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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
Philadelphia Electric Company	)	Docket Nos. 50-352
	)	50-353
(Limerick Generating Station,	)	
Units 1 and 2)	)	

APPLICANT'S TRANSMITTAL OF PROPOSED FINDINGS
OF FACT AND CONCLUSIONS OF LAW REGARDING
SEVERE ACCIDENT RISK ISSUES

In accordance with the Atomic Safety and Licensing Board's ("Board") June 22, 1984 "Order Correcting Schedule for Proposed Findings on NEPA Severe Accident Contentions," the Applicant hereby transmits proposed findings of fact and conclusions of law for Contentions DES-1, -2, -3 and -4, and CITY-13, -14, -15, as admitted by the Board. While the proposed findings have been separated into three sections to comply with the page limitations set forth in the above Order, it should be noted that Paragraphs 3 through 23 of the proposed findings relating to Contentions DES-1-4 and City 14A have applicability to all contentions.

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The Applicant is also submitting a title page for the Partial Initial Decision and updated exhibit and witness lists. The Staff and City have concurred in their listing of appearances on the title page.

Respectfully submitted,
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July 5, 1984

PARTIAL INITIAL DECISION
(On LEA Contentions DES-1, DES-2, DES-3, DES-4 (in part)) and CITY-14A

Preliminary Statement

1. At the first prehearing conference held January 6-8, 1982, this Atomic Safety and Licensing Board ("Board") admitted, subject to further specification, *inter alia*, Limerick Ecology Action's ("LEA") general contention relating to the Probabilistic Risk Assessment ("PRA") performed by the Applicant, Philadelphia Electric Company ("PECO").[1/] On February 14, 1984, the City of Philadelphia ("City") also filed a number of contentions relating to severe accidents.

2. In our unpublished "Order Confirming Rulings and Schedules Made at Special Prehearing Conference on NEPA Severe Accident Contentions," dated April 20, 1984, LEA Contentions DES-1, DES-2, DES-3 and DES-4 (in part) and, *inter alia*, Contention CITY-14A were admitted, as respecified. Evidentiary hearings on these contentions took place in Philadelphia, Pennsylvania on May 22-24 and May 29-30, 1984. LEA and the City, which was admitted to the Limerick operating license proceeding as an interested governmental participant, took part in the litigation of these issues.[2/]

1/ *Philadelphia Electric Company* (Limerick Generating Station, Units 1 and 2), LBP-82-43A, 15 NRC 1423, 1494 (1982).

2/ *Id.* at 1456.

General Introduction

3. The essential question before this Board is the adequacy of the environmental impact assessment performed by the NRC Staff under the National Environmental Policy Act of 1969 ("NEPA"), as challenged by LEA and the City and in their contentions.[3/] The need to consider low probability severe accidents during the NEPA review arises as a result of the Commission's Statement of Interim Policy.[4/] The results of the Staff's review of this matter is contained in a Final Environmental Impact Statement ("FES"), which was preceded by a Draft Environmental Statement and a supplement thereto devoted solely to the consideration of severe accidents.[5/]

4. The assessment of environmental impacts is admittedly an imprecise science, particularly so the examination of extremely low probability, i.e., beyond design basis, accidents which presently need not even be considered in the NRC's safety review. In these circumstances, this Board would have been well within its discretion to give

3/ 42 U.S.C. §4321 et seq.

4/ Nuclear Power Plant Accident Considerations Under the National Environmental Policy Act of 1969, Statement of Interim Policy, 45 Fed. Reg. 40101 (June 13, 1980).

5/ The Board notes that neither LEA or the City choose to comment on the draft supplement in accordance with the opportunity granted under NRC regulations and thereby put the Staff on notice as to the specific areas which they felt should be modified or improved. The litigation could have been simplified and shortened had this been done. While we have the authority to penalize parties for failing to make their views known in this manner, 10 C.F.R. §51.73, Vermont Yankee Nuclear Power Corp. v. NRDC, 435 U.S. 519, 553-54 (1978), we have nevertheless examined the adequacy of the FES as challenged by the contentions without penalizing those parties.

credence to the judgments made in the FES unless they were shown by LEA or the City to be unreasonable. The Board has gone one step further, however, and in the areas challenged by LEA and the City has independently satisfied itself as to the reasonableness of the judgments, assumptions, methodology, results, and conclusions of the Applicant and Staff's analyses.

5. The contentions put forth by LEA and the City generally allege that additional material should have been included in the FES or that different methodologies or assumptions should have been employed. The portion of the FES dealing with the environmental impacts associated with extremely low probability accidents at Limerick is already lengthy and discusses in detail the scope, assumptions, inputs, methodology and conclusions regarding severe accidents. While it could always be argued that additional detail or studies are desirable, such arguments must be balanced against increasing the length and decreasing the comprehensibility and focus of the FES. The ultimate question is whether the Staff has reasonably performed its function and, as a corollary, whether LEA or the City have shown that a significant impact has been unreasonably excluded from consideration. This, LEA and the City have failed to do. After reviewing the evidence, the Board finds that the NRC's environmental review has considered and disclosed all significant impacts of severe accidents and that the FES, as published, is adequate to fulfill the requirements of NEPA and the Statement of Interim Policy.

6. Nevertheless, the Board has discussed the evidence related to each of the admitted contentions and issues and the reasons for its conclusions so that this decision may serve as the disclosure vehicle

LEA and the City apparently seek. This purpose is in full accord with the Commission's regulations.[6/]

7. In addition to the Staff's evaluation of the risk of severe accidents, the Applicant performed a similar, extensive evaluation at the Staff's request to assist it in the preparation of the FES. The Board finds that with regard to the issues before it, the Applicant's Severe Accident Risk Assessment ("SARA"), as supplemented by its testimony, is comprehensive and valuable in assisting its decisionmaking. While the strict question before us is the adequacy of the Staff's environmental review, the Board believes that it can and should place significant weight on the analysis requested by the Staff under the NRC's regulations[7/] and that it is valuable to examine two independent approaches in judging the reasonableness of the overall evaluation. While, as might be expected, the approaches and analyses were somewhat different, both were reasonable and the conclusions regarding each contention and the ultimate conclusions were the same. The uncontroverted evidence indicates that the comparable results of the Applicant are sufficiently close, given the range of uncertainties, that they validate and reinforce the Staff's conclusions.[8/] Thus, the Board accepts the substantial effort put forth by the Applicant and, by this

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6/ 10 C.F.R. §51.102(c). As a matter of convenience, the tables, diagrams and figures referenced in this decision should be considered a part of it for all purposes.

7/ 10 C.F.R. §51.53; Statement of Interim Policy, supra, note 4, at 40103.

8/ See Daebeler, et al., ff. Tr. 11114, at 9.

decision, incorporates that work within the scope of the NRC's environmental review.

8. In viewing the results of the Staff and Applicant's studies, the Board has been mindful of the inherent uncertainties in such analyses. In its Statement of Interim Policy, the Commission recognized that "there are and will likely remain for some time to come many uncertainties in the application of risk assessment methods, and it expects that its Environmental Impact Statements will identify major uncertainties in its probabilistic estimates."[9/] The uncertainties arise for a variety of reasons including an inadequate data base associated with the rare event nature of reactor accidents and from uncertainties in the modeling of the physical progression of accidents. While the Applicant and Staff took different approaches in quantifying and characterizing the uncertainty factor, both recognized that they are relatively large. See e.g., Daebeler, et al., ff. Tr. 11114, at 8-9.

9. The Staff and Applicant each estimated the uncertainty factor inherent in their risk estimates. The Staff concluded that its risk estimates could be too low by a factor of 40 or too high by a factor of 400. Daebeler, et al., ff. Tr. 11114, at 9; Tr. 11176-79, 11183, 11290 (Hulman, Acharya). Because the state of the art for the precise quantification of uncertainty is not well developed, specific numbers representing uncertainty factors were not assigned. Instead, an informed judgment was made, based on past experience, as to the overall uncertainty. Tr. 11176-83, 11286-90 (Hulman, Acharya).

9/ Statement of Interim Policy, supra, note 4, at 40103.

10. In recognition of the inherent uncertainties in such analyses, the Applicant presented the results of its assessments in SARA as a family of CCDF's rather than as a single CCDF. A range of results including a lower and an upper estimate was presented. The lower (95th percentile) and upper (5th percentile) estimates are not absolute bounds, but rather define the range in which there is a large degree of assurance that the actual result would lie. The uncertainties characterized by these different estimates take into account the uncertainties in the frequencies of accident sequences as well as in the consequence magnitudes. Typically, the area under the upper estimate CCDF's in SARA is on the order of a factor of 100 greater than the area under the lower estimate CCDF's. Any comparison of the results of sensitivity studies must be made with the range of uncertainty in mind. Therefore, if the uncertainty ranges of two estimates are large and overlap to a large extent, the results cannot be regarded as significantly different. Daebeler, et al., ff. Tr. 11114, at 8-9; Tr. 11326-29 (Kaiser, Levine).

11. Matters related to the sensitivity of the results to different assumptions and inputs must be judged on the basis of the overall uncertainty. In reviewing the record, this Board did not give any weight to numerical exercises which attempted only to isolate and examine the worst combination of inputs and to examine the "worst" outcome. See Tr. 11316 (Levine). This approach is simply not in accord with the Commission's new Part 51 and NEPA, which provide that the focus

of the environmental review should focus upon the "expected" and not "worst possible" outcome.[10/]

12. A related matter is the Board's firm view that to be consistent with the Statement of Interim Policy, the consequences of an accident must be viewed with the probability of such an occurrence. Therein, the Commission stated that "[t]he environmental consequences of releases whose probability of occurrence has been estimated shall also be discussed in probabilistic terms."[11/] The Board sees no value in viewing only the consequences of an accident with its occurrence probability set artificially at unity.

Scope

13. LEA and the City complained that the FES and SARA did not include all of the consequences or categories of consequences that might be expected from severe accidents at Limerick. As discussed above, it is neither reasonably possible or necessary to describe all impacts of severe accidents, particularly in the detail suggested. Confronted with a long list of potential health effects, as well as other effects of reactor accidents, the Staff and Applicant reviewed the literature and selected a representative sampling of the more important effects for analysis. This approach is supported by the developing consensus in the risk assessment community that reactor accident risks can be characterized very well by limiting discussion to early fatalities, latent

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10/ See Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions and Related Conforming Amendments, 49 Fed. Reg. 9352, 9356-58 (March 12, 1984).

11/ Statement of Interim Policy, supra, note 4, at 40103.

cancer fatalities, man-rem, and economic costs since the other risks are all much smaller, or have a lesser impact in comparison to ambient risk levels. Tr. 11272-76 (Hulman, Acharya); Tr. 11329-32 (Levine). This conclusion was ultimately borne out by the evidence before us. The health and economic impacts examined in the FES and SARA were clearly the most significant that would occur and were sufficient to adequately describe the environmental impact from Limerick. Moreover, although other impacts were not described quantitatively, they were considered, and in a number of cases, the consequence categories were presented in a manner that would allow the results sought by the City and LEA to be derived. See, e.g., Tr. 11273-76 (Hulman, Acharya).

14. For example, with respect to genetic effects, although certain information sought by LEA was not specifically set forth in FES Table 5.11h,[12/] it is stated in Section 5.9.4 that the number of genetic effects can be scaled from the information presented on population exposure. Tr. 11200-01 (Acharya). The Staff also noted the appropriate references in its FES so that the specific effects discussed only generally in the FES could be further identified. Finally, by examining the probability levels on the CCDF curves for the different kinds of consequences that were evaluated, one can get a sense of the different consequence levels for events that have the same probability. Tr. 11203-08, 11272-74 (Hulman, Acharya).

12/ All specific references to the Staff's FES refer to that portion of the FES that was admitted into evidence as Staff's Ex. 29.

15. Moreover, given the fact that the accident derived risks of major health effects are themselves exceedingly small when judged against the existing natural risks, the minor effects do not constitute significant impacts which need to be discussed. For example, it is not possible to equate the risk of death with the risk of temporary sterility. While such effects may be numerically comparable or even larger in number, they have less significance than those described in the FES and SARA. Certainly, they would not change the conclusions contained in the FES or SARA. Tr. 11276 (Hulman, Richter, Branagan, Acharya); Tr. 11331-32 (Levine).

Introduction and Summary

16. The contentions and issues put forward by LEA and the City solely concern the consequence analysis portion of the Applicant and Staff's risk assessments. Consequence analysis is the determination of offsite costs and the impacts on public health due to the hypothetical accidental release of radioactive material from a nuclear power plant. Inputs to the consequence analysis are the frequencies, magnitudes and timing of accidental releases of radionuclides associated with each accident sequence, as determined by plant accident sequences, containment behavior, accident processes, and source term analyses. These inputs were unchallenged. The consequence analysis includes the calculation of the environmental transport of radionuclides, the calculation of radiation doses and the determination of the resulting health effects and economic consequences. Daebeler, et al., ff. Tr. 11114, at 2-3.

17. The consequence analyses contained in the FES and SARA utilized two variants of a computer code known as the Calculation of Reactor Accident Consequences ("CRAC") Code. The Staff utilized CRAC and the

Applicant utilized a later version known as CRAC2. The environmental transport of radionuclides, radiation exposure, health effects, and economic consequences were predicted using these codes for a series of meteorological sequences selected from site specific meteorological records and the site specific population distribution (See Applicant's Ex. 152, Table 10-2). The frequency (probability) of the radionuclide releases was combined with the probability of the various meteorological sequences to produce a frequency distribution, i.e., CCDF, for the predicted consequences. Daebeler, et al., ff. Tr. 11114, at 3.

18. The CRAC code elements have been validated against theory and actual data to ensure their accurate representation of physical reality. The CRAC codes were likewise evaluated against codes from other countries that had been designed to perform consequence analyses to determine their conformity. It was found that most codes were quite consistent, thus indicating their reliability. Tr. 11171-78 (Hulman, Acharya); Tr. 11171-79, 11334-36 (Levine).

19. The health effects model used in the CRAC codes is based on theory, data and the judgment of experts. The data supporting the health effects model was derived from experiments conducted with animals and studies of human beings exposed to radioactivity. Tr. 11171-79 (Hulman, Acharya); 11334-36 (Levine). The judgment of the many experts who studied this data was described mathematically and then approved by its contributors. Its validity is therefore well-supported. Tr. 11334-36 (Levine)

20. LEA asserted that incorrect input could have been entered into the CRAC runs. To the contrary, the evidence indicated that sufficient controls were in place to prevent this and checks were conducted to

ensure that the code functioned properly. For example, one person entered the input and another person checked its correctness. Tr. 11336-37 (Kaiser). Also, specific results were checked against the results of other runs for consistency. Furthermore, the output was checked against evaluations of a similar type for inconsistencies and magnitude of numbers. Tr. 11170, 11188-91 (Hulman, Acharya). The Board is satisfied that the codes were properly run.

21. The Board has carefully examined the alleged deficiencies in the FES regarding excluded information or inappropriate assumptions. The bases for decisions not to explicitly include certain information and the appropriateness of the challenged assumptions have been examined by the Board and found to be reasonable. Nevertheless, information related to each deficiency alleged in the contentions has been discussed in this initial decision. Where assumptions or inputs were challenged, the results of sensitivity studies show that the FES conclusions would not change for a wide variety of alternate assumptions. The Board thus finds that these contentions are without merit.

22. The Applicant presented the testimony of a panel of witnesses relating to the admitted LEA DES contentions, as well as CITY-13 and -14. This panel included George Daebeler, Supervising Engineer, Environmental Branch, PECO; Saul Levine, Vice President, NUS Corporation ("NUS"); Morton Goldman, Senior Vice President - Technical Director, NUS (Contention DES-4 only); Geoffrey Kaiser, Manager, Consequence Assessment Department, NUS; and E. Robert Schmidt, Director, Systems Analysis, NUS. These witnesses are well qualified in their respective technical disciplines and the Board has relied heavily upon their testimony.

23. The Staff also presented the testimony of a panel of witnesses on LEA's DES Contentions and Contentions CITY-13 and -14. This panel included Lewis Hulman, Chief of the Accident Evaluation Branch, NRC; Dr. Sarbeswar Acharya, Senior Radiological Engineer, Accident Evaluation Branch, NRC; Brian Richter, Economist, Site Analysis Branch, NRC; Edward Branagan, Senior Radiobiologist, Radiological Assessment Branch, NRC; and William Pratt, Group Leader, Accident Analysis Group, Brookhaven National Laboratory. These witnesses were also qualified and the Board has relied heavily on their testimony as well. Neither LEA or the City presented witnesses on these issues.

Contention DES-4(A)(1)

Genetic Effects

The DES Supplement[13/] fails to adequately disclose or consider:

> (1) Total latent health effects due to both initial and chronic radiation exposure, other than those resulting in fatalities, including genetic effects, non-fatal cancers, spontaneous abortions, and sterility (see, e.g., BEIR I-III);

24. LEA contended that the FES failed to consider the genetic effects resulting from initial and chronic radiation exposure. To the contrary, the evidence indicated that while the FES does not set forth a specific Complementary Cumulative Distribution Function ("CCDF") listing genetic effects, it contains the information necessary to construct one. The Staff assumed with respect to the dose-effect relationship for the projection of radiation induced adverse genetic effects that 260 cases

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13/ All references to the DES have been understood by the Board to apply to the FES.

of genetic effects might occur in all succeeding generations for each million person-rem to the exposed generation. This value is equal to the sum of the geometric means of the risk of specific genetic effects and the risk of effects with complex etiology. Thus, the numerical value of the Staff's risk estimator for genetic effects is 260 cases divided by 10^6 person-rem, which equals 2.6×10^{-4} cases/person-rem. This risk estimator is consistent with BEIR-I (1972), WASH-1400 and BEIR-III (1980). Hulman and Acharya, ff. Tr. 11148, at 5-6.

25. The Staff's estimate of risk in terms of total population exposure from Limerick for the entire region is set forth in FES Table 5.11h as 1×10^3 person-rem per reactor-year, which includes both early and chronic exposures. The corresponding CCDF for population exposure is represented by the upper curve in FES Figure 5.4c. Multiplying 1×10^3 person-rem per reactor-year by the risk estimator for genetic effects results in an estimated risk of 2.6×10^{-1} cases of genetic effects per reactor-year. A corresponding CCDF for genetic effects can then be obtained for the entire site-region by multiplying the consequence magnitude on the x-axis of Figure 5.4c by the factor of 2.6×10^{-4}. Hulman and Acharya, ff. Tr. 11148, at 6.

26. The Applicant derived an estimate of genetic effects using current estimates which suggest that the total number of genetic effects is of the same order as the number of latent-cancers. Thus, using the Applicant's data, there would be an estimated risk of about 0.13 genetic defects per reactor year in the population surrounding Limerick, which compares with an expected 6,000 cases per year from other causes in the population out to 50 miles. Estimates of genetic effects can also be calculated using the expected value for population dose (SARA,

Supplement 3, Table 1) of 444 man-rem per reactor year and the most recent genetic risk estimator of 150 per million man-rem; the estimated risk from genetic damage is then calculated to be 0.067 per reactor year. Daebeler, et al., ff. Tr. 11114, at 32-33. Using either the Applicant or Staff's approach, the contribution of genetic effects to the total risks of an accident is small, especially in comparison to other individual risks; Tr. 11275-81 (Branagan, Hulman); Tr. 11338-40 (Goldman).

Spontaneous Abortions

27. LEA also asserted that the FES failed to adequately disclose or consider estimates of radiation-induced spontaneous abortions that might result from early and chronic radiation exposure. The risk estimators for spontaneous abortions are indicated in WASH-1400, Appendix VI, Tables VI 9-11 and VI 9-12. Daebeler, et al., ff. Tr. 11114, at 33; Hulman and Acharya, ff. Tr. 11148, at 9. From these tables it can be derived that for a given level of exposure, the ratio of the number of cases of spontaneous abortion to those of the other genetic effects shown in the tables, calculated on the basis of live-births, is 0.58. This Staff derived number is consistent with the Applicant's estimate of 33 to 76% of total genetic effects estimated for live births. Hulman and Acharya, ff. Tr. 11148, at 9; Daebeler, et al., ff. Tr. 11114, at 33. The risk estimate of genetic effects discussed above (2.6×10^{-1} per reactor-year) is based solely on live-births and, therefore, excludes spontaneous abortions. Multiplying this estimate by a factor of 0.58 indicates that the risk per reactor-year of radiation-induced spontaneous abortions is 1.5×10^{-1}. The corresponding CCDF for spontaneous abortions can then be obtained from FES Figure 5.4c for total

person-rem for the entire region by multiplying the consequences magnitudes on the x-axis by 1.5×10^{-4} (which is $0.58 \times 2.6 \times 10^{-4}$). Hulman and Acharya, ff. Tr. 11148, at 9-10. The Board finds that this health effect is a small contributor to the environmental impact from severe accidents and is adequately discussed.

Sterility

28. LEA also contended that the FES failed to adequately consider estimates of radiation-induced sterility resulting from initial and chronic radiation exposure. Preliminarily, the evidence indicated that sterility consequences are generally not reported in risk assessments because they are subordinate to more serious radiation effects such as fatalities or early radiation illnesses. Daebeler, et al., ff. Tr. 11114, at 33. Nonetheless, the Applicant's evidence indicated that for males, radiation doses between 10 and 400 rads could produce temporary sterility beginning six to seven weeks after exposure and lasting a few months to several years. Doses delivered to the whole body at the upper end of this range would have a significant likelihood of resulting in a fatality; localized exposure at this level, however, would be insufficient to produce permanent sterility. Daebeler, et al., ff. Tr. 11114, at 33-34.

29. For females, fertility impairment could result from doses to the ovaries of 300-400 rads. Doses in this range might produce a threat of permanent sterility in women approaching menopause, but only temporary sterility in younger women. Again, an acute whole body exposure at this level would have a significant likelihood of being lethal. Daebeler, et al., ff. Tr. 11114, at 34. In short, cases of permanent sterility would not be expected because doses necessary to induce

permanent sterility would likely be accompanied by lethal doses to other organs. Also, temporary sterility is less serious than other early radiation illnesses because most individuals conceive children intermittently and thus the vast majority of these cases would not be aware of their temporary sterility. Hulman and Acharya, ff. Tr. 11148, at 10. The Board finds that this health effect is a small contributor to the risk of environmental impact from severe accidents and is adequately discussed.

Non-Fatal Cancers

30. LEA then contended that the FES failed to adequately disclose or consider estimates of radiation-induced non-fatal cancers resulting from early or chronic exposure to radiation. The evidence indicated, however, that the necessary information concerning estimates of radiation-induced non-fatal cancers could be obtained from the FES.

31. Generally, the discussion as to estimates concerning non-fatal cancers was divided into cancers from thyroid exposures and cancers from exposures to other organs. According to the thyroid cancer fatality model contained in WASH-1400, upon which the Limerick FES estimates are based, approximately 10% of cancerous thyroid nodules may be fatal and 90% are non-fatal. The risk estimate of thyroid cancer fatality for the entire site-region shown in FES Table 5.11h is 1×10^{-2} per reactor year from both early and chronic exposures, the CCDF for which is identified in Figure 5.4d. Thus, multiplying the estimated thyroid cancer fatality risk of 1×10^{-2} per reactor year by a factor of 9, the estimated risk of non-fatal thyroid nodules is 9×10^{-2} per reactor year. The corresponding CCDF for non-fatal thyroid cancers can be obtained by multiplying the consequence magnitudes on the x-axis of the thyroid cancer

fatality CCDF contained in Figure 5.4d by a factor of 9. Hulman and Acharya, ff. Tr. 11148, at 6-7; Tr. 11247-50 (Hulman, Acharya). As explained on FES page 5-73, this can be done solely on the basis of information contained in the FES. The FES references also provide the basis for deriving this estimate. Tr. 11248-50 (Hulman).

32. In actuality, the evidence indicated that a 10% mortality rate for malignant thyroid cancers is too high by a factor of two or three, thus significantly overstating the number of fatal thyroid cancers that might result from a postulated severe accident. The appropriate thyroid cancer mortality rate is actually three to five percent. Daebeler, et al., ff. Tr. 11114, at 30-31; Tr. 11320-25 (Goldman).

33. Radiation-induced non-fatal cancers other than thyroid cancers can also be obtained from the FES and SARA. The BEIR-III Report, Table V-15, indicates the organ-weighted ratios of cancer incidences. Excluding the previously considered thyroid ratio from this table, the organ-weighted ratios of cancer incidence to cancer mortality for males and females is 1.31 and 1.63, respectively. The risk of cancer fatality from organs other than the thyroid for the entire site region from early and chronic exposures is shown in FES Table 5.11h as 7×10^{-2} per reactor-year. The corresponding CCDF is represented by the top curve of Figure 5.4d. Conservatively multiplying this risk by the incidence-to-mortality-ratio of 1.63, the estimated risk of cancer is 1.1×10^{-1} per reactor year. Of this figure, the risk of fatal cancers would be 7×10^{-2} per reactor year; non-fatal cancers would be 4.4×10^{-2} per reactor-year. The corresponding CCDF for non-fatal cancer can then be obtained by multiplying the consequence magnitudes on the x-axis of the

top curve of Figure 5.4d by a factor of 0.63. Hulman and Acharya, ff. Tr. 11148, at 7-8.

34. The point estimate public risk of latent cancer fatality presented in SARA, excluding thyroid cancers, is 0.033 per reactor year and the public risk of thyroid cancer fatality is estimated to be 0.0064 per reactor year. Applying the mortality fractions for thyroid (10%) and non-thyroid (50%) to the fatal cancer risks yields a combined risk for all non-fatal latent cancers of 0.091 per reactor year, with thyroid cancers comprising more than half the total. Thus, non-fatal cancers are approximately 2 to 2.5 times greater in number than the reported fatal latent cancer fatalities. This figure of 0.091 non-fatal latent cancers per reactor year, together with the 0.04 fatalities per year (0.033 + 0.0064) can be compared to the expected number of cancer fatalities per year from all causes in the population around Limerick Generating Station out to 50 miles, of about 20,000 cases per year. Daebeler, <u>et</u> <u>al</u>., ff. Tr. 11114 at 31-32. The Board notes that the total number of cancers (nonfatal and fatal) in the surrounding area would be significantly greater than this figure.

35. During the course of the hearing, LEA also suggested other possible genetic effects that should have been considered, such as in utero radiation injuries. The evidence indicated that such effects are a trivial fraction of the consequences to the remainder of the population Tr. 11317-18 (Goldman). Similarly, premature aging due to radiation was not considered because there is no concensus that such effect exists, and in any event represents a miniscule risk. Tr. 11341-45 (Goldman). Considering all genetic effects, the impact of the operation of the Station is small.

Contention DES-4A(2)(3) and (8)

The DES Supplement fails to adequately disclose or consider:

> (2) The total land area in which crops will be interdicted;
> (3) The total land area in which milk will be interdicted;
> (8) The population within the land areas to be interdicted.

36. In Contention DES-4A, parts (2), (3) and (8), LEA asserts that the total land area in which crops and milk would need to be interdicted, and the population within the land areas to be interdicted, were not adequately disclosed or considered. Preliminarily, contaminated areas would be identified by emergency response personnel after an accident and controls put into effect for both the ingestion of milk and crops and access to contaminated areas. Relatively simple measurements of the levels of radioactive contamination would be sufficient to identify such areas. Daebeler, et al. ff. Tr. 11114, at 34-35; Tr. 11389-90 (Kaiser). The Department of Energy ("DOE") has aircraft which have sensitive measuring devices and which could quickly measure large areas for contamination. Tr. 11391 (Levine). Such instrumentation is also available through various Federal and state agencies. Tr. 11391 (Hulman). National radiation plans and emergency plans within the NRC and DOE specifically provide for surveys of this kind. Tr. 11391-92 (Hulman, Acharya).

37. In the event of a severe accident, milk and crops would be impounded and people would be denied access to highly contaminated areas. The criteria used by the CRAC code to determine the relevant areas and population are contained in Table 4, "Dose Criteria Used in CRAC and CRAC2 to Define Interdiction Requirements," Daebeler, et al., ff. Tr. 11114, at 60. The principal impact of such actions are

economic; they would not contribute to health effects because interdiction would be employed to prevent people from accumulating radiation doses above such levels. The CRAC and CRAC2 codes were used to estimate the different areas affected by certain dose levels and the costs associated with the interdiction of crops and milk. Daebeler, et al., ff. Tr. 11114, at 35-37.

38. The areas in which crops would require interdiction are all areas within which levels of deposited strontium and/or cesium would be above the number of curies per square meter corresponding to the dose level contained in Table 4, Daebeler, et al., ff. Tr. 11114, at 60. Consequently, areas other than farmland are considered in this analysis. The fraction of farmland in Pennsylvania is 0.28, therefore, on the average only about 30% of any contaminated area would actually contain farmland in which crops and milk might have to be interdicted. Daebeler, et al., ff. Tr. 11114, at 36-37.

39. The evidence also indicated that the assumption of invariant wind direction contained in CRAC2 may result in the determination of unrealistically large contaminated areas. In actuality, the downwind range in which significant contamination could occur is generally limited to within 50 miles of the plant because of wind shifts during releases and the plume travel time. Daebeler, et al., ff. Tr. 11114, at 37-38.

40. Crop and milk interdiction, and the relocation of people from highly contaminated areas, make up less than 5% of predicted costs of a severe accident; the remainder is dominated by cost of decontamination. The estimated expected value of offsite economic risk associated with severe accidents at Limerick is $15,600 per reactor year. Thus, the

total offsite economic risk is small and the contamination effects mentioned in the contentions constitute only a small fraction of this risk. Daebeler, et al, ff. Tr. 11114, at 35-36. The Board concludes that this Contention is without merit.

Contention DES-4A(6)

The DES Supplement fails to adequately disclose or consider:

> (6) The quantification of the cost of medical treatment of health effects.

41. LEA also asserted that the cost of medical treatment was not adequately disclosed or considered. Preliminarily, the evidence indicated that the quantification of the cost of medical treatment of health effects is generally not considered in probabilistic risk assessments, but that the FES referred to a calculation which indicated that the cost of medical treatment is a fraction of the costs of other offsite consequences of reactor accidents. Daebeler, et al., ff. Tr. 11114, at 40.

42. In its response to this assertion, the Staff estimated the direct, indirect and total health care costs of the 37 different accident sequences defined in FES Table 5.11d. Direct costs are all costs associated with treatment of the patient, e.g., physician fees, hospital changes, the cost of medicines, etc. Indirect costs are those losses due to reduced productivity caused by disability or premature death. Richter, ff. Tr. 11148, at 2; Tr. 11401-02 (Richter).

43. The risk per reactor-year was then calculated by multiplying cost times the probabilities of occurrence of the various accident sequences. The accident probabilities were Limerick specific; health costs were based on national data, which the evidence indicated is not

significantly different from that of the Limerick area. The likely increase in the rate of treatment costs over the next 20-30 years was also taken into account. Richter, ff. Tr. 11148, at 2-5; Tr. 11400-01, 11407 (Richter).

44. Based on this analysis, the Staff concluded that while health costs could constitute a substantial portion of the total economic impact of a reactor accident, the probability of the more severe releases are so low that, expressed as a dollar value of risk, the cost is relatively insignificant. Richter, ff. Tr. 11148, at 5; Tr. 11416-17 (Richter). The Applicant likewise concluded that there would be a small increase in the calculated offsite economic risk if health effect costs were included in those calculations. Daebeler, et al., ff. Tr. 11114, at 40. The Board concurs.

Contention DES-4B

> By treating some environmental costs in a CCDF format and treating other quantifiable costs in a non-quantitative subjective manner, the DES format obscures the total impact of severe accidents at Limerick.

45. The evidence indicated that some environmental costs were treated in a CCDF format while others were treated non-quantitatively because of the capabilities of the models used to calculate those costs or because of their relative importance. For example, the CRAC code provides data results utilizing CCDF curves. Health care costs on the other hand are obtained using free-standing models which, because of their design, cannot provide the large numbers of simulations that CRAC provides. Therefore, their impacts are expressed as average values and the risks are expressed in a per reactor year reactor basis. Richter, ff. Tr. 11148, at 6. Obviously, one must look at the entire FES and

SARA to understand the risks associated with the operation of Limerick. As presented, (and more so as modified by this decision) these documents completely fulfill the Commission's requirements. The Board finds no legal or substantive merit to this contention.

Contention DES-3

LEA Contention DES-3 asserts that:

> The DES' severe accident consequence modeling fails to account for the probability that a portion of the population will fail to take protective action despite planning and instructions, thus understating the actual consequences of a severe accident at Limerick.

46. In its basis for Contention DES-3, LEA asserted that an EPA evacuation study by Hans and Sell, "Evacuation Risks - An Evaluation" estimated that between 6% and 50% of the population might not evacuate in the event of an emergency. Actually, the referenced study stated that approximately only 6% of the population in the evacuations studied refused to evacuate. The 50% figure was taken from a separate report quoted by Hans and Sell studying the response to Hurricane Carla in 1961. That report considered the evacuation behavior of people not only in the county in which the hurricane came ashore, but also an adjacent county, two cities located 100 miles to the northeast and an area located 200 miles away. Daebeler, et al., ff. Tr. 11114, at 24-25.

47. The inclusion of people living great distances from the eye of the hurricane invalidates the application of the non-evacuation percentage reported in that study to an emergency at Limerick. Moreover, a post-storm survey indicated that a majority of people in the affected area were not at any time advised or ordered to evacuate. Given the prompt notification systems required for nuclear plants, this could not

occur at Limerick. This conclusion is reinforced by a Sandia generic evacuation model developed specifically for nuclear power plant studies which excluded nonevacuation statistics from natural disasters such as hurricanes as inappropriate for nuclear reactor accidents because of differences in warning times, evacuation movements and the character of the accident. Daebeler, et al., ff. Tr. 11114, at 25-27; Tr. 11535-37 (Kaiser).

48. The evidence that only a very small percentage of the population in the plume exposure Emergency Planning Zone would fail to evacuate was buttressed by the report of an evacuation that took place in the vicinity of the Waterford Nuclear Station in 1982. In that case, an area of approximately 60 square miles, with the reactor situated fairly close to the center, was evacuated as a result of a non-nuclear transportation accident. The nonevacuating fraction of the population was approximately 0.2%, or 50 people out of 16,000. Significantly, the authorities knew the names and addresses of all nonevacuating individuals shortly after the accident. Tr. 11514-16 (Kaiser); Tr. 11517 (Hulman). While this evidence is sufficient to decide that people would indeed evacuate, the Board nevertheless examined the effect upon the risk evaluation if a small percentage of the population chose to remain.

49. To evaluate this effect, the Applicant modified its CRAC2 runs to include a 6% nonparticipating fraction in the evacuation and relocation model. In other words, 6% of the population out to 25 miles was assumed not to take the protective actions which the rest of the population was assumed to take, i.e., evacuation within 10 miles of Limerick or normal activities for 12 hours after plume passage with subsequent relocation for people between 10 and 25 miles from the plant. Daebeler,

et al., ff. Tr. 11114, at 27. The 6% nonparticipating fraction of the population was assumed to be uniformly dispersed throughout the area. Tr. 11503-04 (Kaiser).

50. These individuals were then assumed to remain outdoors for 24 hours after the declaration of a general emergency, which is the equivalent of two or three days of normal activity, and then to rapidly relocate. This assumption increased the predicted public risk of early fatalities by 49%, which is a small increase for calculations of this type. Other uncertainties discussed in SARA are much more significant. Daebeler, et al., ff. Tr. 11114, at 27-28; Tr. 11504-06 (Kaiser).

51. The Staff, although agreeing that the vast majority of affected persons would evacuate, also provided an alternative analysis in FES Appendix M using the "Early Reloc" mode of emergency response, which was postulated in lieu of evacuation from the 10-mile EPZ. In this scenario, those people within the footprint of the plume within a radius of 10 miles were assumed not to evacuate until six hours after the plume's passage. Beyond 10 miles, people were assumed to evacuate 12 hours after plume passage. Hulman and Acharya, ff. Tr. 11148, at 4; Tr. 11511, 11519-22, 11534-35. This model provides a measure of sensitivity of results to evacuation assumptions in that it is assumed that all individuals receive a ground dose for six hours in addition to the plume dose. Therefore, it bounds all the results of reasonable nonevacuation percentages. Hulman and Acharya, ff. Tr. 11148, at 4; Tr. 11519-22, 11529-33 (Acharya, Hulman). The Board is satisfied that using either the Applicant or Staff's approach, the risk is not significantly changed. It thus finds that this Contention has no merit.

Contention DES-1

> The DES' severe accident consequence modeling assumes the relocation of the public from contaminated areas beyond the 10 mile plume exposure EPZ. (DES, Supp. 1, pp. 5-21 to 5-22). Such an assumption in Limerick's case is implausible and without foundation in fact.

52. The evidence demonstrated that it is not unreasonable to assume that appropriate protective actions could and would be taken as necessary for persons residing beyond the approximately 10-mile plume EPZ. Both NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants," and NUREG-0654, "Criteria for Preparation of Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," indicate that actions could be taken on an ad hoc basis beyond the 10 mile plume EPZ using the same considerations that formed the initial action determinations within the 10 mile plume EPZ and that the detailed planning therein could provide a substantial base for expansion of response efforts to beyond that distance. Daebeler, et al., ff. Tr. 11114, at 10-11; Hulman and Acharya, ff. Tr. 11543, at 3-4.

53. Moreover, generic emergency preparedness planning discussions for relocation of the population beyond the 10 mile plume EPZ have taken place at the Federal level. While these discussions were of an ad hoc nature, they necessarily entail a certain degree of planning that could be applied to Limerick. This planning, plus experience gained with natural disasters and the Three Mile Island incident, indicate that it is reasonable to assume that protective actions could be taken for the population beyond the 10 mile plume EPZ. Tr. 11544, 11558-59, 11564-66 (Hulman).

54. If there were a significant release of radioactive materials from Limerick, the radioactive plume and any radioactive materials deposited on the ground would be closely monitored. Health physics teams of the licensee and State and local governments would measure and define the radioactive plume and the amount of radioactive material deposited on the ground in the area extending beyond 10 miles to identify contaminated areas in general and highly contaminated areas in particular. Daebeler, et al., ff. Tr. 11114, at 11-12; Hulman and Acharya, ff. Tr. 11543, at 3.

55. For most source terms, the probability of occurrence of early health effects among the population outside the plume EPZ is very small. For lower probability sequences, exposure to the initial radiation dose arising from airborne fission products, together with extended exposure to ground deposited fission products, could result in early health effects. To simulate the ad hoc measures that would be taken to protect the people living in such areas, it was conservatively assumed in SARA that people in the special sheltering zone extending 10 to 25 miles from the plant continued their normal activities for 12 hours after passage of the plume and then rapidly relocated. Daebeler, et al., ff. Tr. 11114, at 12.

56. The evidence indicated that the assumption of normal activity followed by rapid relocation is not the only course of action which could lead to comparable or greater dose reduction factors. For example, requesting people in the special sheltering zone to shelter in their basements for 24 hours would reduce the radiation dose; sheltering in schools or other large buildings would afford even greater protection. The assumption of 12 hours of normal activity followed by

rapid relocation is merely a calculational convenience reflecting the reduction in radiation dose that could be achieved in various ways. Daebeler, et al., ff. Tr. 11114, at 13-14. The Board finds this to be a reasonable approach.

57. The Applicant also conducted a series of sensitivity runs using CRAC2 to determine the effects of alternative modeling assumptions concerning shielding and relocation. Even utilizing conservative relocation assumptions, these runs indicated that the results are insensitive, i.e., a factor of two or less, to such assumptions. Daebeler, et al., ff. Tr. 11114, at 14-15, 57. Thus, the conclusion is clear that the treatment of population relocation outside the 10-mile plume exposure EPZ presents a reasonable estimate of the risk to that population.

58. Moreover, contrary to LEA's assertions, it is extremely unlikely that it would be necessary to relocate large numbers of people in the event of a radiological release. Of the 680,000 people projected to be in Sector SE between 10 and 25 miles from the plant, only 117,000 would be within 20 miles. Of the approximately 500,000 people projected to be in Section ESE between 10 and 25 miles in the year 2000, only 169,000 would be within 20 miles. Even if protective actions were not taken for 48 hours, the likelihood of any persons in these sectors beyond 20 miles receiving a large dose, i.e., 200 rem bone marrow over 48 hours, is approximately one in 750 million per year. The potential that persons beyond 20 miles could accumulate radiation doses over 48 hours sufficient to lead to clinically detectable early effects, i.e., 25 rem whole body dose, is only one in 16 million per year. Daebeler, et al., ff. Tr. 11114, at 15-16.

59. The Staff conducted runs to estimate the number of persons that might have to be relocated from outside the 10-mile EPZ in the event of a large atmospheric release of radionuclides. It assumed that all persons for whom the projected 7-day ground dose would be more than 200 rems to the total bone marrow would be relocated. Utilizing all release categories in FES Table 5.11c that are not initiated by severe earthquakes, it determined that the probability that 5,000 or more persons would be affected is 1×10^{-6} per reactor-year. The probability that 50,000 or more persons would be affected is about 1×10^{-7} per reactor year; the probability that 300,000 or more would be affected is about 1×10^{-8} per reactor year. Hulman and Acharya, ff. Tr. 11543, at 4-5; Tr. 11560-61 (Acharya).

60. Even if it were necessary to relocate large numbers of people, the evidence indicated that such evacuations have taken place quite expeditiously in the past. For example, Baton Rouge, Louisiana, population 150,000, was almost totally evacuated within two hours following an accident involving a chlorine barge. Wilkes Barre, Pennsylvania, population 75,000, was efficiently evacuated to a level of 96% in one hour after a flood warning. Downtown Portland, Oregon, population 100,000, was evacuated in one hour during a civil defense exercise. In Mississauga, Ontario, Canada's ninth largest city, 216,000 people were evacuated from a 50 square mile area around the accident site within 24 hours following the derailment of a freight train carrying flammable and toxic materials. Therefore, there is clearly precedent for the _ad hoc_ relocation of large numbers of people. Daebeler, _et al_., ff. Tr. 11114, at 16-17.

61. With regard to the Staff's assumption regarding the criteria for relocation, i.e., 200 rems to the total bone marrow in 7 days, the evidence indicated that 200 rems delivered to the total bone marrow over a short period of time constitutes the threshold level for early fatalities in the absence of medical treatment. The evidence further indicated that although a 7-day period was utilized in the relocation criteria, protective actions would be taken long before these levels were reached. Tr. 11561-64 (Acharya, Hulman). They were used for this analysis only because they yield more conservatively stated health effects than would a lower criterion. The Board finds that the assumptions used by the Applicant and Staff to model the relocation of individuals within the 10 to 25 mile range from the plant to be reasonable and the Contention to be without merit.

Contentions DES-2 and CITY-14A

Contentions DES-2 (LEA) and CITY-14A assert that:

DES-2 (LEA)

> The DES' severe accident consequence modeling uses an assumption of a uniform two-hour evacuation delay time in its emergency response model. (DES, Supp. 1, pp 5-21 to 5-22). This assumption understates the likely delay time for a high population density site such as Limerick. This understatement of delay time results in an understatement of Limerick's risk, because accident consequence calculations are sensitive to evacuation time delay assumptions.

CITY-14A

> The DES does not accurately reflect either the median or upper estimates of the radiological effects which could result from an accident at Limerick because several key input assumptions associated with human activity after a severe accident are not realistic.

(a) The base case average evacuation time of 2.5 mph is based on an 1980 study which is now inaccurate. See also Statement of Issues of the Commonwealth of Pennsylvania with Respect to Offsite Emergency Planning, January 30, 1984.

62. DES-2 asserts that the likely delay time for a Limerick-related evacuation is understated because of the high population density surrounding the site. As reflected in the Hans and Sells study, the time required to evacuate an area does not increase, but rather appears to decrease, with population density increases. As applied to Limerick, population density _per se_ is not a sufficient reason for modifying the evacuation delay time. Daebeler, _et al_., ff. Tr. 11114, at 19-21.

63. LEA further contended that the Sandia Generic Study, which gives a mean delay time of three hours, implies that a longer delay time for Limerick would be incurred because of its higher than average population density. To the contrary, the Hans and Sell report, upon which the Sandia Generic Study is based, contains examples of evacuations from areas with population densities greatly exceeding the 700 persons per square mile located within 10 miles of Limerick. Again, it would be inappropriate to increase the delay time for Limerick simply because the population density surrounding it is higher than average. Daebeler, _et al_., ff. Tr. 11114, at 21.

64. In order to examine the effects of changes in delay times and evacuation speeds on the risk results, the Applicant performed sensitivity analyses using various delay time and evacuation speed parameters, the results of which indicated that the FES and SARA models produce risk estimates that do not greatly differ even though the two models use different delay times and evacuation speeds. The Applicant

also conducted further sensitivity studies in which the evacuation clear times were varied from four to 13 hours and another case in which the delay times (one, three and five hours) were combined with a 2.5 mph evacuation speed. The results did not vary from the SARA base case by more than a factor of approximately two and all were within a factor of three of the results generated using the FES evacuation model. Given the range of uncertainties that apply to such estimates, these are small changes. Therefore, predictions of public risk do not differ significantly when evacuation speeds are varied from 2.5 to 10 mph and when large variations in total evacuation time are taken into account. Daebeler, et al., ff. Tr. 11114, at 22-23, 58.

65. The Staff's evidence indicated that a two hour evacuation delay time as used in the FES is quite reasonable. Inasmuch as Limerick will have an emergency plan in place; that periodic testing of the notification systems and procedures is conducted; and that exercises and drills maintain the emergency plan in constant readiness, it is very unlikely that the mean delay time before evacuation could be significantly higher than two hours. The evidence additionally indicated that this delay time is appropriate even for moderately adverse site conditions such as light snow, ice, and moderately severe hurricanes and earthquakes. Hulman and Acharya, ff. Tr. 11543, at 6-7. Accordingly, the assertions put forward in Contentions DES-2 and CITY-14A are without basis and the Board finds that the challenged modelling assumptions are reasonable and that even substantial variations would not significantly affect the Applicant and Staff's conclusions.

Conclusions of Law

66. Based on the foregoing Findings of Fact, which are supported by reliable, probative and substantial evidence as required by the Administrative Procedure Act and the Commission's Rules of Practice, and upon consideration of the entire evidentiary record in this proceeding, the Board reaches the following conclusions pursuant to 10 C.F.R. §2.760a:

a. The specific genetic effects enumerated by LEA are not required to be disclosed to fulfill the requirements of NEPA; however, they have now been adequately disclosed and discussed and have been appropriately factored into the environmental analysis.

b. It was not necessary to separately disclose the total land area in which crops and milk would be interdicted, or the population within the land areas to be interdicted; however, they have now been adequately disclosed and discussed and have been appropriately factored into the environmental analysis.

c. It was not necessary to separately disclose or consider the quantification of the cost of medical treatment of health effects; however, this cost has now been adequately disclosed and discussed and has been appropriately factored into the environmental analysis.

d. The treatment of some environmental costs in a CCDF form and others in a nonquantitative manner does not obscure the total impact of severe accidents.

e. The consequence modelling appropriately accounts for the possibility that a portion of the population might fail to take protective actions; even reasonable variations in this factor would not change the conclusions reached.

f. The consequence modelling regarding relocation of the public from areas beyond the 10 mile plume EPZ is reasonable; reasonable variations in this factor would not change the conclusions reached.

g. Consideration of these contentions does not alter any of the conclusions in the FES nor does it affect the cost benefit balance contained therein.

h. With respect to the requirements of section 102(2)(A), (C) and (E) of the National Environmental Policy Act, and in accordance with 10 C.F.R. Part 51, the operating licenses should be issued as proposed.

PARTIAL INITIAL DECISION
(ON CONTENTIONS CITY-13 AND CITY-14)

Preliminary Statement

1. On February 14, 1984, the City of Philadelphia ("City" or "Philadelphia") filed, inter alia, Contentions CITY-13 and CITY-14. In our unpublished "Order Confirming Rulings and Schedule Made at Special Prehearing Conference on NEPA Severe Accident Contentions," dated April 20, 1984, Contentions CITY-13 and CITY-14 were admitted in part. Evidentiary hearings on these contentions took place in Philadelphia, Pennsylvania on May 29-30, 1984.

Summary

2. The Board has analyzed Contentions CITY-13 and CITY-14 and determined that they have no merit. With respect to CITY-13, we examined the FES and SARA and determined that both analyses had taken the population of Philadelphia into account in calculating the risk associated with a postulated severe accident at Limerick. We also determined that data pertinent to the risks to the population of Philadelphia was contained in or could be derived from those documents, or was unnecessary. Nonetheless, we examined the dose-distance curves and specific probability-consequence relationships developed for the City of Philadelphia for this hearing and concluded that the level of societal and individual risk from severe postulated accident releases for this population is extremely small.

3. While recognizing that as part of the basis of a contention it has no evidentiary weight, we also examined the example cited by the City regarding the effects of an accident on Philadelphia. Our review

indicated that this example shed little light on the risk associated with the operation of the Station because it presented only the consequences of various postulated accidents without any concern for their associated probabilities. Clearly, consequences cannot be appropriately viewed separately from probabilities in terms of risk analysis.

4. In any event, our review of the City's assertion that exposure from severe accidents could reach 10.5 million person-rem and result in as many as 8,400 latent induced cancers, including 4,200 latent cancer fatalities, indicated that claim was highly unrealistic. First, the dose response relationship used by the City to convert dose to latent cancers approached the upper end of the range of uncertainty of that relationship, thus lessening its validity for that purpose. Second, the City did not apply the central estimate for determining health effects to the figure of 10.5 million person-rem. Finally, as noted above, the City's analysis did not associate the results it obtained with their frequency of occurrence. The Applicant and Staff, on the other hand, took these factors into account. Thus, we conclude that the Staff and Applicant's analyses accurately represent the expected results of such severe accidents, and that those results are small compared to the risk from non-nuclear hazards and the normally occurring risk of cancer fatalities.

5. With respect to the City's assertion that CCDF's and dose distance relationships should have been provided specifically for Philadelphia, we examined the time, effort and expense that would be required and the limited contribution that would be made to the understanding of the risk to Philadelphia and concluded that it was

unnecessary to provide such information. Nevertheless, dose distance curves were prepared by the Applicant and are now part of the record.

6. With respect to the City's assertion that evacuees would be slowed up on the outskirts of Philadelphia, thus increasing the radiological effects of an accident at Limerick, we first examined whether evacuees would be traveling in the same direction as the plume and concluded that emergency planners would have sufficient knowledge to determine the plume's direction and would instruct people to follow routes that would enable them to avoid the plume. Nonetheless, we examined what would happen if evacuees were exposed to the plume for some time. We concluded that even if this event were to occur, there is only an extremely small probability that the evacuees would accumulate significant additional doses.

7. Finally, we examined whether the health effects of an accident postulated to occur during bad weather were fully considered. We concluded that the Staff and Applicant's methods of sampling weather conditions and integration of them into their CRAC and CRAC2 analyses, respectively, fully considered the complete range of weather consequences, including bad weather.

8. As discussed below, we therefore conclude that the risks to the citizens of Philadelphia were fully considered and presented by the Staff and Applicant and that such risks are very low and not disproportionate to the risks of all individuals living in the area surrounding the Station; that evacuees would not be trapped on the outskirts of Philadelphia, and even if they were, would not incur substantially increased doses; and that the health effects of bad weather conditions

were fully considered and found not to pose a serious risk to Philadelphia.

Contention CITY-13

CITY-13 Consequences to the citizens of Philadelphia in terms of dose-distance relationships are not presented in the DES analysis, nor, in fact are such consequences for any area. The absence of this explicit data makes it impossible for this Commission to accurately ascertain the likelihood of the public receiving doses in excess of Protective Action Guide ("PAG") levels, or in excess of some other unacceptable level of societal risk, at, for example the 21 miles which is the distance a plume would have to travel to reach the City of Philadelphia. Computer analysis by the City has developed preliminary specific dose-distance consequence data for the high density Philadelphia area.* These findings raise serious questions about the adequacy of the DES.

Under these values, should there be a severe accident at Limerick with the winds moving toward the SE Sector, the chance of citizens of Philadelphia receiving a whole-body dose of 5 rems at the City boundary 21 miles down wind from Limerick is 70%; the chance of a 30 rem dose is 40%. (At the eastern boundary of the City on the Delaware River, some 30 miles from the plant, the public has a 55% chance of receiving a 5 rem dose and 15% chance of 30 rems). In 50% of such severe accident releases, given wind direction toward Philadelphia, the total exposure within the SE Sector in the 20-30 mile range could reach 10.5 million person-rems. This could result in as many as 8,400 latent induced cancers including 4,200 latent cancer fatalities.

*For purposes of this presentation source terms from the DES case II-T/WW were used. This sequence is 1/500,000. The ingestion pathway assumptions as to no protective action as developed in NUREG-0396, were also used for these purposes. This analysis is not in all respects one that would be presented, for example, in testimony. It is a limited analysis made under constraint of the filing deadline for the sole purpose of presenting some dose-distance data and some high density population data to the Board to demonstrate the seriousness of the City's contentions.

9. Contention CITY-13 initially alleges that consequences to the City of Philadelphia were not presented in terms of dose-distance relationships. The evidence indicated, however, that both the Staff and Applicant accounted for the population of Philadelphia in calculating the societal risk associated with Limerick by using the CRAC and CRAC2 codes which utilize actual site meteorological data and the population around the facility, including that of the City of Philadelphia. The evidence further indicated that it was unnecessary in terms of disclosing the environmental risk to prepare dose-distance curves specifically for the sectors including the City inasmuch as this is merely another way of presenting accident results which had already been used in deriving the risk values presented in the FES. Daebeler, et al., ff. Tr. 1114, at 44-45; Tr. 11783-84 (Levine).

10. Nonetheless, in order to specifically respond to the contention, the Applicant developed a family of dose-distance curves for the sectors, SE and ESE, which encompass Philadelphia. Tr. 11779 (Kaiser). These curves, which present the whole body dose and thyroid dose, were calculated using the CRAC2 code in a way similar to that employed in SARA for the calculation of CCDF's, except that an intermediate result, i.e., dose versus distance curves for a given direction, were selected. The CRAC2 runs, which utilized the source terms summarized in SARA Tables 12-7 and 12-8 (Applicant's Ex. 152), were used to calculate the individual whole body dose and individual thyroid dose as a function of distance using the assumptions set forth in SARA, with the following major exceptions: (1) the radiation dose from inhaled

radionuclides was integrated to one year and (2) people between 0 and 50 miles were assumed to continue their normal activities for 24 hours. These assumptions were made in order to be consistent with the way in which dose-distance curves are calculated in NUREG-0396, the reference contained in the statement of the contention. Daebeler, et al., ff. Tr. 11114, at 45-46. The relationships presented by these curves indicate that the level of societal and individual risk arising from severe but low probability postulated accidental releases from Limerick is extremely small for people within the City of Philadelphia. Daebeler, et al., ff. Tr. 11114, at 44 and Figures 2 and 3; Tr. 11780-81 (Kaiser).

11. Additional results pertinent to the risk to the citizens of Philadelphia, including the predicted frequency with which there might be one or more early fatalities, one or more persons with bone marrow doses in excess of 200 rem, or one or more persons with whole-body doses in excess of 25 rem, were calculated by the Applicant to provide further perspective. These results were calculated using the methods described in Chapter 10 and Appendix F of SARA, except that it was assumed that emergency countermeasures were not taken for 48 hours, which is even more conservative than the NUREG-0396 type results presented in the whole body dose-distance curves. The only population considered in these runs was that of the City of Philadelphia; consequently, their results apply specifically to Philadelphia. Even using the conservatisms discussed above, the predicted risks to Philadelphia inhabitants were found to be extremely small. Daebeler, et al., ff. Tr. 11114, at 46, 64, 65; Tr. 11784-85 (Kaiser).

City Analysis

12. As part of Contention CITY-13, the City stated it had done an analysis in which it developed preliminary dose-distance consequence data specifically for the Philadelphia area and which it claimed raised questions about the adequacy of the FES. The City presented no witnesses, however, and this example, therefore, has no evidentiary weight. Nevertheless, the results were analyzed by the Applicant and Staff and were shown to be without significance. Preliminarily, the results of the City's analysis do not provide useful insights into the effects of severe accidents on Philadelphia because of the way in which they were calculated and presented. The City calculated only the consequences of various postulated accidents. To put such an analysis into proper perspective, it is necessary to combine this information with the frequency of such consequences, which can only be done by factoring in the probabilities concerning how often an event is likely to occur, i.e., including the predicted frequency of the accident sequence itself. It is universally accepted that in measuring risk the use of anything less than the absolute values of probabilities and consequences is not very productive. Daebeler, et al., ff. Tr. 11114, at 46-47; Tr. 11781-83 (Kaiser), 11786-90 (Kaiser, Levine).

13. A more helpful perspective would have been provided by factoring in the frequency of occurrence of a case such as the release category II-T/WW, which was used in the City's analysis and whose frequency of occurrence is 1/500,000; and the probability of the wind blowing towards the SE and ESE sectors of Philadelphia, which is 0.27. Using the frequencies provided in the FES and the conditional probabilities provided in the Contention itself, the evidence established that the probability

of exceeding 5 rem or 30 rem in the City of Philadelphia is very small and, more importantly, that such doses would not lead to clinically detectable early effects. Daebeler, et al., ff. Tr. 11114, at 46-47.

14. Based on its analysis, the City also asserted that the total exposure within the SE sector in the 20-30 mile range could reach 10.5 million person-rem and could result in as many as 8,400 latent induced cancers, including 4,200 latent cancer fatalities. The conversion of 10.5 million person-rem to 4,200 latent cancer fatalities implies a dose-response relationship of about 400 fatalities per million man-rem. The evidence indicated that this figure approaches the upper end of the range of this relationship and does not reflect the concensus of experts of the use of such relationships. By contrast, in CRAC2 the corresponding point estimate relationship is about 168 fatalities per million man-rem. Daebeler, et al., ff. Tr. 11114, at 48. The Board finds that this latter value is proper for use in predicting the expected risk.

15. The evidence further indicated that since 10.5 million person-rem spread out over the population of Philadelphia corresponds to approximately 5 rem per person, the central estimate must be applied and a further reduction of this figure by a factor of five is in order. See Applicant's Ex. 152, at pp. 10-15. Thus, the 10.5 million person-rem could actually be expected to lead to approximately 350 fatalities, which would be spread out over a period of about 30 years, or approximately 12 per year. This compares with a death rate due to cancer from all causes of about 4,500 per year. Tr. 12116 (Levine). Furthermore, these results must be associated with their frequency of occurrence, which is calculated by multiplying 1/500,000, the probability of the source term, times 0.27, the probability the wind would be blowing

towards the City, times 0.5, the figure representing the occurrence of less favorable diffusion conditions referenced in the Contention, for a probability of an event occurring in any one of the two sectors comprising Philadelphia of 3×10^{-7}, or approximately one chance in three million. Daebeler, et al., ff. Tr. 11114, at 48; Tr. 11821 (Kaiser).

16. The Staff also calculated the conditional downwind individual whole-body dose from early exposure versus distance utilizing release category II-T/WW, which represents one of the worst accident sequences analyzed in the FES. The results of this analysis indicated that the conditional mean values of downwind individual whole body dose from early exposure in the Philadelphia area would be 27 rems within a radius of 20-25 miles and 16 rems within a radius of 25-30 miles. Hulman and Acharya, ff. Tr. 11543, at 23.

17. On this basis, the Staff calculated that the conditional mean values of population exposures from early exposure would be about 18 million person-rems in the SE sector within 20-30 miles and about 13 million person-rems in the ESE sector within the same distance. It then determined that there could be approximately 1,100 latent cancer fatalities within 20-30 miles if the wind were blowing in the SE direction and about 800 latent cancer fatalities if the wind were blowing in the ESE direction, each figure conditional upon the occurrence of the accident. As indicated in FES Table 5.11e, the probabilities of the wind blowing towards the SE and ESE directions are 16% and 11%, respectively. Additionally, the probability of occurrence of release category II-T/WW is about 2×10^{-6} per reactor year. Therefore, the probability of a II-T/WW type accident impacting inhabitants of the SE sector is 3×10^{-7} per reactor year, and 2×10^{-7} per reactor year for people in

the ESE sector, for a combined probability of 5 x 10^{-7}. Hulman and Acharya, ff. Tr. 11543, at 23-24; Tr. 11856-65 (Acharya). As noted previously, the Applicant had calculated this probability to be 3 x 10^{-7}, an insignificant difference. The evidence otherwise indicated that the Staff's estimate of 18 million person-rem and the City's estimate of 10.5 million person-rem are of the same order. Tr. 11819, 11821 (Kaiser).

Specific Information for Philadelphia

18. Finally, the City contended that CCDF's and dose distance relationships should have been provided in the FES specifically for Philadelphia. The evidence established that the development of such information would add nothing to the overall understanding of risks and consequences and that the risk to Philadelphia was calculated along with that to the rest of the surrounding area in any event. Moreover, the information contained in the FES can be used to calculate the impact on any population in any direction from the plant up to 50 miles, including the City of Philadelphia. However, the value of such an exercise on the record is not apparent. By way of illustration, any CCDF prepared specifically for Philadelphia would have to be smaller than those presented for the entire region. Therefore, the information contained in the FES is that which a decision on environmental impacts should be based and upon which the public should be informed of the severity of those impacts. Tr. 11653-54, 11657-58 (Levine); Tr. 11833-36 11848-51 (Acharya, Hulman).

19. The reason why the FES does not present the results of calculations specifically for the City is also clear from an examination of Table 8 appended to the Applicant's testimony. As indicated in this

table, the chances that there would be one or more early fatalities in Philadelphia is essentially the intercept on the frequency axis of the CCDF for early fatalities for the City only. If that CCDF were plotted, it would be only a tiny curve in the corner, thus indicating the small contribution of the City. This contribution would, of course, change with the effect in question, but would always be small. Tr. 11647-48, 11653 (Kaiser).

20. Aside from the fact that the information necessary to ascertain the risk to Philadelphia is already presented in the FES, it would take a great deal of time, effort and expense to develop the specific information requested by the City, all of which the evidence has indicated would be of no corresponding benefit. A large number of computer runs would have to be conducted to single out Philadelphia as a population group. Moreover, the inclusion in the FES of conditional individual dose instance curves for all accidents would result in a substantial increase in the bulk of the Staff's assessment to several times its current size without providing any additional perspective regarding important impacts. Tr. 11831-37, 11839-49 (Hulman, Acharya). The Board finds this contention to have no merit.

<u>Contention CITY-14(b) and (e)</u>

> The DES does not accurately reflect either the median or upper estimates of the radiological effects which could result from an accident at Limerick because several key input assumptions associated with human activity after a severe accident are not realistic.
>
> (b) Not included in the base case is the known phenomenon that as evacuees approach the City outskirts, their speeds would reduce, backups would occur and consequences due to trapped evacuees would increase.

(e) The DES does not separately portray the health consequences of an accident under a bad weather scenario. Many weather scenarios, including theoretically bad weather conditions, are averaged together.

Contention CITY-14(b)

21. The CRAC and CRAC2 codes assume that the wind direction is invariant and that the evacuating population moves radially. These assumptions are solely a calculational convenience and do not reflect the actual planned or expected situation. Daebeler, et al., ff. Tr. 11114, at 3, 50; Hulman and Acharya, ff. Tr. 11543, at 14-15. As a practical matter, the plume direction and the evacuees' direction of travel would be variable and would not likely coincide. Thus, the plume and any evacuees that might be initially headed toward Philadelphia would not likely arrive together or in succession in Philadelphia or its outskirts. Hulman and Acharya, ff. Tr. 11543, at 15. More importantly, the personnel implementing the emergency plan would be aware of the direction of the plume and would advise evacuation routes by which the plume could be avoided. Thus, it is unlikely that large numbers of people would evacuate towards Philadelphia if the plume were blowing in that direction. Rather, they would evacuate laterally or crosswind. Daebeler, et al., ff. Tr. 11114, at 50-51; Hulman and Acharya, ff. Tr. 11543, at 15-16.

22. Nonetheless, the Staff made additional calculations specifically to bound the estimates of what would happen if large numbers of people evacuated towards Philadelphia in conjunction with plume travel in that direction and were stranded on the outskirts of the City for some time. Specifically, the Staff assumed that all evacuees in the

plume exposure pathway from within the 10-mile EPZ in the SE and SSE sectors traveled directly towards Philadelphia and became stranded 20 to 25 miles from the plant, i.e., in Philadelphia and its outskirts, before the plume arrived. This assumption is bounding because many evacuees would obviously not go toward the City if the plume were moving in that direction. Hulman and Acharya, ff. Tr. 11543, at 16-17; Tr. 11710-12, 11714-16, 11723-26 (Hulman, Acharya).

23. Moreover, the evacuees were assumed to have incurred 12 hours of ground exposure before relocating; this prior exposure was included within the exposure they were assumed to incur during the course of their normal activities in the Philadelphia area. The shielding factors utilized by the Staff during the delay time before evacuation were .75 for cloudshine and .33 for groundshine. The shielding factors assumed during evacuation were 1.0 for cloudshine and .5 for groundshine. The shielding factors assumed for all other times were those associated with normal activities. The City asserted that it would have been more realistic to utilize the shielding factors associated with evacuations rather than those associated with normal activities for the evacuees assumed to be stranded in and around Philadelphia. The evidence indicated, however, that the shielding factors associated with normal activities are more realistic because the taller, more closely packed structures in the City and its suburbs would reduce cloudshine and open ground contamination. Thus, the use of the normal activities shielding factor was more appropriate for those people assumed to be delayed around Philadelphia. Tr. 11712-16, 11721-28 (Acharya, Hulman).

24. The results of the Staff's studies of this scenario were presented in separate tables. Preliminarily, the latent health effects

listed on Table 3 apply to the entire 360° area surrounding the plant. Table 4 includes this information and also reflects the additional health effects that would be incurred by the supplemental population from the SE and ESE sectors within 10 miles of the plant that were assumed to be stranded on the outskirts of Philadelphia. Thus, the latent health effects that could be ascribed solely to this population could be derived by comparing Tables 3 and 4. Tr. 11721-22, 11738-40 (Acharya). These differences, which were presented in Table 2 on an expected risk basis per reactor year, are very small. Moreover, the evidence further indicated that even if evacuation sheltering factors were used instead of the more appropriate normal activity sheltering factors, the risk per reactor year would not change significantly from that depicted in Table 2 and that any such increase would be lost in the background of uncertainty. Tr. 11753-57 (Hulman, Acharya). Based on these calculations, it is clear that there would be no appreciable increase in the risks and the corresponding CCDF's. Finally, as indicated by the foregoing, the risks from such a postulated scenario were already adequately represented by the estimates provided in the FES. Hulman and Acharya, ff. Tr. 11543, at 17.

25. The Applicant's analysis of this issue likewise proved that there is only a very small probability that additional significant radiation doses could be accumulated by persons assumed to be delayed on the outskirts of Philadelphia, even if the delay amounted to a number of hours. The City contended, however, that these results were inapplicable to its postulated scenario because the shielding values used by the Applicant were developed for the normal activity case and not specifically for an evacuation scenario. The evidence, however, indicated

that the health effects calculated by the Applicant would not increase if the case were run using evacuation shielding factors because the normal activity case used in the Applicant's analysis assumed a long period, i.e., 48 hours, of normal activity. Clearly, evacuees would not be delayed in their automobiles for any length of time approaching 48 hours. Therefore, even though the shielding factors while evacuating are not quite as low, the additional time factor would more than compensate for this effect and the consequences would not be greater. Tr. 11632-36 (Kaiser).

Evacuation Speed

26. The City also queried whether the 2.5 mph evacuation speed used in the FES properly accounted for the population densities in the direction of Philadelphia. Preliminarily, the 2.5 mph evacuation speed is based on the evacuation time estimate for 0-10 miles and does not apply beyond that distance. The evidence indicated that this query is irrelevant in any event because when the wind is blowing toward Philadelphia, people would evacuate crosswind rather than radially and thus would not be traveling toward the City. Moreover, the sectors in the direction of Philadelphia are not unique in terms of population density. For example, in the ESE sector towards Philadelphia there are 31,000 people between 10 and 12.5 miles; there are 21,000 people in this range in the SE sector. Away from Philadelphia towards the south there are 18,000 people between 10 and 12.5 miles. To the WNW there are 25,000 people in this range. Tr. 11636-40, 11644-45 (Levine, Schmidt, Kaiser). Finally, a slowing down effect on the outskirts of the City was accounted for in the low evacuation speed used in the FES in any event. The 2.5 mph evacuation speed used in that document is an average

over the total distance traveled by the evacuees and, therefore, accounts for a certain amount of time spent moving slowly in congested conditions such as were postulated to occur on the outskirts of Philadelphia. Daebeler, et al., ff. Tr. 11114, at 51; Tr. 11642-43 (Kaiser).

27. The City also questioned whether changes in the wind direction might make it impossible to determine which way the plume would be traveling. The evidence indicated that meteorological instrumentation at the plant and the Philadelphia Airport weather service would indicate the wind direction in the event of an accident. Also, additional meteorological equipment could be sited and used if necessary. Moreover, based on their familiarity with meteorological conditions and wind direction changes, emergency planners would likely know in advance which direction the wind would be blowing. The persistence factor at Limerick, which is a measure of variability in wind direction, is very high, i.e., it is likely that the wind will blow in the same direction as the previous hour. Finally, if the wind changed from a direction away from Philadelphia to a direction towards Philadelphia, it would have to travel a longer distance and would thus be at lower concentrations and would have a lesser impact on the public health. Tr. 11644-46 (Daebeler, Levine); 11696-700, 11751-53, 11767-72 (Hulman, Acharya). The Board concludes that the approach of evacuees towards the City has been adequately treated in the severe accident risk analyses and that this Contention has no merit.

Contention CITY-14(e)

28. Contrary to the City's contention, various weather conditions were integrated into the Staff and Applicant's calculations. Specifically, the Staff used a stratified sampling program based on the sampling programs used in WASH-1400 whereby weather conditions were sampled on a four-day, 13-hour basis during a representative base year to obtain a reasonably large number of weather samples; the 13-hour difference was used to add in weather scenarios alternately associated with the AM and PM hours of a day. This succession of times enabled the consideration of a representative number of good and bad weather scenarios. The base year for this analysis was 1976. The evidence indicated that 1976 is representative of the other years of record and that studies have found that the use of different years of meteorological data do not produce distinctly different CRAC results in any event. Also, a review conducted by the Applicant found that there is no substantial difference in using one year of data or data for five years at one time in the CRAC runs. Hulman and Acharya, ff. Tr. 11543, at 19; Tr. 11761-65 (Acharya, Hulman).

29. The four-day, 13-hour sampling process produced ninety-one sequences of hourly weather conditions. Each severe accident was then postulated to occur at each of the 91 different start times. Each start time was associated with its own progression of weather conditions, leading to an associated set of consequences for the particular accident. Contrary to the City's assertion, the weather conditions used in these runs were not averaged. Only the consequence magnitudes were averaged to obtain a conditional (upon occurrence of the accident) mean value of the consequences. Accident consequences for each of the 91

sequences of weather conditions, computed separately, are included in the CCDF curves presented in the FES. Hulman and Acharya, ff. Tr. 11543, at 18; Tr. 11743-45 (Hulman).

30. Various weather sequences were taken into account in the Applicant's CRAC2 analysis. Specifically, weather sequences were sorted into 29 bins spanning the range of weather conditions that might be encountered. These bins were designed to include, inter alia, bad weather sequences, i.e., those conditions such as rain that would maximize the number of health effects. The weather sequences from each bin were then sampled by the CRAC2 code as it calculated the CCDF's, thus ensuring that all weather sequences were included in the calculation of the consequences of reactor accidents. Generally, the most severe consequences that arise from such weather conditions are explicitly displayed at the right-hand end or "tail" of each CCDF. Daebeler, et al., ff. Tr. 11114, at 52; Tr. 11647, 11672, 11685 (Kaiser).

31. While the evidence indicated that it was possible that a few weather scenarios worse than those that were sampled may have not occurred during the sampled start times, it also indicated that such an occurrence would be of little import. Although uncertainties would be introduced into the tail ends of the CCDF's both in consequence magnitudes (which could be somewhat higher) and in probabilities (which would be lower), the risks, as portrayed in the areas under the CCDF's, would remain largely unaffected inasmuch as those areas tend to be dominated by lower consequence, higher frequency events. Daebeler, et al., ff. Tr. 11114, at 53; Hulman and Acharya, ff. Tr. 11543, at 19-20; Tr. 11671-72, 11683-84 (Kaiser); Tr. 11745 (Acharya).

32. To bound the impact of bad weather scenarios on the projection of risk from Limerick, the Staff utilized the Early Reloc mode of offsite emergency response, which was meant to be used only for very bad weather scenarios, for all weather sequences. As described in the FES, this response mode was intended to cover adverse site conditions that would cause long delays before evacuation, i.e., six hours. The use of this mode indicates that even if long delays were to occur all of the time, the public risk of early fatalities from causes other than severe earthquakes would increase by only a factor of four. The inclusion of severe earthquakes in this analysis shows only a very small change in the predicted risk of early fatalities. Thus, as indicated by this bounding analysis, the increase in public risk that would follow an explicit inclusion of bad weather into the analysis would be very small. Hulman and Acharya, ff. Tr. 11543, at 20; Tr. 11744 (Acharya, Hulman); Daebeler, et al, ff. Tr. 11114, at 53; Tr. 11680-81 (Kaiser).

33. Although some allowance was made for bad weather within the CRAC2 evacuation model used in SARA since the data base upon which that model was predicated included fog, rain and snow, the Applicant nonetheless performed a sensitivity study to determine what additional effects there might be from weather conditions which would produce a serious reduction in evacuation speed. In this study, the Applicant chose 4% as an upper bound time for which weather conditions would be such that the assumptions for evacuation speeds for the seismic evacuation case, i.e., 3-hour delay and 1 mph evacuation speed, would be appropriate. The evidence indicated that this assumption is conservative inasmuch as the Department of Commerce has determined that the snowfall in the

Philadelphia area exceeds one inch only 5-10 days per year. Daebeler, et al., ff. Tr. 11114, at 54; Tr. 11681-83 (Kaiser).

34. Using the methodology set forth in SARA to calculate risk, the Applicant determined that slowing the evacuation speed to 1 mph with a three hour delay 4% of the time would increase the results by less than 5%, a very small figure, especially given the magnitude of the uncertainties in such an analysis. Although the Applicant did not calculate what would happen if bad weather occurred a greater or lesser percentage of the time, the evidence indicated that there would be essentially a linear effect over this range. Thus, if bad weather occurred only 2% of the time, the increase in risk would be only approximately 2.5%. Daebeler, et al., ff. Tr. 11114, at 54; Tr. 11681-83 (Kaiser). The Board finds that the effects of adverse weather have been adequately treated in the severe accident risk analyses and that this Contention has no merit.

Conclusions of Law

35. Based on the foregoing Findings of Fact, which are supported by reliable, probative and substantial evidence as required by the Administrative Procedure Act and the Commission's Rules of Practice, and upon consideration of the entire evidentiary record in this proceeding, the Board reaches the following conclusions pursuant to 10 C.F.R. §2.760a:

a. Consequences to the citizens of Philadelphia from a release of radioactive material as a result of postulated severe accidents at Limerick have been specifically accounted for or presented. The societal and individual risks resulting from severe accidental releases from Limerick for people within the City of Philadelphia are extremely small.

b. The severe accident analyses conducted by the Applicant and NRC Staff accurately reflect the estimates of radiological effects that would result from an accident at Limerick. Evacuees would be directed away from Philadelphia if the plume were blowing in that direction and would not incur additional exposure. Even if there were extended exposure of the evacuating people, their exposure levels would not be appreciably increased.

c. The weather scenarios examined in the Applicant and Staff's analyses did not average bad weather conditions together. The consequences of accidents postulated to occur during bad weather conditions are evaluated in those analyses.

d. Consideration of these contentions does not alter any of the conclusions in the FES nor does it affect the cost benefit balance contained therein.

e. With respect to the requirements of section 102(2)(A), (C) and (E) of the National Environmental Policy Act, and in accordance with 10 C.F.R. Part 51, the operating licenses should be issued as proposed.

PARTIAL INITIAL DECISION
(ON CONTENTION CITY-15)

1. On February 14, 1984, the City of Philadelphia ("City" or "Philadelphia") filed, inter alia, Contention CITY-15. In our unpublished "Order Confirming Rulings and Schedule Made at Special Prehearing Conference on NEPA Severe Accident Contentions," dated April 20, 1984, we admitted Contention CITY-15. As admitted, this Contention states that:

> The DES does not adequately analyze the Contamination that could occur to nearby liquid pathways, and the City's water supplies sources therefrom, as a result of precipitation after a release. A reasoned decision as to environmental impacts cannot be made without a site specific analysis of such a scenario.
>
> The DES addresses at great length releases to groundwater (DES at 5-34 et seq.), but gives only a cursory and conclusory discussion of contamination of open water (DES at 5-33). This issue is of crucial concern here as the two major water bodies at and near the facility are the City's only water supplies. The City also has open reservoirs within its boundaries which could be contaminated through precipitation. For an issue of such great importance, insufficient consideration has been given here. The mandate of NEPA to take a hard look at environmental consequences has been ignored.

Evidentiary hearings on this Contention took place in Philadelphia, Pennsylvania on June 19-20, 1984.

Summary

2. In response to this Contention, both the Applicant and Staff developed calculational computer models which translated deposition on the watershed, either wet or dry, as predicted by the CRAC codes, into concentrations over time in the two rivers that supply drinking water to

the City of Philadelphia, the Schuylkill and Delaware. These models were then used to predict the effects of the deposition of radioactive materials on the City's water supplies. The Applicant also examined the special case of deposition directly on the City's reservoirs as a result of postulated severe accidents at the Limerick Generating Station.

3. The Applicant analyzed the same accident categories that were examined in SARA and produced a water pathway evaluation comparable to that performed for the air pathway which had been the subject of other contentions in this proceeding. The Staff analyzed release category II-T/WW, which is one of the most severe release categories contained in the FES, and used it to produce a bounding estimate of the health impacts of the water pathway. In its calculations of health effects, the Applicant assumed no interdiction of the water supply, but did assume in accordance with information provided by the City, that 93% of the residents utilized water from the Delaware and only only 7% used water from the Schuylkill. The assumption of no interdiction of the water supply increased the calculated health effects. The Staff, on the other hand, assumed conservative interdiction levels and presented the health effects that would result at those levels.

4. Both approaches demonstrated that the chances of severely contaminating the Delaware River are vanishingly small. While the probability of contaminating the Schuylkill River is somewhat higher because of the physical relationship of its watershed to the facility, such probabilities and the resulting risks are also small. The probability of contamination of the City's reservoirs because of direct deposition is likewise small.

5. Moreover, both the Staff and Applicant, while disclaiming any attempt to prepare the details of a contingency plan, determined that reasonable measures could be taken to reduce the amount of radioactivity in the City's finished water supply, thus reducing even further the already small health effects.

6. Both studies concluded that the risks in terms of health effects associated with this waterborne pathway are small in comparison to the risks from the airborne pathway, which are, in turn, small in relation to other risks to which the public is exposed. The Board therefore concludes that specific consideration of this pathway does not affect any of the conclusions of the severe accident or overall environmental impact reviews.

Discussion

7. The Applicant calculated the amount of radioactive material that would be deposited on the Schuylkill and Delaware River watersheds as a result of a severe accident at Limerick with the CRAC2 code utilizing the methods and assumptions described in the Severe Accident Risk Assessment ("SARA") to calculate point estimate CCDF's. For each weather sequence and source term, CRAC2 was used to calculate the activity of each radionuclide deposited on the ground as a function of distance from the reactor. This information, together with information on plume width as a function of distance downwind, was then utilized by the LIQPATH computer code to calculate the total amount of strontium and cesium that would be deposited in the Schuylkill and Delaware watersheds. This was done with the computer code by overlaying the footprint of the plume on a map of each watershed and intergrating the deposited activity over that part of the plume lying within the

watershed. Strontium and cesium were used in this analysis because they are the most important contributors to the long term contamination of water supplies. The deposition in the watershed, as calculated by the Applicant, also included that directly deposited in the river. Bartram, et al, ff. Tr. 12007, at 2, 4-5.

8. Once the total amount of each radionuclide deposited within the watersheds had been calculated, the LIQPATH code was then used to predict the subsequent temporal variation of the concentration of each radionuclide in Philadelphia's drinking water. The LIQPATH code contains an empirical correlation that allowed the quantity of radionuclides deposited in the Schuylkill and Delaware watersheds to be related to the subsequent concentration in the City's drinking water. This correlation was based on an analysis which connected the measured rate of fallout of Cs-137 and Sr-90 from atomic bomb tests with measured concentrations of Cs-137 and Sr-90 in Philadelphia and New York City tap water over a period of approximately 20 years. Bartram, et al., ff. Tr. 12007, at 5-6, 10 and Appendix 1, at 27-30.

9. The calculation of drinking water concentrations was then repeated for each combination of weather sequence, wind direction and source term. The output of those calculations form the CCDF representing concentrations in tap water. Bartram, et al., ff. Tr. 12007, at 10-11 and Figures 4(a), 4(b), 5(a), and 5(b).

Method Used to Calculate Public Risk

10. In the calculation of the risk to the public via the water pathway, it was not necessary to consider doses resulting from water used outside the body because the evidence indicated that all such uses would contribute very little to the total exposure. The only questions

regarding the use of the City water supply as related to health effects was for drinking purposes; the evidence indicated that for other purposes, principally firefighting and sanitary, the water could be utilized. Tr. 12219, 12221, 12240-42 (Wescott, Fliegel, Acharya); Tr. 12111, 12127 (Schmidt, Guarino).

11. In its calculations, the Applicant assumed that the affected population consumed water containing concentrations of strontium and cesium for 50 years; the resulting population doses were then calculated in accordance with the methods set forth in Reg. Guide 1.109, as incorporated in the LADTAP II computer code. The ingestion dose conversion factors from WASH-1400 were used instead of the Reg. Guide 1.109 factors, however, to be consistent with the airborne ingestion pathway analysis provided in SARA. The evidence indicated that the conversion factors set forth in Reg. Guide 1.109 are based on older recommendations of the International Commission on Radiological Protection ("ICRP"), whereas the WASH-1400 conversion factors more closely correlate to the more recent recommendations of that body. Bartram, et al., ff. Tr. 12007, at 11-12; Tr. 12024-28, 12119, 12126 (Bartram). The conversion factors contained in WASH-1400 represent a consensus of informed individuals in the field and are the best values to use at this time. Tr. 12026, 12105B-06 (Kaiser). However, even if the conversion factors provided in Reg. Guide 1.109 had been used, they would have made only a small difference in the Applicant's calculation of the risk of latent cancer fatalities and would not have altered its ultimate conclusions. Tr. 12106, 12119 (Kaiser).

12. The uncontroverted evidence indicated that it is likely that the Schuylkill River would be more heavily contaminated by a release

from Limerick than the Delaware River because of its location surrounding the Station. Compare, e.g., Figure 4(a) with Figure 5(a) attached to the Applicant's testimony at Tr. 12007. A radioactive plume would have to travel some distance over the Schuylkill watershed before reaching the Delaware watershed. Even if the wind were blowing in the direction of the Delaware, it is highly probable under some weather conditions that the entire contents of the plume would be deposed onto the Schuylkill watershed before reaching the Delaware watershed. Also, the plume would not travel over the Delaware watershed at all for some wind directions. Bartram, et al., ff. Tr. 12007, at 1?; Tr. 12028-29 (Kaiser); Tr. 12274-75 (Fliegel).

13. The Philadelphia Water Department distributes an average of 345 million gallons per day ("mgd") to 1.69 million people and industry within the City. Approximately half of this requirement normally comes from the Schuylkill and the other half from the Delaware. According to information supplied by the City Water Department, the Baxter Plant, which takes water from the Delaware River, can supply the entire needs of the City except for the Belmont and Roxborough High Service Districts, which represent about 7% of the City's total needs. Accordingly, the Applicant assumed that 93% of the City's population would be served from the Delaware River and 7% would be supplied from the Schuylkill River if necessary. Bartram, et al., ff. Tr. 12007, at 12; Tr. 12031 (Kaiser); Tr. 12038 (Schmidt); Lehr, ff. Tr. 12141, at 3-5.

14. The evidence indicated that while the Belmont and Roxborough High Service Districts cannot be currently supplied from the Baxter Plant because of their elevation above that facility, an emergency line could be run to supply these areas from that plant within a week or two.

Moreover, these districts have their own plant which contains covered, filtered water which if used only for human consumption would supply the area for several weeks. Tr. 12109-10, 12125 (Guarino).

15. Starting from the initial probabilistic treatment of concentrations of radionuclides in the river water, the population dose resulting from strontium and cesium was calculated. The calculational methodology was applied separately to the Delaware and Schuylkill Rivers and to each fission product source term since the proportions of strontium and cesium would differ between the two rivers, and among the different source terms. Since the calculations were done on the basis of strontium and cesium, the resulting estimates represent the chronic or long term contribution to the population dose. Bartram, et al., ff. Tr. 12007, at 12-13.

16. With respect to the contribution of other more short-lived radionuclides, such as radioiodine, a more simplified bounding calculation was made as follows. For each source term, weather sequence and wind direction, the isotopes of iodine deposited on the Schuylkill or Delaware watersheds were assumed to pass into the rivers immediately at a rate approximately 50 times that of strontium. The population of Philadelphia was then assumed to consume this water and the resulting incremental population dose was calculated. Bartram, et al., ff. Tr. 12007, at 13.

17. A further potential source of radiation dose would be the consumption of water from the City's treatment works that might be contaminated by direct deposition (dry or wet) on raw water or finished water basins. Bartram, et al., ff. Tr. 12007, at 13-14 and Figures 6 and 7. While, in reality, much or all of the contaminated water could

be bypassed, discharged to the river or sewers, or flushed out through the fire hydrants, for purposes of its analysis, the Applicant assumed that this water was processed through the City's distribution system at the usual rate of consumption and the LADTAP II methodology was used to calculate the resulting doses. Bartram, et al., ff. Tr. 12007, at 13-14.

18. A CCDF of population dose results was then derived to obtain an overall view of the population dose to the people of Philadelphia. The area under this CCDF was determined to be 0.67 man-rem per reactor year, which consists of 0.02 man-rem per reactor year from the consumption of water contaminated by direct deposition into the system; 0.16 man-rem per reactor year from strontium and cesium deposited on the watershed; and 0.49 man-rem per reactor year from the iodine deposited on the watershed using the bounding case described above. The resulting figure, 0.67 man-rem per reactor year, must be compared with 70 man-rem per reactor year that is calculated to occur to the people of Philadelphia from the airborne pathway. Bartram, et al., ff. Tr. 12007, at 14.

19. Also, the calculation of the population dose via the water pathway was derived with many fewer assumptions concerning countermeasures than that which was calculated for the atmospheric pathway. For example, protective actions such as the interdiction of milk and decontamination of land are routinely assumed in CRAC2. Although countermeasures are possible with the liquid pathway case which could give a further reduction in risk, credit for these measures was not taken by the Applicant. Nonetheless, the public risk via the water pathway is clearly a small fraction of that which would result via the atmospheric

pathway. Bartram, et al., ff. Tr. 12007, at 14-15; Tr. 12014-15 (Levine).

20. The evidence also indicated that the assumption that iodine would pass into the drinking water at a rate 50 times that of strontium, was highly conservative. In reality, most of the iodine would become associated with sediments and would not make its way into the drinking water. Ultimately, only about 5% of the iodine would actually be dissolved and enter the water if preventive measures were not taken. Moreover, the half-life of iodine is eight days; therefore, no radioactive I-131 would be left after two months. Tr. 12047-51 (Toblin, Kaiser, Levine). Consequently, the contribution of iodine to the total risk is properly a factor of approximately ten less than that initially calculated by the Applicant.

21. In recognition of this fact, the Applicant subsequently conducted a more realistic evaluation of the effect of iodine than that contained in the bounding calculations previously described. Utilizing the proper conversion factor, the figure of 0.49 man-rem per reactor year attributed to iodine is actually 0.06 and the value of 0.67 man-rem per reactor year from all sources is reduced to 0.24. Tr. 12048 (Kaiser). Moreover, the health effect risks in terms of cancer fatalities predicted from the water pathway using the more realistic values for iodine would only be one ten-millionth of the cancer fatalities already occurring in Philadelphia from other causes and 6% of those associated with airborne contamination. Tr. 12015, 12054-55 (Levine). Thus, on a more realistic basis appropriate for the purposes under consideration, the contribution of the health effects resulting from the waterborne pathway are extremely small.

22. The Applicant also conducted an analysis in which it was assumed that water consumption in Philadelphia following an accident proceeded as normal, i.e., 55% of the City's water was assumed to be taken from the Delaware and 45% from the Schuylkill, to bound any problems that might occur in supplying most of the City from the Delaware. This analysis indicated that such action would result in only a factor of three or four increase in the total public risk values from the water pathway. Tr. 12036-38, 12121 (Kaiser, Levine). Thus, the water pathway would still be a small fraction of the health effects due to the air pathway even conservatively assuming that no effort was made to maximize or increase the use of the less contaminated water supply. Tr. 12135 (Levine). The Staff agreed that the risk presented by the water pathway is of small importance compared to the risks that would result from fallout onto land. Tr. 12257 (Acharya, Fliegel, Wescott).

23. The City postulated that problems would be encountered in switching over from the Schuylkill River to the Delaware River as a source of supply of drinking water for Philadelphia because of problems such as malfunctioning valves in the water supply system. Preliminarily, the evidence indicated that historically such problems have not been encountered and that even if they were, repairs could be quickly made and the switchover could be accomplished in approximately 24 hours. Moreover, the Applicant did not assume instantaneous switchover in its analysis because the City has two days supply at normal consumption rates of covered, finished water that would not be contaminated by a release from Limerick. If conservation measures were imposed, this supply would last much longer. Tr. 12040-45, 12081-82, 12113 (Schmidt, Levine, Guarino). The evidence also established that the City has the

authority to limit the industrial use of water and that this capability has been exercised in the past. Tr. 12113-15 (Guarino).

24. The City also postulated that increases in salinity levels in the Delaware River as a result of large withdrawals from that River might render its water unusable at Philadelphia. The evidence indicated, however, that even if the City drew all or most of its water from the Delaware, salinity levels would not change appreciably because most of the withdrawn water is returned above the salt line, which even in the worst of times, is located approximately 10 miles downstream of the City's intake. Tr. 12032-34, 12101, 12128 (Guarino).

The Staff's Analysis

25. To provide a reasonably bounding probabilistic risk analysis of liquid pathway contamination, the Staff selected a release category from those listed in FES Table 5.11c involving relatively large quantities of radionuclides in an atmospheric release and, in its bounding calculation of risk, artificially assigned it a probability which represented the sum of the probabilities of all release categories, as reflected in FES Table 5.11d. Release category II-T/WW was selected because the quantities of radionuclides in the atmospheric release associated with it are among the highest values of all release categories in Table 5.11c. The sum of the probabilities in FES Table 5.11d is approximately 9 X 10^{-5} per reactor year. Acharya, ff., Tr. 12141, at 3-4; Tr. 12147-48, 12245-46 (Acharya). In short, this accident was selected because it provides the largest combination in terms of probabilities and consequences. Other accidents might give more deposition, but would have a lower probability; or would be of a higher probability, but would result in less depositions. Tr. 12163-64 (Fliegel).

26. The CRAC code was then used to estimate the initial deposition that would result from atmospheric fallout. The dispersion model contained in the code was also used to calculate the area that would be covered by the plume as a function of distance from the reactor. Acharya, ff. Tr. 12141, at 4-5. The ground concentrations of radionuclides and the cloud areas over given spatial intervals were calculated for release category II-T/WW, but the probability of the occurrence was not factored into the Staff's calculations. Since a reactor accident could occur at any time of the year, 91 different accident start times uniformly distributed throughout a one-year period were used to derive probability distributions of radionuclide concentrations and cloud areas for each spatial interval for each sequence. Acharya, ff. Tr. 12141, at 5-6; Wescott and Fliegel, ff. Tr. 12141, at 4-5; Tr. 12149, 12159 (Fliegel).

27. As a result of this analysis, the Staff concluded that a wind direction which would cause a high deposition of radionuclides on one watershed (either the Schuylkill or Delaware) would generally preclude a high deposition on the other watershed. Wescott and Fliegel, ff. Tr. 12141, at 4; Acharya, ff. Tr. 12141, at 7. The Staff also concluded that, given the use of the dose conversion factor contained in Regulatory Guide 1.109, Sr-90 would largely dominate the radiological significance of Philadelphia water supply contamination from an atmospheric release of type II-T/WW. Acharya, ff. Tr. 12141, at 6-7; Tr. 12256 (Acharya); Tr. 12213-15 (Fliegel, Wescott, Lehr).

28. The Staff also determined that, for release category II-T/WW for the first year average Sr-90 concentration in the Schuylkill River, the probability of not exceeding the 10 C.F.R. Part 20 limit on

concentration for unrestricted area use (1 MPC (maximum permissible concentration), which is 300 pico-Curie/liter ("pCi/l")), is 14%; and the probability of not exceeding 1/3 MPC is less than 5%. Acharya, ff. Tr. 12141, at 7. For this release category, the Staff found that for Sr-90 concentrations in the Schuylkill, the probability of not exceeding 1 MPC after the initial runoff is 50%, but there is a 99% probability that the concentration would fall below 1 MPC 20 years after the accident. The probability of not exceeding 1/3 MPC after 30 years is less than 50%, but there is a 99% probability that this concentration would fall below 1/3 MPC 53 years after the accident. The Staff thus concluded that the Schuylkill River as a source of drinking water, given the occurrence of a severe accident and a II-T/WW type release, would have a high probability for interdiction for a long period of time. Acharya, ff. Tr. 12141, at 8-9. The evidence indicated that cesium was not considered in this analysis because it is much more readily bound up in the soil and would not end up in solution in the water pathway. Tr. 12215 (Fliegel); Tr. 12254, 12270 (Acharya).

29. For the Delaware, conditional upon the occurrence of release category II-T/WW, for the first year average Sr-90 concentrations the probability of not exceeding 1 MPC is 98%; the probability of not exceeding 1/3 MPC is 85%; the probability of not exceeding 15 pCi/l is 50%; and the probability of no contamination is 38%. In addition, the probability of not exceeding 1/3 MPC after the initial runoff is 95% and there is a 99% probability that Sr-90 concentration would fall to 1/3 MPC within 7.5 years after the accident. The Staff also concluded that there was a very high probability that the Delaware water, if contaminated at all, would be interdicted for a period of less than two months

(based upon consideration of interdiction until Sr-90 concentrations fall to 1/3 MPC). Acharya, ff. Tr. 12141, at 10-11; Tr. 12266-67 (Wescott).

30. As previously noted, the Staff concluded that it is highly unlikely that both rivers would be severely contaminated at the same time. However, if that situation were to occur, the Delaware could serve as the source of drinking water for the entire City of Philadelphia after an initial period of about two months. Acharya, ff. Tr. 12141, at 12.

31. The Staff derived the risks of population exposure from Philadelphia drinking water contamination due to release category II-T/WW by multiplying the probability of II-T/WW (2×10^{-6} per reactor year) times the estimates of residual population exposures for all time after Sr-90 concentrations fall to 8 pCi/l. It was determined that the results would be 0.3 person-rem whole body dose per reactor year and 1.2 person-rem bone dose per reactor year. Conservatively, using the sum of the probability of all release categories in FES Table 5.11c (which is 9×10^{-5} per reactor-year), the results would be 13 person-rem whole body dose per reactor year and 52 person-rem bone dose per reactor-year. These results are conservative because not all release categories in Table 5.11c would produce levels of water contamination as high as those that would result from release category II-T/WW. Also, the risk of 13 whole body person-rem per reactor year to the population of Philadelphia via the drinking water pathway contamination is small compared with the risk of 160 whole body person-rem per reactor year to the same population via the air and the ground pathways contamination estimated from

FES Figure 5.41. Acharya, ff. Tr. 12141, at 13; Tr. 12257 (Acharya, Fliegel, Wescott).

32. Nonetheless, the Staff performed an assessment to determine the degree of conservatism in its calculations and found that instead of 13 person rem whole body dose per reactor year and 52 person rem bone dose per reactor year, the respective values would actually be at most 7 whole body and 29 bone person rem. Tr. 12248-51 (Acharya).

33. The Staff also testified that if the WASH-1400 dose conversion factors, which are similar to the ICRP-30 recommendations, were utilized, the man-rem and health effects doses they calculated would decrease. Tr. 12255-57 (Acharya, Fliegel); Tr. 12269-72 (Acharya). The Staff also testified that its approach regarding the waterborne pathway was bounding and thus could not be compared directly against the air pathway. Tr. 12244-46 (Acharya).

Comparison with State and Federal Guidelines

34. The Applicant developed CCDF curves of the postulated concentration of Sr-90 in drinking water obtained from the Schuylkill and Delaware Rivers averaged over the first month and the first year, and then at one month, six months and five years after the initial deposition. Based on these curves, which we incorporate by reference, it is apparent that the concentration of Sr-90 during the first month would be considerably higher than at later times. After one month, the concentration in the Delaware and Schuylkill Rivers would slowly decline. While no interdiction was assumed in the analysis, the Applicant compared the concentrations with Federal and state guidelines to judge their significance. Bartram, et al., ff. Tr. 12007, at 15-16 and Figures 4(a), 4(b), 5(a), and 5(b).

35. The NRC's standards for normal releases are set forth in 10 C.F.R. Part 20, Appendix B. The Commonwealth of Pennsylvania Emergency Management Agency ("PEMA") has also published Protective Action Guides ("PAG's"), which are based on the United States Environmental Protection Agency's ("USEPA") National Interim Drinking Water Regulations. PEMA has two sets of PAG's which are applicable to the instant situation. For uncontrolled discharges to surface water and in circumstances where the water supply is influenced by contaminated run-off and fallout, the USEPA Appendix B concentrations multiplied by 12 would apply. The use of this guide assumes that the exposure time would not exceed one year. The associated dose commitment to any organ is 50 mrem. PEMA also provides that for acute crisis conditions where no other water supply is available and the duration is less than 30 days, the average concentration may reach 1,000 times the USEPA Appendix B concentrations. The associated dose commitment to any organ is 330 mrem. For accidents affecting Philadelphia's drinking water, the PEMA guidelines were assumed to apply. Bartram, et al., ff. Tr. 12007, at 16-17.

36. Since Sr-90 is principally a contributor to the long term accumulation of radiation dose, the most appropriate PEMA guide for purposes of comparison is that for circumstances in which the water supply is influenced by contaminated run-off and fallout. The probability that the Schuylkill River would be contaminated above this guideline is one in 300,000 per reactor year; the probability that the Delaware River would be contaminated above this guide is one in 7 million per reactor year, both of which are very small. Bartram, et al., ff. Tr. 12007, at 17; Tr. 12011-12 (Levine, Kaiser).

37. These probabilities were obtained by assuming that preventive actions were not taken. If the available procedures which could substantially reduce the long term impact of Sr-90 were implemented in one month, the probability of exceeding the PEMA one year limit in the subsequent year would be in the range of one in 2.5 million to one in 17 million per reactor year for the Schuylkill and about one in 100 million to less than one in one billion per reactor year for the Delaware. Thus, there is a very small probability that the long term interdiction of the Schuylkill would be required, and a vanishingly small probability that the long term interdiction of the Delaware would be required. Bartram, et al., ff. Tr. 12007, at 17-18.

38. The PEMA one-month PAG would apply in the short term. For Sr-90 alone, the probability of exceeding this limit is about one in three million per reactor year for the Schuylkill and less than one chance in one billion per year for the Delaware. The one-month average is complicated, however, by the fact that other radionuclides cannot be neglected. Using the bounding model for iodine concentration discussed above averaged over the first month, it could be determined whether the PEMA short term PAGs would be exceeded. The evidence indicated that there would be approximately one chance in 100,000 per reactor year that the PEMA short-term PAGs might be exceeded in the Schuylkill River, and about one in 150,000 that they might be exceeded in the Delaware River. The evidence further indicated that these are upper bound probabilities and do not account for any countermeasures that might be used. Bartram, et al., ff. Tr. 12007, at 19.

Mitigative Actions

39. As noted previously, except for the assumption that the use of the Delaware River was maximized to supply the water needs of the City of Philadelphia, mitigative actions were not taken into account in the Applicant's calculation of the risks presented by the water pathway. The evidence indicated that a number of actions exist which could be utilized to reduce the risks resulting from an accident. For example, the effects of direct deposition into the uncovered portion of the East Park Reservoir could be accommodated by isolating and bypassing that reservoir. Direct deposition on the City's raw water facilities could be most readily accommodated by bypassing those basins and processing the raw water without the pre-sedimentation provided by the basins. The contaminated water from the basins could be eliminated by returning it to the Delaware and Schuylkill Rivers or flushing it from the system. Bartram, et al., ff. Tr. 12007, at 21-22.

40. At lower contamination levels involving watershed deposition which would likely persist for more extended periods of time, the evidence indicated that modifications to the water treatment processes could be made to reduce the activity concentrations in the finished water. Research on the removal of various fission products in water indicates that the decontamination factor provided by the current treatment processes in use by the Philadelphia Water Department could remove about 50% of the total radioactivity and somewhat less of the dissolved strontium, cesium and iodine. Bartram, et al., ff. Tr. 12007, at 22-24. The Staff likewise agreed that municipal treatment systems such as those used by the City could achieve moderate levels of removal

of the total activity associated with radioactive fallout. Lehr, ff. Tr. 12141, at 6-10; Tr. 12209-11 (Lehr).

41. The evidence further indicated that modifications to the current treatment processes in use in Philadelphia are feasible which could reduce the concentration of certain nuclides by an additional factor of 5 to 10. For example, the addition of activated carbon with other chemicals prior to flocculation would give a decontamination factor for iodine from 4 to 5. Adding a layer of activated carbon to the surfaces of the sand filters would provide additional decontamination, perhaps by a factor of 2, for a total decontamination factor for radioiodine from 8 to 10. Dissolved strontium can be effectively removed by the use of a lime-soda softening process. Decontamination factors of from 5 to 10 can be obtained by co-precipitation in an initial softening step with dosages of soda ash in excess of those indicated by stoichiometric requirements alone. A process known as repeated-precipitation, in which a small quantity of calcium is added and removed, was indicated to provide an equal decontamination factor in each step. Thus, a second step in which a decontamination factor of between 5 and 10 was obtained would produce an overall decontamination of between 25 and 100. If it were necessary to provide this second stage of processing without constructing a major plant addition, the treated effluent from one-half of the plant could be returned to the rapid mixing stage of the other half to provide the second stage of the treatment. Bartram, et al., ff. Tr. 12007, at 24-25.

42. The City asserted that various treatment processes which could remove radioactive materials from the water supply might not be used because of their cost or unavailability. To the contrary, the evidence

indicated that certain of these processes, such as the use of activated carbon, are currently in use at Philadelphia water treatment plants or could be easily installed. Tr. 12086-96 (Waller). Also, the costs associated with the use of these treatment methods appear to be small, particularly judged in the context of an emergency situation.

43. As noted previously, based on its review of the decay times of fission products, the Staff concluded that only strontium-90 would contribute significantly to population dose over a period of time and that only it would, therefore, require a high level of removal from the City's drinking water. It further concluded, based on its estimated first year average activity concentration due to strontium-90, that the plants treating water taken from the Schuylkill, i.e., Queen Lane and Belmont, could not reduce the activity concentrations to within the EPA MCL for strontium-90. The Baxter plant, however, could achieve the necessary removal levels. Consequently, until strontium-90 activity concentration in the Schuylkill decreased to a level at which the treatment processes used by the Queen Lane and Belmont plants could deliver water within the EPA limit, or until modifications were installed at these plants capable of treating water with higher influent Strontium-90 activity levels, the Baxter plant could provide the entire water needs of the City, with the exception of the Belmont High Service District, which is located at too high an elevation to be served by gravity flow, but whose needs could be met by emergency means such as tank trucks or emergency water pipeline construction. Lehr, ff. Tr. 12141, at 11-13.

44. The Board concludes that the waterborne pathway has been adequately considered and produces only a small fraction of the risks

produced by the airborne pathway, which itself is small in comparison with other non-nuclear risks. The Board concludes that this Contention has no merit and that the conclusions of the Severe Accident Risk Assessment and Environmental Impact Statement are correct.

Conclusions of Law

45. Based on the foregoing Findings of Fact, which are supported by reliable, probative and substantial evidence as required by the Administrative Procedure Act and the Commission's Rules of Practice, and upon consideration of the entire evidentiary record in this proceeding, the Board reaches the following conclusions pursuant to 10 C.F.R. §2.760a:

a. The health effects due to the water pathway from severe accidents at the Limerick Generating Station are small in comparison to those from the air pathway, which are in turn quite small compared to the risks from non-nuclear sources. The assumptions regarding actions to mitigate the already small health effects are not unreasonable and the assumptions regarding actions that the City of Philadelphia could take are also not unreasonable.

b. Consideration of these contentions does not alter any of the conclusions in the FES nor does it affect the cost benefit balance contained therein.

c. With respect to the requirements of section 102(2)(A), (C) and (E) of the National Environmental Policy Act, and in accordance with 10 C.F.R. Part 51, the operating licenses should be issued as proposed.

APPENDIX A

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PECO Ex. 8	Color Photograph of Cooling Tower Plumes Coming from the John Amos Plant.	6236	6236
PECO Ex. 9	Cooling Towers and the Environment, Major Contributors: Maynard Smith, Mark Kramer and David Seymour, October 1974.	6413	6413
PECO Ex. 10	Amos Cooling Tower Flight Program, Test No. 48A, March 11, 1975.	6649	6649
PECO Ex. 11	Douglas Point Power Plant Site Evaluation Final Report, Vol. 1, Part 2, L.C. Kohlenstein, Project Engineer, Published by the Johns Hopkins University Applied Physics Laboratory, January 1976.	6650	

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PECO Ex. 12	John E. Amos Cooling Tower Flight Program Data, Conducted for the American Electric Power Service Corporation by Smith-Singer Meteorologists, Inc., December 1975-March 1976.	6765	
PECO Ex. 13	Environmental Measurements of Power Plant Cooling Tower and Stack Plumes, Final Report for AEC, ERDA and DOE, Conducted by the Department of Meteorology, Pennsylvania State University, Edited by D.W. Thomson, R.G. de Pena, J.A. Pena, Updated.	6868	
PECO Ex. 14	Table 2.2-3 of the Limerick Generating Station Final Safety Analysis Report, "Airports Within Ten Miles of the Site," Rev. 4, 05/82.	6972	
PECO Ex. 15	Figure 1, One page document, Free Air-Burst Blast Environment.	8214	8214
PECO Ex. 16	Figure 1, One page document entitled "Air-Burst Blast Environment."	8214	8214
PECO Ex. 17	Figure 2, One page document entitled "Surface-Burst Blast	8214	8214

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	Environment."		
PECO Ex. 18	Figure 3, One page document entitled "Site Plan" AB-207392-5 indicating the postulated line of centroids of detonation (parallel to Columbia Pipe Line).	8214	8214
PECO Ex. 19	Figure 4, one page document entitled "Cooling Tower General Arrangement."	8214	8214
PECO Ex. 20	Figure 5, One page document entitled "Cooling Tower Section Looking North."	8214	8214
PECO Ex. 21	Figure 6, One page document entitled "Cooling Tower Looking West."	8214	8214
PECO Ex. 22	Figure 7, Single page, large scale drawing entitled "Seismic Category I Underground Facilities."	8214	8214
PECO Ex. 23	Figure 8, single page, large scale sheet entitled "Profiles of RHR & ESQ Pipes Showing Ground Cover."	8214	8214
PECO Ex. 24	Figure 9, single page, large scale sheet entitled "Profiles of Cat. 1 Electrical Duct Banks Showing	8214	8214

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	Ground Cover."		
PECO Ex. 25	Figure 10, one page document entitled "Intense Storm Site Runoff Pattern: General Plan," Figure 2.4-4, LGS FSAR.	8214	8214
PECO Ex. 26	Figure 11, one page document entitled "Intense Storm Site Runoff Pattern: Spary Pond and Cooling Tower Areas," Figure 2.4-5, LGS FSAR.	8214	8214
PECO Ex. 27	Figure 12, one page document entitled "Duct Bank Sections."	8214	8214
PECO Ex. 28	Figure 13, one page document entitled "Buried Pipe Bedding."	8214	8214
PECO Ex. 29	Environmental Qualification Report for Limerick Generating Station, Units 1 and 2. October 1983.	9531	9532
PECO Ex. 30	Letter dated January 16, 1984 transmitting document entitled "Additional Information Required for Limerick Environmental Qualification Program."	9534	9534
PECO Ex. 31	Letter dated February 16, 1984 from J.S.	9537	9537

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	Kemper to A.S. Schwencer conveying Figure 4, "Calculated Reactor Enclosure LOCA Temperature Profile" and Enclosures 1 and 2.		
PECO Ex. 32	Emergency Plan, Limerick Generating Station, Units 1 and 2 (through Rev. 8), Section 3, Section 4, Section 5.2.2, Section 5.3.2, Section 5.3.3 (Table 5-5), Section 6, Section 7.1, Section 7.3, Section 7.4, Section 7.5 (Table 7-3, Table 7-4, Table 7-5, Figure 7-2), Section 8.1.1, Section 8.3 (Table 8-1), Appendices A, B, E, I, Answers to NRC Questions 810.5b, 810.13, 810.18, 810.24, 810.30, 810.32, 810.33, 810.35, 810.37, 810.40, 810.41, 810.45, 810.46, 810.47, 810.48, 810.49, 810.53, 810.54, 810.55, 810.57 and 810.59.	9772	9773, 9996
PECO Ex. 33	Emergency Plan Implementing Procedures, Limerick Generating Station, EP-101 (Classification of Emergencies), EP-102 (Unusual Event Response), EP-103 (Alert Response), EP-104 (Site Emergency Response),	9772	9773, 9996

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	EP-105 (General Emergency Response), EP-110 (Personnel Assembly and Accountability), EP-201 (Technical Support Center (TSC) Activation), EP-202 (Operations Support Center (OSC) Activation), EP-203 (Emergency Operations Facility (EOF) Activation), EP-208 (Security Team Activation), EP-210 (Dose Assessment Team), EP-220 (Radiation Protection Team Activation), EP-221 (Personnel Dosimetry, Bioassay, and Respiratory Protection Group), EP-222 (Field Survey Group), EP-230 (Chemistry Sampling and Analysis Team Activation), EP-250 (Personnel Safety Team Activation), EP-251 (Plant Survey Group), EP-252 (Search and Rescue/First Aid), EP-254 (Vehicle and Evacuee Control Group), EP-255 (Vehicle Decontamination), EP-260 (Activation of the Firefighting Group), EP-291 (Staffing Augmentation 60 Minute Call Procedure), EP-305 (Site Evacuation), EP-307 (Reception and Orientation of Support Personnel),		

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	EP-313 (Distribution of Thyroid Blocking Tablets), EP-316 (Cumulative Population Dose Calculations for Airborne Releases - Manual Method), EP-317 (Determination of Protective Action Recommendations), EP-325 (Use of Containment Radiat on Monitors to Estimate Release Source Term), EP-401 (Entry for Emergency Repair and Operations), EP-500 (Review and Revision of Emergency Plan).		
PECO Ex. 34	Revised Table 4-2 Emergency Plan.	9772	9773
PECO Ex. 35	Emergency Procedure Corporate, EP-C-326.	9772	9773
PECO Ex. 36	Emergency Procedure Corporate, EP-C-315.	9772	9773
PECO Ex. 37	Surveillance Test Procedure ST-7-EPP-351-0, Limerick Generating Station.	9772	9773
PECO Ex. 38	Final Safety Analysis Report, Limerick Generating Station, Sections 1.3 (page 1.13-18b), 2.1.2.3, 2.3.3, 2.3.3.2, 3.7.4, 7.5.1.4.2.1.5, 7.5.2.5.1.1.2, 7.6.1.1.6, 11.5, 11.5.2.2.1, 11.5.2.2.11, 11.5.2.3.1, 11.5.4, 11.5.5, 12.3.4,	9772	9773

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	Section 2.2.3.1.3 and Tables 2.2-1, 2.2-5, 2.2-6.	10284	10285
PECO Ex. 39	Environmental Report - Operating License Stage, Limerick Generating Station, Section 6.1.5.	9772	9773
PECO Ex. 40	Letter of Agreement dated August 16, 1983 between Hospital of the University of Pennsylvania and Radiacion Management Corporation (including attached Radiation Plan entitled "Decontamination and Treatment of Radioactively Contaminated Patient at Hospital of the University of Pennsylvania").	9772	9773
PECO Ex. 41	Letter of Agreement dated June 25, 1982 between Keystone Helicopter Corporation and Radiation Management Corporation.	9772	9773
PECO Ex. 42	Letter of Agreement dated January 1, 1984 between Radiation Management Corporation and Applicant.	9772	9773
PECO Ex. 43	Letter of Agreement dated April 5, 1984	9772	9773

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	between Pottstown Memorial Medical Center and Applicant.		
PECO Ex. 44	Letter of Agreement dated April 2, 1984 between Linfield Fire Company and Applicant.	9772	9773
PECO Ex. 45	Letter of Agreement dated April 2, 1984 between Limerick Fire Company and Applicant.	9772	9773
PECO Ex. 46	Applicant's Analysis of Minimum Staffing Requirements for NRC Licensees for Nuclear Power Plant Emergencies as required under NUREG-0654, Table B-1.	10173	10220
PECO Ex. 47	PECO Letter to NRC dated 6/10/84.	10328	10328
PECO Ex. 48	PECO Letter to NRC dated 9/15/83.	10328	10328
PECO Ex. 49	NRC IE Report 50-352/82-06 (Weld Inspection-Mobile NDE Lab).	10328	10328
PECO Ex. 50	NRC IE Report 50-352/82-16 (CAT Inspection-Appendix B).	10328	10328
PECO Ex. 51	NRC 1982 SALP Report (pages 7 through 10).	10328	10328
PECO Ex. 52	NRC 1983 SALP Report (pages 12 through 15).	10328	10328

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PECO Ex. 53	NRC IE Report 50-353/76-06.	10328	10328
PECO Ex. 54	PECO Finding Report N-093.	10328	10328
PECO Ex. 55	Bechtel NCR 1980.	10328	10328
PECO Ex. 56	Bechtel NCR 1998.	10328	10328
PECO Ex. 57	Bechtel NCR 2000.	10328	10328
PECO Ex. 58	PECO Letter to NRC dated 12/15/76.	10328	10328
PECO Ex. 59	Bechtel FIR C-63-7.	10328	10328
PECO Ex. 60	Bechtel FIR C-63-8.	10328	10328
PECO Ex. 61	Bechtel FIR C-63-9.	10328	10328
PECO Ex. 62	Bechtel FIR C-63-10.	10328	10328
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PECO Ex. 67	Bechtel FIR C-63-15.	10328	10328
PECO Ex. 68	Bechtel FIR C-63-16.	10328	10328
PECO Ex. 69	Bechtel FIR C-63-17.	10328	10328
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PECO Ex. 71	Bechtel FIR C-63-19.	10328	10328
PECO Ex. 72	NRC IE Report 50-353/77-01.	10328	10328
PECO Ex. 73	Bechtel FIR C-63-20.	10328	10328
PECO Ex. 74	Bechtel FIR C-63-21.	10328	10328
PECO Ex. 75	Bechtel FIR C-63-22.	10328	10328
PECO Ex. 76	NRC IE Report 50-353/77-06, page 5.	10328	10328
PECO Ex. 77	Bechtel FIR C-63-24.	10328	10328
PECO Ex. 78	Bechtel FIR C-63-25.	10328	10328
PECO Ex. 79	Bechtel FIR C-63-26.	10328	10328
PECO Ex. 80	Bechtel FIR C-63-27.	10328	10328
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PECO Ex. 82	Bechtel FIR C-63-29.	10328	10328
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PECO Ex. 85	Bechtel FIR C-63-32.	10328	10328
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PECO Ex. 88	Bechtel NCR	10328	10328

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PECO Ex. 89	Bechtel NCR 2710.	10328	10328
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PECO Ex. 91	NRC IE Report 50-353/77-02, page 6.	10328	10328
PECO Ex. 92	PECO Response to NRC dated 5/13/77 (77-02).	10328	10328
PECO Ex. 93	NRC IE Report 50-352/77-07, pages 3 and 4.	10328	10328
PECO Ex. 94	NRC IE Report 50-352/78-03, pages 14 and 15.	10328	10328
PECO Ex. 95	PECO Letter to NRC dated 6/12/78.	10328	10328
PECO Ex. 96	PECO Letter to NRC dated 9/18/78.	10328	10328
PECO Ex. 97	NRC IE Report 50-352/78-07, page 4.	10328	10328
PECO Ex. 98	PECO Letter to NRC dated 12/4/78.	10328	10328
PECO Ex. 99	NRC IE Report 50-352/79-11, page 7.	10328	10328
PECO Ex. 100	NRC IE Report 50-352/78-04 pages 10 and 11.	10328	10328
PECO Ex. 101	PECO Letter to NRC dated 7/20/78.	10328	10328

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PECO Ex. 102	NRC IE Report 50-352/79-94, page 2.	10328	10328
PECO Ex. 103	PECO Letter to NRC dated 3/2/79.	10328	10328
PECO Ex. 104	NRC IE Report 50-352/79-12, page 6.	10328	10328
PECO Ex. 105	PECO Letter to NRC dated 10/31/79.	10328	10328
PECO Ex. 106	NRC IE Report 50-352/80-02, page 5.	10328	10328
PECO Ex. 107	NRC IE Report 50-352/81-06, page 3.	10328	10328
PECO Ex. 108	NRC IE Report 50-352/81-16, page 4.	10328	10328
PECO Ex. 109	NRC IE Report 50-352/80-03, page 12.	10328	10328
PECO Ex. 110	NRC IE Report 50-352/79-11, pages 9 and 10.	10328	10328
PECO Ex. 111	PECO QA Field Office Memorandum No. 882 dated 1/23/80.	10328	10328
PECO Ex. 112	NRC IE Report 50-352/80-12, pages 17 and 18.	10328	10328
PECO Ex. 113	PECO Letter to NRC dated 9/26/80.	10328	10328
PECO Ex. 114	NRC IE Report 50-352/81-04, pages 11 and 12.	10328	10328

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PECO Ex. 115	NRC IE Report 50-352/77-12, pages 3, 4 and 5.	10328	10328
PECO Ex. 116	PECO Letter to NRC dated 12/9/77.	10328	10328
PECO Ex. 117	NRC IE Report 50-352/80-20 (entire).	10328	10328
PECO Ex. 118	NRC IE Report 50-352/81-12, page 4.	10328	10328
PECO Ex. 119	PECO Letter to NRC dated 1/20/81.	10328	10328
PECO Ex. 120	NRC IE Report 50-352/82-05, page 4.	10328	10328
PECO Ex. 121	NRC IE Report 50-352/81-01, page 5.	10328	10328
PECO Ex. 122	PECO Letter to NRC dated 3/12/81.	10328	10328
PECO Ex. 123	NRC IE Report 50-352/80-21, page 6.	10328	10328
PECO Ex. 124	PECO Letter to NRC dated 7/17/81.	10328	10328
PECO Ex. 125	PECO Letter to NRC dated 7/17/81.	10328	10328
PECO Ex. 126	NRC Letter to PECO dated 8/27/81.	10328	10328
PECO Ex. 127	NRC IE Report 50-352/82-05, page 5.	10328	10328

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PECO Ex. 128	PECO Letter to NRC dated 3/21/81.	10328	10328
PECO Ex. 129	NRC IE Report 50-352/81-12, pages 6 and 7.	10328	10328
PECO Ex. 130	PECO Letter to NRC dated 6/26/81.	10328	10328
PECO Ex. 131	NRC IE Report 50-352/82-04, pages 3 and 4.	10328	10328
PECO Ex. 132	NRC IE Report 50-352/81-06, page 7.	10328	10328
PECO Ex. 133	NRC IE Report 50-352/82-03, pages 3 and 4.	10328	10328
PECO Ex. 134	PECO Letter to NRC dated 3/11/82.	10328	10328
PECO Ex. 135	NRC IE Report 50-352/82-10, page 3.	10328	10328
PECO Ex. 136	Cover page of Bechtel NCR 1366 (Also identified as AWPP 180B).	10992	
PECO Ex. 137	"Calculation of Accident Consequences," Appendix VI of Reactor Safety Study - An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, WASH-1400 (Appendix VI, Sections 9.3, 9.4, including Tables 9-10, 9-11, 9-12, Sections 11.1, 11.2, 11.3, including Table 11-6 and	11116	

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	Figures 11-6, 11-7, Appendix J, including Table J-1, Appendix I).		
PECO Ex. 138	"A Model of Public Evacuation for Atmospheric Radiological Releases," SAND 78-0092 (Entire).	11116	
PECO Ex. 139	"Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (pages 15-17, App. I-7, I-46, Figure I-11, p. I-38).	11116	
PECO Ex. 140	"Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants" (page 12).	11116	
PECO Ex. 141	"Examination of Offsite Emergency Protective Measures for Core Melt Accidents" (III 7-4 and 7-5).	11116	
PECO Ex. 142	"Evacuation Risks-An Evaluation" (pages 40, 41, 42, 48, App. B).	11116	
PECO Ex. 143	"Mississauga Evacuates: A Report on the Closing of Canada's Ninth Largest City"	11116	

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	(page VIII).		
PECO Ex. 144	"Before the Wind- A Study of the Response to Hurricane Carla."	11116	
PECO Ex. 145	"Health-MARC: The Health Effects Module in the Methodology for Assessing the Radiological Consequences of Accidental Releases" (Table 1).	11116	
PECO Ex. 146	UNSCEAR, "Sources and Effects of Ionizing Radia- tion" (Annex G, page 385).	11116	
PECO Ex. 147	BEIR III, "The Effects of Popu- lations of Expo- sures to Low Levels of Ionizing Radiation" (Tables IV-2, V-15, pp. 498-99).	11116	
PECO Ex. 148	UNSCEAR, "Ionizing Radiation, Sources and Biological Effects" (Annex I, Section E; Section II, paragraph 45).	11116	
PECO Ex. 149	"Estimates of the Financial Conse- quences of Nuclear Power Reactor Accidents" (pages 1-17).	11116	
PECO Ex. 150	"PRA Procedures Guide, NUREG/CR- 2300" (pages 9-53 and 9-54).		
PECO Ex. 151	"CRAC2 Model		

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	Description" (pages 3-2 through 3-5).		
PECO Ex. 152	"Severe Accident Risk Assessment" (Chapter 10, pages 11, 12, 15, 25; Tables 2, 4, 8, 9, 11; Chapter 12, page 18, Tables 7, 8, 9; Appendix F, page 10; Supplement 3, Table 1. All except Supplement 3-Table 1 and Table 12.8 from original submittal).	11117	11119 (Bound in ff. 11119)
PECO Ex. 153	Direct Testimony of Richard Codell before the ASLB concerning Commission Question No. 1.	12010	
PECO Ex. 154	Richard B. Codell, 1984. Potential Contamination of Surface Water Supplies by Atmospheric Releases from Nuclear Plants.	12010	
PECO Ex. 155	T.C. Helton, A.B. Muller and A. Bayer, Contamination of Surface Water Bodies After Reactor Accidents by Erosion of Atmospherically Deposited Radionuclides.	12010	
PECO Ex. 156	USNRC, 1975 Calculation of Reactor Accident Consequences - Appendix VI of Reactor Safety Study.	12010	
PECO Ex. 157	Health and Safety Laboratory, U.S.	12010	

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	Energy Research and Development Administration, 1977. Final Tabulation of Monthly 90 Sr Fallout Data: 1954-1976.		
PECO Ex. 158	Richard J. Larsen, 1983. Worldwide Deposition of 90 Sr through 1981.	12010	
PECO Ex. 159	USEPA, 1976. Radiological Quality of the Environment.	12010	
PECO Ex. 160	E.P. Hardy and L.E. Toonkel, 1982. Environmental Measurements Laboratory Environmental Report.	12010	
PECO Ex. 161	VSHEW, 1960-68. Radiological Health Data, Volumes 1-9.	12010	
PECO Ex. 162	Limerick Generating Station Radiological Environmental Monitoring Program, 1971-1977, Prepared for Philadelphia Electric Company by Radiation Management Corporation, May, 1979.	12010	
PECO Ex. 163	USEPA, 1976-1982, Environmental Radiation Data, Reports 6, 10, 15, 18, 23-24, 25-26, and 29.	12010	
PECO Ex. 164	Donald G. Menzel, 1975. Land Surface Erosion and Rainfall as Sources of Strontium-90 in	12010	

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	streams.		
PECO Ex. 165	US Geological Survey, 1982. Water Resources Data for Pennsylvania Water Year 1982 Volume 1-Delaware River Basin and Volume 2-Susquehanna and Potomac River Basins.	12010	
PECO Ex. 166	City of Phildelphia Water Department, 1982. How Water in Phildelphia is treated and distributed.	12010	
PECO Ex. 167	USNRC, 1977. Calculations of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 C.F.R. Part 50.	12010	
PECO Ex. 168	D.B. Simpson and B.L. McGill, 1980. User's Manual for LADTAPII - A Computer Program for Calculating Radiation Exposure to Man from Routine Releases of Nuclear Reactor Liquid Effluents.	12010	
PECO Ex. 169	Bruce S. Aptowicz, 1984. Letter to Robert E. Martin, USNRC, dated 4/23/84 and private communication, S. Gibbon, PECO and B. Aptowicz, City of Philadelphia, 5/25/84.	12010	
PECO Ex. 170	Philadelphia Water	12010	

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	Department, 1982. Table of Pumping, Treatment, and Consumption Rates for FY '82.		
PECO Ex. 171	Commonwealth of Pennsylvania Disaster Operations Plan, Annex E, Fixed Nuclear Facility Incidents, February, 1984.	12010	
PECO Ex. 172	C.P. Straub, 1964. Level Radioactive Wastes, Their Handling, Treatment and Disposal.	12010	
PECO Ex. 173	E.P. Hardy, Jr., 1981. Environmental Measurements Laboratory Environmental Report, EML-390.	12010	
	Limerick Ecology Action		
LEA Ex. 1	Compilation of Attachment P's from Draft #5 of Municipal RERP's regarding service by Goodwill Ambulance.	10283	
	Staff		
Staff Ex. 6	NUREG-0911 "Safety Evaluation Report Related to the Operation of Limerick Generating Station," Section 2.2.2, August 1983.	6137	6138 (Bound in ff. 6138)
Staff Ex. 7	Regulatory Guide 1.91 (Revision 1), "Evaluations	6150	6153

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	<u>of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants,</u>." February 1978.		
Staff Ex. 8	VFR Terminal Area Chart for the Philadelphia Area, 18th Edition, September 2, 1983.	7104	
Staff Ex. 9	National Transportation Safety Board Pipelines Accident Report. No. NTSB-PAR-76-8, Los Angeles, California, cover pg. and fig. 3, June 16, 1976.	7145	
Staff Ex. 10	NUREG-0570, "<u>Toxic Vapor Concentrations Control Room Following a Postulated Accidental Release,</u>" June 1979.	7145	
Staff Ex. 11	Army Technical Manual, TM 5-1300, "<u>Structures to Resist the Effects of Accidental Explosions,</u>" TM 5-1300, cover pg., fig.4-4 and 4-12, June 1969.	7146	
Staff Ex. 12	National Transportation Safety Board Pipeline Accident Report No. NTSB-DAR-80-6. Bayamon, Puerto. Rico, cover pg., summary pg. and pgs. 5,12, January 30, 1980.	7147	

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Staff Ex. 13	U.S. Atomic Energy Commission, "Meteorology and Atomic Energy 1968," July 1968.	7147	
Staff Ex. 14	NUREG/CR-1748, "Hazards to Nuclear Power Plants from Nearby Accidents Including Hazardous Materials - Preliminary Assessment," Chemical Engineering, cover page and pgs. F-2, F-4, F-8 and F-11, Undated.	7148	
Staff Ex. 15	"Unconfined-Vapor Cloud Explosions," V.C. Marshall, June 14, 1982.	7148	
Staff Ex. 16	"Conditions of External Loading of Nuclear Power Plant Structures by Vapor Cloud Explosions and Design Requirements," W. Geiger, Undated.	7149	
Staff Ex. 17	"Transactions of the 4th International Conference on Structural Mechanics in Reactor Technology," August 19, 1977.	7151	
Staff Ex. 18	Department of Transportation, "Explosions Hazards Associated with Spills of Large Quantities of Hazardous Materials Phase II," Report No. CG-D-85-77, C.D. Lind and J.C. Whitson, November 1977.	7151	

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Staff Ex. 19	NRC Testimony of Jacques B.J. Read Relating to Safety Implications of the Natural Gas Pipelines which Passes by the Hartsville Site, In the Matter of Tennessee Valley Authority (Hartsville Nuclear Plants Units 1A, 2A, 1B, and 2B), Undated.	7152	
Staff Ex. 20	Army Technical Manual, TM 5-1300, "Structures to Resist the Effects of Accidental Explosions," dover page and figures 4-3, 4-4, 4-5, 4-6, 4-7 and 4-12, June 1969.	9050 (Bound in ff. 9055)	
Staff Ex. 21	One page graph, "Limerick Peak Positive Reflected Overpressure and Positive Phase Pulse Time Due to 56 Tons of TNT," Undated.	9051	9054 (Bound in ff. 9055)
Staff Ex. 22	U.S. Atomic Energy Commission, "The Effects of Nuclear Weapons," Samuel Gladstone, Editor,cover page and pgs. 147 and 151, April 1962	9051 (Bound in ff. 9055)	
Staff Ex. 23	Table I, "Summary of Accidental Explosion Pressures," Undated.	9051	9055 (Bound in ff. 9055)
Sfaff Ex. 24	Figure 1 "Selection of Critical Element for Purpose o	9052 (Bound in ff. 9055)	

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	Analysis and Design," February 8, 1984.		
Staff Ex. 25	Figure 2, "Typical Load Deformation Curve Idealized Elastic-Plastic System," February 13, 1984.	9052	
Staff Ex. 26	1979 Supplement "Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-76) and Commentary on Code Requirements for Nuclear Safety Concrete Structures (ACI 349-76), Appendix C, Undated.	9053 (Bound in ff. 9055)	
Staff Ex. 27	Memorandum from Norman D. Romney, Structural Engineer, NRC, to George Lear, Chief, Structural and Geotechnical Engineer Branch, NRC, "Limerick Conference Call Between NRC Staff, Bechtel Corporation and Philadelphia Electric Company," March 13, 1984.	9071	9073 (Bound in ff. 9073)
Staff Ex. 28	Regulatory Guide 1.142 (Revision 1) "Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)," October 1981.	9211	
Staff Ex. 29	Portions from	111154	111154

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	the Staff FES, Section 5 9.4, page 5-51, through Section 5.9.4.6, page 5-126, Appendices H, I, J, K, L, M and N, and Section 6		
Staff Ex. 30	FES Table 5.11c "Summary of the Atmospheric Release Specifications Used in Consequence analysis for Limerick Units 1 and 2."	11360 (bound in ff. 11360)	11368
	FOE		
FOE Ex. 1	Nuclear Power, Armory Lovins, pg. 161, Undated.	5542 (Rejected)	
FOE Ex. 2	National Transportation Safety Board Pipeline Accident Report No. NTSB-PAR-75-2, Hearne, Texas. August 1, 1973.	5257	5258
FOE Ex. 3	National Transportation Safety Board Pipeline Accident Report No. NTSB-PAR-75-3, Farmington, New Mexico, March 15, 1974.	5758	5759
FOE Ex. 4	Transactions of the ASME "Decompression of Gas Pipelines During Longitudinal Ductile Fractures," G.G. King, March 1979.	5768 (Rejected)	
FOE Ex. 10	Journal of the Soil Mechanics and Founda-	8881	

Exhibit Number	Description	Identified at Transcript Page	Admitted at Transcript Page
	tion Division, "Depth Prediction for Earth-Penetrating Projectiles" C. Wayne Young, May 1969.		
FOE Ex. 5	Figure 6-2, "Structures to Resist the Effects of Accidental Explosions," Undated.	8979	
FOE Ex. 11	"Nuclear Safety-Related Concrete Structures, ACI-349-80," pg 349-83, Undated.	9007	
FOE Ex. 9	LGS FSAR Table 3.5-5, "Railroad-Accident-Generated Missile Parameters," Undated.	9009	
FOE Ex. 6	Post Card Depicting Limerick Generating Station.	9253	
	AWPP		
AWPP Ex. 1	The New Private Pilot, Published by Pan American Navigation Service, 8th Edition, Cover Page and Pages 53-54.	6949	
AWPP Ex. 2	Those Icy Fingers in Your Carburetor, Aviation Consumer Magazine, January 1, 1982.	7046	
AWPP Ex. 3	Letter from Dr. Gudmund R. Iverson to Frank Romano, dated April 26, 1984, containing	10436 (Rejected)	

Exhibit Number	Description	Identified at Transcript Page	Admitted at Transcript Page
	professional qualifications of Dr. Iverson, and a four page attachment entitled "Testimony of Gudmund R. Iverson Concerning Auditing and Sampling as it relates to Quality Assurance Re Welding at the Limerick Generating Station."		
AWPP Ex. 4	"Testimony of Air and Water Pollution Patrol (Romano) Concerning Contention VI-1 (Infractions Related to Welding)" consisting of pages A-J and attachments AWPP-30 through AWPP-49.	10533 (Rejected)	
AWPP Ex. 5	NRC Combined Inspection Report 352/84-14 and 353/84-04, pp. 10-12.	10973	10973

CITY

Exhibit Number	Description	Identified at Transcript Page	Admitted at Transcript Page
City Ex. 1	One page document entitled "Frequency Distributions II-T/WW. WB.DS.VS. Distances."	11874	11883
City Ex. 2	Map entitled "Ingestion Exposure Pathway EPZ Limerick Generating Station Pennsylvania Emergency Management Agency August 1983."	11880	11881

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:

Lawrence Brenner, Esq., Chairman
Dr. Richard F. Cole, Member
Dr. Peter A. Morris, Member

In the Matter of	)	
	)	
Philadelphia Electric Company	)	Docket Nos. 50-352-OL
	)	50-353-OL
(Limerick Generating Station,	)	
Units 1 and 2)	)	

APPEARANCES

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