Some Consequences of Catastrophic Accidents at Indian Point and Their Implications for Emergency Planning

Brian Palenik
and
Jan Beyea

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD
Before Administrative Judges:
Louis J. Carter, Chairman
Frederick J. Shon
Dr. Oscar H. Paris

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In the Matter of	)	Docket Nos.
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. (Indian Point, Unit No. 2)	)	50-247 SP 50-286 SP
	)	
POWER AUTHORITY OF THE STATE OF NEW YORK (Indian Point, Unit No. 3)	)	June 7, 1982 (Revised June 23, 1982) (Revised July 6, 1982)

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"Some Consequences of Catastrophic Accidents at Indian Point and Their Implications for Emergency Planning"

Direct Testimony of
Brian Palenik
and
Dr. Jan Beyea

On Behalf of
New York State Attorney General
Union of Concerned Scientists (UCS)
New York Public Interest Research Group (NYPIRG)
New York City Audubon Society

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QUALIFICATIONS OF DR. JAN BEYEA

Dr. Beyea received his doctorate in physics from Columbia University in 1968. Since then he has 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, Dr. Beyea prepared a critical quantitative analysis of attempts to model reactor accident consequences. The lessons learned from this general study of nuclear accidents and the computer codes written to model radioactivity releases have been applied by Dr. Beyea to specific problems at the request of governmental and nongovernmental bodies around the world. Major reports on the safety of specific nuclear facilities have been written for the President's Council on Environmental Quality (TMI reactor), for the Swedish Energy Commission (Barsebeck reactor), and the state of Lower Saxony in West Germany (Gorleben waste disposal site). He has also examined, in less detail, safety aspects of specific sites for the California Energy and Resources Commission, the Massachusetts Attorney General's Office, and the New York City Council.

While at Princeton, Dr. Beyea wrote a computer program useful for reactor emergency planning for the New Jersey Department of Environmental Protection. This program, appropriately modified, has been used for many of the calculations presented in this testimony.

After joining the National Audubon Society, Beyea continued to work as an independent consultant on nuclear safety issues. He participated in a study, directed by the Union of Concerned Scientists at the request of the Governor of Pennsylvania, concerning the proposed venting of krypton gas at Three Mile Island. The U.C.S. study, for which Beyea made the radiation dose calculations, essentially confirmed official dose projections made by the N.R.C. and the State of Pennsylvania. The fact that an organization critical of nuclear power confirmed official dose calculations was the major reason the Governor gave for approving the venting.

Dr. Beyea participated in the international exercise on consequence modelling (Benchmark Study) coordinated by the Organization for Economic Cooperation & Development (O.E.C.D.). Scientists and engineers from fourteen countries around the world calculated radiation doses following hypothetical "benchmark" releases using their own consequence models. Participants from the United States, in addition to Dr. Beyea, included groups from Sandia Laboratories, Lawrence Livermore Laboratory, Batelle Pacific-Northwest, and Pickard, Lowe and Garick, Inc.

Dr. Beyea also served as a consultant from the environment community to the N.R.C. in connection with their development of "Safety Goals for Nuclear Power Plants."

In addition to reports written about specific nuclear facilities, an article of Beyea's on resolving conflict at the Indian Point reactor site and an article on emergency planning for reactor accidents have appeared in The Bulletin of the Atomic Scientists. A joint paper with Frank von Hippel of Princeton University on the value of improving reactor containment systems is in press.

Dr. Beyea has also prepared risk studies covering sulfur emissions from coal-burning energy facilities.

A complete resume is included in Appendix I.

QUALIFICATIONS OF BRIAN PALENIK

Brian Palenik received his Bachelor of Science in Civil Engineering degree with honors from Princeton University. His area of concentration was operations research and its use in public policy decisions. While an undergraduate at Princeton, Mr. Palenik worked with Dr. Beyea on the consequence calculations for "Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere from Three Mile Island"--Dr. Beyea's report to the President's Council on Environmental Quality. After graduation, Mr. Palenik joined the staff of National Audubon's Policy Research Department to continue working on nuclear accident consequence modelling, as well as other energy policy issues.

1. PLEASE SUMMARIZE YOUR TESTIMONY.

The purpose of this testimony is to present the results of our investigation into the adequacy of the current emergency plans for the Indian Point nuclear reactors in the case of a large release of radioactivity. We address the adequacy of the plans for protecting the population within the ten mile Emergency Planning Zone (EPZ) from early death. In addition we have set this study in the context of the larger question: What are the consequences around Indian Point--early deaths, latent cancer deaths, thyroid nodules and land contamination--from a specific large release (a PWR2 release in the notation of the NRC's Reactor Safety Study).

Using official estimates of evacuation times and standard dispersion models, we show that the present emergency plans are not adequate to protect the population within ten miles from early deaths. We pinpoint those emergency response preparation areas (ERPAs) around the plant where early deaths in the general population would be expected under frequently occurring weather conditions. We also show that many more ERPAs would be in danger if it were raining during the release, or if a relatively large fraction of the radioactive materials released into the air during the accident were to remain close to ground level while being blown downwind.

We have also looked at the consequences of a PWR2 release beyond ten miles. In addition to the possible occurrence of some early deaths, we show that, for a wind blowing towards New York City, 6,000 to 50,000 delayed cancer deaths and 400,000 to 2,000,000 delayed cases of thyroid nodules would be expected from doses received relatively soon after the accident. (The range of numbers reflects scientific uncertainty in the quantitative relationship between radiation dose and human injury.) With the wind blowing toward New York City, a large section of the city would be contaminated with radioactive deposition and would have to be evacuated as soon as possible to reduce subsequent cancers, injuries,and deaths that would occur from prolonged exposure to radiation from contaminated ground. Some areas would have to be abandoned for decades.

For a wind blowing towards the north at the time of release, the number of expected health effects from short-term exposure within 10-50 miles would be less than for a wind blowing south towards New York City. However, a large number of health effects and land contamination would be expected beyond 50 miles for this wind direction. (Whereas with a wind towards New York City, only water lies beyond 50 miles.) The inital amount of land in which occupation restrictions would be required would equal 5300 square miles, using a standard threshold for land contamination.

These serious consequences, due in part to the heavily populated region around Indian Point, should be considered by policy makers before deciding upon the future of operations at Indian Point.

If the nuclear reactors there are allowed to operate in the future, we have suggested some possible strategies for mitigating the short-term radiation exposures resulting from a large release. Strategies considered are 1) expanded evacuation; 2) sheltering in buildings; 3) use of potassium iodide as a protective drug; and 4) breathing through makeshift filters.

Improvements in the existing emergency plans for residents within the ten mile EPZ could also be made. For instance, a strategy of beginning preparations for an evacuation or beginning the evacuation itself earlier than under the current policies could ensure greater time for an evacuation.

In addition, an apparent defect in the plans that calls for directing evacuees into possibly contaminated ground should be corrected. Emergency plans should not be blind to the fact that downwind congregation centers can be contaminated even though they are located outside the ten mile EPZ.

Finally, we have found that use of potassium iodide would be useful within the ten mile EPZ. We recommend that the Board require the reactor owners to pay for distribution costs if health authorities recommend potassium iodide distribution at any time in the future. This would ensure that the decision to distribute potassium iodide would be made only on the basis of public health considerations.

It should be noted that all mitigating strategies only reduce consequences; they do not eliminate them. Furthermore, we are not aware of feasible mitigation strategies that can effectively reduce consequences of long-term contamination.

A PWR2 release was chosen for our base calculations because it is considered a physically plausible release category by those analysts at government laboratories who have studied melt-down accident sequences in detail. A PWR2 release is expected, for instance, following certain large pipe break accidents because sufficient amounts of water would not be available to scrub the radioactive fission fragments from the escaping gases as occurred in the "small pipe break" accident at Three Mile Island. We do not examine the consequences of the more serious PWR1 release because most analysts have downgraded the possibility of the initiating steam-explosion scenario.

Many different accident sequences could lead to a PWR2 release. The total probability for such a release is the sum of the probabilities of all accident sequences that have a PWR2 release as a final state. The total probability of a PWR2 release at the Indian Point site is very uncertain, so uncertain that it is misleading to state a central estimate. There is not sufficient experience with reactors over their life cycle to allow a reliable probability estimate. The fact that new accident sequences are constantly being discovered suggests that additional sequences are yet to be found and that current probability estimates must be incomplete. In addition, the probability of sabotage is so uncertain that no one, to our knowledge, has even attempted its calculation.

The true probability of PWR2 release could be orders of magnitude higher or lower than the limited estimate given in the Reactor Safety Study or in the Indian Point Probabilistic Risk Analysis. As a result, there is no way to guarantee the public safety at Indian Point. Nor is it even possible to state that there is reasonable assurance that the public safety can be protected. If the board allows continued operation of Indian Point, with its current emergency plans, it is making the implicit assumption that the probability of a PWR2 release (and its associated consequences) is too low to consider--an assumption for which there is no sound scientific basis.

2. DESCRIBE IN GENERAL TERMS HOW RADIOACTIVE MATERIAL IS RELEASED TO THE ENVIRONMENT.

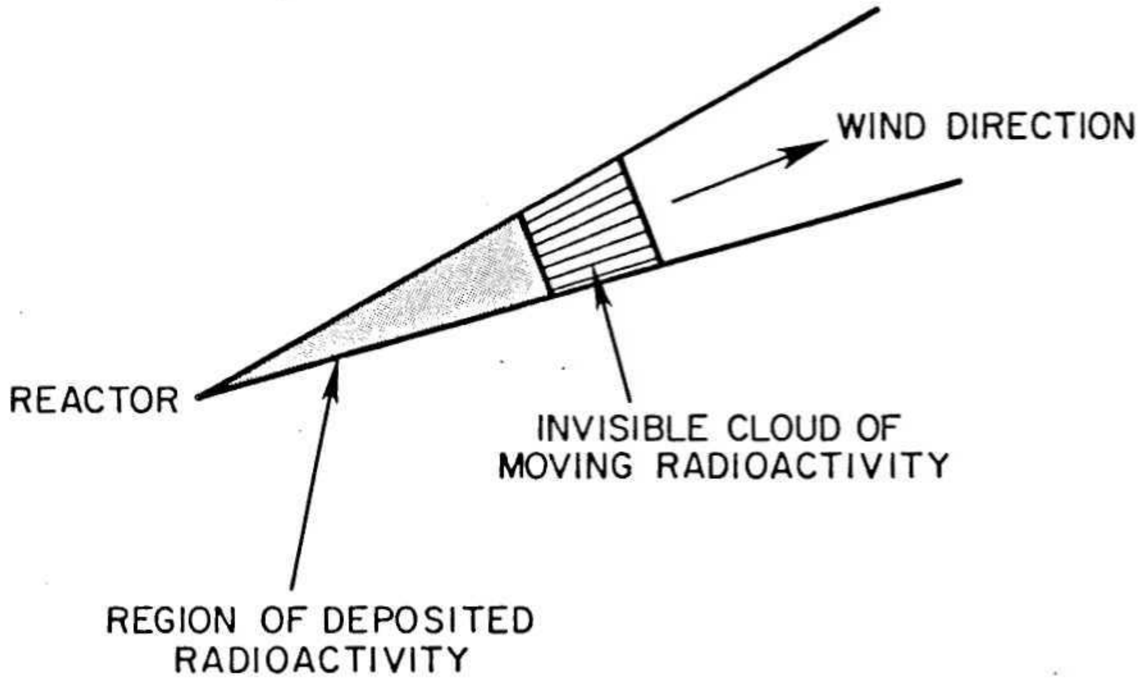
For a large release of radioactive material to occur following an accident, a "release pathway" from the core to the environment is required. One set of pathways is generated by failure of the reactor's pressure vessel followed by failure of the containment building surrounding the vessel. Researchers have outlined some, though not all, possible sequences and conditions for these failures. Recent work of importance to these proceedings has particularly focussed on failure of the containment building through overpressurization. Some suggested scenarios for overpressurization, examined by Sandia Labs, Battelle Labs, and others include: steam explosion, hydrogen burning, and rapid (for example, a steam spike) or slow static overpressurization.[1]

A second set of release pathways would lead to releases through an interface system. For example, excessive pressure differentials between the cooling loops could lead to releases through the secondary system. Similarly, massive steam generator failure due to aging steam generator tubes might lead to a large release through the secondary cooling system.[2]

If a large release of radioactive material to the environment occurs, such as a PWR2 release in the notation of the Reactor Safety Study,[3] the material will leave the reactor as a "plume" of gases, aerosols and water droplets. Most of the release will occur over a period of thirty to sixty minutes.

This plume will rise to a height which is theoretically dependent on such variables as 1) the amount of heat released in the accident, 2) the weather conditions existing at the time, and 3) whether or not the release takes place at the top or bottom of the structure. As will be shown later, there is no satisfactory formula that predicts the magnitude of plume rise.

The plume will be carried by the prevailing wind. Under the action of wind fluctuations and other weather conditions, the plume will spread in both the horizontal and vertical directions, so that the average concentration of radioactive material in the plume will decrease with time as it travels away from the reactor. (See Figure I) After a short



TOP VIEW OF PLUME

FIGURE I

time, the expanding edge of the plume will "touch" ground, and radioactive material will be dispersed along the ground, on vegetation, buildings, cars, etc. The rate at which material is removed from the plume, referred to as the deposition velocity, depends on the "stickiness" of these surfaces This deposition will also cause the concentration of material in the plume to decrease with time.

The plume may disperse radioactive material along the ground for more than a hundred miles if there is no reversal of wind direction. Much of the area where the plume has passed will be contaminated for decades and "permanent" evacuation of the original population will be required there. In addition, as much as 10 percent of the material will be resuspended by the action of wind and blown about in succeeding weeks.[4] The area of contamination will increase, causing residents who live outside the initial plume path to be exposed to radiation.

Immediately after the release, the plume will be visible, due to the escape of large amounts of cloud-forming water droplets. As the plume travels downwind and as the water droplets evaporate, the plume will most likely disappear from view.

3. HOW DOES THE POPULATION RECEIVE RADIATION DOSES?

The population in the area under the plume would receive most radiation doses via three dose pathways[5] (See Figure II):

1) From external radiation received directly from the radioactive plume itself. In these catastrophic accidents, unlike Design Basis Accidents considered in Safety Analysis Reports, the main part of the plume passes by very quickly, within one half hour or so.

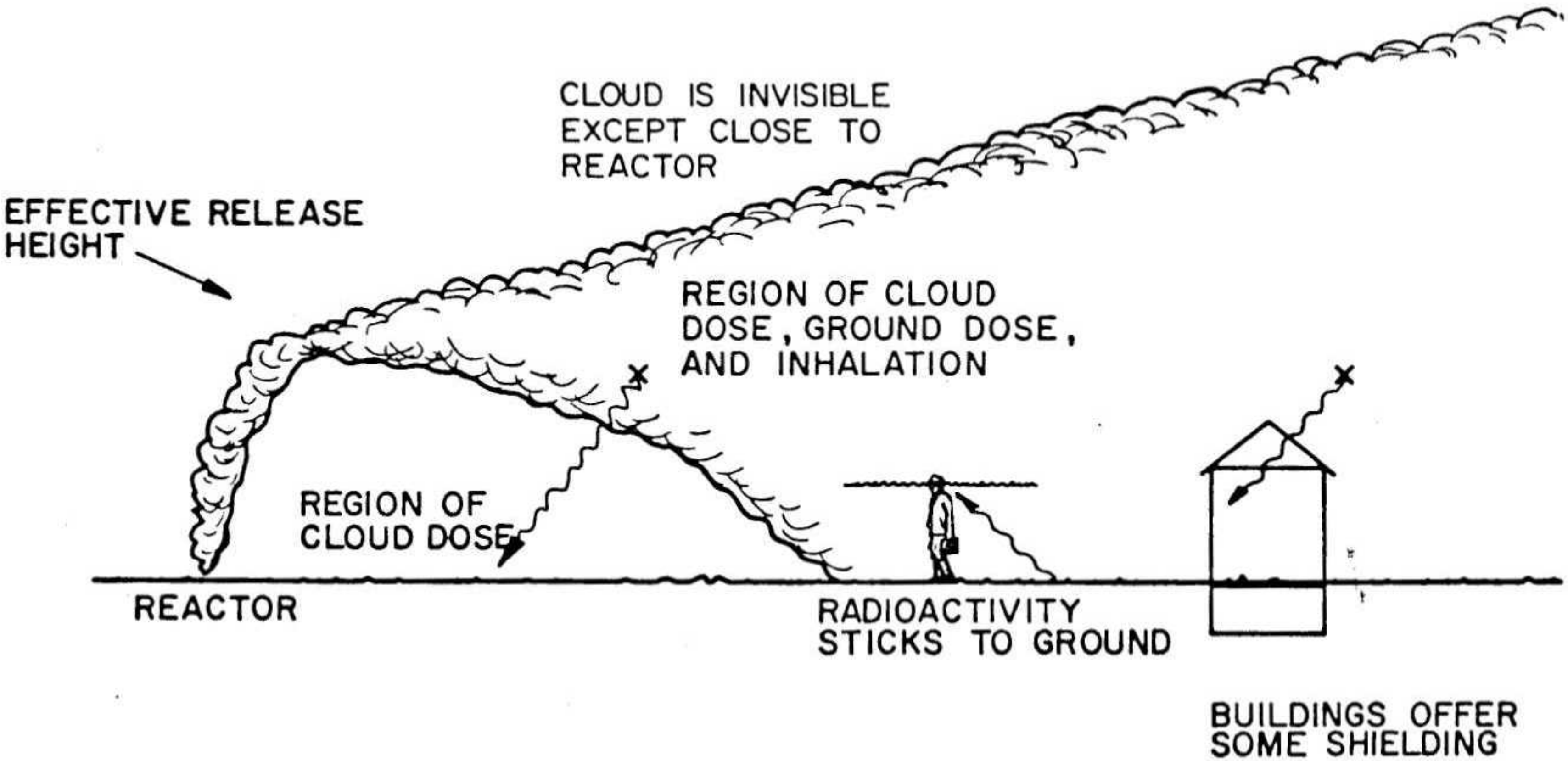
2) From radiation received following inhalation. The inhalation pathway would be the most important contributor to the thyroid dose.

3) From radiation received from material deposited on the ground or other surfaces. It is this "ground dose" which would usually be the most important contributor to early fatalities because it would continue after the plume has passed. Evacuation after the plume goes by is needed to stop the accumulation of ground dose; the faster the evacuation, the lower the total ground dose.

We have concentrated on these three pathways in our testimony.

Other important dose pathways exist for persons not under the original plume. These include inhalation and ground doses from resuspended and redeposited radioactive material. (As much as 10 percent of the plume's material may be resuspended within a few weeks.)[4] Doses are also possible through ingestion of contaminated food or water.

The existence of many dose pathways implies that emergency plans, to be effective, must incorporate different dose reduction methods, including evacuation, sheltering, possibly potassium iodide administration, decontamination, milk and food impoundment, etc.[6]



SIDE VIEW OF RADIOACTIVE PLUME

FIGURE II

4. IN WHAT UNITS ARE DOSES MEASURED?

Individual doses are measured in "rems." This unit expresses the accumulated amount of damaging energy deposited by the radioactive material per unit mass of absorbing material. "Person-rem" is used in this study and elsewhere as a measure of the total population dose, the sum of all individual doses. Long-term health consequences of radiation can be calculated, even when the distribution of individual doses is unknown, by using an estimated total population dose.

5. WHAT ARE THE POTENTIAL HEALTH CONSEQUENCES OF RADIATION DOSES?*

The health consequences of radiation depend upon the magnitude of the dose received. Radiation doses on the order of 100 rem or higher--doses that occur relatively close to the plant--lead to immediate sickness (e.g., nausea) and "early death." At a dose of 100 rems for example, 15-25 percent of the exposed persons would suffer from vomiting within 2 days. (WASH-1400, Appendix VI, Figures VI, f-9, f-10.)

"Early death," a technical term in the radiological health field, refers to death within sixty days of exposure to a given dose. The threshold for early deaths is between 100-200 rem, while the probability of early death increases with increasing dose and changes with "supportive" medical treatment** as shown in Table 1 . Large hospitals might each be able to handle 5-10 patients requiring supportive treatment; the total capacity in the U. S. for handling such patients would be 2500-5000 people.[7]

The quantitative analysis of supportive medical treatment presented in Table 1 was unique to the Reactor Safety Study and has not received widespread acceptance. Although there appears to be agreement that supportive medical treatment will shift the early death probability curve it is not clear that the exact shift projected by the Reactor Safety Study is correct. (Private communication, Edward Radford, University of Pittsburgh.)

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* In this proceeding, we do not testify as expert witnesses in the effects of radiation. Instead, we have surveyed the relevant literature in order to obtain quantitative information relating dose to injury.

** "Supportive" treatment is defined in Wash-1400, Appendix VI, FI, as such procedures as reverse isolation, sterilization of all objects in patient's room, use of laminar-air-flow systems, large doses of antibiotics, and transfusions of whole-blood packed cells or platelets.

Table 1

EARLY MORTALITY TABLE

(BASED ON WASH-1400 FIG. VI 9-1)*

PROBABILITY OF EARLY DEATH (WITHIN 60 DAYS)

Dose Range (Rem)	Minimal Treatment	Supportive Treatment**
0-50	0	0
50-100	0	0
100-150	.0001	0
150-200	.0065	0
200-250	.11	0
250-300	.26	0
300-350	.54	.0008
350-400	.78	.02
400-450	.93	.16
450-500	.985	.38
500-550	1.0	.7
550-600	1	.85
600-650	1	.97
650	1	1

The definition of supportive treatment as given in WASH-1400, Appendix VI, F1; "indicates such procedures as reverse isolation..., sterilization of all objects in patient's room, use of... laminar-air-flow systems, large doses of antibiotics, and transfusions of whole-blood packed cells or platelets." (See also VI 9-3.) Minimal treatment is anything less than this.

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* Our table represents a 25 rem downward shift of the WASH-1400 curve. Our curve is thus slightly more conservative.

** This quantitative analysis of supportive treatment was original to WASH-1400 and has not received widespread acceptance. (See text)

Cancer, diseases, and developmental and genetic birth-defects will occur with some probability among all exposed populations; however, the incidence decreases with decreasing dose.[8] These consequences of radiation may occur many years after exposure. Since experts disagree on the exact magnitude of the dose/effect relationship for these injuries, we have used a range of coefficients in our calculations broad enough to encompass most expert opinions.

For instance, based on our review of the literature, we have used a coefficient range of 50 to 500 cancer deaths (non-thyroid) per million person-rem to the whole body--a range which the Environmental Protection Agency has agreed is reasonable.[8a,*,**]

Table 2 lists the coefficients for calculating health consequences used in this study and in other reports.

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* We assume, as is customary, a direct proportionality between doses and the probability of each health effect. This "linear hypothesis", although almost standard in applications such as ours, is nevertheless the subject of considerable controversy as to its accuracy and as to its validity as an approximation to actual dose-effect relationships. We treat it simply as a mathematical convenience whose uncertainty can be adequately represented, for our purposes, by the uncertainty assigned to the proportionality constant.

** The number of non-thyroid cancer deaths would be higher if radiation-dose/cancer-death coefficients were used based on the work of Mancuso, Stewart and Kneale. Assuming one out of three cancers is fatal and that cancer represents 20% of the current death rate and using a linear fit to the 30 rad doubling dose for cancer proposed by Alice Stewart (personal communication), we obtain a death coefficient of about 2,000 per million person rem. This would be four times the highest coefficient used in this study.

TABLE 2

RANGE OF HEALTH CONSEQUENCES PER MILLION PERSON REM

FATAL CANCER INCIDENCE:	This Study	1980 BEIR Report[a)]	1972 BEIR Report[b)]	Reactor Safety Study WASH-1400 (1975)	APS Study (1975)[c)]
Whole-body	50-500	67-226	115-621	65[d)]	130
Thyroid					
Child	.5-3			5[e)]	.5-3
Adult	1.8-11			5[e)]	1.8-11
Population Weighted[f)] Thyroid	1.9-12[f)]				
THYROID NODULE INCIDENCE					
Child	130[g)]-1300[h)]			330[e)]	275-1300
Adult	130[g)]-650[i)]			330[e)]	
Weighted[f)]	200-1500[f)]				

a) National Academy of Sciences, BEIR Report, 1980, Table V-4. The upper number was lowered by about a factor of two for the final report (1980) as a result of internal criticisms of the use of a pure linear dose effects model.

b) From Table V-4 of Ref. a). The 1972 BEIR Report used a pure linear model.

c) Revs. Mod. Phys. 47, S1.

d) WASH-1400 mid-range values. (The so-called, "upper-bound" numbers in WASH-1400 were calculated to be about two times higher.) To obtain its mid-range dose/effects coefficients, WASH-1400 used a linear model weighted by dose reduction factors depending on the dose magnitude. The number shown represents a weighted average of coefficients ranging from a low 24 to an "upper bound" of 122.

e) The Environmental Protection Agency uses coefficients for thyroid effects which would give a similar number. The number shown is a weighted average of the effects of Iodine 131 and other iodine isotopes. For example, in the case of fatal cancer incidence, the number 5 in the table is a weighted average of 1.3 deaths per million rem for I^{131} and 13 deaths per million rem for other iodine isotopes. (See WASH-1400 App. VI, pp. 9-26, 27) Note, because of the shorter lifetime of I^{133}, the weighted average would drop by a factor of four if the hypothetical release occurred many days after fission stopped.

f) The weighted numbers are defined so that the entire population can be treated as adults. They are weighted according to the percentage of children and adults in the population and renormalized to the adult dose. The numbers are based on 1) the APS coefficients for children and adults, 2) a 5 times higher dose for children than adults for the same exposure, and 3) an assumed 15 percent fraction of children in the populations. [For example, 1.9 = .85 X 1.8 + .15 X 5 X .5, 12 = .85 X 11 + .15 X 5 X 3.]

g) The WASH-1400 value reduced by a factor of 2.5 to account for decay of short-lived Iodine isotopes should the accident occur a day or so after shutdown.

h) The APS value.

i) New data on the Marshallese victims suggests that the adult rate is 1/2 that of children, rem-for-rem. [Robert Conard, "Thyroid Lesions in Marshallese, July 1978," Brookhaven National Laboratory, Upton, Long Island (Mimeo).] Insufficient data was available in 1975 for the APS study group to determine a range for adult nodule incidence.

6. HOW HAVE YOU MODELLED THE PLUME MOVEMENT AND DOSE PATHWAYS?

The plume movement and the three major dose pathways*discussed previously have been modelled by us in several computer programs. The original programs have been cited in other reports[9], while some modifications have been made for this study.** The dose to the population caught directly in the plume in a "PWR2" release was calculated by these programs as a function of time after release for a range of weather conditions and for a range of model parameters. Ranges of model parameters were used because the appropriate values of parameters are currently uncertain.

The basic modelling used is similar to the approach taken by radiological protection agencies around the world, including the NRC.***

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* The major sources of radiation that contribute to early death or delayed cancer considered in this testimony are inhaled radioiodine, as well as external radiation (whole-body gamma) from the plume and from contaminated ground.

** For this study, we have explored the significance of the urban terrain in the vicinity of New York City. We have substituted urban dispersion parameters for rural dispersion parameters (with an effective release point adjusted to keep the plume shape continuous) when the plume reached the city of Yonkers on its way to New York City. Although doses in New York City increased under some conditions, the increase turned out not to be of major significance.

*** Note that our programs do not include time-varying weather such as changing wind speed and changing turbulence, the major contributor to early deaths in the Reactor Safety Study. However, our programs allow for variations in deposition velocity and plume rise--variations which the Reactor Safety Study did not consider.

7. IN WHAT WAYS HAVE YOUR CALCULATIONS TAKEN INTO ACCOUNT THE UNCERTAINTIES IN THE CURRENT STATE OF CONSEQUENCE MODELLING?

The treatment of plume rise due to thermal buoyancy illustrates the current uncertainty that exists in dose calculations due to inadequate knowledge of model parameters. Since calculated doses can be very sensitive to whether or not the edge of the plume has "touched" ground, knowledge of the initial rise of the plume can be critical--especially within the EPZ. Yet, lack of understanding, both experimental and theoretical, about plume rise makes prediction of this parameter difficult.

Figure III shows the enormous spread in airborne concentration of radioactivity (and therefore dose) predicted for the same release of radioactivity by modellers from different countries under one set of weather conditions. Most of this spread arises because of different predictions of plume rise. These results from the international exercise in consequence modelling[10] demonstrate that dose predictions from a particular computer code may be highly uncertain within about 20 miles from a reactor if based on one set of model parameters. (Output from the computer codes used to develop our testimony were included in this consequence modelling exercise.)

As weather conditions are varied, the range of doses predicted by different computer codes shows much less of a spread. It is for this reason that we consider dose ranges in this study rather than relying exclusively on predictions using one set of model parameters. The dose ranges used in our testimony fall well within the full range given in Figure III. Our calculations using mid-range model parameters fall in the middle.

FIGURE III: RANGE OF AIR CONCENTRATIONS OF RADIOACTIVITY PREDICTED BY DIFFERENT MODELLERS FOR THE SAME RELEASE SCENARIO. (MOST OF THE VARIATION IS DUE TO VARIATION IN THE TREATMENT OF PLUME RISE.)

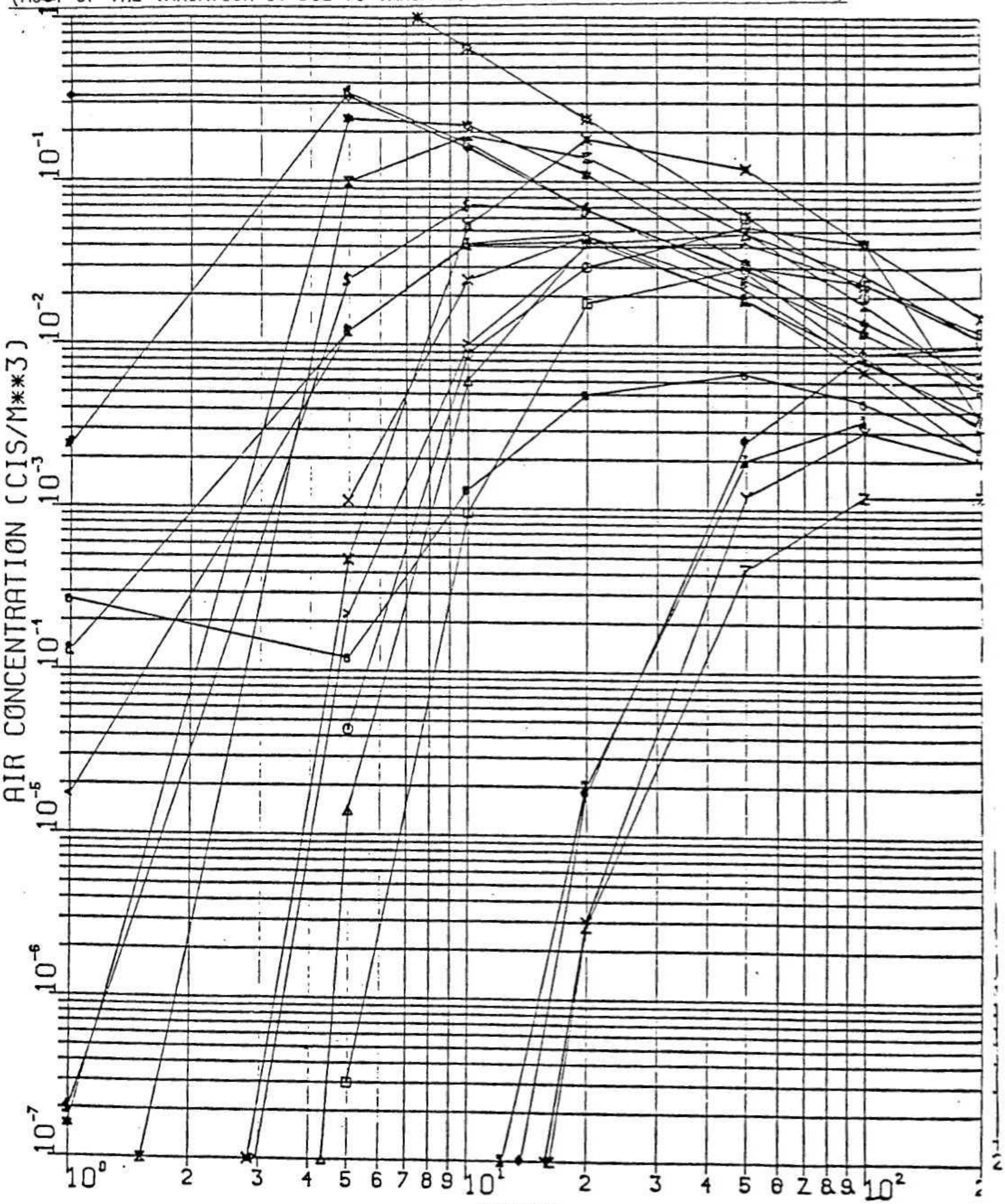

ABB. 21 : BENCHMARK PROBLEM 1

INTEGRATED AIR CONCENTRATION (CIS/M**3)

BMR2 D STABILITY NO RAIN

8. WHAT ARE THE CHARACTERISTICS OF THE RELEASE TYPE YOU HAVE CONSIDERED AND WHY HAVE YOU CHOSEN TO USE IT?

The consequence calculations presented in this testimony have been made using, in WASH-1400 terminology, a "PWR2" type of radioactivity release as an input to the computer codes. There are many accident sequences, all requiring core uncovery and breach (or bypass) of containment, that could lead to a PWR2 release. The common element of these accident sequences is that an expected 70 percent of the iodines and 50 percent of the alkali metals would escape to the atmosphere.[3] This was not the worst possible release type envisioned in the Reactor Safety Study (WASH-1400), but close to it.

The probability of a PWR2 release is the sum of the probabilities of all accident sequences that have a PWR2 release as a final state. WASH-1400 assigned the PWR2 release the highest probability of occurrence of any catastrophic accident release. Its estimate of this probability was between one in ten thousand and one in a million per reactor per year [WASH-1400, Appendix VI, p. 86] This probability is very uncertain at the present time--even more uncertain than indicated in the Reactor Safety Study. According to the official NRC review (The review that led the NRC to withdraw support from the executive summary):

> "We are unable to determine whether the absolute probabilities of accident sequences in WASH-1400 are high or low, but we believe that the error bounds on those estimates are, in general, greatly understated. This is true in part because there is in many cases an inadequate data base, in part because of an inability to quantify common cause failures, and in part because of some questionable methodological and statistical procedures."[12]

Although some improvements have been made in probabilistic risk studies carried out since the Reactor Safety Study, the same basic inadequacies quoted above remain.

We have picked a PWR2 release for our base calculations because it is considered a physically plausible release category by those analysts at government laboratories who have studied melt-down accident sequences in detail. A PWR2 release is expected, for instance, following certain large pipe break accidents because sufficient amounts of water would not be available to scrub the radioactive fission fragments from the escaping gases as occurred in the "small pipe break" accident at Three Mile Island. We did not examine the consequences of the more serious PWR1 release because most analysts have downgraded the possibility of the initiating steam-explosion scenario.

By choosing to examine a PWR2 release, we implicitly reject claims by the nuclear industry that all of the Reactor Safety Study release categories are unphysical. In response to the Three Mile Island accident, the industry mounted a concerted campaign to convince both the public and government that even in case of containment failure, the resulting release of radioactivity to the atmosphere would be much less than has always been thought. In particular, the electrical utilities' Electric Power Research Institute (EPRI) published a study which concluded that, even in the event of a core melt-down accident and a containment failure,

> [d]ue to the solubility of the volatile fission product compounds and the aerosol behavior mechanisms, the offsite dispersion of radioactive materials (other than gases) following a major LWR [Light Water Reactor] accident will be small.[13]

The electric utilities' public relations departments and the nuclear industry press sprang into action and advertized these claims with great fanfare, noting that:[14]

> If findings like these are verified...it would go far toward deflating the doomsday predictions of anti-nuclear groups.

The fact that the Nuclear Regulatory Commission, aside from a few staff comments in the trade press, expressed no public reservations concerning the significance of the claims tended to lend them additional credibility.

The NRC did, however, commission an effort to examine the EPRI claims as a collaborative enterprise between NRC staff members and technical experts at three major national laboratories. In March 1981 this team reported back in a draft report that:[15]

> The results of this study do not support the contention that the predicted consequences of the risk dominant accidents have been overpredicted by orders of magnitude in past studies. For example, the analysis in this report indicates that...10% to 50% of the core inventory of iodine could be released to the environment...

Under pressure from the industry, the NRC subsequently rewrote this summary language so that it no longer appeared to be a rebuttal to the EPRI report. Nevertheless, the technical conclusions remained the same.*

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* The basic points made in the NRC experts' review had been immediately apparent to knowledgeable readers of the EPRI report. For accidents in which the damage is sufficient to open large pathways from the core to the containment, there will not be sufficient water available to significantly trap the radioactive materials of concern, nor will the pathway be so torturous that a significant amount will stick to surfaces before reaching the containment atmosphere. Similarly, if the containment fails early enough, there will be insufficient time for aerosols to settle to the reactor building floor. These three mechanisms are the basis for the claims made in the EPRI report.

9. FOR A PWR2 RELEASE, WHAT ARE THE HEALTH CONSEQUENCES BEYOND TEN MILES THAT ARE NOT SIGNIFICANTLY REDUCED BY THE PRESENT EMERGENCY PLANS?

Currently there are no evacuation plans beyond approximately ten miles. Radiation doses will not stop at this distance, however, and persons in the plume path may receive early death doses, or develop fatal latent cancers from doses below the early death threshold. In Tables 3 and 4 we have attempted to quantify the number of fatal latent cancer deaths in the area from 10 to 50 miles from the accident site and show how the number of deaths will vary with the amount of time that passes between the release and ad hoc evacuation. The range of deaths shown for each calculation reflects the range in cancer/dose coefficients that appears in the literature. (See Table 2) Similarly, Table 5 projects the number of thyroid cancers that might be caused by a PWR2 release.

The results here are presented for two wind directions (towards the North and South) and for two weather scenarios out to 50 miles from the site. (Details are given in the tables and later in the testimony.)

Results for non-thyroid cancer fatalities are presented assuming that evacuation takes the same length of time for everyone. In the case of a real accident it is unlikely that the three sectors (10-20 miles, 20-35 miles, 35-50 miles) would evacuate in the same average time interval. Nevertheless, these tables can be used to calculate a more likely scenario. As an illustrative example, consider an average one day evacuation time for the 10-20 mile sector, two days for the 20-35 mile sector, and three days for the 35-50 mile sector. The range of latent cancer deaths from this limited exposure (excluding thyroid cancer deaths) for average conditions and wind toward New York City would be in the range of 85-850 deaths in the 10-20 mile sector; 950-9500 in the 20-35 mile sector; and 1425-14,250 in the 35-50 mile sector, for 2460-24,600 total deaths.

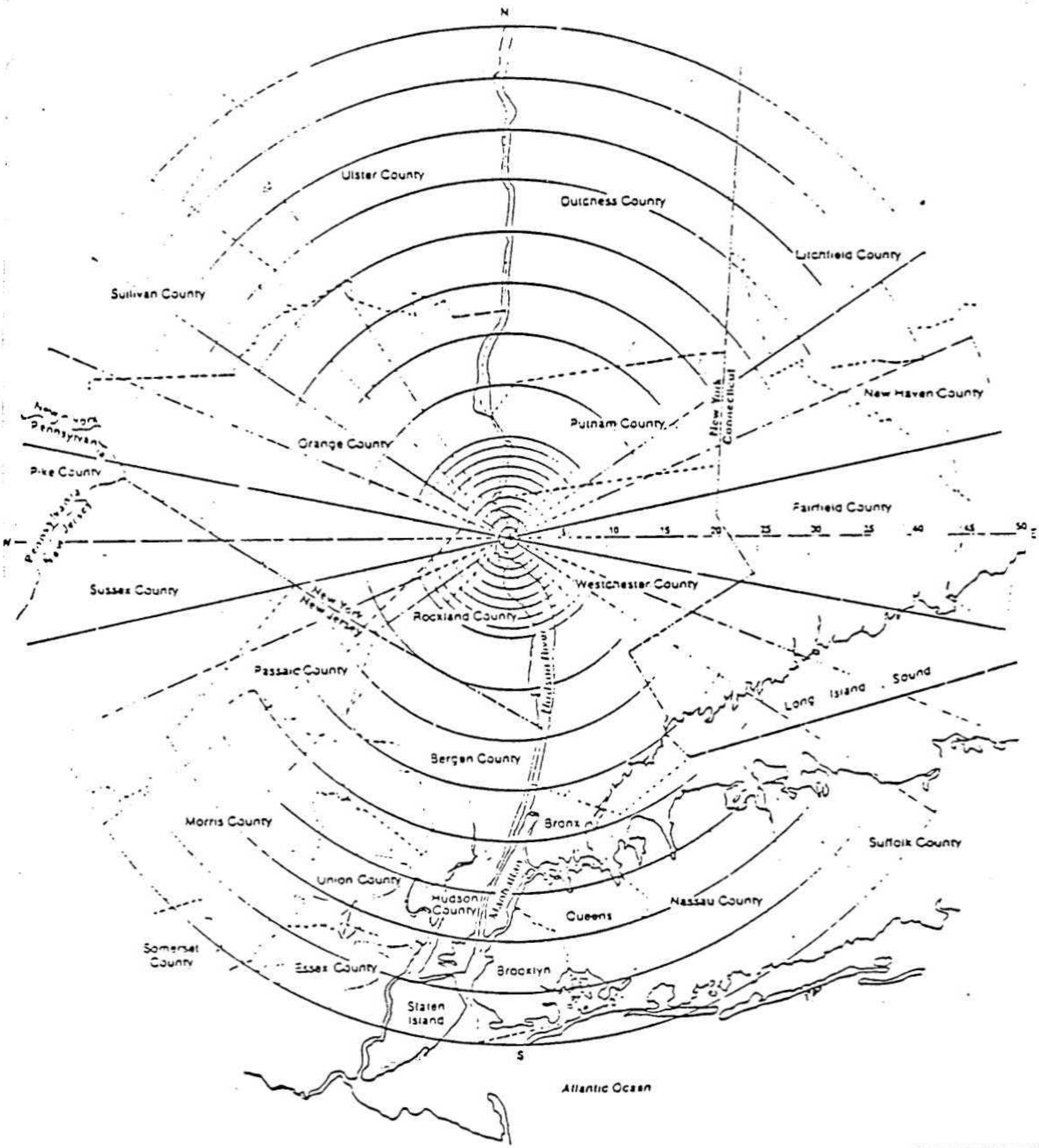

Figure IV

Legend

—— State Boundary

—·— County Boundary

N

Source: New York State Radiological Emergency Preparedness Plans, Figure 2, P. IP-6

Indian Point Site

50-Mile Region

TABLE 3

DELAYED CANCER DEATHS FROM SHORT-TERM EXPOSURE IN THE 10-50 MILE SECTOR WHEN WIND IS BLOWING TOWARD NYC FOLLOWING A PWR2 RELEASE[a)]

Assumed Evacuation Time b)	Sector Boundaries (miles) c)	Pop. In Sector d)	Average Conditions e) Dose at Outer edge (Rems)	Average Conditions e) Deaths g)	Precipitation f) Dose at Outer edge (Rems)	Precipitation f) Deaths g)
1 Day	10-20	31508	54	85-850	97	153-1530
	20-35	884021	14	619-6190	27	1193-11930
	35-50	1424653	9	641-6410	10	712-7120
				1345-13450		2058-20580
2 Days	10-20	31508	82	129-1290	163	257-2570
	20-35	884021	21.5	950-9500	50	2210-22100
	35-50	1424653	15.5	1104-11040	19.5	1389-13890
				2183-21830		3856-38560
3 Days	10-20	31508	102	161-1610	213	336-3360
	20-35	884021	27	1193-11930	68	3006-30060
	35-50	1424653	20	1425-14250	27	1923-19230
				2779-27790		5265-52650
4 Days	10-20	31508	120	189-1890	256	403-4030
	20-35	884021	32	1414-14140	82	3624-36240
	35-50	1424653	24	1710-17100	33.5	2386-23860
				3313-33130		6413-64130

a) Delayed cancer deaths not including thyroid cancer deaths.

b) Average evacuation time for population.

c) Sector is the segment of a 7.5 degree wedge with the boundaries indicated.

d) Derived from 1980 population data from the New York State Radiological Emergency Preparedness Plans by dividing the figures there (for 22.5 degree wedges) by one-third to represent a 7.5 degree wedge.

e) Mid-range parameters used are .01 meters/sec deposition velocity; D (Pasquill) stability class; 4m/sec wind speed; Briggs dispersion parameters with a change over to Briggs urban dispersion parameters at 20 miles: Briggs theoretical plume rise; .3 ground shielding factor.

(Continued)

f) Precipitation case parameters are the same as above, but use a washout coefficient of .0001 sec^{-1}.

g) Dose/effects coefficient used was 50-500 per million person rem. This range includes most coefficients found within the literature. It is considered reasonable by the Environmental Protection Agency.

TABLE 4

DELAYED CANCER DEATHS FROM SHORT-TERM EXPOSURE IN THE 10-50 MILE SECTOR WHEN WIND IS BLOWING TOWARDS THE NORTH FOLLOWING A PWR2 RESLEASE[a)]

Assumed Evacuation Time b)	Sector Boundaries (miles) c)	Pop. In Sector d)	Average Conditions e)		Precipitation f)	
			Dose at Outer edge (Rems)	Deaths g)	Dose at Outer edge (Rems)	Deaths g)
1 Day	10-20	13,547	54	37-370	97	66-660
	20-35	42,700	14	30-300	27	58-580
	35-50	25,143	9	11-110	10	13-130
				78-780		137-1370
2 Days	10-20	13,547	82	56-560	163	110-1100
	20-35	42,700	21.5	46-460	50	107-1070
	35-50	25,143	15.5	19-190	19.5	25-250
				121-1210		242-2420
3 Days	10-20	13,547	102	69-690	213	144-1440
	20-35	42,700	27	58-580	68	145-1450
	35-50	25,143	20	25-250	27	34-340
				152-1520		323-3230
4 Days	10-20	13,547	120	81-810	256	173-1730
	20-35	42,700	32	68-680	82	175-1750
	35-50	25,143	24	30-300	33.5	42-420
				179-1790		390-3900

a) Delayed cancer deaths not including thyroid cancer deaths and the many deaths beyond 50 miles.

b) Average evacuation time for population.

c) Sector is the segment of a 7.5 degree wedge with the boundaries incicated.

d) Derived from 1980 population data from the New York State Radiological Emergency Preparedness Plans by dividing the figures there (for 22.50 wedges) by one-third to represent a 7.5 degree wedge.

e) Mid-range parameters used are .01 meters/sec deposition velocity; D (Pasquill) stability class; 4m/sec wind speed; Briggs dispersion parameters with a change over to Briggs urban dispersion parameters at 20 miles; Briggs theoretical plume rise case; .3 ground shielding factor.

(Continued)

f) Precipitation case parameters are the same as above, but use a washout coefficient of .0001 sec^{-1}.

g) Dose/effects coefficient used was 50-500 per million person rem. This range includes most coefficients found within the literature. It is considered reasonable by the Environmental Protection Agency.

TABLE 5

THYROID NODULES AND FATAL THYROID CANCERS WITHIN 10-50 MILES WHEN WIND IS BLOWING TOWARD NEW YORK CITY OR NORTH FOLLOWING A PWR2 RELEASE

Wind Blowing Towards NYC

Sector[a)]	Population in Sector (NYC)[b)]	Dose at Outer Edge (Rems)[c)]	Nodules[d)]	Fatal Thyroid Cancers[e)]
10-15	13,400	5103	13,400	--
15-20	18,108	3325	12,042- 18,108	--
20-35	884,021	937	165,666- 884,021	1575- 9,940
35-50	1,424,653	708	201,731-1,424,653	1915-12,100
			393,000-2,300,000	3500-22,000

Wind Blowing Towards the North

Sector[a)]	Population in Sector (North)[b)]	Dose at Outer Edge (Rems)[c)]	Nodules[d)]	Fatal Thyroid Cancers[e)]
10-15	1,300	5103	1,300	--
15-20	12,247	3325	8,144-12,247	--
20-35	42,700	937	8,002-42,700	76-480
35-50	25,143	708	3,560-25,143	34-214
			21,000-81,000	110-690

a) Sector is the segment of a 7.5 degree wedge with the boundaries indicated.

b) Derived from 1980 population data from the New York State Radiological Emergency Preparedness Plans by dividing the figures there (22.5 degree wedges) by one third to represent a 7.5 degree wedge.

c) 24-hour dose calculated using mid-range parameters: .01 deposition velocity; D Stability Class; 4 m/sec wind speed; Briggs dispersion parameters with a changeover to Briggs urban dispersion parameters at 20 miles; Briggs theoretical plume rise case; .3ground shielding factor. The dose would not be significantly smaller or larger if a shorter or longer exposure time was used, because most of it is delivered through inhalation of radioiodine during plume passage.

d) Dose/effects coefficients used are 200-1500 nodules per million thyroid person rem. If thyroid doses exceed 1000 rem ablation would likely occur rather than nodularity. See Table 2.

e) Dose/effects coefficients used are 1.9-12 fatal thyroid cancers per million thyroid person-rem. See Table2.

When the 3500-22000 range of thyroid cancer fatalities from Table 5 is added to the previous numbers, a total of approximately 6000 to 50,000 delayed cancer deaths from short term exposures is projected.* (Note that the range of deaths is based on uncertainty in the dose/effects coefficients.)

Thus 0.2 to 2 percent of the 2.3 million exposed persons are projected to eventually die from short-term exposure in this illustrative example. It should be noted that the fear of developing cancer as a result of a reactor accident could be a serious psychological consequence. Also, a large fraction of the exposed population would eventually develop cancer from other causes and might suspect that they were, in fact, radiation victims.

The absolute number of fatalities from 10-50 miles projected in the tables for a wind blowing toward the north is smaller than for the New York City case. However, when the much greater number of health effects expected beyond 50 miles for this wind direction are taken into account, (there is no population beyond 50 miles in the New York City direction), the total number of delayed cancer deaths from short-term exposure would be much larger then presented in the tables--probably by a factor of ten if our experience with calculations for the Three Mile Island site are a reliable guide.[16]

Although dose calculations beyond ten miles are not affected as much by uncertainties in plume rise, as within ten miles, it must be recognized that an additional uncertainty factor of two or three must be assigned to all cancer death totals due to modelling uncertainties.

The delayed health effects of the type considered in this section are assumed to be linear with dose.** Consequently, the number of health effects

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* Because the thyroid dose is dominated by the inhalation pathway, it does not change significantly with time after the passage of the plume.

for releases scaled down from a PWR2 release can be approximately determined by scaling the entries in the tables by an equivalent factor. Thus, in an accident by which only 10% as much radioactivity was released as in a PWR2 release, only one-tenth the number of delayed cancer deaths would be expected--say, 600 to 5,000 rather than 6,000 to 50,000.

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*Note that we use the linear hypothesis for relating dose to health effects as a mathematical convenience, assuming that possible non-linear effects are effectively contained in the range of coefficients assigned.

10. WHAT ARE THE EARLY DEATH CONSEQUENCES BEYOND TEN MILES THAT ARE NOT SIGNIFICANTLY REDUCED BY THE CURRENT EMERGENCY PLANS?

Table 10 shows that early deaths can occur beyond 10 miles relatively soon after the accident. Most of these deaths will occur in the 10-20 mile sector. Prior planning for an evacuation in areas between 10 to 20 miles from the plants would reduce the expected number of early deaths in this zone.

11. WHAT ARE THE LAND CONTAMINATION CONSEQUENCES OF A PWR2 RELEASE

Tables 6 and 7 show the approximate areas where agricultural activities and human occupation might be restricted due to contamination in a PWR2 type release.[17]

In the case of a wind blowing toward the South, most of the area considered to be contaminated would lie over the Atlantic ocean. However, the plume would pass through New York City, greatly increasing the economic and social disruption resulting from the accident. The map in Figure V indicates the size of the long-term ground contamination area (considering only the dose from cesium) assuming no decontamination efforts. Effective decontamination of built-up areas has never been demonstrated.

With the wind blowing toward the North, the contamination area would be as large as indicated in the tables. Decontamination of some of this area (the rural areas) would be possible by carting away top soil; even in rural areas, however, the magnitude of the decontamination task is so enormous that only partial decontamination is considered feasible.

Note that in the testimony we have not estimated any cancer fatalities that would result from long-term exposure to contaminated ground and buildings, or from ingestion of contaminated food, milk or water.

FIGURE V. LONG-TERM LAND CONTAMINATION CONTOURS

FOR WIND BLOWING TOWARDS NEW YORK CITY

FOLLOWING A PWR2 RELEASE

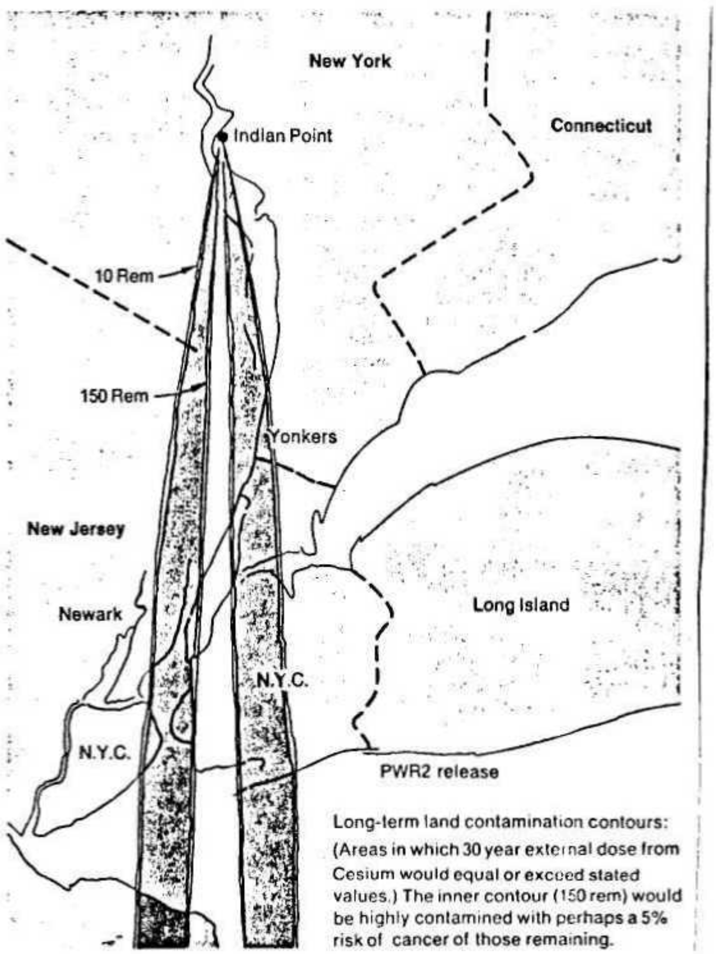

TABLE 6

AREAS IN WHICH INITIAL AGRICULTURAL USE AND LONG-TERM HUMAN OCCUPATION MIGHT BE RESTRICTED IN THE ABSENCE OF SUCCESSFUL DECONTAMINATION a)

FOR A PWR2 RELEASE AT INDIAN POINT

Initial Area b)		Contaminated Area b)	
Limited Occupation c)	Limited Agriculture d)	After 10 Years c, e)	After 40 Years c,e)
---------- square miles ----------			
5300 f)	18000 g)	550-4300	240-3300

NOTES:

a) For typical meteorological conditions. Ground shielding factor = .33.

b) Approximate area of 7.5° wedge extending from the plant. No decontamination is assumed. The length of the wedge for various areas is given below:

Maximum length of Wedge	Area of Wedge
525 mi	18,000 mi^2
260	4,300
240	3,700
100	650
30	60

c) We assume for illustrative purposes that occupation would be restricted if the resident population would otherwise receive more than a 10 rem whole body radiation dose over 30 years. This is similar to the criterion used in the Reactor Safety Study and corresponds to about a three-fold increase over the natural background dose in the same period. (A 10 rem whole body dose has associated with it a risk of a .05 to .5 percent chance of cancer death.) The 10-rem criterion is arbitrary. Should a more stringent threshold be insisted upon by the public, the restricted area would be larger.

d) Using criterion for cesium 134 with the infant as critical individual. Food grown in this area would not be allowed to be fed to infants. Restrictions apply to crops growing at the time of the accident; we do not attempt to calculate the more difficult problem of determining agricultural contamination after the first year.

e) The land contamination threshold used to calculate the lower number in the table is 10 rem in 30 years. In some sense, the threshold is set to balance the (small) individual risk of cancer against the hardships involved in uprooting people. Criteria which would be used to allow re-entry might be stricter. The higher number assumes that a 10-fold stricter criterion (corresponding to a one third increases over natural background) is applied in deciding whether vacant land can be re-used.

f) For comparison purposes, we note that the maximum corresponding figure in WASH-1400 was 3300 mi^2 (App. VI, Fig. 13-35).

g) Some of this area might be water.

TABLE 7

AREAS IN WHICH CATTLE GRAZING MIGHT BE RESTRICTED TO PREVENT MILK CONTAMINATION BY RADIOACTIVE IODINE FOLLOWING A PWR2 TYPE RELEASE AT INDIAN POINT[a)]

Time After Release	Area [b)]
0	175,000 [c)]
1 month (s)	50,000 [c)]
2 "	3,400
3 "	170
4 "	5

NOTES:

a) The affected areas decrease in time because the radioiodines are decaying. The half life for the principal isotope, iodine 131, is 8 days. The areas were calculated using a threshold of 4 uCi/m^2 of Iodine 131 deposition, a value which lies between those recommended by the Food and Drug Administration for consideration of protective action for infants and adults. These calculations have been carried out for typical meteorological conditions.

b) Approximately the area of 7.5° wedge extending from the plant. The length of the wedge is given below for the various cases shown in the table.

Maximum Length of Wedge	Wedge Area
1600 mi	175,000 mi^2
880 mi	50,000
620 "	25,000
230	3,400
200	2,500
50	170
45	130
9	5

c) Much of this area could lie over water.

12. ARE THERE ANY WAYS TO MITIGATE THE HEALTH CONSEQUENCES BEYOND THE 10 MILE ZONE?

Obviously, if the Indian Point reactors were to be shut down, the consequences mentioned previously could not occur. However if the plants are allowed to continue operation, attempts should be made to reduce the number of injuries and deaths from short-term exposure by expanding the emergency planning zone beyond ten miles. The ten mile radius, it should be noted, is a guideline not a rigid distance. [18]

13. IS EXPANDING THE EVACUATION ZONE AN EFFECTIVE MITIGATING STRATEGY?

In the case of a PWR2 release, residents beyond the ten-mile EPZ would need to be evacuated, at least on an ad hoc basis, to avoid early death doses and to reduce the number of latent cancer deaths and the other health effects. The sooner the evacuation takes place, the fewer the effects. While current emergency plans imply that ad hoc evacuation is adequate, prepared plans for an evacuation beyond ten miles would reduce the necessary evacuation time and thus reduce the consequences of the release. We have quantified one aspect--latent cancer deaths--of this reduction in consequences.

Table 7a and 7b suggest that many lives could be saved by evacuation plans that would reduce the average evacuation time in the 10-20 mile region by 10 hours. If the wind were blowing south, through Westchester County, between 33-330 lives would be saved from latent cancer death; if it were raining or snowing, 82-820 lives would be saved. If the wind were blowing north, between 13-130 lives would be saved from latent cancer death; if it were raining or snowing, 31-310 lives would be saved. The range in these estimates is due to the scientific uncertainty in relating doses to health effects.

Evacuation plans for 10-20 miles would also save some residents from receiving "early death" doses under some of the scenarios we have considered, for example, during a low plume rise case as shown in Table 10.

We assume in the tables that the average evacuation time in the 10-20 mile region can be reduced from an (arbitrarily) chosen 20 hours for ad hoc evacuation to 10 hours for a planned evacuation. Ad hoc evacuation efforts could take on average 20 hours or longer because efforts to evacuate the population would be delayed. Most official efforts to protect populations would be concentrated initially on evacuating the population within ten miles, verifying that the evacuation has occurred, settling the population in care centers, caring for emergency personnel and evacuees that have received radiation doses, clearing traffic accidents, etc. This work will absorb most of the energy

TABLE 7A

ESTIMATION OF LIVES SAVED BY INCREASING PLANNED EVACUATION DISTANCE AT INDIAN POINT WHEN WIND IS BLOWING SOUTH FOLLOWING A PWR2 TYPE RELEASE[a)]

(Assuming average evacuation time beyond ten miles is shortened by ten hours)

	Assumed Evacuation Time (average hours)[b)]	Sector Boundaries (Miles)[c)]	Population in Sector[d)]	Average Conditions: Dose at Outer Edge[e)]	Average Conditions: Deaths[g)]	Precipitation: Dose at Outer Edge[f)]	Precipitation: Deaths[g)]
Planned Evacuation:	10	10-15	13,400	48 (Rems)	32-320	66(Rems)	44-440
		15-20	18,108	29.5	27-270	38	34-340
					59-590		78-780
Ad Hoc Evacuation:	20	10-15	13,400	73.5	49-490	132	88-880
		15-20	18,108	47	43-430	80	72-720
					92-920		160-1600
Lives saved by reducing average evacuation time by ten hours:					33-330		82-820

a) Delayed cancer deaths not including thyroid cancer deaths.

b) Average evacuation time for population.

c) Sector is the segment of a 7.5 degree wedge with the boundaries indicated.

d) Derived from 1980 population data from the New York State Radiological Emergency Preparedness Plans by dividing the figures there by one-third to represent a 7.5 degree wedge.

e) Mid-range parameters used are .01 deposition velocity; D stability class; 4 m/sec wind speed; Briggs dispersion parameters with a change over to Briggs urban dispersion parameters at 20 miles; Briggs theoretical plume rise case; .3 ground shielding factor.

f) Precipitation case parameters are the same as above, but use a washout coefficient of .0001.

g) Dose/effects coefficient used was 50-500 latent cancer deaths per million person rem.

TABLE 7B

ESTIMATION OF LIVES SAVED BY INCREASING PLANNED EVACUATION DISTANCE

AT INDIAN POINT WHEN WIND IS BLOWING NORTH FOLLOWING A PWR2 TYPE RELEASE a)

(Assuming average evacuation time beyond ten miles is shortened by ten hours)

				Average Conditions		Precipitation	
	Assumed Evacuation Time (average hours) b)	Sector Boundaries (Miles) c)	Population in Sector d)	Dose at Outer Edge e)	Deaths g)	Dose at Outer Edge f)	Deaths g)
Planned Evacuation:	10	10-15	1,300	48 (Rems)	3- 31	66 (Rems)	4- 43
		15-20	12,247	29.5	18-180 / 21-210	38	23-230 / 27-270
Ad Hoc Evacuation:	20	10-15	1,300	73.5(Rems)	5- 48	132	9- 86
		15-20	12,247	47	29-290 / 34-340	80	49-490 / 58-580
Lives saved by reducing average evacuation time by ten hours:					13-130		31-310

a) Delayed cancer deaths not including thyroid cancer deaths.

b) Average evacuation time for population.

c) Sector is the segment of a 7.5 degree wedge with the boundaries indicated.

d) Derived from 1980 population data from the New York State Radiological Emergency Preparedness Plans by dividing the figures there (for 22.5 degree wedges) by one-third to represent a 7.5 degree wedge.

e) Mid-range parameter used are .01 meters/sec. deposition velocity; D (Pasquill) stability class; 4m/sec. wind speed; Briggs dispersion parameters with a change over to Briggs urban dispersion parameters at 20 miles; Briggs theoretical plume rise; .3 ground shielding factor.

f) Precipitation case parameters are the same as above, but use a washout coefficient of .0001 $sec.^{-1}$

g) Dose/effects coefficient used was 50-500 latent cancer deaths per million person rem.

of available emergency personnel. As some EPRA's are estimated to have evacuation times up to 15 hours (adverse conditions), it seems unlikely to us that the evacuation of residents beyond 10 miles would occur sooner than an average of 20 hours after the release.*

Although expanding evacuation plans to the 10-20 mile zone at this site would reduce delayed cancer fatalities, determination of the optimal starting time for such an evacuation requires careful study. The highest priority for evacuation must be given to the population within ten miles--those who would be exposed to a serious risk of early death following a catastrophic accident. Unfortunately, immediate evacuation of persons beyond 10 miles might block the escape of those living closer. What is needed to resolve this dilemma is a study of the effects of immediate evacuation (either "spontaneous" or planned) on the evacuation time estimates of persons within 10 miles. This study could suggest the optimal time for beginning the planned evacuation beyond 10 miles.

It should be noted that the very existence of plans for an immediate or delayed evacuation beyond ten miles might serve to reduce the amount of "spontaneous" evacuation in that zone that would otherwise cause unnecessary delays for persons evacuating from within ten miles.

In any case, delayed evacuation (within a few days) would be necessary even at distances as great as 35 miles (e.g., Times Square towards the south) as shown in Figures Va and Vb in order to prevent large accumulation of ground doses from contaminated ground. It would seem prudent to make such plans ahead of time.

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*Some persons beyond 10 miles may evacuate "spontaneously." On the other hand, some persons from within 10 miles may have evacuated to emergency centers or homes in contaminated areas beyond 10 miles. To keep our calculations from becoming overly complex and dependent on debatable assumptions, we have ignored these effects.

CUMULATIVE DOSE AT 35 MILES AS A FUNCTION OF TIME AFTER PWR2 RELEASE

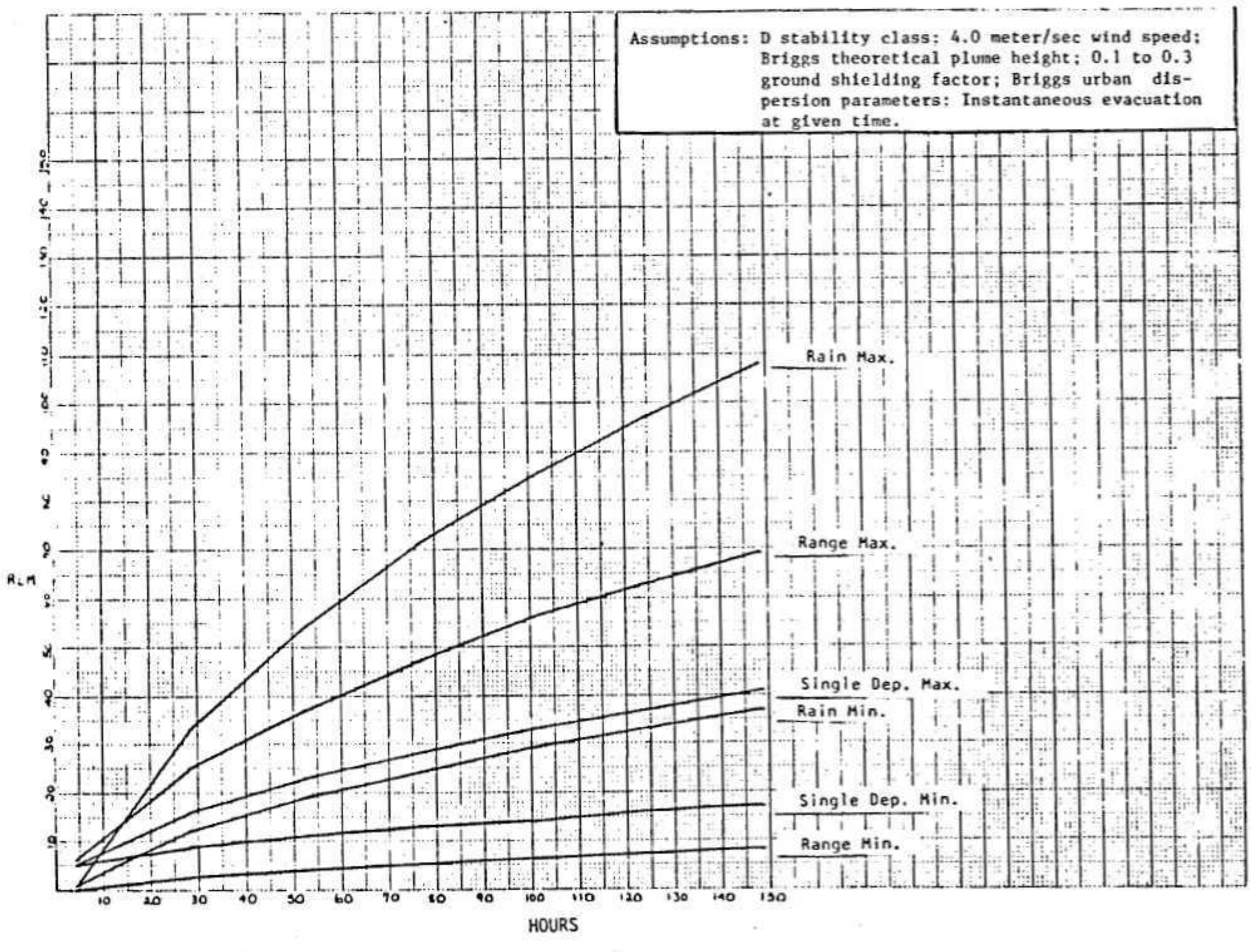

FIGURE Va. CUMULATIVE DOSE AT 35 MILES AS A FUNCTION OF TIME AFTER PWR2 RELEASE

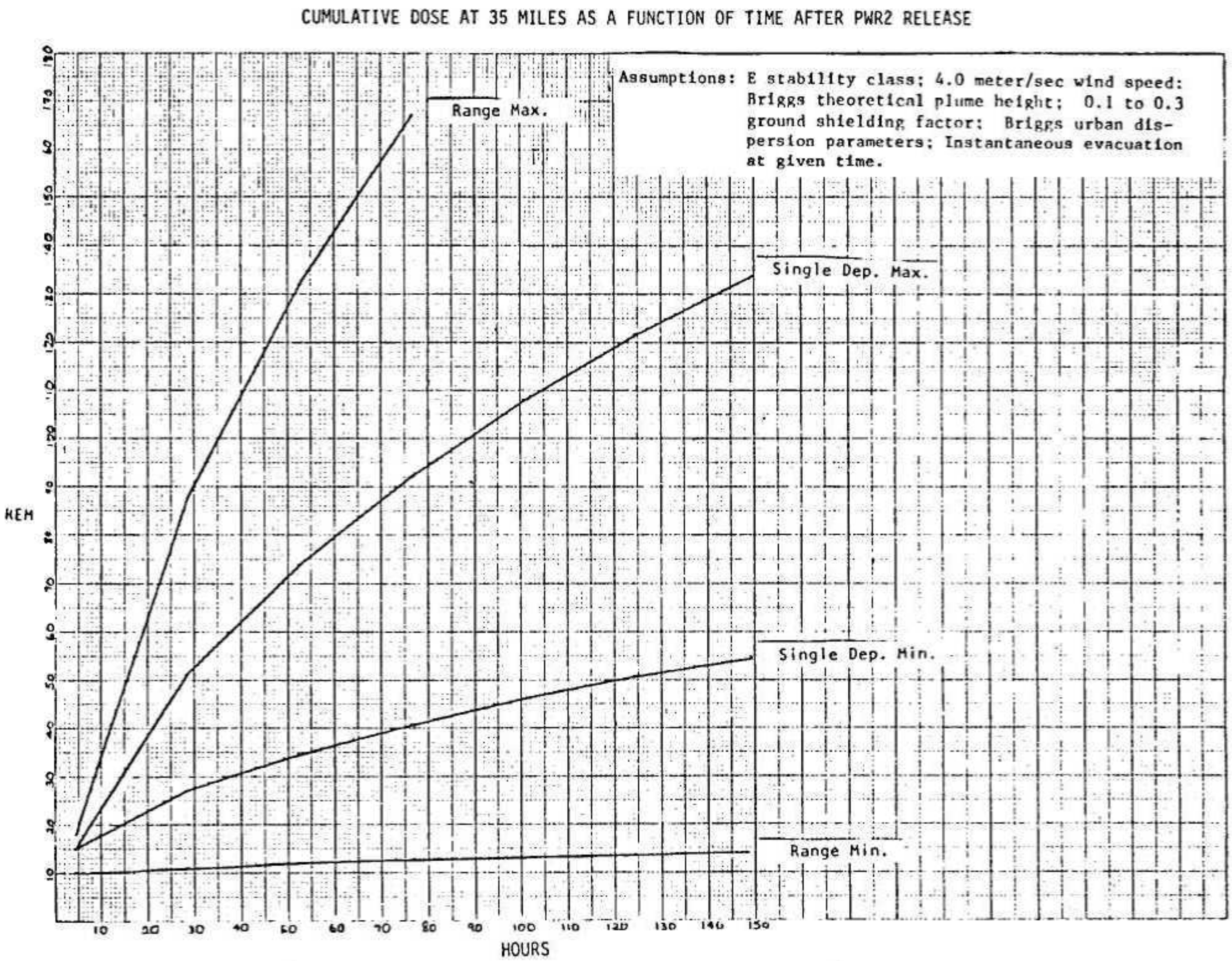

FIGURE Vb. CUMULATIVE DOSE AT 35 MILES AS A FUNCTION OF TIME AFTER PWR2 RELEASE

14. WHAT OTHER MEASURES BESIDES EVACUATION WOULD REDUCE THE HEALTH CONSEQUENCES OF A PWR2 RELEASE FOR RESIDENTS BEYOND 10 MILES?

In view of the distances at which the long-term health consequences of major releases would occur, it is not sufficient to plan only for people living within ten miles of the reactor if the goal is to significantly reduce long-term accident consequences. Dose reduction measures such as thyroid-blocking medication might be needed beyond a hundred miles. Long-term population removal at such distances might also be needed in the years following the accident.

THYROID-BLOCKING MEDICINE

Potassium iodide pills taken before inhalation or ingestion of radioactive iodine would reduce thyroid doses by 10 to 100 times due to the blocking of radioactive iodide uptake by the already saturated thyroid.[19] Although not the most serious health consequence of radiation, thyroid damage could effect more people in an accident (in the absence of thyroid-blocking) than any other radiation effect. Hence, development of a potassium iodide distribution strategy is advisable.

Potassium iodide is cheap and quite safe at the recommended doses according to the Food and Drug Administration (it is a form of iodine added to iodized salt), and could significantly reduce the number of people affected by an accident.

The fact that significant thyroid doses can be received out to hundreds of miles for a catastrophic release of, say, 50 percent of the radioiodine in the core is not a subject of debate (see for example, Ref. 20). However, it is not immediately obvious to what distance protective actions would provide a net health benefit. It seems reasonable to propose that protective actions should be taken out to distances where the risks of such actions become comparable to the health risks from projected radiation doses. Making this principle quantitative is difficult but it appears that thyroid-blocking medication would certainly be justified out to a distance of a hundred miles for a PWR 2 release, and possibly much farther. This distance extends considerably beyond the 10 mile EPZ and beyond the 20 mile distance at which evacuation plans might be feasible.

Our calculation of 100 miles as the distance within which potassium iodide would provide a net benefit has been made using assumptions based on the position of Rosalyn Yalow, the principal critic of the use of potassium iodide in a radiation emergency.* These are more conservative than those of the Food and Drug Administration.

* Dr. Yalow, a physicist with a Nobel prize in medicine, does not believe protective action should be taken to prevent a thyroid dose from iodine 131 below a projected dose of 100 rem. (Private Communication, 1981.) Although 100 rem is ten times the level considered a reasonable threshold by the FDA, we use 100 rem as a threshold in this paper to avoid irrelevant controversy. For a PWR2 release, adult thyroid doses remain above 100 rem out to about 100 miles from the point of release for typical weather conditions. Child thyroid doses remain above 100 rem out to several hundred miles.

To compare the benefit of blocking a 100 rem dose with the risk of administering potassium iodide, it is necessary to estimate the number of thyroid nodules that would result from 100 rem thyroid dose. The most conservative nodule risk coefficient in Table 2 is 200 nodules per million person rem. Taking one-tenth of this number, the risk of nodularity to an individual exposed to 100 rem would be 0.2%, well above the risk of mild side effects from taking potassium iodide, even as estimated by Dr. Yalow. Dr. Yalow, in disagreement with the Food and Drug Administration, argues that the risk of side effects is 0.006% per potassium iodide dose. (Testimony at Congressional hearing Ref. 23)

In New York State, a decision to distribute KI around the Indian Point site, either inside or outside the ten mile EPZ, would most likely need to be confirmed or initiated by the Department of Health, or by local health departments. A ruling by the Atomic Safety and Licensing Board (ASLB) would not be sufficient. However, the ASLB could rule that the owner of the Indian Point Reactors should pay for KI distribution, should state or local health departments recommend distribution at some future time.

<u>OTHER MITIGATING STRATEGIES</u>

Two other strategies offer some important possibilities for protecting people living more than ten miles beyond the reactor and for those within ten miles for whom evacuation is not attempted or is not successful:

- sheltering in buildings, and
- breathing through makeshift cloth filters or distributed respirators.

Complete logistical details for these strategies need to be carefully worked out. None should be rejected prematurely merely because satisfactory implementation may appear, at first sight, to have some difficulties. A combination of these two strategies with thyroid blocking would be most effective and most likely to prevent disorganized behavior among those not included in evacuation plans. Successful use of these mitigating measures has three prerequisites, however:

- monitoring and forecasting of the position of the radioactive cloud;
- communication of detailed instructions to the public;
- and, in the case of thyroid blocking medicine and respirators, a satisfactory distribution system.

These strategies do not represent absolute protection against reactor accident consequences. They do not mitigate at all against long-term exposures, and even with careful planning they only reduce, rather than eliminate short-term doses. In addition, it is unlikely that the necessary instructions or equipment would reach the entire targeted population. Nevertheless, if the Indian Point reactors are allowed to continue operating, these measures could significantly reduce the risk of illness and cancer in the case of a catastrophic accident.

15. WHAT ARE THE EARLY DEATH IMPLICATIONS WITHIN TEN MILES OF A PWR2 RELEASE GIVEN THE CURRENT EVACUATION PLANS?

If a resident is evacuated before the plume passes by, no radiation dose is accumulated.* If a resident is not evacuated before the plume passes by, then the total dose is the sum of the "cloud" dose, the inhalation dose, the external ground dose accumulated during evacuation, and the "internal" ground dose accumulated as a result of radiation passing through the building walls while the resident is indoors.

Tables have been prepared to indicate, for the weather conditions and time of day shown, and for mid-range model parameters, whether or not all of the residents of 19 selected ERPA'a will be evacuated before their accumulated radiation dose reaches the 200 rem threshold for early death. The evacuation time estimates used for these calculations have been derived from the New York State Radiological Emergency Response Plans. (If evacuation should proceed more slowly than estimated in the official plans, the consequences would of course be worse.)

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* For these calculations, we assume residents are not transported to locations subsequently exposed to radiation.

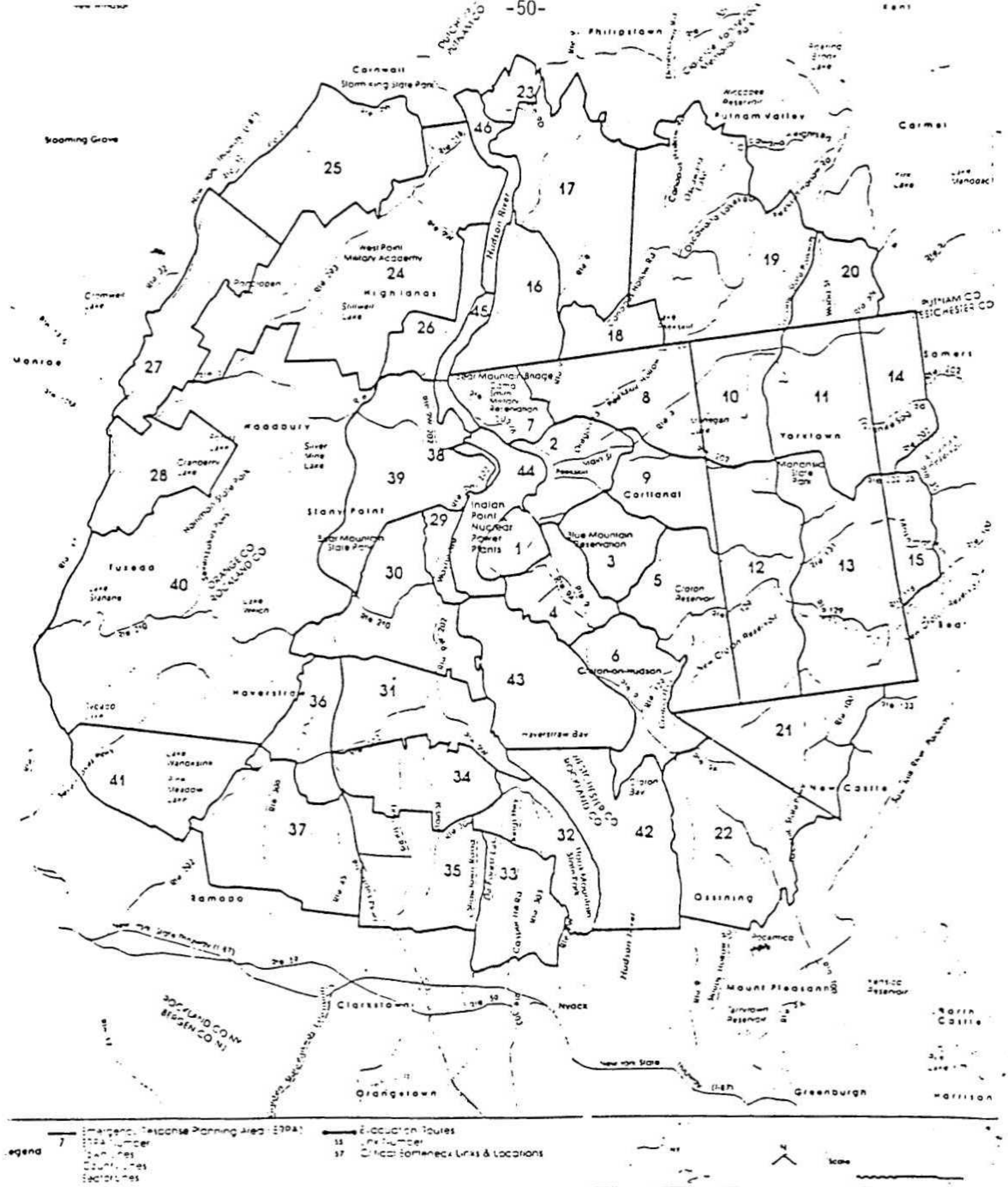

Figure VI

Indian Point
Emergency Response Plan
10-Mile EPZ
ERPAS

Source: New York State Radiological Emergency Preparedness Plans, Figure 6, p. 1P-14.

One sample table, for ERPA2, is included in the text; all 19 are found in Appendix B. It is assumed for each table that the wind is blowing towards the particular ERPA.

Examination of these tables will indicate that, even using official estimates of evacuation times, the present emergency plans are not adequate to protect the population from early death following a PWR2 release. Populations in all 19 ERPAS are vulnerable under the precipitation case. However, even under average weather conditions and for average model parameters, the population of several ERPAs are not always protected. Furthermore, the enormous uncertainty in dose prediction should be recalled before concluding that protection is available under any weather conditions. As mentioned previously, the models used to compute radiation doses within 10 miles suffer in their predictive ability because of uncertainties about how high the plume will rise above the reactor due to its thermal buoyancy. If the actual plume rise during an accident should fall towards the low end of the range of theoretical predictions, 200-rem doses would accumulate more quickly.

Besides the possibility of plume rise lower than the mid-range theoretical prediction, there is the possibility of an "effectively" lower plume height.[21] Because the Indian Point plants are on relatively low terrain, the plume rise will be effectively lower for areas with elevations higher than the plants.*

Although not shown in the tables, calculations made using a low plume rise (or, for that matter, a high deposition velocity) give results approximately equivalent to the precipitation case. With a low plume rise, a large fraction of ERPAs would receive lethal doses even under typical weather conditions.

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* For areas with elevations below the initial plume rise height, the plume height will be effectively lowered by approximately one half the elevation of the area above the plant. For areas with elevations above the initial plume rise height, the plume rise at that area will be approximately one half the initial plume rise height.[21]

Although not considered in our program, a sudden change in wind speed or change in weather condition can also cause extremely high doses. In total, we estimate that extreme doses equivalent to the D-4m/sec. case* would occur with a probability in excess of 30 percent, (See Table 9), and doses approximately equivalent to the precipitation case would occur with a probability in excess of 20%.

Were it possible to provide supportive treatment for all persons exposed to 200 rem or greater doses and should supportive treatment turn out to be as effective as estimated in the Reactor Safety Study, early deaths would not occur for doses of 200 rem.

Although we believe that hospitals will be overwhelmed by persons exposed to low doses, effectively preventing administration of supportive treatment to those who most need it, we have made calculations for a 350 rem threshold similar to those made for a 200 rem threshold. These are discussed later in the text.

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* D (Pasquill) stability class with a 4 meters/second wind speed.

TABLE 8

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a]

WESTCHESTER COUNTY ERPA 2[b]

Typical Weather

Time of Day	Weather Conditions[e]	High Estimated Evacuation Time[c]	Protection of General Population[d]	Low Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	10:15	No	6:40	Yes
Early Evening	D, 4m/sec	7:15	Yes	4:20	Yes
Early Evening	E, 4m/sec	7:15	Yes	4:20	Yes
Late Evening	E, 4m/sec	5:40	Yes	3:25	Yes

Precipitation

Time of Day	Conditions	High Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	12:40	No
Early Evening	D, 4m/sec	9:00	No
Late Evening	D, 4m/sec	7:00	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.3 miles. At this distance, the dose reaches 200 rem in 7.8, >24 and 1.7 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

16. WHAT SPECIAL FACILITIES WITHIN TEN MILES ARE AT RISK WITH RESPECT TO EARLY DEATH?

Any study of the adequacy of emergency planning measures must include consideration of special facilities such as schools and hospitals. These institutions often have longer preparation and evacuation times than the general population due to the large concentration of evacuees and their special transport requirements. They are thus at greater risk of being exposed to early death doses in the case of a catastrophic release.

There are several major facilities within ten miles that are of concern to emergency planners: Peekskill Community Hospital (3.5 miles from the plant), Helen Hayes Rehabilitation Center (4.1 miles), Letchworth Village (5.0 miles), Ossining Correction Facility (9.1 miles), and the FDR Veterans Administration Hospital (2.5 miles). With a possible 1600 to 2200 persons evacuating, the FDR Veterans Administration Hospital is of special concern. If the wind were blowing past the hospital, doses could reach the early death threshold of 200 rem in a few hours.

17. ARE THE WEATHER CONDITIONS YOU USE ABNORMAL?

According to the Draft Environmental Statement (See Table 9, Footnote b) stability class occurs about 33 percent of the time at Indian Point. Weather conditions with this class and a wind speed range of 3-5.7m/sec. (which includes and has consequences similar to our 4 meters/sec. case) occur about nine percent of the time.

The E stability class occurs about 40 percent of the time, while a 3-5.7 meters/sec. wind speed range in this class occurs 12 percent of the time.

More important than the frequency of the specific cases we have used is the frequency with which the early death consequences will be as bad as or worse than the D-4 meters/sec case. In Table 9 we have estimated this frequency by looking at 84 percent of all weather conditions and comparing the early death consequences within five miles to that of the D-4 m/sec case. We have assumed for these calculations that a low plume rise and a high plume rise each occur 25 percent of the time for any given set of weather conditions. This calculation suggests that the early death consequences within five miles will be as bad as or worse (sometimes much worse) than the D-4 m/sec case 30 percent of the time. This calculation does not include other technical factors that could make the consequences worse, particularly variations in deposition velocity. It does, for the most part, include the probability of serious consequences within five miles from a precipitation case, as discussed later.

It should also be noted that there are conditions other than the D-4 m/sec case that could lead to early deaths, especially with delays in evacuation.

TABLE 9

COMPARISON OF OTHER WEATHER AND PLUME RISE SCENARIOS

WITH THE D-4m/SEC (.01 DEP. VELOCITY, .5 GROUND SHIELDING FACTOR) CASE FOR EARLY DEATH CONSEQUENCES[a)]

Weather Scenario	Frequency[b)] of Weather	Plume Rise	Assumed Frequency[c)] of Plume Rise	Seriousness of Early Death Consequences	Frequency of Scenarios[c] Worse or same as D-4m/s
	.145	Low	.25	Worse	.036
D, <3m/sec.	.145	Th.	.5	Better	-
	.145	High	.25	Better	-
	.094	Low	.25	Worse	.024
D, 3-5.7m/sec.	.094	Th.	.50	Same	.047
	.094	High	.25	Better	-
	.091	Low	.25	Worse	.023
D,>5.7m/sec.	.091	Th.	.50	Worse	.046
	.091	High	.25	Better	-
	.212	Low	.25	Worse	.053
E, < 3m/sec.	.212	Th.	.5	Better	-
	.212	High	.25	Better	-
	.119	Low	.25	Worse	.030
E, 3-5.7m/sec.	.119	Th.	.50	Better	-
	.119	High	.25	Better	-
	.071	Low	.25	Worse	.018
E, > 5.7m/sec.	.071	Th.	.50	Better	-
	.071	High	.25	Better	-

	.105	Low	.25	Worse	.026
F, < 3m/sec.	.105	Th.	.50	Better	-
	.105	High	.25	Better	-
	.84				.30

a) A comparison of these weather scenarios for effects other than early deaths would be different.

b) Frequency data from Draft Environmental Statement (Oct. 1973) Consolidated Edison Company of New York, Docket No. 50-286 for a 33 ft. release height. Frequency data may be different for a higher measurement height.

c) Assumed distribution for the probability of the plume rise height.

d) This does not include consideration of scenarios where the deposition velocity is higher than .01 meters/sec. or other uncertainties that increase the frequency of worse-than-D,4m/sec. cases.

18. HOW MUCH WARNING TIME* WOULD BE NEEDED TO AVOID ALL EARLY DEATHS.

The results presented in the "early death tables" in Appendix II can be used to calculate how much warning time would be needed to avoid all early deaths. This calculation is done by comparing the time estimated for evacuation with the time by which the accumulated dose would reach 200 rem. The difference between the two represents an estimate of the amount of warning time necessary to avoid all early deaths.

This calculation shows that to avoid all early deaths under average conditions (D stability class, 4m/sec wind speed), the longest warning time, for ERPA 29, would have to be greater than 4 hours. For four other ERPA's the warning time would have to be greater than 2.5 hours. In the case of precipitation or other adverse conditions (such as low release height), the longest warning time, for ERPA's 29 and 39, would have to be greater than about 13 hours in order to avoid all early deaths. Other ERPA's examined in the appendix often required between 7 and 13 hours warning under adverse conditions.

These calculations ignore special population evacuation times which are generally longer than those for the general population.

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*The amount of time between the public notification of evacuation and the release.

19. HOW MANY PEOPLE WOULD REQUIRE HOSPITALIZATION FOR IMMEDIATE TREATMENT OF LIFE-THREATENING RADIATION DOSES?

It has been suggested that "supportive" treatment would reduce the number of early deaths from a PWR2 or other catastrophic release. Little consideration has been given, however, to how the persons requiring supportive treatment would be identified before transporting them to hospitals with the necessary facilities. The difference in symptoms between a person who has received a 200 rem dose and one who has received a 100 rem dose, for example, may not be observable. Furthermore, symptoms of stress such as nausea can be confused with radiation sickness. As a result, supportive treatment would probably be provided to more than just those individuals who received a 200 rem dose or above.

For illustrative purposes, we have estimated the number of persons that would receive 100 rem doses or higher following a PWR2 release. If the wind were blowing towards the north under average (D stability class, 4m/sec wind speed) weather conditions, between 3 and 148 persons within ten miles would receive 100 rem doses or higher. If the wind were blowing south through Westchester County, between 70 and 509 persons would receive 100 rem doses or higher within ten miles. In the case of a wind towards Peekskill, the figure would range from 418 to 2434 persons. The lower number in these ranges assumes an evacuation of 7 hours for the last residents; the higher number assumes an evacuation time of 11 hours for the last residents.*

In the case of a low plume rise or precipitation conditions, the number of persons receiving at least 100 rem doses would be much higher. In addition, the number of persons beyond ten miles receiving 100 rem doses should be added to these ranges. We have not calculated this number, which could be significant, because the evacuation time estimates for an ad hoc evacuation beyond ten miles are not available.

20. WHAT WOULD YOUR RESULTS BE LIKE FOR A 350 REM THRESHOLD?

Even with supportive treatment as effective as estimated in the Reactor Safety Study Study, some persons would die within sixty days (early deaths) at dose levels of 350 rem and above. Using the metholology employed to prepare the early death tables for average conditions (Appendix II), we have found ERPA's in which at least some residents would receive 350 rem doses under conditions of precipitation or low plume rise. Under D stability class conditions with a 4 meter/sec wind speed and low plume rise, between 1 and 9 ERPA's would not be protected from 350 rem doses. Under E stability class, conditions with a 4 meter/sec wind speed and low plume rise, between 5 and 10 ERPA's would not be protected from 350 rem doses. Under rain conditions, between 8 and 17 ERPA's would not be protected from 350 rem doses. The ranges in these cases result from different assumptions about the time of day in which the release and evacuation occurs.

21. WHAT ARE THE OTHER HEALTH CONSEQUENCES, BESIDES EARLY DEATHS, THAT THREATEN THE POPULATION WITHIN TEN MILES?

We have found that under virtually every weather condition, exposed persons will accumulate some radiation dose--especially to the thyroid. Residents exposed to doses below the early death threshold will still face the possibility of early radiation illness, marked by vomiting, as well as a significant risk of developing fatal cancer years after the accident.

22. WHAT STRATEGIES ARE AVAILABLE TO REDUCE THE HEALTH CONSEQUENCES TO THE POPULATION WITHIN TEN MILES?

Given a serious release, or impending release, the top priority is to get the population out of the plume path as quickly as possible, if possible, before it arrives. Strategies to achieve this goal include technical fixes that increase the time before a release (core catchers) to give the population more time to evacuate; improved communications to convey an evacuation notice; and pre-prepared evacuation, hospitalization, and other emergency plans to decrease the necessary evacuation time. Most of these strategies are being considered or attempted with varying degrees of success.

What has been given less attention are strategies involving consideration of the plume path itself. As currently prepared, the plans seem to assume that once the evacuees reach their school reception and congregate care centers, between 15 and 20 miles away, that they are safe. If any of these centers are within the plume path, a very likely occurrence given the distribution of the centers, the evacuees there will continue to be exposed to radiation, as will emergency personnel staffing the center. A look at Table10 shows that doses at 15 and 20 miles can be significant, reaching early death levels even for emergency personnel and others not previously exposed. It would be tragic if centers designed to assist evacuees actually increased the health consequences by detaining evacuees, school children, etc., in the plume path at a relatively close distance to the plant.

Several approaches exist for minimizing this danger. A "secondary" evacuation from the initial center is one possibility, but it may be too difficult to achieve both in the time frame required and from a logistics point of view. Also parents and others arriving at the center and finding friends and relatives re-evacuated might act less calmly than otherwise. A local traffic tie-up could occur while evacuees attempted to leave the initial center, and the chance of local traffic accidents would increase. Delays in evacuation would inevitably result.

A second important mitigating strategy would be to increase the distance at which these centers are located.

Third, efforts should be made to choose centers that are not down wind from prevailing wind directions. Many of the sites are currently directly south of the plant. Wind data suggest that sites west of the plant might be preferrable.

Another strategy would be to build wind direction into the emergency plans by having alternate evacuation sites at 180 degrees from each other. Evacuees would be notified to follow either plan "A" or plan "B" at the time of the accident.

All of the above strategies merit consideration if the Indian Point reactors are allowed to continue operating.

Finally, it is worth mentioning that a strategy of "preventive evacuation" could serve to gain considerable time. Under such a strategy, evacuation would be ordered even before all control measures had been tried. In this way many hours could be gained. Of course, in most cases, the evacuation would prove unnecessary, just as evacuations from potential toxic chemical releases following train or truck accidents often prove unnecessary. Had a policy of preventive evacuation been in force during the Brown's Ferry fire or the Three Mile Island accident, the resulting evacuation would have had little impact. However, should the day arise when a large release occurs, a policy of preventive evacuation could save many lives.

23. IS SHELTERING EVER A PREFERRED STRATEGY TO EVACUATION?

Some incomplete calculations, in which dose accumulations have been truncated at an arbitrary time, have been used by those who do not understand the calculations to suggest that sheltering for 24 hours is a better strategy than evacuation in a large release. What is missing from such calculations is consideration of the necessity for subsequent evacuations to prevent accumulation of radiation passing through the building walls. Thus, the strategy that some have called "sheltering" is really, in the case of a large release, a strategy of delayed evacuation. . While dose calculations for delayed evacuation have not been published to our knowledge, it is obvious that delayed evacuation only makes sense, if it makes sense at all, if evacuation after 24 hours can be expected to take place much faster than would be the case for an immediate evacuation.

Of course, at distances from the plant where rapid evacuation would not be feasible or would interfere with the escape of those at high risk, sheltering is the preferred strategy until delayed evacuation is begun.

Finally, it should be noted that an "ideal" evacuation for a large release at Indian Point would, because of traffic congestion problems, combine sheltering with evacuation. People could shelter themselves until told their escape route was clear. This strategy does not seem logistically feasible, but it might be worth further study.

24. SHOULD POTASSIUM IODIDE BE DISTRIBUTED WITHIN THE TEN MILE EPZ?

Yes. We have found many ERPAs for which evacuation might be rapid enough to prevent early death following a PWR2 release, yet not rapid enough to prevent inhalation of radioiodine during plume passage. In these situations potassium iodide would be extremely helpful. Without this protective medicine, exposed residents within the ten mile EPZ would have their thyroids destroyed through ablation.

In Sweden, potasium iodide has been distributed by mail to the ten percent of the population that lives within 6 miles of the nuclear plant.[22] The state of Tennessee has distributed KI (paid for by TVA) to residents within 5 miles of the Sequoyah nuclear plant. The Health Commissioner of Tennessee justified his decision in the following words:[23]

> "In 1979 I was asked to serve on a staff panel working with the President's Commission on Three Mile Island. We listened to a great deal of testimony and engaged in discussions with many knowledgeable people in the fields of radiation safety and nuclear medicine. The use of potassium iodide as a thyroid blocking agent in nuclear emergencies was a major topic of discussion. As I heard the formal presentations and talked informally with many people, it became clear to me that the administration of KI has the potential of being a valuable preventive tool in the type of nuclear emergency in which radioactive iodine might be released. As a public health officer, my primary interest is in the preventive aspects of health care, and the use of KI appeared to be one of few preventive technologies available for dealing with the health effects of exposure to one type of radiation. In fact I live within a few miles of a plant now under construction. I have frequently been asked if I would want KI in my medicine cabinet, available to my family. The answer is yes. I have confidence in the safety of the plant. I don't intend to move away, but I will have KI available for the additional bit of safety it will provide. How could I do less for the people of our state whose health and safety are my responsibility?"

As stated previously, the Atomic Safety and Licensing Board has an important role to play in connection with potassium iodide. By requiring Indian Point plant owners to pay for KI distribution at any time in the future that health authorities recommended its use, the board would be ensuring that the decision to distribute KI at Indian Point would be based purely on public health considerations.

25. ASSUMING YOUR DESCRIPTION OF ACCIDENT CONSEQUENCES IS CORRECT, HOW LIKELY IS IT THAT A PWR2 TYPE RELEASE WILL OCCUR IN THE FIRST PLACE?

The nuclear industry dismisses this grim scenario by stating that the likelihood of such a catastrophic accident is almost zero, or that its risk is within the risks accepted by the public every day. The industry assumes that the probability of such accident can be determined beforehand by theoretical calculations. Therefore the debate hinges on the probability of hypothetical events which have never occurred in the past--events for which there is no historical record to estimate risk and settle the dispute.

Our attitude on probabilistic risk assessment in this case revolves on two points. First, we believe that no technological claims should be accepted uncritically, but especially not those of avid believers in a technology. Neither the nuclear industry nor the NRC (or its predecessor)have been noted for their impartiality. Too often these actors have treated the possibility of catastrophic accidents as a public relations problem. Studies have been shaped to reassure the public not to find and make reactor improvements.

Secondly, we believe that the "real" probability of a catastrophic accident is not known with enough certainty to be used in public safety decisions. The possible systems failures, possible defects in design and construction, possible operator errors, and the possible activities of madmen and terrorists are not known well enough to allow reliable probability estimates.

The only probability estimates before the Board are estimates based on probabilistic risk analysis methodology. Yet the official NRC review of this methodology finds it highly uncertain and recommends against it for the determination of <u>absolute</u> probabilities.

> "In general, avoid use of the probabilistic risk analysis methodology for the determination of absolute risk probabilities for subsystems unless an adequate data base exists and it is possible to quantify the uncertainties. However, the methodology can also be used for cases in which the data base will only support a bounding analysis, and for other cases in the absence of any better information if the results are properly qualified."[24]

This cautious attitude toward probabilistic risk assessment is supported by a look at the historical record of accident prediction. The design goal for the probability of complete failure of reactor safety systems was less than one in a million per reactor per year of operation. This number was not based on any substantial mathematical calculation, but rather on a convenient number that the industry came up with in the 1950s. This goal was assumed to have been achieved until 1974 when the authors of the Reactor Safety Study actually tried to calculate the probability of a meltdown (excluding sabotage) and came up with one in 20,000 reactor-years.

The occurrence of the Three Mile Island accident so early in the nuclear era suggests that the Reactor Safety Study itself was optimistic. According to the report's mid-range probability estimate, an accident as severe as TMI should not have occurred for several more decades. The accident implies that this probability estimate is a factor of 10 or so too low. Furthermore, it suggests that the Reactor Safety Study probability calculations are probably as optimistic for accidents more serious than TMI.

The Brown's Ferry Fire in 1975 was another crucial accident sequence that the NRC and the Reactor Safety Study failed to anticipate. In a "post-facto" analysis, the Reactor Safety Study group downplayed their neglect of fires by calculating that fires of the Brown's Ferry type would only increase the probability of a meltdown by 25 percent. This was a self-serving result, since a higher number would have invalidated their $3-million study. Other analyses suggest that the risk from a Browns Ferry type fire was much higher.[25]

Incidents that have occured after the 1975 report cast additional doubt on the ability of the Reactor Safety Study to anticipate important accident sequences. On June 1980, at Browns Ferry Unit 3, water seeped into the hydraulic mechanism which drives the control rods. As a result 40 percent of the control rods failed to scram properly into the core. Though this incident did not escalate into a major accident, engineers had believed previously that a "failure to scram" was virtually impossible.[26]

The possibility of massive vessel failure due to embrittlement and the possibility of massive steam generator failure (either resulting from aging or from a steam spike following core melt) both serve to increase concern.

The total probability of a PWR2 release at the Indian Point site is very uncertain, so uncertain that it is misleading to state a central estimate. The fact that new accident sequences are constantly being discovered suggests that additional sequences are yet to be found and that current probability estimates must be incomplete. In addition, the probability of sabotage is so uncertain that no one , to our knowledge, has even attempted its calculation.

There is not sufficient experience with reactors over their life cycle to allow a realistic probability estimate. The true number could be orders of magnitude higher or lower than the limited estimate given in the Reactor Safety Study. (The same holds true for the Indian Point Probabilistic Risk Analysis.) As a result, there is no way to <u>guarantee</u> the public safety at Indian Point. Nor is it even possible to state that there is reasonable assurance the public safety can be protected. If the board allows continued operation at Indian Point, with the current emergency plans, it is making the implicit assumption that the probability of a PWR2 release is too low to consider--an assumption for which there is no sound scientific basis.

26. NOW THAT YOU HAVE COMPLETED THE PRESENTATION OF THE RESULTS OF YOUR CALCULATIONS, PLEASE COMPLETE YOUR TESTIMONY BY ANSWERING SOME QUESTIONS ABOUT THE METHODOLOGIES AND ASSUMPTIONS FOR INSTANCE, HOW WERE YOUR EARLY DEATH TABLES DETERMINED?

Using a modified version of a computer program developed for the New Jersey Department of Environmental Protection, we modelled--for a given distance, set of weather parameters, shielding factor deposition velocity, and plume rise--the dose as a function of time after the release. For illustrative purposes, we have graphed the data for a sample case in Figure VII.

From this graph of the program data, the time at which the dose reaches 200 rem (or any desired value) can be found, as also illustrated in Figure VII. By repeating this procedure for a set of distances, the "time after release to reach 200 rem" can be constructed as a function of distance from the plant. An example of this function can be found in Figure VIII, while a table of these functions can be found in Table 10.

For a given ERPA, the midpoint or "representative distance" is estimated by averaging the distance from the plant to the closest and furthest ERPA boundaries. The time at which an individual at this "representative" distance receives a 200 rem dose is assumed for our purpose to be the average time by which the population at all locations in the ERPA has received a 200 rem dose. Of course, the population in the ERPA further from the plant will receive a lower dose and the population closer to the plant will receive a higher dose. For example ERPA 2 's representative distance is about 2.3 miles from the plant. The average time for the dose in this ERPA to reach 200 rem, under the D-4 meters/sec case, is 7.8 hours.

This time estimate can be compared to an estimated evacuation time for that ERPA. When it is shorter than the estimated evacuation time it can be reasonably assumed that the population is under the risk of early death for that case. In the example above, the estimated (and adjusted) evacuation time for ERPA2 is 10:15-6:40 in the Midday evacuation (school-in-session) case. The population there is thus not protected from early death for a PWR2 accident.

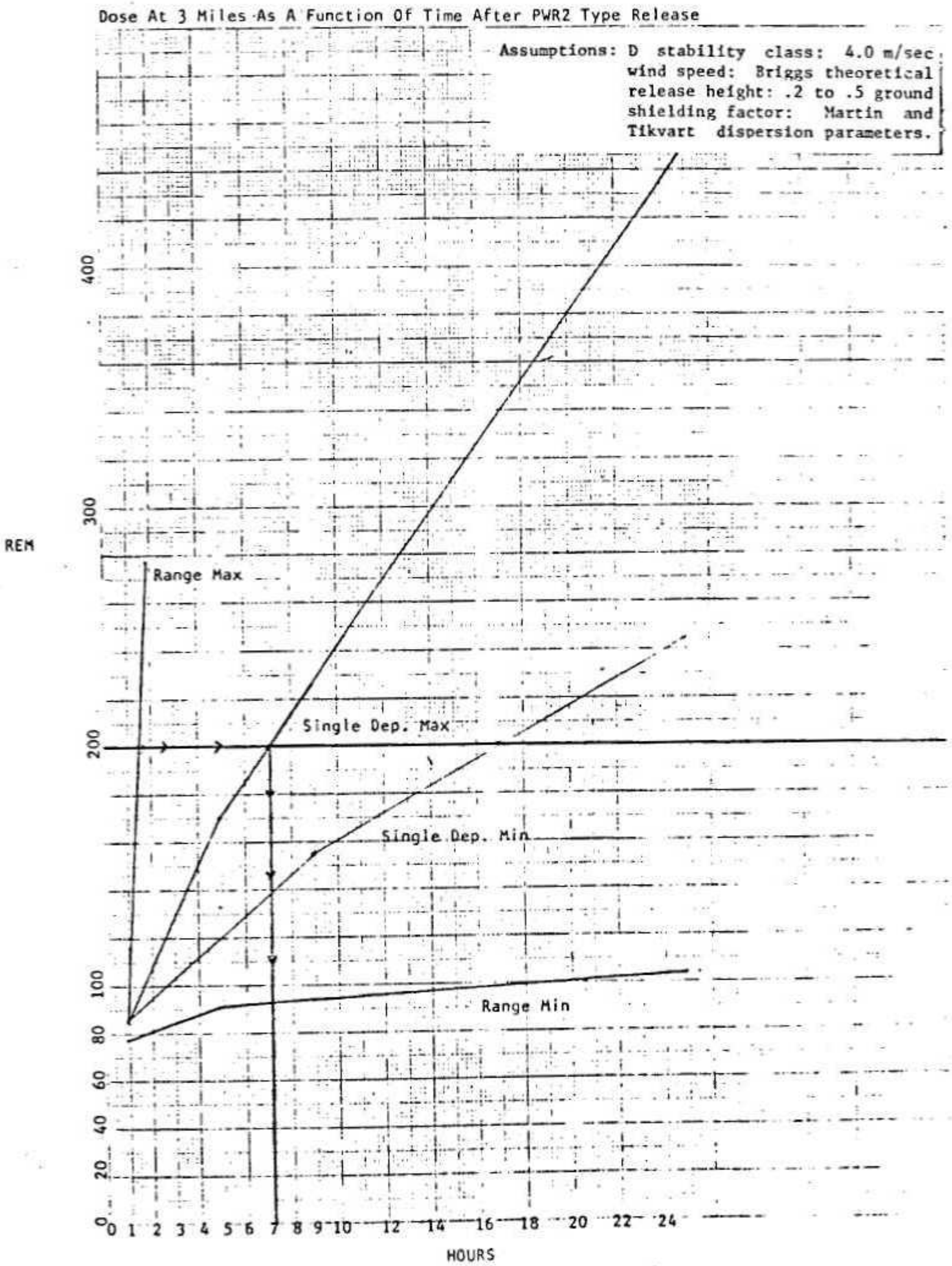

FIGURE VII. DOSE AT 3 MILES AS A FUNCTION OF TIME AFTER PWR2 TYPE RELEASE

FIGURE VIII. TIME (IN HOURS) AFTER PWR2 TYPE RELEASE AT WHICH DOSE REACHES 200 REM

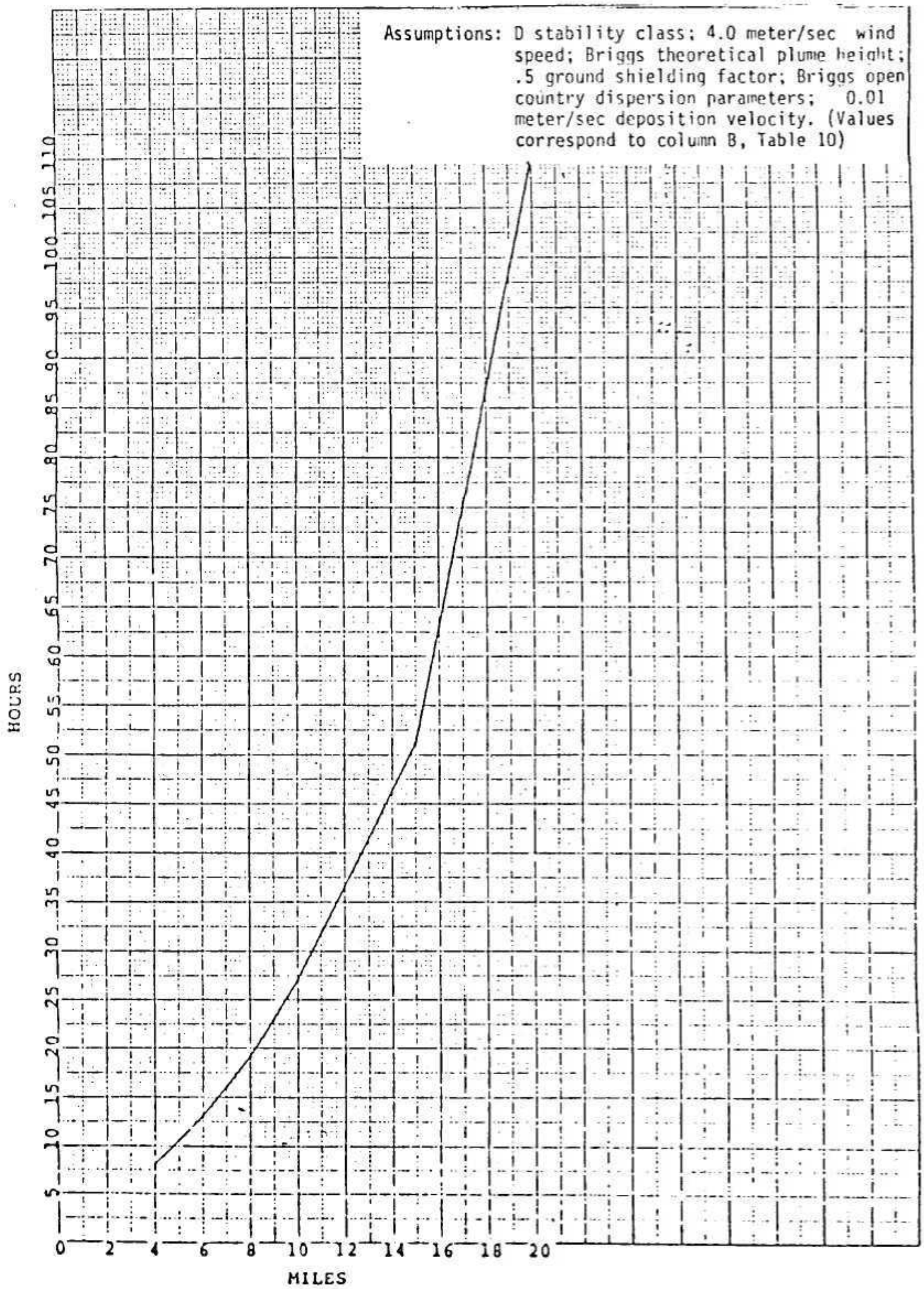

TABLE 10

TIME AFTER PWR2 TYPE RELEASE IN WHICH DOSE REACHES 200 REM (IN HOURS)

For D (Pasquill) stability class and 4.0m/sec. wind speed

Miles	A Range Dep.	B Single Dep.	C Low Rel. Hit.	D Rain
4	1.8- *	8.1-20	3.1-6.3	2.8-4.9
6	2.6-*	13-26	7.1-17	4.2-8.2
8	4.3- *	19-58	14-44	6.7-15
10	6.8- *	27-93	19-73	9.8-22
15	20- *	51- *	48- *	16-55
20	36- *	110- *	110- *	33-120

*---greater than 6 days

A--No rain, Range of deposition velocity (.1 to .001m/sec), Briggs theoretical rel. ht.
B--No rain, Single deposition velocity (.01m/sec), Briggs theoretical release height.
C--No rain, Single deposition velocity (.01m/sec), low release height.
D--Rain, Washout coefficient of .0001 $sec.^{-1}$ Briggs theoretical release height.
Range in columns is due to range in ground shielding factor from .5 to .2.

27. WHY CONSIDER A LOW PLUME RISE CASE?

As mentioned earlier in this testimony (Question 7.), the doses predicted by various consequence models for a given set of weather conditions can show a wide spread (See Figure III). Much of this spread can be accounted for by the modellers different predictions of plume rise, a parameter for which theoretical and experimental knowledge is currently limited. Because of the uncertainty in the plume rise parameter, we have examined both a low plume rise and high plume rise case, though only the results of the low plume rise case are reported because of its especially serious consequences.

Also, as mentioned previously, the topography of the Indian Point terrain may result in effectively lower plumes reaching areas with elevations above the reactors' site.[21]

28. WHAT DOES A "RANGE MAX" CASE REPRESENT?

The "range max" case represents the worst case at each distance as deposition velocity is varied over its allowed range.* (The worst case cannot occur at every distance at once.) In addition, the range max case assumes the building shielding factor to be the least effective in its assumed range, rather than an average value.**

*Between .001 and .1 meters/second for D stability, and between .001 and .003 meters/second for E stability.

**0.3 rather than 0.2 in urban buildings, 0.5 in suburban and rural buildings rather than 0.4.

29. WHY IS THE "RAIN" CASE AN ESPECIALLY BAD SCENARIO?

Any precipitation occurring during the passage of the plume increases the rate at which radioactive material is removed from the plume and deposited on the ground. This removal occurs within the precipitation cloud when the radioactive aerosol acts as condensation nuclei or when the aerosol becomes attached to existing cloud droplets. Removal of material under the cloud occurs as a result of the falling precipitation impacting on and collecting the aerosol. The increased amount of radioactive material on the ground increases the resulting ground dose to the population.*

The risk to the population in the "rain" case is also increased due to increased expected evacuation times. Precipitation would be expected to decrease visibility, decrease safe road speeds, and increase the possibility of accidents. It would also probably stress the evacuees further, lowering their ability to react calmly and safely.

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*The deposition rate is proportional to the amount of material in the plume. Because we have assumed that the precipitation falls continuously from the time of release, more material will be deposited closer to the plant, while less will be deposited to areas farther from the plant, in comparison with a similar no-rain case. The result is that doses will accumulate more quickly closer to the plant and more slowly after some distance from the plant.

If the precipitation started after the release, for example when the plume cloud was at four miles, the dose would follow a no-rain case up to four miles and would follow the rain case (or higher doses) after four miles.

30. DESCRIBE HOW THE EVACUATION TIMES YOU USED WERE DERIVED AND THE ASSUMPTIONS BEHIND THEM.

After an "initiating" event at a nuclear reactor, the nuclear facility operator (referred to as the NFO) notifies appropriate state and local officials of an "unusual event", or depending on the seriousness of the event, of a higher emergency level[27]. The emergency level may eventually reach a general level emergency in which the NFO may recommend, in consultation with other officials and technical support staff, that an evacuation is necessary due to the occurence or high probability of a large release. The appropriate county officials, who may or may not have received prior warning, are then told that an evacuation is recommended, and the emergency warning system will presumably be activated as soon as possible. The time between an initial notification of an occurring or pending large release by the NFO and the time an evacuation is begun by county officials has been estimated by CONSAD(a consulting firm to FEMA) to take 19-78 minutes; they suggest 40 minutes during the day and 50 minutes at night[28]. Their review of historical date shows these kinds of estimates can range from one to many hours for a range of natural disasters and false alerts. In view of this, our testimony assumes 60 minutes for this stage.

A further assumption made in our study is that the NFO declares a general emergency one hour before the actual release. This was the assumption made in WASH-1400.[29] For this study, then the notification of the public (by sirens, etc) and the release begin simultaneously.*

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* The release may occur many hours after the first sign of trouble at the plant. However, an evacuation will be recommended, under current policies, not at the first sign of trouble, but when the NFO decides that there is nothing that can be done to prevent a large release.

There is currently some uncertainty about how long it would take to notify all the population within the EPZ. With an effective siren system covering 100 percent of the population, this would presumably be short. The effectiveness of a siren system during a release may be less than 100 percent coverage, however, due to malfunctioning, "blank areas, etc. Although the current system of sirens, with tone-alerts in special facilities, itself does not cover all the population, we assume conservatively that all of the population will be notified instantaneously after an order from county officals.

We also assume along with Parsons Brinckerhoff that the population will require twenty minutes to prepare, though we believe this is a conservative estimate.[30]

Our calculations use an estimate of the total evacuation time (time to clear the EPZ from the time of release) found by summing the 20 minutes preparation time and the response times, prepared by Parsons Brinckerhoff, in the New York State Radiological Emergency Preparedness Plans.

For investigating the adequacy of the emergency plans to protect the population from early death, we chose to approximate the average dose to an ERPA's population as the dose at the "representative" distance, the average of the distances from the nuclear plant to the ERPA's closest and farthest boundaries. The time of dose accumulation was approximated as the time an evacuee would spend in the ERPA. We estimated this time for the last evacuees by assuming that the last evacuees would leave their ERPA and clear the EPZ in the last twenty minutes. We thus subtracted twenty minutes from the "total evacuation time" (the time to clear the EPZ) estimated above. The result is an estimate of the time from release to when the last evacuees leave the ERPA. We used this estimate in our calculations of the early death tables.

31. WHY DIDN'T YOU ESTIMATE THE NUMBER OF EARLY DEATHS FROM A PWR2 ACCIDENT?

Because radiation (ground)doses depend on both the length of time spent in a contaminated area and the ground concentration of that area, it is particularly difficult to calculate the dose to someone who is moving through areas of varying concentration (e.g. during an evacuation). This calculation requires not only plume dose modelling such as we have done, but also assumptions about the rate and path by which persons evacuate. Estimates of the rate at which persons evacuate were not available to us, making an estimate of early deaths impossible. In addition, we believe that the current uncertainty in path and rate assumptions makes any estimate of early deaths highly uncertain.

* For making an approximation of the number of early deaths, the percentage of persons from an ERPA clearing that ERPA as a function of the evacuation time would be the most useful for setting a lower bound on the number of early deaths. The time at which the dose reached the early death threshold at the ERPAs representative distance could be used to find the approximate percentage of persons remaining in the ERPA. This could be used to find an approximate estimate of early deaths in that ERPA by multiplying by the appropriate coefficients.

The functions mentioned would vary from ERPA to ERPA due to congestion problems, the functioning of the notification system, etc. While estimates of these functions can be prepared, especially in dynamic evacuation models, they were not available from Parsons Brinckerhoff. This made a valid estimate of the number of early deaths essentially impossible.

Parsons Brinckerhoff makes available graphs of the percentage of the whole population clearing the ten mile EPZ as a function of evacuation time, and seems to suggest that this represents a useful guide to the rate at which persons evacuate.[31] We believe this type of graph is inappropriate for even roughly estimating the number of early deaths. First, the data are too aggregated to be useful. As mentioned, the ERPAs close to the plant will experience more congestion and have more difficulty evacuating to beyond ten miles than outer ERPAs. Thus a curve similar to Parsons Brinckerhoff's for a single inner ERPA population would be different, generally with a greater percentage clearing the EPZ during the later hours. The relationship of this curve to the curve desired for our suggested approximation --the distribution of persons from an ERPA clearing that ERPA--is also unclear, though it might be approximated.

Secondly, the methodology used to derive the Parsons Brinckerhoff curves may be inadequate. The curves of the percentage of passenger car equivalents clearing the EPZ as a function of time are converted to those reported using an average estimate of passengers per passenger car equivalent. (PCEs) This would be satisfactory if buses and cars evacuated at the same rate, but as Parsons Brinckerhoff suggests, the buses will evacuate on average later than cars. Each of the last PCEs evacuating could represent 20 persons (a bus with 40 persons rated at 2 PCEs) rather than an average number of persons. Thus a larger percentage of the population will be evacuating in the later hours than is suggested by the Parsons Brinckerhoff curves.

32. HOW ACCURATE ARE THE EMERGENCY EVACUATION ("RESPONSE") TIME ESTIMATES?

We first should note that the evacuation time estimates during an actual PWR2 type release would be biased toward the high estimates provided by Parsons Brinckerhoff. Using the criteria from their own reports: "Upper bound evacuation travel times (longer times) are representative of a situation where . . . a low state of operational readiness results from minimal mobilization of the emergency work force."

We believe minimal mobilization could easly occur; first because Parsons Brinckerhoff assumes an optimistic notification scenario, especially for some PWR2 accident scenarios. Their notification scenario for the "low estimates" seems to be the following:*

1) The public notification system was activated; the public tuned to an Emergency Broadcast System (EBS) station; the public was informed of the situation, instructed to read a predistributed emergency public information pamphlet for possible actions to take and to stay tuned to the EBS station for further specific instructions.

2) One half hour later, the public notification system was activated again. The public, listening to an EBS station, was instructed to evacuate according to the pamphlet instructions. Evacuation zones, routes, and reception centers were reiterated over the EBS network.

The half hour pre-warning in the scenario allows emergency personnel to be stationed for the evacuation. Without this warning time, personnel will obviously not be in a high state of readiness, at their assigned stations, for the evacuation. In some cases, however, there might not be enough time for this warning.

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* From p. 11 of Methodology to Estimate Roadway Travel Times During Evacuation, January 1981.

Secondly, in the case of a PWR2 release, it would appear that traffic personnel in the plume area would rapidly receive doses above the protective action guidelines. The use of personnel to direct traffic at crucial points in the plume area during a substantial portion of the evacuation seems doubtful, though it is assumed in Parsons Brinckerhoff's low evacuation time estimates. In this case, with low mobilization of personnel, evacuation would be delayed, and according to Parsons Brinckerhoff, the upper range of their evacuation times better predicts the likely evacuation time.

In addition, because it is standard procedure in analytical work to have an understanding of the assumptions and uncertainties on which the results are based, we have scrutinized the evacuation time modelling in order to outline some of their possible uncertainties.

The first uncertainty in the estimates is the basic assumption of the transportation model that evacuees will follow the plans. In fact deviation from the plans could easily occur in several ways that would change the estimates:

1) Some residents will, at least initially, refuse to evacuate.

2) Some will follow more familiar routes during an evacuation, either because they have forgotten or misplaced the plans, or because these routes feel "safer."

3) Probably the most important is that during a school-in-session evacuation, many parents will first go to their children's school, causing major traffic tie ups and delays in the area of the school. This natural reaction will delay evacuation of the parents and of many of the children.

A second uncertainty is that Parsons Brinckerhoff has modelled, for the most part, an ideal evacuation infrastructure. The model assumes that the necessary agreements for assistance have been made. For example, it is assumed that agreements exist for the use of privately owned buses and drivers, that these drivers will know their assigned routes, that they will make multiple trips, etc. Many of these agreements do not seem to have been made yet. It also assumes these agreements will be followed by bus drivers and other personnel, who might prefer to evacuate their own families first, or who might be unwilling to receive radiation doses, especially from multiple trips.

Similarly, Parsons Brinckerhoff assumes that an extensive "ideal" notification system is in place and will operate as planned. The system they assume includes:

1) Sirens giving 100 percent coverage of the permanent residents.
2) Sirens covering recreational facilities and transient population centers.
3) Tone-alerts in all special facilities.

If these systems are not in place or don't work (as they didn't in the test of the plans), then actual evacuation times may be longer than the estimates.

A third uncertainty is that because of the use of an optimistic scenario that may not be credible for a PWR2 release, bus travel times may have been underestimated. It was assumed that buses have already arrived at the start of their routes when notification occurs. Because buses are constraining factors, especially during a school-in-session scenario, an additional half-hour might need to be added to some evacuation time estimates.

A fourth uncertainty was mentioned by Parsons Brinckerhoff, suggesting that approximately 12 percent of multicar families might utilize their additional vehicles in an evacuation. The effect of these or a larger number of additional vehicles was not quantified by Parsons Brinckerhoff except to say that the increase in time would be proportional to the percent increase in the number of cars used to evacuate along critical evacuation routes.*

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*From Methodology to Calculate Evacuation Travel Time, Estimates for the Indian Point Emergency Planning Zone, November 1981, p. 32-33.

A fifth and major uncertainty is that the model neglects the effects of a "spontaneous" evacuation beyond ten miles on the evacuation time estimates. From Figures IX and X from "Methodology to Calculate Evacuation Travel Time Estimates for the Indian Point Emergency Planning Zone," it is obvious that many "bottlenecks" occur at the EPZ boundary. The limiting effects of these bottlenecks on evacuees could be increased if "spontaneous" evacuees made use of them or nearby succeeding links.

The many uncertainties in the evacuation time estimates suggest that the evacuation times during an actual PWR2 release will probably be as high or higher than the upper bound estimates provided by Parsons Brinckerhoff.

APPENDIX A

RESUME FOR DR. JAN BEYEA

Resume for Jan Beyea
March 1982

EDUCATION:

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

EMPLOYMENT HISTORY:

1980 to date, Senior Energy Scientist, National Audubon Society, 950 Third Avenue, New York, New York 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 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; and various citizens' groups in the United States.

PUBLICATIONS CONCERNING ENERGY CONSERVATION AND ENERGY POLICY:

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

"The Audubon Energy Plan Technical Report," Peterson, Beyea, Paulson and Cutler, National Audubon Society, April 1981.

"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, Sinden. ASME Technology and Society Division paper 78-TS-5, Houston, Texas, 1978.

"Comments on the proposed FTC trade regulation rule on labeling and advertising of thermal insulation," Jan Beyea and Gautam Dutt, testimony before the Federal Trade Commission, January 1978.

"Critical Significance of Attics and Basements in the Energy Balance of Twin Rivers Townhouses," Beyea, Dutt Woteki, Energy and Buildings, Volume 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 International Journal, 3, 657, (1978).

"Energy Conservation in an Old 3-Story Apartment Complex," Beyea, Harrje, Sinden, Energy Use Management, Fazzolare and Smith, Pergamon 1977, Volume I, Page 373.

"Load Shifting Techniques Using Home Appliances," Jan Beyea, Robert Weatherwax, Energy Use Management, Fazzolare and Smith, Pergamon 1978, Volume III/IV, Page 121.

PUBLICATIONS CONCERNING ENERGY RISKS (PREDOMINANTLY NUCLEAR POWER):

Articles:

"Containing a Nuclear Reactor Melt-Down" (with Frank von Hippel), Bulletin of the Atomic Scientists, to be published.

"Second Thoughts (about Nuclear Safety)," to appear in Nuclear Power: Both Sides, W. W. Norton and Co. (Publication date: October 1982.)

"Indoor Air Pollution," Commentary in the Bulletin of the Atomic Scientists, 37, Page 63, February 1981.

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

"Dispute at Indian Point," Bulletin of the Atomic Scientists, 36, Page 63, May 1980.

Published Debates:

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

Nuclear Reactors: How Safe Are They?, panel discussion sponsored by the Academy Forum of The National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C. 20418, May 5, 1980.

Reports:

"Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere 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, Environmental Policy Department 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.

Published Debates (Cont'd.):

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

Testimony:

"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 New York, November 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.

"Stockpiling of Potassium Iodide for the General Public as a Condition for Restart of TMI Unit No. 1," direct testimony 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.

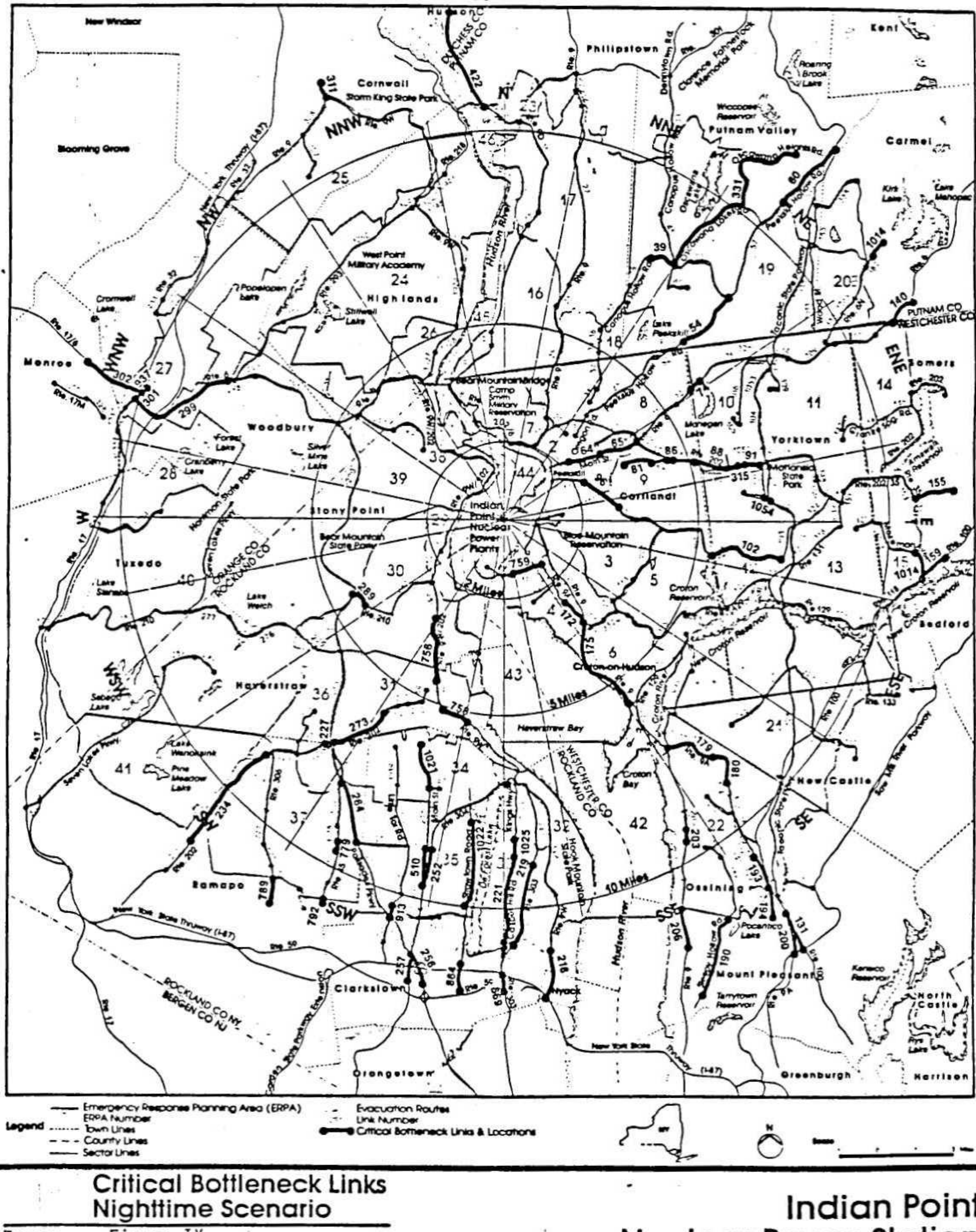
"Short-Term Effects of Catastrophic Accidents on Communities Surrounding the Sundesert Nuclear Installation," testimony before the California Energy Resources and Development Commission, December 3, 1976.

"Consequences of Catastrophic Accidents at Jamesport." Testimony before the New York State Board on Electric Generation Siting and the Environment in the Matter of Long Island Lighting Company (Jamesport Nuclear Power Station, Units 1 and 2), May 1977.

Miscellaneous:

"Comments on WASH-1400," Statement to the Subcommittee on Energy and the Environment, Oversight Hearings on Reactor Safety, June 11, 1976, Serial No. 94-61, Page 210.

"Upper Limit Calculations of Deaths from Nuclear Reactors," Bull. Am. Phys. Soc. 21, 111 (1976).

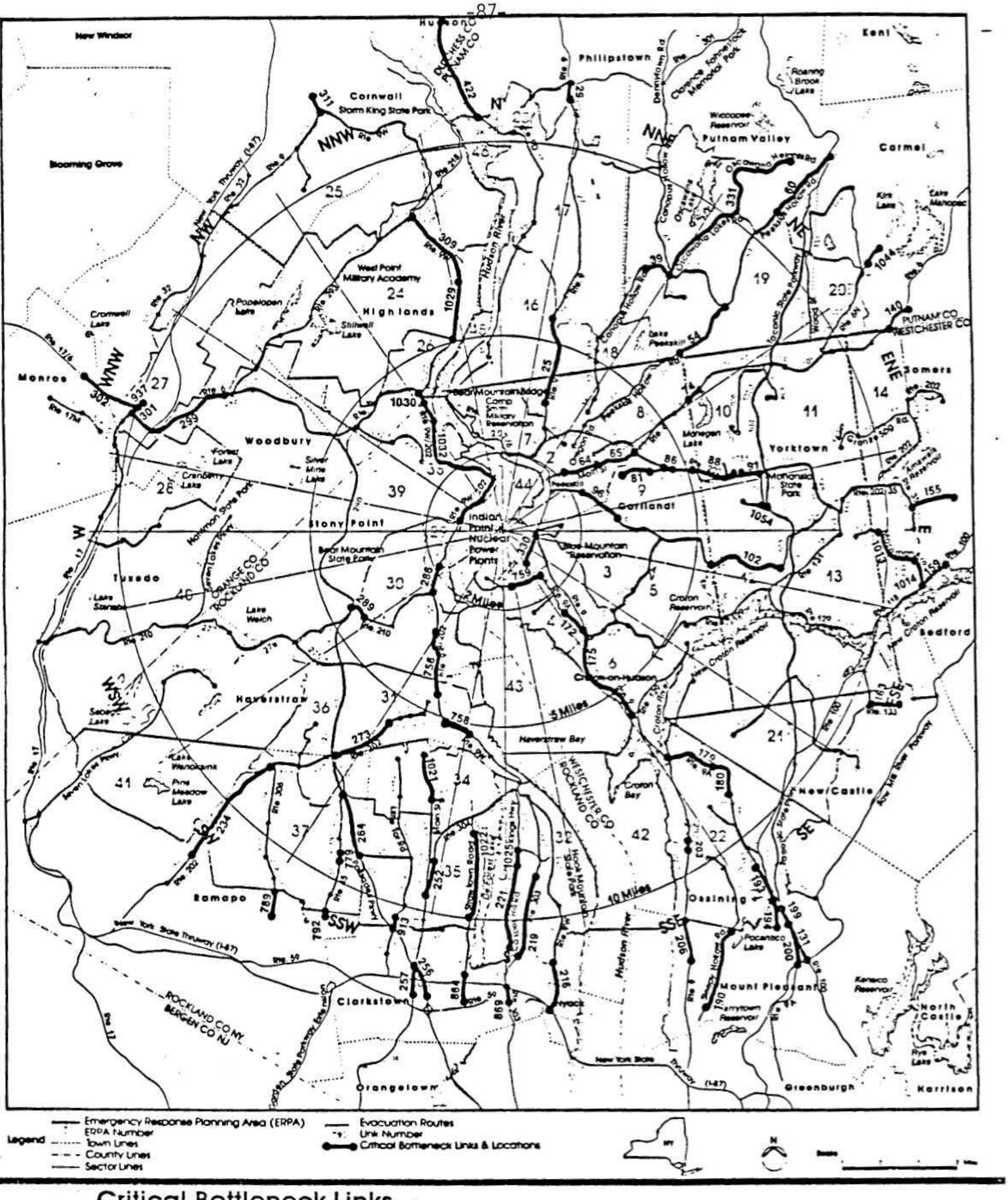


Critical Bottleneck Links
Nighttime Scenario

Figure IX

Indian Point
Nuclear Power Station

Source: Methodology to Calculate Evacuation Travel Time Estimates for the Indian Point Emergency Planning Zone, November 1981.



Critical Bottleneck Links School In Session Scenario

Indian Point Nuclear Power Station

Figure X

Source: Methodology to Calculate Evacuation Travel Time Estimates for the Indian Point Emergency Planning Zone, November 1981.

1. (Footnote 1 is divided into four parts, 1a-1d).

1a. If the containment fails to isolate--perhaps because valves have been left open or because seals fail to function properly--then the containment offers negligible protection. However, if the containment does isolate, substantial pressures may be necessary to breach the containment. (Scenarios in which sufficient pressure is generated are discussed in References 1b-1d.)

The Indian Point containments are designed to withstand internal pressures of three to four atmospheres and may maintain their integrity at more than six atmospheres internal pressure. They also have water sprays, whose purpose is to reduce pressures by removing steam from the containment atmosphere.

Reactor containment buildings today are not designed to contain a reactor core meltdown accident, however. Their "design basis accident" is a loss-of-coolant accident in which large amounts of volatile radioisotopes are released from a temporarily overheated core, but in which the uncontrolled release of energy from the core into the containment atmosphere is terminated by a flood of emergency core cooling water before an actual meltdown occurs. This is essentially what happened during the accident at Three Mile Island although, due to various errors, the core remained only partially cooled for a period of hours. (According to the Rogovin Report, a full core meltdown would have occurred if the emergency cooling system had remained turned off for an additional period of perhaps an hour. [Nuclear Regulatory Commission Special Inquiry Group, M. Rogovin, G. T. Frampton, Jr., et. al, Three Mile Island, A Report to the Commissioners and to the Public (Washington, D. C., 1980 Volume I, Pages 20, 91; Volume II, Pages 553-570).])

If for any reason the emergency core cooling system were not effective and a core meltdown occurred, the build up of internal pressure in a sealed reactor containment building could rupture it within a matter of hours. The threat would come from steam, hydrogen and other gases.

For an extended period of time after a reactor shutdown, the radioactive fission products in the reactor core generate heat at a rate great enough to turn hundreds of metric tons of water into steam per day. It would take only about 300 metric tons of steam to increase the pressure inside one of the Indian Point containment buildings by about eight atmospheres. It is apparent, therefore, that unless the containment cooling system operates reliably and effectively to keep this steam pressure from building up, the containment will quickly be overpressured by steam alone.

1b. U. S. Nuclear Regulatory Commission, Reactor Safety Study (Washington, D. C., WASH-1400 or NUREG-75/014, 1975).

1c. U. S. Nuclear Regulatory Commission, Report of the Zion/Indian Point Study, NUREG/CR-1410, August 1980. (Steam spikes are discussed in this reference.)

1d. U. S. Nuclear Regulatory Commission, Technical Bases for Estimating Fission Product Behavior During LWR Accidents (Draft, NUREG-0722, March 6, 1980; final, June 1981).

2. The weakened state of steam generator tubes in reactors has been a frequent topic in the news recently. Less well-known is a new accident sequence described in Reference 1c in which steam generator tubes can burst due to an enormous pressure spike generated as water suddenly strikes a molten core. (In some accident scenarios the primary pressure system around the reactor core and its attached piping remain intact until the core actually melts its way through the pressure vessel. The melt-through would relieve the steam pressure in the primary system with the result that water in the primary loop or water stored in the "accumulators" could be released into the pressure vessel on top of the molten core. This could cause a rapid pressure rise sufficient to rupture the steam generator tubes according to Reference 1c.)

3. Features of a PWR2 release are listed in Table VI 2-1 on Page 2-5 of Volume VI of the Reactor Safety Study, Reference 1b.

4. The Reactor Safety Study assumed a 50 percent retention rate for radioactivity deposited on vegetation. [See Appendices E and K of Reference 1b.] Although most of this loss is probably caused by subsequent rain, experimental data indicates that removal begins immediately after deposition. This initial loss must be due to wind action. Ten percent removal by wind seems a reasonable estimate.

5. See Volume VI of Reference 1b.

6. Present emergency plans to reduce direct exposures are limited to the ten mile emergency planning zone. Plans for dealing with food and water contamination are limited to 50 miles from the site.

7. Pages 9-3, Volume VI, Reference 1b.

8. National Academy of Sciences, BEIR Report, 1980.

8a. Page E-7 of Reference 9b.

9. (Footnote 9 is divided into three parts, 9a-9c.)

9a. Jan Beyea, Program BADAC-1, "Short-Term Doses Following a Hypothetical Core Meltdown (with Breach of Containment)" (1978), prepared for the New Jersey Department of Environmental Protection.

9b. Jan Beyea and Frank von Hippel, "Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere from Three Mile Island," report to the President's Council on Environmental Quality (1979), Appendix E.

9c. A detailed discussion of the basic dose calculations used in these programs can be found in the Appendices of "A Study of the Consequences of Hypothetical Reactor Accidents at Barseback," Jan Beyea (Stockholm: Swedish Energy Commission, 1978).

10. International Exercise in Consequence Modelling (Benchmark Study), sponsored by the Organization for Economic Cooperation and Development (O.E.C.D.), Nuclear Energy Agency, 38, Blvd. Suchet, 75016 Paris, France.

    Figure III has been taken from S. Vogt, CNSI Benchmark Study of Consequence Models, International Comparison of Models Established for the Calculation of Consequences of Accidents in Reactor Risk Studies, Comparison of Results Concerning Problem 1. SINDOC(81) 43.

11. There is no footnote 11.

12. Lewis et. al, "Risk Assessment Review Group Report to the U. S. Nuclear Regulatory Commission," NUREG/CR-0400, 1978, p. viii.

13. M. Levenson and F. Rahn (Electric Power Research Institute), "Realistic Estimates of the Consequences of Nuclear Accidents," paper presented at the International Meeting of the American Nuclear Society, Washington, D. C., November 20, 1980.

14. John O'Neill, "Scientists Say NRC Greatly Overestimates Accident Risks," Nuclear Industry, December 1980, p. 27.

15. Reference 1d, Summary.

16. Reference 9b.

17. Interdiction criteria for agricultural and human use that were assumed in deriving Tables 6 and 7:

    A. Milk: We have used 4 microcuries per square meter of I^{131} deposition during the grazing season as the threshold for milk interdiction. This value lies between the 1.4 $\mu Ci/m^2$ and 18 $\mu Ci/m^2$ recommended for infants and adults, respectvely, by the Food and Drug Administration as criteria for considering milk interdiction. [Food and Drug Administration, "Accidental Radioactive Contamination of Human and Animal Feeds and Potassium Iodide as a Thyroid-Blocking Agent in a Radiation Emergency," Department of Health, Education and Welfare, Federal Register, Friday, December 15, 1978, Part VII, p. 58790.]

    Thus, the areas given in Table 7 underestimate the area which would produce milk with levels of iodine too high for infants and overestimate the areas involved which would produce milk with levels of iodine too high for adults.

    B. Crops: The FDA has also recommended threshold levels at which emergency protective action should be considered for crops, but only for Cesium-137 and Strontium-90, not Cesium-134. To obtain a threshold for Cesium-134, we have simply divided the 18 $\mu Ci/m^2$ guideline threshold for Cs^{137} by two, since Cesium-134 delivers approximately twice as much energy per decay as does Cs^{137}. Each of the three isotopes has been considered separately and the largest resulting area (Cs^{134}) has been taken as indication of the amount of crop restrictions which would be imposed. This procedure underestimates the total area somewhat.

    C. Occupation: We have used a 10-rem-in-30-year threshold for rural land contamination--about three times the average natural background dose over 30 years. This is the same criterion used in WASH-1400 for rural land. Residents at the edge of the contaminated region, in the absence of decontamination, might face an additional risk of death of .05 to .5 percent due to the radiation from the land and property contamination. Residents closer to the plant, where 30 year doses would be higher, would face a proportionately higher risk.

18. (Reference 18 is divided into three parts, References 18a-18c.)

18a. Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness Support of Nuclear Power Plants. NUREG-0654, FEMA-REP-1, Rev. 1.

18b. See also U. S. Nuclear Regulatory Commission and U. S. Environmental Protection Agency, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," NUREG 0-396, EPA 520.1-78-016 (Washington, NRC and EPA, 1978).

18c. For a discussion of the logic which went into the arbitrary choice of a 10-mile cutoff distance for immediate population protection, see T. Lombardo and T. Perry, Spectrum, 17 (July 1980), 30.

19. Potassium iodide was approved for this purpose by the U. S. Food and Drug Administration in December 1978. See Department of Health, Education and Welfare, Food and Drug Administration, Federal Register, "Potassium Iodide as Thyroid-Blocking Agent in a Radiation Emergency" (December 15, 1978), pp. 58798-58800; and Federal Register (February 22, 1980), p. 11912. (See also, Food and Drug Administration, "Background Material for the Development of the Food and Drug Administration's Recommendations on Thyroid-Blocking with Potassium Iodide," FDA 81-8158, March 1981.)

It is the current position of the Nuclear Regulatory Commission that, based on accident probabilities calculated in the Reactor Safety Study, distribution of potassium iodide to the general public before an accident is not cost-effective. See D. C. Alrich and R. G. Blond, "Examination of the Use of Potassium Iodide (KI) as an Emergency Protective Measure for Nuclear Reactor Accidents," NUREG/CR-1433 (Washington, D. C.: NRC, March 1980).

However, in our opinion, this argument misses the point. Potassium iodide is useful precisely because it has no direct connection with the (uncertain) calculation of accident probabilities. It is an emergency measure that would be desirable to have available should the accident probabilities estimated in the Reactor Safety Study prove to be optimistic.

20. D. C. Aldrich, P. E. McGrath, N. C. Rasmussen, Examination of Offsite Radiological Emergency Measures for Nuclear Reactor Accidents Involving Core Melts, (Sandia Laboratories, Albuquerque, New Mexico, 1978, Sand 78-0454), Figures 5.12 and 5.13.

21. "Turbulent Diffusion in Complex Terrain," Bruce Egan, Env. Res. and Tech., Inc. in Chapter 4 of Lectures on Air Pollution and Environmental Impact Analyses, sponsored by American Meteorological Society, 45 Beacon Street, Boston, Massachusetts, 02108, 1975.

22. Thomas Johansson, University of Lund, Sweden, Private Communication, 1982. See also Nucleonics Week (January 8, 1981, p. 10).

23. Eugene W. Fowinkle, "Statement before the Subcommittee on Oversight and Investigations Committee on Interior and Insular Affairs," U. S. House of Representatives, March 5, 1982, p. 1.

24. Reference 12, p. xi.

25. Subsequent analysis of this type of accident by the NRC uncovered other significant accident sequences involving control rod failure. (Private communication, Robert Bernero, Probabilistic Risk Analysis Branch, U. S. Nuclear Regulatory Commission, 1981.)

26. Union of Concerned Scientists, The Risks of Nuclear Power, (Cambridge, MA, 1977).

27. A discussion of emergency action levels is found in Reference 18a.

28. "An Assessment of Evacuation Time around the Indian Point Nuclear Power Station," June 20, 1980; revised June 23, 1980, p. 2.7-2.9. [CONSAD Research Corporation, 121 North Highland Avenue, Pittsburgh, Pennsylvania 15206, and Center for Planning and Research, 5600 Columbia Pike, Baileys Crossroads, Virginia 22041.]

29. Reference 3.

30. Parsons Brinckerhoff Quade & Douglas, Inc., 1 Penn Plaza, New York, New York, "Evacuation Time Estimates for Areas Near the Site of Indian Point Power Plants," January 31, 1980 (prepared for the Power Authority of the State of New York and Consolidated Edison of New York, Inc.).

31, Parsons, Brinkerhoff, Quade and Douglas, Methodology to Calculate Evacuation Travel Time Estimates for the Indian Point Emergency Planning Zone, November 1981, P. 50.

APPENDIX B

SUPPLEMENTARY EARLY DEATH TABLES FOR VARIOUS ERPAS

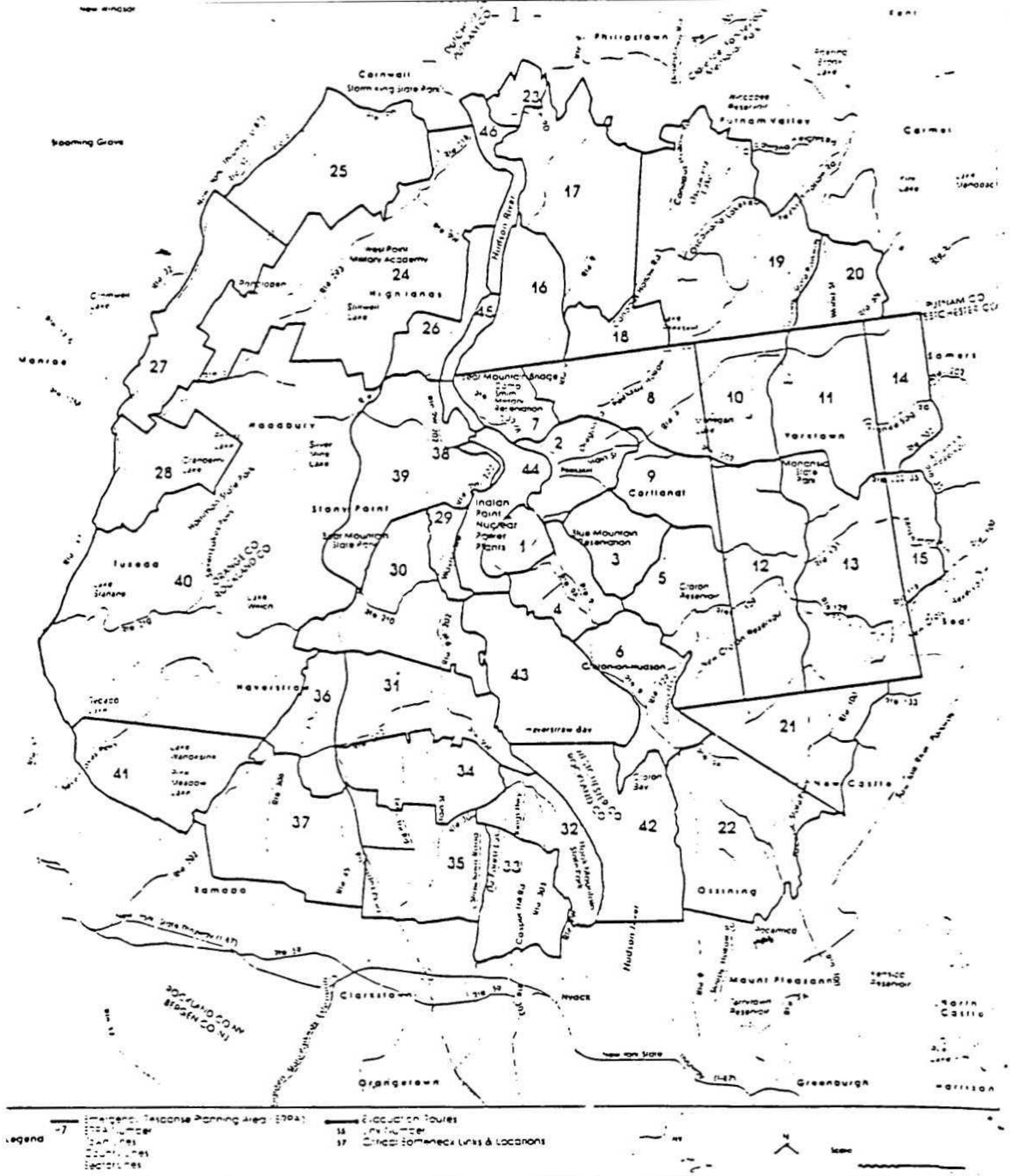


Figure B-I

Indian Point
Emergency Response Plan
10-Mile EPZ
ERPAS

Source: New York State Radiological Emergency
Preparedness Plans, Figure 6, P. 1P-14

TABLE B1

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 2[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	10:15	No	6:40	Yes
Early Evening	D, 4m/sec	7:15	Yes	4:20	Yes
Early Evening	E, 4m/sec	7:15	Yes	4:20	Yes
Late Evening	E, 4m/sec	5:40	Yes	3:25	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:40	No
Early Evening	D, 4m/sec	9:00	No
Late Evening	D, 4m/sec	7:00	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.3 miles. At this distance, the dose reaches 200 rem in 7.8, >24 and 1.7 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B2

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a]

WESTCHESTER COUNTY ERPA 3[b]

Typical Weather

Time of Day	Weather Conditions[e]	High Estimated Evacuation Time[c]	Protection of General Population[d]	Low Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	8:20	No	7:15	No
Early Evening	D, 4m/sec	4:45	Yes	3:00	Yes
Early Evening	E, 4m/sec	4:45	Yes	3:00	Yes
Late Evening	E, 4m/sec	4:05	Yes	2:45	Yes

Precipitation

Time of Day	Conditions	High Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	9:55	No
Early Evening	D, 4m/sec	5:45	No
Late Evening	D, 4m/sec	4:55	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.7 miles. At this distance, the dose reaches 200 rem in 5, >24, and 1.9 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B3

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 4 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	10:30	No	7:25	Yes
Early Evening	D, 4m/sec	4:15	Yes	2:55	Yes
Early Evening	E, 4m/sec	4:15	Yes	2:55	Yes
Late Evening	E, 4m/sec	4:10	Yes	2:55	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:40	No
Early Evening	D, 4m/sec	5:10	No
Late Evening	D, 4m/sec	5:05	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.3 miles. At this distance, the dose reaches 200 rem in 7.8, >24, and 1.7 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B4

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH (MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 5[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	10:40	Yes	7:40	Yes
Early Evening	D, 4m/sec	4:45	Yes	3:10	Yes
Early Evening	E, 4m/sec	4:45	Yes	3:10	Yes
Late Evening	E, 4m/sec	4:30	Yes	3:05	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:55	No
Early Evening	D, 4m/sec	5:45	No
Late Evening	D, 4m/sec	5:30	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.4 miles. At this distance, the dose reaches 200 rem in 11.7, >24, and 3.7hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B5

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 6 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	8:15	Yes	7:15	Yes
Early Evening	D, 4m/sec	3:20	Yes	2:55	Yes
Early Evening	E, 4m/sec	3:20	Yes	2:55	Yes
Late Evening	E, 4m/sec	3:15	Yes	2:50	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:55	No
Early Evening	D, 4m/sec	4:00	No
Late Evening	D, 4m/sec	4:00	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.3 miles. At this distance, the dose reaches 200 rem in 11.4, >24, and 3.6 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B6

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 7 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	1:45	Yes	0:40	Yes
Early Evening	D, 4m/sec	0:35	Yes	0:30	Yes
Early Evening	E, 4m/sec	0:35	Yes	0:30	Yes
Late Evening	E, 4m/sec	0:35	Yes	0:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	2:10	No
Early Evening	D, 4m/sec	0:40	Yes
Late Evening	D, 4m/sec	0:40	Yes

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.8 miles. At this distance, the dose reaches 200 rem in 7.2 >24, and 2 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B7

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 8 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d]
Midday	D, 4m/sec	10:10	No	6:30	Yes
Early Evening	D, 4m/sec	7:20	Yes	4:25	Yes
Early Evening	E, 4m/sec	7:20	Yes	4:25	Yes
Late Evening	E, 4m/sec	5:45	Yes	3:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:35	No
Early Evening	D, 4m/sec	9:05	No
Late Evening	D, 4m/sec	7:05	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 4.5 miles. At this distance, the dose reaches 200 rem in 9.8, >24 and 3.1 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B8

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 9 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:55	No	6:40	Yes
Early Evening	D, 4m/sec	4:40	Yes	2:55	Yes
Early Evening	E, 4m/sec	4:40	Yes	2:55	Yes
Late Evening	E, 4m/sec	4:25	Yes	2:45	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	11:55	No
Early Evening	D, 4m/sec	5:40	No
Late Evening	D, 4m/sec	5:25	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 4.0 miles. At this distance, the dose reaches 200 rem in 8.1, >24, and 2.8 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B9

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a]

WESTCHESTER COUNTY ERPA 10[b]

Typical Weather

Time of Day	Weather Conditions[e]	High Estimated Evacuation Time[c]	Protection of General Population[d]	Low Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	10:15	Yes	6:05	Yes
Early Evening	D, 4m/sec	6:55	Yes	4:10	Yes
Early Evening	E, 4m/sec	6:55	Yes	4:10	Yes
Late Evening	E, 4m/sec	5:20	Yes	3:15	Yes

Precipitation

Time of Day	Conditions	High Estimate[c]	Protection of General Population[d]
Midday	D, 4m/sec	12:40	No
Early Evening	D, 4m/sec	8:35	No
Late Evening	D, 4m/sec	6:30	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 6.8 miles. At this distance, the dose reaches 200 rem in 15, >24, and 5 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B10

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

WESTCHESTER COUNTY ERPA 12 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	10:00	Yes	6:50	Yes
Early Evening	D, 4m/sec	4:40	Yes	3:55	Yes
Early Evening	E, 4m/sec	4:40	Yes	3:55	Yes
Late Evening	E, 4m/sec	2:50	Yes	2:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:05	No
Early Evening	D, 4m/sec	5:40	No
Late Evening	D, 4m/sec	4:45	Yes

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 6.9 miles. At this distance, the dose reaches 200 rem in 15.5, $\geq$24, and 5.2 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B11

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

PUTNAM COUNTY ERPA 16 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	7:35	Yes	5:10	Yes
Early Evening	D, 4m/sec	2:50	Yes	1:50	Yes
Early Evening	E, 4m/sec	2:50	Yes	1:50	Yes
Late Evening	E, 4m/sec	2:50	Yes	1:50	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:05	No
Early Evening	D, 4m/sec	3:20	Yes
Late Evening	D, 4m/sec	3:20	Yes

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.5 miles. At this distance, the dose reaches 200 rem in 11.8, >24, and 3.8 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B12

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

PUTNAM COUNTY ERPA 18[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:15	Yes	6:20	Yes
Early Evening	D, 4m/sec	7:10	Yes	4:15	Yes
Early Evening	E, 4m/sec	7:10	Yes	4:15	Yes
Late Evening	E, 4m/sec	5:35	Yes	3:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	11:00	No
Early Evening	D, 4m/sec	8:55	No
Late Evening	D, 4m/sec	6:55	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.3 miles. At this distance, the dose reaches 200 rem in 11.4, >24, and 3.6 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B13

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ORANGE COUNTY ERPA 26[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:25	Yes	5:40	Yes
Early Evening	D, 4m/sec	4:35	Yes	2:40	Yes
Early Evening	E, 4m/sec	4:35	Yes	2:40	Yes
Late Evening	E, 4m/sec	4:30	Yes	2:45	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	11:40	No
Early Evening	D, 4m/sec	5:35	No
Late Evening	D, 4m/sec	5:30	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.5 miles. At this distance, the dose reaches 200 rem in 11.8, >24, and 3.8 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B14

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ROCKLAND COUNTY ERPA 29[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	11:45	No	7:00	Yes
Early Evening	D, 4m/sec	5:50	Yes	3:30	Yes
Early Evening	E, 4m/sec	5:50	Yes	3:30	Yes
Late Evening	E, 4m/sec	5:45	Yes	3:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	14:30	No
Early Evening	D, 4m/sec	7:05	No
Late Evening	D, 4m/sec	7:05	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 1.8 miles. At this distance, the dose reaches 200 rem in 8.2 · >24, and 1.4 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B15

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ROCKLAND COUNTY ERPA 30 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:00	No	7:15	Yes
Early Evening	D, 4m/sec	6:05	Yes	3:50	Yes
Early Evening	E, 4m/sec	6:05	Yes	3:50	Yes
Late Evening	E, 4m/sec	6:05	Yes	3:50	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	14:50	No
Early Evening	D, 4m/sec	7:20	No
Late Evening	D, 4m/sec	7:20	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 4.1 miles. At this distance, the dose reaches 200 rem in 8.4 , ≥24, and 2.8 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B16

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ROCKLAND COUNTY ERPA 31[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population
Midday	D, 4m/sec	11:40	No[f)]	6:55	Yes
Early Evening	D, 4m/sec	5:45	Yes	3:30	Yes
Early Evening	E, 4m/sec	5:45	Yes	3:30	Yes
Late Evening	E, 4m/sec	5:45	Yes	3:30	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	14:30	No
Early Evening	D, 4m/sec	7:00	No
Late Evening	D, 4m/sec	7:00	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 5.5 miles. At this distance, the dose reaches 200 rem in 11.8, >24, and 3.8 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

f) Given the uncertainties of both the transportation and dispersion/dose models, we do not consider all the population protected under this evacuation time estimate.

TABLE B17

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ROCKLAND COUNTY ERPA 36 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	7:40	Yes	5:25	Yes
Early Evening	D, 4m/sec	3:45	Yes	2:10	Yes
Early Evening	E, 4m/sec	3:45	Yes	2:10	Yes
Late Evening	E, 4m/sec	3:45	Yes	2:10	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	8:15	No
Early Evening	D, 4m/sec	4:35	Yes
Late Evening	D, 4m/sec	4:35	Yes

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 6.8 miles. At this distance, the dose reaches 200 rem in 15, >24, and 5 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B18

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ROCKLAND COUNTY ERPA 38[b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:50	No	6:05	Yes
Early Evening	D, 4m/sec	4:55	Yes	3:10	Yes
Early Evening	E, 4m/sec	4:55	Yes	3:10	Yes
Late Evening	E, 4m/sec	4:55	Yes	3:10	Yes

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	12:05	No
Early Evening	D, 4m/sec	6:00	No
Late Evening	D, 4m/sec	5:55	No

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2 miles. At this distance, the dose reaches 200 rem in 8.2, >24, and 1.5 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

TABLE B19

CONDITIONS UNDER WHICH THE GENERAL POPULATION IS NOT PROTECTED FROM EARLY DEATH

(MID-RANGE MODEL PARAMETERS)[a)]

ORANGE AND ROCKLAND COUNTY ERPA 39 [b)]

Typical Weather

Time of Day	Weather Conditions[e)]	High Estimated Evacuation Time[c)]	Protection of General Population[d)]	Low Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	9:55[f)]	No	5:45[f)]	Yes
Early Evening	D, 4m/sec	4:30	Yes	2:45	Yes
Early Evening	E, 4m/sec	4:30	Yes	2:45	Yes
Late Evening	E, 4m/sec	g)		g)	

Precipitation

Time of Day	Conditions	High Estimate[c)]	Protection of General Population[d)]
Midday	D, 4m/sec	11:50[f)]	No
Early Evening	D, 4m/sec	5:35	No
Late Evening	D, 4m/sec	g)	g)

a) Mid-range parameters assume a .01 meter/sec. deposition velocity, a Briggs theoretical plume rise, and a 0.5 ground shielding factor. "Protection" implies protection from early death (a 200 rem dose) only assuming these mid-range parameters. The population might not be protected assuming other possible values of parameters such as a low plume rise.

b) The "representative" distance is calculated by averaging the distances from the plant to the closest and farthest ERPA boundaries. The representative distance for this ERPA is 2.8 miles. At this distance, the dose reaches 200 rem in 7.2 , > 24, and 2.0 hours for the D-4m/sec, E-4m/sec and D-rain cases, respectively.

c) High and low evacuation time estimates are the adjusted evacuation time estimates based on those given in the New York State Radiological Emergency Preparedness Plans; for an explanation of the assumptions and adjustments see text. The "real" evacuation times may be higher than the estimates here due to evacuation model uncertainties.

d) Protection from a dose at or exceeding 200 rem, the threshold for early death. The population is not protected from latent cancer deaths, thyroid cancers, birth defects, etc., that would be caused by lower doses.

e) Pasquill stability class.

f) The evacuation time estimates for this ERPA are highly time and season dependent. For example the midday evacuation time when school is not in session is 12:30-7:25. The estimated adverse evacuation time when school is not in session is 15:25.

g) The time estimates are incomplete for these cases.