA 01610
617-793-7683

137 Gardner Road
Brookline, MA 02146
617-566-4574

Present Position

Research Associate Professor of Environment, Technology, and Society, and Adjunct Associate Professor of Physics, Clark University.

Education

B.A. (Honors), Physics, Swarthmore College, June 1962
Ph.D., Physics, University of Wisconsin, January 1967

Previous Employment

1984 - 85	Princeton University, Center for Energy and Environmental Studies and Department of Philosophy: Hewlett Fellow
1976 -	Clark University, Physics Department and Program on Science, Technology, and Society: Visiting Assistant Professor, Research Associate Professor (on leave 1984-85)
1974 - 76	Montana State University, Physics Department: Assistant Professor, Adjunct Assistant Professor
1972 - 74	University of Utah, Physics Department: Research Associate/ Associate Instuctor
1969 - 72	University of Minnesota, Physics Department: Research Associate
1966 - 69	Yale University, Physics Department: Research Staff, Instructor
1962 - 66	University of Wisconsin, Physics Department: NSF Cooperative Fellow, Research Assistant

Current Research

Air Quality/Acid Deposition:	Assessments and Reviews Tracer and Transport Studies Local Air Quality
Risk Assessment/Hazard Mangement:	Comparing Hazards and Hazard Assessment Methodologies Ethical Issues in Hazard Management Planning Issues for Waste Disposal Radon Exposure and Health Effects Emergency Planning for Nuclear Power Plants

Recent Research Activities

1983 - Emergency Planning for Nuclear Power Plants (Consultant to New Hampshire Attorney General's office, Three Mile Island Public Health Fund, Massachusetts Attorney General's Office, Ontario Nuclear Safety Review Board) Reviews, Testimony, Consequence Analysis. Major Planning Project at TMI.

1985 - Risk Assessment and Socio Economic Impacts in Radioactive Waste Management (Consultant to State of Mississippi, Citizens Against Nuclear Trash, and State of Nevada/Mountain West Inc.) Several reports, testimony.

1977 - Ethical Issues in Hazard Management (supported by NSF-EVIST, Hewlett Foundation, Principal Investigator and Co-Principal Investigator). Book in progress; articles on radioactive waste, occupational and environmental hazards comparison, susceptible workers.

1983 - 86 Acid Deposition Assessment, (Consultant, U.S. EPA). Co-author, Acid Deposition and its Effects: Critical Assessment Document, 1985. Section Author, 1985 Assessment section on Sulfur Mass Balance.

1982 - 83 Implementation of the Occupational Lead Standard. Supported by OTA; (Principal Investigator, four researchers). Report published as attachment to OTA Report: Preventing Illness and Injury in the Workplace.

1977 - 82 Nuclear Power Plant Performance, (supported in part by DOE, Principal Investigator, three researchers). Articles relating nuclear power plant performance to general plant characteristics.

1976 - 83 Demonstration of a Grid-Connected Cogeneration System at Clark University; technical advisor and coordinator for Clark University. The program resulted in the construction of a $2.5 million National Demonstration Power Plant, based on a gas-fired 1.8 MW diesel engine with heat recovery from the exhaust and jacket. The plant began operation in Summer 1982; it supplies approximately half Clark's thermal energy needs and enough excess electricity so that half the output will be sold to the utility.

Teaching and Student Research Supervision

Dissertation Advisor for M. Yersel, May 1984 Ph.D.
Atmospheric Turbulence and Diffusion in an Urban Environment.

Student Research Projects:
Supervision of more than 20 graduate and undergraduate students in energy, air pollution, and physics: High Energy Cosmic Ray Showers; Clark Energy Use Profiles and Models; Environmental Tradeoffs in Cogeneration; Cogeneration Road Map for Colleges and Universities; Measurements of Worcester Weather; Pollutant Dispersal in Urban Areas; Effects of Buildings on Pollutant Dispersal; Cogeneration System Monitoring; Radon in Indoor Air; Radon - Induced Health Effects; AIDS and Health Care Programs in Zaire;

Environment, Technology, and Society:
Introductory Case Studies on Population and Food; Special Topics in Alternative Energy: Cogeneration; Alternative Energy Systems Laboratory, Graduate Core Course: Limits of the Earth, Science Writing Seminar.

Physics for Non-Science Student:
Einstein's Ideas; Cultural Astronomy; College Physics; Particle Physics (an honors course with laboratory); Urban Meteorology

Undergraduate Physics:
Electricity and Magnetism; Classical Physics

Graduate Physics:
Quantum Mechanics; Advanced Quantum Mechanics; Mathematical Methods

Professional Societies

American Association for the Advancement of Science
American Physical Society: Forum on Science and Society; Division of Particles and Fields
Sigma Xi
Society for Risk Analysis
Air Pollution Control Association

Service

1976 - 83	City of Worcester Energy Task Force
1977 -	Clark Science, Technology, and Society, Program Committee
1978 - 80	Alternate, Clark Graduate Board
1978 -	Clark Energy Task Force
1981 - 84	Faculty Lounge Committee (installation and operation of new faculty dining room)
1983 -	CENTED Steering Committee

Recent Individual Awards and Honors

National Science Foundation/National Endowment for the Humanities:
Individual Incentive Award (Jan. 1984-Jan. 1986)
Princeton University: Hewlett Fellow (Sept. 1984-June 1985)
American Association for the Advacement of Science: Summer Fellowship in Environmental Science (Summer 1982)

Other Activities

Consulting Agreements:

1986 - 88 Massachusetts Attorney General's Office, Sheltering in the Emergency Plans for the Seabrook Nuclear Reactor.

1986 - 87	Rhode Island Dept. of Environmental Management. Risk Assessment Methods for Toxic Substances in Seafood.
1986 - 88	State of Nevada/Mountain West Inc., Risk Analysis for Radioactive Waste Disposal.
1986	Citizens Against Nuclear Trash - Socio Economic Impacts of Radioactive Waste Disposal.
1985	Mississippi Health and Safety Office — Radioactive Waste Risk Analysis.
1983	New Hampshire Attorney General - Nuclear Emergency Planning.
1982 - 86	U.S. EPA: Acid Deposition Assessment.
1986	Lecturer, Harvard School of Public Health, Short Course on Risk Assessment and Occupational Health.
1981	Lecturer, Department of Engineering and Applied Science, University of Wisconsin--Extension Program on Industrial Facility Cogeneration.

GRANTS AND AWARDS

University Grants

Demonstration of a Grid-Connected Integrated Community Energy System

DATE	TITLE	AMOUNT
1982 - 84	Mass Electric Company/Colt Industries/ Mass Electric Construction. Grants for Cogeneration Monitoring	20,000
1981 - 83	Mass Energy Office/DOE-Energy Conservation Measures in Schools and Hospitals, 2 matching grants for cogeneration heat recovery equipment co-authored with J. Collins and B. Kimball) #DE-FG41-81R 113973 #DE-FG41-82R 143391	104,000 13,750
1980 - 82	HUD: Loan for Plant Construction (co-authored with J. Collins, B. Kimball)	1,200,000
1980 - 82	DOE Phase III: Constuction: grid connection and constuction management costs (co-authored with J. Collins)	330,000

1977 - 78	DOE Phase II: Detailed Feasibility and Preliminary Design (co-authored with C. Hohenemser	206,000
1977	DOE Phase I: Preliminary Feasibility Study (co-authored with C. Hohenemser)	149,000

Other Grants and Grant Support Received

DATE	TITLE	AMOUNT
1987 - 88	Ontario Nuclear Safety Review Board — Modelling Consequences of Reactor Accidents (Principal Investigator)	12,160
1987 - 88	Rhode Island/EPA — "Risk Assessment Methodology for Contaminated Seafood (Co-Principal Investigator with H. Brown)	10,000
1984 - 86	NSF/NEH — Interdisciplinary Incentive Award Ethical Issues in Hazard Management (Principal Investigator- Individual Award)	45,800
1983 - 85	NSF — Sensitive Workers, Ethical Issues and Differential Sensitivity to Workplace Hazard (Co-Principal Investigator with R. Kasperson) #RII 8217297	170,500
1983 - 84	Clark University — Elemental Analysis of Particulates (Jointly with C. Hohenemser-Faculty Development Award)	1,500
1982 - 83	OTA — Implementation of Occupational Lead Standard (Principal Investigator) Contract #233-7040.0	29,000
1982	DOE — Nuclear Power Plant Performance (Principal Investigator) Purchase Order #DE-AP01-82 E119625	9,000
1982	AAAS — Summer Fellowship in Environmental Sciences (for work on Acid Rain in EPA's Office of Strategy Assessment and Long Range Planning)	5,800

1980 - 82	NSF — Labor/Laity:Comparison of Worker & Public Protection from Technological Hazards (Co-Principal Investiator with R. Kasperson) #OSS 79-24516	240,000
1979 - 80	Association of Physical Plant Administration — Preparation of a Cogeneration Reference Manual for Colleges and Universities (Principal Investigator)	4,000
1979	Argonne Laboratories — Testing Computer Models for Cogeneration System Design (Principal Investigator) Univ. #98456-01	5,240
1977 - 80	NSF — Equity Issues in Radioactive Waste Management #oss 77-16564 (Co-principal Investigator with Roger Kasperson)	190,000

PUBLICATIONS

Articles (Energy/Hazards/Air Quality)

1988

"The Social Amplification of Risk: A Conceptual Framework" (with R.E. Kasperson, O. Renn, P. Slovic, H.S. Brown, J.E. Emel, J.X. Kasperson, and S. Ratick) Risk Analysis (to be published).

"Methodology for Assessing Hazards of Contaminants in Seafood" (with H.S. Brown, and L. Teitelbaum) Regulatory Toxicology and Pharmacology, 8:76 - 101 (1988).

1986

"Turbulence Parameters in an Urban Environment" (with M. Yersel), Boundary Layer Meteorology, V. 37, #3 p.271 (1986).

"Methods for Analyzing and Comparing Technological Hazards: Definitions and Factor Structures" (with C. Hohenemser, J. Kasperson, R. Kasperson, R. Kates, P. Collins, P. Slovic, B. Fischoff, S. Lichtenstein and T. Layman.) In Risk Evaluations and Management, V. Covello, J. Menkes and Y. Mumpower, eds. Plenum Press, New York, 1986.

1985

"Protecting Workers, Protecting Publics: The Ethics of Differential Protection" (with P. Derr, R. Kasperson, R. Kates) in V.T. Covello (ed.) Risk Analysis in the Private Sector, Plenum Press, New York, 1985.

1983

"Time Scales in the Radioactive Waste Problem" Equity Issues in Radioactive Waste Management, R. Kasperson, Ed. Oelgeschlager Gunn, Hain, Cambridge 1983, Chapter 6, p. 139-174.

"Short Distance Diffusion in an Urban Atmosphere" (with M. Yersel, J. Morrill), Atmospheric Environment, V. 17, No. 2, 275 (1983).

"Responding to the Double Standard of Worker/Public Protection (with P. Derr, R. Kasperson, R. Kates), Environment V. 25, No. 6, 6 (1983).

1982

"Airborne Lead: A Clear-cut Case of Differential Protection," (with D.Hattis and N. Ashford), Environment V. 24, No. 1, 14 (1982).

"Technological Risk Perception and Nuclear Power Costs: The Quantification of Uncertainty" (with D. Shakow) Technological Forecasting and Social Change, V. 21, No. 3, 185 (1982).

1981

"Worker/Public Protection: The Double Standard" (with P. Derr, R. Kasperson, R. Kates), Environment, V. 23, No. 7, 6 (1981).

1979

"Nuclear Power Plant Performance: An Update," (with C. Hohenemser) Environment V. 21, No. 8, 32 (1979).

1978

"Power Plant Performance" (with C. Hohenemser), Environment V. 20, No.3, 25, (1978).

Technical Monographs

1988

Potential Retrieval of Radioactive Waste at Proposed Yucca Mountain Repository: A Review of Risk Issues (with D. Golding, R. Kasperson) (1988) 17 p.

Postclosure Risk at the Proposed Yucca Mountain Repository: A Review of Methodological and Technical Issues (with J. Emel, R.E. Kasperson, and O. Renn) (1987) 53 p.

1987

Methodology for Assessing Hazards of Contaminants in Seafood, (with H.Brown, and L. Teitelbaum), for the Naragansett Bay Project, U.S. EPA and Rhode Island Department of Environmental Management, 47 p.

Preclosure Risks at the Proposed Yucca Mountain Repository, (with R.E.Kasperson, J. Emel, J.X. Kasperson, and O. Renn), (1987) 40 p.

Nuclear Waste System Risks at the Proposed Yucca Mountain Repository, (with J. Emel, J.X. Kasperson, R.E. Kasperson, and O. Renn), (1987) 116 p.

1986

Evaluation of the Radtran III Model: Usefulness and Practicability, (with O.Renn), CENTED, Clark University.

Site-Characterization Risks at the Yucca Mountain Site: A Preliminary Review, (with J. Emel, R. Kasperson, O. Renn), CENTED, Clark University.

The proposed Sebago Lake nuclear waste repository area: A preliminary assessment of selected risk and social impact considerations, (with J. Emel, J. Kasperson, and R. Kasperson.) Worcester, MA: Hazard Assessment Group, CENTED, Clark University.

1985

Risk Issues Associated with a Salt-dome Repository at Richton, Mississippi, (with H. Brown, J. Emel, J. Kasperson, and R. Kasperson.) New York: Social Impact Assessment Network.

1983

Methods for Analyzing and Comparing Technological Hazards: Definitions and Factor Structures, (with C. Hohenemser, J. Kasperson, R. Kasperson, R. Kates, P. Collins, A. Goldman, P. Slovic, B. Fischoff, S. Lichtenstein, and M. Layman), CENTED Research Report #3, October 1983.

1982

Atmospheric Processes Affecting Acid Deposition: Assessing the Assessments and Suggestions for Further Research, AAAS, Fall 1982.

1980

Cogeneration: A Campus Option, (with W. Goble) Association of Physical Plant Administrators, Washington, 1980).

1978

Statistical Analysis of Nuclear and Coal Power Plant Performance, (with C. Hohenemser) Scientists Institute for Public Information, New York, 1978.

Government Papers

1985

Implementation of the Occupational Lead Standard, (with D. Hattis, M. Ballew, D. Thurston), CENTED Working Paper HAG/WP 83-1, October 1983; in Preventing Illness and Injury in the Workplace, Vol. 2, NTIS. Office of Technology Assessment, Washington, Spring, 1985.

The Acid Deposition Phenomenon and Its Effects: Critical Assessment Document Co-authors D. Bennett, R. Linthurst) U.S. EPA, EPA/60018-851001, August 1985.

1977-78

"Grid-Connected Integrated Community Energy System, Clark University":

Phase I, Preliminary Feasibility Study,
v.1: Executive Summary, DOE Report #C00-4211-1/1 (NTIS, 1977)
v.2: Final Report, DOE Report #C00-4211-1/2 (NTIS, 1977).

Phase II, Detailed Feasibility and Preliminary Design
Preliminary Report, DOE Report #C00-4211-2 (NTIS, 1978).
v.1: Final Report, DOE Report #C00-4211-3/1 (NTIS, 1978).
v.2: Appendices, DOE Report #C00-4211-3/2 (NTIS, 1978).

(These reports were produced by the Clark Demonstration Team and consultants. I wrote the main text and edited each volume.)

Conference Proceedings (Energy, Hazards, Air Quality).

1987

Estimation of Economic Consequences of a Severe Accident at the Pickering Nuclear Power Station, (with S. Lonergan, C. Corcoraton). Brief Presented to Ontario Nuclear Safety Review Board, September 24-26, 1987.

Radioactive Wastes and the Social Amplification of Risk, (with R.E. Kasperson, J. Emel, C. Hohenemser, J.X. Kasperson, and O. Renn). In R.G. Post (ed.) Waste Management '87. Tucson, AZ: Arizona Board of Regents (1987).

Can Risk Assessment be Transplanted to Developing Countries (with H. Brown) Invited paper for the Fourth Tallories Seminar on International Development Entitled "Managing Environmental Risk in the Economic Development of Newly Industrializing Countries" May 12-14, 1987, Tufts University Tallories European Center, France.

"Potential use of ^{210}Pb as a Biological Marker of Exposure to Radon, "First International Symposium on Environmental Health," Pittsburgh, PA, June 198 .

1985

"The Variation in Worker Response to Occupational Hazards" in Symposium on Managing High Risk Workers, Society for Risk Analysis, October 1985.

1984

"Acid Rain." Invited talk presented at American Institute of Hydrology Conference, Future Issues in Hydrology, May 31, 1984.

1983

"Short Range Dispersion from a Point Source in an Urban Area," (with M. Yersel), Proceedings of the 6th Symposium on Turbulence and Diffusion American Meteorological Society, Boston (1983).

1981

"A Participatory Approach to Undergraduate Energy Education: the Case of Clark University" (with D. Ducsik) Proceedings of the International Conference on Energy Education, Providence, Rhode Island, 1981.

"Clark University's Grid-Connected Cogeneration Plant," (with J. Rodousakis, J. Cook), District Heating, V. 67, No. 1, 4 (1981).

1979

"A Micrometeorological Study in the Worcester Area" (with A. Molod, M. Yersel), Proceedings of the Conference on the Meteorology of Northern New England and the Maritime Provinces, Gorham, ME (1979).

1978

"Grid-Connected Cogeneration at Clark University: The Effect of Terms of Utility Interconnection: (with S.E. Nydick), Proceedings of the International Conference on Energy Use Management, Tucson (1978).

1977

"Energy Profiles at Clark University: Implications for Cogeneration" (with R. Collins, A. Gottlieb), Proceedings fo the First National Conference on Technology for Energy Conservation, Washington, D.C. (1977).

Testimony

1988

Nuclear Regulatory Commission. Before the Atomic Safety Licensing Board: Sheltering in the New Hampshire Radialogical Emergency Response Plans for the Seabrook Reactor — Concord, N.H. May 1988.

1986

Before Department of Energy, Office of Civilian Radioactive Wastes Management: Social and Economic Consequences of a Proposed Sebago Lake Repository — Naples, Maine. April 1986.

Articles (Particle Physics)

1975

"Determination of the Δ^{++} - Δ^0 Mass Difference (with J.S. Ball), Phys. Rev. D 11, 1971 (1975).

1973

"Two Pion Intermediate States in Decay $K^S{}_0$ - 2γ ," Phys. Rev. D 4, 931 (1973).

1972

"Soft Pion Production in Electron-Positron Collisions" (with J.L. Rosner), Phys. Rev. D 5 2345 (1972).

1971

"Current Algebra and Analyticity: Bootstrapping the ρ and σ with the Pion Decay Constant Setting the [illegible]' (with (L.S. Brown), Phys. Rev. D 4 723 (1971).

1968

"Pion-Pion Scattering, Current Algebra, Unitarity, and the Width of the Rho Meson" (with L.S. Brown), Phys. Rev. Lett. 20 346 (1968).

"Soft Photons and the Classical Limit" (with L.S. Brown), Phys. Rev. 173, 1505 (1968).

1965

"Cross Section for the Production of a Possible Bound Cascade-Nucleon System" (with M.E. Ebel) Phys. Rev. B 140 1675 (1965).

Conference Proceedings (Particle Physics)

1988

"Pion Pair Production by Two Photons at Low Energy," Proceedings from the VIII International Workshop on Photon-Photon Collisions (Israel, 1988).

1973

"Pion Form Factor and Inelastic π - π Scattering," Proceedings of the International Conference on π - π Scattering (Tallahassee, 1973).

PROFESSIONAL QUALIFICATIONS OF

DR. JAN BEYEA

Resume for Jan Beyea
July 1986

EDUCATION:

Ph.D., Columbia University, 1968 (Physics).
B.A., Amherst College, 1962.

EMPLOYMENT HISTORY:

1980 to date, Senior Staff Scientist and, as of 1985, Director of the Environmental Policy Analysis Department, National Audubon Society, 950 Third Avenue, NY, NY 10022.

1976 to 1980, Research Staff, Center for Energy and Environmental Studies Princeton University.

1970 to 1976, Assistant Professor of Physics, Holy Cross College.

1968 to 1970, Research Associate, Columbia University Physics Department.

CONSULTING WORK:

Consultant on nuclear energy to the Office of Technology Assessment, the New Jersey Department of Environmental Protection; the Offices of the Attorney General in New York State and the Commonwealth of Massachusetts; the State of lower Saxony in West Germany; the Swedish Energy Commission; the Three Mile Island Public Health Fund; and various citizens' groups in the United States.

PUBLICATIONS CONCERNING ENERGY CONSERVATION, ENERGY POLICY, AND ENERGY RISKS:

Articles:

"Oil and Gas Resources on Federal Lands: Wilderness and Wildlife Refuges," Stege and Beyea, Annual Review of Energy (to be published, October 1986). [An earlier version appeared as National Audubon Society Report, EPAD No. 28, June 1985.]

"U.S. Appliance Efficiency Standards," Rollin and Beyea, Energy Policy, 13, p. 425 (1985).

"Computer Modeling for Energy Policy Analysis," Medsker, Beyea, and Lyons, Proceedings of the 15th Annual Modeling and Simulation Conference, Pittsburgh, PA, 15, part 3, p. 1111 (1984).

"Containment of a Reactor Meltdown," (with Frank von Hippel), Bulletin of the Atomic Scientists, 38, p. 52 (August/September 1982).

"Second Thoughts (about Nuclear Safety)," in Nuclear Power: Both Sides, W. W. Norton and Co. (New York, 1982).

"Indoor Air Pollution," Bull. At. Scientists, 37, p. 63 (Feb. 1981)

Articles (Con't)

"Emergency Planning for Reactor Accidents," Bulletin of the Atomic Scientists, 36, p. 40 (December 1980). (An earlier version of the article appeared in German as Chapter 3 in Im Ernstfall hilflos?, E. R. Koch, Fritz Vahrenholt, editors, Keipenheuer & Witsch, Cologne, 1980.)

"Dispute at Indian Point," Bull. At. Scientists, 36, p. 63, (May 1980).

"Locating and Eliminating Obscure but Major Energy Losses in Residential Housing," Harrje, Dutt, and Beyea, ASHRAE Transactions, 85, Part II (1979). (Winner of ASHRAE outstanding paper award.)

"Attic Heat Loss and Conservation Policy," Dutt, Beyea, and Sinden. ASME Technology and Society Division Paper 78-TS-5, Houston, Texas, 1978.

"Critical Significance of Attics and Basements in the Energy Balance of Twin Rivers Townhouses," Beyea et al., Energy and Buildings, Vol. I (1977), Page 261. Also Chapter 3 of Saving Energy in the Home, Ballinger, 1978.

"The Two-Resistance Model for Attic Heat Flow: Implications for Conservation Policy," Woteki, Dutt, Beyea, Energy--The Intl. Journal, 3, 657(1978)

Published Debates:

Proceedings of the Workshop on Three Mile Island Dosimetry, Three Mile Island Public Health Fund, 1622 Locust Street, Phila., Pa., Dec. 1985

"Land Use Issues and the Media," Ctr. for Communication, NYC, Oct. 1984.

Nuclear Reactors: How Safe Are They?, panel discussion sponsored by the Academy Forum of the National Academy of Sciences, Wash., D.C., May 5, 1980.

The Crisis of Nuclear Energy, Subject No. 367 on William Buckley's Firing Line, P.B.S. Television. Transcript printed by Southern Education Communications Assoc., 928 Woodrow Street, P. O. Box 5966, Columbia, S.C., 1979.

Reports:

The Audubon Energy Plan, Beyea et al., 2nd Ed., July 1984 (1st Ed., 1981) [See also, Intro. to Special Issue on Legal Issues Arising From The Audubon Energy Plan 1984, Columbia Journal of Environmental Law, 11, p.251, (1986)]

A Review of Dose Assessments at Three Mile Island and Recommendations for Future Research, Report to the Three Mile Island Public Health Fund, August 1984. [See also, "Author Challenges Review," Health Physics Newsletter, March, 1985, and "TMI—Six Years Later," Nuclear Medicine, 26, p. 1345 (1985).]

Reports (Con't)

"Implications for Mortality of Weakening the Clean Air Act," (with G. Steve Jordan), National Audubon Society, EPAD Report No. 18, May 1982.

"Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atomosphere from Three Mile Island," Report to the President's Council on Environmental Quality, December 1980.

"Decontamination of Krypton 85 from Three Mile Island Nuclear Plant," (with Kendall, et al.), Report of the Union of Concerned Scientists to the Governor of Pennsylvania, May 15, 1980.

"Some Comments on Consequences of Hypothetical Reactor Accidents at the Philippines Nuclear Power Plant" (with Gordon Thompson), National Audubon Society, EPAD Report No. 3, April 1980.

"Nuclear Reactor Accidents: The Value of Improved Containment," (with Frank von Hippel), Center for Energy and Environmental Studies Report PU/CEES 94, Princeton University, January 1980.

"The Effects of Releases to the Atmosphere of Radioactivity from Hypothetical Large-Scale Accidents at the Proposed Gorleben Waste Treatment Facility," report to the Government of lower Saxony, Federal Republic of Germany, as part of the "Gorleben International Review," February 1979.

"Reactor Safety Research at the Large Consequence End of the Risk Spectrum," presented to the Experts' Meeting on Reactor Safety Research in the Federal Republic of Germany, Bonn, September 1, 1978.

A Study of Some of the Consequences of Hypothetical Reactor Accidents at Barseback, report to the Swedish Energy Comm., Stockholm, DS I 1978:5, 1978.

Testimony:

"Responses to the Chernobyl Accident," before the Senate Committee on Energy and Natural Resources, U. S. Senate, June 19, 1986.

"Dealing with Uncertainties in Projections of Electricity Consumption," before the Comm. on Energy and Natural Resources, U. S. Senate, July 25, 1985.

"Some Consequences of Catastrophic Accidents at Indian Point and Their Implications for Emergency Planning," testimony and cross-examination before the Nuclear Regulatory Commission's Atomic Safety and Licensing Board, on behalf of the New York State Attorney General and others, July 1982.

Testimony (Con't)

"In the Matter of Application of Orange and Rockland Counties, Inc. for Conversion to Coal of Lovett Units 4 and 5," testimony and cross-examination on the health impacts of eliminating scrubbers as a requirement for conversion to coal; Department of Environmental Resources, State of N.Y., Nov. 5, 1981.

"Future Prospects for Commercial Nuclear Power in the United States," before the Subcommittee on Oversight and Investigations, Committee on Interior and Insular Affairs, U. S. House of Representatives, October 23, 1981.

"Comments on Energy Forecasting," material submitted for the record at Hearings before the Subcommittee on Investigations and Oversights of the House Committee on Science and Technology; Committee Print No. 14, June 1-2, 1981.

"Stockpiling of Potassium Iodide for the General Public as a Condition for Restart of TMI Unit No. 1," testimony and cross-examination before the Atomic Safety and Licensing Board on behalf of the Anti-Nuclear Group Representing York, April 1981.

"Advice and Recommendations Concerning Changes in Reactor Design and Safety Analysis which should be Required in Light of the Accident at Three Mile Island," statement to the Nuclear Regulatory Commission concerning the proposed rulemaking hearing on degraded cores, December 29, 1980.

"Alternatives to the Indian Point Nuclear Reactors," statement before the Environmental Protection Committee of the New York City Council, December 14, 1979. Also before the Committee, "The Impact on New York City of Reactor Accidents at Indian Point, June 11, 1979. Also "Consequences of a Catastrophic Reactor Accident," statement to the New York City Board of Health, August 12, 1976 (with Frank von Hippel).

"Emergency Planning for a Catastrophic Reactor Accident," testimony before the California Energy Resources and Development Commission, Emergency Response and Evacuation Plans Hearings, November 4, 1978, Page 171.

"Comments on the Proposed FTC Trade Regulation Rule on Labeling and Advertising of Thermal Insulation," Beyea and Dutt, before the FTC, 1978.

"Consequences of Catastrophic Accidents at Jamesport," testimony before the N.Y. State Board on Electric Generation Siting and the Environment in the Matter of Long Island Lighting Co. (Jamesport Nuclear Power Station), May 1977.

"Short-Term Effects of Catastrophic Accidents on Communities Surrounding the Sundesert Nuclear Installation," testimony before the California Energy Resources and Development Commission, December 3, 1976.

ATTACHMENT 2

WASH-1400
(NUREG 75/014)

CALCULATION OF REACTOR ACCIDENT CONSEQUENCES

APPENDIX VI
to
REACTOR SAFETY STUDY

U.S. NUCLEAR REGULATORY COMMISSION
OCTOBER 1975

TABLE VI 2-1 SUMMARY OF ACCIDENTS INVOLVING CORE

Release Category	Probability (reactor-yr^{-1})	Time of Release (hr)	Duration of Release (hr)	Warning Time for Evacuation (hr)	Elevation of Release (meters)	Energy Release (10^6 Btu/hr)	Fraction of Core Inventory Released[a]: Xe-Kr	Organic I[b]	I[c]	Cs-Rb	Te-Sb	Ba-Sr	Ru[c]	La[d]
PWR 1	9×10^{-7}[e]	2.5	0.5	1.0	25	20 and 520[e]	0.9	6×10^{-3}	0.7	0.4	0.4	0.05	0.4	3×10^{-3}
PWR 2	8×10^{-6}	2.5	0.5	1.0	0	170	0.9	7×10^{-3}	0.7	0.5	0.3	0.06	0.02	4×10^{-3}
PWR 3	4×10^{-6}	5.0	1.5	2.0	0	6	0.8	6×10^{-3}	0.2	0.2	0.3	0.02	0.03	3×10^{-3}
PWR 4	5×10^{-7}	2.0	3.0	2.0	0	1	0.6	2×10^{-3}	0.09	0.04	0.03	5×10^{-3}	3×10^{-3}	4×10^{-4}
PWR 5	7×10^{-7}	2.0	4.0	1.0	0	0.3	0.3	2×10^{-3}	0.03	9×10^{-3}	5×10^{-3}	1×10^{-3}	6×10^{-4}	7×10^{-5}
PWR 6	6×10^{-6}	12.0	10.0	1.0	0	N/A	0.3	2×10^{-3}	8×10^{-4}	8×10^{-4}	1×10^{-3}	9×10^{-5}	7×10^{-5}	1×10^{-5}
PWR 7	4×10^{-5}	10.0	10.0	1.0	0	N/A	6×10^{-3}	2×10^{-5}	2×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-6}	1×10^{-6}	2×10^{-7}
PWR 8	4×10^{-5}	0.5	0.5	N/A[f]	0	N/A	2×10^{-3}	5×10^{-6}	1×10^{-4}	5×10^{-4}	1×10^{-6}	1×10^{-8}	0	0
PWR 9	4×10^{-4}	0.5	0.5	N/A	0	N/A	3×10^{-6}	7×10^{-9}	1×10^{-7}	6×10^{-7}	1×10^{-9}	1×10^{-11}	0	0
BWR 1	1×10^{-6}	2.0	0.5	1.5	25	130	1.0	7×10^{-3}	0.40	0.40	0.70	0.05	0.5	5×10^{-3}
BWR 2	6×10^{-6}	30.0	3.0	2.0	0	30	1.0	7×10^{-3}	0.90	0.50	0.30	0.10	0.03	4×10^{-3}
BWR 3	2×10^{-5}	[illegible]	3.0	2.0	25	20	1.0	7×10^{-3}	0.10	0.10	0.30	0.01	0.02	4×10^{-3}
BWR 4	2×10^{-6}	5.0	2.0	2.0	25	N/A	0.6	7×10^{-4}	8×10^{-4}	5×10^{-3}	4×10^{-3}	6×10^{-4}	6×10^{-4}	1×10^{-4}
BWR 5	1×10^{-4}	3.5	5.0	N/A	150	N/A	5×10^{-4}	2×10^{-9}	6×10^{-11}	4×10^{-9}	8×10^{-12}	8×10^{-14}	0	0

(a) Background on the isotope groups and release mechanisms is presented in Appendix VII.
(b) Organic iodine is included with other iodines since it is a negligible contribution to consequences since release fraction is relatively small for all large release categories.
(c) Includes Ru, Rh, Co, Mo, Tc.
(d) Includes Y, La, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm.
(e) Accident sequences within PWR 1 category have two distinct energy releases that affect consequences. PWR 1 category is subdivided into PWR 1A with a probability of 4×10^{-7} per reactor-year and 20×10^6 Btu/hr and PWR 1B with a probability of 5×10^{-7} per reactor-year and 520×10^6 Btu/hr.
(f) Not applicable.

from Appendix VI of
WASH-1400

Table 2. SUMMARY OF RELEASE CATEGORIES REPRESENTING HYPOTHETICAL ACCIDENTS

(from Table VI 2-1 of WASH-1400)

Release Category	Probability (reactor-yr^{-1})	Time of Release (hr)	Duration of Release (hr)	Warning Time for Evacuation (hr)	Elevation of Release[c] (meters)	Energy Release (10^6 Btu/hr)
PWR 1	9×10^{-7}[a]	2.5	0.5	1.0	25	20 and 520[e]
PWR 2	3×10^{-6}	2.5	0.5	1.0	0	170
PWR 3	4×10^{-6}	5.0	1.5	2.0	0	6
PWR 4	5×10^{-7}	2.0	3.0	2.0	0	1
PWR 5	7×10^{-7}	2.0	4.0	1.0	0	0.3
PWR 6	6×10^{-6}	12.0	10.0	1.0	0	N/A
PWR 7	4×10^{-5}	10.0	10.0	1.0	0	N/A
PWR 8	4×10^{-5}	0.5	0.5	N/A[b]	0	N/A
PWR 9	4×10^{-4}	0.5	0.5	N/A	0	N/A

(a) Accident sequences within PWR 1 category have two distinct energy releases that affect consequences. PWR 1 category is subdivided into PWR 1A with a probability of 4×10^{-7} per reactor-year and 20×10^6 Btu/hr and PWR 1B with a probability of 5×10^{-7} per reactor-year and 520×10^6 Btu-hr.

(b) Not applicable.

(c) A 10 meter elevation is used in place of zero representing the mid-point of a potential containment break. Any impact on the results would be slight and conservative.

TABLE 2. (cont.) SUMMARY OF RELEASE CATEGORIES REPRESENTING HYPOTHETICAL ACCIDENTS*

(from Table VI 2-1 of WASH-1400)

Release Category	Fraction of Core Inventory Released(d)						
	Xe-Kr	I(e)	Cs-Rb	Te-Sb	Ba-Sr	Ru(f)	La(g)
PWR 1	0.9	0.7	0.4	0.4	0.05	0.4	3×10^{-3}
PWR 2	0.9	0.7	0.5	0.3	0.06	0.02	4×10^{-3}
PWR 3	0.8	0.2	0.2	0.3	0.02	0.03	3×10^{-3}
PWR 4	0.6	0.09	0.04	0.03	5×10^{-3}	3×10^{-3}	4×10^{-4}
PWR 5	0.3	0.03	9×10^{-3}	5×10^{-3}	1×10^{-3}	6×10^{-4}	7×10^{-5}
PWR 6	0.3	8×10^{-4}	8×10^{-4}	1×10^{-3}	9×10^{-5}	7×10^{-5}	1×10^{-5}
PWR 7	6×10^{-3}	2×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-6}	1×10^{-6}	2 x 10-7
PWR 8	2×10^{-3}	1×10^{-4}	5×10^{-4}	1×10^{-6}	1×10^{-8}	0	0
PWR 9	3×10^{-6}	1×10^{-7}	6×10^{-7}	1×10^{-9}	1×10^{-11}	0	0

(d) Background on the isotope groups and release mechanisms is presented in the Reactor Safety Study, Appendix VII.

(e) Organic iodine is combined with elemental iodines in the consequence calculations. Any error is neglible since its release fraction is relatively small for all large release categories.

(f) Includes Ru, Rh, Mo, Tc.

(g) Includes Y, La, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm.

*The release categories and probability information were derived from Reference 4 and based upon an analysis of the design of the Surry Nuclear Power Plant.

THE COMMONWEALTH OF MASSACHUSETTS

DEPARTMENT OF THE ATTORNEY GENERAL

JOHN W. McCORMACK STATE OFFICE BUILDING
ONE ASHBURTON PLACE, BOSTON 02108-1698

JAMES M. SHANNON
ATTORNEY GENERAL

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of

PUBLIC SERVICE COMPANY OF
NEW HAMPSHIRE, ET AL.
(Seabrook Station, Units 1 and 2)

Docket No.(s)
50-443/444-OL

CERTIFICATE OF SERVICE

I, Carol S. Sneider, hereby certify that on July 7, 1988, I made service of the following: (1) REBUTTAL TESTIMONY OF DR. GORDON THOMPSON, DR. ROBERT L. GOBLE, AND DR. JAN BEYEA ON BEHALF OF THE ATTORNEY GENERAL FOR THE COMMONWEALTH OF MASSACHUSETTS ON SHELTERING CONTENTIONS (with tables); and (2) ATTACHMENTS TO REBUTTAL TESTIMONY OF DR. GORDON THOMPSON, DR. ROBERT L. GOBLE, AND DR. JAN BEYEA ON BEHALF OF THE ATTORNEY GENERAL FOR THE COMMONWEALTH OF MASSACHUSETTS ON SHELTERING CONTENTIONS, by mailing copies thereof, postage prepaid, by first class mail or by Federal Express mail as indicated by [*], to:

*Ivan Smith, Chairman
Atomic Safety & Licensing Board
U.S. Nuclear Regulatory Commission
East West Towers Building
4350 East West Highway
Bethesda, MD 20814

*Gustave A. Linenberger, Jr.
Atomic Safety & Licensing Board
U.S. Nuclear Regulatory Commission
East West Towers Building
4350 East West Highway
Bethesda, MD 20814

*Dr. Jerry Harbour
Atomic Safety & Licensing Board
U.S. Nuclear Regulatory Commission
East West Towers Building
4350 East West Highway
Bethesda, MD 20814

*Sherwin E. Turk, Esq.
U.S. Nuclear Regulatory Commission
Office of General Counsel
15th Floor
11555 Rockville Pike
Rockville, MD 20852

*H. Joseph Flynn, Esq.
Assistant General Counsel
Office of General Counsel
Federal Emergency Management Agency
500 C Street, S.W.
Washington, DC 20472

*Docketing and Service
U.S. Nuclear Regulatory Commission
Washington, DC. 20555

Roberta C. Pevear
State Representative
Town of Hampton Falls
Drinkwater Road
Hampton Falls, NH 03844

Atomic Safety & Licensing Appeal Board Panel
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Atomic Safety & Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Matthew T. Brock. Esq.
Shaines & McEachern
25 Maplewood Avenue
P.O. Box 360
Portsmouth, NH 03801

Sandra Gavutis, Chairperson
Board of Selectmen
RFD 1, Box 1154
Rte. 107
E. Kingston, NH 03827

Senator Gordon J. Humphrey
U.S. Senate
Washington, DC 20510
(Attn: Tom Burack)

Senator Gordon J. Humphrey
1 Eagle Square, Suite 507
Concord, NH 03301
(Attn: Herb Boynton)

Stephen E. Merrill
Attorney General
George Dana Bisbee
Assistant Attorney General
Office of the Attorney General
25 Capitol Street
Concord, NH 03301

Paul A. Fritzsche, Esq.
Office of the Public Advocate
State House Station 112
Augusta, ME 04333

Diana P. Randall
70 Collins Street
Seabrook, NH 03874

Robert A. Backus, Esq.
Backus, Meyer & Solomon
116 Lowell Street
P.O. Box 516
Manchester, NH 03106

Jane Doughty
Seacoast Anti-Pollution League
5 Market Street
Portsmouth, NH 03801

J. P. Nadeau
Board of Selectmen
10 Central Road
Rye, NH 03870

Calvin A. Canney
City Manager
City Hall
126 Daniel Street
Portsmouth, NH 03801

Angelo Machiros, Chairman
Board of Selectmen
25 High Road
Newbury, MA 10950

Edward G. Molin
Mayor
City Hall
Newburyport, MA 01950

Donald E. Chick
Town Manager
Town of Exeter
10 Front Street
Exeter, NH 03833

William Lord
Board of Selectmen
Town Hall
Friend Street
Amesbury, MA 01913

Brentwood Board of Selectmen
RFD Dalton Road
Brentwood, NH 03833

Gary W. Holmes, Esq.
Holmes & Ellis
47 Winnacunnet Road
Hampton, NH 03841

Philip Ahrens, Esq.
Assistant Attorney General
Department of the Attorney General
State House Station #6
Augusta, ME 04333

Ellyn Weiss, Esq.
Harmon & Weiss
Suite 430
2001 S Street, N.W.
Washington, DC 20009

*Thomas G. Dignan, Esq.
Ropes & Gray
225 Franklin Street
Boston, MA 02110

Richard A. Hampe, Esq.
Hampe & McNicholas
35 Pleasant Street
Concord, NH 03301

Beverly Hollingworth
209 Winnacunnet Road
Hampton, NH 03842

Ashod N. Amirian, Esq.
376 Main Street
Haverhill, MA 01830

William Armstrong
Civil Defense Director
Town of Exeter
10 Front Street
Exeter, NH 03833

Michael Santosuosso, Chairman
Board of Selectmen
Jewell Street, RFD 2
South Hampton, NH 03827

Robert Carrigg, Chairman
Board of Selectmen
Town Office
Atlantic Avenue
North Hampton, NH 03862

Anne E. Goodman, Chairperson
Board of Selectmen
13-15 Newmarket Road
Durham, NH 03824

Allen Lampert
Civil Defense Director
Town of Brentwood
20 Franklin Street
Exeter, NJ 03833

Sheldon J. Wolfe, Chairperson
Atomic Safety and Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Charles P. Graham, Esq.
McKay, Murphy & Graham
Old Post Office Square
100 Main Street
Amesbury, MA 01913

Barbara St. Andre, Esq.
Kopelman & Paige, P.C.
77 Franklin Street
Boston, MA 02110

Judith H. Mizner, Esq.
Lagoulis, Clark, Hill-Whilton
& McGuire
79 State Street
Newburyport, MA 01950

R. Scott Hill-Whilton, Esq.
Lagoulis, Clark, Hill-Whilton
& McGuire
79 State Street
Newburyport, MA 01950

Carol S. Sneider

Carol S. Sneider
Assistant Attorney General
Nuclear Safety Unit
Department of the Attorney General
One Ashburton Place
Boston, MA 02108-1698
(617) 727-2265

DATED: July 7, 1988