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SUMMARY OF THE ENVIRONMENTAL DOSE MODELS USED AT DOE NUCLEAR SITES IN 1979

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ABSTRACT

Methods for assessing public exposure to radiation from normal operations at DOE facilities are reviewed in this report. This review includes a summary of the methods used in 1979 as described in annual environmental reports submitted by Department of Energy (DOE) contractors. The methods used ranged from estimating public doses based on environmental measurements and comparison to the DOE concentration guides, to complex methods using environmental pathway modeling and estimated radionuclide releases. No two sites used the same combination of measurements and pathway models in their analysis. While most sites used an atmospheric dispersion model to predict air concentrations of radioactive material, only about half of the sites provided enough information about the model used to permit proper model evaluation. The waterborne pathways related to drinking water or ingestion of fish were generally well described, while the external exposure or terrestrial food pathways were often not considered. The major recommendation resulting from this review was that complete documentations of the models used should be included either within the annual reports or as separate readily available documents. In addition, most sites could make better use of graphics (i.e., tables and figures) to better communicate the findings of their analyses.

CONTENTS

ABSTRACT iii

1.0 INTRODUCTION 1.1

2.0 SITE SUMMARIES 2.1

2.1 ALBUQUERQUE OFFICE 2.1

2.1.1 Los Alamos Scientific Laboratory 2.2

2.1.2 Mound Facility 2.3

2.1.3 Pantex Plant 2.4

2.1.4 Pinellas Plant 2.4

2.1.5 Rocky Flats Plant 2.5

2.1.6 Sandia Laboratories 2.6

2.2 CHICAGO OFFICE 2.6

2.2.1 Ames Laboratory 2.6

2.2.2 Argonne National Laboratories 2.7

2.2.3 Battelle Columbus Laboratories 2.7

2.2.4 Brookhaven National Laboratory 2.9

2.2.5 Fermi National Accelerator Laboratory 2.10

2.3 NAVAL REACTORS DIVISION 2.11

2.3.1 Bettis Atomic Power Laboratory 2.11

2.3.2 Knolls Atomic Power Laboratory 2.12

2.3.3 Shippingport Atomic Power Station 2.13

2.4 OAK RIDGE OFFICE 2.14

2.4.1 Paducah Gaseous Diffusion Plant 2.14

2.4.2 Portsmouth Gaseous Diffusion Plant 2.15

2.4.3 Feed Materials Production Center 2.16
2.4.4 Oak Ridge Facilities 2.17
2.5 SAN FRANCISCO OFFICE 2.18
2.5.1 Lawrence Berkeley Laboratory 2.18
2.5.2 Lawrence Livermore Laboratory 2.19
2.5.3 Stanford Linear Accelerator Center 2.19
2.6 ALL OTHER FIELD OFFICES 2.20
2.6.1 Idaho National Engineering Laboratory 2.20
2.6.2 Nevada Test Site 2.21
2.6.3 Hanford Site 2.22
2.6.4 Savannah River Plant 2.23
2.7 SUMMARY 2.25
3.0 SUMMARY AND RECOMMENDATIONS 3.1
3.1 EVALUATION OF METHODS 3.1
3.2 RECOMMENDATIONS 3.2
4.0 REFERENCES 4.1

TABLES

2.1-1 Summary of the Environmental Dose Evaluation Methods In Use at DOE Sites in 1979 DOE Albuquerque Office 2.27

2.2-1 Summary of Environmental Dose Evaluation Methods In Use at DOE Sites in 1979 DOE Chicago Office 2.29

2.3-1 Summary of the Environmental Dose Evaluation Methods In Use at DOE Sites in 1979 Naval Reactors Division . . . 2.31

2.4-1 Summary of the Environmental Dose Evaluation Models in Use at DOE Sites in 1979 DOE Oak Ridge Office 2.33

2.5-1 Summary of the Environmental Dose Evaluation Methods in Use at DOE Sites in 1979 DOE San Francisco Office . . . 2.35

2.6-1 Summary of the Environmental Dose Evaluation Methods in Use at DOE Sites in 1979 All Other Field Offices . . . 2.37

3.1-1 Summary of Environmental Analysis Model Evaluation . . . 3.2

1.0 INTRODUCTION

This report is a review of the methods used by the Department of Energy (DOE) and its contractors to assess public exposure to radiation from normal operations at DOE facilities. Included is a summary of the methods used at each DOE nuclear site and a review of currently available models. Criteria reported by Corley, et al. (1981) can be used to establish the need for pathway analysis at a given site.

Section 2 summarizes methods used at each DOE nuclear site to estimate the radiation doses received off-site during 1979 from operation of the DOE controlled facilities. A summary table for each DOE field office is presented indicating the methods that were used in evaluating the radiological impact of the DOE controlled facilities. The review considers models for airborne pathways, waterborne pathways and penetrating radiation exposure. The methods used by DOE contractors ranged from estimating doses based on environmental measurements and the 1979 applicable ERDA Manual Chapter Appendix 0524 (recently superseded by DOE 5480.1 Chapter XI; DOE 1981) to the complex modeling of pathways.

The term "environmental pathway" is used in this report to represent a transport or accumulation process or a sequence of such processes that result in uptake of radioactivity by man. Inhalation of airborne material and consumption of contaminated milk are examples of environmental pathways.

The terms "model", "computer program" and "parameter" often cause confusion. This report uses the term "model" to represent the mathematical expression or algorithm used to describe the process being simulated. A "computer program" is a means of implementing a given model and/or sets of submodels on a computer. "Parameters" are a part of the mathematical expression of a model and the values adjusted to fit the conditions being simulated. As an example consider the overall environmental consequence analysis model for the release of radionuclides to a river. A submodel for this pathway estimates water concentration at some location downstream. Parameters used in this submodel include river flow rate and width defined for the location being studied.

2.0 SITE SUMMARIES

This section contains summaries of the environmental radiation dose evaluation methods used at each Department of Energy (DOE) nuclear site in 1979, and the radiation doses reported. The environmental pathway radiation dose models are identified in this section. For each DOE field office, a summary table is presented that shows the model information used in the site annual monitoring reports, and the types of environmental sampling data collected. Environmental sampling programs may include a determination of radionuclide concentrations in the gaseous and liquid effluents from site operations, and a determination of radionuclide concentrations in environmental media such as milk, food crops, fish, wildlife, and soil. In 1979, the applicable ERDA Appendix 0513 required: "realistic estimates of (a) the 'fence-post' dose at the location at the site boundary where the maximum exposure rates exist, (b) the dose to an individual and population group(s) in those locations where the highest dose rates occur, and (c) the 80-kilometer (50 mile) man-rem (whole-body) dose" (ERDA 1974). The model information referenced includes the types of atmospheric and water dispersion calculations that are performed and the models that are used to calculate the radiation doses. The following sections contain summaries for all of the nuclear sites reporting to the DOE for 1979.

The environmental pathway analysis performed at each of the DOE nuclear sites was found to depend heavily on the characteristics of the site and the purpose of the facilities. Most of the sites gave careful consideration to the types of releases at their facilities and to the expected pathways of interest. However, the selection of pathways considered in the annual reports varied considerably from site to site. While most of the sites estimated atmospheric dispersion based on the Gaussian plume model, several of the sites used average conditions for wind speed or atmospheric stability. In addition, several sites failed to consider the terrestrial pathways.

2.1 ALBUQUERQUE OFFICE

The DOE nuclear sites reporting to the Albuquerque DOE field office include: the Los Alamos Scientific Laboratory, the Mound Facility, the Pantex

Plant, the Pinellas Plant, the Rocky Flats Plant, and the Sandia Laboratories. Table 2.1-1 contains a summary of the environmental dose evaluation methods in use at these sites in 1979. This table shows both the types of information reported for each site and the model information referenced. The following sections contain narrative descriptions of the environmental dose evaluation methods used at the DOE nuclear sites reporting to the Albuquerque field office.

2.1.1 Los Alamos Scientific Laboratory

The radiological exposure pathways considered for the Los Alamos area in 1979 (LASL 1980) were atmospheric transport of airborne radioactive effluents, hydrologic transport of liquid effluents, food chains, and direct exposure to penetrating radiation. For airborne effluents, reported doses included the maximum dose at the site boundary, dose to an individual or to population groups where highest dose rates occur, and the whole body cumulative dose for the population within an 80-km radius of the site. Exposure to ^{3}H (as HTO), ^{11}C, ^{13}N, ^{15}O, ^{41}Ar and Pu were reported. Doses from all other releases of airborne radionuclides were found to be insignificant. Methods for dose calculations were described in Appendix D of the 1979 environmental surveillance report (LASL 1980). Where appropriate, 50-year commited dose equivalents were calculated using dose factors (ERDA 1976).

Liquid effluents did not flow beyond the LASL boundary but were absorbed in alluvium of receiving canyons; excess moisture was lost primarily by evapotranspiration. A maximum dose from small quantities of radioactive contaminants transported beyond the LASL boundary during periods of heavy runoff was calculated for the Final Environmental Impact Statement (DOE 1979) (eating liver from a steer that drank water from and grazed in lower Los Alamos Canyon).

There were no known significant aquatic pathways or food chains to humans in the local area defined in 1979. Fruit, vegetable, honey, and fish sampling documented that any exposure attributable to LASL operations via those pathways

was insignificant. A possible minor exposure pathway was identified and a maximum individual dose was calculated for eating venison from deer who cross into Laboratory property to graze and drink. No details or references were given for the assumptions and base data used in that calculation. Measurements of external penetrating radiation at regional and perimeter stations indicated only one area with any discernible increase in radiation levels that could be attributed to LASL operations. Based on occupancy and shielding, a maximum individual dose was reported. Onsite doses to members of the general public were also reported.

Cumulative 1979 whole body doses to Los Alamos County residents attributable to LASL operations were compared to exposure from natural radiation and medical radiation. Also, several risk estimates of health effects from radiation doses to the public resulting from LASL operation were given. Maximum boundary and individual doses were compared to the applicable radiation protection standards given in ERDA Manual Chaper 0524 (ERDA 1977). The concentrations of radioactive contaminants in air and water were compared with pertinent standards contained in the regulations of several federal and state agencies. These include ERDA Manual Chapter 0524 (ERDA 1977) for most radioactive materials, ICRP (1964) for uranium in water, and EPA regulations contained in Title 40 CFR Part 141 (1980) for radioactivity in public water supplies.

2.1.2 Mound Facility

The 1979 annual environmental monitoring report for the Mound Facility (Farmer and Carfagno 1980) includes calculated radiation dose estimates for an individual located at the fence line, a maximum offsite individual, and an offsite population group residing within 32-km of the site (no significant contamination was found beyond 32-km). Doses were estimated for two radionuclides: ^{238}Pu and ^{3}H (in the oxide form). Inhalation and drinking water ingestion doses were calculated using equations and data from the ICRP (IRCP 1959; Marrow et. al. 1966, ICRP 1972) and by ratio to the applicable ERDAM 0524 Concentrations Guides (ERDA 1977).

Measured environmental concentrations of ^{238}Pu and ^{3}H in air and ground water were used in the dose estimates. Measured annual average air concentrations were compared to the ERDAM 0524 Concentration Guides, and water concentrations were compared to the EPA National Interim Primary Drinking Water Regulations for Radionuclides (20×10^{-6} μCi/ml). No air or water dispersion calculations were used. The man-rem dose estimates were based on data from environmental air and drinking water measurements.

2.1.3 Pantex Plant

Radiation doses were reported in the 1979 environmental monitoring report for the Pantex Plant (Alexander and Cornelius 1980) to an individual residing at the fence line, the individual residing nearest to the plant boundary, and to the population within an 80-km radius. The doses were calculated for ^{238}U and ^{3}H by ratio to the applicable ERDA Manual Chapter 0524 Concentration Guides (ERDA 1977). Offsite air concentrations were calculated from estimated annual atmospheric releases using local climatological data and the EPA climatological dispersion computer program, CDM (Busse and Zimmerman 1973). There were no effluents to surface waters.

2.1.4 Pinellas Plant

The 1979 environmental monitoring report for the Pinellas Plant (General Electric Company 1980) contains calculated radiation doses to the fence line individual, the individual located at the nearest residence, and the population within an 80-km radius. Annual atmopheric releases of ^{3}H, ^{14}C, ^{85}Kr, ^{238}Pu, and ^{239}Pu were estimated from stack monitoring information. Air concentrations for the dose calculations were estimated using local wind information, Sutton's equations (Slade 1968), and the stack monitoring information. Radiation dose estimates were made by multiplying the air concentrations of each radionuclide at each location times dose factors for ^{3}H, ^{14}C, and ^{85}Kr. No dose estimates for the isotopes of plutonium were included since the estimated and measured concentrations were nearly equal to the natural background levels from fallout. Dose factors for ^{3}H were obtained from Anspaugh (1973); however, it is not clearly stated which exposure pathways were included. Dose factors for ^{85}Kr were referenced from the ERDA Manual Chapter 0524 on

Standards for Radiation Protection (ERDA 1977). No reference was listed for ^{14}C dose factors. Comparisons of air concentrations with ERDAM 0524 Concentration Guides were given, and calculated doses were compared with ERDAM guidelines and natural background levels. No dose calculations for liquid pathways were attempted.

2.1.5 Rocky Flats Plant

The 1979 environmental monitoring report for the Rocky Flats Plant (Barker 1980) contains calculated radiation doses to the fence line individual, the maximum offsite individual, and to the population residing within an 80-km radius of the site. Average measured concentrations of ^{3}H, ^{233}U, ^{234}U, ^{238}U, ^{239}Pu, ^{240}Pu, and ^{241}Am in air and drinking water were used in the dose calculations. The doses resulting from swimming and consuming food including fish were found to be insignificant compared to the doses from inhalation and ingestion of drinking water. This was because only very limited swimming and fishing occur in the area, and most locally consumed food was grown at a considerable distance from the site. Regional and community drinking water monitoring results were compared with EPA-NPDES permit limits and with Colorado state drinking water regulations, (EPA 1974a; State of Colorado 1977). Airborne concentrations are compared to the ERDA Manual Chapter 0524 guidelines (ERDA 1977).

Radiation doses were estimated using dose factors contained in the Rocky Flats environmental impact statement. The doses reported were 70-year committed dose equivalents from a one-year continuous exposure. Dose factors for the radionuclides considered were calculated using the DACRIN computer program (Houston, Strenge, and Watson 1974) for inhalation, and the PABLM computer program (Napier, Kennedy, and Soldat 1980) for drinking water ingestion. These computer programs use the data contained in ICRP Publication 2 (ICRP 1959). The DACRIN program is based on the task group on lung dynamics model (Houston, Strenge, and Watson 1974). Since the dose calculations were based on measured radionuclide concentrations, no atmospheric or liquid dispersion calculations were performed.

2.1.6 Sandia Laboratories

Sandia Laboratories reported doses to the fence line individual and the population within 80-km of the site for annual releases of radioactivity during 1979 (Simmons 1980). Estimates were made of the annual atmospheric releases of ^{3}H, ^{41}Ar and ^{85}Kr for the dose calculations. Environmental samples were also monitored for ^{137}Cs, gross alpha, gross beta, and uranium; however, these data were not used in the dose calculations. Only atmospheric releases were considered. Atmospheric concentrations were estimated using the annual release information and the Guassian diffusion model (Slade 1968). The location of the fence line individual was determined using site-specific joint frequency information. Dose factors were derived from the ERDA Manual Chapter 0524 Concentration Guides (ERDA 1977), but they were not listed separately in this annual report. An equation was presented for calculating population doses, but it is not clear if the air concentration considered was a function of distance and wind direction.

2.2 CHICAGO OFFICE

The DOE nuclear sites reporting to the Chicago DOE field office are: the Ames Laboratory, the Argonne National Laboratory, the Battelle Columbus Laboratories, the Brookhaven National Laboratory, and the Fermi National Acceleration Laboratory. Table 2.2-1 contains a summary of the environmental dose evaluation methods in use at these sites in 1979. This table shows both the types of information reported for each site and the model information referenced. The following sections contain narrative descriptions of the environmental dose evaluation methods used at the DOE nuclear sites reporting to the Chicago field office.

2.2.1 Ames Laboratory

An average individual dose at the fence line and the 80-km population dose were reported for the Ames Site (Voss 1980). No maximum individual dose estimates were reported. The 80-km population estimate was based on 1970 census data. Doses were estimated by ratioing calculated tritium concentrations to the ERDAM 0524 Appendix (ERDA 1977) Concentration Guide for uncontrolled areas.

The 80-km population dose estimate was based on a calculated average tritium concentration. The tritium was assumed to be homogenously mixed in a cylinder with an 80-km radius and 305 m height (approximate height of inversion conditions). Tritium concentration at the exclusion fence was calculated by applying principles of meteorological diffusion to the stack effluent, particularly Section 3-3.5.4, Long-Period Average Concentrations, from Slade (1968). Specific application of this information was not given. Also, details about how the average individual at the fence line was selected were not given.

2.2.2 Argonne National Laboratories

Dose estimates were made for full-time residents and the 80-km population for airborne releases of radionuclides, and for individuals who use water containing the same concentrations as those found in Sawmill Creek (Golchert, Duffy, Seldet 1980). However, this stream is not used for drinking, swimming or boating and has few fish. Doses and dose rates were also reported for external penetrating radiation. The 80-km population used was centered on the CP-5 reactor and was an update of the 1970 U.S. Census data.

Where measured radionuclide concentrations in air and water were available, conversion of concentration to dose was based on the ratio of environmental concentrations to ERDAM 0524 Appendix (ERDA 1977) Concentration Guides for uncontrolled areas and one-tenth of the 168 hour occupational values specified by the ICRP (ICRP 1959 and 1972) for nuclide-organ combinations not given by the applicable ERDA guidance. For argon-41, tritiated water vapor, and iodine-131 released from the reactor stacks, doses were calculated from an atmopheric dispersion model which made use of a source term and meteorological data. However, documentation was not given for this model. External penetrating radiation dose estimates were made either by direct measurements or were based on exponential absorption of the radiation (a decrease in intensity with the square of the distance, and an increase in intensity with distance due to the buildup factor).

2.2.3 Battelle Columbus Laboratories

Radiation doses from releases of radioactivity at Battelle Columbus Laboratories (BCL) were reported in the 1979 annual Environmental Report (Evans

and Heinlen 1980). For atmospheric releases, doses were reported for an individual at the site boundary, an individual and population group at a radius of 3.2-km, and for the 80-km integrated population group. For liquid effluents, doses were calculated for individuals who swim and eat fish from the outfall creek. Measured or calculated concentrations of radionuclides in the atmospheric emissions and liquid effluents were also compared to ERDAM 0524 Appendix (ERDA 1977) Concentration Guides.

Atmospheric concentrations were estimated using X/Q values calculated by the air quality display model computer program (TRW Systems Group 1969) and measured stack concentrations. Columbus meteorological data (U.S. Weather Bureau 1963) were reported to be used in the X/Q calculations; however, details of these calculations and the resulting X/Q values were not available for review. Radiation doses from atmospheric releases were calculated using a model that assumes continuous immersion in an infinite hemispherical cloud containing radionuclides.

Critical organ doses were calculated assuming that the radionuclides were in the most biologically sensitive form, either soluble or insoluble. The dose calculations were based on methods recommended by the ICRP (1959), but specific details about the models used were not available. It was not clearly stated in the annual environmental report if inhalation, air submersion, or both pathways were considered in the dose calculations.

The impact of liquid effluents was estimated by calculating doses to individuals who use the outfall creek for recreation. Doses to a swimmer were calculated for the external radiation received during submersion in the liquid effluent for 8 hours a week during 4 months in the summer. Water concentrations were considered both at the outfall with a dilution factor of 10, and downstream where the annual discharge was divided by the annual average creek flow. Again, specific dose factors or models were not available for review.

Doses to an adult, teen, and child who ingest fish caught in the outfall creek were also presented. The concentrations of radionuclides in the water were the same as those considered for the swimmer. Concentrations in fish were calculated based on bioaccumulation factors described in Regulatory Guide 1.109

(USNRC 1977b). These factors and the concentrations in fish were not tabulated in the annual report, thus the dose calculations could not be checked. Dose factors from Regulatory Guide 1.109 were also used in the dose calculations along with the assumed consumption of 4.8 kg/yr of fish.

2.2.4 Brookhaven National Laboratory

The 1979 environmental report for Brookhaven National Laboratory (Naidu 1980) contains a calculation of a fence line dose to an individual and population dose estimates out to a radius of 80 km. Census data from 1970 was used with a 1979 population survey to determine the offsite population distribution. Population doses were reported from four sources: airborne radioactive effluents (^{3}H), radioactive liquid effluents, direct exposure from the gamma forest ^{137}Cs source, and skyshine from the Alternating Gradient Synchrotron (AGS).

The average annual dose equivalent rate to an individual at the site boundary from airborne effluents was calculated for ^{3}H releases based on the ratio to the ERDAM 0524 Concentration Guide (ERDA 1977) values. Offsite X/Q values were next obtained from an EPA preliminary document (Holzworth 1972). Even though these values were referenced, it was not clear how they were calculated since they were distance dependent, but independent of wind direction. The dose rate from ^{3}H for each downwind distance was found by using the dose rate at the site boundary times the corresponding X/Q ratio. These dose rates were multiplied by the number of people residing at each distance. The total collective dose was compared to the annual external background dose.

Population dose to a limited group from ingestion of fish from the outfall stream was estimated for both adults and infants using NRC Regulatory Guide 1.109 dose factors (USNRC 1977b). Radionuclide concentrations in the fish were assumed to equal the maximum reported ^{90}Sr and ^{137}Cs concentrations observed from the fish sampling program conducted during the year. Total dose was found by summing total body and bone doses to an individual, and multiplying by the total number of people in the population group. (Note: This is an incorrect procedure since critical organ doses from Regulatory Guide 1.109 are not additive.)

Direct external exposures from the gamma forest ^{137}Cs source and from the Alternating Gradient Synchrotron were estimated at the site boundary from dosimeter information. The population dose is calculated for each of 16 directions out to 4.8-km. The method for calculating population dose was not clearly stated.

2.2.5 Fermi National Accelerator Laboratory

The environmental monitoring report for 1979 from the Fermi National Accelerator Laboratory (NAL) contains an estimate of the fence line individual dose and the population exposures received within an 80-km radius of the site (Baker 1980). Census data from 1970 was used with an overall increase of 20 percent to reflect population increase. Three types of population exposures were included in the analysis: exposure to penetrating muons from the neutrino area, exposure to airborne radioactivity from the neutrino area, and exposure to penetrating gamma-rays from Laboratory 7. These exposures were all for sources external to the human body, with no internal deposition pathways such as ingestion or inhalation. Airborne and liquid release concentrations were also compared to ERDA Manual Chapter 0524 Concentration Guides (ERDA 1977). Doses to a fencepost maximum individual were reported for muon exposures. Direct gamma-ray exposures from Laboratory 7 are also calculated for an individual residing in an adjacent house. The doses to this individual were included as if he were a member of the total offsite population group.

Direct dose measurements at the site boundary were used to determine the muon dose rates. Population doses were estimated using these dose rates and the direction specific population distribution with the inverse square relationship.

Measured airborne releases are reported to be mostly ^{3}H and ^{11}C. Doses from ^{3}H were not calculated since the mean air concentration was calculated to be less than 1% of the ERDAM 0524 Concentration Guides. Dose rates from air submersion were calculated at the site boundary for ^{11}C using measured stack concentrations and a Gaussian plume dispersion model (Slade 1968). The same dispersion model was used to calculate air concentrations out to 80-km from the site, including radioactive decay of ^{11}C. Since most of the

dose was received within a 16 km radius of the site, the population within this radius was increased by 40% to reflect post-1970 housing developments. The exact method and data used to calculate the dose rates at the site boundary, based on stack measurements, are not available for review at this time.

The dose from direct gamma-rays near Laboratory 7 was calculated based on dose rate information measured during 1979. It was assumed that a "worse-case" total dose comes from exposing individuals for 24 hours per day at Laboratory 7. It was not clear how many individuals were included in the calculation, and the resulting dose to onsite individuals was included in the total population exposure summary for 1979.

2.3 NAVAL REACTORS DIVISION

The Naval Reactors Division includes Bettis Atomic Power Laboratory, Knolls Atomic Power Laboratory (which includes three separate sites), and Shippingport Atomic Power Station. Table 2.3-1 contains a summary of the environmental dose evaluation methods in use at the Naval Reactor facilities in 1979. This table shows both the types of information reported for each site and the model information referenced. The following sections contain narrative descriptions of the environmental dose evaluation methods used at the Naval Reactors Division sites.

2.3.1 Bettis Atomic Power Laboratory

The maximum radiation exposure to an individual at the Bettis site perimeter and the 80-km population radiation exposure attributed to Bettis Atomic Power Laboratory operations during 1979 were reported in the annual monitoring report (Bettis Atomic Power Laboratory 1980). Estimated doses were given for the whole-body and the limiting organ for liquid, airborne, and direct exposure pathways. Doses estimated for the liquid and airborne pathways were reported for radiation exposure potentially received by an individual over a 50-year period following the ingestion or inhalation of the radionuclides released from Bettis in 1979.

Radiation doses to man for both liquid and airborne pathways were calculated using the standards and calculational models recommended by the International Commission on Radiological Protection (ICRP) and the Nuclear Regulatory Commission (NRC) (ICRP 1959; USNRC 1977c; USNRC 1977b; Hoenes and Soldat 1977). Radiation doses from radioactive liquid releases were calculated using methods and parameters recommended by the NRC (USNRC 1977c; Hoenes and Soldat 1977). Atmospheric disperion of the radioactive airborne materials released from the laboratory and radiation doses were calculated using a computer program developed at Bettis which was based on a methodology similar to that defined by Slade (1968). Furthermore, the program met the general guidelines of the NRC (USNRC 1977b; Hoenes and Soldat 1977). The specific radionuclide composition of airborne and liquid releases was factored into the assessment. The dose for each exposure pathway was explicitly calculated for each radionuclide and its daughters. Atmospheric pathway calculations used wind direction data and meteorological parameters typical of the Bettis area. The population distribution in the vicinity of the Bettis site was based on 1970 census data.

2.3.2 Knolls Atomic Power Laboratory

Estimated annual exposure to maximum individuals, average members of the nearest population groups, and residents within 80-km of each Knolls Atomic Power Laboratory (KAPL) site were reported in the KAPL annual environmental monitoring report (KAPL 1980). Air and water pathways were considered in estimating radiation exposures. Air pathways included external exposure from airborne radioactivity and radioactivity deposited on the ground, ingestion of foodstuffs, and inhalation of airborne radioactivity. Water pathways included ingestion of water and fish, swimming, and boating.

In estimating doses, the dose contribution from each radionuclide present (in the gaseous and liquid effluents) to the dose to the various organs of the body was calculated using the appropriate usage and dose factors from Hoenes and Soldat (1977), Nuclear Regulatory Guide 1.109 (USNRC 1977b), and ERDA-1541 (1976).

Estimates of concentrations and exposures via air pathways were calculated using an EPA computer code (EPA 1974b). Atmospheric diffusion parameters reported in Wind Roses and Annual Joint Percentage Frequency of Wind Speed and Direction for the Kesselring Site of Knolls Atomic Power Laboratory (Environmental Systems Corporation 1975) were used in the calculations for the Kesselring and Knolls Sites.

The computer program described in the report by Environmental Systems Corporation (1975) was used to calculate the exposure for each radionuclide as a function of direction and distance from the release site for each Pasquill stability class. Exposures for each sector segment were summed over all stability classes and the radionuclides contributing dose to the same organ. Total population exposures were obtained by summing the product of the exposure and population for each sector segment. The population residing within 80-km of the site was based on the 1970 census data.

Calculated radiation exposures from KAPL operations were compared with average exposures received from other sources (natural and man-made) of radiation and with NRC (10 CFR Part 50 Appendix I 1980) and EPA (40 CFR Part 141 1980) guides.

2.3.3 Shippingport Atomic Power Station

The maximum annual radiation exposure potentially received by an individual residing at the site boundary and to the entire population within 80-km of the site were reported in the Shippingport 1979 Annual Radiological Environmental Report (Duquesne Light Company 1980). The atmospheric dose pathways considered were inhalation, immersion in gaseous and suspended particulate radioactivity, and the ingestion of food products and milk produced in the Shippingport vicinity. It was assumed that food products consumed by the public are produced in the Shippingport area. Liquid pathways were not considered because no radioactive liquids were released from the Shippingport Station during 1979.

Dose estimates were made using calculational models recommended by the ICRP (ICRP 1959) and the general guidelines of the Nuclear Regulatory Commission (USNRC 1977b). Model parameters and usage factors for the exposure

pathway analysis were also consistent with the values recommended in Nuclear Regulatory Guide 1.109. Site-specific meteorological data were used. The population distribution within 80-km of the site was based on census data projections for 1979.

2.4 OAK RIDGE OFFICE

The DOE nuclear sites reporting to the Oak Ridge DOE field office include: the Paducah Gaseous Diffusion Plant, the Portsmouth Gaseous Diffusion Plant, the Feed Materials Production Center, and the Oak Ridge National Laboratory Facilities. Table 2.4-1 contains a summary of the environmental dose evaluation methods in use at these sites in 1979. This table summarizes both the types of information reported in the annual monitoring report, and the types of model information referenced. The following sections contain narrative descriptions of the environmental dose evaluation methods used at the DOE nuclear sites reporting to the Oak Ridge field office.

2.4.1 Paducah Gaseous Diffusion Plant

The 1979 environmental monitoring report for the Paducah Gaseous Diffusion Plant contains radiation doses calculated for the fencepost individual, the nearest offsite resident, the nearest community resident, and the cumulative population residing within an 80-km radius of the plant (Paducah 1980). Inhalation and ingestion of radionuclides resulting from atmospheric releases were the only exposure pathways considered. Immersion in contaminated air was assumed to be a negligible exposure pathway and was therefore not included. Fifty-year committed dose equivalents to the bone, lung, kidney, GI-tract, and total body were estimated using measured emmission rates, wind speeds, and wind frequencies. Dose conversion factors from the INREM computer code were used to calculate the 50-year committed dose equivalents (Killough and McKay 1976). Doses to the fencepost individual were estimated using both the measured alpha activity in ambient air and calculated air concentrations. However, it was not clearly indicated whether or not the ambient air concentrations were annual-averaged concentrations, or which meteorological conditions were used in the diffusion calculations. For inhalation, 10% of the uranium and 100% of the technetium released were assumed to be in a soluble form. Ingestion doses to

the nearest offsite resident were calculated for the consumption of a diet consisting of terrestial crops, beef, and milk produced in the vicinity of the plant. Cumulative population doses were calculated using site-specific population distribution data. Although grab sample data were available from the Ohio River, Big Bayou Creek, and groundwater sources, no dose calculations were made for liquid pathways since there was no detectable change in water quality.

2.4.2 Portsmouth Gaseous Diffusion Plant

Potential radiation doses to man were included in the 1979 environmental monitoring report for the Portsmouth Gaseous Diffusion Plant (Acox et al. 1980). Dose estimates were made for the fencepost (site boundary) individual, individuals residing in the nearest community, and the total population residing within an 80-km radius of the plant. All dose calculations were made using the models and data given by Killough and McKay (1976) in A Methodology for Calculating Radiation Doses From Radioactivity Released to the Environment. Both atmospheric and liquid releases were considered in the radiation dose analysis.

For atmospheric releases, the dose pathways considered were: immersion in air, direct exposure from contaminated ground, inhalation, and ingestion of food products. Fifty-year committed dose equivalents were reported for total-body, bone, kidneys, GI-tract, and lungs of the exposed individuals. Total body fifty-year committed dose equivalents were reported for the population. The doses to the fencepost individual were estimated for both measured and calculated air concentrations. Calculated air concentrations are used to estimate doses to the individual in the nearest community and to the total population within a radius of 80-km. No radiation above background was found in any of the food products sampled within an 18-km radius of the site. Thus, the dose estimates obtained using dose assessment models were considered to be conservatively large. However, the exact data, assumptions, and methods for performing atmospheric dispersion calculations were not clearly documented beyond a general reference to Meteorology and Atomic Energy (Slade 1968).

For liquid releases, the average river concentration was calculated using the annual average river flow rate and the total annual release as determined by effluent monitoring data. The aquatic exposure pathways considered include: submersion in water (swimming), ingestion of fish, and ingestion of drinking water. Fifty-year committed dose equivalents were reported to the maximum-exposed individual for total-body, bone, kidneys, and GI-tract.

2.4.3 Feed Materials Production Center

The 1979 environmental monitoring report for the Feed Materials Production center reported radiation dose estimates for an individual at the site boundary, the maximum individual at an offsite residence, the average member of the nearest community, and the total population residing within an 80-km radius of the site (Boback and Ross 1980). Fifty-year committed dose equivalents were calculated using the models and data given by Killough and McKay (1976). Direct exposure, inhalation, ingestion of terrestrial food products, and ingestion of drinking water were the exposure pathways considered.

At the site boundary, the inhalation 50-year committed dose equivalent was determined using the highest annual average air concentration measured at the site boundary. Also the maximum annual direct dose rate at the site boundary, as measured with thermoluminescent dosimeters, was used to determine the maximum potential annual dose from penetrating gamma radiation. The maximum dose to an offsite individual was reported for the nearest offsite residence from inhalation. Air concentrations for the maximum offsite individual were obtained using a diffusion model; however, no details of the calculations were included apart from a general reference to Meteorology and Atomic Energy (Slade 1968). The maximum dose to an individual in the nearest population group was reported for inhalation of airborne uranium and thorium. Again, no details of the diffusion calculations were reported. An estimate of the total population dose within an 80-km radius was included; however, no details about the total-body dose calculations were given. Dose estimates were also included for an individual who ingests a limited amount of locally grown food that contains the average concentration of uranium found in vegetables grown near the site.

River water was not used as a drinking water supply. However, the 50-year committed dose equivalent was calculated for an individual who drinks 2.2ℓ of river water per day for the year. The annual average concentration of the water used in the calculations was not stated.

All of the calculated doses were compared to the applicable 1979 ERDA radiation protection standards for the general population (ERDA 1977).

2.4.4 Oak Ridge Facilities

The radiation dose estimates given in the 1979 environmental monitoring report for the Oak Ridge Facilities (ORF 1980) included doses to: the point of maximum potential exposure (at the fencepost), the "hypothetical maximum individual" (at the fencepost), the individual living nearest to the site, the average resident in the community of Oak Ridge, and the cumulative population residing within an 80-km radius of the site. The dose at the point of maximum potential exposure at the fencepost was reported for the location of highest direct dose rate for an exposure time of 24 hours/day for the entire year. A more reasonable dose to the "hypothetical maximum individual" was also reported for the same location with an exposure time of 240 hours/year. The radiation exposure pathways considered in estimating offsite doses (at other locations than the fencepost) included direct exposure to gamma-rays (from "sky-shine" and deposited ground or sediment contamination), inhalation, and ingestion of milk, drinking water, and fish. These radiation doses were calculated using the models of the International Commission on Radiological Protection(ICRP) as encorporated in the EXREM and INREM computer codes (ICRP 1959, 1964, 1966, 1972, 1975; Turner et al. 1968; Turbey and Kaye 1973).

For gaseous effluents, all of the discharges were assumed to occur from either a 10m or an elevated stack at each of three sites. Meteorological data collected at the Oak Ridge National Laboratory site was used with a Gaussian plume model (Pasquill 1962; Gifford 1962) incorporated in a computer program to calculate air concentrations at all receptor locations (Reeves, Fowler, and Cowser 1972). Fifty-year committed dose equivalents were calculated for total-body, thyroid, lungs, bone, liver, kidneys, and GI-tract for an average adult. Total-body and critical organ (lung) doses were reported for inhalation. The dose to a maximum individual drinking milk from the atmosphere-pasture-cow-milk pathway was calculated based on measured milk concentrations.

For liquid releases, dose estimates were made for a maximum individual drinking water. These dose estimates were made based on measured concentrations in river water, and were reported for total-body and bone. Estimates of the fifty-year committed dose equivalent from ingestion of fish were made for the highest sample concentration in fish and for the average sample concentration.

The radiation doses calculated for the annual report at ORNL were compared to the applicable ERDA Manual Chapter 0524 Concentration Guides (ERDA 1977). Corrections for natural background were made to the environmental monitoring samples that were used as the basis for the ingestion calculations.

2.5 SAN FRANCISCO OFFICE

Four DOE nuclear sites report to the San Francisco DOE field office: the Atomics International Site, the Lawrence Berkeley Laboratory, the Lawrence Livermore Laboratory, and the Stanford Linear Accelerator Center. Table 2.5-1 contains a summary of the environmental dose evaluation data and methods used at three of these sites in 1979. Atomics International was not required to submit an annual report in 1979. This table shows both the types of information reported for each site in their annual environmental monitoring reports and the types of model information referenced. The following sections contain narrative descriptions of the environmental dose evaluation methods used at the DOE nuclear sites reporting to the San Francisco field office.

2.5.1 Lawrence Berkeley Laboratory

Fencepost individual and 80-km population dose estimates from penetrating radiation attributable to Lawrence Berkeley Laboratory (LBL) accelerator operations for 1979 were reported by Schleimer (1980). Population dose estimates from penetrating radiation were based on the maximum measured dose at the site boundary. The estimates accounted for variation of dose equivalent with distance from LBL, the population distribution, and shielding

factors for hills and buildings (Thomas 1976). A stable population was assumed. A 50-km population dose attributable to LBL airborne releases of radionuclides was also reported for 1979 (Schleimer 1980).

Man-rem per curie released constants were calculated for LBL based on the 80-km population distribution, site specific averaged meteorology, a Gaussian dispersion model, and the applicable Concentration Guide data listed in ERDA Manual Chapter 0524 (ERDA 1977). These constants along with measured stack releases of radionuclides were used to estimate the 80-km population committed dose equivalents attribuable to LBL airborne releases.

2.5.2 Lawrence Livermore Laboratory

Radiation doses were reported for the fencepost individual, the maximum individual (nearest offsite resident), and the total population residing within an 80-km radius of the site in the 1979 environmental monitoring report for the Lawrence Livermore Laboratory (Silver et al. 1980). Inhalation and ingestion of both potable water and food were the exposure pathways considered in the dose calculations. A continuous,point source (CPS) computer code was used to calculate atmospheric dispersion (Peterson, Crawford, and Lawson 1976). The CPS code was based on the Gaussian plume model (Slade 1968), and it uses local meteorological data adjusted for topography differences. Dose estimates were based on the dose conversion factors from NRC Regulatory Guide 1.109 (USNRC 1977b). Annual penetrating radiation doses at perimeter locations were derived from TLD measurements. Neutron doses were also reported from measured data.

2.5.3 Stanford Linear Accelerator Center

Exposure pathways considered in the Stanford Linear Accelerator Center (SLAC) annual environmental monitoring report (SLAC 1980) were direct exposure to penetrating radiation, drinking wellwater, and exposure to airborne radionuclides. Maximum individual and population doses were given (SLAC 1980) but they were considered to be below significant levels for the penetrating and airborne pathways (0.1% of standard for maximum annual dose). No water samples or dose estimates were reported for the water pathway for 1979 because

of heavy site construction activities. (No measurable increase in radioactivity in groundwater attributable to SLAC operations has been reported since 1966).

Population doses from penetrating radiation were estimated for the population exposed to 1 mrem or more for the calendar year. This corresponds to the population that was less than 2-km from a central point representative of the source of neutrons. Penetrating radiation monitoring data, distance, and population density were used in the population and individual dose estimates. Doses at distances other than the point of measurement were estimated by using a method by Lindebaum (1961) for evaluating skyshine neutrons with a quality factor of 10.

Dose estimates for airborne radioactivity were based on measured releases which were corrected for dilution. An empirical mathematical model developed specifically for SLAC was used to estimate the off-site concentration. The method used for estimating dose based on population was not given.

2.6 ALL OTHER DOE FIELD OFFICES

Four DOE field offices have only one DOE nuclear site each reporting to them. These are: the Idaho Office, the Nevada Office, the Richland Office, and the Savannah River Office. This section contains site summaries for the Idaho National Engineering Laboratory, the Nevada Test Site, the Hanford Site, and the Savannah River Plant. Table 2.6-1 contains a summary of the information reported in the 1979 environmental monitoring reports for these sites, and a summary of the model information that they reference. The following sections contain narrative descriptions of the environmental dose evaluation methods used at these four DOE nuclear sites.

2.6.1 Idaho National Engineering Laboratory (INEL)

The maximum fencepost dose, maximum dose to a member of a population group and an 80-km population dose were reported in the 1979 Environmental Monitoring Program Report for Idaho National Engineering Laboratory Site (INEL 1980). The doses reported were for whole-body, 50-year committed dose equivalents from inhalation and air submersion, and doses to an individual from ingestion of

meat from wild duck and antelope. Atmospheric transport was the principal exposure pathway from the site. There were no surface streams from onsite to offsite locations, and the low-level radioactive waste released to the aquifer has never been observed within 4.8 km of the southern boundary of the site. The principal indirect exposure pathway involved offsite hunting or fishing for game species that have spent some time on the site.

INEL calculations were based on a mesoscale air dispersion program called MESODIF. MESODIF (Start and Wendell 1974) combined an objective regional trajectory analysis scheme with a Gaussian diffusion model. The trajectory analysis scheme utilized wind data from a network of tower-mounted wind sensors to consider the effects of spatial variability of horizontal wind flow near the surface, incorporated time changes in rates of diffusion, and used an upper level lid to vertical mixing. Decay of radionuclides was considered from release out to 14 km (distance to southern site boundary). Whole-body dose estimates were made using parameters given by Corley et al. (1977) and Hoenes and Soldat (1977). The doses reported are 50-year committed dose equivalents from one year of exposure.

The estimated dose to the public within 80 km of the TRA-ICPP complex was made by summing the potential individual doses to the people of each city within the 80-km radius. Dose to an individual at a particular city was a fraction of the maximum individual dose. This fraction was the ratio of the air concentration isopleth at each city to the air concentration value used to calculate the maximum individual dose.

2.6.2 Nevada Test Site

Maximum individual 50-year committed dose equivalents for 1979 Nevada Test Site operations were identified for individuals residing at each location where measurable radioactivity was found (Grossman 1979). These doses were estimated by ratioing the measured environmental sample data to the applicable Concentration Guides for uncontrolled areas given in ERDA Manual Chapter Appendix 0524 (ERDA 1977). No fenceline dose estimates were made. The population 50-year committed dose equivalent was calculated by multiplying the maximum

individual dose, for locations within 80-km of the Nevada Test Site control point, by the total population at each location and summing over all locations.

Radioactivity from past underground tests has been observed in surface or well-water samples. Because the affected water was not used for drinking, no dose estimates were made.

2.6.3 Hanford Site

The 1979 maximum fencepost exposure rate, and the annual and 50-year committed dose equivalents for maximum individuals and 80-km populations were reported in Environmental Surveillance at Hanford for CY-1979 (Houston and Blumer 1980). Radiation doses were reported for both atmospheric and liquid releases. For atmospheric releases, the exposure pathways considered were: inhalation, air submersion, direct exposure from deposited radionuclides and ingestion of food containing deposited radionuclides. The liquid exposure pathways considered were: ingestion of drinking water, ingestion of irrigated foods, ingestion of fish and aquatic recreation. Dose estimates from airborne pathways were reported for each of the 80-km populations surrounding the three major operating areas. Three separate estimates were made because the major operating areas were located far enough apart that different population distributions and meteorological conditions exist for each area. Dose calculations were made using site specific meteorological data and the computer codes DACRIN (Houston, Strenge and Watson 1976), GRONK (Soldat, Robinson and Baker 1974), FOOD and ARRRG (Napier et al. 1980).

Atmospheric dispersion was calculated using the cross wind average Gaussian model (Slade 1968). The vertical dispersion parameters, σ_z were derived from Hanford Site work by Fuquay (1964) and Pasquill (1962) as modified by Gifford (Sagendorf 1977). DACRIN (Houston, Strenge and Watson 1976) was used to estimate radiation doses from the inhalation pathway. It uses the model of the International Commission on Radiological Protection (ICRP) Task Group on Lung Dynamics (1966) to account for radionuclide movements through the respiratory system. Once radionuclides reach the blood stream, the doses to organs other than the lung were calculated using a single exponential retention function (ICRP 1959). Air submersion doses were estimated using the computer

program GRONK (Soldat, Robinson and Baker 1974) and a semi-infinite cloud geometry was used. The dose factors used in GRONK were listed by Soldat, Robinson and Baker (1974).

The FOOD (Napier et al. 1980) computer program was used to estimate radiation doses from terrestrial pathways. FOOD models the transfer of radionuclides (except for ^{3}H and ^{14}C) from air or irrigation water to plants through leaves and soil to food products as described in Soldat (1971). For ^{3}H and ^{14}C, the concentrations were assumed to have the same specific activity as in the contaminating media. Aquatic exposure pathways were evaluated with the program ARRRG (Napier et al. 1980). ARRRG calculated internal dose from ingestion of drinking water, fish, other aquatic animals and water plants, as well as external doses from swimming, boating, and shoreline exposure. Annual average mixing of radionuclides in the river was assumed. Radionuclide removal efficiencies for water treatment plants were based on experience at Richland and Pasco, Washington water treatment plants. Radiation doses calculated using ARRRG were based on the single exponential retention function recommended by the ICRP (1959).

2.6.4 Savannah River Plant

Dose commitments to the public from 1979 atmospheric and liquid releases of radioactive materials from the Savannah River Plant (SRP) are reported in the SRP 1979 environmental monitoring report (SRP 1980). Specific dose commitments were reported for: the average and maximum individual at the SRP perimeter, the population living within 80-km of the center of the SRP, individuals drinking water from a water treatment plant downstream of the SRP, and the population drinking water from the two water treatment plants downstream of the SRP. External exposure from radioactive materials in the atmosphere and on the earth's surface and internal exposure from radioactive materials entering the human body from SRP 1979 releases were considered in calculating the 70-year committed dose equivalents. Internal pathways included inhalation, ingestion of food and water containing radioactive materials deposited from the atmosphere, and consumption of river water. Since there was no known use of river water for irrigation downstream from SRP and fish from the water were not an important source of food for any large segment of the population, these pathways were not considered.

An integrated air concentration and gamma dose factor were calculated for each radionuclide for each of 320 grid points representing the area within a 100-km radius of the SRP. These quantitites were corrected for decay according to radionuclide and measured meteorology for each data period. They represent a yearly integrated concentration (curie-seconds per cubic meter) and gamma dose associated with each grid point for a one curie release over the year. For each of the 320 grid points, the integrated air concentration and gamma dose factor for a one curie release were multiplied by the number of curies of each radionuclide released in a year to obtain integrated air concentrations and gamma cloud dose for subsequent calculations of dose commitment.

Factors calculated for the SRP environmental impact statement (EIS) for converting integrated air concentrations of each radionuclide to a 70-year lifetime dose commitment via each exposure pathway were used to calculate dose commitments. Techniques for calculating dose were patterned after the methods recommended by the ICRP (1959, 1964, 1975). Standard man data were used for deriving dose factors for the general population; dose factors for infants were also used when infants are the critical members of the population. Whole-body dose, as calculated using dose factors, was added to the gamma plume dose to obtain the total whole-body dose.

The external dose from gamma-emitting radionuclides deposited on the ground was calculated assuming the radionuclides are on the surface of the soil and on surfaces of vegetation during the first year following release, and in succeeding years are distributed exponentially with depth in the soil as a result of rain washoff and infiltration. Lifetime dose from deposited radionuclides was calculated assuming that each person was exposed throughout life only at the location of his/her residence. No corrections were made for surface runoff, surface roughness or shielding by buildings.

Radionuclides in SRP liquid effluents were analyzed at the point of release, in surface streams on the SRP site (before entry into the Savannah River swamp), and in the Savannah River (upstream and downstream from SRP). Many radionuclides that were measurable at the point of release are below the analytical limit of sensitivity after being diluted with river water. Only tritium oxide and trace amounts of ^{137}Cs and ^{90}Sr were routinely measurable in the Savannah River. Only tritium oxide was measured at the two downstream water treatment plants. Dose commitments to consumers of river water downstream from SRP were based on the release inventory and the following assumptions (SRP 1980).

- All radionuclides, as measured at the point of release, moved down the Savannah River during the year of release.
- No depletion in the quantity of radionuclides occured except for natural radioactive decay. Approximately 5 days elapse between time of release of radionuclides and entry into the two water treatment plants approximately 100 miles downstream. For the radionuclides released in 1979, no decay corrections were made.
- The flow rate of the river at the water treatment plants in 1979 averaged 13,170 ft^3 per second (annual flow = 1.2×10^{10} m^3).
- No allowance was made for removal of radionuclides in the water treatment plants.
- Dose commitment from tritium was based on measured concentrations at the water treatment plant.
- Individuals served by the water treatment plants consumed an average of 1.2ℓ of water per day (standard man).

Dose factors were used to convert concentrations of each radionuclide in water to a 70-year lifetime dose commitment.

2.7 SUMMARY

The type of environmental pathway analysis performed at a site was found to vary considerably based on the characteristics of the site and the purpose

of the facility. Most of the sites gave careful consideration to the types of releases at their facilities and to the expected pathways of interest. However, the selection of pathways to include in the final analysis varied considerably from site to site. Several sites used monitoring results and sample analyses to argue that a particular pathway was not of concern and that it could safely be eliminated from the analysis. Other sites included all pathways no matter what the exposure potential. A few pathways (such as water-irrigation-crop-man) were not considered by most sites either because the pathway was not important for the site or other pathways overshadowed its importance; in some cases no reason was given.

The level of detail provided by the annual reports in describing the pathway models used in the analysis varied considerably. Some reports gave good details of the models and assumptions used in the analysis with reference to readily available backup information reports. Other reports gave only vague descriptions of the models or referenced reports that are no longer available.

TABLE 2.1-1. Summar
Evaluation Metho
Sites in 1979 DO
Office

DOE SITE	REPORTED INFORMATION FOR 1979																					
	SAMPLING DATA											RADIATION DOSE ANALYSIS										
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-yr)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2O INGESTION	TERRESTRIAL FOOD INGESTION	AQUATIC FOOD
LOS ALAMOS SCIENTIFIC LABORATORY	●	●	●	●	●	●	●			●	●	●	●	●		●	●	●	●			
MOUND LABORATORY			●	●	●	●	●			●	●	●	●	●		●		●	●	●		
PANTEX PLANT			●	●		●			●		●	●	●	●		●		●	●			
PINELLAS PLANT	●		●	●							●	●	●	●	●			●	●			
ROCKY FLATS PLANT	●	●	●	●		●					●	●	●	●					●	●		
SANDIA LABORATORIES					●		●				●	●		●	●			●	●			

DOE Richland, WA

y of the Environmental Dose
is in Use at DOE
Albuquerque

MODEL INFORMATION REFERENCED														COMMENTS
AIR DISPERSION						WATER DISPERSION			DOSE MODELS					
OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	ENV. MEASUREMENT	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER	
	●	●	●	●										DOSES ARE CALCULATED FOR EXPOSURE TO ^{3}H, ^{11}C, ^{13}N, ^{15}O, ^{41}Ar, AND THE ISOTOPES OF Pu. ATMOSPHERIC RELEASE PATHWAYS ARE ANALYZED FOR INHALATION AND AIR SUBMERSION. DIRECT EXPOSURE AT THE SITE BOUNDARY IS ALSO CONSIDERED. NO LIQUID PATHWAY DOSES ARE ANALYZED SINCE NO LIQUID EFFLUENTS LEAVE THE SITE BOUNDARY.
				●				●	●		●	●		DOSES ARE CALCULATED FOR ^{238}U AND ^{3}H CONCENTRATIONS AS MEASURED IN THE AIR AND WATER BOTH ON AND OFFSITE. HAND CALCULATIONS ARE PERFORMED FOR INHALATION, DRINKING WATER, AND AIR SUBMERSION PATHWAYS USING ICRP 2. ^{3}H DOSES ARE FOUND BY RATIO TO ERDAM 0524 GUIDES. A RATIO OF ^{3}H WATER CONCENTRATION TO EPA GUIDANCE IS ALSO INCLUDED.
	●										●			DOSES ARE CALCULATED FOR ^{238}U AND ^{3}H BY RATIO TO AIR STANDARDS FROM ERDAM 0524 GUIDES. AIR CONCENTRATIONS ARE CALCULATED USING THE EPA CLIMATOLOGICAL DISPERSION MODEL. NO LIQUID PATHWAY DOSES ARE INCLUDED.
	●										●	●		DOSES ARE CALCULATED FOR ^{3}H, ^{85}Kr, AND ^{14}C RELEASES. IT IS NOT CLEAR WHICH PATHWAYS ARE CONSIDERED. DOSE FACTORS DERIVED FROM ERDAM 0524 ARE USED FOR ^{85}Kr AND ^{14}C. AIR CONCENTRATIONS ARE CALCULATED USING SUTTON'S EQUATIONS AND LOCAL WIND DIRECTION DATA.
●				●				●	●	●				DOSES ARE CALCULATED FOR ^{3}H, $^{233, 234, 238}U$, $^{239, 240}Pu$, AND ^{241}Am AS MEASURED IN THE AIR AND WATER BOTH ON AND OFFSITE. INHALATION AND DRINKING WATER INGESTION ARE CONSIDERED, BUT IT IS STATED THAT FOR THIS SITE CONSUMPTION OF FOODSTUFFS AND FISH, AND SWIMMING RESULT IN AN INSIGNIFICANT DOSE. CALCULATED 70-yr DOSE COMMITMENTS FROM ONE YEAR OF EXPOSURE ARE REPORTED BASED ON DOSE FACTORS USING ICRP 2 AND TGLM MODELS.
	●	●	●								●			DOSES ARE CALCULATED FOR ^{3}H, ^{41}Ar, AND ^{85}Kr AIRBORNE RELEASES. AIR CONCENTRATIONS ARE CALCULATED USING PASQUILL TYPE D (NEUTRAL) CONDITIONS. DOSE FACTORS ARE DERIVED FROM ERDAM 0524 CONCENTRATION GUIDES. NO LIQUID PATHWAYS ARE CONSIDERED.

TABLE 2.3-1. Summar
Evalua
Sites
Divisi

DOE SITE	REPORTED INFORMATION FOR 1979																				
	SAMPLING DATA											RADIATION DOSE ANALYSIS								
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-yr)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2O INGESTION	TERRESTRIAL
BETTIS ATOMIC POWER LABORATORY	●	●	●	●	●	●						●		●		●	●	●	●	●	
KNOLLS ATOMIC POWER LABORATORY	●	●		●	●	●				●	●		●	●	●			●	●		
SHIPPINGPORT ATOMIC POWER STATION	●	●	●	●	●	●	●	●		●		●	●	●		●		●	●		

DOE-Richland, WA

of the Environmental Dose
ion Methods in Use at DOE
1979 Naval Reactors

MODEL INFORMATION REFERENCED														
		AIR DISPERSION					WATER DISPERSION			DOSE MODELS				
AQUATIC FOOD INGESTION (FISH)	OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	ENV. MEASUREMENT	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER	COMMENTS
				●						●			●	RADIATION DOSES TO THE FENCEPOST INDIVIDUAL AND THE POPULATION ARE CALCULATED USING ICRP 2 METHODS AND RADIATION DOSE FACTORS FROM RG 1.109. BOTH LIQUID EFFLUENT AND MUNICIPAL INFLUENT CONCENTRATIONS ARE DETERMINED. ATMOSPHERIC DISPERSION IS CALCULATED USING A COMPUTER.
		●		●						●			●	RADIATION DOSES ARE ESTIMATED FOR MAXIMUM INDIVIDUALS, AN AVERAGE MEMBER OF THE NEAREST POPULATION GROUP, AND THE POPULATION RESIDING WITHIN 80 km OF THE SITE USING DOSE FACTORS FROM RG 1.109. FOR AIRBORNE PATHWAYS, CONCENTRATIONS AND DOSES ARE OBTAINED FROM AN EPA COMPUTER PROGRAM. (EPA 1974)
				●						●			●	RADIATION DOSES ARE CALCULATED TO THE FENCEPOST INDIVIDUAL AND TO THE POPULATION RESIDING WITHIN 80 km OF THE SITE USING THE METHODS OF ICRP 2 AS FOUND IN THE DOSE FACTORS FROM RG 1.109.

TABLE 2.4-1. Summary of
Evaluation
Sites in 1
Office

DOE SITE	REPORTED INFORMATION FOR 1979																				
	SAMPLING DATA											RADIATION DOSE ANALYSIS									
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-yr)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2O INGESTION	TERRESTRIAL FOOD INGESTION
PADUCAH	●		●	●		●					●	●	●	●		●			●		●
PORTSMOUTH		●	●	●	●		●	●			●	●	●	●		●	●	●	●	●	●
FEED MATERIALS PRODUCTION CENTER	●	●	●	●							●	●	●	●		●	●		●		●
OAKRIDGE FACILITIES	●	●	●	●	●		●	●	●	●	●	●	●	●		●	●	●	●	●	●

DOE-Richland, WA

he Environmental Dose
Methods in Use at DOE
:79 DOE Oak Ridge

INGESTION (FISH)	MODEL INFORMATION REFERENCED													COMMENTS
	AIR DISPERSION						WATER DISPERSION			DOSE MODELS				
OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	ENV. MEASUREMENT	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER	
			●	●	●				●	●			DOSES ARE CALCULATED USING 50-yr DOSE CONVERSION FACTORS FROM THE INREM COMPUTER CODE. INHALATION AND INGESTION DOSES ARE CALCULATED FOR ATMOSPHERIC RELEASES ONLY. LITTLE INFORMATION ON THE ATMOSPHERIC DISPERSION CALCULATIONS AND RESULTING AIR CONCENTRATIONS IS PRESENTED. DOSES ARE PRESENTED FOR THE FENCEPOST INDIVIDUAL, NEAREST OFFSITE RESIDENT, NEAREST COMMUNITY RESIDENT, AND THE CUMULATIVE POPULATION RESIDING WITHIN 80 km.
●				●	●		●		●	●			50-YR COMMITTED CONVERSION FACTORS FROM THE INREM COMPUTER CODE ARE USED FOR CALCULATING DOSES FOR BOTH AIRBORNE AND LIQUID RELEASES OF RADIONUCLIDES. LITTLE INFORMATION ON THE ATMOSPHERIC DISPERSION CALCULATIONS IS GIVEN. DOSES ARE PRESENTED FOR THE FENCEPOST INDIVIDUAL, NEAREST COMMUNITY RESIDENT, AND TOTAL POPULATION RESIDING WITHIN 80 km OF THE SITE. FOR LIQUID RELEASES, SWIMMING, INGESTION OF FISH AND INGESTION OF DRINKING WATER ARE INCLUDED.
				●	●				●	●		●	INREM DOSE CONVERSION FACTORS ARE APPLIED TO ATMOSPHERIC RELEASES. LITTLE INFORMATION IS GIVEN ON THE ATMOSPHERIC DISPERSION CALCULATIONS. DOSES ARE PRESENTED FOR THE SITE BOUNDARY INDIVIDUAL, MAXIMUM INDIVIDUAL, NEAREST COMMUNITY AVERAGE RESIDENT, AND TOTAL POPULATION WITHIN 80 km OF THE SITE. FOR LIQUID RELEASES, A MAXIMUM INDIVIDUAL IS DEFINED FOR DRINKING WATER.
●	●		●						●	●			50-YR COMMITTED DOSE EQUIVALENTS ARE CALCULATED USING VERSIONS OF THE EXREM AND INREM COMPUTER CODES. A GAUSSIAN PLUME MODEL IS USED IN A COMPUTER CODE TO CALCULATE ATMOSPHERIC CONCENTRATIONS. BOTH AIRBORNE AND LIQUID RELEASES ARE CONSIDERED IN AN ENVIRONMENTAL DOSE PATHWAY ANALYSIS. DOSES ARE PRESENTED FOR THE SITE BOUNDARY INDIVIDUAL, MAXIMUM INDIVIDUAL, NEAREST COMMUNITY AVERAGE RESIDENT, AND TOTAL POPULATION WITHIN 80 km OF THE SITE.

TABLE 2.5-1. Summary
Evaluati
Sites in
Office

DOE SITE	REPORTED INFORMATION FOR 1979																					
	SAMPLING DATA											RADIATION DOSE ANALYSIS										
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-yr)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2O INGESTION	TERRESTRIAL FOOD INGESTION	AQUATIC FOOD
LAWRENCE BERKLEY LABORATORY	●	●	●	●								●		●	●	●	●	●	●			
LAWRENCE LIVERMORE LABORATORY	●	●	●	●		●	●	●			●	●	●	●		●	●		●	●	●	
STANFORD LINEAR ACCELERATOR CENTER	●	●	●										●		●		●	●				

DOE-Richland, WA

f the Environmental Dose
n Methods in Use at DOE
1979 DOE San Francisco

MODEL INFORMATION REFERENCED													
AIR DISPERSION					WATER DISPERSION			DOSE MODELS					
OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	OTHER	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER	COMMENTS
	●		●						●		●	●	FIRST-YEAR RADIATION DOSES ARE CALCULATED FOR THE FENCE-POST INDIVIDUAL AND A POPULATION WITHIN 5 km FROM PENETRATING RADIATION, ALPHAS AND NEUTRONS. FOR ATMOSPHERIC RELEASES, DOSE FACTORS ARE USED THAT ARE BASED ON ERDAM 0524 mpc VALUES AND SITE-SPECIFIC METEOROLOGY AND POPULATION DISTRIBUTIONS.
	●		●						●			●	FIFTY-YEAR COMMITTED DOSE EQUIVALENTS ARE CALCULATED USING DOSE FACTORS FROM RG 1.109. THE DOSES CALCULATED INCLUDE THE FENCEPOST INDIVIDUAL, THE MAXIMUM INDIVIDUAL, AND THE POPULATION RESIDING WITHIN AN 80-km RADIUS OF THE SITE. A COMPUTER CODE IS USED TO CALCULATE GAUSSIAN PLUME ATMOSPHERIC DISPERSION FACTORS.
			●		●						●	●	PENETRATING RADIATION, AND NEUTRON DOSE MEASUREMENTS ARE USED TO CALCULATE THE MAXIMUM INDIVIDUAL AND POPULATION DOSES WITHIN 2 km OF THE SITE. WATER SAMPLES ARE NOT REPORTED FOR 1979 BECAUSE OF CONSTRUCTION ACTIVITIES AT THE SITE. THE 80-km POPULATION DOSE IS REPORTED TO BE BELOW "SIGNIFICANT LEVELS." AIRBORNE DOSE ESTIMATES ARE BASED ON AN EMPIRICAL MATHEMATICAL MODEL DEVELOPED SPECIFICALLY FOR THE SITE.

TABLE 2.6-1. Summary
Evaluati
Sites in
Offices

DOE SITE	REPORTED INFORMATION FOR 1979																				
	SAMPLING DATA											RADIATION DOSE ANALYSIS									
	STACK	DIRECT EXPOSURE	AIR	WATER	SEDIMENTS	WELL WATER	FOOD PRODUCTS	MILK	WILDLIFE	FISH	SOIL AND VEGETATION	FENCE LINE INDIVIDUAL	MAXIMUM INDIVIDUAL	POPULATION (80-km)	ANNUAL DOSE (FIRST-YEAR)	COMMITTED DOSE EQUIVALENT (50-yr)	DIRECT EXPOSURE	AIR SUBMERSION	INHALATION	H_2C INGESTION	TERRESTRIAL FOOD INGESTION	AQUATIC FOO
IDAHO NATIONAL ENGINEERING LABORATORY	●	●	●	●		●	●	●	●		●	●	◕	●		●		●	●		●	
HANFORD SITE		●	●	●		●	●	●					◕	●		●		●	●			
NEVADA TEST SITE	●	●	●	●	●	●	●	●	●	●	●	●	◕	●	●	●	●	●	●	●	●	
SAVANNAH RIVER PLANT		●	●	●		●	●	●	●	●	●	●	◕	●		●		●	●	◕	●	

DOE Richland, WA

f the Environmental Dose
n Methods in Use at DOE
1979 All Other Field

INGESTION (FISH)	MODEL INFORMATION REFERENCED												COMMENTS
	AIR DISPERSION					WATER DISPERSION			DOSE MODELS				
OTHER PATHWAYS	GAUSSIAN PLUME	X/Q DATA	STACK MEASUREMENT	ENVIRONMENTAL MEASUREMENT	OTHER	ANNUAL AVERAGE MIXING	EFFLUENT MEASUREMENT	ENV. MEASUREMENT	ICRP 2	TGLM	RATIO TO ERDAM 0524 CONC. GUIDES	OTHER	
●			●		●				●			●	FENCEPOST INDIVIDUAL AND TOTAL POPULATION DOSES WITHIN AN 80-km RADIUS OF THE SITE ARE CALCULATED USING DOSE FACTORS FROM NUREG-0172 AND ERDA 77-24. AIR DISPERSION IS CALCULATED USING THE MESODIF COMPUTER CODE. PUBLIC DRINKING WATER SUPPLIES AND LOCAL WELLS ARE MONITORED FOR RADIONUCLIDE (INCLUDING ^{3}H) CONTENT.
				●							●		MAXIMUM INDIVIDUAL AND POPULATION DOSES ARE FOUND FOR ATMOSPHERIC RELEASES BASED ON MEASURED AIR CONCENTRATIONS AND A RATIO TO ERDAM 0524 CONCENTRATION GUIDES. SURFACE OR WELL WATER THAT CONTAINS RADIOACTIVE MATERIALS IS NOT USED AS A DRINKING WATER SOURCE.
	●	●	●			●			●	●		●	FENCEPOST INDIVIDUAL, MAXIMUM INDIVIDUAL, AND TOTAL POPULATION DOSES ARE REPORTED FOR THREE RELEASE SITES ON THE HANFORD RESERVATION. THREE DIFFERENT POPULATION DISTRIBUTIONS ARE USED SINCE THE RELEASE POINTS ARE A SIGNIFICANT DISTANCE APART. RADIATION DOSE FACTORS ARE FROM THE DACRIN, FOOD, ARRRG, AND GRONK COMPUTER CODES.
	●		●	●		●		●	●			●	70-YR COMMITTED DOSE EQUIVALENTS ARE CALCULATED FOR THE AVERAGE AND MAXIMUM FENCEPOST INDIVIDUAL, THE TOTAL POPULATION WITHIN AN 80-km RADIUS AND INDIVIDUALS AND THE POPULATION DRINKING WATER DOWNSTREAM OF THE PLANT. THE METHODS OF THE ICRP ARE USED TO CALCULATE THE RADIATION DOSE FACTORS. DEPOSITION RATES ARE DETERMINED BY RAINWATER ANALYSIS. LIQUID CONCENTRATIONS (INCLUDING ^{3}H) ARE DETERMINED AT MUNICIPAL WATER INTAKES.

3.0 SUMMARY AND CONCLUSIONS

The methods used by DOE contractors to estimate public exposure to radiation from normal operations covered a variety of approaches. These ranged from estimating doses based on environmental measurements and comparison to Concentration Guides of ERDA Manual Chapter Appendix 0524 (applicable in 1979) to complex methods using environmental pathway modeling and estimated radionuclide releases. No two sites used the same combination of measurements and pathway models in their analysis.

3.1 EVALUATION OF METHODS

The models used in environmental pathway analyses for each of the DOE nuclear sites are evaluated in Table 5.1-1. Results of this evaluation are shown for the five main modeling areas; atmospheric dispersion, airborne pathways, waterborne pathways, penetrating radiation and internal dosimetry. The first column of the table indicates the number of sites that performed an analysis for each of these modeling areas. This number does not include sites that based dose calculations on measurement of environmental concentrations and comparison to ERDAM 0524 concentration guides. For some sites, individual pathways were not applicable and are so indicated. For other sites, no mention of a particular pathway was made, as indicated in the column labeled "Not Considered in the Analysis".

While most sites used an atmospheric dispersion model only half of the sites provided sufficient information to allow evaluation of the models. Several reports gave a general reference to Slade (1968) with no further explanation. This was considered to be insufficient because many dispersion models and submodels are described in Slade.

Of the five airborne pathways listed in Table 5.1-1, most sites did a good job on the plume exposure pathways (external and inhalation) while several sites failed to consider the terrestrial pathways resulting from deposition onto the ground. The omission of these pathways may not be significant depending on the circumstances at the particular sites. The

TABLE 3.1-1. Summary of Environmental Analysis Model Evaluation

	Number of Sites Performing an Analysis	Insufficient Information Provided for Evaluation	Not Applicable for the Site	Not considered in the Analysis
Atmospheric Dispersion	22	11	-	-
Airborne Pathways	16	1	-	-
External Plume Dose		1	2	-
Inhalation of Plume		-	1	-
Crops		1	3	6
Milk		1	4	6
Meat		1	2	8
Waterborne Pathways	9	-	-	-
Drinking Water		-	2	-
Aquatic Foods		-	1	3
Irrigated Crops		-	3	5
Animal Products		-	2	4
External from Boating/ Swimming		-	1	5
External from Shoreline		-	3	5
Penetrating Radiation	6	1	-	-
Internal Dosimetry	15	1	-	-

waterborne pathways related to direct intake of drinking water or fish were fairly well described, while the external exposure and terrestrial pathways were often not considered.

3.2 RECOMMENDATIONS

As a result of our review of the 1979 environmental monitoring reports and the radiation dose models used by the twenty-five DOE nuclear sites, we have formulated the following recommendations.

- To provide complete documentation of the models used and reproducibility of results, the annual report should include a detailed description of the models or else reference readily available reports. Any site-specific data used in the pathway models (such as annual average joint frequency of occurrence of meterological conditions) should be included in the report.
- Most sites could make better use of tables and graphics to better communicate the findings of their analyses.
- The method used to determine total annual radionuclide releases to air or water should be described.
- The DOE guide for environmental radiological surveillance, DOE/EP0023, (Corley, et al. 1981) presents criteria useful in determining which environmental pathways are significant at a given site. The analysis performed to satisfy these criteria should be referenced in the discussion of pathways considered for each annual report.

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