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HOUSE OF DELEGATES

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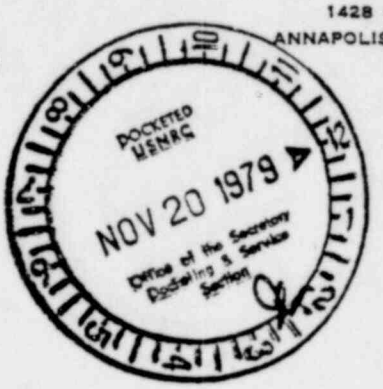
November 6, 1979



Joseph M. Hendrie
Chairman
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Hendrie:

Your assistance in evaluating the enclosed materials relating to the radiological impact of the operation of the Calvert Cliffs Nuclear Power Plant is earnestly solicited.

The enclosed compilation of findings is taken from the November 1978 "Power Plant Cumulative Environmental Impact Report" of the Maryland Power Plant Siting Program. In addition to your overall evaluation of the degree and type of radioactive releases into the waters of the Chesapeake Bay and the atmosphere it would be most helpful if you could answer the following questions:

1. In 1976, BG&E predicted amounts of only 19 radioactive elements entering the Bay as liquid effluents. Through December 1977 at least 48 such elements were identified. Is this cause for concern?

2. Of the 19 predicted liquid radioactive effluents, BG&E's cumulative predictions through December 1977 were frequently underestimated by factors of at least 10 and in the case of Cr-51 the estimates were off by a factor of over 9,000. Is this cause for concern?

3. Has adequate research been done to assess the long term impacts of the radiation releases, such as tritium, into the waters of the Chesapeake Bay? What about the cumulative impact on such organisms as oysters and the people who may eat them?

4. Is the release of the liquid radioactive effluents "as low as is reasonably achievable" as required?

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5. Storm water runoff samples at the Calvert Cliffs plant have contained these radioactive isotopes: Co-60, Co-58, Mn-54, Cx-134, and Cs-137. Is this cause for concern?

6. Ag-110m has been found in oysters six miles from the plant. This isotope was not one of the predicted liquid effluents. Is this concentration of Ag-110m in sediments and oysters near and as far as six miles from the plant cause for concern?

7. Can you comment on the analysis on page IV-19 and the chart at Page IV-21 that Ag-110m, Co-58 and Co-60 doses found in oysters near the plant produce risk levels when eaten by humans that "are minuscule compared to the normal risk levels. ..of the U.S. population today"?

8. BG&E predicted 18 radioactive isotopes in varying amounts would be released to the atmosphere. However, 45 such isotopes, some at much higher rates than predicted, have been released. Are these failures to predict and under-predictions cause for concern?

9. Generating Unit 2 began commercial operation on April 1, 1977 so that the cumulative impact measured in the enclosed report only includes Unit 2's impact for nine months. Are you satisfied that the accuracy of predictions and impacts of cumulative discharges are and will be within safe limits?

10. BG&E has recently applied for authorization to nearly double its storage of spent fuel rods. Is this long term storage, perhaps into the 1990's, cause for concern?

11. Are you convinced that the airborne and liquid effluent discharges from the Calvert Cliffs plant present no threat to human health or safety?

12. Can you comment on the potential for serious calamity given the nearness to Calvert Cliffs of the Cove Point Liquid Natural Gas facility?

I am a member of the House Environmental Matters Committee. This committee reviews legislation involving the operating of the Calvert Cliffs facility. Your comments and answers will greatly aid me in my legislative work.

Thank you for your attention to this matter.

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Sincerely,

Gerald W. Winegrad

Gerald W. Winegrad

GWW/pb

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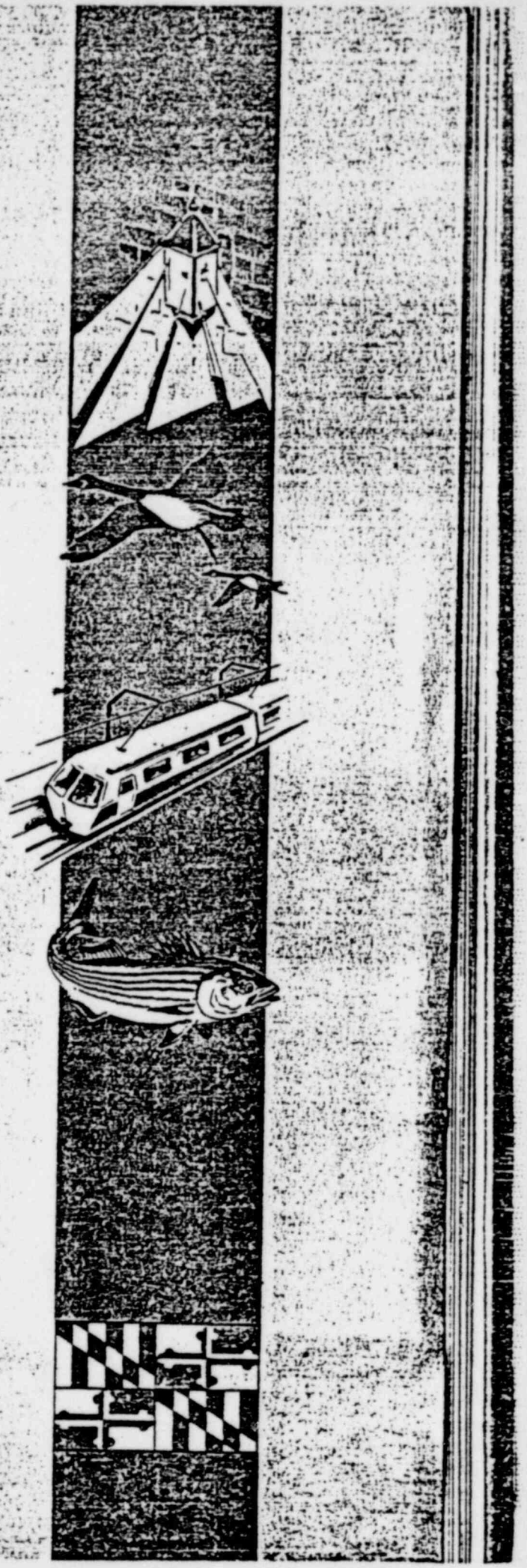
POWER PLANT CUMULATIVE ENVIRONMENTAL IMPACT REPORT



NOVEMBER 1978

ARYLAND POWER PLANT SITING PROGRAM

ARTMENT OF NATURAL RESOURCES ■DEPARTMENT OF HEALTH AND
ITAL HYGIENE ■DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOP-
NT ■DEPARTMENT OF STATE PLANNING ■ COMPTROLLER OF THE TREASURY
UBLIC SERVICE COMMISSION

CHAPTER IV

RADIOLOGICAL EFFECTS

The first Cumulative Environmental Impact Report has presented a discussion of general siting, safety and health issues pertinent to nuclear power plants. It also presented projections of radiological impacts in Maryland, based upon the utility companies' projections for additional nuclear plants, as delineated in their 1975 Ten Year Plans.

Since 1975, extensive changes have occurred in the utility companies' scheduling for new generation. In addition, the Calvert Cliffs Nuclear Power Plant has commenced operation, providing an opportunity to compare actual impact measurements with preoperational predictions.

This Chapter summarizes the current planning for additional nuclear power in Maryland and focuses on the operations to date at Calvert Cliffs. The quantities of electrical energy produced, effluents released and wastes created are discussed. Results of radiological environmental monitoring activities are presented and radiation doses from plant operation are estimated. Comparisons are made, where appropriate, to regulatory limits and to predictions made prior to reactor start-up. Emphasis is placed on continued compliance with NRC guidelines for keeping radiation doses to the public "as low as reasonably achievable". Finally, radiation doses from plant operations to date are compared to variations in natural dose levels measured in Maryland, and the health risks from low level dose increments are tabulated.

A. Status of Nuclear Power in Maryland

The Calvert Cliffs Nuclear Power Plant, owned by the Baltimore Gas and Electric Company, is the only operating nuclear power plant in Maryland. Each of its two units has a Pressurized Water Reactor licensed at 2700 MW (thermal), with design net electrical power output of 845 MWe. Present ratings are 820 MWe for Unit 1 and 855 MWe for Unit 2 in the winter but 810 MWe for both units in the summer, when maximum discharge temperature restrictions may limit plant power (1).

The Peach Bottom Atomic Generating Station, owned by Philadelphia Electric Company, is situated in Pennsylvania on the Susquehanna River, approximately 3 miles north of the Maryland border. Peach Bottom Unit 1, a 40 MWe High Temperature Gas Cooled Reactor, was decommissioned in January 1975. It was originally placed in service on May 25, 1967 as a demonstration plant. During its operating lifetime, it generated more than 1 billion kilowatt hours of electrical energy (2). Peach Bottom Units 2 and 3 are both 1065 MWe Boiling Water Reactor systems. Unit 2 began commercial operation in July of 1974, and was followed by Unit 3 in December of the same year (3).

According to their 1978 Ten-Year Plans filed with the Maryland Public Service Commission, none of the State's utilities now plan new nuclear units for at least the next ten years (4). The Douglas Point Nuclear Generating Station planned by

the Potomac Electric Power Company has been deferred indefinitely. PEPCO intends to retain the site and to pursue a regulatory determination of the site's suitability.

The Baltimore Gas and Electric Company has deleted from its current ten-year plan the nuclear units scheduled for the Perryman site. On December 1, 1977, the staff of the Nuclear Regulatory Commission issued a report recommending that BG&E's application for an early site review and construction permit be denied on the basis that at least one other site available to the Company was superior overall to the Perryman site, particularly with respect to the safety-related issues of surrounding population density and nearby military activities (5).

The Philadelphia Electric Company does not plan for any new nuclear capacity near Maryland before the 1992-1994 time frame. The prime location is their Fulton site, in Pennsylvania directly across the Susquehanna River from Peach Bottom. Three alternative sites include two properties already owned by the Company at Chesapeake City on the C&D Canal, and Seneca Point on the Northeast River, plus the Bainbridge site, currently sought by the Power Plant Siting Program for its site land-bank. All three of these alternatives are located in Maryland.

Delmarva Power and Light Company currently holds a Limited Work Authorization to begin construction of a nuclear plant at Summit Bridge, Delaware, on the C&D Canal three miles east of the Maryland border. Current plans do not specify the type of reactor to be used and indicate an on-line date beyond their current ten-year planning period.

The Potomac Edison Company is selling its Black Oak site, but retaining its Point of Rocks site, both on the Potomac River. The Point of Rocks site was originally obtained for a nuclear plant with an ultimate capacity of 2500 MWe. However, the Company currently has no plans to use the site.

B. Operations at Calvert Cliffs Nuclear Power Plant

Electrical Power Production

Calvert Cliffs Unit 1 achieved initial criticality on October 7, 1974. Following start-up test procedures, it was placed in commercial service on May 8, 1975. Unit 2 achieved initial criticality on November 30, 1976, and was declared commercial on April 1, 1977. As of January 1, 1978, Unit 1 had produced a total of 14,778,865,000 kilowatt hours of electrical energy, and Unit 2 had produced 4,541,354,000 kilowatt hours (6). This corresponds to an average capacity factor of 75.2% for Unit 1 and 81.4% for Unit 2. The environmental impact calculations made by the Baltimore Gas & Electric Company and by the Atomic Energy Commission for the Calvert Cliffs Plant assumed an 80% capacity factor, and attempted to estimate an annual discharge value that would be representative of the average over the plant's 30 year lifetime (7). In the comparisons of reported vs predicted discharges which follow, the "predicted" values given are based upon 3.42 reactor years of operation at 80% capacity factor. The reader should bear in mind that the plant produced virtually the same amount of the power assumed by the predictions for an equivalent period of time after start-up, but neither reactor has yet built-up its internal inventory

of the longer-lived radioactive materials to the levels that will be representative of the average values over the lifetime of the plant.

Radioactive Effluent Releases

Tables IV-1a and IV-1b present listings of the total reported releases from the Calvert Cliffs plant through December 31, 1977, for liquid and atmospheric pathways, respectively (8,9,10,11,12,13,14). Reported releases are derived from measured total releases or from sampling of continuous or semi-continuous low-level discharges. Also included in the tables for comparison are the release values predicted by the Atomic Energy Commission in its Final Environmental Statement before plant start-up, and the values predicted by the Baltimore Gas & Electric Company in 1976 for its "Appendix I Evaluation Report"* (15).

The tabulated quantities of radionuclides released to the environment are small fractions of the releases that are allowable under the portion of the plant's operating license which limits concentrations and quantities of radioactive materials in plant effluents.** The various limitations on plant effluents are summarized in Table IV-2, along with the maximum fraction of the limits actually reached in plant operations through December of 1977.

In addition to the limitations on the quantities and concentrations of radionuclides in effluents, the plant is also required to keep the radiation doses to the public "as low as reasonably achievable". Guideline dose values delineating what the NRC considers reasonably achievable will be discussed later in the impact section of this Chapter. It has been customary for estimates of probable plant radioactivity effluents to be made prior to plant start-up, and to predict maximum dose rates which the power plant could deliver to members of the public, assuming that the plant released effluents at the predicted rate, rather than the maximum allowable rate. Two such sets of effluent predictions have been included in Tables IV-1a and IV-1b. It is useful to assess the accuracy of these predictions as well as trends in the actual release rates in order to assess the level of confidence for prediction of the plant's future performance in keeping doses "as low as reasonably achievable".

In general, the total quantity of radioactive material released to the water has been about one third the level predicted before startup. Total atmospheric releases, which are predominantly Xe-133, have exceeded predictions because the release rate of this radionuclide was underpredicted by more

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* Appendix I to 10CFR50 established "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Power Plant Effluents". All licensed nuclear power plant owners were required to file a report with the NRC by June of 1976, demonstrating that their reactor design complied with the provisions of the Appendix I.

** Effluent concentrations and quantities are limited by Section 2.3 of Appendix B, Environmental Technical Specifications to the Calvert Cliffs Nuclear Power Plant Facility Operating License issued by the U.S. Nuclear Regulatory Commission.

Table IV-1a. Liquid radioactive effluents cumulative to December 31, 1977

Radionuclides	Total Releases Reported by BG&E	AEC Prediction (1973 Est. x 3.42)	BGSE Prediction (1976 Est. x 3.42)
Tritium	1110. Curies	3420. Curies	1160. Curies (a)
Dissolved Noble Gases	38.9	-	-
Other	6.14	17.1	2.120
TOTAL	1155.04 Curies	3437.1 Curies	1162.12 Curies
Na-24	0.0356	-	-
Ar-41	0.0000239	-	-
Cr-51	0.320	0.137	0.0000342
Mn-54	0.104	0.205	-
Mn-56	0.000532	-	-
Fe-55	-	0.787	0.0000342
Fe-59	0.371	0.171	-
Co-57	0.00321	-	-
Co-58	1.93	7.18	0.0140
Co-60	0.263	0.205	0.0298
Kr-85m	0.000117	-	-
Kr-87	0.000626	-	-
Kr-88	0.0000726	-	-
Rb-86	-	0.000445	0.00171
Sr-85	0.000729	-	-
Sr-89	0.118	0.00410	-
Sr-90	0.0123	0.000137	-
Sr-91	0.00127	-	-
Y-90	-	0.000185	-
Y-91	-	0.855	0.0000342
Zr/Nb-95	0.406	0.00137	-
Zr-97	0.00391	-	-
Mo-99	0.0156	0.342	0.00157
Tc-99m	-	-	0.00168
Ru-103	0.0789	0.000479	-
Ru-106	0.000639	0.000133	-
Rh-103m	-	0.000479	-
Rh-105	-	0.0000787	-
Ag-110m	0.10[illegible]	-	-
Cd-109	0.0[illegible]437	-	-
Sn-113	0.00264	-	-
Sn-125	-	0.00000445	-
Sb-124	0.00518	-	-
Sb-125	0.0103	-	-
Sb-127	-	0.0000257	-
Te-125m	-	0.000410	-
Te-127	-	0.00325	-
Te-127m	-	0.00325	-
Te-129	0.00422	0.342	-

Table IV-1a. Liquid radioactive effluents cumulative to December 31, 1977 (Continued)

Radionuclides	Total Releases Reported by BG&E	AEC Prediction (1973 Est. x 3.42)	BG&E Prediction (1976 Est. x 3.42)
Te-129m	-	0.342	-
Te-131	-	0.000889	-
Te-131m	-	0.00479	-
Te-132	0.000300	0.161	0.000308
I-130	-	-	0.0000684
I-131	0.872	0.923	0.0332
I-132	0.00805	-	0.00103
I-133	0.281	-	0.0195
I-134	0.00201	-	-
I-135	0.0268	-	0.00277
Xe-133	38.0	-	-
Xe-133m	0.242	-	-
Xe-135	0.523	-	-
Cs-134	0.286	3.76	0.718
Cs-136	0.00781	1.27	0.229
Cs-137	0.848	0.205	0.581
Cs-138	0.00658	-	-
Ba-133	0.000172	-	-
Ba-137m	-	0.239	0.445
Ba/La-140	0.233	0.00821	-
Ce-139	0.00206	-	-
Ce-141	-	0.000718	-
Ce-143	-	0.000106	-
Ce-144	-	0.000410	-
Pr-143	-	0.000581	-
Nd-147	-	0.000233	-
Pm-147	-	0.0000445	-
Pm-149	-	0.00171	-
W-187	0.000762	-	-
Au-198	0.000163	-	-
U-235	0.000161	-	-
Np-239	0.0385	-	-
Unidentified	> 0.0295		0.000171 (b)
	< 0.136		

(a) BG&E also used the 1976 vintage NRC model which would have predicted a release of 1,810 curies of tritium in the 3.42 reactor-years of operation.

(b) This item contains "all other" releases predicted by the BG&E model.

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Table IV-1b. Airborne releases cumulative to December 31, 1977

Radionuclides	Total Releases Reported by BG&E	AEC Prediction (1973 Est. x 3.42)	BG&E Prediction[a] (1976 Est. x 3.42)
Total Noble Gases	39400. Curies	12300. Curies	28700. Curies
Total Halogens	.311	0.855	0.79
Particulate Gross β	0.619	-	-
Particulate Gross α	>0.00000181 <0.00000345	-	-
Tritium	159.	-	-
Na-24	0.000992	-	1160.[b]
Ar-41	9.20	-	-
Cr-51	0.00674	-	-
Mn-54	0.0494	-	-
Mn-56	0.000330	-	0.000787
Fe-59	-	-	-
Co-57	0.0000249	-	0.000257
Co-58	0.00634	-	-
Co-60	0.0103	-	0.00257
Ni-65	0.00000317	0.00116	-
Cu-64	0.0125	-	-
Br-82	0.00107	-	-
Kr-85	7.94	-	-
Kr-85m	38.0	2570.0	6500.
Kr-87	11.9	-	13.7
Kr-88	21.4	20.5	3.42
Rb-88	1.47	68.4	27.4
Sr-89	0.000370	-	-
Sr-90	0.0000147	-	0.0000547
Sr-91	0.00116	-	0.0000103
Zr/Nb-95	0.00774	-	-
Mo-99	0.000271	-	-
Ru-103	0.00135	-	-
Cd-109	0.00000440	-	-
Sn-113	0.000107	-	-
Sn-133	0.00000436	-	-
Te-129	0.0000000805	-	-
Te-132	0.0000389	-	-
I-131	0.313	0.855	0.342
I-132	0.0685	-	-
I-133	0.247	-	0.410
I-134	0.0231	-	-
I-135	0.189	-	-
Xe-131m	23.1	109.	236.
Xe-133	37600.	9400.	21900.
Xe-133m	176.	-	147.
Xe-135	1500.	123.	68.4
Xe-138	1.28	20.5	0.00

Table IV-1b. Airborne releases cumulative to December 31, 1977 (Continued)

Radionuclides	Total Releases Reported by BG&E	AEC Prediction (1973 Est. x 3.42)	BG&E Prediction (1976 Est. x 3.42)
Cs-134	-	-	0.000787
Cs-137	0.00108	-	-
Cs-138	0.9516	-	-
Ba-133	0.00105	-	-
Ba/La-140	0.00564	-	-
Ce-139	0.000498	-	-
Au-198	0.00000634	-	-
Np-239	0.000292	-	-

(a) This model neglects any noble gases contributing less than 3.42 curies to this table and any iodines contributing less than 0.000342 curies to this table.

(b) BG&E also used the 1976 vintage NRC model which would have predicted a release of 1,850 curies of tritium in the 3.42 reactor years of operation.

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Table IV-2. Regulatory limitations on radioactivity in Calvert Cliffs effluents

Type of Effluent	Limited Value or Equation	Maximum Fraction of Limit Actually Reached
Total quantity of radionuclides, excluding tritium and dissolved noble gases, in aqueous effluents	10 ci/unit/calendar quarter	0.07
Aqueous concentration for all radionuclides, including tritium and dissolved noble gases	Limits specified in 10 CFR20, Appendix B for concentrations in waters in unrestricted areas	0.000111 (tritium) 0.00393 (dissolved noble gases) 0.0244 (others)
Average quarterly rate of release in atmospheric effluents of all radionuclides except I-131 and particulates with half-lives > 8 days	$\sum_i \frac{(\text{Quantity of nuclide "i"})}{(3.85 \times 10^5)\ (\text{MPC}_i)} \leq 0.6$ Where MPC_i values are defined in Appendix B, Table II, Colum 1 of 10 CFR20	0.0763
Average annual rate of release in atmospheric effluents of all radionuclides except I-131 and particulates with half-lives > 8 days	$\sum_i \frac{(\text{Quantity of nuclide "i"})}{(3.85 \times 10^5)\ (\text{MPC}_i)} \leq 0.08$ Where MPC_i values are defined in Appendix B, Table II, Colum 1 of 10 CFR20	0.0732
Quarterly average release rate of I-131 and particulates with half-lives > 8 days	0.16 μ Ci/sec (I-131 equivalent)	0.0538
Annual average release rate of I-131 and particulates with half-lives > 8 days	0.08 μ Ci/sec (I-131 equivalent)	0.0719

than a factor of three.* In order to understand the significance of differences between the predicted and reported release values, it is necessary to make comparisons for individual radionuclides or groups of radionuclides in the context of the various pathways by which they deliver radiation doses to the public.

Atmospheric releases are predominantly radioactive isotopes of the inert or "noble" gases krypton and xenon. These gases do not accumulate in biota or soil, but will give a radiation dose as they blow past an individual. Xenon-133 makes up 95% of the reported airborne releases, and is averaging approximately four times the AEC's predicted release rate. Although relatively large batch releases of Xe-133 during the first half of 1977 resulted in quarterly totals two of three times greater than the average for the remainder of the operating period, it is still clear that the average release rate for the plant will exceed the AEC's predicted value by a factor of three to four. The more recent calculations by BG&E assumed a Xe-133 release rate of 6,000 Ci/yr/unit which has been exceeded by 50% to 70% in operations reported to date. Since Xe-133 has only a 5.27 day half-life, production and discharge of this isotope has already reached equilibrium in the reactors, and an increase is not to be expected with increasing cumulative generation. Since Xe-133 is a gas produced within the fuel road during fission of uranium, it can be expected that the release rate for this isotope will vary somewhat among fuel batches, depending upon the number of imperfections in the fuel cladding. Changes in the leakage rate from the primary coolant loop could also result in future changes in atmospheric release rates for Xe-133.

Except for Xe-135, reported releases of other noble gases have been near or below their predicted values. Kr-89 is the only noble gas radionuclide with a half-life long enough (10.2 years) to allow for continued build-up in the reactor over a period of years. However, reported releases of Kr-85 have been only a few thousandths of the predicted values, and it appears that the turnover of fuel, water and air in the reactors and containments will prevent future increases of the magnitude necessary to approach predicted levels.

Atmospheric releases of radioactive halogens (i.e., iodines and bromines) may be bioaccumulated in the human thyroid gland through several pathways, including inhalation and absorption through the lungs, ingestion of leafy vegetables with radiohalide deposition, and ingestion of milk containing radiohalogens bioaccumulated by cows. Because I-131 has an 8 day half-life and constitutes the majority of radiohalogen releases, it is responsible for the majority of radiohalogen delivered doses.

Releases of radioactive I-131 were approximately one-third of the value originally predicted by the AEC, but closely approximated the values predicted later by BG&E. Releases of the other detected isotopes of iodine were not predicted, except for BG&E's prediction for I-133. Because of their low release rates and very short half-lives, these isotopes are often neglected in impact predictions. Again, because radioactive halogen isotopes all have short half-lives (except for I-129, which has not been predicted or detected), the reactors already should have attained their equilibrium releases rates for this group of radionuclides.

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* As will be discussed later, this release rate is still well below allowable limits, and has not resulted in environmental dose rates of any significance.

Tritium is released from the power plant in the form of water or water vapor (HTO instead of H_2O) and can potentially deliver a radiation dose to the public only by inhalation, absorption through the lungs and subsequent inclusion in body fluids. Atmospheric release of tritium was not predicted by the AEC in their pre-operational calculations. However, more recent NRC dose assessment models predict atmospheric tritium release rates nearly twelve times greater than reported by BG&E for operations to date. BG&E's own recent predictions indicate a release rate more than seven times greater than they have actually reported. Since tritium has a 12.3 year half-life, reported releases might be expected to increase somewhac in the future as concentrations increase in internal plant water systems. Since internal water residence time is more important than either radioactive decay or atmospheric release rate in limiting concentrations, this increase will be less than if the equilibrium concentrations were principally controlled by radiological half-life. Quarterly release data does show a general increase in release rate with time until the last two quarters of 1977, when the rate dropped by two orders of magnitude. BG&E personnel indicate that this decrease in reported releases occurred because of a change in the method of estimating the activity discharged during purges of air in the containment buildings, rather than because of an actual change in the plant's internal concentrations or operating procedures (16). Such variability in discharge estimating procedures is one reason for the large variability in the model predictions, which are based upon earlier observations at other operating reactors.

Original AEC predictions did not include estimates of the isotopic composition for radioactive particulates to be released to the atmosphere. The more recent BG&E predictions do include predictions for 8 isotopes. Actual measurements indicate 29 different radionuclides being released in particulate form, including 6 of the 8 predicted by BG&E. Radioactive particulate releases may potentially enter the human body by deposition in lungs or on leafy vegetables, but these pathways are usually insignificant because of the small quantities of radioactive particulates actually released. Reported release rates approximate BG&E's predictions only for Sr-90 and Cs-137, the other predictions being low by factors ranging from 2.6 to 63. Of the particulate activity actually released, 90% was Rb-88, an isotope not included in the predictions. The presence of this isotope is to be expected, however, since it is produced by the radioactive decay of Kr-88 as well as directly by fission of uranium. Excluding Rb-88, the total of the other particulates released exceed the total BG&E predictions by a factor of 23. Still, the total quantity of particulate releases is quite small, amounting to less than 2 millicuries, exclusive of the Rb-88.

Aqueous releases can roughly be divided into three categories: 1) dissolved noble gases, which do not participate in biological processes, 2) tritium, which does not bioaccumulate, but which does enter biological systems in the same manner as stable hydrogen, and 3) the other elements which chemically interact in both biological and inorganic processes of the environment.

The quantity of radioactive noble gases dissolved in the aqueous releases was not estimated by the AEC in their original predictions for Calvert Cliffs. Since they are chemically inert and the water shields aquatic biota from radiation emitted only a short distance away, dissolved noble gases have insignificant effect in the aquatic ecosystem. Most of the dissolved gas discharge is Xe-133, but the quantity discharged to the water is only about 0.001 of the quantity of Xe-133 discharged directly to the atmosphere.

Aqueous releases to Chesapeake Bay have contained one-third of the AEC's predicted quantities of tritium. The more recent predictions by BG&E indicate that this will be the equilibrium release rate, while the newer NRC model (see footnote to Table 1a) indicates that the release rate will increase with time by nearly a factor of 2. The quarterly total release data are somewhat difficult to extrapolate because Unit 2 has just recently begun operation. However, it does appear that BG&E's predictions are most consistent with the data to present. If so, it indicates that tritium concentrations reach equilibrium between production and discharge within several months of commercial reactor operation, and that both the aqueous and gaseous releases of tritium will remain stable near their present values.

The total of other radionuclides contained in the aqueous discharges has been about one-third the pre-start-up prediction, but is about three time greater than BG&E predicted in its Appendix I Evaluation Report, which considered relatively few isotopes. The radionuclides which have been reported in plant releases and are most likely to be of significance in the Chesapeake Bay ecosystem are Cr-51, Mn-54, Co-58, Co-60, Zr/Nb-95, Ru-103, Ag-110m, I-131, Cg-134, and I-131. Of these, only the two cesium isotopes were predicted in the proper range by the BG&E Appendix I Evaluation Report, while the others were either greatly under-predicted or not included in these predictions at all. The earlier predictions by the AEC more reasonably approximate the reported releases for all these isotopes except Zr/Nb-95, Ru-103 and Ag-110m. Because the ecological portions of the impact prediction models were grossly pessimistic, however, actual measurements of these radionuclides in biota are used later in this Chapter to assess the significance of this under-prediction of releases insofar as it affects actual radiation doses to the public.

Solid Radioactive Waste

Low level radioactive waste shipments from the Calvert Cliffs plant during calendar year 1977 are given in Table IV-3, tabulated by the type of waste and the estimated radionuclide content. There were 19 separate shipments of radioactive wastes by truck from the Calvert Cliffs Nuclear Power plant to Barnwell, S.C. during 1977. Prior to 1977, BG&E was not required to tabulate such shipments and report them to the NRC.

Spent Fuel Accumulation

As of January 1, 1978, Unit 1 had refueled only once and Unit 2 not at all, giving an on-site inventory of 72 spent fuel assemblies in the storage pool. During 1978, both Units 1 and 2 will refuel, bringing the total of spent fuel stored on site to 216 assemblies (17). To date, no spent fuel has been shipped off-site.

In the spring of 1977, President Carter initiated a major change in federal policy by prohibiting the commercial reprocessing or disposal of spent nuclear reactor fuel. Although he announced plans for the federal government to begin acquiring spent fuel from utility companies for federal disposal, the time-table now specified by the Department of Energy does not anticipate that federal acquisition could begin before 1982. Permanent federal disposal sites are not expected to be available before 1988, and perhaps as late as 1993 (18).

Table IV-3. Solid wastes shipped off-site during 1977

Type of Waste	Quantity of Wastes: Volume	Radioactivity
a. spent resin, filter sludge evaporator bottoms, etc.	28.8 m^3	33.9 curies
b. dry compressible wastes, contaminated equipment, etc.	232.0 m^3	0.807 curies
c. irradiated components, control rods, etc.	48.7 m^3	63.6 curies

Composition by Radionuclides

Nuclide	Total Activity
Mn-54	1.75 curies
Co-57	0.102 curies
Co-58	9.94 curies
Co-60	68.3 curies
Zr-95	0.0142 curies
Nb-95	0.0279 curies
I-131	1.74 curies
Cs-134	4.65 curies
Cs-137	10.9 curies
Ba-140	0.267 curies
La-140	0.385 curies

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When the Calvert Cliffs plant was designed and constructed, it was assumed that spent fuel assemblies would be stored on-site for cool-down for approximately one year, followed by shipment off-site to a commercial spent fuel reprocessing plant. The spent fuel storage pool was therefore designed to hold 410 fuel assemblies, so that it could accommodate one annual discharge (72 assemblies) from each reactor plus one complete core (217 assemblies), in case it ever became necessary to empty one reactor.

Under the new federal policy, the Calvert Cliffs Nuclear Power Plant would completely fill its spent fuel storage pool in 1980. Unless BG&E makes arrangements to store additional spent fuel on-site, this would force a shutdown of the plant. In response to this situation, BG&E has redesigned the racks which contain the spent fuel in the storage pool (19-23). The new densely-packed racks can accommodate 528 spent fuel assemblies on each of the two sides of the storage pool. On January 4, 1978, the NRC issued amendments to the Facility Operating Licenses for both units at Calvert Cliffs, allowing the new rack design to be placed in both halves of the spent fuel pool. BG&E has since changed the racks in the Unit 2 side, thus providing sufficient storage for continued operation until January of 1982. A similar substitution of racks on the Unit 1 side can be used to extend operations through September 1984, without shipping spent fuel off-site. As of January 1982, 720 assemblies are expected to be in storage. This number could increase to 1000 by 1984 if there is no shipment to a federal facility before that date.

Spent fuel elements are kept at much lower temperatures in the spent fuel pool than they experienced in the reactor core. Experience has shown that even fuel rods which leaked fission products while in the reactor will cease leaking when cooled-down and transferred to the spent fuel pool. In addition, Zircoloy cladding has been demonstrated to withstand storage for many years in demineralized water. Consequently, the storage of additional spent fuel elements is not expected to cause any significant increase in the discharge of radioactivity in effluents from the reactor site.

Safety issues investigated for spent fuel pool rack modifications include the possibility of accidently initiating a fission chain-reaction in the spent fuel pool and the consequences of accidently releasing a puff of radioactive noble gases by damaging fuel rods while they are stored in the pool (e.g., by dropping a heavy object on them). The additional risks involved in utilizing the densely-packed racks at Calvert Cliffs were found to be insignificant in investigations by BG&E (24) and the NRC (25).

C. Radiological Effects Around the Calvert Cliffs Plant Site

Extensive radiological sampling is conducted around the Calvert Cliffs site by both BG&E and the State. In addition, other radiological sampling activities of the State Government elsewhere in Maryland provide context for interpreting the results around Calvert Cliffs.

Sampling methods used to detect atmospheric discharges from the plant in the surrounding environment include:

- Measurement of monthly external radiation dose by thermoluminescence dosimetry (TLD) techniques at multiple sites, to detect radiation doses given by noble gases.

- Collection of iodine and atmospheric particulates by air pump/filter devices at several locations, with gross α, gross β, radiostrontium and γ spectrum analyses of the samples, to detect radionuclides which may give a dose through inhalation.

- Collection of precipitation, local vegetation and soils for γ spectrum analysis to detect deposition of particulate effluents on crops and soils.

- Collection of milk from nearest dairy for radiostrontium and γ spectrum analysis to detect bioaccumulation in cows milk of radionuclides inhaled by cattle or ingested by grazing.

Data reports addressing methodologies and results of these analyses have been published by the various investigators (26-37). Only the overall conclusions will be addressed here.

Detection of power plant effects is complicated by two factors. First, the natural radiation in the environment is not constant. Variations in rainfall and sunspot activity, and disturbances of soils by human activities such as bulldozing and fertilizing all produce variations in the level of natural background radiation. The second complicating factor is fallout from nuclear weapons testing, which continues to deposit some of the same types of radioactive material that are released by the power plant. To date, no measured doses and only one concentration of a radionuclide detected around Calvert Cliffs can reasonably be attributed to airborne releases from the power plant.

Two measurements of atmospheric concentrations of radioiodine by BG&E on-site for the weeks of March 30 to April 6 and April 20 to 27, 1976 are most likely due to plant effluents (29), as radioiodine was not detected at any other location or in precipitation, in milk, or on grass. Inhalation at these measured concentrations, which averaged 0.02 and 0.01 pCi/m^3 for their respective periods, could potentially result in dose rates of 0.0074 and 0.0037 mrem/week, respectively, to an infant's thyroid gland.* NRC regulations set the limit for such doses to 30 mrem/year (0.6 mrem/week average) off-site. Radioactive iodine was again detected in the atmosphere during each of the fallout periods from the Chinese nuclear weapons tests on September 26, 1976, November 17, 1976 and September 17, 1977. Only during fallout from the 1977 test did calculations based on the plant's release rate and meteorological measurements indicate that the plant could have contributed detectable quantities to any of the radioiodine concentrations measured. Plant contributions to measurements could have been as high as 10% of the measured value at an on-site location during the week of September 27 through October 4, 1977 (31), when fallout iodine was detectable at all stations. Two on-site stations also showed detectable concentrations the following week. BG&E's calculations indicate that the plant

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* The thyroid gland of an infant will receive a greater radiation dose than the thyroid gland of an older individual who breaths air with the same concentration of radioactive iodine. Consequently, the infant thyroid gland dose calculation is the controlling parameter for compliance with standards for maximum dose to any organ of an individual in the general public.

may have contributed to these values (31). The equivalent maximum individual thyroid dose due to inhalation of these concentrations was only 0.005 mrem/week. No measurements of radioiodine in milk are attributed to Calvert Cliffs effluents.

Measurable concentrations of radionuclides in atmospheric particulates, precipitation, vegetation and milk have all been attributed to fallout, rather than to the power plant. These conclusions are based upon comparisons of near-field and farfield data during the periods of fallout.

Measurements of external radiation doses by TLD techniques have resulted in several instances when the BG&E operational phase data exceeded the range expected from their preoperational measurements of ambient doses. Calculations of dose based on the plants release records and meteorological data were used to aid in interpreting these differences. Typically, variations in quarterly doses during the operational phase, which are above the range expected in ambient dose, are on the order of 1 mrem, while calculated plant contributions are on the order of 0.001 mrem or less for the same periods (29,30,31). Since the BG&E control station in Baltimore has also exceeded its expected value by a significant margin, these occurrences have been attributed to the random fluctuations and systematic variations incumbent on any TLD system used to monitor for small increases above natural dose rates.

As previously discussed, release rates of Xe-133 and Xe-135 have been significantly higher than predicted. Calculation of the maximum site boundary dose due to these isotopes for the first quarter of 1977, when the greatest release was reported, produces an estimate of 0.23 mrem total body dose increment and 0.62 mrem skin dose increment (36). These estimates are based on the annual average dispersion factor to a point on the site boundary 1190 m SE of the plant. Calculations using actual meteorological data for that quarter may vary, but the accuracy is sufficient to conclude that the maximum external dose increment due to the plant's operations should be of the same order or smaller than the fluctuations in the TLD monitoring systems used for this work. These calculated dose rates, even if they continued for the entire year, are only about 5% and 6% respectively, of the NRC guidelines applicable to the plant.

For additional perspective, it should be noted that the State's TLD data at Calvert Cliffs and elsewhere have shown over the past two years that the external dose rate near the power plant, including whatever increment is being contributed by the plant, is among the lowest in Maryland (36): about 55 mrem/year compared to a value of 95 mrem/year tabulated by EPA as the Maryland average (41). Moving from the Calvert Cliffs area to the Baltimore area can be expected to increase the annual dose rate by an average of 24 mrem/year. Moving from a wooden frame house to a stone house may add 14 mrem/year. Even the variation of soil composition among sites within the Calvert Cliffs area has been shown to account for differences of 30 mrem/year. Consequently, the dose increments from the Calvert Cliffs airborne releases are not considered significant in the context of normal human activities.

Sampling activities used to address the radiological impact of Calvert Cliffs in the aquatic ecosystem of Chesapeake Bay include sampling water, sediment, and aquatic biota, both edible and forage species.

Discharges of radionuclides to the Bay were predicted to occur only through the cooling water discharge conduit (see Figure IV-1). However, sampling of storm water runoff and the sand below the storm water outfall pipe 002 have revealed that minor amounts of radioactivity are also being discharged by this path (37). At least two discrete incidents (38,39) reported by BG&E to the Maryland Water Resources Administration have been responsible for discharges of radioactive material from this outfall. Continued discharge of barely detectable radioactivity may be due either to continued flushing of contamination caused by these two incidents, or by some other source. Isotopes associated with this discharge include Co-60, Co-58, Mn-54, Cs-134, and Cs-137. Sampling of shorezone fishes, oysters and sediments in close proximity to this outfall has indicated that the radioactivity discharged from the storm drain has probably not made any detectable contribution to radionuclide concentrations in the Bay. This is due in part to the (assumed) small quantity of radionuclides discharged, but also, in large degree, it is due to the rapid dispersion of effluents once they cross the beach and enter Chesapeake Bay. This finding, that some radioactivity may be discharged into stormdrains, should be carefully considered when evaluating other nuclear power plant designs which may be proposed for sites where storm water runoff enters creeks or other natural water bodies with poor natural flushing.

Radionuclides discharged through the cooling water conduit at Calvert Cliffs have been detected in sediments, oysters and crabs (31,32,33,35,37). Although fallout contributions have also been detected, especially in shore zone fishes, the plant's contribution can be ascertained by the near-field/far-field distribution or, in the case of Co-58 and Ag-110m, the additional fact that these isotopes were not detected in recent atmospheric fallout samples.

Table IV-4 presents a list of the maximum concentrations of radionuclides which have been detected in various media and attributed to the power plant's discharges. Of the items listed, it can be seen that Ag-110m has accumulated in the greatest concentrations. This finding was somewhat surprising because discharges of Ag-110m had not been included in the plant's predicted releases nor reported in the plant's effluents prior to the time that the geographic correlation of Ag-110m concentrations in oysters with distance from the plant's cooling water discharge location lead to the conclusion that this radionuclide was coming from the plant. However, Ag-110m had previously been detected in effluents from other nuclear plants, and NRC models current in the summer of 1977 were predicting Ag-110m discharges. The discrepancy between field data and release reports was resolved when it was discovered that an error in BG&E's computerized effluent analysis routine caused AG-110m to be misidentified as Zr-97. Zr-97 (probably actually Ag-110m) was first reported released by the plant in the first quarter of 1976. Ag-110m was first detected in oysters near Calvert Cliffs in the fourth quarter of 1976. By the summer of 1977, the concentration of Ag-110m in oysters near the plant had reached its maximum value to date. While the nearfield concentrations in oysters remained essentially unchanged, Ag-110m reached detectable levels in sediments near the plant and also in oysters near Kenwood Beach, some 6 miles away, by the winter of 1977-78. At this point, it is not yet possible to predict equilibrium concentrations and distributions for the life of the power plant. Ag-110m has a 253 day radiological half-life. Biological turnover in biota and physical movements of water and sediment can be expected to produce a shorter effective half-life for media near the plant's discharge. This may be the case insofar as the Ag-110m concentration in oysters there has remained relatively stable for three quarters, whereas the concentrations could be expected to continue to rise for a period of a few years if radioactive

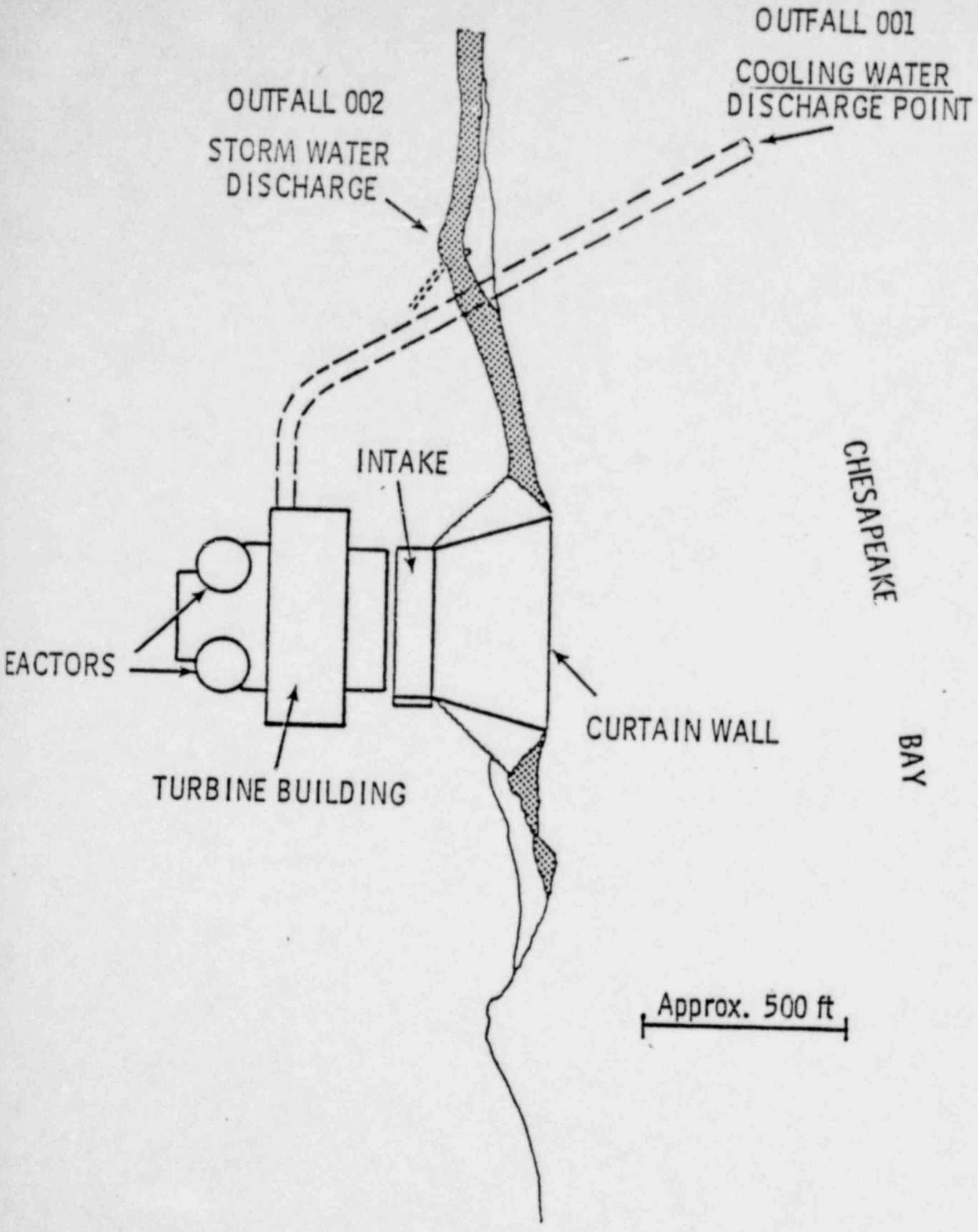

Figure IV-1. Locations of radionuclide discharges into Chesapeake Bay

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Table IV-4. Maximum concentrations of radionuclides attributed to plant operation* in various environmental media

Media	Radionuclide Concentration			
	Ag-110m	Co-58	Co-60	Units
Estuarine Biota				
Oysters	620 ± 20	6 ± 5	3 ± 1	pCi/Kg ± 1.96σ (wet)
Crab				
Meat	14 ± 8	--	--	pCi/Kg ± 1.96σ (wet)
Shell	72 ± 7	15 ± 5	--	pCi/Kg ± 1.96σ (dry)
Fishes	--	--	--	
Estuarine Sediments				
Sand	(5 ± 7)	17 ± 5	18 ± 6	pCi/Kg ± 1.96σ (dry)
Clay	31 ± 10	60 ± 7	53 ± 10	pCi/Kg ± 1.96σ (dry)
Beach Sand				
Discharge 002 Area	--	12 ± 4	53 ± 4	pCi/Kg ± 1.96σ (dry)
Other Areas	--	--	--	pCi/Kg ± 1.96σ (dry)

* The radionuclides Zr-95, Nb-95, Ru-102, Ru-106 have also been detected in these media. Although documented as constituents of plant releases they are also fallout products. Levels in the plant area are not significantly different from control area concentrations, thus any plant contribution to the existing fallout-contributed level is unassessable. Such possible contributions have been neglected here as insignificant contributers to total impact.

decay were the only operable removal mechanism. However, variations in the plant's discharge rate and seasonal fluctuations make such treatments of the data very speculative at this time. A program has been started in which uncontaminated oyster stock is placed directly in the Calvert Cliffs effluent for various periods of time to provide a properly controlled experiment for the evaluation of these various effects.

Figure IV-2a and IV-2b demonstrate that Ag-110m has become the predominant radioisotope in oysters near the power plant discharge. However, the dose received by an individual eating these oysters is quite small. An adult would receive a dose of 0.000009 mrem to the whole body and 0.006 mrem to the gastrointestinal tract by eating one dozen "select" (large) oysters with a Ag-110m concentration of 500 pCi/Kg.*

When computing doses to the "maximum exposed individual", the NRC's Regulatory Guide 1.109 (40) recommends an assumption, in lieu of more specific data, that an adult will eat 5 kg of seafood other than fish, each year. Five kilograms of oysters corresponds to about 24 dozen "select" or 29 dozen "standard" oysters. Five kilograms of crab meat corresponds to about 15 dozen medium crabs. Rather than arbitrarily divide the assumed 5 kg intake between crabs and oysters, Table IV-5 gives the doses that individuals of various ages would receive if they ate 5 kg of oysters and 5 kg of crab meat that contained the radionuclide concentrations given in Table IV-4 as the maximum contributions yet detected from the power plant. None of these doses is considered significant in comparison with the fluctuations created in an individual's natural dose rate by routine human activities, as was discussed in the section on impacts of the airborne effluents.

For purposes of absolute risk evaluation, it has been customary to assume that any incremental radiation dose, no matter how small, increases the risk of certain biological disorders, including cancers, thyroid nodules and genetic defects in progeny. Table IV-6 gives the assumed incremental risk of each effect due to 1 mrem of dose to the appropriate organ (41). In this context, an individual who lived for a year at the site boundary where the maximum dose rate occurs and who ate 5 kg of oysters and 5 kg of crabs from the plant discharge area would expose himself to an additional risk of about one in three million that the nuclear power plant's effluents would induce a biological disorder in him, and an additional risk of about one in five hundred million that it would cause a serious genetic effect in his progeny. Such additional risk levels are miniscule compared to the normal risk levels (43) associated with the same effects in the U.S. population today.

D. Conclusions

Although the Calvert Cliffs Nuclear Power Plant is reporting releases to the atmosphere which are several times greater than originally predicted, and although the reported aqueous releases of the more important radionuclides are greater than BG&E predicted when demonstrating compliance with NRC's design bases dose values, it is still concluded that operations of the plant to date have resulted

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* The value of 500 pCi/kg is used for illustration because it is a reasonable approximation of the concentrations in oysters in the plant vicinity, where values ranged from 620 pCi/kg directly in the discharge plume, to 420 pCi/kg at Camp Canoy.

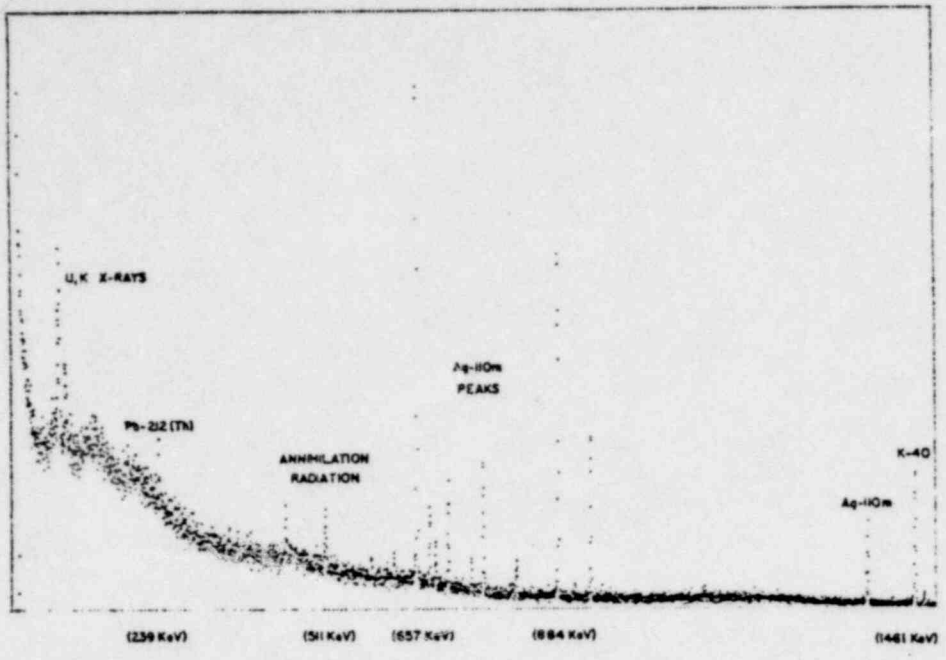

Figure IV-2. (A) Gamma spectron of oysters from Calvert Cliffs Nuclear Power Plant discharge area showing effluent radionuclide bioaccumulation

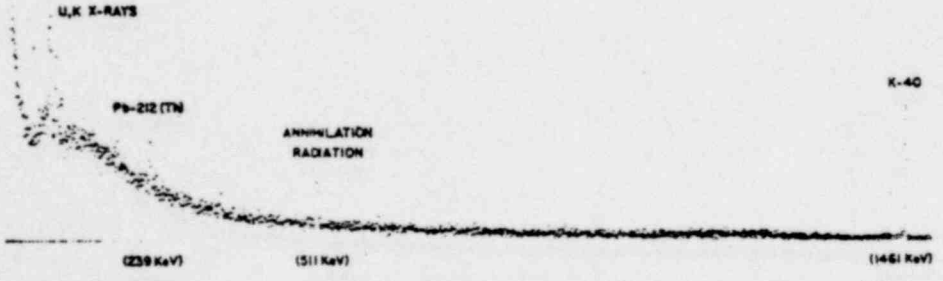

Figure IV-2. (B) Gamma spectrum of oysters from Kenwood Beach area showing only natural radioactivity

Table IV-5. Dose commitment[a] due to Calvert Cliffs Nuclear Power Plant effluents for an individual who takes all his seafood from the plant vicinity (assumes radionuclide concentrations given in Table IV-4).

Age Group	Adult	Teen	Child
Consumption:			
Oysters	5.0 Kg/yr (29 dozen)	3.8 Kg/yr (22 dozen)	1.7 Kg/yr (10 dozen)
Crabs	5.0 Kg/yr (15 dozen)	3.8 Kg/yr (11 dozen)	1.7 Kg/yr (5 dozen)
Total Body Dose:			
Co-58	0.0000543 mrem/yr	0.0000553 mrem/yr	0.0000609 mrem/yr
Co-60	0.0000708	0.0000722	0.0000796
Ag-110m	0.000279	0.000284	0.000314
Total	0.00040	0.00041	0.00045
Bone Dose:			
Co-58	(b)	(b)	(b)
Co-60	(b)	(b)	(b)
Ag-110m	0.000507	0.000494	0.000581
Total	0.00051	0.00049	0.00058
Liver Dose:			
Co-58	0.0000242	0.0000240	0.0000119
Co-60	0.0000321	0.0000320	0.0000270
Ag-110m	0.000469	0.000467	0.000392
Total	0.00053	0.00052	0.00043
Kidney Dose:			
Co-58	(b)	(b)	(b)
Co-60	(b)	(b)	(b)
Ag-110m	0.000922	0.000891	0.000731
Total	0.00092	0.00089	0.00073
GI Tract Dose:			
Co-58	0.000491	0.000331	0.000116
Co-60	0.000603	0.000417	0.000149
Ag-110m	0.191	0.131	0.0467
Total	0.19	0.13	0.047

(a) The dose commitment from ingestion of a given quantity of a radionuclide is the total dose that will be received by the individual before the radioactive material is lost from the body by excretion and/or radioactive decay.

(b) Dose/concentration conversion factors not available.

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Table IV-6. Dose-risk conversion factors

Incremental probability of a particular health effect caused by radiation dose:
• 1 chance in 5,000,000 per mrem total body does for fatal cancer.
• 1 chance in 5,000,000 per mrem total body does for non-fatal cancer.
• 1 chance in 250,000,000[a] per mrem gonadal dose for serious genetic effect in progeny
• 1 chance in 17,000,000 per mrem thyroid dose for thyroid cancer[b]
• 1 chance in 4,000,000 per mrem thyroid dose for benign thyroid nodule[c]
• 1 chance in 25,000,000 per mrem lung dose for fatal lung cancer

(a) Gonadal dose risk is established on the basis of a continuous annual exposure rate for a 50 year generation time. The value given here is based upon 1/50 of the estimated value for the continuous 50 year exposure. That value is 200 effects/yr for 10^6 person-rem annual exposure in the U.S. population with a 50 year generation time.

(b) Usually not fatal.

(c) The absolute risk level for benign thyroid nodule incidence was not given in reference 41, but is computed here as the risk of thyroid cancer given by reference 41 times the ratio of benign-to-cancerous radiogenically-induced thyroid growths given in Reference 42.

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in doses to maximally exposed individuals which are well within the guidelines established by the NRC. These guidelines are given in Table IV-7, along with estimates of the fraction of the guidelines values which the plant has actually contributed.

Predictions regarding future release rates and environmental concentrations of radionuclides produced by Calvert Cliffs are difficult to make with accuracy, given the present state of predictive models and the short period of actual plant operations available for model tuning. However, in view of the very small fractions of the "as low as reasonably achievable" dose guideline values now resulting from plant operations, and with the absence of any visible trends of increasing radionuclide release rates, it appears that the Calvert Cliffs Nuclear Power Plant should continue to operate well within applicable standards.

Table IV-7. Comparison of Calvert Cliffs radiological impact estimates with NRC guideline dose value

Type of Dose	Appendix I[a] Design Objectives	Fraction Given by Calvert Cliffs (2 Units)	Point of Dose Evaluation
Liquid Effluents			
Dose to whole body from all pathways	3 mrem/yr per unit	(0.007%)	Location of the highest dose offsite.[b]
Dose to any organ from all pathways	10 mrem/yr per unit	(0.46%)	Same as above.
Gaseous Effluents[c]			
Gamma dose in air	10 mrad/yr per unit	(2.5%)	Location of the highest dose offsite.[d]
Beta dose in air	20 mrad/yr per unit	(3.4%)	Same as above.
Dose to whole body of an individual	5 mrem/yr per unit	(<5%)	Location of the highest dose offsite.[b]
Dose to skin of an individual	15 mrem/yr per unit	(<4.8%)	Same as above.
Radioiodines and Particulates[e] Released to the Atmosphere			
Dose to any organ from all pathways	15 mrem/yr per unit	(<0.8%)	Location of the highest dose offsite.[f]

(a) Evaluated for a maximum exposed individual.

(b) Evaluated at a location that is anticipated to be occupied during plant lifetime or evaluated with respect to such potential land and water usage and food pathways as could actually exist during the term of plant operation.

(c) Calculated only for noble gases.

(d) Evaluated at a location that could be occupied during the term of plant operation.

(e) Doses due to carbon 14 and tritium intake from terrestrial food chains are included in this category.

(f) Evaluated at a location where an exposure pathway and dose receptor actually exist at the time of licensing. However, if the applicant determines design objectives with respect to radioactive iodine on the basis of existing conditions and if potential changes in land and water usage and food pathways could result in exposures in excess of the guideline values given above, the applicant should provide reasonable assurance that a monitoring and surveillance program will be performed to determine: (1) the quantities of radioactive iodine actually released to the atmosphere and deposited relative to those estimated in the determination of design objectives; (2) whether changes in land and water usage and food pathways which would result in individual exposures greater than originally estimated have occurred; and (3) the content of radioactive iodine in foods involved in the changes, if they occur.