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The Tennessee Valley Region Study: Potential Year 2000 Radiological Dose To Population Resulting From Nuclear Facility Operations

Volume II

June 1978

Prepared by
The Tennessee Valley Authority
and
U.S. Department of Energy
Assistant Secretary for Energy Technology

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PREFACE

In 1970 the United States Atomic Energy Commission (AEC), the predecessor of the U. S. Energy Research and Development Administration (ERDA) initiated a series of studies aimed at estimating the radiological dose to the population of the United States resulting from the combined operation of large numbers of nuclear facilities for the production of electric energy. In order to provide a scenario considering numbers of nuclear facilities considerably greater than those currently in operation, under construction, or on order -- and yet avoid extensive extrapolation from today's technology -- these studies were addressed to conditions as they might appear in the year 2000.

The first of these studies, considering the area comprising the watersheds of the Upper Mississippi and Lower Missouri rivers, was performed by the Hanford Engineering Development Laboratory (HEDL). This first regional evaluation, begun in 1970, was completed in 1972 and was reported in WASH-1209, "The Potential Radiological Implications of Nuclear Facilities in the Upper Mississippi River Basin in the Year 2000," which was published in January, 1973. Results of this study indicated that the radiological dose in the year 2000 to the average individual in the study area which was attributable to the operation of nuclear facilities within the area would be 0.17 millirem (mrem). This dose is considerably lower than the guideline dose of 5 mrem per year at the fenceline of an operating nuclear power plant, and is several orders of magnitude lower than the dose from natural radiation or from other man-made sources such as diagnostic x-rays or color television.

At the conclusion of the Upper Mississippi River Basin (UMRB) study, it was felt desirable to corroborate the results of the study by performing a

second study in an area distinctly different in physiographic and demographic characteristics. The performance of such a study would also provide an opportunity to improve on the HERMES computer model and make it less regionally dependent. In addition, the development and promulgation of "As Low as Reasonably Achievable" (ALARA) guidelines for radionuclide effluents from light water reactor (LWR) power plants by the AEC Office of Regulation, the predecessor of the U. S. Nuclear Regulatory Commission, provided a new baseline against which radiological effects could be compared. The ALARA guidelines had been anticipated in the UMRB study, but release values assumed for some radionuclides differed considerably from the ALARA values as finally adopted. A second study referenced to those guidelines was judged to be of value.

The area chosen as the subject of this second study consisted of the combined watersheds of the Tennessee and Cumberland rivers. The study was undertaken by AEC/ERDA and the Tennessee Valley Authority (TVA), and was performed cooperatively by HEDL, TVA, the Oak Ridge National Laboratory (ORNL), and the Atmospheric Turbulence and Diffusion Laboratory (ATDL) of the National Oceanic and Atmospheric Administration (NOAA). This study was an excellent example of interagency and interlaboratory cooperation. The diversity of expertise made available by this cooperative approach added considerably to the quality of the study, and the interlaboratory structure of the study organization provided a built-in system of checks and balances for evaluation of input data, calculational techniques, and results of the study.

The Tennessee Valley Region (TVR) Study was directed by a four-man steering committee, consisting of one representative each from ERDA, TVA, HEDL, and ORNL. Efforts involved in execution of the study were divided among the participants. TVA and ORNL provided the bulk of the physiographic, demographic, and agricultural production data for the region. TVA selected

hypothetical nuclear facility sites for use in the study, and also provided recreational data for the population of the region for use in dose calculations. The calculations of radionuclide releases from operating nuclear facilities were apportioned among the participants. LWR releases were calculated by TVA based on Appendix I to Part 50, Title 10, Code of Federal Regulations (10CFR50). Using guidelines similar to those for Appendix I, ORNL calculated releases from high-temperature gas-cooled reactors (HTGR's) and from reprocessing plants; releases from liquid metal fast breeder reactors (LMFBR's) and fuel fabrication plants were provided by HEDL.

Meteorological data required for atmospheric transport calculations were gathered by HEDL, primarily from National Weather Service (NWS) sources, with TVA assistance. Modifications to the air transport code, ARTRAN, needed to represent the complex meteorology of the region, were made by HEDL with consultation by ATDL. Hydrologic data for the region were supplied primarily by TVA, with ORNL providing laboratory analyses of regional river waters for estimation of the relationship between radionuclide concentrations adsorbed on sediments and concentrations in solution. TVA cooperated with HEDL in adapting the WTRAN water transport code to the river systems of the TVR.

ORNL performed a critique of the dose calculations performed by HEDL in the earlier UMRB study and together with TVA, assisted HEDL in modifying and improving the DOSE code calculations.

HEDL performed all calculations and resulting evaluations in the study. These were reviewed by the four-member Steering Committee and by cognizant individuals in each participating organization. Because of the large volume of data collected and processed, and the detailed information resulting from calculations performed, it was decided to publish two separate volumes

constituting the final report on the study. A companion report, DOE/ET-0064/1, presents a profile of the Tennessee Valley Region study area, containing physical descriptions and projections of demographic data, food production and consumption, recreational activities, and electric energy demand which were used as input data for the regional study. The present report, the second of the series, describes the calculations of radionuclide release and transport and of the resultant dose to the regional population.

An electric power demand projection made in 1973, and used as a basis for the study, assumed an installed capacity of 222,000 megawatts in the year 2000 for the Tennessee Valley Region (TVR) study area and the "air envelope" region immediately surrounding the study area proper. Of that capacity, about 144,000 megawatts were assumed to be nuclear plants. The nuclear plant mix was assumed to include boiling-water and pressurized-water reactor plant (BWR's and PWR's), high-temperature gas-cooled reactors (HTGR's), and liquid-metal fast breeder reactors (LMFBR's). All elements of the fuel cycle were assumed to be in operation, and both fuel fabrication plants and fuel reprocessing plants were included in the study.

In the years past inception of the study, several events have transpired to throw into question the details of assumptions made in the scenario of nuclear facilities used in the study. Recent developments in the national energy scene indicate that the projection of nuclear facilities installed in the year 2000 may be high. The HTGR is not now commercially offered in the United States (although a plant of this type might conceivably be marketed by the year 2000). Further, recent changes in policies of the Administration have stressed deferral of the implementation of nuclear fuel reprocessing and of the breeder reactor pending a thorough study of considerations of possible proliferation of nuclear weapons. Consequently, it is difficult to assess the commercial availability in the year 2000 of either fuel reprocessing or of the breeder.

In consideration of these changes, the radiological dose to the population of the Tennessee Valley Region, as calculated in this study, appears to be conservative. However, this conservatism, and the fact that inclusion of a complete fuel cycle permits evaluation of the relative effects on dose of operation of the various facilities, appear to justify use of the above scenario in the study.

As was previously mentioned, radionuclide releases from LWR's were calculated using methods and guidelines of the ALARA decision, expressed as Appendix I to 10CFR50, which was promulgated by the U. S. Nuclear Regulatory Commission. Releases from other nuclear facilities were calculated using equivalent guidelines.

The regional atmospheric transport of radionuclides released to the air was calculated by the ARTRAN code of the HERMES model. This code calculated radionuclide dilution en route through atmospheric dispersion, radioactive decay, and wet and dry fallout, providing resultant radionuclide concentrations in the air and on the ground as average values for each county in the study area.

WTRAN, the water transport code in HERMES, was used to calculate the transport of radionuclides in the region's stream systems, and also to calculate radionuclide concentrations in local lakes and ponds and in ground water. In the regional river systems the effect of waterborne sediments in adsorbing radionuclides was considered, as was the sediment-trapping action of reservoirs behind dams in the region.

The calculated radionuclide concentrations in the air, in water and accompanying sediments, and on the ground were utilized in calculating estimated radiological dose to the population of each county and of the entire region. Dose was calculated as a one-year dose based on ingestion of 35 different food types as well as for nine non-food pathways, and was reported as dose to the total body and for six specific organs for each of four age groups (infant, child, teen, and adult). In addition, a 50-year dose commitment was calculated in parallel

with the one-year dose. This dose commitment was defined as the 50-year residual dose resulting from internal assimilation of radionuclides in the body during the year 2000, assuming no further exposure after 2000.

Results of the study indicated that the average individual living in the TVR study region would receive an incremental dose of 7×10^{-4} millirems (0.0007 mrem) in the year 2000 from the operation of nuclear facilities within and adjacent to the region. This incremental dose is more than five orders of magnitude smaller than the dose from naturally occurring radiation in the area, which averages about 130 mrem per year and ranges from about 120 to 170 mrem per year. The population dose (product of dose and population) for the TVR was calculated to be about 5 man-rems. The major contributor to dose was found to be tritium, and the most significant pathways were immersion in air, inhalation of air, transpiration of tritium (absorption through the skin), and exposure to radionuclide-containing soil.

Large differences were observed in dose calculated for various counties in the TVR region. Average adult dose in counties of the region ranged from about 3×10^{-6} to 7×10^{-3} mrem.

Dose calculated for the TVR was considerably lower than that calculated earlier for the Upper Mississippi River Basin (UMRB). The lower values resulted in part from better definition of the radionuclide releases which might be expected to occur under Appendix I (ALARA) guidelines, and in part from the lower population density of the TVR and the greater average distance between nuclear plants and centers of population.

Results of this study confirm those of the earlier UMRB study, that dose to the population of a region containing large numbers of nuclear facilities, resulting from operation of those facilities, will be insignificant in itself or in comparison with other sources of radiation, both natural and man-made.

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I. INTRODUCTION

This comprehensive study of the radiological implications of large scale use of nuclear power generation, addressed to the Tennessee-Cumberland River basin region in the year 2000, has been undertaken jointly by the United States Energy Research and Development Administration (ERDA) and the Tennessee Valley Authority (TVA), with participation by the Hanford Engineering Development Laboratory (HEDL), the Oak Ridge National Laboratory (ORNL) and the Atmospheric Turbulence and Diffusion Laboratory (ATDL). This study builds upon a previous study of the Upper Mississippi River Basin (UMRB)[1] which was performed by HEDL under ERDA sponsorship. A computer model, HERMES,[2] was developed during the UMRB study to permit evaluation over a large region of the relationships involving the release of radionuclides from normal operation of nuclear facilities, the transport of these radionuclides in the environment, and the resulting radiological dose to the population of the region.

The Tennessee-Cumberland River basin region is approximately 58,830 square miles in area and includes portions of seven southeastern states. Since the population within this area could be affected by airborne radionuclides originating outside the study area, the potential contribution to dose from nuclear plant sites in adjacent areas is included in the study.

This study area and adjacent areas include several major centers of population and industry, as well as some of the more important agricultural production areas in the United States. The area also encompasses one of the major power supply/demand regions of the country, a region in which nuclear power is expected to play an increasingly important part in electrical energy generation. In the past, hydroelectric plants supplied a large portion of the region's electrical energy needs, but this energy source has been almost fully developed and future needs must be supplied by other sources.

A large amount of information concerning the characteristics of the region, and needed for the study, was already available. This information included demographic data, power and industrial projections and regional environmental data. Finally the region includes within its boundaries all reaches and tributaries of two river systems (the Tennessee and Cumberland) from their origins to their confluences with the Ohio River.

The study area has a population (1970 census) of slightly over 4 1/2 million, roughly 46% of which may be classified as urban, 12% as farming, and 42% as rural nonfarm. By the year 2000 this population is expected to reach almost 7 million. Today the area accounts for about 7% of the total electrical energy generation and consumption of the United States. Recent increases in nuclear energy generation are expected to continue; nuclear energy will likely be the predominant source for regional power generation in the year 2000, when it is estimated that over 60% of the projected generation will be provided by nuclear plants.

Within the study area proper there are six major natural land subdivisions. The study area is as diverse in topographic and physiographic features as any region in the United States. Consequently there are wide variations in elevation, mean annual precipitation, and mean annual temperature. The hydrology is dominated by the Tennessee-Cumberland drainage system. Practically 100% of the runoff is supplied by precipitation within the area.

The boundaries of the study area are established along county lines and the majority of the data used were collected at the county level. Within each of the 140 counties, all activities pertaining to the transport of radionuclides and the exposure of the population to radiation are assumed to occur at a single point, designated as the centroid of the county area. Calculations were made in accordance with the centroid structure and consisted of the following five major steps:

1. Using projected power plant and reprocessing plant siting patterns and radionuclide release rates, based on assumed selection of radioactive waste treatment systems, a "source map" of release locations was established as a function of time.
2. The transport, diffusion, and deposition, by county, of the radionuclides released to the atmosphere by the nuclear facilities was computed. The washing of surface-deposited radionculides into regional waterways, addition of directly injected nuclides, and the subsequent dilution, transport and deposition within the waterways were calculated.
3. The uptake of deposited radionuclides and their subsequent concentration in the various food types was estimated.
4. Transportation of food to meet subregional demand (by county) was simulated.
5. The estimated dose to man was calculated. These calculations made an accounting of dietary, work, and recreational patterns of the population. The calculated dose was based on anticipated direct exposure to airborne, deposited, and dissolved radionuclides as well as those ingested or inhaled.

A mix of generating plant types was assumed that provides an adequate capacity to meet projected electrical power demands in the year 2000. The mix includes capacity of approximately 144,000 MW from 122 nuclear generating units, consisting of Pressurized Water Reactors (PWR) (42%), Boiling Water Reactors (BWR)(18%), Liquid Metal Fast Breeder Reactors LMFBR (22%), and High Temperature Gas-Cooled Reactors (HTGR) (18%). Also included are four reprocessing plants and six fuel fabrication plants, sufficient to serve the

nuclear plants in the study area and the pertinent external adjacent areas. The 48 generating and four reprocessing sites, as well as the six fuel fabrication sites, were located to supply the various load centers in the area. Appropriate consideration was given to particular siting requirements for each type of plant (availability of cooling water, transmission distance, nuclear plant siting criteria, etc.). Simulation of the month-by-month operation of each power plant accounted for seasonal variations in the several subregions.

Recent developments in the U. S. energy situation, together with the current Administration position on nuclear fuel reprocessing and utilization of breeder reactor, bring into question the details of the year 2000 nuclear power scenario assumed. The changes which have occurred, however, tend to make the results of this study conservative. Further, inclusion of the various nuclear facilities as described provides insight as to their relative contributions to regional population dose.

The air transport part of the model, which simulates the spreading of the released radionuclides into the environment via atmospheric mechanisms, uses the long-term average version of the Gaussian plume model to estimate the diffusion of radionuclides based on wind speed and atmospheric stability criteria. Calculations of the receptor concentrations are based on the meteorological statistics for each of 16 compass-point sectors for each source. During the transit of the radionuclides, depletion by radioactive decay and the introduction of daughter nuclides are taken into account. Depletion of airborne concentrations by wet and dry deposition processes are calculated, as are the ground concentrations resulting from deposition. Additionally, calculations are made of ground concentrations in the year 2000 which result from previous years' operation of each nuclear facility considered in the study, under the assumption that the study year characteristics are representative of prior years.

The water transport segment of the model, which simulates the radionuclide dispersion in the regional waterways, estimates the dissolved and suspended concentrations of radionuclides in streams and the bed sediments, resulting from runoff and from direct release from nuclear facilities into waterways. The code also calculates radionuclide concentrations in ground water and standing surface water. For these calculations the deposition data calculated by the air transport code module are used. For both stream transport and surface runoff calculations, the distribution of radionuclides between solution in water and sorption on sediments or soil is estimated based on sediment and soil types.

Together, the air and water transport models provide comprehensive estimates of radionuclide concentrations in air and water throughout the study area. In addition, water concentration calculations are made for locations considered to be important in the evaluation of radiological dose--municipal water intakes, recreation areas, water used for irrigation water supply, and the like.

Major factors considered in projecting dose to the population include eating habits, food production techniques, recreational habits, and population growth patterns. A data bank containing information pertinent to the population and living patterns of the region was established. Included are data on population distribution (by location, age group, and urban-rural classification), dietary habits and work/recreational patterns, drinking water supply and treatment, food production, consumption, transport within the study area, and food imports from outside the region. These data have been obtained from public documents issued by organizations such as the U. S. Geological Survey, the U. S. Army Corps of Engineers, NOAA, the Bureau of Census, the Department of Agriculture, the Tennessee Valley Authority, the Oak Ridge National Laboratory, the Atmospheric Turbulence and Diffusion Laboratory, State Fisheries Departments, and regional planning and conservation committees.

Ten separate pathways leading to possible human exposure are considered. These include contributions from direct exposure to radionuclides in air and water and on the ground, air inhalation, and ingestion of water and of 35 separate categories of foods. Food-chain relationships of radionuclide concentrations are calculated for each type of food and for each of the 48 separate fission and activation products included in the study. The potential contribution to dose is evaluated for the total body and for each of six organs; 50-year dose commitments are calculated in addition to the annual calculations. Calculation methodology to derive the radiation potentially received in the course of a year, and the 50-year commitment are:

- Annual dose (millirem) for the year 2000 is summed from 12 monthly values. External dose is calculated from exposure to concentrations in the environment during each month. Internal dose from each month's assimilation of radionuclides is calculated for the remainder of the year.
- The dose commitment is the long-term contribution due to uptake during the year 2000. This value, termed 50-year dose commitment in this report, is the dose an individual would be committed to during the following 50 years due to the body burden from radioactive materials internally assimilated during the year 2000 (no further assimilation beyond 2000 is considered).

The doses and dose commitments were calculated for each county of the region, for average individuals in each of four age groups (infant, child, teenager, and adult). Values of integrated population dose (man-rem) were also calculated for each county for for the entire region. Values were provided for dose to the total body and to six specified organs; contributions to dose by radionuclide and by pathway were listed.

Sensitivity calculations were performed in which values of major parameters were changed. This procedure allowed identification of critical pathways and important radionuclides as an assessment of the effect of uncertanties in input

data. This evaluation, in turn, may be helpful in identifying the potential effects of technological advancements in disposal and treatment of radioactive waste materials, and to the sensitivity of many factors that might be large contributors to the population dose.

This study is concerned with normal releases of radionuclides from nuclear facilities during operation. No consideration was made of potential accident conditions. While accidents can be postulated which might result in increased release of radionuclides, comprehensive studies[3] have shown that the probability of occurrence of such conditions is low, and that the probability of accidents involving major radionuclide releases is very low indeed. Thus, for a regional study such as this, the releases during normal operation appear to be the correct criteria for projecting dose to the population.

II. SUMMARY

This study has as its goal the estimation of the potential radiological dose to the population of the Tennessee Valley Region (TVR) -- the combined basins of the Tennessee and Cumberland rivers -- which might result from the operation of large numbers of nuclear power plants and their supporting nuclear facilities. The study was addressed to the year 2000, a period in which significant numbers of nuclear facilities are expected to be in operation in the region and in surrounding areas. For the study a nuclear generating capacity of about 144,000 MWe was assumed to be in operation in the TVR and adjacent areas, supported by four fuel reprocessing facilities and six fuel fabrication plants.

Radionuclide releases from these facilities during normal operation were estimated, their transport through the region was modeled, and the resulting concentrations were used to calculate radiological dose in the year 2000, and the 50-year dose commitment from exposures occurring in the year 2000, to the projected 6,965,000 inhabitants of the TVR study area.

The study indicated that, for the types and siting patterns of nuclear facilities assumed (see Chapter IV), an average individual in the TVR would receive an incremental dose in the year 2000 of 7×10^{-4} millirem from operation of those facilities. By comparison, dose from naturally occurring radiation in the region averages about 130 mrem per year, ranging from about 120 to 170 mrem; medical and dental sources of radiation (excluding radiotherapy) average about 70 to 80 mrem per year; and radiation from other manmade sources (luminous watch dials, color television, etc.) accounts for an additional 20 to 25 mrem per year. Figure II-1 illustrates the comparison between dose from nuclear facility operation and that from natural radiation and other sources.

As might be expected over a region as large and diverse as the study area, the spread in estimated dose from nuclear facility operation is substantial.

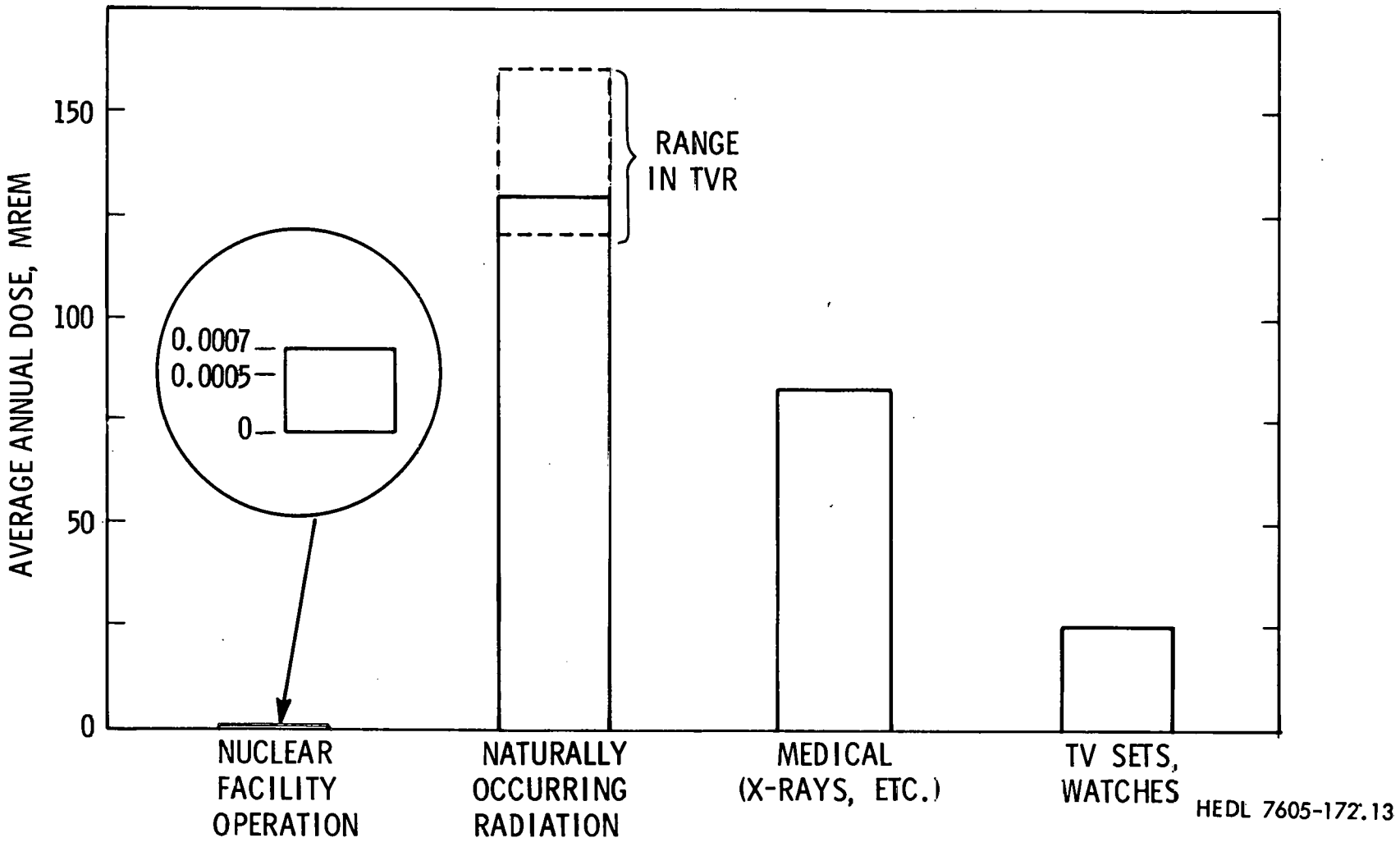

FIGURE II-1

Radiological Dose Comparisons for the Tennessee Valley Region in the Year 2000

Nevertheless, as indicated in Figure II-2, 99 percent of the year 2000 regional population were estimated to incur individual total body doses from operation of nuclear facilities of less than 5×10^{-3} mrem in that year. Dose patterns for the four age groups considered (infant, child, teenager, and adult) differed only slightly from the average for the entire population.

The dose distribution shown in Figure II-2 was derived from calculations of average dose to the population of each of the 140 counties in the TVR.

A few individuals living near the boundaries of nuclear faciliites might incur doses somewhat above the averages indicated. Federal guidelines are intended to limit the dose of any individual to less than 5 mrem for the total body and 15 mrem to other organs from radionuclides in gaseous effluents, and 3 mrem for the total body and 10 mrem to other organs from liquid effluents. These limits apply to individuals assumed to live continuously at the boundary of a nuclear reactor site. The magnitude of the dose is expected to decrease as distance from the site increases (some possible exceptions may occur, attributable to local terrain features). Sample calculations made for several nuclear sites in the TVR indicated that dose at a distance of one mile from these facilities ranged upwards to 0.2 mrem; at five miles this was reduced to a range of 2×10^{-5} to 0.02 mrem, depending on plant types and specific site conditions. However, the very few individuals expected to incur these relatively higher (but still very low) doses do not affect the population-weighted averages indicated in Figure II-2.

In addition to total body dose, the dose to skin and to each of six internal organs were calculated in the study. Differences in metabolic activities of the organs, and in some cases differences in the amount of exposure to radionuclides in the environment (e.g. skin, lungs, and GI tract) can result in differences in organ doses which may be substantial, especially when considering individuals of different age groups. Table II-1 summarizes total body dose and organ doses for average individuals in each of the four age groups considered in the study.

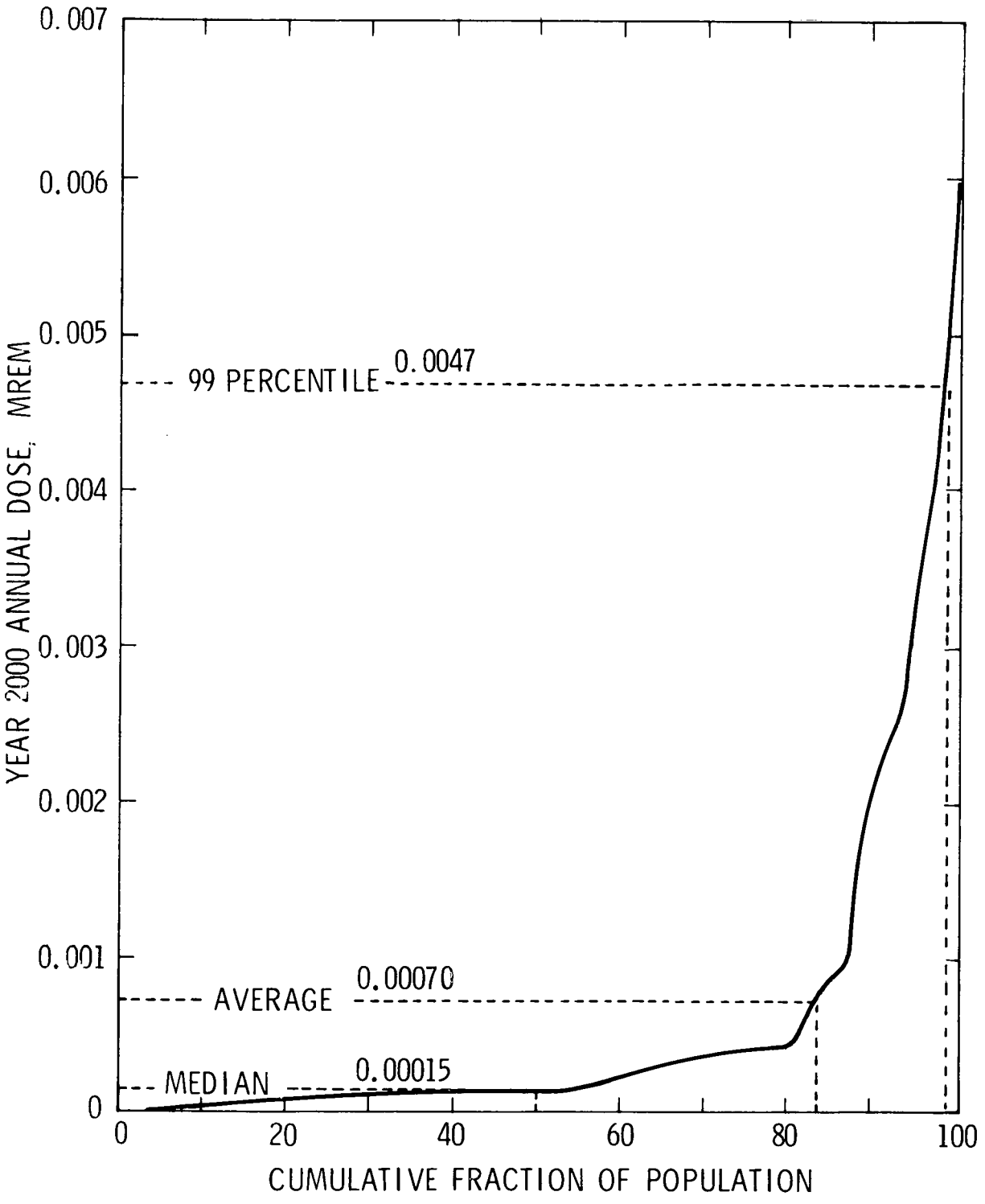

FIGURE II-2

Distribution of Year 2000 Radiological Dose from Operation of Nuclear Facilities in the Tennessee Valley Region Population

	Annual Dose*				50-year Commitment*			
Organ	Infant	Child	Teen	Adult	Infant	Child	Teen	Adult
Total Body	7.09	6.29	5.92	7.45	7.09	6.33	5.50	6.97
GI Tract	7.01	6.29	5.92	7.66	5.74	5.01	4.91	6.54
Thyroid	13.51	8.97	7.47	9.19	12.67	7.74	6.34	8.28
Bone	1.77	1.50	1.25	1.19	5.74	5.56	3.11	3.92
Lungs	7.18	6.29	5.92	7.45	6.08	5.21	4.91	6.54
Skin	16.05	15.17	11.06	12.56	5.66	5.00	4.79	6.54
Liver	7.01	6.29	5.92	7.45	5.91	5.14	4.91	6.75

* expressed in 10^{-4} mrem

TABLE II-1

DOSE COMPARISONS FOR TVR AGE GROUPS

Radionuclide Ingestion and Dose Commitment

Radionuclides ingested or absorbed into the body tend to be eliminated gradually, exhibiting characteristic periods of retention (biological half-lives). These half-lives vary widely among different nuclides, ranging from about 10 days to several years. For some nuclides the effective half-lives may vary among the various organs, or among indiviudals of different ages. Some variation is also observed between individuals in the same age group.

The retention phenomenon gives rise to an additional component of dose; the body burden of radionuclides accumulated over a given period continues to contribute to dose in later times. This dose commitment, from radionuclides ingested during the year 2000, was calculated over the succeeding 50 years for the population of the TVR, assuming no further ingestion of radionuclides beyond the year 2000. The average dose commitment over this period was about 7×10^{-4} mrem, or about the same as the annual dose.

Relative Importance of Pathways

One signfiicant finding of the study is that the contribution to population dose in the TVR is governed primarily by air transport of radionuclides; water transport and ingestion of foods play secondary roles, although they can be significant for certain radionuclides. Four of the pathways considered in the study were found to contribute the bulk of the calculated radiation dose. These four -- submersion in air, inhalation of air, transpiration of tritium, and exposure to soil -- all hinge principally on air transport.

Figure II-3 indicates the relative contributions of the various pathways to year 2000 annual dose for the average adult in the region. The four previously mentioned pathways account for from 75% to 90% of the calculated dose; ingestion of foods accounts for most of the remainder. Of the latter pathways, ingestion of fresh whole eggs, milk, beef, lamb, and fresh pork are the most important. A more

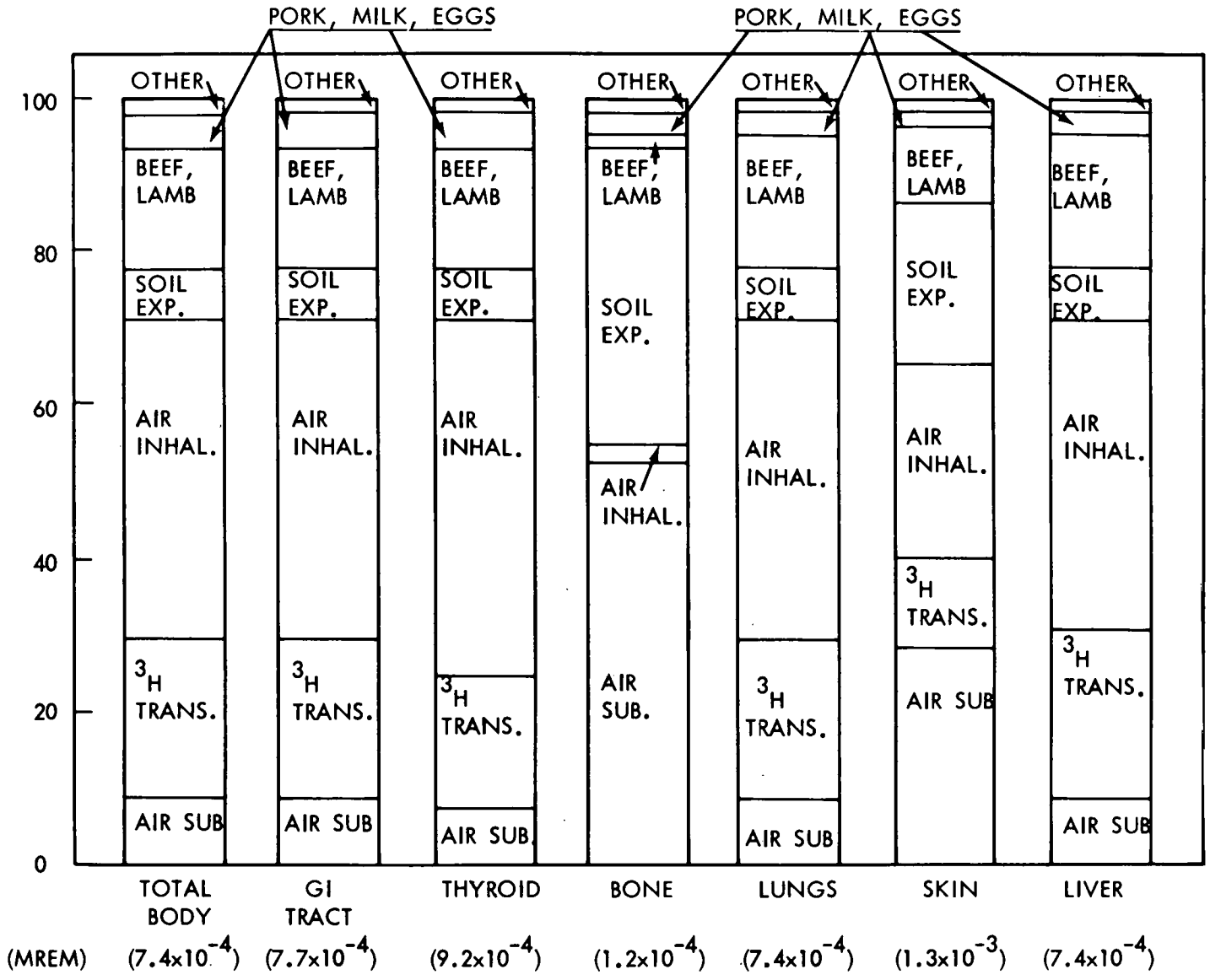

FIGURE II-3

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Pathway Contributions to Year 2000 Annual Dose (Average Adult)

detailed breakdown of pathways for bone and thyroid in the average adult and infant is shown in Figure II-4.

For the 50-year dose commitment, dose from external pathways is not a factor; the internal pathways provide the total contribution. The relative importance of these pathways, however, is not greatly changed (Figure II-5).

Radionuclide Contributions

Of the 48 radionuclides considered in the study (Appendix D), isotopes of only four elements contributed to the bulk of calculated dose. These nuclides (tritium, and isotopes of iodine, xenon, and cesium) contribute about 96% of the total body dose and 71% or more of the dose to the other organs considered. The breakdown of radionuclide contributions for the various organs considered is given in Figure II-6.

Examination of this figure reveals tritium to be a major contributor for most organs and for the total body. This is due partly to the fact that tritium is the only gaseous radionuclide for which extensive gaseous waste stream removal was not assumed. The potential impact of tritium removal was examined in sensitivity studies. There are some indications based upon examination of test mixed oxide stainless steel clad fuels designed for the fast reactor use, that most of the tritium generated in that fuel diffuses into the primary sodium coolant system. As a result, tritium removal may be an important consideration for LMFBR's as well as for reprocessing plants. The use of cold traps in the sodium coolant of LMFBR's promises to be a powerful means of removing tritium (as sodium hydride).

Iodine is of principal interest in relation to the thyroid. The contribution is relatively large despite radwaste treatment because of the affinity of the thyroid for iodine. It also contributes to other organs because it is a major

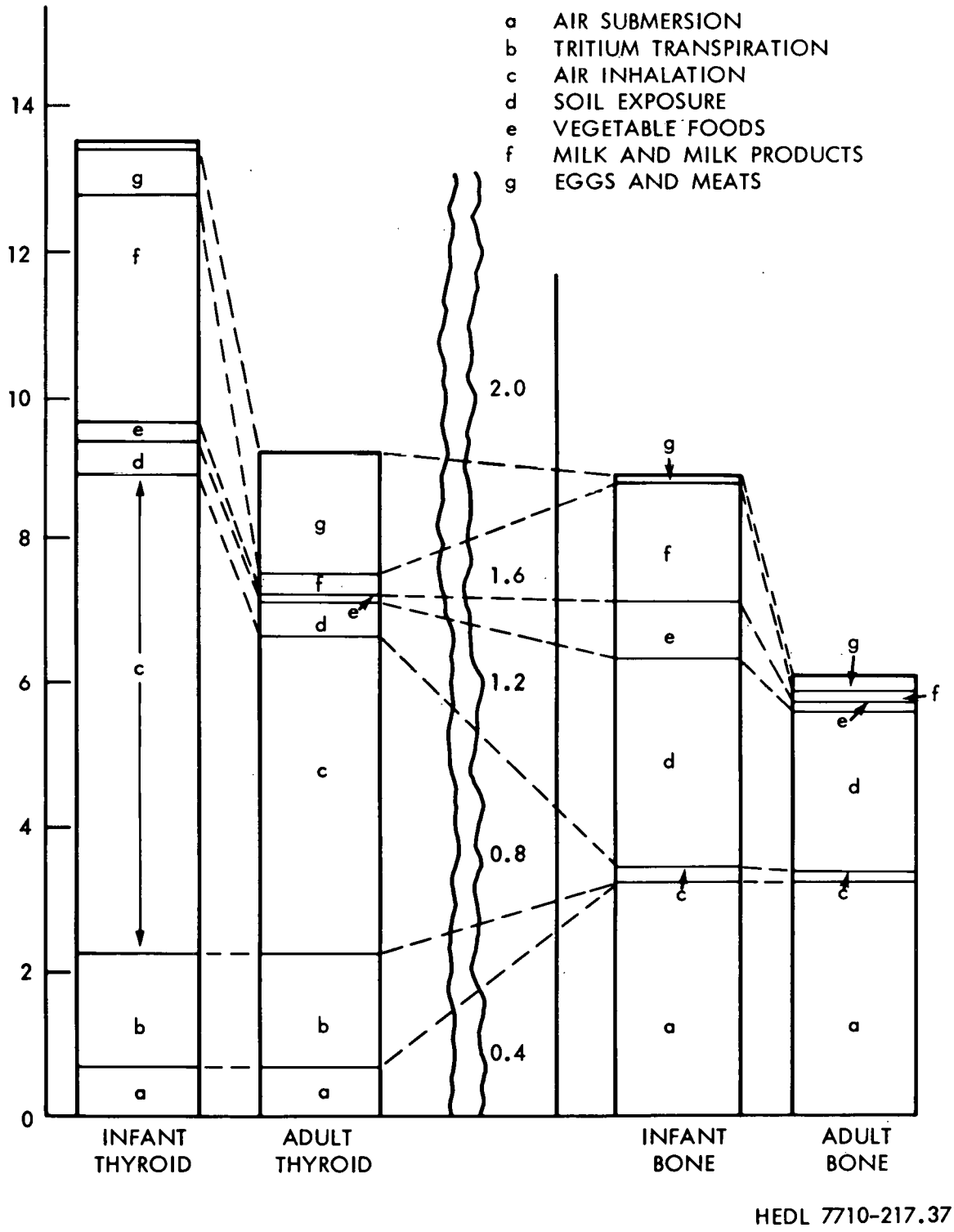


FIGURE II-4

Detailed Pathway Contributions to Bone and Thyroid Dose for Adult and Infant

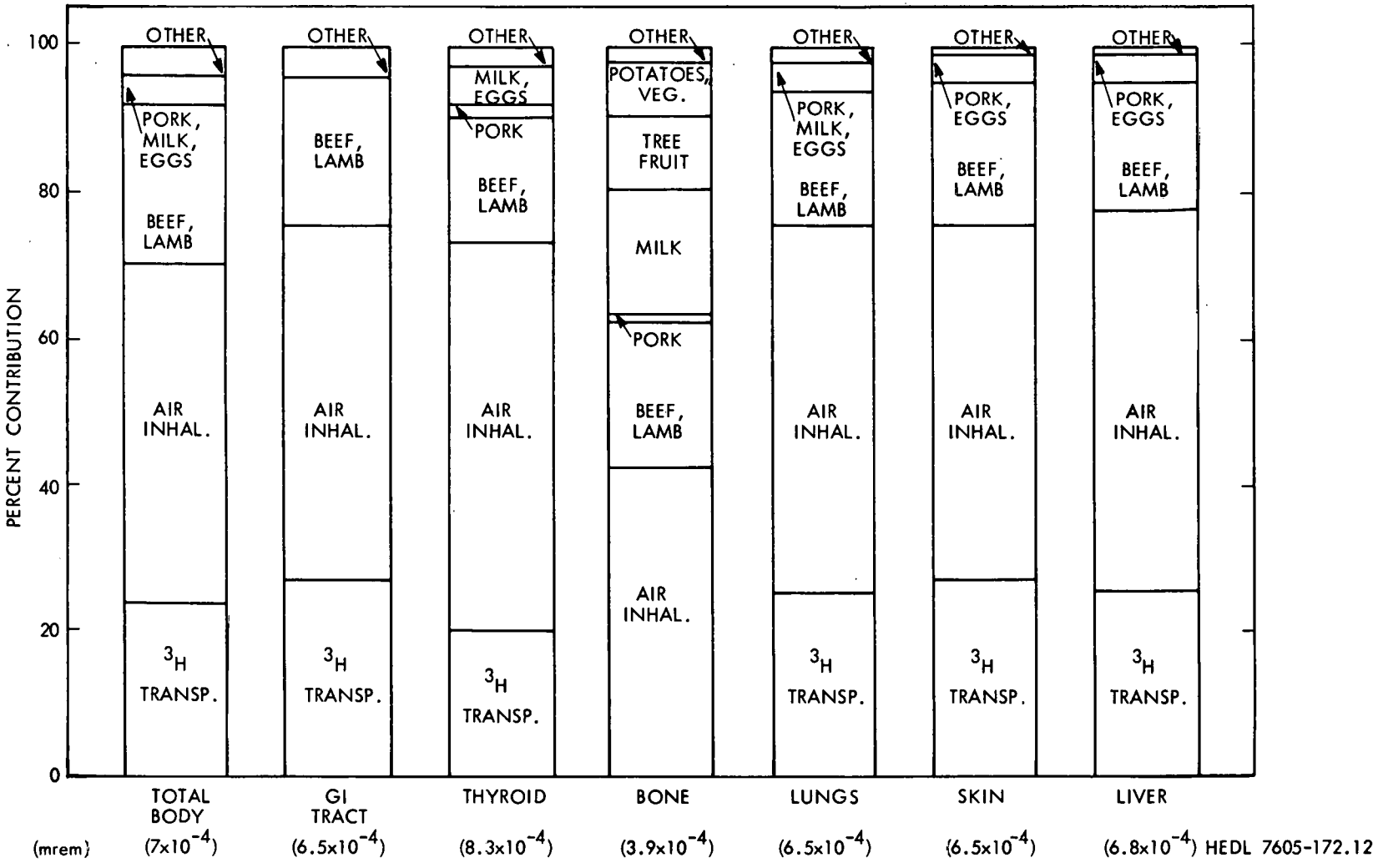


FIGURE II-5

Pathway Contributions to 50-Year Dose Commitment (Average Adult)

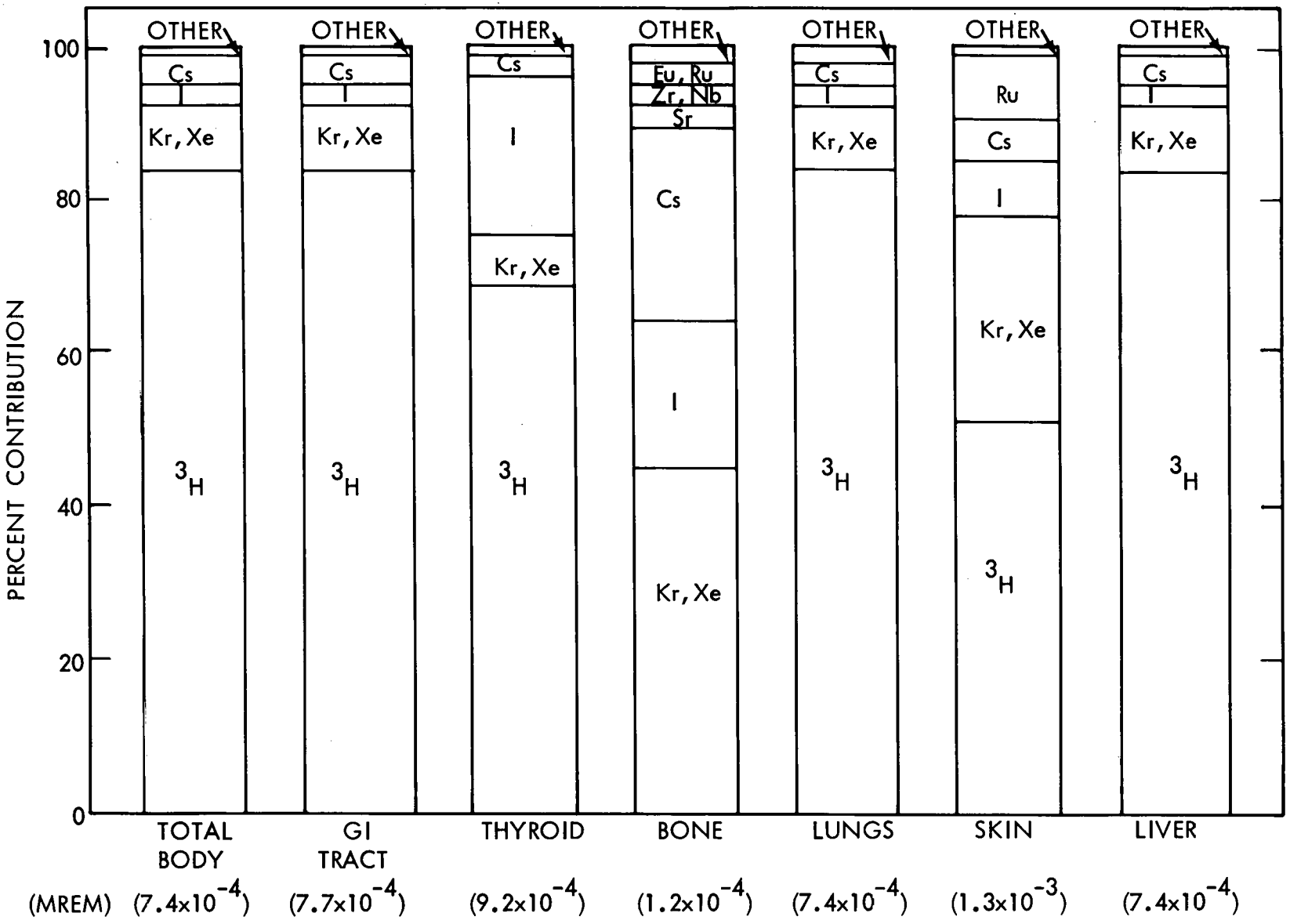


FIGURE II-6

Radionuclide Contributions to Year 2000 Annual Dose (Average Adult)

fission product -- that is, a relatively large fraction of fissions yield iodine as a fission product, and in spite of effective removal systems, some minor iodine releases still occur.

Cesium isotopes are also major fission products and contribute to the dose in bone, liver, total body, and GI tract. The principal pathways involved are drinking water and exposure to soil.

Krypton-85, considered by many to be a problem radionuclide, is found to be an important factor only in the dose to the skin. This could be expected partly because of the short-range beta emission which contributes only to the skin dose and also because of the assumed long-termed retention of noble gases in the radioactive waste treatment processes in operation in the year 2000.

Strontium-90, also generally considered to be a radionuclide of concern, was not found to be an important factor. With the nuclear plant emissions assumed in this study, its contribution was only about 4% of adult bone dose, increasing to about 25% for infant bone dose. It is a contributor to dose in the GI tract because of its ^{90}Y daughter, and is significant to the bone dose commitment.

Cerium-144 is a factor to be considered only in the GI tract. The very low solubilities of cerium compounds appear to inhibit its absorption in the body.

Transuranium elements were considered in this study but are not major contributors to the study year dose. However, ^{238}Pu and ^{241}Pu contribute 18% and 14% respectively to the 50-year dose commitment to the adult bone.

Power Projections

For the purpose of the study, approximately 144,000 MW of the 222,000 MW of electric generating capacity required for the region was assumed to be nuclear. Reprocessing plants in the area were assumed to service only the nuclear power plants included in the study. It was determined that for the radioactive waste treatment systems assumed for the nuclear facilities, the primary source of the population exposure is the reprocessing facilities and not the power plants (see Chapter X).

Studies have been made of the effects of clustering nuclear sites into small and large nuclear parks with sufficient reactors to support various sizes of reprocessing plants (Chapter X). Although indications were obtained that some slight decrease in dose may be achievable where large nuclear parks are assumed, the sensitivity of results to the specific sites studied made generalization difficult. For the study wherein several small nuclear parks were assumed the average regional dose increased. There, the increase is undoubtedly due to statistically shorter distances between regional population centers and reprocessing plants.

Tritium Diffusion Effects

In the base study, most of the tritium produced in reactor fuel was assumed to remain in the fuel (except for LMFBR's) until released during reprocessing. Thus, the release of tritium at reprocessing facilities became the dominant factor in contributing to dose to the population in the study area since no tritium removal systems were assumed for these plants.

At the time when a large fraction of the nuclear capacity is provided by the LMFBR (about 22% in year 2000) much of the gaseous tritium that is assumed to be released from reprocessing plants in the base case may, as noted in the section entitled "Radionuclide Contributions to Dose Rate," diffuse instead into the LMFBR sodium coolant systems. Tritium removal systems for the LMFBR would then be a major factor in reducing tritium releases.

The tendency of tritium to hydride sodium leads to its possible removal in cold traps (as assumed in the study). Other potential recovery means - sorption in zirconium or other metals, entrapment in molecular sieves, or oxidation followed by recovery and disposal of the tritiated water -- may apply equally to LMFBR's or to reprocessing plants.

Radionuclide Transport Considerations

Because of the large contributions from airborne radionuclides, uncertainties in meteorological parameters can have relatively large effects on dose to the population. In the study, average meteorological conditions for each month were derived for each location involved, by evaluation and interpretation of long-term recorded weather data.

A series of calculations was made to estimate the effects of variations in meteorological conditions on airborne radionuclide transport. Changes were assumed in the distribution of atmospheric stability and wind speed. Variations of any one parameter could affect concentrations by a factor of ten or greater. However, variations of this type would be expected to be short lived and would not affect the season-average values used in the study.

Calculations of releases with and without stacks for reactors indicate that the concentration difference between releases at ground level and at 100 meters are relatively small (using season-average meteorology) at distances beyond about 5000 meters.

In the waterborne transport of radionuclides, few data are available on the sorptivity of radionuclides on various types of soils or waterborne sediments, or on conditions (temperature, pH, etc.) which might affect sorption. Distribution coefficients, defining the relative concentrations of radionuclides adsorbed on sediments and those in solution, have been chosen based upon laboratory work done at ORNL. Because of the large uncertainties in radionuclide behavior, however, the coefficients are subject to considerable uncertainty (although this does not appreciably affect the overall dose calculation; water pathways contributed only a small percentage of dose).

To test the effects of these uncertainties, radionuclide concentration calculations have been made in which the distribution coefficients of radionuclides subject to sorption were varied over a large range. Changes in dissolved

radionuclide concentrations were relatively small -- usually, by factors of 10 or less. However, the calculations indicated that ground water concentrations and concentrations retained in soils and sediments could potentially vary over several orders of magnitude (again, only minor perturbations to overall dose would result). In this respect, the assumptions on ground water concentrations as used in the base study appear to be conservative.

Tests of the contribution of air deposited radionuclides to river water activity show wide variations within the region. The greatest part of the activity in the rivers is attributable to radionuclides deposited from airborne plumes. Direct injection of radionuclides into the waterways is less important. Few of the nuclear facilities considered were assumed to release radionuclides to water bodies.

Conclusions

This Year 2000 Study represents a detailed and thorough analysis of radiological dose to the public due to nuclear facility effluents, projected to a time when the generation of electricity in nuclear power plants will exceed the total amount of electricity generated by all types of plants at the present time. Present practices in the treatment of effluents from nuclear facilities are such that discharges of radionuclides are held to very low levels. Contributions to dose from these discharges represent only a very small fraction of that from natural background radiation. The results of the study indicate that dose from the nuclear industry can be maintained at an extremely small fraction of the unavoidable radiation received from the natural background.

Differing regional nuclear facility siting practices will cause some differences in the calculated dose to the population from one region to another. It does not appear practical to generalize on the full range of possible differences since this problem is compounded by the very large number of variables that must be considered. However, the calculated levels of radiological dose obtained from

this study and from the previous study of the Upper Mississippi River Basin give convincing evidence that the dose from operation of large numbers of nuclear facility is insignificant in comparison to dose from other radiation sources, both natural and man-made, and presents no hazard to human health or safety.

III. DESCRIPTION OF STUDY AREA

Of fundamental importance to a regional radiological study such as this one is the compilation of data on the physical characteristics of the study area, on the demographic patterns and pertinent characteristics of the regional population, and on patterns of land use, particularly of agricultural production. The great amount of information gathered for this study on the Tennessee Valley Region and its inhabitants is described in a companion report.[4] Excerpts from that report are repeated below to assist in correlation with the calculated dose to the regional population. A map of the region is shown in Figure III-1.

The valleys of the Tennessee and Cumberland rivers encompass 140 counties and parts of seven Southeastern states. This region is as diverse in its topographic features as any area in the eastern United States. It includes the flat lands and low, rolling hills of western Kentucky and Tennessee, the sharply delineated Appalachian Valley system, and the rugged Great Smoky Mountains along the eastern border. Through the region there are wide ranges in elevation, precipitation, and mean annual temperature. Similarly, there are large differences in the gradients and streamflow patterns of streams. Compounding the differences in streamflow characteristics is the system of power and navigation dams which has been built along the major waterways of the region.

The year 2000 population of the TVR study area is projected to be 6,965,600, an increase of approximately 51.5% over the 1970 population of 4,596,733.

The regional population density varied in 1970 from less than 13 people per square mile in Perry County, Tennessee, to 882 people per square mile in Davidson County (Nashville), Tennessee. The year 2000 projected population indicates increases in density to 17.4 people per square mile in Perry County and to 1,333.1 people per square mile in Davidson County. For comparison

FIGURE III-1

Tennessee-Cumberland Valley Study Area

purposes the 1970 population density of Kansas City was 1,443.6 people per square mile, with a total population of 644,950 people.

The projections of county populations made by two agencies, the Tennessee Valley Authority and the Environmental Protection Agency, have been found to be in sufficient detail and character to provide reasonable statistics for the entire study area.

Table III-1 summarizes the present population, and that projected for the year 2000, by state. The table includes only those counties from each state that are included within the study area. The inclusion of only the counties within the study area from each state tends to present a somewhat distorted growth rate when compared to projections for an entire state. This is primarily due to the characteristics specific to the area from each state that is included in the study region.

TABLE III-1

POPULATION OF THE TENNESSEE VALLEY REGION

STATE(1)	NUMBER OF COUNTIES	ACTUAL 1970	PROJECTED 2000
Alabama	10	609,806	1,019,300
Georgia	6	113,605	168,000
Kentucky	23	438,561	565,600
Mississippi	1	14,940	18,500
North Carolina	14	377,331	570,500
Tennessee	79	2,810,002	4,347,400
Virginia	7	232,206	276,300
TOTAL	140	4,600,541	6,965,600

(1) Includes only the counties of each state that are within the study area.

Much of the available data for the study area relating to dietary habits and recreational patterns is categorized by three population groupings which are defined and used by the Bureau of the Census:

- URBAN - Households in localities with at least 25,000 inhabitants and in closely settled fringes surrounding cities of 50,000 or more inhabitants.
- RURAL NON-FARM - Households outside of urban localities but without farm operator.
- RURAL FARM - Households outside of urban localities which have a farm operator.

Each county in the study area would have within its boundaries areas that would qualify for at least one of the above groupings. In some counties all three groupings would be applicable. To characterize the population of each county into one or all of the three groupings is not feasible within the scope of this study.

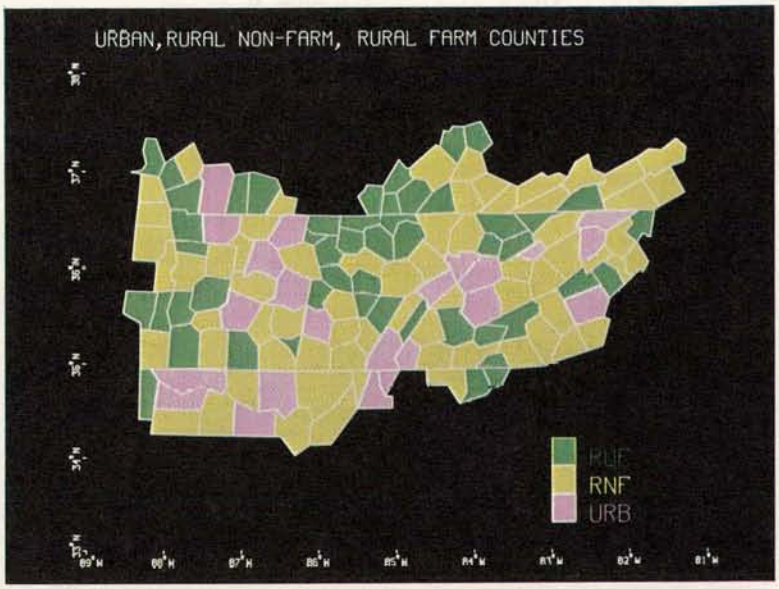
The people who are a part of each group do have distinct characteristics -- types and amounts of foods consumed, recreational activities, etc. -- that differ from the other groups. Analysis of the 1970 census data by TVA indicated that for the study area as a whole the population distribution is 46% urban, 42% rural non-farm and 12% rural farm. Using these values as a guide, each county was classified as to its dominant population group. The entire county population was assumed to belong to this dominant group.

This procedure generally approximates the composition of the study area as a whole, and reflects the shifts that may occur by the year 2000. The procedure resulted in the classification of 24 counties as "urban", 63 as "rural non-farm" and 53 as "rural farm" with 54%, 36% and 10% of the population, respectively. The classification of the counties is graphically displayed in Figure III-2.

This procedure thus simplified the selection and description of the typical individual from each county, as is required for dose evaluations.

FIGURE III-2

TVR County Classification



A complete, detailed calculation of the potential dose to each individual in the study region resulting from the exposure to radionuclides in the environment would be far beyond today's computer technology, even if the masses of data were available. Utilization of the centroid concept allows the mass of data and the subsequent required computations to be reduced to a manageable number.

With the assumption that the concentrations of radionuclides in the air and on the ground are relatively uniform over an area of reasonable size and that all activities that pertain to the dose required by an individual -- food production and consumption, the environmental exposure of the individual, recreational activities, etc. -- occur within that area, the required computations are manageable.

The calculations may then be made at a single selected point within an area. For this study the area selected is a county. The point of calculation is designated the centroid of the area.

For regional evaluations, as used in this study, use of the centroid concept provides a reasonably close approximation of the dose to the average individual living in the county. For those specific segments of the population that live near the fencelines of nuclear facilities, the centroidal evaluations are supplemented by additional, more detailed calculations.

The food consumption patterns of individuals form an important aspect of the overall living pattern. Evaluation of the potential radiation dose received through food pathways, moreover, requires detailed analysis of dietary habits and the relationship between production and consumption of foods. Considerable attention, therefore, is directed toward evaluating these relationships within the study area.

Food production and consumption data for the 1964-1970 period, used to establish the basic patterns for the area, are assumed to be escalated uniformly to meet requirements of the year 2000 population. This procedure skirts the question of the effects of evolution of farming practices and of dietary preferences during the intervening period. However, the assumption of uniform escalation of today's patterns is made deliberately, to avoid introduction of many unknowns and to provide a positive frame of reference.

The Tennessee Valley Region includes important food producing areas in the central, southern and southwestern parts of the study area. The region produces more meat -- beef, lamb, pork and poultry -- than is consumed within the region. Dairy products (fresh milk and butter), grain and grain products (corn, oats,

barley and rye), fresh potatoes, fresh berries and fresh eggs are also produced in sufficient quantities to satisfy the demand within the study area. Details of the production statistics are given in Reference 4.

The effect of crop irrigation was considered because irrigation involves a water borne route, other than rainfall, for the potential deposition of radionuclides. Reference 4 provides data summarizing the importance of irrigation in food crop production within the study area. Irrigation is not extensively practiced and is not an absolute requirement in order to produce foods.

The pattern of food consumption varies with the degree of urbanization. Families in urban areas tend to select more commercially prepared foods than the families in the rural area. The food types considered in data on food production were condensed into 35 categories of food consumption. This categorization provides a reasonable correlation between food production and consumption and provides a convenient model for handling data. Processed food categories were added for numerous fresh foods to allow subsequent dose calculation for consumption of that food category on a year-round basis, including the effects of decay of radioactivity in stored feed.

The food consumption habits of modern man are cosmopolitan. The food consumption categories considered in the study include several food types such as seafoods that obviously cannot be supplied from within the study area. It is also apparent that the highly urbanized counties will not be able to produce sufficient foods to satisfy their consumptive demand.

Radionuclide concentrations in foods produced near nuclear facilities tend, naturally, to be somewhat higher than in foods produced in more distant areas. However, because of the complexities in modern systems of food distribution, it is difficult to estimate the locations where those foods will be consumed and thus contribute to human dose. Foodstuffs are transported, sometimes over great

distances, to processing centers and to various marketing regions for eventual consumption by the population of the TVR.

To accommodate these factors (shipment between counties, imports from outside the study area and production-consumption within counties) the sources for the foods consumed were estimated using the following assumptions:

- Production of a county is applied first to satisfy consumption requirements of that county (this establishes a pattern of food surpluses and deficits).
- Deficits in a county are satisfied preferentially by food shipment from the nearest county having a surplus.
- Any remaining deficits after intra-study area shipments are satisfied are supplied from outside the study area.
- Fresh food deficits are satisfied first; any remaining surplus is available to satisfy the demands for processing food.

Three production sources were allowed to fill each deficit: the county under consideration and two sources from outside the county. If the deficit was not satisifed from within the study area, it was assumed that sufficient food would be imported from outside the study area to satisfy the demand. All foods that originated from outside the study area were assumed to be free of radionuclides.

An additional factor considered is food that is produced for home consumption. The home-produced foods reduced the total consumption requirement for that food type, for the appropriate county, prior to determination of any surplus or deficit for that particular food type.

The recreational activities of an individual create exposure patterns that contribute to the overall dose he might receive. Standing or sitting on a

river bank while fishing may bring an individual in contact with material that has been transported by the river and deposited on the river bank. Likewise, an individual submerged in water while swimming may be exposed to radioactive material suspended in the water.

Recreational activities, while not significant contributors to the total body dose, were included in the overall evaluation to account for all likely pathways. The recreational activities included were swimming, boating and water skiing, fishing, water fowl hunting and upland game bird hunting. Fishing indicates only bank fishing while "boating and water skiing" includes canoeing, sailing, and barge or boat fishing. The seasonal characteristics of the activity, degree of urbanization, proximity to a desirable location and age levels were considered in estimating the number of hours per month devoted to such recreational activities.

IV. POWER GENERATION PROJECTIONS

Regional Power Supply Characteristics

For the purpose of making power generation projections, the central study region and the "air envelope", the immediately contiguous area containing nuclear facilities considered in the study, are considered as a single entity. This extended region, which is entirely contained within the area defined by the longitudes 79° and 91° west and the latitudes 33° and 39° north, includes the entire TVA power service area (PSA 20) as well as portions of nine other power supply areas (PSA) as designated by the Federal Power Commission (FPC).

In 1970 approximately seven percent of the national electrical generating capacity was located within this area. While hydroelectric plants have, in the past, been major contributors, most of the capacity is now supplied by coal-fired steam plants. The first commercial nuclear power plant in the air envelope was Oconee, while within the central study region, Browns Ferry was the only nuclear plant plant in commercial operation at the time the study was performed. In the next decade, however, a substantial number of other nuclear plants will begin operation, making nuclear energy dominant in the region in the late 1980's. This is expected despite the presence of major coal reserves in the region.

Forecast of Capacity Additions

Since the study period, the year 2000, extends considerably beyond the time period for which it is practicable for utilities to make detailed projections for committed capacity, it was necessary to base the forecasts of capacity additions on extrapolations of existing projections. As a result, it is not likely that actual power system expansions will closely follow the forecasts presented here. Nevertheless, since they were made by utility personnel experienced in making power demand projections for this region, the forecasts

used for this study are considered to be the most realistic estimates available for this region's total demand for electrical energy and the portion to be supplied by nuclear power plants.

For the TVA power service area (PSA 20), the forecast of capacity additions was made by TVA and based on TVA's power expansion computer program. In this manner, factors (such as interest rates, tax rates, and the debt-to-equity ratio) which are different for a Federal agency when compared with private utilities were taken into account. Also included in the consideration were the effects of various other types of plants, such as gas turbines and pumped storage, or the need for new base loaded stations.

For the portions of the air envelope which are not within TVA's power service area, the method used to make forecasts of capacity additions was necessarily somewhat different. The 1970 National Power Survey,[5] prepared by the FPC, but dependent upon the input of individual utilities, was used as the basis for the projections. This report contains predictions of the peak demands for power for the major load centers within each PSA for the period 1970-1990, in 10-year increments. It also contains projections for the peak demands for the entire PSA's so that the portion of the power needs for areas within the air envelope but not within a specific load center could be estimated. This latter quantity, when added to the sum of the power demands for all the load centers of a given PSA, gives a projection for 1980 and 1990 of the peak demand for the portion of a given PSA that is within the air envelope. This procedure was repeated for all of the PSA's included in the air envelope.

The projections of peak power demands for the year 2000 were extrapolated from those for 1980 and 1990 as follows. An examination of TVA's projections showed a significant decrease in the rate of system capacity growth for the 1990's. This is predicted for several reasons: (a) the average residential energy use in the TVA region is now approximately twice that of the national

average and is not expected to increase significantly, (b)the sizable load from the ERDA uranium enrichment plants is expected to remain essentially constant, (c) the rate of power usage by large industrial users (aluminum and chemical industries) is not expected to increase signficiantly, and (d) an adequate capacity reserve margin ($\sim$ 20 percent) will have been restored. While not all of these factors are applicable to the utilities supplying power to the air envelope region, some decrease in the rate of power system expansion for the 1990's is expected to occur for these areas also. To provide an estimate, this decrease in the peak demand growth rate for each PSA for the 1990's was reduced from its rate for the 1980's by the ratio of TVA's predicted demand growth rate for these decades. The result was that the rate of capacity additions for all PSA's was reduced for the 1990's but was still greater than that for TVA.

With the exception of hydroelectric plants, power generating stations are usually located near load centers in order to minimize transmission costs (see the section on plant siting for more details). While this pattern may be changed somewhat by the availability of cooling water and by the tendency toward clustering nuclear plants in more remote sites, it was assumed that for each PSA the amount of generating capacity within the air envelope will be proportional to the corresponding peak demand. All the energy consumed in the region was assumed to be produced in the region. A proportionality constant of 1.20 was chosen to establish a 20 percent reserve capacity for each PSA. This then gave the total applicable generating capacity for 1970 through the year 2000, as shown in Table IV-1.

The projected capacities, made in the early phases of the study, may appear high in the light of subsequent developments in the energy supply picture. Use of this projection in the study leads to conservatism in the resulting estimate of dose to the population of the region.

TABLE IV-1

PROJECTED CAPACITY FOR EXTENDED STUDY REGION, 1970-2000

(MW)

	1970	1980	1990	2000
Area Total	45,000	78,900	144,100	222,000
Nuclear Capacity	0	22,678	79,053	143,853

Projection of Generating Plant Mix

TVA's power system expansion computer code calculated the fraction of the total system capacity which should be provided by base loaded nuclear generating plants. This same fraction was used for the air envelope because a study of the projections presented in (a) the 1970 National Power Survey[5] report, (b) the MAIN,[6] ECAR,[7] and SERC[8] reports for 1972, and (c) the annual reports for each utility showed that, when taken as a whole, the utilities surrounding TVA were expecting nuclear generating stations to make up about the same percentage of their total capacity as was TVA. Consequently, enough nuclear generating capacity was added each decade to each PSA to make the nuclear capacity equal to approximately 30 percent, 55 percent, and 65 percent of the total applicable generating capacity for 1980, 1990, and 2000. The number of nuclear units required was determined by assuming a 1200 MW capacity for all units, except for those already existing, under construction, or ordered. However, since some PSA's, especially those to the north of the study area, are not likely to turn to nuclear power as fast as TVA, a few of the nuclear units which might have been sited in these areas were assumed to be located in other areas which have indicated a more significant nuclear commitment.

For this study, it was assumed that the types of reactors which would constitute the nuclear capacity would be LWR's (both PWR's and BWR's), LMFBR's and HTGR's. After reviewing a number of long-range projections of the market penetration for these reactor types, it was decided to use the following criteria for choosing the percentage of each reactor to be included in the study: (a) the HTGR's will be available starting in 1985 and will comprise approximately 20 percent of the 1985-1990 capacity additions and 30 percent of the new nuclear capacity added in the 1990's, (b) the LMFBR's will be available (except the LMFBR demo plant which is listed as starting up in 1980) starting in 1990 and comprise approximately 40 percent of the total capacity added during the 1990's with most of them starting up after 1995, (c) LWR's will complete the total required with approximately one-third of the new reactors being BWR's and two-thirds PWR's.

Again, subsequent developments in the national nuclear energy scene, and the recently promulgated Administration policies on nuclear power, call into question the specifics of the scenario used in the study. HTGR's are not currently commercially available in the U. S. Utilization of the fast breeder reactor, and of reprocessing of spent reactor fuel, are now under intensive study in efforts to reduce the potential proliferation of nuclear weapons. Consequently, the existence in the year 2000 of a nuclear plant mix such as the one used in the scenario is highly speculative. The inclusion of these plant types, however, adds substance to the study in allowing evaluation of the relative contribution to population dose from each of the plant types considered.

The assignment of a reactor type to a given plant site was essentially arbitrary, except for cases where utilities had already announced a reactor type for a given site. Startup dates for the units were chosen to give a fairly uniform load growth for each PSA through each decade.

Plant Siting Considerations

In order to calculate population dose with the HERMES model, it was necessary to assign specific locations for all nuclear power plants and fuel fabrication and reprocessing plants. Because the doses calculated by the model are very sensitive to the sites chosen, it was necessary that the sites be realistic. This was especially critical for the reprocessing plants, since they were indicated to be the main sources of radioactivity in the study.

Consequently, for plants already built or under construction, the actual locations of those plants were used. In all other cases sites were chosen as realistically as possible and were required to satisfy usual siting criteria for nuclear power plants: located in reasonable proximity to the load centers to be served by the plant but at the same time located in mostly rural areas on reservoirs or major rivers. However, it should be emphasized that these site locations are purely hypothetical and were chosen solely for the purpose of permitting the dose calculations of this study.

For nuclear plants in the TVA power service areas, it was considered necessary (because of TVA's direct involvement in the study) to completely avoid having a site list containing a mixture of actual or hypothetical plant locations. Accordingly, rather than locate projected nuclear additions at new hypothetical sites, they were located at the actual existing sites of TVA coal-fired steam plants which are closest to the loads to be served. In this manner it is obvious that the locations used in the study have no bearing on where actual future plants may be located. For plants outside the TVA power service area, however, new hypothetical sites were chosen, without consultation with the utilities in whose areas the plants were located, as discussed above.

The sites assumed in the study, for nuclear power plants and for their supporting fuel cycle facilities, are shown in Figure IV-1. A listing of these

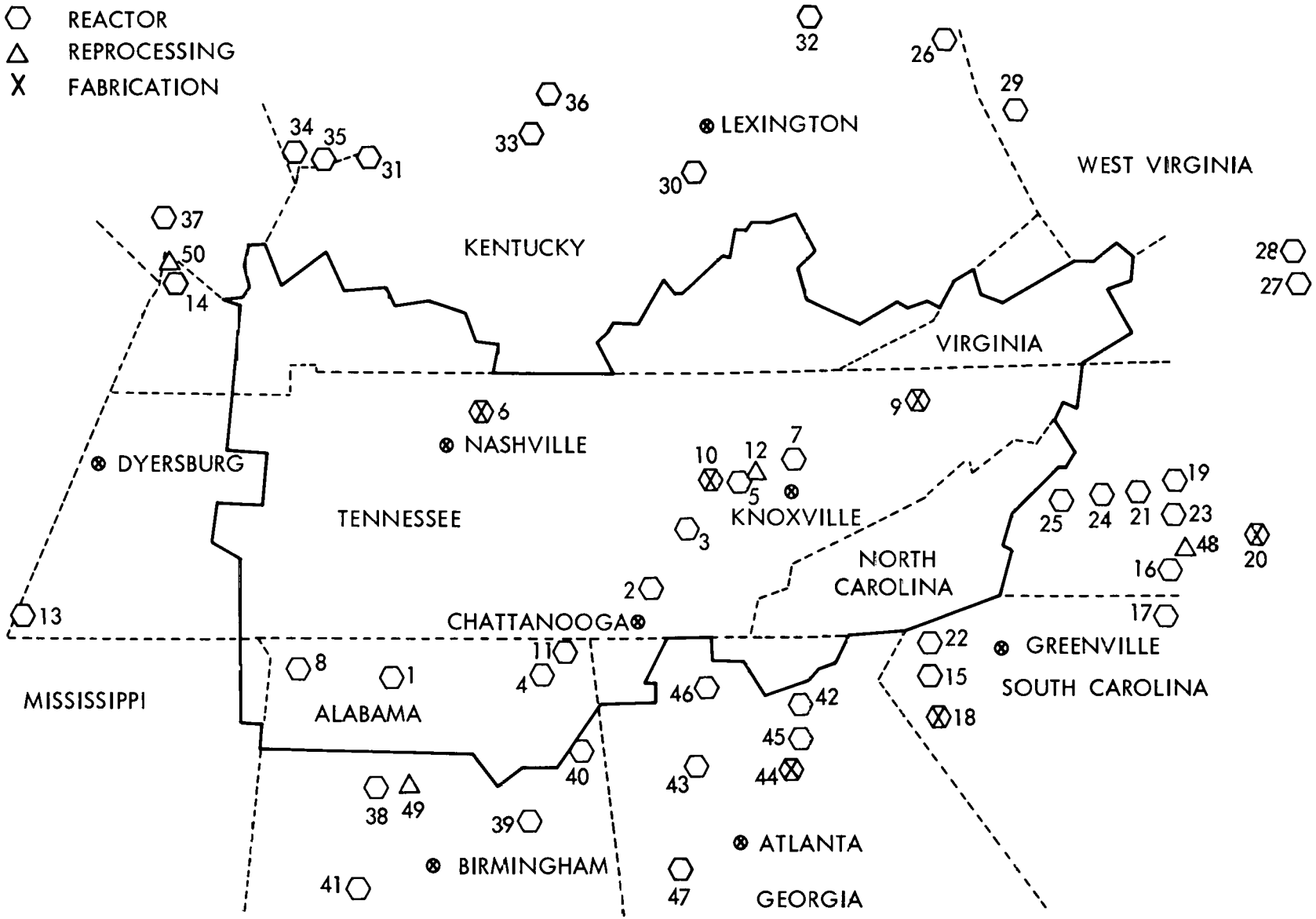


FIGURE IV-1

Potential Nuclear Facility Sites in the TVR

sites is given in Appendix A; additional details on plant siting assumed for the study area are given in Reference (4).

For sensitivity analyses, sites were selected to examine the clustering, or nuclear park, concept. These were essentially self-contained locations containing a number of nuclear power plants with fuel fabrication and reprocessing facilities servicing those plants. Two sizes of cluster sites were assumed, centered around reprocessing plants of, respectively one and five metric tons per day capacity. Sites assumed for the "clustering" study are shown in Appendix B.

Monthly Plant Operating Characteristics

Predictions of the probable monthly power generation in the year 2000 are, of course, quite conjectural. Nevertheless, by making use of the historical monthly operating characteristics of the utilities involved, it is believed that a reasonable simulation of the monthly operation of the power systems forecasted for this study can be made. For example, for the TVA region the power system has both winter and summer peaks. Consequently, during these months, and particularly in January and August, all units are required to be on-line, with annual refueling outages scheduled primarily during the spring and fall. Similarly, monthly operating schedules were set for each PSA separately, following the criteria that all units were on-line during the peak demand period, with annual outages distributed throughout the other months to ensure that the monthly demands of the subregion would be met. All nuclear plants were assumed to have an annual capacity factor* of 75 percent,** obtained by having each on-line at 90 percent load factor for ten months and completely off-line for the other two months. The resulting operating schedule for the year 2000 is given in Appendix C.

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* The capacity factor of a generating plant is the ratio of the actual energy generated, over a specified time period, to the possible energy produced if the plant were operating at full capacity over that period.

** More recent TVA studies assume a 70% capacity factor.

Reprocessing Plant Requirements

The number of fuel reprocessing plants required within the extended region was determined by making the following assumptions: (1) all the spent fuel generated in the region (including the air envelope) is reprocessed within the region; (2) fast reactor (LMFBR) and HTGR fuels are reprocessed in aqueous separation plants at one-half the design feed rate for LWR fuel; and (3) LWR reprocessing plants have a capacity of 1500 tons/yr. The startup date for each plant was chosen to be the year in which it could receive enough spent fuel to operate at 50 percent capacity. Using these criteria, it was indicated that four plants would be necessary. The site locations and startup dates for these plants are shown in Appendix A. The reprocessing loads for these plants are shown in Figure IV-2.

Fuel Fabrication Requirements

Fuel fabrication requirements, based on calculated requirements of the nuclear power plants operating in the central study region and the air envelope, were assumed to be satisfied by six fabrication plants operating in the year 2000. Three of these plants were located within the study region proper and three were in the air envelope. Each plant was considered to be dedicated to fabricating fuel for a single reactor type; for convenience in the study, these plants were assumed to be located at selected reactor sites. The site locations, startup dates, and capacities of the fabrication plants are shown in Appendix A.

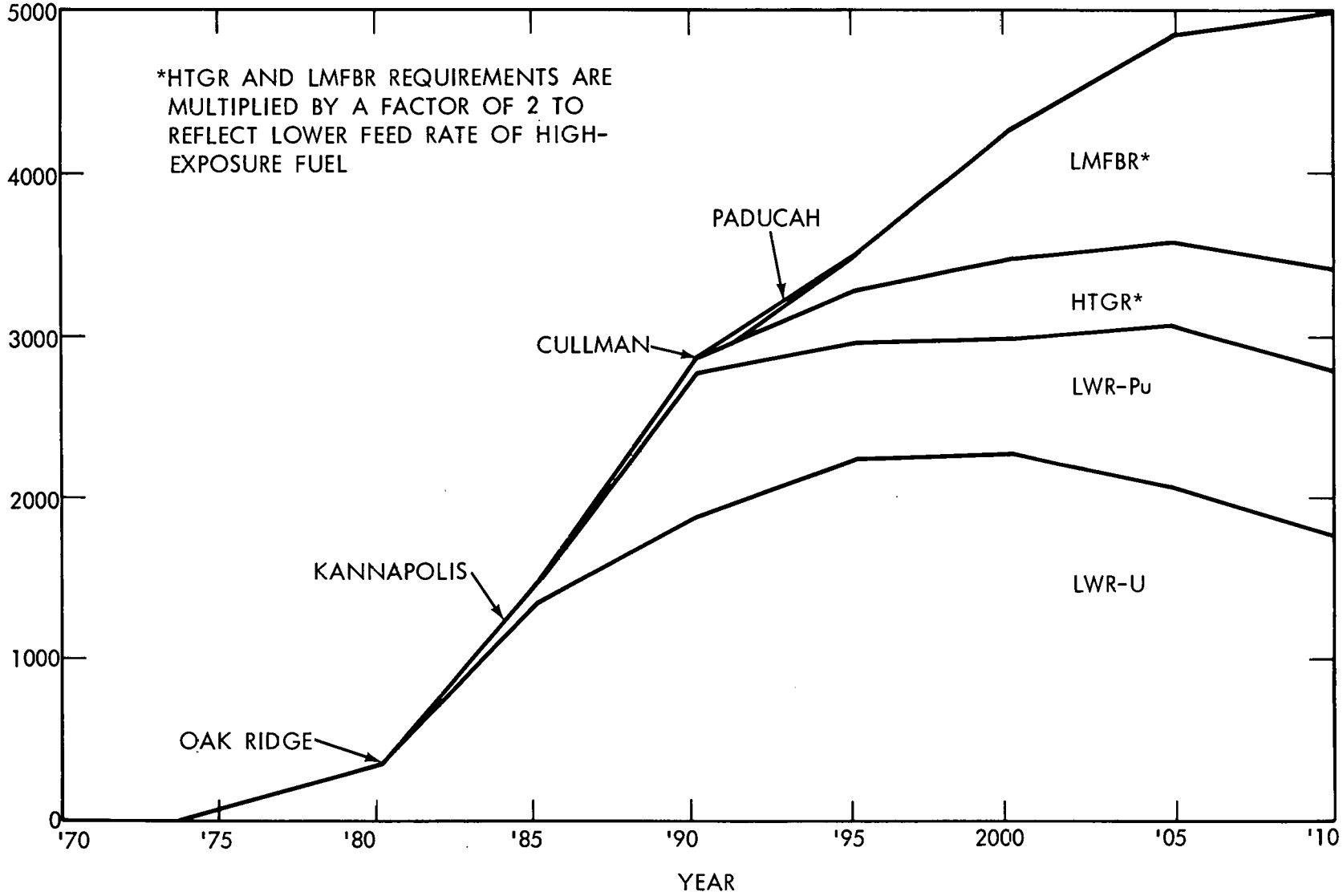


FIGURE IV-2

Reprocessing Loads for TVR Year 2000 Study

V. RADIONUCLIDE RELEASE CALCULATIONS

The calculation of estimated radionuclide releases from potential nuclear facilities is essential for the estimation of radiation dose. The calculation tool used in this study for the compilation of regional radionuclide releases is the RADREL module of the HERMES[1] set of computer codes.

Radionuclide release calculations performed in the RADREL code are represented in the form of a "source map", a snapshot in time of radionuclide releases from all potential nuclear facilities sites considered in the study. To provide a month-by-month history of radionuclide releases, RADREL utilizes data sets defining potential site locations, plant types, plant capacities, monthly plant operating data and unit radionuclide releases by plant type.

Radionuclide release quantities in the source map are expressed as an average release rate representative of each month in a year. Releases to the atmosphere and releases to the regional waterways are considered separately in the model used for this study. Nuclear facilities considered in this study are:

- Nuclear power plants
    - . Light Water Reactors (LWR)
        - . Pressurized Water Reactors (PWR)
        - . Boiling Water Reactors (BWR)
    - . High Temperature Gas-cooled Reactors (HTGR)
    - . Liquid Metal Fast Breeder Reactors (LMFBR)
- Reprocessing plants
    - . Early LWR fuel reprocessing plant (REPLWR)
    - . Advanced multipurpose fuel reprocessing plant (REPADV)

- Fabrication plants
  - . LWR uranium fuel fab plant (FABLWU)
  - . LWR plutonium-mixed oxide fuel fab plant (FABLWP)
  - . HTGR fuel fab plant (FABHTG)
  - . LMFBR fuel fab plant (FABLMF)

The abbreviations in parentheses are the symbols used for these plants in computer calculations.

Radionuclide releases were computed for 48 isotopes (Appendix D) for each nuclear power plant, fuel reprocessing plant and fuel fabrication plant. Typical unit radionuclide release rate data for ^{3}H, ^{85}Kr, ^{90}Sr, ^{137}Cs and ^{238}Pu are listed in Table V.1 for each type of nuclear facility. A detailed compilation of release rates for all isotopes and all plant types may be found in Appendix E.

Nuclear Power Plants

The RADREL code calculates both liquid and air releases to the atmosphere from all nuclear reactor types considered in the study by scaling the unit radionuclide release data with two parameters, the plant capacity (MWe) and the plant capacity factor.

Estimates of atmospheric and liquid releases from different reactor types are obtained from sources defined below and then normalized into unit radionuclide release data having dependency only on the parameters of plant capacity and monthly plant capacity factor.

Light Water Reactors

Radioactive effluent systems and management programs postulated for the light-water reactor nuclear power plants in the TVR study region are designed to reduce the radioactivity in both atmospheric and liquid effluents to levels which are very low, and which will result in doses less than the limits specified

TABLE V-1

TYPICAL UNIT RADIONUCLIDE RELEASE ESTIMATES
FROM NUCLEAR FACILITIES

REACTORS, $\frac{Ci}{MWe\text{-}yr}$		^{3}H	^{85}Kr	^{90}Sr	^{137}Cs	^{238}Pu
PWR	Atm.	8.66×10^{-1}	1.006	0	0	0
	Water	8.66×10^{-1}	0	0	1.16×10^{-7}	0
BWR	Atm..	3.46×10^{-2}	8.03×10^{-1}	0	0	0
	Water	3.46×10^{-2}	0	0	4.61×10^{-8}	0
HTGR	Atm.	7.40×10^{-2}	2.83	5.00×10^{-10}	2.4×10^{-9}	0
	Water	7.40×10^{-2}	0	3.90×10^{-7}	8.4×10^{-6}	0
LMFBR	Atm.	6.00×10^{-2}	4.00×10^{-4}	1.7×10^{-12}	4.2×10^{-11}	7.40×10^{-13}
	Water	6.00×10^{-2}	0	0	0	0
REPROCESSING PLANTS[1], $\frac{Ci}{MT\text{-}yr}$						
LWR-U	Atm.	692.	110.	7.69×10^{-6}	2.14×10^{-5}	8.46x10-7
LWR-Pu	Atm.	908.	69.	4.54×10^{-6}	2.20×10^{-5}	5.67×10^{-6}
HTGR	Atm.	4200.	618.	2.89×10^{-5}	1.51×10^{-4}	5.64×10^{-6}
LMFBR	Atm.	58.	93.	5.30×10^{-6}	2.82×10^{-5}	3.27×10^{-6}
FABRICATION PLANTS[2], $\frac{Ci}{MT\text{-}yr}$						
LWR-U	Atm.	0	0	0	0	0
LWR-Pu	Atm.	0	0	4.49×10^{-15}	1.09×10^{-14}	1.89×10^{-8}
HTGR	Atm.	0	0	2.86×10^{-14}	3.00×10^{-14}	1.88×10^{-8}
LMFBR	Atm.	0	0	5.25×10^{-15}	1.40×10^{-14}	1.09×10^{-8}

(1) Atmospheric releases only; no liquid releases.

(2) Liquid releases from fabrication plants assumed to be a factor of 100 higher than atmospheric releases.

in "ALARA" guidelines (Appendix I to 10 CFR Part 50).[9] The quantity of radioactivity released annually in atmospheric and liquid effluents is estimated using the analytical models and computer codes which were developed by the AEC (later by NRC) as part of its effort to determine "as low as practicable" (ALAP) levels of radioactivity in reactor effluents.[10] The ALAP computer code used to calculate radionuclide releases from LWR's does not provide release rates for any nuclides which would contribute less than 1% to the population dose.

In contrast, release calculations for HTGR's and LMFBR's did not utilize a low-level cutoff such as was used in LWR calculations. As a consequence, releases for several radionuclides, taken as zero values for LWR's, were calculated to have very small but finite values for the other reactor types. This difference is evident in the table in Appendix E, which lists calculated releases for all plant types. This deletion from LWR release calculations of radionuclides with small release values has no appreciable impact on resultant dose calculations.

The light-water reactors postulated in this study have a thermal power of 3,530 MW and a net thermal to electric efficiency of about 34 percent. A plant capacity factor of 75 percent is assumed. TVA believes this value, which is lower than the referenced value, is more representative of actual use over the 40 year life of the plant because in its later years the plant will probably be used for load following operations. Except for radioactive corrosion products and certain tritium releases, virtually all radioactive releases from light-water reactors result from the assumption that the reactors will be operated with defective fuel cladding. Thus, radwaste systems are provided to purify the gaseous and liquid streams and remove radioactive materials from effluents before discharge to the environment.

In addition to radioactive effluents deliberately discharged to the atmosphere, there may be inadvertent atmospheric release from such sources

as leakage from certain valves and seals, degassing and/or desorption from radioactive liquids which results from various leaks, and evaporation of tritiated water especially during refueling. Even when the best available technology is used, a portion of this activity may leak to the building ventilation system. This inadvertent release from the ventilation system generally accounts for much of the radioactive content of the total atmospheric effluent from the plant. The releases tabulated include allowances for such inadvertent releases.

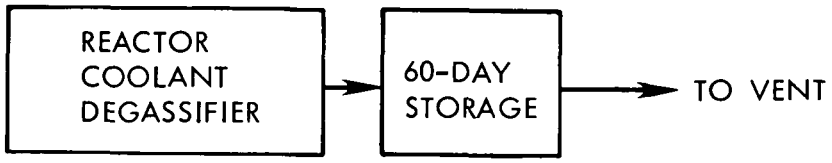
Because of expected release of tritium during refueling of LWR's, this study assumes that LWR tritium releases are constant throughout the year, i.e., release continues during shutdown periods.

Pressurized Water Reactors (PWR)

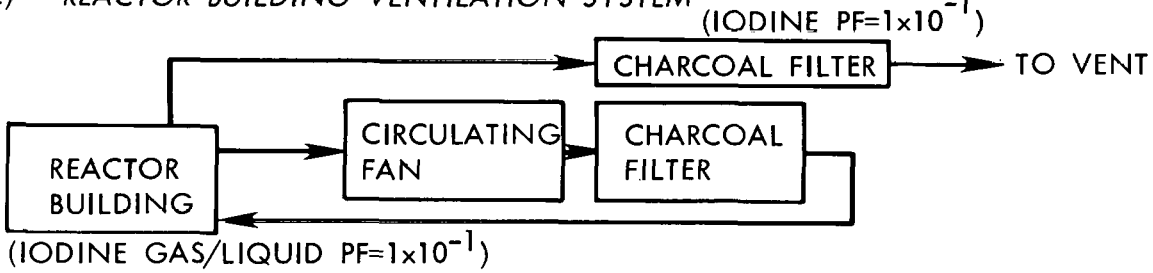
In this study radioactivity released in PWR effluents is determined for a model PWR design which is characterized by a recirculating U-tube steam generator and a condensate demineralizer which also processes blowdown. The model PWR gaseous and liquid radioactive waste systems are shown in Figure V-1.

The major sources of tritium in the reactor coolant system of a PWR are: (1) diffusion of ternary fission product tritium from the fuel through the Zircaloy cladding and (2) neutron reactions with the boron used for reactivity control. It had been previously estimated that only about one percent of the fission product tritium diffuses through the cladding because it tends to form a hydride with the Zircaloy and thus remains trapped in the cladding. Recent nuclear plant operating experience indicates, however, that perhaps as much as 10 percent (approximately 1,140 Ci/yr) of the fission product tritium may diffuse through the cladding. Thus, during most of the life of the plant approximately 1,560 Ci of tritium may have to be removed annually from the reactor coolant in order to maintain the coolant concentrations at a level

(1) GAS STRIPPING SYSTEM

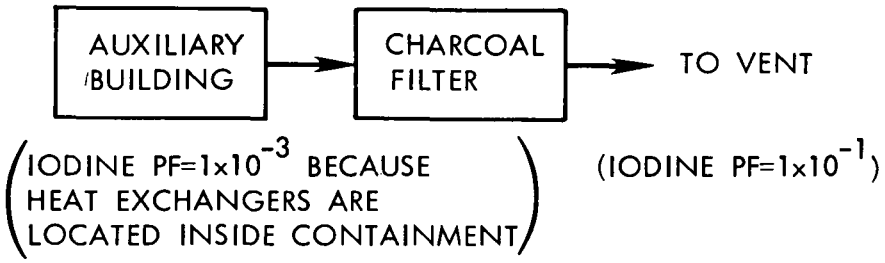


(2) REACTOR BUILDING VENTILATION SYSTEM

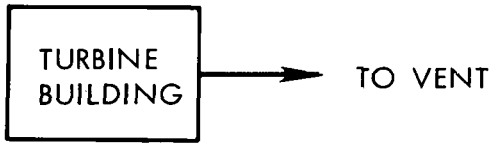


NOTE: REACTOR BUILDING IS PURGED TO THE VENT SIX TIMES A YEAR AFTER THE BUILDING ATMOSPHERE HAS BEEN CIRCULATED THROUGH THE CHARCOAL FILTER FOR EIGHT HOURS TO REMOVE IODINE.

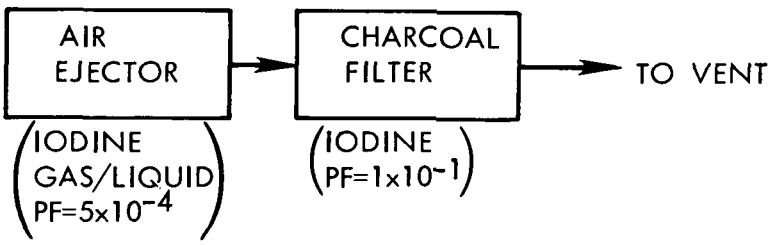
(3) AUXILIARY BUILDING VENTILATION SYSTEM



(4) TURBINE BUILDING VENTILATION SYSTEM



(5) AIR EJECTOR EXHAUST

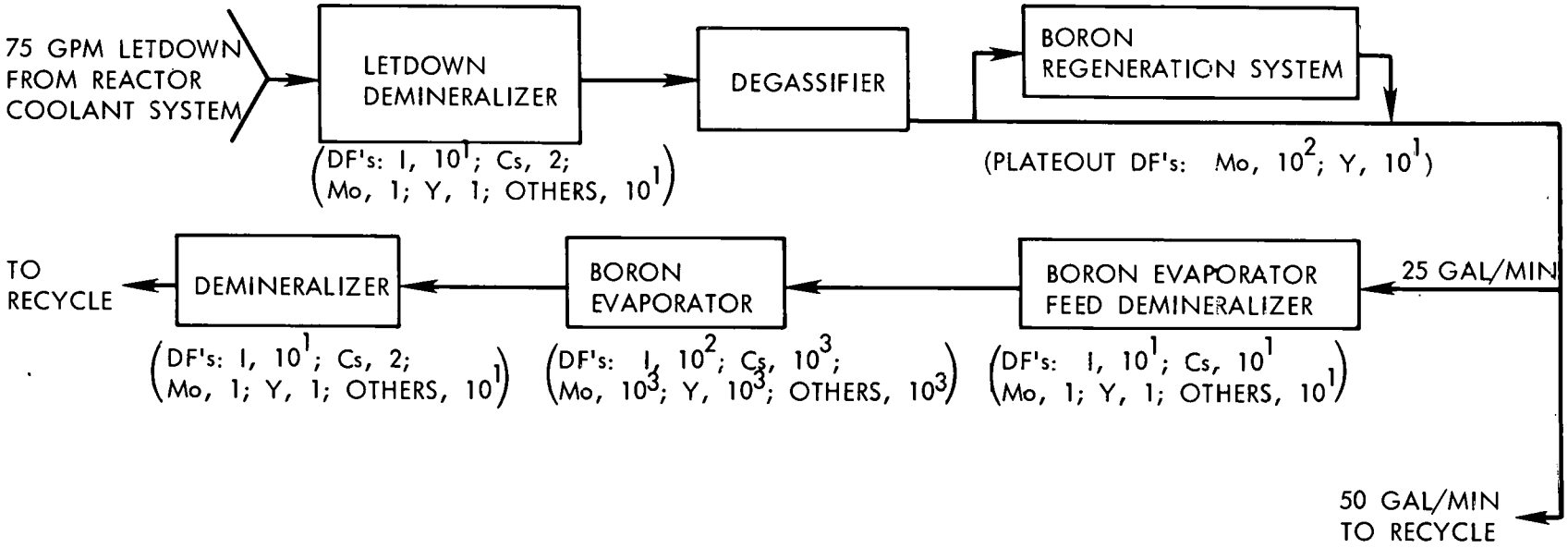


NOTE: PF SIGNIFIES PARTITION FACTOR OR THE RATIO OF MATERIAL IN THE EFFLUENT FROM A PROCESS TO THAT IN THE INFLUENT.

FIGURE V-1a

Model PWR Gaseous Waste Systems

(1) REACTOR COOLANT PURIFICATION SYSTEM (SHIM BLEED)



(2) SECONDARY COOLANT PURIFICATION SYSTEM

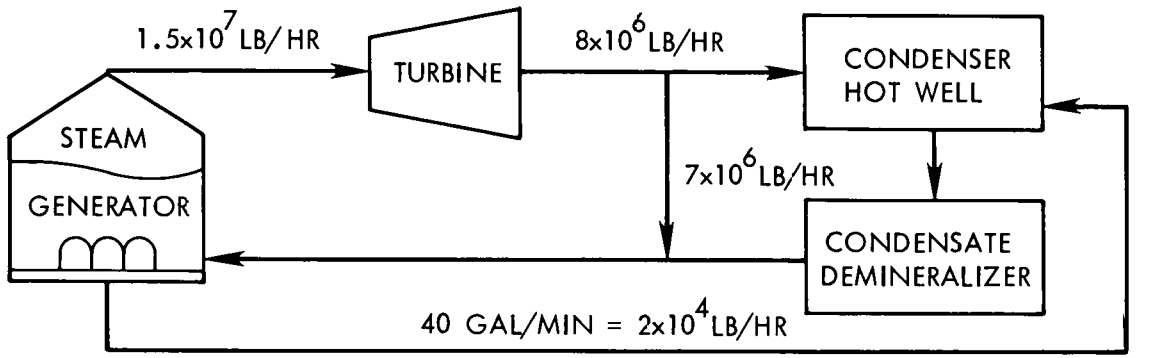
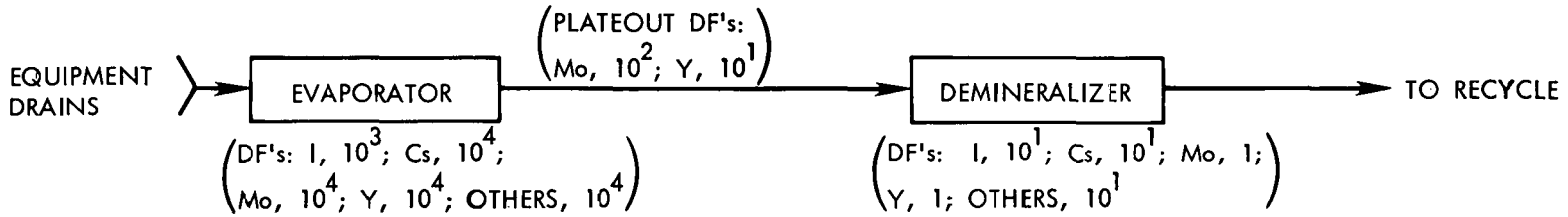


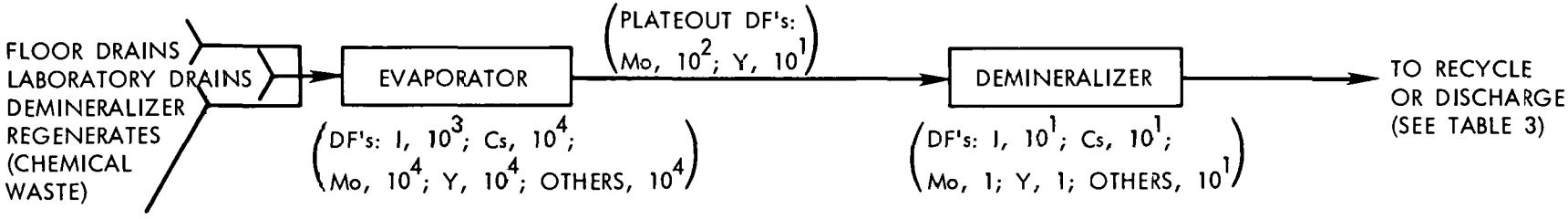
FIGURE V-1b

Model PWR Liquid Waste Systems

(3) EQUIPMENT DRAIN SYSTEM



(4) DIRTY WASTE SYSTEM



(5) TURBINE BUILDING DRAIN SYSTEM

TURBINE BUILDING DRAINS ——————→ TO DISCHARGE

NOTE: DF (DECONTAMINATION FACTOR) SIGNIFIES THE RATIO OF THE AMOUNT OF MATERIAL IN THE PROCESS INFLUENT TO THAT RETAINED BY THE PROCESS.

FIGURE V-1b (cont'd)

Model PWR Liquid Waste Systems

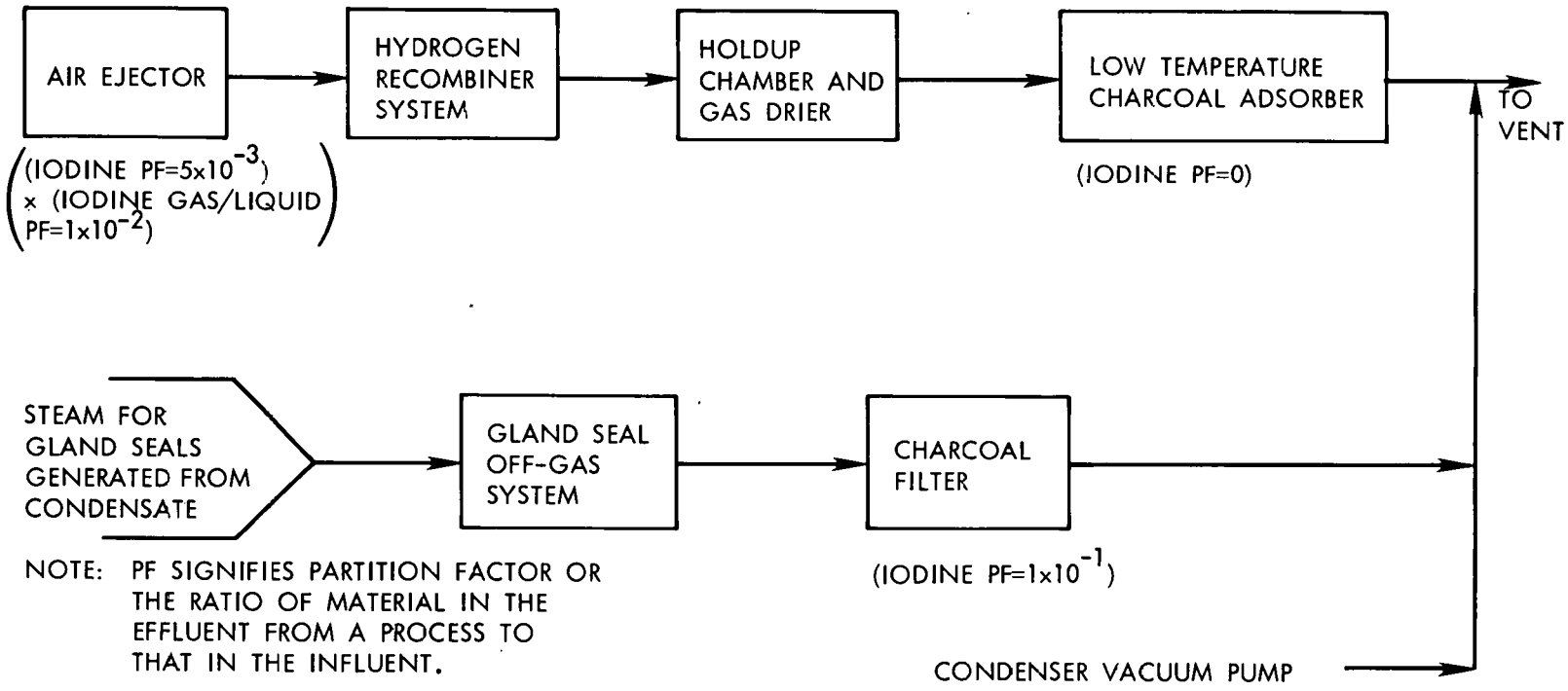
that would provide acceptable dose protection for operating personnel. It is expected that about 30 percent of this tritium would be inadvertently released to the atmosphere principally by water evaporation during refueling operations. Information regarding the increased diffusion of tritium has only recently become available, and this information is based on limited data, therefore plans and techniques for removing the remainder of the 1,560 Ci/yr from the reactor coolant are not yet formulated. Therefore, for the purposes of this study, it is assumed that half of the 1,560 Ci/yr would be released as gaseous effluent and the other half would be released as liquid effluent.

Boiling Water Reactors (BWR)

The model BWR gaseous and liquid radioactive waste systems are presented in Figure V-2. Releases of noble gases from the reactor building due to leakage of water from equipment are not considered by the computer code. These have been hand calculated assuming the concentration in the leakage water to be 10 percent of that in the coolant. For the purpose of this study, tritium releases are assumed to be evenly divided between gaseous and liquid effluents; it is assumed that 31 Ci/yr would be released as gaseous effluent and 31 Ci/yr would be released as liquid effluent.

High Temperature Gas-Cooled Reactors (HTGR)

During the operation of HTGR plants radioactive material will be produced by fission and also by neutron activation of reactor structural materials and impurities in the primary helium coolant. Most of the fission products will remain within the coated fuel particles. However, small quantities are expected to escape through the pyrolytic graphite coating of the fuel elements and diffuse into the primary helium coolant. Thereafter the gaseous and liquid radioactive waste systems designed for use on typical HTGR plants control the releases to the environment.



(2) BUILDING VENTILATION SYSTEMS

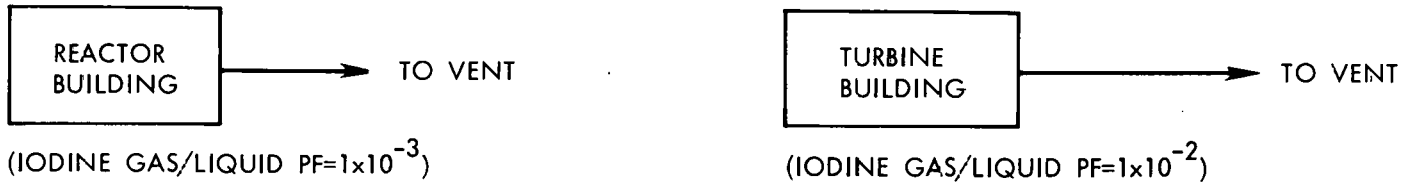
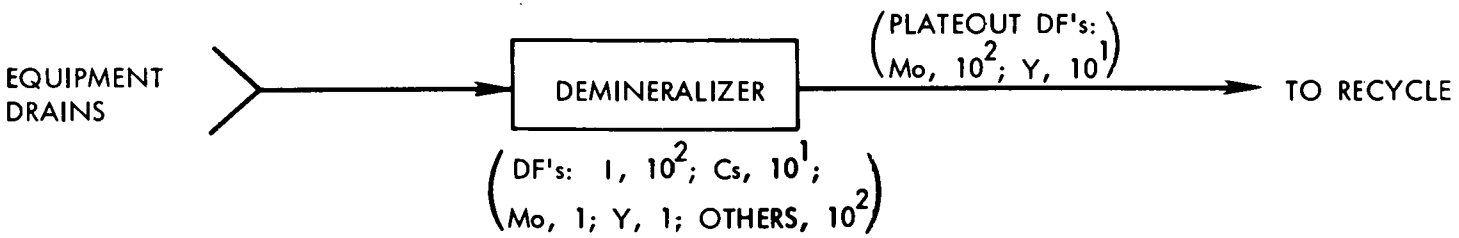


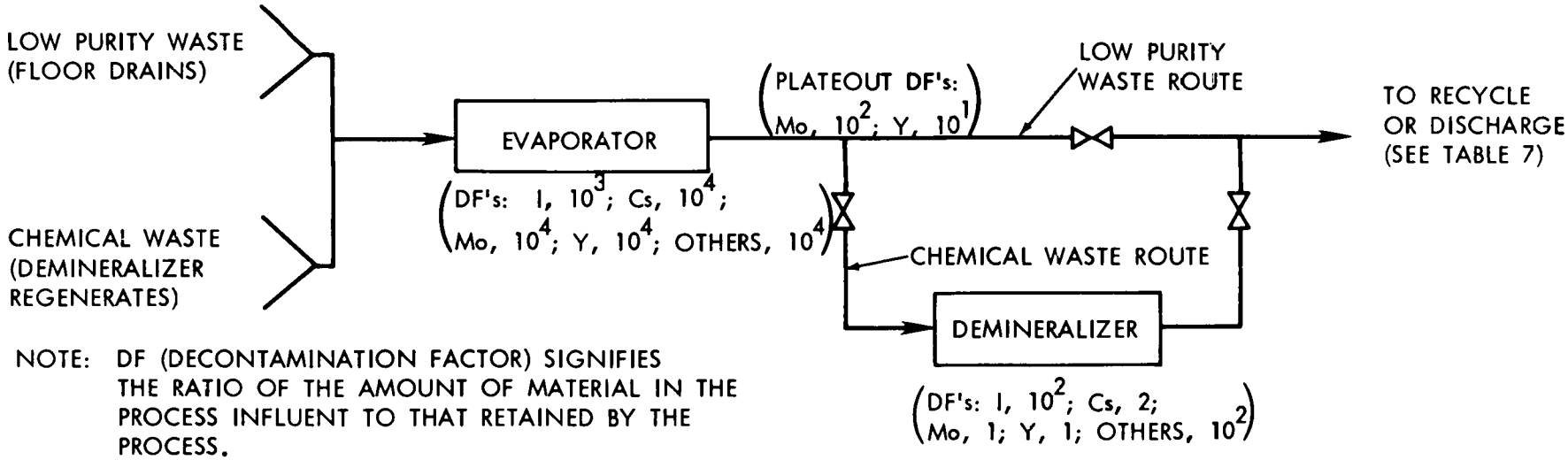
FIGURE V-2a

Model BWR Gaseous Waste Systems

(1) HIGH PURITY WASTE SYSTEM



(2) LOW PURITY AND CHEMICAL WASTE SYSTEM



NOTE: DF (DECONTAMINATION FACTOR) SIGNIFIES THE RATIO OF THE AMOUNT OF MATERIAL IN THE PROCESS INFLUENT TO THAT RETAINED BY THE PROCESS.

FIGURE V-2b

Model BWR Liquid Waste Systems

For this study the HTGR model postulated is a design similar to the Fort St. Vrain (330 MWe) and the now-cancelled Summit (761 MWe) HTGR plants. Estimated radionuclides releases presented in the environmental statements for these two HTGR plants[12,13] are used as a basis for unit release calculations for the RADREL code. Estimated radionuclide releases are based on operation with 1% failed fuel.

The principal source of radioactive gaseous effluents originates from the helium purification system. Small amounts of contaminated gaseous waste are also expected from purging of fuel storage and handling systems, purging of the helium circulator and fuel handling cask, and from the pre-stressed concrete reactor vessel (PCRV) support floor vent and liquid waste tank vent headers. The gaseous radioactive waste treatment system is shown schematically in Figure V-3.

The helium purification systems consist of two complete gas processing streams which operate alternately to allow for radioactive decay and regeneration. Each stream consists of various filter-adsorber components to remove particulates, halogens (mostly iodines), and gaseous hydrogen and tritium. After the periodic regeneration of each gas processing stream the adsorbed waste gases (primarily ^{85}Kr) are vented to the radioactive gas waste system.

The radioactive gas waste system consists of a high level waste system primary for handling the helium purification regeneration offgas, and a low level waste system for lower activity effluents. The radioactive gases will be compressed, cooled, and then stored in gas waste surge tanks until radioactive decay will allow safe release to the atmosphere.

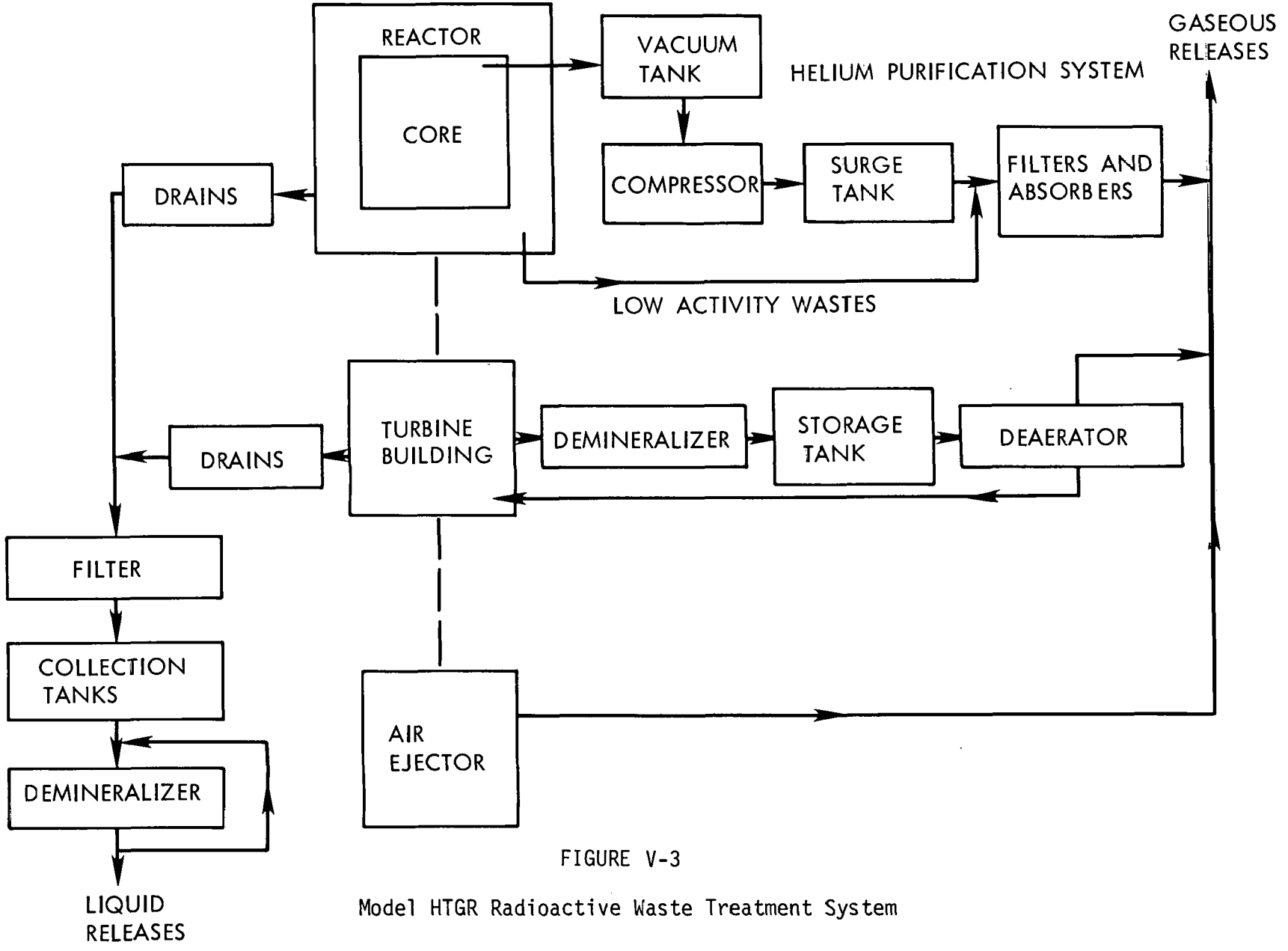


FIGURE V-3

Model HTGR Radioactive Waste Treatment System

The principal source of radioactive liquid wastes originates from decontamination of control rod drives. Other minor sources of radioactive liquid wastes include drains from the helium regeneration system, leaks in the PCRV liner cooling system and from leaks in the steam generator feedwater system. The liquid radioactive waste treatment system is shown schematically in Figure V-3.

All liquid radioactive wastes are stored in either a liquid waste sump or receiver tank after filtering. Higher activity wastes may require further processing through demineralizers and recycling through the system before release to the environment through the cooling tower blowdown line.

Liquid Metal Fast Breeder Reactor (LMFBR)

The LMFBR has inherent advantages for fission product containment relative to an LWR. The LMFBR coolant system is a relatively low pressure system and by necessity the interface between the sodium and aqueous systems in the steam generator is of very high integrity. Entrained fission or activation products can be continuously removed in a cold trap.

Three primary effluent pathways for a LMFBR have been postulated and evaluated, as described below:

A. Fission product tritium diffuses through stainless steel fuel cladding; then the fission and activation product tritium diffuses through the coolant system piping to the environment.

B. Radioactive noble gases escape from the reactor head following treatment in the cover gas clean-up system.

C. Entrained radionuclides in sodium are released as evaporator overheads from the chemical waste treatment system during cleaning of sodium from spent fuel elements.

Effluent calculations have been made treating each of the pathways listed above separately. The reactor postulated is a 1000 MWe (2500 MWt) LMFBR operating with 0.25% failed fuel. The cover gas is argon. The sodium coolant is assumed to contain 1000 ppm potassium (the limit established in RDT Standards for reactor-grade sodium).

The tritium effluent (Pathway A) calculations are based on previous work for the FFTF.[14] For the purposes of the effluent calculations all fission product and control-rod activation product tritium is assumed to reach the coolant (actually about 10% of the tritium remains in the fuel and is handled at the reprocessing plant). Essentially all of the tritium is assumed to be available as a driving force for tritium diffusion through piping in the primary and secondary sodium systems. Tritium is removed by cold trapping in both the primary and secondary systems, each with a single-pass decontamination factor (DF) of $\sim$ 3.7. It is assumed that one-half of the tritium escaping from the primary system emerges as a gas and that the other half is moved through the secondary system into the steam generator with subsequent release as a liquid.

Radioactive noble gases are released from failed fuel into the coolant and are then discharged to the cover gas. The cover gas treatment system (Pathway B) and the model thereof are similar to FFTF configurations.[15] Cover gas flows through a charcoal delay bed and then a cryogenic distillation column. The charcoal bed provides a delay of 3 days for krypton and 140 days for xenon. The cryogenic system provides a single-pass DF of 100 for krypton and xenon. Overheads from the cryogenic column are returned to a pressurized vessel head cavity (after addition of makeup gas) for service as a buffer gas for seals in the vessel head. Approximately 2 cfm escapes by leakage and permeation through the seals; the remainder returns to the

cover gas space. The computed cryogenic DF for krypton and xenon with recycle is ∿ 2500. An additional DF depending on radioactive half-life results from hold-up in the charcoal bed.

The high-integrity design criteria established for the FFTF indicates that, except for tritium diffusion through steel piping and noble gas diffusion through elastomeric seals, fission and activation product release from the reactor vessel is negligible. However, radionuclides released from failed fuel and entrained in the coolant may be subject to release from sodium washed from fuel elements subsequent to their removal from the vessel. It has been assumed that 215 pounds of sodium (1 lb. per element, 215 elements removed per year) are processed in a chemical waste system (Pathway C) annually. A DF of 100 is assumed for removal in the cold trap and plate-out throughout the reactor to obtain the concentration of radionuclides in the sodium coolant. The radionuclides are assumed to be in an aqueous solution following steam and water washing of the fuel elements. After the radionuclides are in aqueous solution a DF of 1000 is assumed for an evaporator with another DF of 100 for a filter in the evaporator overheads stream. In addition, a 90-day hold-up delay is assumed covering the time allowed for cooling of the discharged fuel elements before the sodium removal operation.

Release rates for each of forty-eight radionuclides have been evaluated using the assumptions above.

Fuel Reprocessing Plants

Estimates of radioactive effluents have been made on the basis of the previous Nuclear Fuel Services (NFS) experience (Table V-1), models developed from data obtained at ERDA facilities,[16] safety analysis reports and

environmental reports for the Barnwell Nuclear Fuel Plant (BNFP),[17-19] and an ERDA development program.[20]

Figure V-4 is a schematic drawing of the effluent treatment system that is planned for the BNFP.

The type of treatment system depicted in Figure V-4 is expected to remove 99 to 99.9% of the iodine and most of the particulate matter. The noble gases and tritium are discharged almost without further treatment.

New technology is being developed to remove tritium and noble gases from gaseous effluents, and to increase the efficiency for removal of iodine.[20] The basic principles followed to achieve these objectives are: (1) to minimize the flow rate of gaseous and liquid effluent streams through the use of extensive recycle and by decreasing the amount of gases and liquids entering the system; (2) to develop improved treatment (purification) systems; and (3) to isolate the tritium before it mixes with water in the dissolver.

A conceptual (but unproven) application of these principles is illustrated in Figure V-5 where the flow rate of gaseous effluent is 1000 cfm compared to 133,000 cfm listed previously for a plant designed in accordance with Figure V-4. Tritium and part of the noble gases and iodine are volatilized in the shearing and voloxidation steps. The tritium is trapped as relatively concentrated tritiated water, which is absorbed in calcium sulfate and stored as a radioactive solid waste. The remainder of the iodine and noble gases is volatilized from the dissolver. Only a trace of iodine would remain in the dissolver solution and pass into the process equipment. The evolved gas would be treated by (1) the Iodex process to remove most of the iodine, (2) the cryogenic distillation or selective absorption processes (fluorocarbons or CO_2) to remove the noble gases for storage as compressed gases

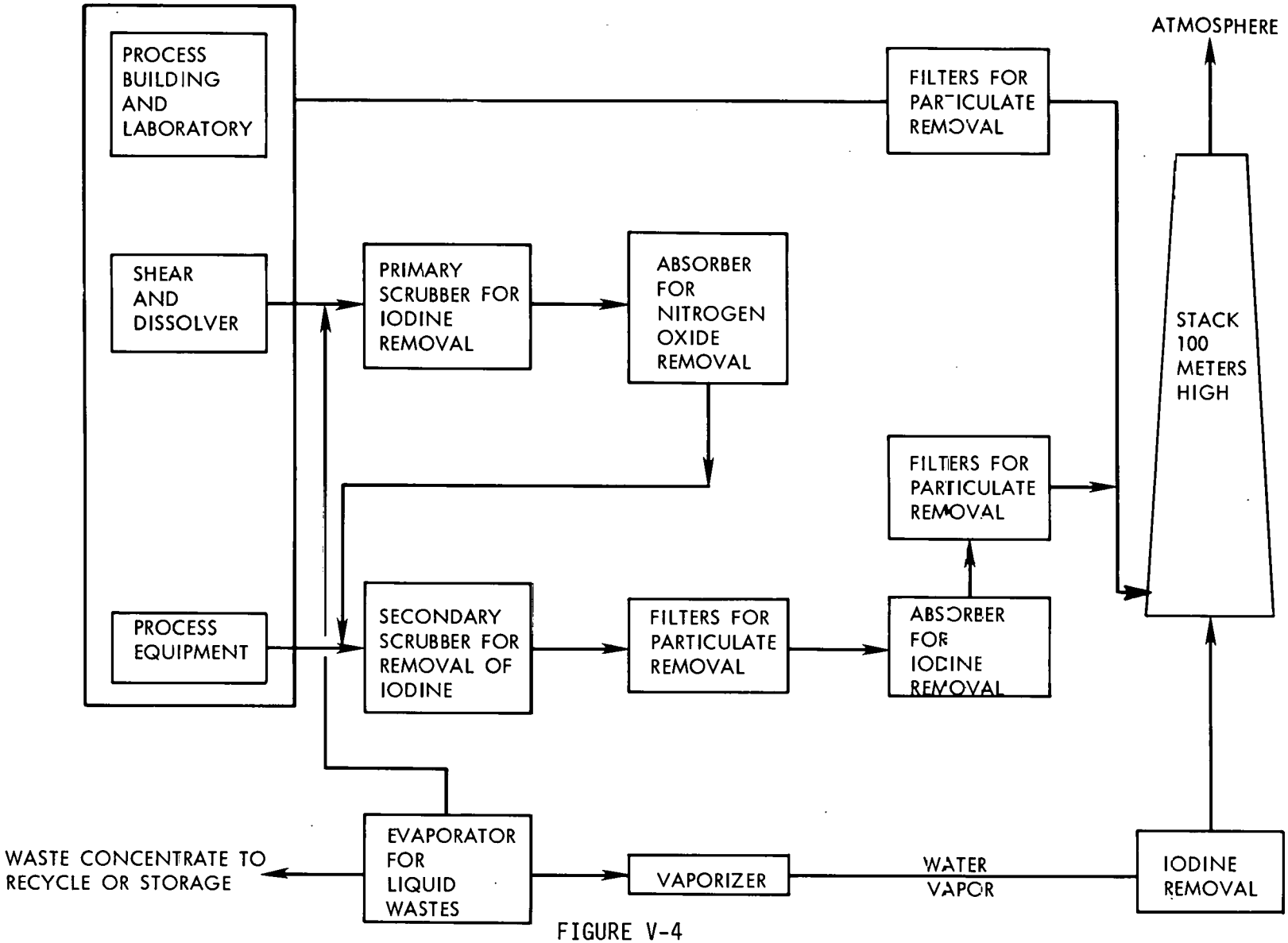


FIGURE V-4

Treatment of Gaseous Effluents From a Fuel Reprocessing Plant

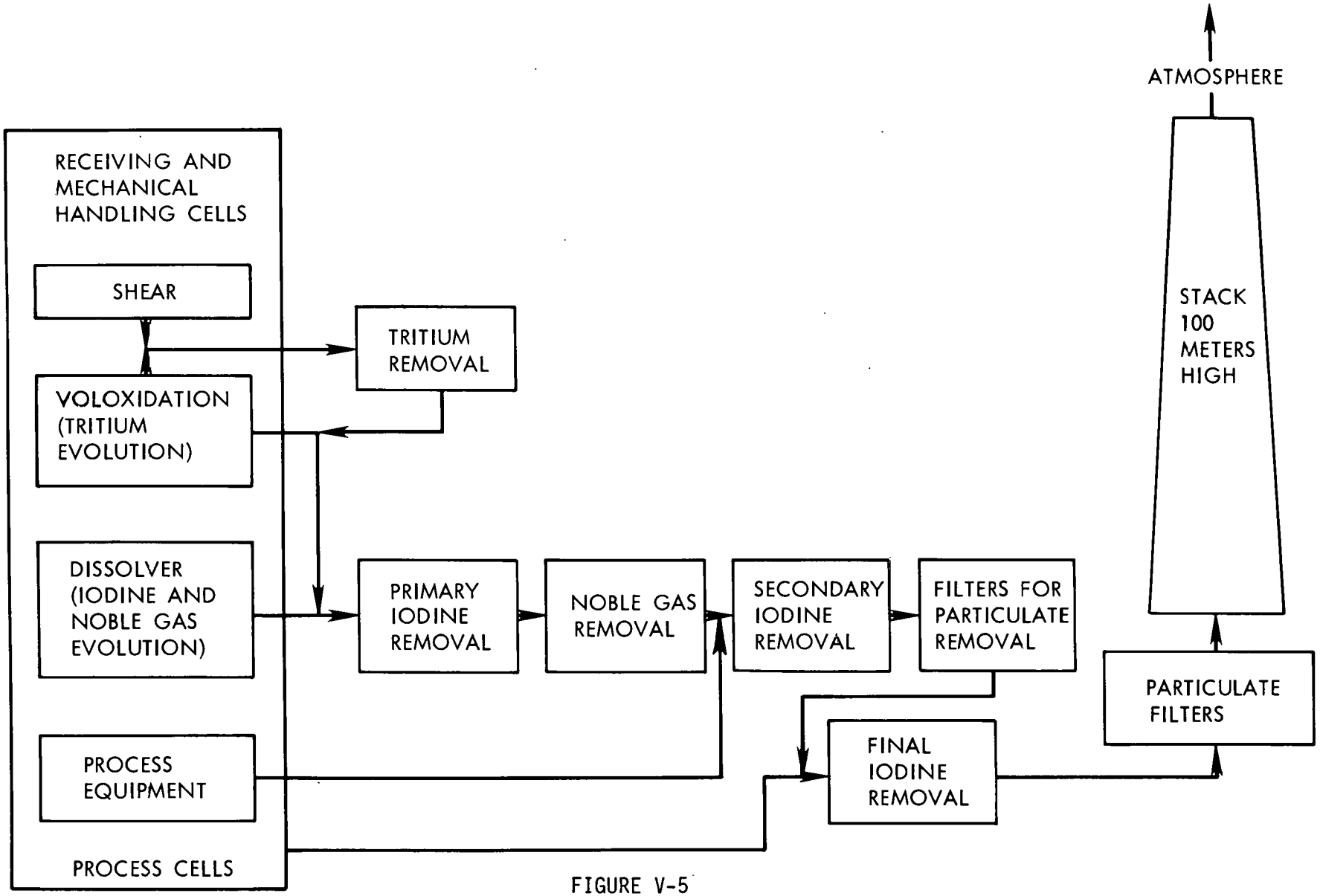


FIGURE V-5

Future Treatment of Gaseous Effluents From a Fuel Reprocessing Plant

in steel cylinders, and (3) final iodine removal by adsorption on a solid zeolite containing a film of silver. The filters would be designed with lower-than-rated superficial velocity to provide for enhanced removal of particulates.

Concentration of Radionuclides in Spent Fuel and Waste

Typical concentrations of radionuclides in spent fuel to be reprocessed have been computed with the ORIGEN[21] program (Table V-2). Also presented in Table V-2 are concentrations of radionuclides that are expected in high level wastes to be solidified at the BNFP plant after approximately five years of storage as solution.

Fractional Releases from Fuel and Waste

Table V-3 presents estimates of the fractional releases of radionuclides to the environment per unit of fuel that is processed and associated high-level waste that is solidified. Data are presented for a Barnwell-type plant and for a plant that would incorporate the developing technology for effluent control.

It is estimated that tritium (as tritiated water) and noble gases will be released without further treatment from the plants using Barnwell technology but that 99 percent of these materials will be removed in an advanced plant. It is conceivable that the plants currently under construction can be retrofitted for removal of 99 percent of the tritium and noble gas by about 1980. For reduction of ^{14}C the KALC (Krypton Absorption in Liquid CO_2) process is assumed for both current and advanced plant designs. The KALC process for removal of krypton combined with precipitation of CO_2 as $CaCO_3$ is assumed to remove 99 percent of the ^{14}C. No reduction in the tritium effluent stream was assumed for this study.

Nuclide	LWR-U		LWR-Pu		HTGR		LMFBR	
	Fuel[a]	Waste[b]	Fuel[c]	Waste[b]	Fuel[d]	Waste[e]	Fuel[f]	Waste[b]
H-3	692	5.22	908	6.85	4,200	30.5	58	
C-14	0.50		0.50		38.6		2.00	
Kr-85	11,000		6,850		61,800		9,340	
Sr-89	97,200		67,700		592,000		170,000	
Sr-90	76,900	67,900	45,400	40,100	289,000	251,000	53,000	47,000
Y-90	76,900	67,900	45,400	40,100	289,000	251,000	53,100	47,000
Y-91	161,000		119,000		729,000		29,300	
Zr-95	277,000		255,000		901,000		612,000	
NB-95	520,000		478,000		160,000		1,090,000	
Ru-103	88,200		99,200		148,000		301,000	
Ru-106	410,000	13,000	682,000	21,700	151,000	3,020	1,120,000	37,900
Sn-123	3,860	0.154	4,940	0.197	10,400	0.107	9,360	0.443
Te-125m	3,200	913	5,320	1,510	8,180	1,950	10,200	3,010
Te-127	6,080	0.055	7,610	0.070	27,000	0.051	16,300	0.177
Te-129m	2,710		3,000		13,200		20,400	
I-129	0.0374	0.00005	0.0480	0.00006	0.125	0.0001	0.0542	0.0001
I-131	2.18		2.27				45.3	
Xe-133					0.54		0.398	
Cs-134	214,000	39,500	187,000	34,400	709,000	104,000	40,200	7,980
Cs-137	107,000	95,100	110,000	97,800	303,000	266,000	141,000	126,000
Ba-140	431		409		4,460		3,200	
La-140	496		470		5,130		3,690	
Ce-141	56,400		52,000		283,000		139,000	

TABLE V-2

TYPICAL CONCENTRATIONS OF RADIONUCLIDES AND WASTES TO BE PROCESSED IN FUEL REPROCESSING PLANTS

Nuclide	LWR-U		LWR-Pu		HTGR		LMFBR	
	Fuel[a]	Waste[b]	Fuel[c]	Waste[b]	Fuel[d]	Waste[e]	Fuel[f]	Waste[b]
Ce-144	771,000	8,930	658,000	7,630	6,910,000			
Eu-154	6,870	5,530	9,270	7,460	13,500	10,600	2,000	1,650
U-232			0.003		292	1.42	0.044	
U-234	0.754		0.324	0.017	88.0	0.44	0.0005	
Pu-238	2,820	99.5	18,900	1,260	18,800	18,000	10,900	312
Pu-239	323	1.62	735	3.75	15.0	15.0	3,270	16.4
Pu-240	475	3.48	1,940	72.9	3.18	32.6	3,860	20.4
Pu-241	102,000	404	607,000	2,400	10,400	8,200	346,000	1,370
Am-241	153	156	1,580	1,590	16.2	101	1,480	1,450
Cm-242	17,700	14.8	240,000	284	2,490	0.739	46,500	111
Cm-244	2,390	1,970	136,000	112,000	1,640	1,320	2,390	1,970

[a] Fuel (3.3% enriched uranium) irradiated at an average specific power of 30 MW/metric ton to an exposure of 33,000 MWd/metric ton and decayed 150 days.

[b] High-level waste aged 5 years after removal of all noble gases, 99% of tritium, 99.9% of halogens, and 99.5% of uranium and plutonium.

[c] Fuel from elements initially charged with plutonium in a PWR with self-sustaining recycle. Fuel irradiated at an average specific power of 30 MW/metric ton to an exposure of 33,000 MWd/metric ton and decayed 150 days.

[d] Fuel from steady-state recycle irradiated at an average specific power of 64.57 MW/metric ton to an exposure of 94,300 MWd/metric ton and decayed 120 days.

[e] High-level waste aged 5 years after removal of all noble gases, 99% of tritium, 99.9% of halogens, and 99.5% of uranium and thorium.

[f] Mixed core and blanket fuel irradiated at an average specific power of 48.18 MW/metric ton to an exposure of 41,200 MWd/metric ton and decayed 120 days.

TABLE V-2 (cont'd)

TYPICAL CONCENTRATIONS OF RADIONUCLIDES AND WASTES TO BE PROCESSED IN FUEL REPROCESSING PLANTS

Plant Intro. Date	Barnwell (BNFP) 1975		Advanced Multipurpose 1985		
	Fuel	Waste	Fuel		Aged Waste
			LWR, LMFBR	HTGR	
	Fraction of Component Released per Unit of Fuel Processed				
Release to Atmosphere					
^{3}H	1.0		1.0	1.0	
^{14}C	.01		.01	.01	
Kr-Xe	0.01		0.01	0.01	
^{131}I	0.001		1×10^{-6}	0.00001	
^{129}I	0.01		0.0001	0.0001	
Semivolatiles[a]	2×10^{-9}	1×10^{-8}	2×10^{-10}	5×10^{-10}	5×10^{-10}
Nonvolatiles					
U	3×10^{-4}	2×10^{-9}	3×10^{-6}	3×10^{-6}	1×10^{-10}
Pu	6×10^{-9}	2×10^{-9}	3×10^{-10}	3×10^{-10}	1×10^{-10}
Others	2×10^{-9}	2×10^{-9}	1×10^{-10}	1×10^{-10}	1×10^{-10}

TABLE V-3

ASSUMED FRACTIONAL RELEASE OF COMPONENTS OF SPENT FUEL AND AGED WASTES FROM REPROCESSING PLANTS TO THE ATMOSPHERE

It is estimated that plants currently under construction will release approximately 0.1% of the ^{131}I and 1% of the ^{129}I (the latter accumulates in the coolant because of its longer half-life). Advanced plants are estimated to recover 99.9999% of the ^{131}I and 99.99% of the ^{129}I. Iodine will be released primarily as the elemental and organic forms, and inorganic iodines and iodates which may be adsorbed on particulates.

It is assumed that semivolatile materials such as ruthenium are released in the high-level waste solidification process. The estimates for semivolatile releases are relatively uncertain because wastes from power reactor fuels have not yet been solidified in typical commercial facilities.

Uranium will be released primarily in the form of UF_6. Plutonium and other nonvolatile species will be released primarily in the form of aqueous nitrate aerosols, dried nitrates, and oxides. The plutonium release is expected to be greater than for most of the other nonvolatiles because of quantities present and the number of process operations that are involved in purifying the plutonium and preparing it for shipment. The basic models that are used for estimating the fractional releases of particulates are presented in Reference 1.

Fuel Fabrication Plants

The radionuclides included in this study are involved in fuel fabrication plant operations only as recycled plutonium or uranium-233 and the trace impurities they may contain. The input of radionuclides to the fabrication process is shown in Table V-4. In the table the radionuclide input data are given in terms of ratios of curies entering the recycle fabrication plant to curies entering a reprocessing plant in one metric ton of spent fuel. A simple mass-balance adjustment converts this to throughput per ton of refabricated fuel.

Radwaste treatment facilities for fabrication plants were not specified in detail for the study, but were assumed to be equivalent to multiple banks of

TABLE V-4

RADIONUCLIDE CONCENTRATION FACTORS

FOR FABRICATION PLANT RELEASE CONCENTRATIONS

Curies entering recycle fabrication per curie in one metric ton spent fuel prior to rprocessing

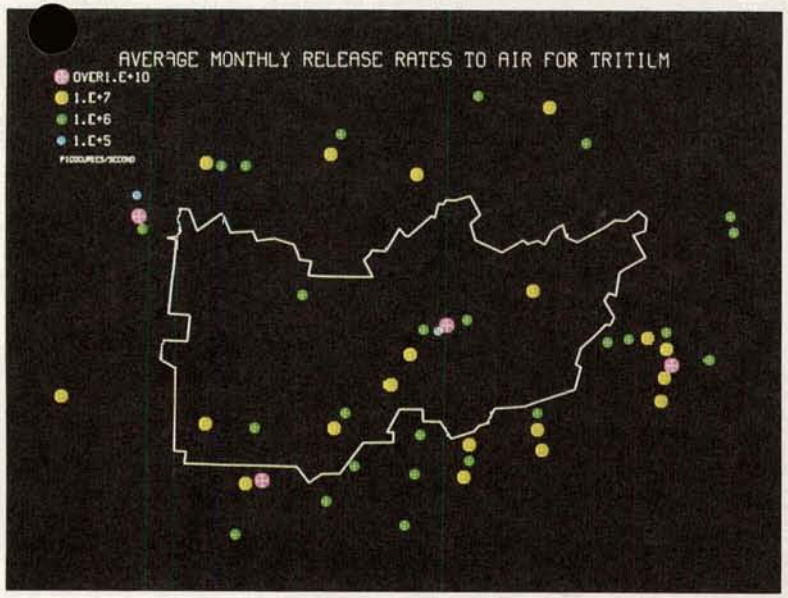
H-3	0	I-129	1.0 E-07
C-14	1.0 E-07	I-131	3.4 E-17
Na-22	0.	I-133	0.
Ar-39	9.	Xe-133	0.
Co-58	1.4 E-08	Xe-135M	0.
Co-60	9.3 E-08	Xe-135	0.
Kr-85M	0.	Xe-137	0.
Kr-85	0.	Xe-138	0.
Kr-87	0.	Cs-134	8.3 E-08
Kr-88	0.	Cs-137	9.9 E-08
Kr-89	0.	Ba-140	2.0 E-12
Sr-89	7.0 E-09	La-140	0.
Sr-90	9.9 E-08	Ce-141	1.5 E-09
Y-90	0.	Ce-144	6.1 E-08
Y-91	9.4 E-09	Eu-154	9.8 E-08
Zr-95	1.2 E-09	U-232	1.0
Nb-95	1.9 E-09	U-234	1.0
Ru-103	3.0 E-09	Pu-238	1.0
Ru-106	6.8 E-08	Pu-239	1.0
Sn-123M	3.3 E-08	Pu-240	1.0
Te-125M	9.3 E-09	Pu-241	1.0
Te-127M	0.	Am-241	1.0 E-07
Te-129M	1.7 E-09	Cm-242	4.3 E-08
Te-132	0.	Cm-244	9.8 E-08

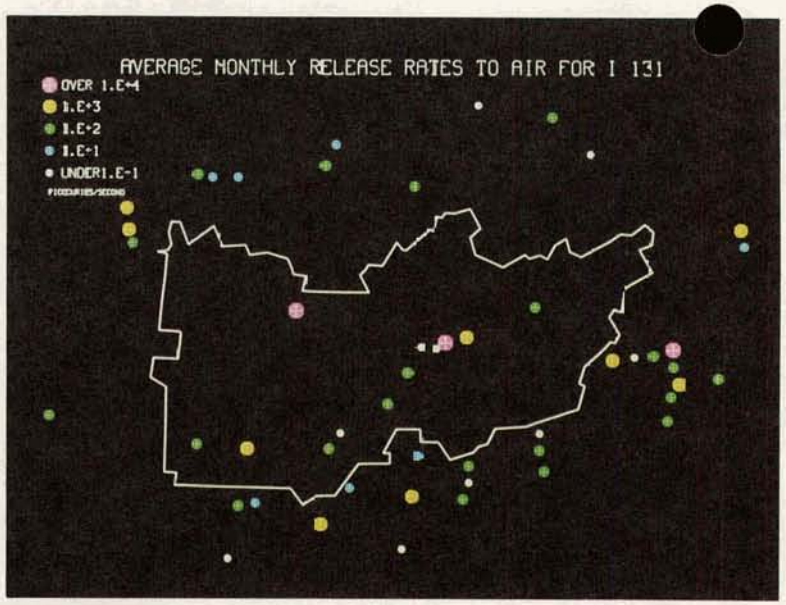
HEPA filters, with decontamination factors of 10^{10} for airborne particles and 10^{8} for particles in liquid effluents. Approximately one percent of the fuel throughput of a plant was assumed to be "lost" from the mainline process and to enter the radwaste system for recovery. Thus, the overall release fractions for radionuclides, referenced to the flow rates in the fabrication process, were 10^{-12} for releases to air and 10^{-10} for water releases. The resulting releases of radionuclides from reprocessing plants, in terms of curies released per metric ton of fuel fabricated, are given in Appendix E for the various fuel types considered in the study. Releases of selected nuclides were shown in Table V-1.

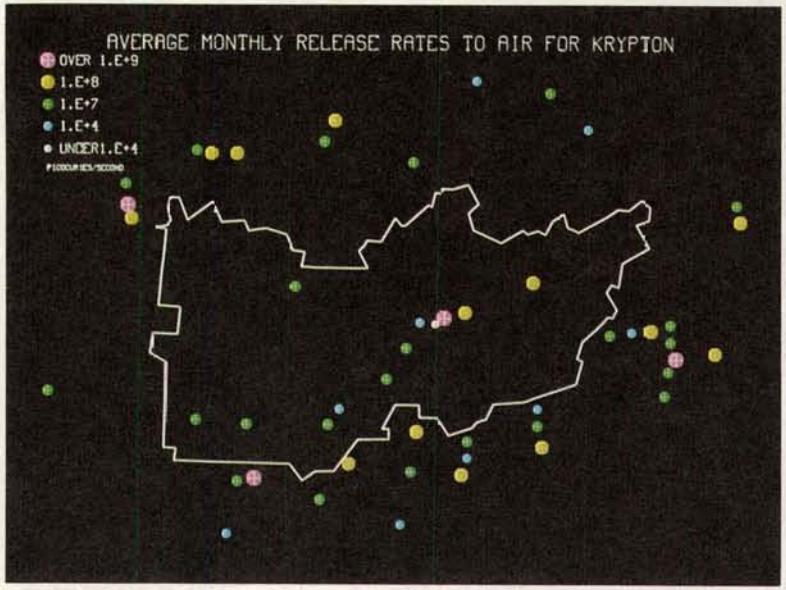
Source Map Release Patterns

The end result of calculations in the RADREL code is the estimated radionuclide releases in the Year 2000 from each of the nuclear facilities in the TVR region. This is represented by a source map which defines the average monthly release rate from each source for each isotope of interest. Radionuclide releases to the air and to the water originate from 50 source locations. The releases from multi-plant facilities at one site are combined and considered as a single source. Radionuclide releases to the air from reprocessing plants are assumed to be from a stack 100 meters high whereas air releases from all other facilities are considered to be released at ground level.

TVR regional source map release patterns for four of the more significant isotopes, ^{3}H, ^{85}Kr, ^{134}Cs, and ^{238}Pu, are shown in Figure V-6. Total radionuclide air releases are shown in Figure V-7.







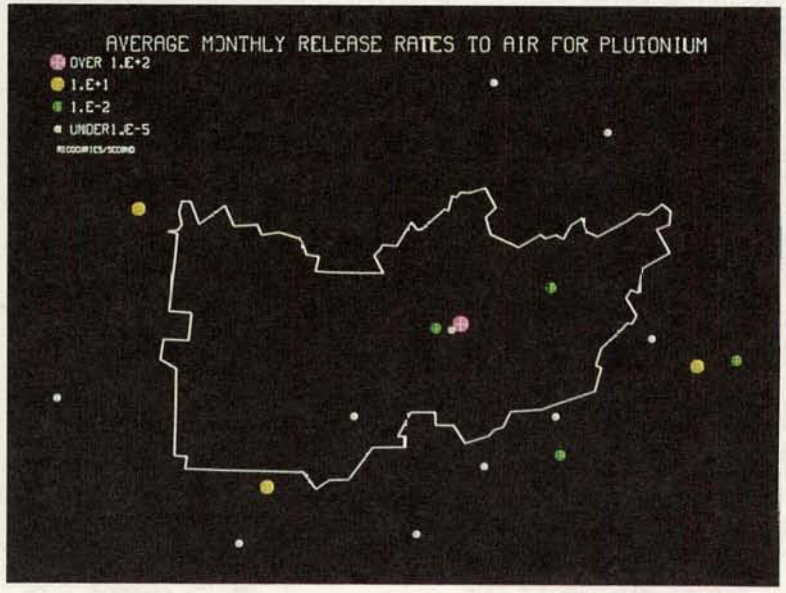


Figure V-6

Year 2000 Release Patterns for Selected Radionuclides (Monthly Average)

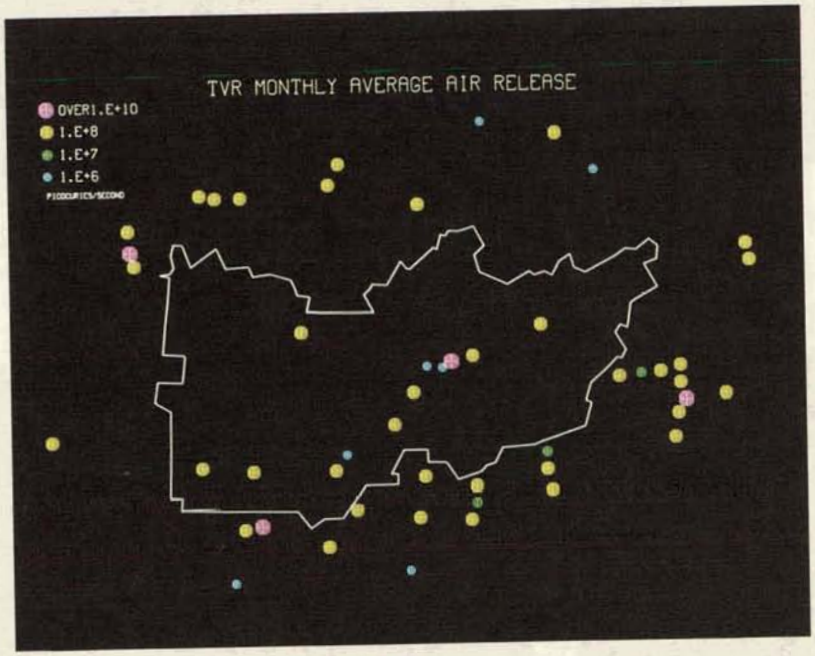


Figure V-7

Total Year 2000 Radionuclide Releases to Air (Monthly Average)

VI. AIR TRANSPORT OF RADIONUCLIDES

Radionuclide materials injected as plumes into the atmosphere from the regional nuclear facilities are diffused by turbulent motion encountered during transit from source to receptor. The plumes are also depleted by deposition mechanisms and radioactive decay. In this study the computer code elements which make these calculations are contained in the HERMES code group ARTRAN. The decrease in plume concentration due to atmospheric diffusion processes is estimated by the long term average (LTA) version of the Gaussian plume model. The plume losses during transit from source to receptor due to dry deposition are estimated by the methods developed by Chamberlain[23]. Precipitation induced deposition losses during transit are estimated by evaluation of a least squares fit equation developed from the data presented in Meteorology and Atomic Energy[24]. Incloud scavenging of radionuclide material is estimated by application of an exponential function of the form $\chi=\chi_o e^{-(\psi t)}$ where the incloud coefficient ψ is taken to be that developed by Byuntner and Gisina[25]. Radioactive decay and daughter production are calculated for the source-to-receptor transit.

The source to receptor geographic relationships are developed from straight lines joining the two points. The compass angle of this joining line is fitted into one of sixteen 22.5 degree sectors to determine the appropriate source meteorological conditions that are then presumed to apply throughout the entire travel. The meteorological data chosen by this method provide the percent frequency of occurrence of wind speed and atmospheric stability versus wind direction sector. The percent frequency of occurrence and mean rate of precipitation events are also provided as functions of wind speed, atmospheric stability and wind direction sector.

The resultant values calculated for the receptor centroid are presumed to apply as average conditions over the entire area of the county. This approach may, under some conditions, result in apparent anomalies in the calculations when portions of counties remote from the centroidal points are considered. Howevever, since the centroids selected as points of calculation represent approximately the centers of population for each county, the county-averaging techniques used provide reasonably accurate estimates of population dose on a county-to-county basis.

The diffusion equation used in this study is

$$\bar{\chi}_{LTA} = \left(\frac{2}{\pi}\right)^{\frac{1}{2}} \frac{0.01\ f\ \dot{Q}}{\sigma_z\ \bar{u}\ (2\pi x/n)} \exp -\frac{1}{2}\left(\frac{h^2}{\sigma_z^2}\right). \qquad 6\text{-}1$$

where $\bar{\chi}$ = the mean air concentration

f = the whole percent of the occurrence statistics

$\dot{Q}$ = the radionuclide release rate

σ_z = the standard deviation of the vertical distribution of the radionuclide

$\bar{u}$ = the mean wind speed

$(2\pi x/n)$ = the length of the crosswind chord at distance x

h = stack height

The source term $\dot{Q}$ shown in Equation 6-1 represents the rate of radionuclide release from each nuclear site. This source term is modified for in-transit losses by successive application of depletion factors. The first of these is the depletion attributable to dry deposition enroute by the expression

$$\left(\frac{\dot{Q}x}{\dot{Q}o}\right)_2 = \left(\frac{\dot{Q}x}{Qo}\right)_1^{\bar{u}_1 V_{d2}/\bar{u}_2 V_{d1}} \qquad 6\text{-}2$$

where V_d = dry deposition velocity

This is calculated in the code by evaluation of a table of initial values derived from the equation:

$$\frac{\dot{Q}x}{\dot{Q}o} = \left[\exp \int_o^x \frac{dx}{\sigma_z \exp\left(h^2/2\sigma_z^2\right)}\right]^{-\left(\frac{2}{\pi}\right)^{\frac{1}{2}} V_d/\bar{u}} \qquad 6\text{-}3$$

The initial values for $\bar{u}_1$ and V_{d1} are implicitly assumed to be 1 meter/second and 0.01 meter/second respectively.

Equation 6-3 was evaluated at a number of points from zero to 500 Km for each of seven atmospheric stability cases. A lower limit cutoff of $1. \times 10^{-7}$ was set to conserve computer core space. Linear interpolation between these points for a source to receptor distance gives an initial ratio in Equation 6-2 that may then be evaluated for a new set of values for V_{d2} and $\bar{u}_2$.

The second plume depletion factor applied is that appropriate for precipitation and incloud scavenging. A least-squares, best-fit expression

$$\Lambda = \exp\left((\ln R * C1) + C2\right) \qquad 6\text{-}4$$

where Λ = precipitation scavenging coefficient

R = precipitation rate

C_1, C_2 = parameters of fit

was developed for a curve that bisected the data in Figure 5.10 in Meteorology and Atomic Energy[24]. An exponential expression incorporating Λ, from Equation 6-4, and ψ, from Byuntner and Gisina[25], along with the appropriate travel time gives an estimate of the enroute plume losses due to precipitation and incloud scavenging. After the losses (or gains due to daughter production) attributable to radioactive decay are evaluated, the remainder is the effective source term for use in Equation 6-1.

The vertical stability term σ_z is evaluated for three distance classes and also for magnitude. First, if the travel distance is less than two kilometers this variable is evaluated by interpolation of a table of values representing the curves given in Meteorology and Atomic Energy. For downwind distances ($2 > X \geq 70$ Km) the term σ_z is approximated by the expression

$$\sigma_z = a\ x^{\ b}. \qquad 6\text{-}5$$

The values for a and b given by Van der Hoven[26], repeated in Table VI-1 below for ready reference, were used. The units for the variable x are kilometers.

TABLE VI-1

SIGMA-Z COMPUTATIONAL FACTORS

Stability	a	b
A	.45	2.1
B	.11	1.1
C	.061	.92
D	.033	.60
E	.023	.51
F	.015	.45

Beyond 70 Km, and whenever the calculated value of σ_z exceeds the mean mixing depth, σ_z is assigned a value equal to the mean mixing depth. The mean mixing depth values used in the code were extracted from the work by Holzworth [27]. This code procedure then assumes that whenever the value for σ_z is equal to the mixing depth the layer of air containing the plume is completely mixed vertically. Any additional plume dilution that would occur is a function of the crosswind dispersion factor only.

As a general rule the code is set up to evaluate the crosswind dispersion factor $2\pi x/n$ in a straightforward manner. However, in recognition of the character of the terrain in the eastern portion of the study region, a capability is included for forcing a restriction on the growth of the plume in the horizontal direction. Included in the ARTRAN input data bank are two parameters representing valley width and height of valley walls. These data are used to restrict the magnitude of $2\pi x/n$ whenever the plume would be completely contained within the valley. When the plume depth exceeds the height of the valley walls this restriction is removed. In order for this technique to yield good results the descriptive data bank would have to be very detailed. In this study, computer run time and storage limitations forced the use of a simple data bank. As a consequence the full impact of this restrictive factor may not have been realized.

The influence of a stack height on downwind air concentrations was evaluated by the exponential, $\exp\left(-\frac{1}{2}h^2/\sigma_z^2\right)$. It was assumed that, in the year 2000, the only nuclear facilities having an elevated release point will be reprocessing plants. An arbitrary value of 100 meters was assigned as the stack height for those plants. It is unlikely that the effect of an elevated release point will have any material influence on the base case results since the travel distances involved in this study are usually well beyond

the point where this factor is significant. However, in the calculation of near-site dose (Chapter IX) the effects of stack height were apparent.

Plume rise considerations which could also cause the effective release point to be elevated above the surface have been included in the code. The techniques used have been taken from Briggs[28]. F. A. Gifford, NOAA Air Turbulence and Diffusion Laboratory, has suggested that when a plume traverses a ridge the effective height of release 'h' must be reduced by some factor. The net effect of this would be particularly acute for receptors located near the top on the upwind face of the ridge. As a first estimate for h in this instance the expression

$$h = \left\{0.5\left(\left(H_s + \Delta H - H_t\right) / \left(H_s + \Delta H\right)\right) + 0.5\right\}\left\{H_s + \Delta H\right\} \qquad 6\text{-}6$$

where H_s = stack height

ΔH = thermal plume rise

H_t = height of terrain above stack

was included in the code.

The meteorological data base used in this study has been derived from the analysis of the synoptic records of 25 National Oceanic and Atmospheric Administration (NOAA) surface observation stations in and around the central study area. The synoptic records were reduced to percent frequency of occurrence statistics by a modified version of the STAR[29] program. This code evaluates the time of day, sky cover, and wind speed to deduce an estimate of the appropriate atmospheric stability classification. The modification to this code as used in the study produces these statistics as a function of six stability and six wind speed classes. In addition, percent frequency of occurrences and rate data are produced that depict precipitation events for the same classifications. The

standard NOAA precipitation ranking scheme is used to determine an appropriate rate to assign to each observational record. These data are than assigned to each source as representative of the mean monthly conditions to be expected in the year 2000. A simple assignment scheme whereby each meteorological site is matched to its nearest source(s) is, in general, used. A reanalysis has been made of this assignment scheme to preclude, insofar as possible, assigning a particular data bank completely out of geographic and terrain context. This is particularly important since it is readily apparent that the wind rose data for areas such as the eastern part of the study region present very strong evidence that the low-level air flow is predominately along the major orientation of the valleys.

The contributions to the receptor monthly air concentration from applicable nuclear facilities, under each of the wind speed and stability conditions included in the meteorological data, are accumulated as weighted mean values. The mathematical expression used for this is

$$\bar{\chi}_W = \frac{\sum w_i \chi_1}{\sum w_i} \qquad 6\text{-}7$$

This methodology provides a means of properly assessing the monthly mean air concentration. This tends to reduce the impact of extremely high values of $\bar{\chi}$ that might be encountered as a result of short term, very stable conditions while still providing a mechanism for accounting for these events.

The air transport code also calculates monthly surface concentrations of radionuclides deposited from the airborne plume at each of the 140 centroidal locations. These estimates are derived as surface concentrations over one square meter at the centroidal point. The calculated concentrations are assumed

to apply to the entire centroidal area. The methodology used considers the contributions of dry and precipitation-induced deposition. The deposited concentrations are calculated from

$$D = \sum_{1}^{F} \sum_{1}^{C} \sum_{1}^{S} \bar{\chi} \left(v_d T_d + \exp \left((\Lambda + \psi) T_\omega \right) \right) . \qquad 6\text{-}8$$

where D = the surface deposition concentration

F = summation factor for all pertinent nuclear facilities

C = summation factor for wind speed classes

S = summation factor for stability classes

T_d = time over which dry deposition occurs

v_d = dry deposition velocity, as used in Equation 6-2

Λ = precipitation scavening coefficient, from Equation 6-4

ψ = incloud wet deposition coefficient

T_ω = time over which wet deposition occurs

The long-term buildup of radionuclide material on the surface is estimated by summing the contributions from each source to the appropriate receptor over the time of operation of the facility. The assumption is made that the material deposited during the appropriate month of the study year is representative of the contribution of all years of prior operation. Depletion by radioactive decay is calculated.

The code processes the input data through a system of nested iteration loops. During the processing through these loops checks are made to ascertain the advisability of proceeding with the particular calculations. These checks include:

- travel distance greater than a preset maximum,
- nuclide injection rate equal to zero,
- percent frequency of occurrence fraction equal to zero,
- the product of nuclide injection rate and the percent frequency of occurrence fraction less than $1. \times 10^{-30}$,
- the travel time required, $T = X/t$, less than the available time for travel (seconds in a month times the percent frequency of occurrence fraction),
- the $\bar{\chi}$ value at the receptor location reduced to less than $1. \times 10^{-30}$ by upwind plume depletions.

Calculations for this study were made for a base case wherein every nuclide was considered for every source and receptor location. In addition, a group of sensitivity studies were made to demonstrate the code response to variations in the input data and different code operational characteristics. The base case and sensitivity study case results are discussed in detail elsewhere in this document. Base case concentrations calculated for four selected nuclides are shown in Figures VI-1 through VI-3. The four nuclides chosen for illustration are relatively significant contributors to dose to man or represent unique types of treatment within the air transport code.

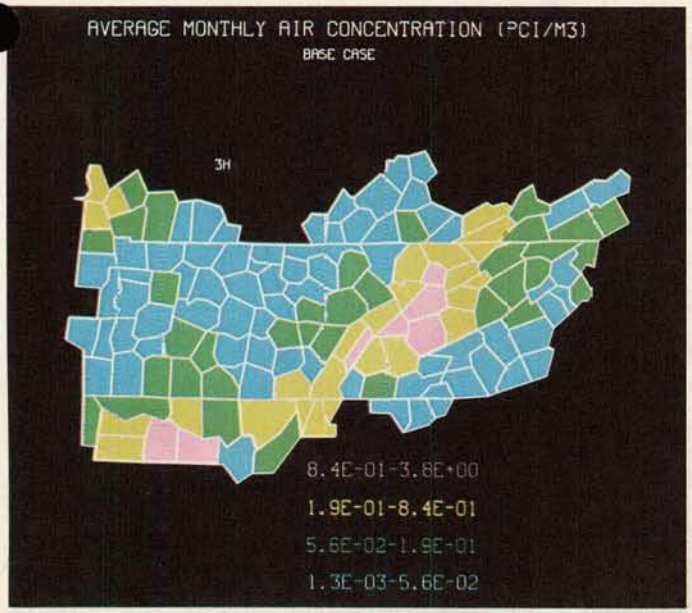
The radionuclides chosen for illustration are:

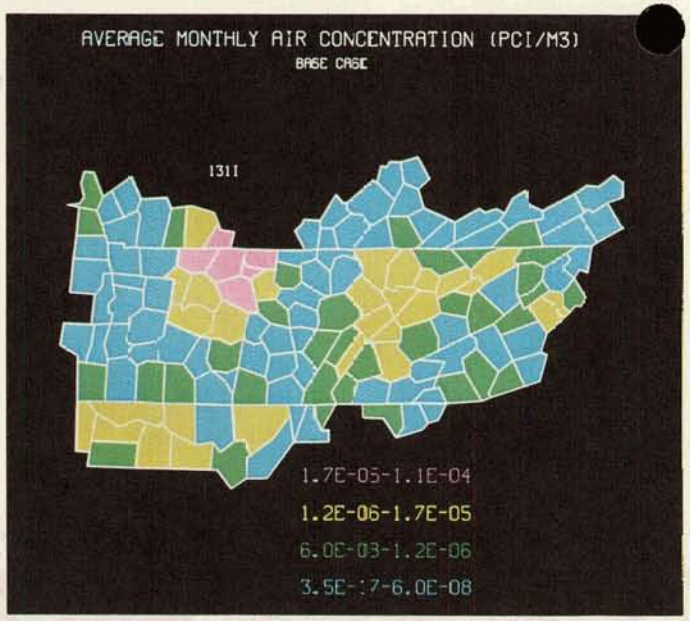
- ^{3}H, a gaseous radionuclide primarily in the form of substituted water (HTO) which is removed from the plume by precipitation processes. ^{3}H also has a high contribution to dose.
- ^{85}Kr, a gaseous radionuclide that has very little depletion from the plume. ^{85}Kr also is a moderate contributor to dose.

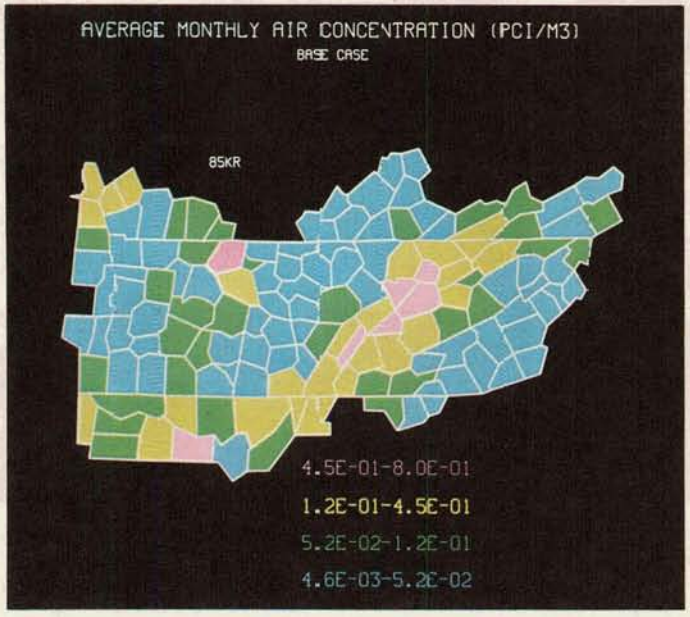
- ^{131}I, a particulate in the halogen group. The wet and dry deposition processes for these materials are different from the normal particulates. ^{131}I also has a marked influence on dose to thyroid.

- ^{238}Pu, a particulate for which plume dry depletion processes have different deposition velocity than for the halogen group. This radionuclide does not provide a high annual dose impact in the very small quantities being considered.

Figure VI-1 shows the annual average regional distribution of the air concentrations of the four radionuclides. Figure VI-2 shows the annual average regional distribution of the short term (monthly) surface depositions of three radionuclides (^{3}H, ^{131}I and ^{238}Pu). Again, ^{85}Kr is presumed to have zero surface deposition. Figure VI-3 shows the regional distribution of the long term accumulation of two radionuclides (^{131}I and ^{238}Pu). The long term buildup is calculated, from the monthly deposition, as a function of the operational life of the nuclear facility of concern. The resultant data are also summed and decayed over the study year.







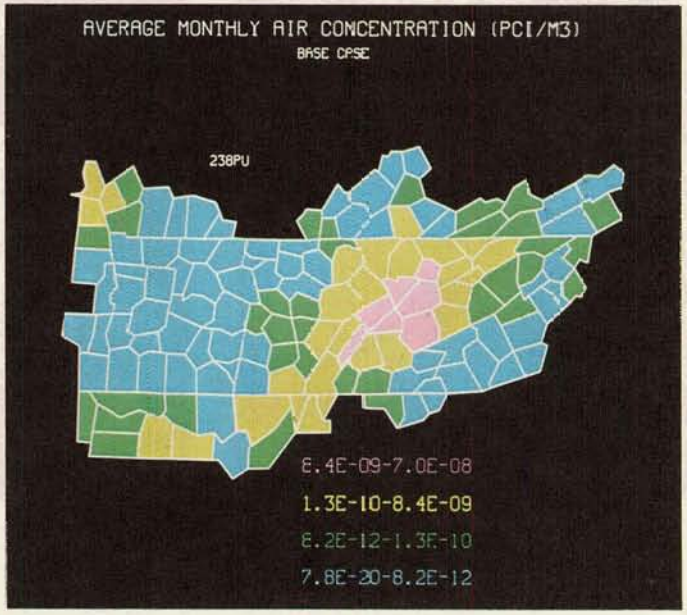


FIGURE VI-1

Annual-Average Air Concentrations for Selected Radionuclides (pCi/m^3)

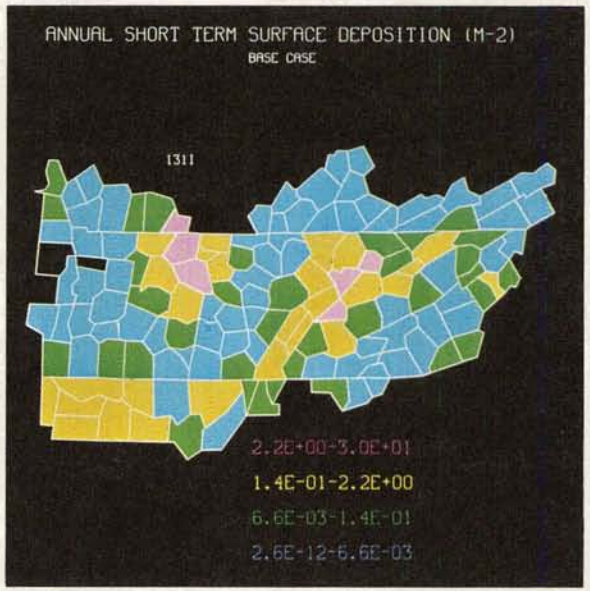
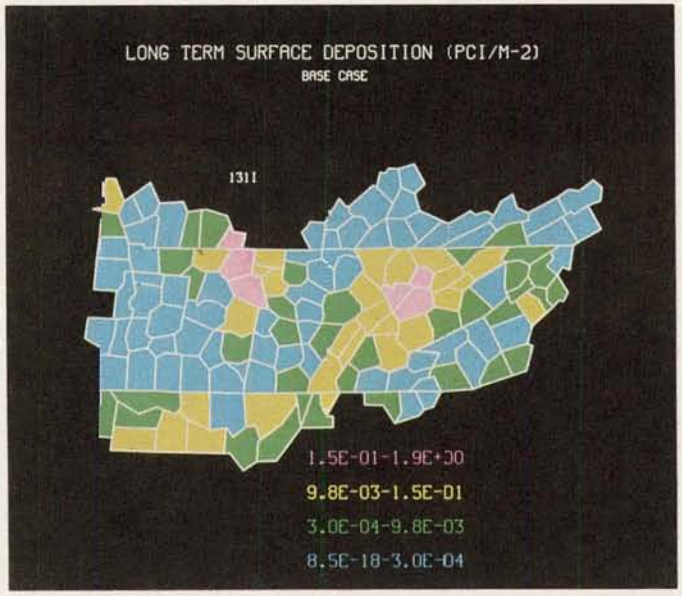


FIGURE VI-2

Short-Term Monthly Deposition of Selected Radionuclides (Averaged Over Year 2000), pCi/m^2



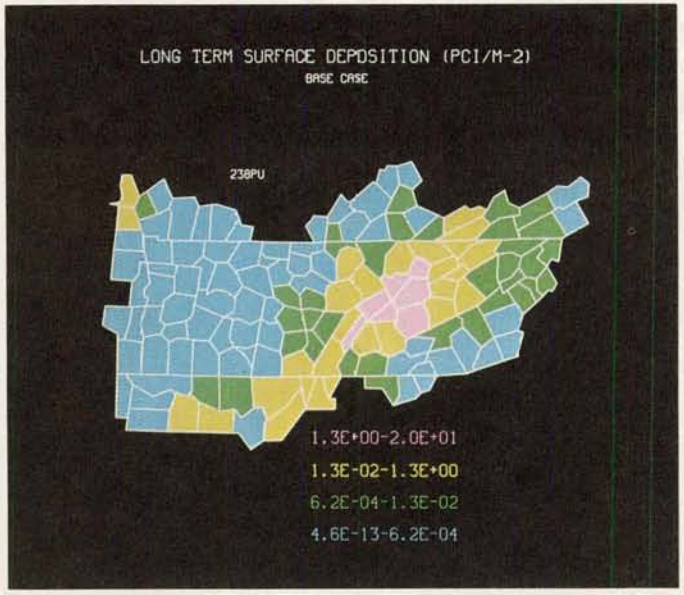


FIGURE VI-3

Long-Term Accumulated Deposition for Selected Radionuclides, pCi/m^2

VII. WATERBORNE TRANSPORT OF RADIONUCLIDES

The water transport subelement of the HERMES code, described in Reference (1) and called WTRAN, is designed to calculate concentrations in streams of both dissolved radionuclides and radionuclides absorbed on sediments. WTRAN uses the data output from the two predecessor HERMES subelements, ARTRAN and RADREL, to simulate the regional transport of radionuclide effluent that has been injected into the waterways of the study region. In addition, concentrations of dissolved radionuclides are calculated for lakes fed by local runoff and shallow ground water recharged locally.

WTRAN provides the calculational routines by which the river water transport of radionuclides is simulated for each stream in the system and concentrations associated with suspended and deposited sediment and dissolved ions are calculated. For each successive river reach downstream nuclides are, where appropriate, added to the stream, i.e., if a nuclear facility outfall, overland runoff point or tributary is encountered, nuclides may be added. If the sedimentation rate is changing, a change in the nuclide load in suspension and deposition or scour of nuclide-bearing sediments is calculated; and if a point of interest (for example, a municipal water intake) is encountered, requested information is stored for later use or printed.

The Tennessee and Cumberland river basins are shown in Figure VII-1. A description of these basins and of their hydrologic features is given in Reference (4).

For computational purposes, the rivers are subdivided into reaches (a "reach" is a portion of a watercourse of arbitrary length, usually a few miles, in which the river characteristics are relatively uniform) to permit an orderly consideration of the entire river system.

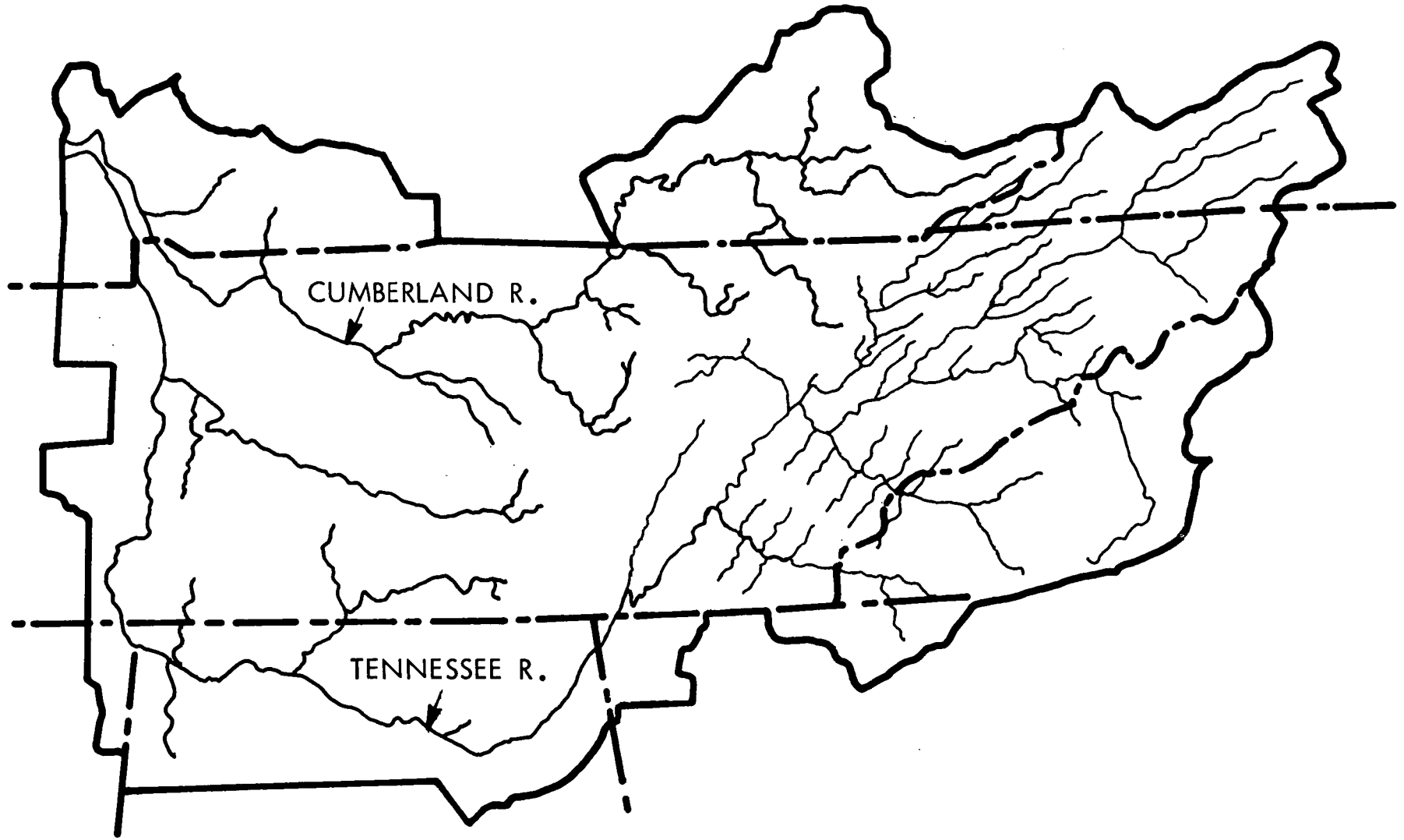


FIGURE VII-1

Tennessee-Cumberland River System

Detailed dimensions of river cross-sections have been modified for computer use by transformation into equivalent trapezoidal sections within which the surfac- and cross-sectional areas are conserved. Historical streamflow patterns, modified by reservoir regulation, provide the basic hydrologic data for the study.[30-34]

The computations are made for each reach from upstream to downstream with the suspended sediment transport algorithm:

$$C_j S_j Q_j = \left[C_o S_o Q_o \exp^{-\lambda_r t} + \sum_{1}^{n} C_i S_i Q_i + \Delta \right] \qquad 7\text{-}1$$

where:

C = radionuclide concentration adsorbed on suspended sediment

S = sediment concentration

Q = streamflow

Δ = addition or depletion due to changes in sediment load in reach

j = new value

o = old value

i = input

n = number of input values

λ_r = decay constant

t = time of travel

Sediment concentrations are obtained from field data that relate sediment load to streamflow:

$$S = a\, Q^b \quad . \qquad 7\text{-}2$$

where

a, b = empirically derived curve fitting parameters representing the drainage area and sediment transport.

Field measurement stations are not normally located at a point where the radionuclide concentration data is desired for use in dose computations. In Equation 7-2 the coeffient "a" is a function of the drainage area involved and requires the following transformation to transfer from the measuring station to the required point on the river.

$$\hat{a} = a \left[\frac{A}{A \pm \Delta A} \right]^{b} \qquad 7\text{-}3$$

where

$\hat{a}$ = coefficient "a" transferred to the new drainage area

A = drainage area at the measuring station

$A \pm \Delta A$ = drainage area for the required river point

The network of multipurpose dams on the TVR river systems provide electric power and most of the dams serve to regulate streamflow by reducing flooding and maintaining higher base flows. Stream flow regulation requires further modification of the coefficient $\hat{a}$ as follows:

$$\hat{\hat{a}} = \hat{a} \left[\frac{A_L}{A \pm \Delta A} + \frac{A_1}{A \pm \Delta A} (1 - TE_1) + \frac{A_2}{A \pm \Delta A} (1 - TE_2) \ldots \right.$$
$$\left. \ldots + \frac{A_n}{A \pm \Delta A} (1 - TE_n) \right] \qquad 7\text{-}4$$

where

$\hat{\hat{a}}$ = translated $\hat{a}$ adjusted for regulation

A_L = local area unaffected by regulation

A_n = drainage area at dam site

TE_n = sediment trap efficiency of the reservoir

Suspended sediment data for streams representing the conditions found in each of the physiographic divisions, Figure VII-2, are used to determine the coefficients in Equation 7.2. The value of the coefficient "a" could then be determined for the desired locations through the application of either Equation 7-3 or 7-4.

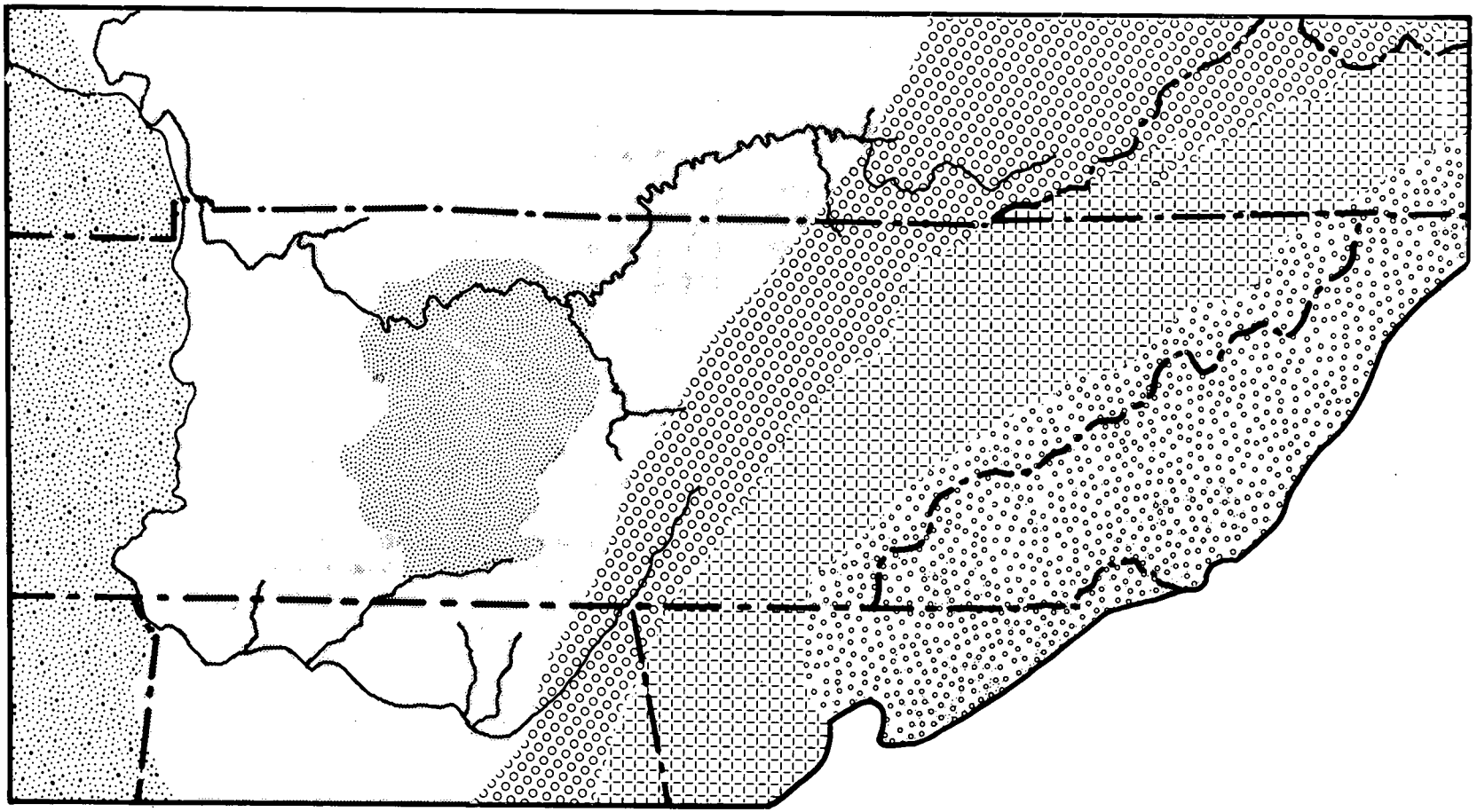
Deposition or scour in a given reach, of sediments with sorbed nuclides, is applied uniformly unless input data specify a special distribution. For reservoirs in the study area, provision is made to permit the patterns of deposition to follow historical data. In the case of the Tennessee River where regulation is continuous, the value for "a" in Equation 7-2 for each reservoir is based upon historical deposition rates and the assumption that sediment transport is proportional to flow (i.e., b = 1.0).

The delta (Δ) in Equation 7-1 is associated with deposition or scour of sediments and adsorbed radionuclides within a given reach:

$$\Delta = C_o S_j Q_j + C_i S_j Q_j - C_o S_o Q_o - C_o S_i Q_i - C_i S_o Q_o - C_i S_i Q_i \qquad 7\text{-}5$$

The dissolved radionuclide burden for the river is obtained by use of a "distribution coefficient" (K_d) that represents the characteristic of the particular reach and radionuclide being considered. Values for K_d are obtained by analysis of bed sediment response to introduction of selected radionuclides. It is assumed that the same characteristics apply to other chemically similar materials.

The distribution coefficient, K_d, is the ratio of the fraction of ions sorbed per unit weight of sediments to the fraction of ions remaining in solution per unit volume of solution. For this study K_d's were determined using a sediment sample collected from a representative river in five of the six major



SYMBOLS:

- APPALACHIAN MOUNTAIN
- APPALACHIAN VALLEY
- CUMBERLAND PLATEAU
- HIGHLAND RIM
- CENTRAL BASIN
- MISSISSIPPI EMBAYMENT

FIGURE VII-2

Physiographic Divisions of the Tennesse Valley Region
Used in K_d Factor Assignment

physiographic divisions of the area (the Central Basin and Highland Rim were assumed to be similar in sediment characteristics). The appropriate K_d table, associated with a given physiographic province, is applied in the calculation of suspended sediment concentrations for a river or sector of a river, as required. Values of K_d are given in Appendix G.

If $K_d \neq 0$, the value for the radionuclide solute concentration in a reach is obtained from

$$C_w = \frac{C_j}{K_d} \quad . \tag{7-6}$$

where

C_w = water concentration of nuclide.

The data files that prescribe the radionuclide input to a stream in association with overland runoff are obtained by solution of

$$C_w = \frac{\sum_{1}^{a} F_M A}{Q(K_d S+1)} \quad . \tag{7-7}$$

where

F_M = monthly average surface deposition of radionuclides from the atmosphere per unit area

A = centroidal area

a = pertinent centroids in drainage area

For the radionuclide tritium, where both C_j and K_d are zero, a modified form of Equation 7-1 is utilized

$$C_{wj}Q_j = \left[C_{wo}Q_o \; e^{-\lambda_r t} + \sum_{1}^{n} C_{wi}Q_1 \right] \tag{7-8}$$

Equation 7-8 differs from Equation 7-1 in that streamflow (Q) is the means of transport in place of sediment flow ($SQ = aQ^{b+1}$) and no deposition-scour term (Δ) is included.

For the Tennessee and Cumberland River Basins which extend from eastern Kentucky, North Carolina, and Virginia to the Ohio River near Paducah, Kentucky, concentrations were calculated in the principal waterways and major tributaries. In cases where a tributary stream was large enough to be considered as a sub-basin, a concentration was calculated at its mouth for each month and stored with its associated flow for input to the trunk stream. The calculations were made for both river basin systems, from upstream to downstream, and were repeated for each nuclide.

The composite of the above calculations were then correlated with the descriptive data for the river drinking water source and recreation points to provide output files of dissolved and suspended radionuclide concentrations and river bed radionuclide concentrations.

Groundwater and local surface water concentrations are calculated with an input function similar to Equation 7-7.

$$C_w = \frac{F}{R(K_d\gamma+1)} \quad . \qquad 7\text{-}9$$

where

R = runoff

γ = specific weight of soil

Typical calculated concentrations of selected radionuclides in surface and ground waters, rivers, and river sediments are summarized in Figures VII-3 to VII-6 for the year 2000.

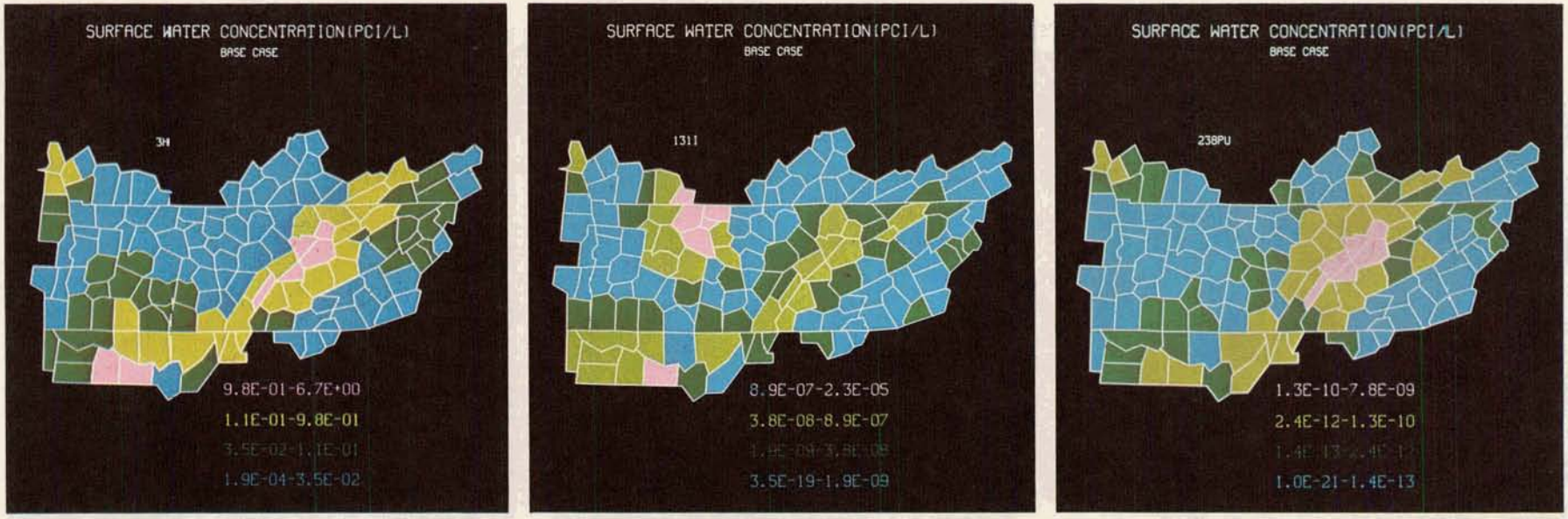


FIGURE VII-3

Annual Average Concentrations of Dissolved Radionuclides in Surface Waters

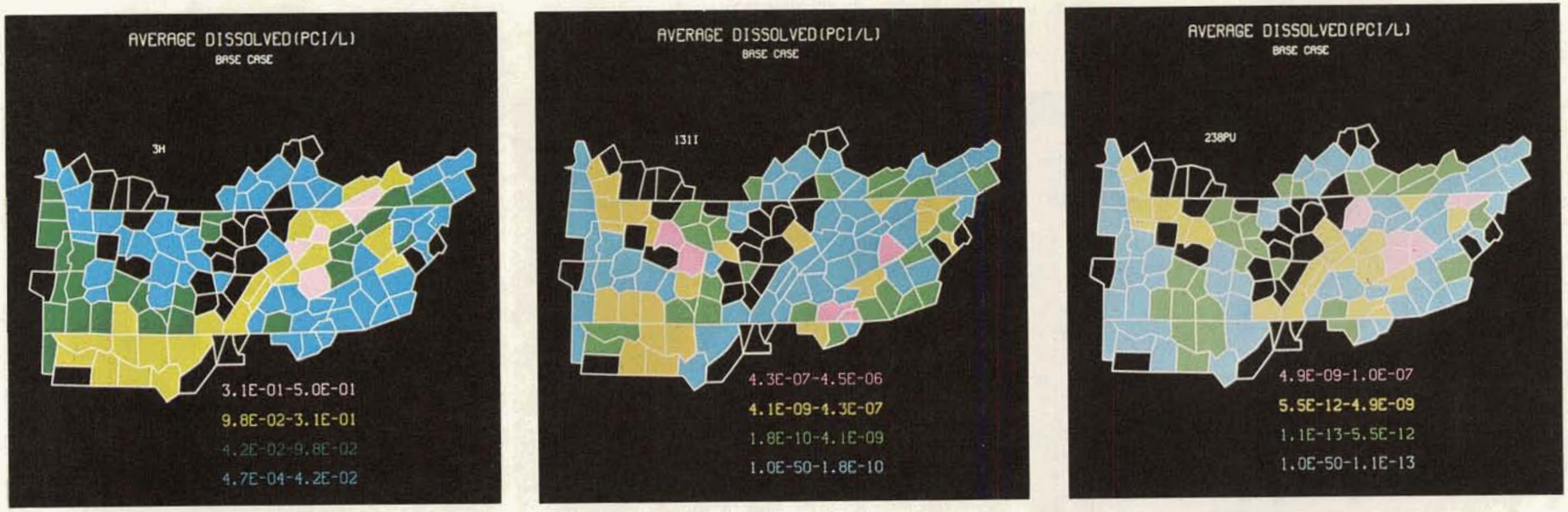
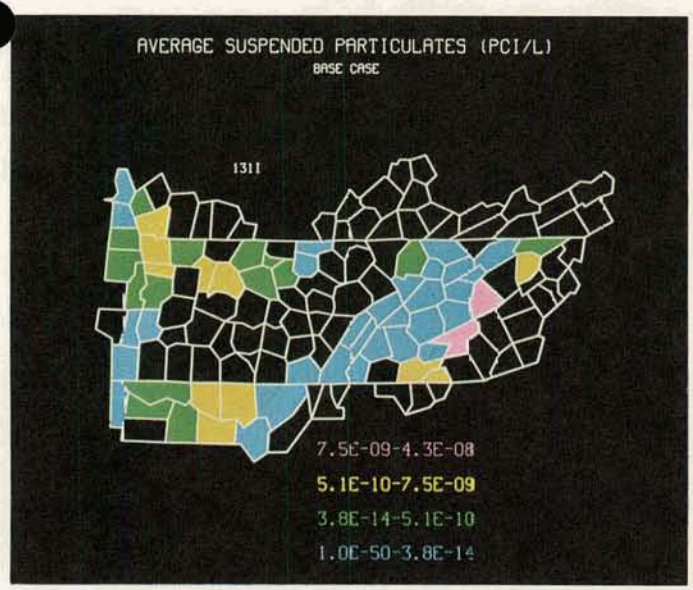


FIGURE VII-4

Annual Average Concentrations of Dissolved Radionuclides in River Systems



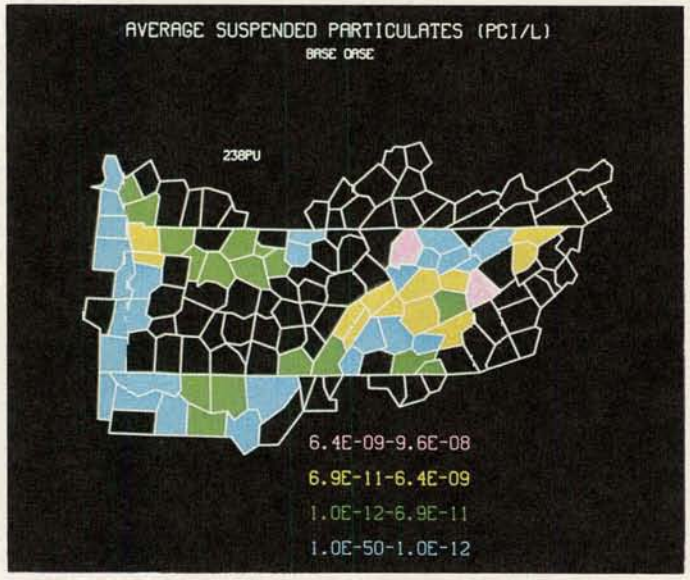
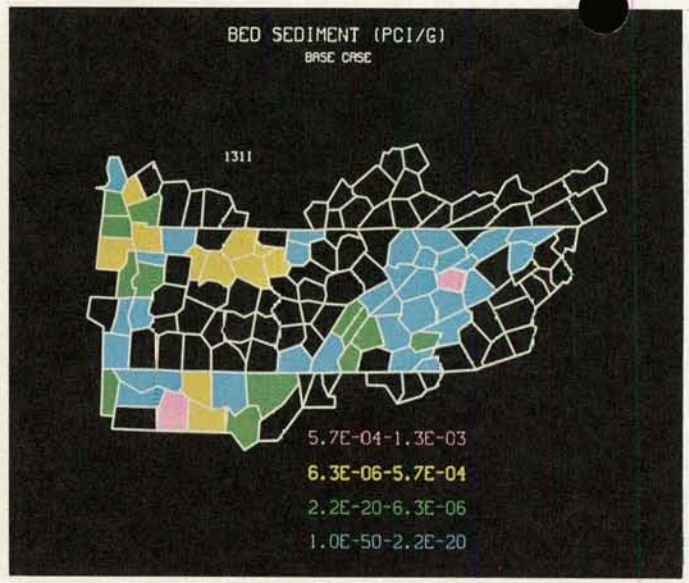


FIGURE VII-5

Annual Concentrations
of Radionuclides in Suspended
Sediments



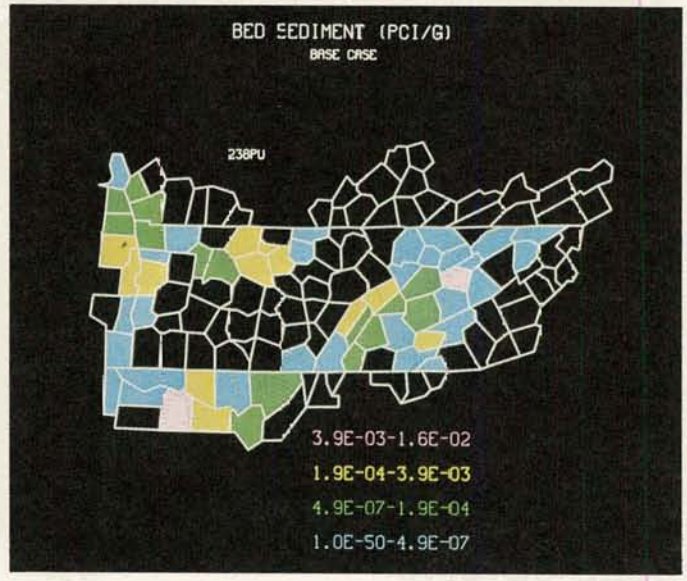


FIGURE VII-6

Annual Average Concentration
of Radionuclides in Bed
Sediments

VIII. POPULATION DOSE PATHWAYS AND CALCULATIONS

Evaluations of population dose in the Tennessee Valley Region were performed using the DOSE code of the HERMES model. This code, which was initially developed and used in a study of the Upper Mississippi River Basin (UMRB)[2], was modified and improved substantially for use in the TVR. The improved code provides a more definitive relationship between environmental concentrations of radionuclides and the resultant dose to man.

Dose to the population region was calculated for each county within the TVR, and except as otherwise noted was calculated as the average dose in each county for each population age group considered. The calculations evaluated the contribution to dose of each nuclide considered, through the various pathways leading to dose, for both external and internal exposure to the whole body and to selected organs (skin, lungs, GI tract, bone, thyroid, and liver). Dose to the gonads was not calculated. However, gonad dose very closely approximates total body dose, and may be inferred from total body dose as recommended by the Federal Radiation Council.[35]

Population dose in the region was calculated, and is given in subsequent sections of this report, in the following categories:

1. The study year dose, incurred during the year 2000 from ingestion of and exposure to radionuclides during that year. This dose was calculated as a summation of 12 monthly exposure values, considering the accumulation of body burden over the year. This dose was calculated, for each county, as the average dose for an individual in each age group, and is expressed in millirems. The integrated population dose for total body, in terms of man-rems, was also calculated.

2. The study year dose commitment, expressed as the dose incurred over the following 50 years (2001-2050) from radionuclides ingested during the year 2000. In these calculations, no further ingestion of nuclides nor exposure to external radiation was assumed to occur after the year 2000. The dose commitment calculations paralleled those for study year dose, and are similarly expressed as individual dose commitment (millirem) and integrated population dose commitments (man-rem).

3. Incremental dose in the year 2000, and incremental dose commitment in following years, which result from ingestion of radionuclides in prior years. These "prior body burden" doses were calculated separately as a sensitivity study; only dose to adults was calculated.

4. Incremental dose received in the year 2000 by those segments of the population living nearer to nuclear sites than the centroidal points at which study year dose was calculated in the county containing the site and, when applicable, in adjacent counties. This calculation, also done as a sensitivity study using the KRONIC[36] computer code, takes into account the limited diffusion of the effluent plume at locations near a site. These calculations were performed only for skin dose and total body dose; recipients were assumed to be adults.

Four population age groups were considered in the calculations. These are:

- Infant (ages 0 to 1) taken as 6 months of age
- Child (ages 1 - 11) taken as 4 years of age
- Teenager (ages 12 - 18) taken as 14 years of age
- Adult (18 years and older)

These four groups exhibit considerable differences in body size, metabolism, activities, and diet which could potentially create significant differences in radiation dose received. In each county, the study year dose and dose commitment were calculated and analyzed for each age group in turn. In these calculations, consideration was taken of the dominant population category (urban, rural-nonfarm, or rural-farm) in each county. Families in those different categories exhibit statistical differences in size and composition of family groups, diets, food sources and preparation means, and recreational patterns which could conceivably effect the radiation dose received.

The integrated population dose, expressed herein in terms of the man-rem, is expressed as the product, summed over all segments of the population, of the average dose received by each segment and the number of individuals in that segment. In this study, the integrated dose was calculated for each age group, in each county of the region, and was summed over all four groups and over all counties.

The man-rem concept is useful in evaluation and resolution of dose distribution over large segments of a population, and is coming into increasing use as a criterion for evaluation of risk to a population from ionizing radiation from various nuclear and non-nuclear sources. Its use in risk evaluation is recommended, although with reservations, by the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiations.[37]

Dose calculations in the study area use as a starting point the calculated patterns of radionuclide concentrations in the air, in the water, and on the ground throughout the study regions, as provided by the air and water transport calculations.

The air and water concentrations contribute directly to human dose through such mechanisms as submersion in air, inhalation of air, consumption of water, and immersion in water (swimming, water skiing, etc). Concentrations in exposed river bottom sediment contribute to external exposure from fishing, hunting, picnicking, etc., along shorelines. Deposition of radionuclides on the ground from air and from irrigation water applied to crops add to external exposure received during outdoor activities.

Ground-deposited radionuclides also enter into the food pathways, involving uptake and transfer in animal feed crops and in animal products and food crops consumed by humans. Appropriate subroutines in the DOSE code calculate the transfer of radionuclides through the food pathways to man, culminating in calculated concentrations and retention periods of the radionuclides in human body tissues. Dose and dose commitment are then calculated based on human intake.

A listing of the exposure pathways leading to human dose which were considered in this study is given in Table VIII-1. Foods included in the ingestion pathways are indicated in Table VIII-2.

FOOD CONCENTRATIONS

The entry of radionuclides into various food chains depends on their concentrations in air, water, and soil; both current rates of surface deposition and long-term accumulation of radionuclides in soil must be taken into account.

Utilizing the concentration patterns provided by the air and water transport models, the Food Pathways Model (FPM) incorporated in the DOSE code calculates the uptake of radionuclides by plants and animals, translocation to

edible parts of the organism, transfer along the food chain (via feed or forage supplied to animals), and the resultant nuclide concentrations in foods at the time of harvest or production. Losses of radionuclides which

TABLE VIII-1

EXPOSURE PATHWAYS CONSIDERED
IN TENNESSEE VALLEY REGION STUDY

EXTERNAL PATHWAYS	INTERNAL PATHWAYS
Air Submersion	Air Inhalation
Water Immersion	Tritium Transporation
- Swimming	Drinking Water
- Boating, Water Skiing	Ingestion of Foods
Exposure to Shoreline Sediments	
- Bank Fishing	
- Waterfowl Hunting	
Exposure to Soil	
- Upland Hunting	
- Other Outdoor Activities	

TABLE VIII-2

FOODS CONSIDERED IN STUDY

TERRESTRIAL FOODS		AQUATIC FOODS
Fresh Berries	Fresh O.A.G. Vegetables[a]	*Fresh Ocean Fish
Processed Berries	Processed O.A.G. Vegetables	*Processed Ocean Fish
Fresh Tree Fruit	Grain & Grain Products	*Shellfish
Processed Tree Fuit	*Rice & Rice Products	Sports Fish
Fresh Melons	Wheat & Wheat Products	Waterfowl
*Fresh Tropical Fruit	Fresh Milk	†Secondary Water
*Processed Tropical Fruit	Processed Milk Products	
*Fresh Citrus Fruit	Butter	
*Processed Citrus Fruit	Eggs	
Fresh Potatoes	Beef and Lamb	
Processed Potatoes	Fresh Pork	
Fresh Root Vegetables	Processed Pork	
*Processed Root Vegetables	Poultry	
Fresh Leafy Vegetables	*Game Birds	
Processed Leafy Vegetables		

(a) Other Above Ground Vegetables

* Foods marked (*) are not produced or processed within the study area, or are produced in only negligible amounts. These foods were assumed to be imported from outside the region. In base calculations they were assumed to be free of radionuclides, although in some sensitivity calculations a specified burden was assumed.

† "Secondary" water intake was combined with tap water intake, as described in the text.

occur during commercial or home processing are estimated, as are the losses by radioactive decay during the time between production and consumption. The various mechanisms contributing to uptake, transfer, and loss of radionuclides are considered individually for each nuclide and each food type during the dose calculations.

The calculation of radionuclide concentrations in foods produced throughout the study region are, of course, subject to several limitations in accuracy. Potential changes in diets and in agricultural practices between now and the year 2000 can at best be only vaguely projected. Hence, the code modeled current practices and dietary information. While this procedure may result in projections which are not fully representative of conditions as they may actually exist in the year 2000, it introduces a minimum of unknowns into the calculations.

Another, more severe, limitation is the paucity of information on the behavior of radionuclides in the soil and in living organisms. Information currently available stems primarily from research on a few selected radionuclides. Frequently, these data have been applied by analogy to chemically similar elements, or from stable to radioactive species, to obtain concentration factors. In this process there is no assurance that chemical and physical differences among "like" elements, or among stable and radioactive nuclides of the same element, are satisfactorily accounted for.

The effective concentration factors for radionuclides in various farm products can also change with differences in soil types, climatic conditions, and farming practices. Although significant differences in these conditions occur over the Tennessee Valley Region, for lack of more definitive data it was necessary to apply a single set of concentration factors over the entire region.

AVERAGE DIETS IN TVR

Average patterns of food consumption for individuals in the TVR were calculated for each of the three population categories considered -- Urban, Rural non-farm, and Rural-farm. These data, correlated by ORNL, were based primarily upon reports published by the U. S. Department of Agriculture.[38,39] However, since data on waterfowl consumption in the TVR were not available, per capita consumption in this region was assumed to be equal to that in the Upper Mississippi River Basin.

Data on food consumption in the TVR are described in Chapter III and in Reference.[4]

Variation in Diet by Age Group

Comparative rates of food intake by individuals in different age groups in the Southern United States were reported by the Agricultural Research Service of the U. S. Department of Agriculture.[38] These data are averaged over the entire Southern portion of the country and over all income levels. In this study it was necessary, for lack of better definition, to apply the data uniformly to the urban, rural non-farm, and rural-farm population categories considered in the TVR. However, since differences in average per capita intake among these categories have already been taken into account, the assumption of uniform variation by age group will not lead to serious errors in intake assumptions.

The relative rates of daily food intake assumed for different age groups are indicated in Table VIII-3. The food groupings in this table differ somewhat from the food consumption categories used in this study. However, the table contains a cross-reference listing of TVR consumption categories as described in Chapter III of this report.

TABLE VIII-3

RELATIVE DIFFERENCES IN FOOD INTAKE BY AGE GROUPS[40]

Southern U. S., all income levels; normalized to adult intake of 1.0.

Food Items	TVR Consumption Categories[a]	Relative Individual Intake			
		Infant	Child	Teen	Adult
Fruit (local)	1-6	1.37	1.20	1.39	1.00
Fruit, Citrus	7-9	0.34	0.91	0.99	1.00
Potatoes	10,11	0.13	0.73	1.06	1.00
Root Vegetables	12,13	0.92	0.69	0.77	1.00
Green Leafy Vegetables	14,15	0.49	0.59	0.85	1.00
Other Above Ground Vegetables	16,17	0.34	0.69	1.06	1.00
Cereals	18,20	0.21	0.81	1.09	1.00
Milk	21	3.45	2.12	1.70	1.00
Milk Products	22	0.08	0.90	1.05	1.00
Butter	23	0.08	0.67	1.08	1.00
Beef and Lamb	25	0.12	0.52	0.92	1.00
Pork	26,27	0.05	0.58	0.97	1.00
Poultry	28,29,34	0.15	0.66	0.79	1.00
Fish and Seafood	30-33	0.07	0.51	0.80	1.00

(a) TVR consumption categories are defined in Chapter III.

In the UMRB study, directly ingested tap water was combined with "secondary" water intake (water included in frozen juices, prepared soups from canned or dried stock, tea, coffee, etc.) to provide a single rate of water intake for each age group. Data available in the literature,[41-43] which were applied both to the UMRB study and to the TVR, considered combined tap water intake in this manner. Information published by the U. S. Department of Agriculture[38,39] on the consumption of "secondary" water indicates that for rural residents "secondary" water may account for up to half the total combined tap water consumption, and for urban dwellers it may account for up to two-thirds of this total.

Rates of combined tap water intake used in calculations for this study are shown in Table VIII-4. These quantities are slightly less than the 1.2 liters per day defined as the tap water intake for the Standard Man by ICRP[44], but are based on surveys directed specifically at U. S. populations.

TABLE VIII-4

AVERAGE INDIVIDUAL COMBINED TAP WATER INTAKE[a] BY AGE GROUP

Age Group	Average Individual Intake	
	Liters/day	Kg/month
Infant	0.7	21.4
Child	0.7	21.4
Teen	0.7	21.4
Adult	1.0	30.5

(a) Includes both directly ingested tap water and water used in prepared foods, juices, coffee, tea, etc.

Consumption of Game Birds and Fish

Food types such as waterfowl, upland game birds, and fresh-water fish constitute only a small portion of the average individual's diet. However, these types consist largely of undomesticated game species; because of their habitat and their often unique diets, these species can be important contributors to human radionuclide uptake. Furthermore, the harvest of these animals can involve recreational activities which potentially contribute to dose through external exposure.

Consumption data for game birds and sports fish, obtained mainly from the previously reference Agricultural Research Service reports, were modified by ORNL to apply to game consumption in the study region. Comparable data for waterfowl were not available; hence, as previously noted, UMRB data were applied.

Since the consumption of fresh-water fish represents the primary aquatic-food pathway in the TVR, specific reviews were made of radionuclide concentration factors applicable to these fish, to adjust them to values representative of regional waters.

INHALATION RATES

Inhalation rates assumed for this study were the same as the rates used for average individuals in the UMRB study. Adult inhalation rate was taken as 20 ^{m3}/day, the value recommended by ICRP[44] for the Standard Man. Inhalation rates for other age groups were obtained from averaging of male and female data for various ages as derived by Rohwer and Kaye.[45] This provided rates of 13.5 ^{m3}/day for the teen (14-year old) and of 7 ^{m3}/day for the child (4-year old). For lack of specific data, the inhalation rate for the 6-month-old infant was assumed equal to that of the child; the smaller lung capacity was assumed to be compensated for by a more rapid respiratory rate.

RECREATIONAL ACTIVITIES

Patterns of recreational activities in the TVR were compiled by the Tennessee Valley Authority Division of Forestry, Fisheries, and Wildlife. Data were assimilated for each of five major categories of activities:

- Swimming
- Boating and water skiing (including fishing from boats)
- Fishing from banks
- Waterfowl hunting
- Upland game bird hunting

Information on these activities was obtained largely from TVA studies of recreational uses of the region's waterways, augmented by information from other government agencies and by correlation with other studies performed in other regions of the U.S.

For each recreational category, estimates were made for each county of the man-hours spent in recreational activities each month of the year. These values were expressed as the time spent each month by the average individual (infants excluded) in the various recreational pursuits.

Correlations were made of preferred areas of recreation for the population of each county. In the case of upland game bird hunting, data to permit these correlations were not available. All upland game bird hunting was assumed to occur in the hunter's county of residence.

Data on recreational activities in the study region are described in Reference (4).

RADIOLOGICAL DOSE CALCULATIONS

Radiological dose calculations in the TVR utilized a series of dose factors which related external exposure to or internal assimilation of radionuclides to the resultant dose. For internal assimilation of radionuclides, these dose factors were expressed in terms of dose received per unit quantity of radionuclide ingested (mrem/μCi) For external exposure, the dose factors related

the rate of dose accumulation (mrem/yr) to unit concentrations in the air, in water, and on the ground. Dose factors were calculated for total body dose and for dose to each of the six specific organs considered in the study and for each combination of population age group, radionuclide, and pathway. For each combination, separate dose factors were derived for contributions to annual dose and to 50-year dose commitment.

Utilizing these dose factors, contributions to dose were made for each combination by multiplying together the appropriate dose factor, the corresponding radionuclide concentration, and the hours of exposure or rates of ingestion for the particular pathway considered. Contributions to annual dose and to 50-year dose commitment were calculated on a monthly basis and summed over the year to obtain the total contribution.

EXTERNAL EXPOSURE

The dose factors for external exposure were derived assuming that the media involved (air, water, or ground surfaces) were large enough in extent to be considered infinite relative to the effective range of emitted radiation. Under these conditions the energy emitted and that absorbed by each unit volume of the media are equivalent. This greatly simplifies the calculations required.

All that is required is to convert the disintegration energy (MeV per disintegration) into rem, to correct for the differences in energy absorption between tissue and the surrounding medium, and to correct for the physical geometry involved in each specific situation.

AIR SUBMERSION

The dose from submersion in air is accumulated by the skin and/or by the total body, depending on the penetrating power of the radiation emitted by airborne radionuclides. Dose to the total body and to internal organs was calculated at a depth of 5 cm in tissue. Beta radiation from airborne radionuclides was not considered to irradiate internal organs; only exceptionally energetic

betas could effectively penetrate to this depth. Dose to the skin was calculated at the basal layer, under an epidermal layer with an effective density of 7 mg/cm^2. Both beta and gamma radiation contribute to this dose.

A 2π geometry was used for a person standing on the ground surrounded by a very large (half-infinite) hemisphere of contaminated gas for both beta and gamma radiation. This geometry follows from the half-infinite volume for gamma. For the beta with shorter ranges in air, the physical arrangement approaches the infinite volume (4π geometry), but since the beta is of limited penetrating power, it will irradiate the skin from only one side, not two sides as with penetrating gamma radiation. The equation for calculating the dose factor for submersion is given below.

$$(D.F.)_{submersion} = 8.87 \times 10^{-7}(\overline{E}_{\beta}+\overline{E}_{\gamma}) \qquad (1)$$

where

D.F. - the dose factor (mrem/hr per pCi/m^3)

E_{β} - the effective beta energy per disintegration (MeV) at the appropriate depth in tissue.

E_{γ} - the effective gamma energy per disintegration (MeV) at the appropriate depth in tissue.

The constant takes into consideration the density of air as well as the conversion from MeV to rem.

In application of this equation, and of the ones for exposure from water immersion and standing on contaminated ground, the dose factors are independent of body size. This follows from an assumption that the presence of the person does not significantly perturb the radiation field.

CONTAMINATED GROUND

Radioactive materials deposited from the air or from irrigation water onto the ground represent a large, nearly uniform, thin sheet of contamination. Subsequent to their deposition, these materials tend to migrate down into the soil, aided by leaching or by physical mixing. To approximate this situation in the calculations, the year 2000 deposition was assumed to be uniformly

distributed on the surface. Materials remaining from deposition in prior years were assumed to be uniformly mixed in the upper five centimeters of soil. In either case dose was calculated at an effective height above the ground surface of one meter for adults and teen-age persons, and of one foot (30.48 cm) for children and infants.

Similar considerations were applied for dose from sediments along the bank of a river. Although the water transport program specifies both annual deposition and the thickness of sediment involved, migration of the nuclides subsequent to deposition was assumed to result in patterns of concentration similar to those assumed for dry land.

For the radionuclides deposited during the year 2000, dose was calculated as from a large, thin, uniform sheet of contamination. Dose factors for this situation have been calculated previously for most important fission products,[46] and the same situation was assumed in the calculation of dose factors from contaminated ground in the UMRB study.[2] As in that study, a factor of 0.5 was introduced to account for roughness of the ground surface.[47,48] The contributions from both gamma and beta radiation were included in calculations of dose from ground surface.

The equation used for dose factors from surface contamination is:

(A) for gamma radiation:

$$\gamma \text{ D.F.}_{(\text{ground, surface})} = (0.5)\ (0.869) \sum_{i=1}^{n} \text{AiRiPi} \qquad (2)$$

where

γ D.F. = the dose factor from gamma radiation, mrem/hr per pCi/m^2

Ai = fractional abundance of photon (i) in the radionuclide under consideration[49]

Ri = exposure rate at one meter (or 30.48 cm) above (mR/hr) an infinite smooth plane uniformly contaminated to one pCi/m^2 (50)

Pi - the fraction of surface dose which penetrates to skin depth (7×10^{-3} cm) (skin dose) or to total-body depth (5 cm) (total body or internal organ dose)

(B) for beta radiation:

$$ {}_{\beta}D.F._{(ground,surface)} = 0.5 \times 1.07 \times 10^{-8} \bar{E}_{\beta} \nu\alpha\sigma \left\{ c \left[\left(1 + \ln \frac{c}{\nu x}\right) - e^{(1-\nu c/x)} \right] + e^{(1-\nu x)} \right\} \quad (3) $$

where:

${}_{\beta}D.F.$ = the dose factor from beta radiation, mrem/hr per pCi/m^2

ν = the apparent attenuation coefficient in air, cm^2/grm, corrected to account for the attentuation in the epidermal tissue layer.

$\bar{E}_{\beta}$ = the average beta energy for the particular beta emission process, MeV

α = a dimensionless parameter, defined as $\alpha = \left[3c^2 - (c^2-1)\, e\right]^{-1}$

C = an energy-dependent parameter, defined as:

$$C = 3.11\, e^{-0.55\, Eo}$$

and Eo is the maximum energy for a given beta emission.

X = the height above ground at which the dose is assumed to be received (one meter for adults and teens, one foot for children and infants).

In calculating skin dose, the gamma and beta dose factor components were summed for each isotope. For total body dose or dose to internal organs only

gamma contributions were considered; beta penetration through a 5 cm depth of tissue is negligible.

In considering effects of deposition during prior years, dose factors were calculated assuming a uniform mixture of radionuclides in soil constituting a laterally infinite slab 5 cm in thickness. Check calculations showed the beta radiation to be effectively absorbed within this slab; hence, only gamma radiation was considered. The equation used is:

$$D.F._{(ground,\ mixed)} = \frac{6.671 \times 10^{-8}}{h} \sum_{i=1}^{N} \frac{\left(\mu_a^a\right)_i}{\left(\mu_a^T\right)} \varepsilon_i \times \left[E_2(b_1) - E_2(b_3)\right] \qquad (4)$$

where:

h = soil layer thickness (5 cm)

N = number of gamma energy levels

$\left(\mu_a^a\right)_i$ = mass attenuation coefficient in air

$\left(\mu_a^T\right)_i$ = mass attenuation coefficient in tissue; separate values for skin and for total body.

ε_i = energy contribution of each energy level:

ε = (energy) x (fractional abundance)

E_2 = the second-order exponential integral function:

$$E_2(b) = \int_0^\infty \frac{e^{-bx}}{x_2} d_x$$

$b_1 = \mu_a^a (x - h)$

$b_3 = \mu_a^a (x + 1236\ h)$

x = elevation from base of slab to point of measurement

(adult, teen): $x = (100 + 5)$ cm

(infant, child): $x = (30.48 + 5)$ cm

1236 = soil density/air density $\left[1.46/\left(1.184 \times 10^{-3}\right)\right]$ @ 25°C

Water Immersion

Exposure from water immersion (swimming) will depend upon the amount of time spent in the water and the concentrations of the nuclides present at the location of the immersion. As for air submersion exposures, the dose factors do not vary with person size. The assumption was made that the swimmer was completely submerged and surrounded on all sides by a large volume of water, even though he might spend most of his time near the surface. For gamma radiation, the physical arrangement leads to a 4π geometry. For beta radiation, the geometry is approximately 2π as explained for air submersion, regardless of whether the person is near the surface or deeply submerged. The following equation can be used to calculate the dose factor for each nuclide.

$$(D.F.)_{\text{water immersion}} = 2.13 \times 10^{-6} \times (\overline{E}_{\gamma} + 1/2\overline{E}_{\beta}) \qquad (5)$$

where:

D.F. = dose factor (mrem/hr per pCi/liter)

$\overline{E}_{\gamma}$ = effective gamma energy per disintegration (MeV).

$\overline{E}_{\beta}$ = effective beta energy per disintegration (MeV).

As before, dose factors were derived for skin and total-body exposure using effective values of $(\overline{E}_{\gamma})$ and $(\overline{E}_{\beta})$, which account for the fractional penetration of the radiation to the skin depth and the total-body depth.

Water surface exposure is received as a result of activities such as water skiing and boating. Dose factors for exposure of this type were taken as one-half those for water immersion. The factor of one-half ignores the loss of the radiation in the distance between the water surface and the center of the body of the person exposed or the shielding provided by a boat. This is compensated for by the fact that a water skier spends a fraction of his time in the water.

INTERNAL ASSIMILATION OF RADIONUCLIDES

The calculation of dose from accumulation of radionuclides within the body is more complex than that of external exposure, involving selective biological pathways and the tendency of the body to retain assimilated nuclides, with the effective half life of retention varying from a few days to several years. This tendency toward retention makes necessary the consideration of dose commitment: the dose in future years resulting from assimilation of radionuclides in a given year. The calculation of dose factors for internal assimilation must also take into account the size and mass of the body or the various organs considered, since the assumption of an essentially infinite medium bearing the radionuclides is no longer valid.

Tritium Transpiration

Tritium, present in the environment principally as tritiated water, is readily and rapidly absorbed through the skin. Until recently, data on rates of this transpiration were not available in the literature. For the previous study of the UMRB, the dose from tritium transpiration was assumed equal to that from inhalation in accordance with ECRP recommendations.[44]

Recent data,[51] however, indicate a slower rate of tritium uptake from transpiration, amounting to approximately half that from inhalation. Consequently, in the present study the tritium dose from transpiration was taken as half the dose from inhalation.

Tritium was assumed to be transferred to most but not all parts of the body following transpiration. The total-body dose calculated for tritium transpiration was therefore applied to all other organs except bone. Mineral bone is relatively low in water content; thus, tritium concentrations would be correspondingly low. The skin, lungs, and GI tract all represent interfaces where tritium enters the body. The equilibrium concentration of tritiated water in these organs was taken to be similar to that in the total body.

Inhalation

The dose from inhalation was calculated by multiplying together (1) the air concentration of the radionuclides in question (pCi/m^3), (2) the person's beathing rate (m^3/hr), (3) an occupancy factor (hrs/month), and the appropriate dose factor (mrem/pCi intake) for the radionuclide. The occupancy factor was assumed to be 730 hours per month (24 hours per day, 30.4 days per month), assuming that an individual spends the major portion of his time each month in his county of residence.

The dose factor for inhalation dose varies with the radioactive emission spectrum and half life of the particular nuclide, its solubility in body fluids, its period of residence (biological half-life) within the body, and the age group and organ considered. Separate dose factors are required for the one-year dose and the 50-year dose commitment.

Soluble isotopes inhaled into the lungs were assumed to reach the internal organs of the body with relatively little time delay, either through direct absorption from the lungs into the blood stream or from transfer to the GI tract and subsequent absorption through the lower large intestine.

Dose factor equations for these soluble isotopes are:

(1) For internal organs other than the GI tract - LLI:

$$(D.F.)_{\substack{\text{inhalation,}\\ \text{internal organs}\\ \text{(soluble)}}} = \frac{0.074\ \varepsilon\tau f_a}{m} \times \left(1 - e^{\frac{-0.693\ t}{\tau}}\right) \qquad (6)$$

(2) For the GI tract:

$$(D.F.)_{\substack{\text{inhalation,}\\ \text{GI Tract-LLI}\\ \text{(soluble)}}} = \frac{0.0256\ \tau'\ \varepsilon f^* f_a}{m} \times \left(e^{\frac{-0.693\ t'}{T_R}}\right) \qquad (7)$$

where

D.F. = Dose Factor (mrem/pCi inhaled).

ϵ = effective energy of the specific nuclide in the specific organ under consideration (MeV/dis).

f* = fraction of the materials which escapes absorption in the GI tract ahead of the LLI (lower large intestine).

f_a = the fraction of the inhaled material that reaches the organ under consideration.

τ = the effective half-life of the nuclide in the organ under consideration (days).

t = length of time over which the dose is calculated (days).

T_R = radioactive half-life of the nuclide under consideration (days).

t' = time of travel from mouth to entrance of LLI (days).

τ' = travel time through LLI (days).

m = mass of the organ (grams), or mass of contents of LLI.

For insoluble isotopes, a fraction of the radionuclide inventory was assumed to be absorbed by the body fluids during the residence time of the isotope in the lungs. Dose factors for internal organs (except the lungs and the GI tract) are calculated as follows:

$$D.F._{\substack{\text{inhalation}\\ \text{internal organs}\\ \text{(insoluble)}}} = \frac{0.0064\ f_a\ \epsilon}{m^{*}0.693\left(\frac{1}{\tau}-\frac{1}{\tau_L}\right)} X \left[\tau_L\left(1-e^{\frac{-0.693 \times 365}{\tau_L}}\right) - \tau\left(1-e^{\frac{-0.693 \times 365}{\tau}}\right)\right] \quad (8)$$

where

τ_L is the effective half-life of the radionuclide in the lungs; the other parameters are as defined in equations (6) and (7).

Ingestion

Equations for calculations of dose factors for ingestion were derived in a manner similar to those for inhalation and are given below:

$$(D.F.)_{\substack{\text{ingestion,}\\ \text{internal organs}}} = \frac{0.074\ \varepsilon\tau f_w}{m} \times \left(1 - e^{\frac{-0.693t}{\tau}}\right) \qquad (9)$$

$$(D.F.)_{\substack{\text{ingestion}\\ \text{GI-LLI}}} = \frac{0.0256\ \varepsilon\tau' f^*}{m} \times \left(e^{\frac{-0.693t'}{T_R}}\right) \qquad (10)$$

where

f_w = the fraction of the ingested nuclide reaching the organ of interest.

The other symbols are the same as defined previously for Equations (6) and (7). The dose factors for ingestion are independent of the media ingested, and Equations (9) and (10) apply for both food and water. All nuclides in these media were assumed to be in soluble form.

Data for Inhalation and Ingestion Pathways

Values of parameters describing the uptake of radionuclides by the body and their distribution to the organs considered were largely taken, for the adult, from those recommended by ICRP.[44] The ICRP parameters for an adult are those for the "standard man". Although this concept is intended to represent the average adult, the body and organ weights of the "standard man" are largely descriptive of the adult male. The inaccuracies introduced by this weighting of the body data are not large, and historically the "standard man" has been used consistently to represent an average member of the adult population.

Body and organ weights used for the four age groups included in the study are shown in Table VIII-5. Values for the adult are those for the "standard man"; weights for the other age groups were derived from the literature.[52-59] Also shown on the table are the calculated effective radii of the organs, used in derivation of effective decay energies for radiation absorption within the organs. This derivation utilized the ICRP model, which assumes the nuclide to be concentrated in the center of a spherical organ. Effective radii for adult organs were taken from the ICRP "standard man" data. Organ radii for other age groups were estimated by assuming that, for a given organ, the radius is proportional to the cube root of the mass. Appropriate values for absorption coefficients for muscle and bone, for use in energy absorption calculations, were then taken from the National Bureau of Standards Handbook 85.[60]

The other parameters used in dose factor calculations were taken from ICRP for the adult. Except for specific instances where data indicated an age dependence of the biological half lives of isotopes (tritium and cesium in the total body, iodine in the thyroid), ICRP parameters for the adult were assumed to apply.

TABLE VIII-5

ORGAN MASSES AND EFFECTIVE RADII FOR AGE GROUPS

Organ	Infant (6 mo)		Child (4 yr)		Teen (14 yr)		Adult	
	Mass (g)	Radius (cm)	Mass (g)	Radius (cm)	Mass (g)	Radius (cm)	Mass (g)	Radius (cm)
Total Body	7,700	14	16,400	20	49,000	27	70,000	30
GI Tract	15[(a)]	2	35[(a)]	3	100[(a)]	4	150[(a)]	5
Thyroid	2	1.4	5	2	15	2.7	20	3
Bone	770	2.4	1,640	3	4,900	4	7,000	5
Lungs	110	5	300	7	580	8	1,000	10
Liver	200	5	530	7	1,200	9	1,700	10

(a) Mass of contents of GI-LLI assumed to be proportional to body weight

The other parameters used in dose factor calculations were taken from ICRP for the adult. In specific instances metabolic data indicated an age dependence of the biological half-lives of assimilated isotopes (tritium and cesium in the total body, iodine in the thyroid), or of other metabolic functions such as breathing rate (previously considered) or of rates of passage of foods through the digestive tract. Where specific age-dependent data were not available, values for the adult were used. Typical age-dependent data are listed in Table VIII-6.

TABLE VIII-6

TYPICAL AGE-DEPENDENT BIOLOGICAL PARAMETERS

Parameter	Value for			
	Infant	Child	Teen	Adult
Travel time, digestive system, days				
- Mouth to LLI	.06	.12	.36	.54
- Through LLI	.08	.18	.5	.75
Inhalation rate, m^3/day	7	7	13.5	20
Biological half-life, days				
- Tritium in total body	3.2	4.5	7	10
- Cesium in total body	10	20	20	115
- Iodine in thyroid	20	20	50	100

DOSE AND DOSE COMMITMENT CALCULATIONS

Using the dose factors derived for the various pathways, the subsequent dose calculations were relatively simple. Basically, dose was calculated as a product of the appropriate dose factor, an index of exposure (for external dose, the product of environmental concentrations of radionuclides and time of exposure; for internal dose, the rate of ingestion or assimilation), and, when appropriate, an exponential term accounting for retention of radionuclides within the body.

Study Year Dose

The dose incurred by the population of the TVR in the year 2000, from ingestion of and exposure to radionuclides during that year, was termed the study year dose. Since the releases and environmental concentrations of radionuclides in the region were calculated as a series of monthly values, the study year dose was similarly expressed as a summation of 12 monthly calculations.

For the dose contributions from exposure to external radiation, the calculations took the form:

$$Dsy = (DF) \sum_{i=1}^{12} C_i \, t_i \qquad (11)$$

where:

Dsy = the study year dose contribution for a specific isotope and pathway

(DF) = the appropriate dose factor $\left(\frac{\text{mrem/hr}}{\text{pCi/M}^3} , \frac{\text{mrem/hr}}{\text{pCi/l}} , \frac{\text{mrem/hr}}{\text{pCi/m}^2} \right)$

C_i = environmental concentration of radionuclide for month i $\left(\text{Ci/}_{\text{m}}3 , \text{pCi/l} , \text{or pCi/}_{\text{m}}2 \right)$

t_i = hours of exposure received by the individual during month i.

The calculations of dose contributions from internally assimilated radionuclides used the relationship shown in Equation (12):

$$Dsy = (DF) \sum_{i=1}^{12} I_i \left(\frac{i - e^{-\lambda \left(\frac{13 - i}{12} \right)}}{i - e^{-\lambda}} \right) \qquad (12)$$

where:

Dsy = the study year dose contribution for a specific isotope and pathway

(DF) = the appropriate dose factor, $^{mrem}/_{pCi}$ intake

I_i = intake of the radionuclide, pCi in month i

$\lambda = \frac{\ln 2}{\tau}$, and

τ = the effective half life for retention of the radionuclide in the body or in the organ considered, expressed in years.

Calculations of dose contributions were made for each isotope and each pathway, and were summed to provide individual study year doses, by age group, in each county. These individual doses were then combined with population data to yield integrated population doses (man-rem) for each county and for the entire region. This "modular" method of calculation provided a great amount of detailed information on contributions to dose and their relative importance throughout the study area.

50-Year Dose Commitment

The 50-year dose commitment, as used in this study, was defined as the dose received over the succeeding 50 years from radionuclides assimilated in the body during the year 2000. No further external exposure or internal assimilation of radionuclides beyond the year 2000 was considered in these calculations.

Dose commitment calculations were performed using equation (13):

$$(DC)_{50} = \sum_{i=1}^{12} I_i \left[\sum_{n=1}^{4} (DF)_n \left(1 - e^{-\lambda t_n} \right) e^{-\lambda \left(t_{n-1} + t_{n-2} + \cdots \right)} \right] \quad (13)$$

where:

$(DC)_{50}$ = the contribution to 50-year dose commitment from a specific isotope and pathway

I_i = monthly radionuclide intake, pCi, from equation (12)

$(DF)_n$ = appropriate dose factor for age group n

n = age group index:

n = 1, infant

n = 2, child

n = 3, teen

n = 4, adult

t_n = the time an individual spends in each age group during the 50-year commitment period, from Table VIII-7.

For the adult, this equation is very similar in form to Equation (12), used for study year dose calculations. However, in calculating dose commitment to juveniles, consideration must be taken of changes in metabolism and body size as the individual matures. In using equation (13), maturation factors are accounted for by assuming that an individual in a given age group spends t_n years in each succeeding age group during the commitment period. The values of the residence periods are specified in Table VIII-7. The age-dependent dose factors, $(DF)_n$, used in equation (13) account for bodily changes associated with maturation.

As with the study year dose, dose commitment calculations are structured by age group, isotope, and pathway, and are summed to obtain individual dose commitment.

TABLE VIII-7

AGE GROUP RESIDENCE TIMES FOR 50-YEAR DOSE COMMITMENT CALCULATIONS

Values of (t_n) for use in Equation (13)

Original (Year 2000) age group	Years assumed to be spent in age group designation:			
	Infant (t_1)	Child (t_2)	Teen (t_3)	Adult (t_4)
Infant	1	10	6	33
Child	0	10	6	34
Teen	0	0	6	44
Adult	0	0	0	50

Prior Body Burden

The HERMES model dose calculations consider only the dose and dose commitment from radionuclide concentrations existing in the study region in the study year. An incremental addition to this dose would in reality be incurred in the study year from the body burdens accumulated in prior years by individuals living in the area. Although this incremental dose was expected to be small, estimates were made of the body burden dose for completeness.

The HERMES model is basically capable of providing the successive patterns of radionuclide concentrations and resulting dose commitments required for these calculations. However, the providing of detailed year-by-year body burden accumulations over the entire study area between now and the year 2000 would either require computer capacity considerably beyond that available, or would require successive computer runs involving costs beyond the scope of this study. Therefore, an estimate of the incremental dose from prior body burden was made by an approximate method.

The increase in nuclear capacity from 1975 until 2000 was approximated by an exponential curve. Annual releases of radionuclides in the study area were assumed to be proportional, each year, to the corresponding value on the nuclear capacity curve (normalized to year 2000 releases) and to be uniform over the entire study area. Then, using a variant of equation (13), the year-by-year internal assimilation of radionuclides from 1975 through 1999 and the resulting dose commitment were calculated for a "typical" adult. Dose commitment was calculated both through the year 1999 and through the year 2000; the difference represents the year 2000 dose from prior body burden. Again using equation (13) the 50-year dose commitment (2001-2050) from this same body burden was calculated.

Although the calculation method is approximate, the results can be compared

with comparatively little error to the year 2000 dose and dose commitment for the "average adult" in the TVR.

Incremental Dose Near Nuclear Facilities

In the HERMES model calculations, activities leading to the accumulation of human dose are assumed to occur uniformly over each county. Radionuclide concentrations in the air and on ground surfaces are calculated for each county at a point designated as the centroid of that county (other locations may be specified for water supply intake, location of recreational activities, etc.).

For the most part this method of calculation provides a reasonable estimate of average dose within the county. However, for some small segments of the population living closer to nuclear facility sites than the distance to the nearest centroid, estimates of external dose may be understated by HERMES.

To assess the effects of these incremental contributions to dose, calculations were made for five sites for which detailed projections of surrounding population were available. For these calculations the KRONIC[36] computer code was used. A polar grid system utilizing 16 compass sectors was set up to represent the environs of each site; a typical grid pattern is shown in Figure VIII-1. Centroids were designated at the mid-point of each grid space; dose calculations were made at each centroid and applied to the population within the corresponding grid zone. Dose calculations were made for the average adult and for integrated (man-rem) dose, by isotope, and were provided for the total body and for internal organs. These dose values are directly comparable to the county-average doses calculated by HERMES.

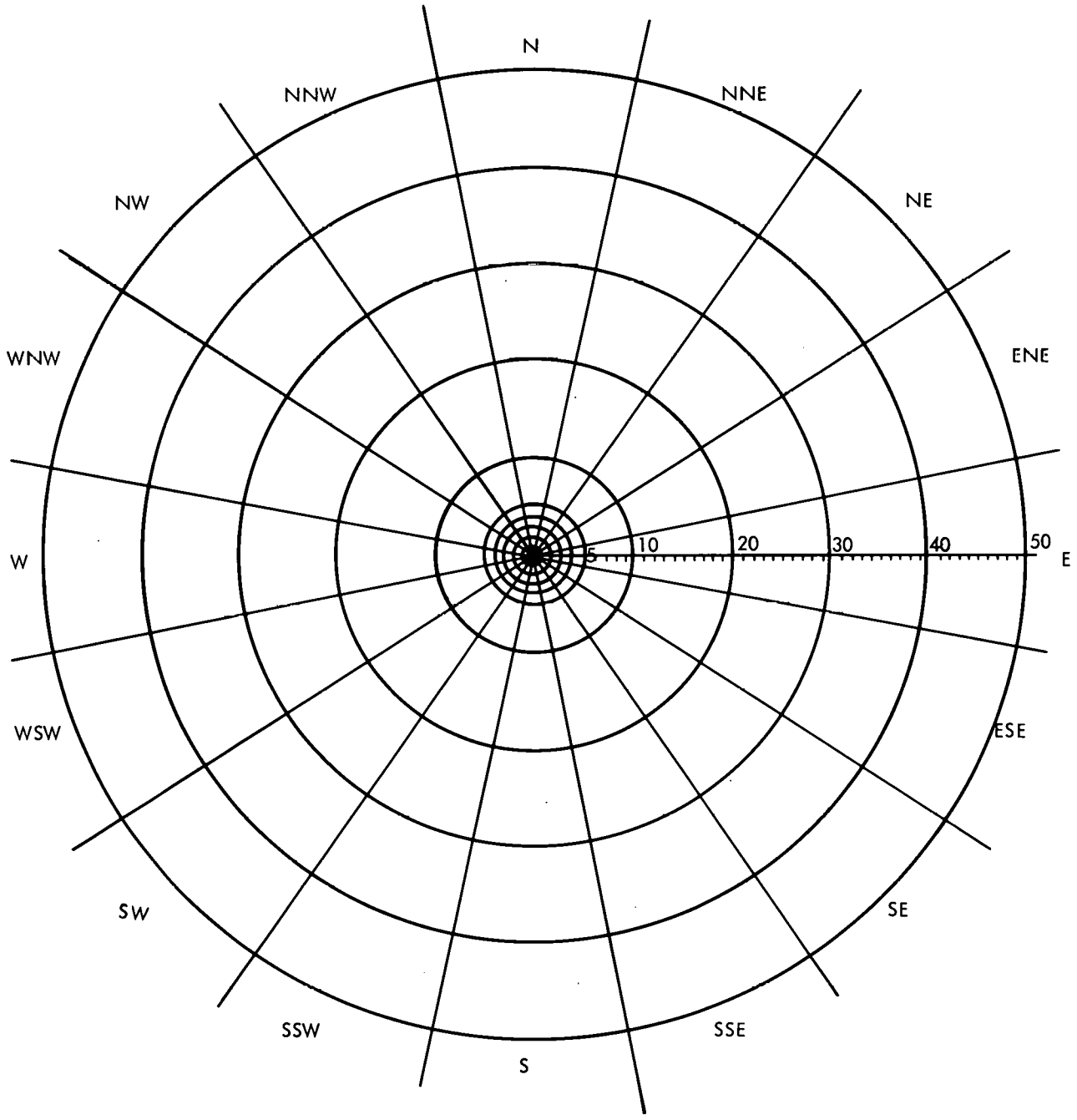


Figure VIII-1

Typical Grid System for Near Site Calculations

IX. POTENTIAL RADIATION DOSE BASE CASE RESULTS

The potential radiological dose to the population of the study area, in the year 2000, is calculated by summing the contributions of all nuclides through all pathways from all pertinent nuclear facilities. An annual dose and fifty-year dose commitment to the total body and six specific organs have been estimated for average individuals in the four age groups at each of the 140 counties in the region. Detailed results of the calculations show the contributions to the estimated dose from each of the 48 nuclides and 10 pathways to each of the four age groups considered. Integrated total-body dose is the estimated dose for the average individual, multiplied by the population for the area of concern.

The integrated total-body dose estimate for the TVR in the year 2000 is approximately five man-rems. The total population of the region in the year 2000 is projected to be about 6,965,600; thus, the average total-body dose would be 7.0×10^{-4} mrem. The regional 50-year dose commitment for intake of radionuclides in the year 2000 is estimated to be 4.7 man-rems, or about 6.7×10^{-4} mrem to the average person. The average regional total-body dose from natural background radiation, medical and dental sources, and other miscellaneous sources (TV sets, etc.) is about 200 mrem per year. For the projected year 2000 population of the region these other sources would result in an integrated total-body dose of about 1.4 million man-rems per year. The supplemental dose associated with nuclear power production is thus a very small fraction of the overall dose that would be accrued in the region.

Model Restraints

There are limitations to the accuracy with which mathematical models may represent the actuality of any real event or process. Additional uncertainties are introduced when the model attempts to simulate future events. A review of

the implicit restraints of the HERMES model will assist in placing the discussion of the dose evaluation in proper perspective.

- The transport calculations which yield estimates of radionuclide concentrations in the environment are made for unique geographical points in each county that approximate the population centroid. The environmental nuclide concentrations that are represented by these calculations are presumed to be constant over the entire county. Radiological dose calculations for the county population are made according to these environmental concentrations. These calculations yield reasonably accurate values for county-wide average dose, but ignore perturbations within a county.
- Radiological dose contributions from 48 nuclides are considered. The list of radionuclides (Appendix D) includes fission and activation products and representative transuranics.
- Living habits for the regional population have been characterized by the Living Patterns Model. Representative sources for food and sites for recreational activities are defined by the data derived from this model for each centroid. Wherever the statistics for production of food or recreational activities for a county specify a location external to the study region the associated nuclide concentrations are presumed to be zero.
- Biological behavior of radionuclides included in the study, as well as behavorial characteristics in the transport processes, are based upon existing but often limited data. In many cases extension and extrapolation of data from chemically similar radioactive or stable istopes was necessary to determine the parameters to complete the model.

- Formulation of the model assumes that the air submersion dose to people close to nuclear facility sites (close-in dose) is not a major contributor to the regional integrated dose. The assumption was manifested in both the centroid population representation and in the atmospheric transport model.

Additional calculations were made to estimate the added contribution of close-in dose using release rates given in Chapter V. These calculations were made for six nuclear facilities within the study region for which population density statistics were available. They show that an average individual living one mile from a typical nuclear power plant site (as an average of six plant sites) would receive an additional dose contribution of about 2.9×10^{-2} mrem per year from the close-in dose. The range of close-in dose for these six plant sites is 1.23×10^{-4} to 9.62×10^{-2} mrem per year. For an average person living one mile from a reprocessing plant the additional dose contribution is estimated to be about 7×10^{-3} mrem per year. It should be again noted that reprocessing plants were assumed to have 100-meter stacks, and other nuclear facilities to have ground level releases.

While persons living near nuclear sites may thus incur doses somewhat greater than the average for a given county, only a very small proportion of the population of any county would actually live near enough to a site to be subject to this additional dose. For the six sites calculated (including the only reprocessing plant site within the study area proper) the additional integrated total body dose was about 0.05 man-rem, or only about one per cent of the integrated dose for the total study area.

General Trends and Patterns

The doses calculated throughout the region have a range of three orders of magnitude. Average adult total body dose for the various centroids, for

example, ranged from 3.4×10^{-6} to 7.3×10^{-3} mrem per year. The average total-body dose distribution in the population of the region (Figure IX-1) shows that 99% of the people could be expected to receive a total-body dose less than 4.7×10^{-3} mrem per year. The total-body dose for adults is slightly higher than for the average individual and that for infants, children and teens is somewhat lower.

The average radiation doses for the region for all organs and for total body are tabulated for both annual dose and 50-year dose commitment for infants, children, teens and adults in Table IX-1. Note that the relative magnitude of the doses calculated for the four age groups considered is not constant for different organs. Since external pathways contribute the same exposure to individuals in each each group (with few exceptions), the variations in dose among the age groups are affected only by internal pathways.

TABLE IX-1

AVERAGE ANNUAL DOSE AND 50-YEAR DOSE COMMITMENT RECEIVED FROM RADIONUCLIDE RELEASES BY POPULATION OF STUDY AREA

	Annual Dose*				50-Year Commitment*			
Organ	Infant	Child	Teen	Adult	Infant	Child	Teen	Adult
Total Body	7.09	6.29	5.92	7.45	7.09	6.33	5.50	6.97
GI Tract	7.01	6.29	5.92	7.66	5.74	5.01	4.91	6.54
Thyroid	13.51	8.97	7.47	9.19	12.67	7.74	6.34	8.28
Bone	1.77	1.50	1.25	1.19	5.74	5.56	3.11	3.92
Lungs	7.18	6.29	5.92	7.45	6.08	5.21	4.91	6.54
Skin	16.05	15.17	11.06	12.56	5.66	5.00	4.79	6.54
Liver	7.01	6.29	5.92	7.45	5.91	5.14	4.91	6.75

* expressed in 10^{-4} mrem

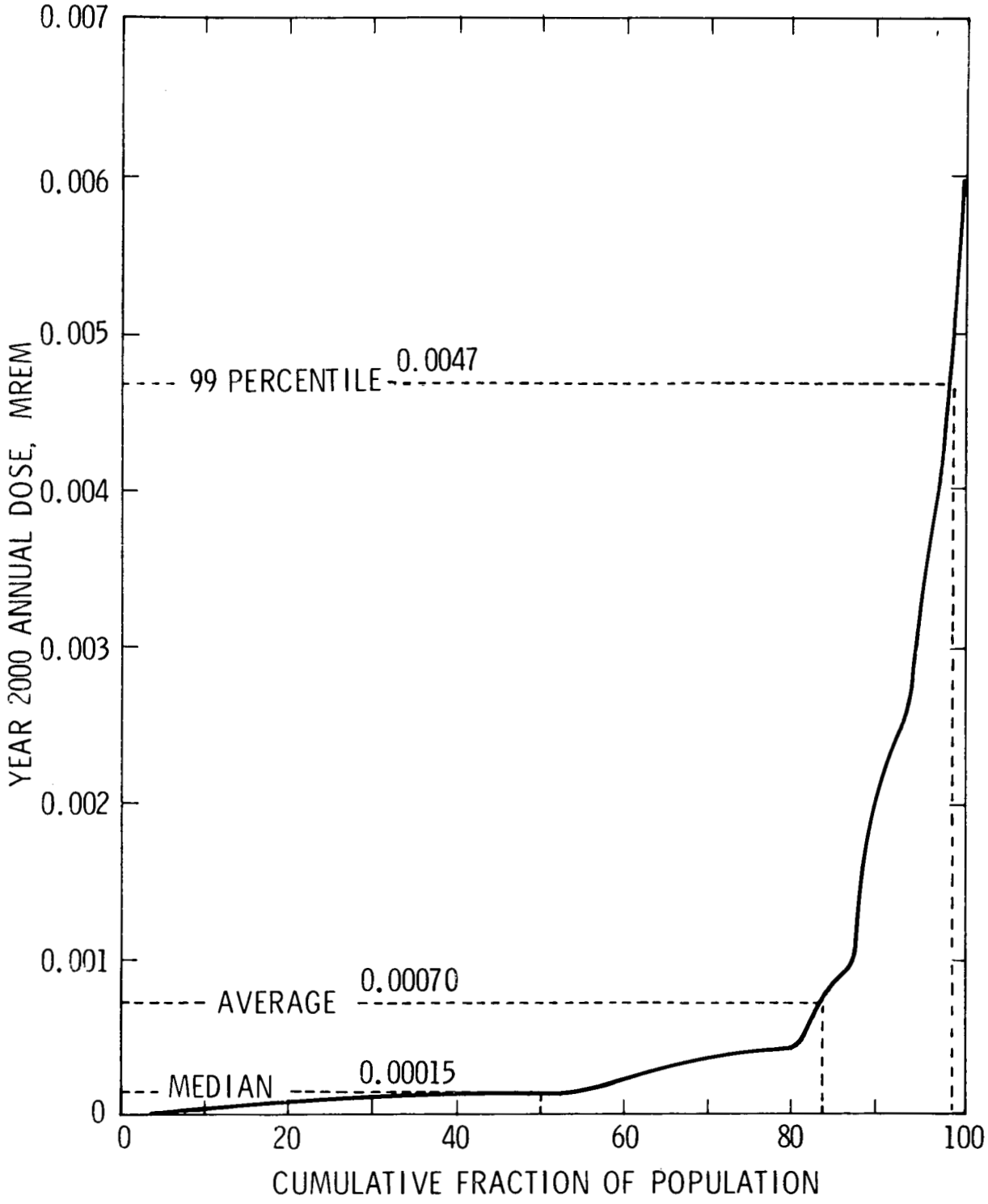


FIGURE IX-1

Total Body Dose Distribution from Nuclear Facility Operation in the Year 2000 in Tennessee Valley Region

The internal pathways are in turn affected by age-dependent diet patterns and organ masses. Radiation dose distribution without age dependence would be represented by that of the skin dose, which results from tritium transpiration and external exposure only.

As is indicated in Table IX-1, dose to individual organs may be either greater or smaller than to the total body. These variations are dependent on the specific radionuclides contributing to dose, and on such factors as radionuclide concentration in specific organs, differences in size of the various organs, the extent to which internal organs are shielded from external radiation, and on the relative effectiveness of absorption of radiation within the tissues of an organ.

These differences can be illustrated by consideration of the thyroid, which has a high affinity for iodine. The decay of, say, one picocurie of radioiodine within the thyroid contributes a much greater dose to that organ than would be contributed to the total body if the same decay energy were to be absorbed uniformly by the body. On the other hand, the thyroid is much less affected by external radiation from ^{85}Kr than is the skin.

Operation of nuclear power facilities in the region before the year 2000 would result in the population starting the study year with a residual dose. This prior body burden is a function of the power demand growth curve in the years before 2000 and the radiological and biological half-lives of the nuclides. Calculations to estimate this dose from prior body burden were described in Chapter VIII.

There is no prior body burden for skin and GI tract (lower large intestine), since the biological half-life in these organs is short. The average year 2000 dose from prior body burden for total-body, thyroid, bone, lungs and liver ranges from 6×10^{-7} to 9.85×10^{-5} mrem. The lung dose has the largest value. The

50-year dose commitment from the prior body burden is confined primarily to the total-body, bone and liver. The range of values for these organs covers a range of about 7×10^{-6} to 2×10^{-5} mrem; the bone dose is the largest of these.

This analysis shows that inclusion of the dose from the prior body burden in the year 2000 calculations would not materially add to the results. For the individual nuclides contributing to dose, the dose from prior body burden ranges from 5% or less to about 15% of the dose from year 2000 accumulations.

Annual dose and 50-year dose commitment estimates for the study area display very similar regional distributions. Figure IX-2 graphically portrays the distribution of adult annual dose for the seven organs. In addition, the total air releases are shown for ready reference. Close inspection of this figure shows that the regional distribution of dose to six of the organs are very similar, except for scalar factors. The seventh organ, bone, displays a different regional distribution that most nearly approximates the courses of the regional waterways.

Adult dose to the total body, GI tract, lungs and liver is derived primarily from inhalation and transpiration of tritium. Tritium contribution to thyroid and skin dose is also important, via the air submersion pathway. Iodine contributions to dose of infants and children are significant. This dose is largely due to ingestion of milk. Soil exposure is a contributing pathway to some extent for all organs. The most significant doses from this pathway are to the skin and bone.

Radionuclide Contributions to Potential Dose

Forty-eight radionuclides were considered in the study. These were selected for study based upon the probability of their occurrence in nuclear facility releases and on their potential for contribution to human dose via at least one exposure pathway. Study results show that only a few of the nuclides

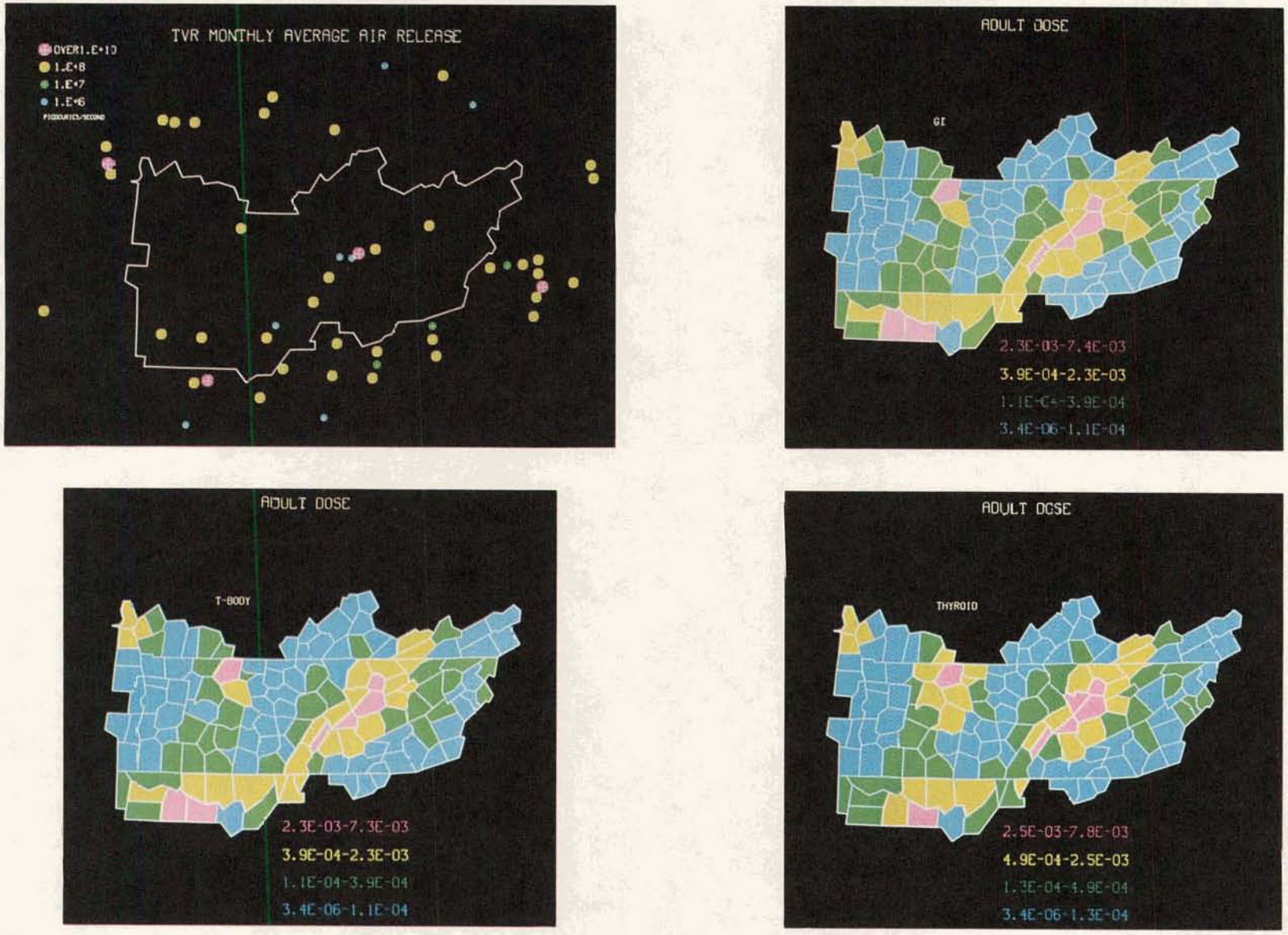
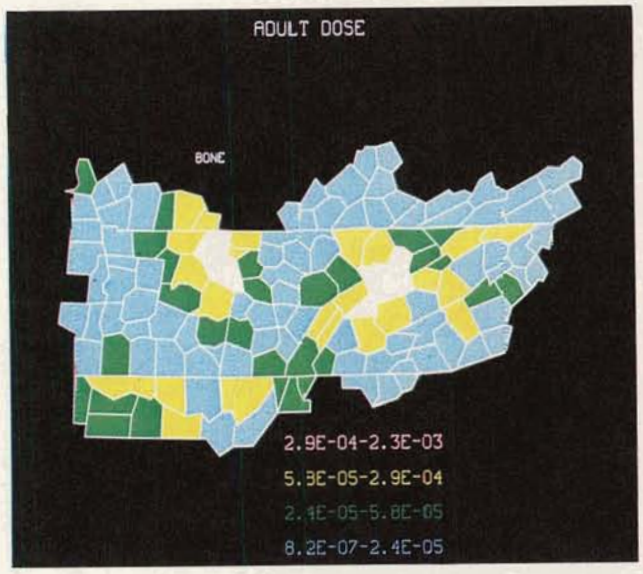
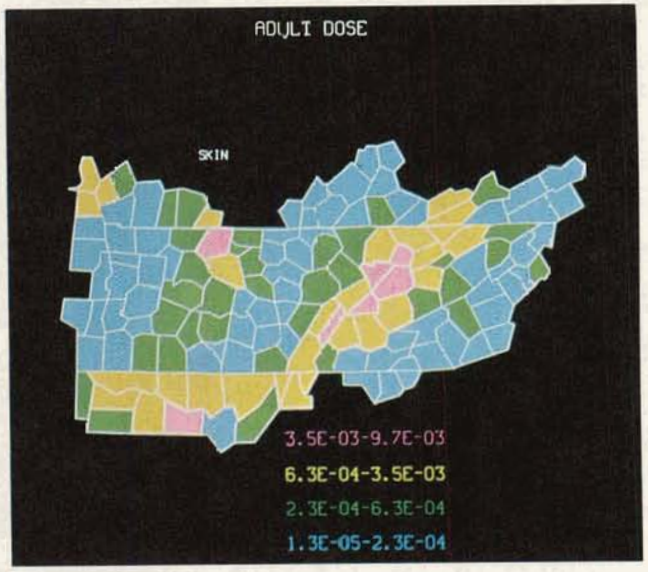
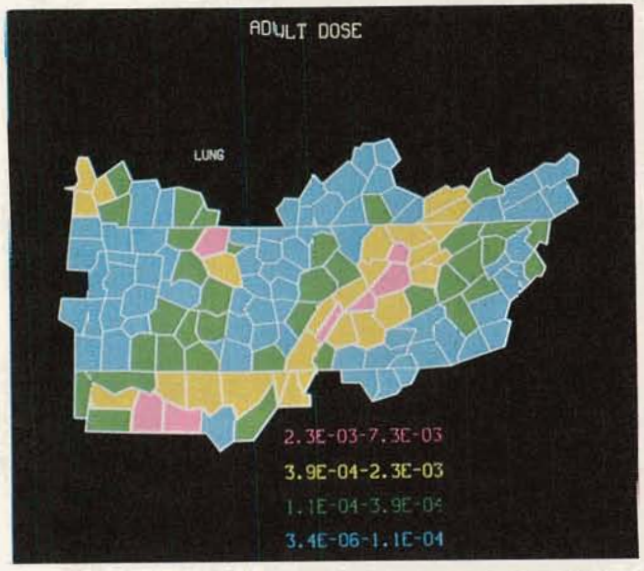


FIGURE IX-2

Distribution of Year 2000 Dose in TVR (Air Releases Shown for Reference)







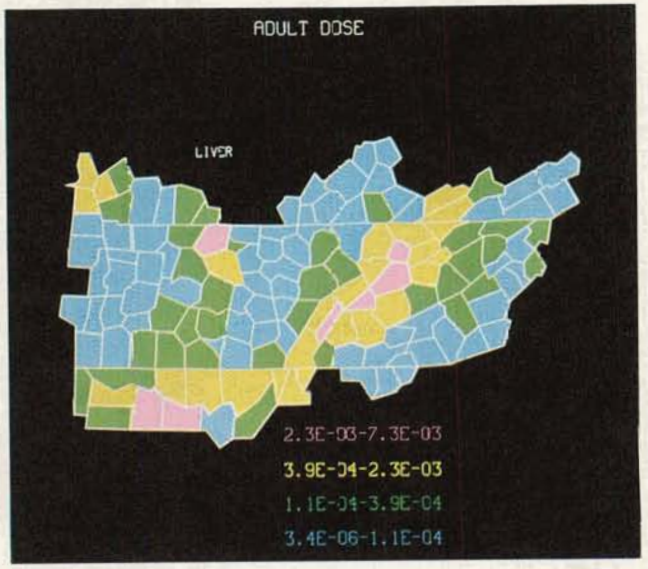


FIGURE IX-2

Distribution of Year 2000 Dose in the TVR (cont'd)

considered are likely to have significant contribution to dose. A summary of nuclide contributions to dose and dose commitment are given in Figures IX-3 and IX-4

Tritium is the largest contributor to dose. It is responsible for 83% of the total-body dose of the average adult, and is also responsible for a large part of the dose to all organs except bone. Tritium is also a major contributor to the estimated 50-year dose commitment. The range of this dose commitment for an average adult is from 79% for thyroid to 100% for skin.

Contributions to dose from noble gases are primarily due to ^{85}Kr and ^{133}Xe. These nuclides contribute mainly to skin dose; ^{85}Kr accounts for about 16% of the adult dose to skin, and ^{133}Xe about 5%. Xenon is also a contributor to dose to other organs (about 6% of adult total-body, 34% of adult bone dose).

The nuclides ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{100}Ru and the transuranics have been generally considered to be problem radionuclides. In this study their aggregate contribution in the study year for an average adult was less than 1% for all organs except bone and skin. For these organs their contribution to the year 2000 dose was less than 10%. However, the 50-year aggregate dose commitment attributable to these nuclides (in particular ^{90}Sr, ^{238}Pu and ^{241}Pu) for bone is estimated to be 90%. Strontium 90 alone contributed 58% of the total dose commitment to bone.

Iodine isotopes are potentially important contributors to dose, particularly for the infant and child, because of the strong affinity of iodine for the thyroid. Three iodine isotopes, ^{129}I, ^{131}I and ^{133}I, were considered in this study. Table IX-2 gives the percentage contribution to the study year thyroid dose and 50-year dose commitment for the three iodine isotopes.

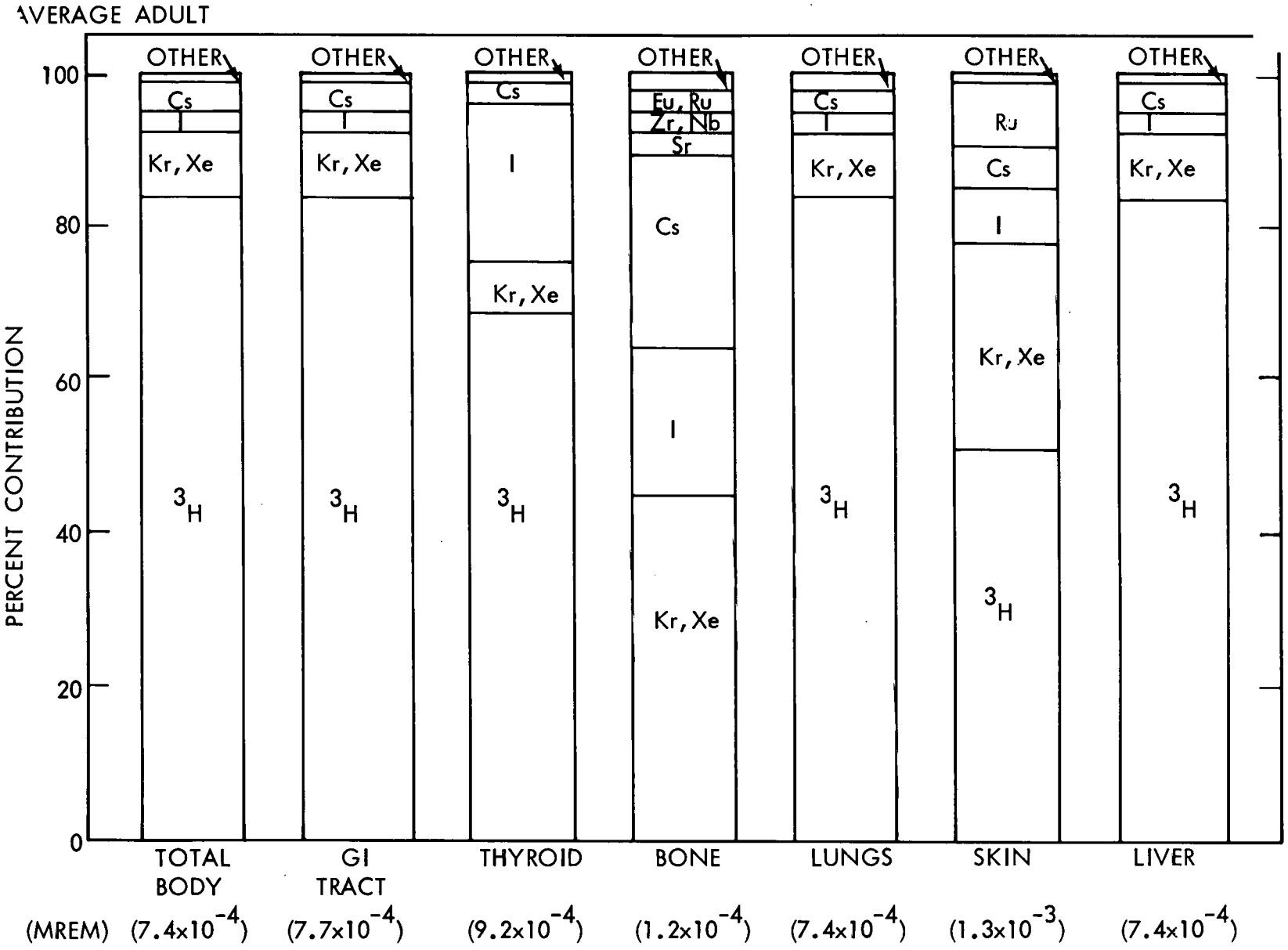


FIGURE IX-3

Nuclide Contributions to Annual Dose

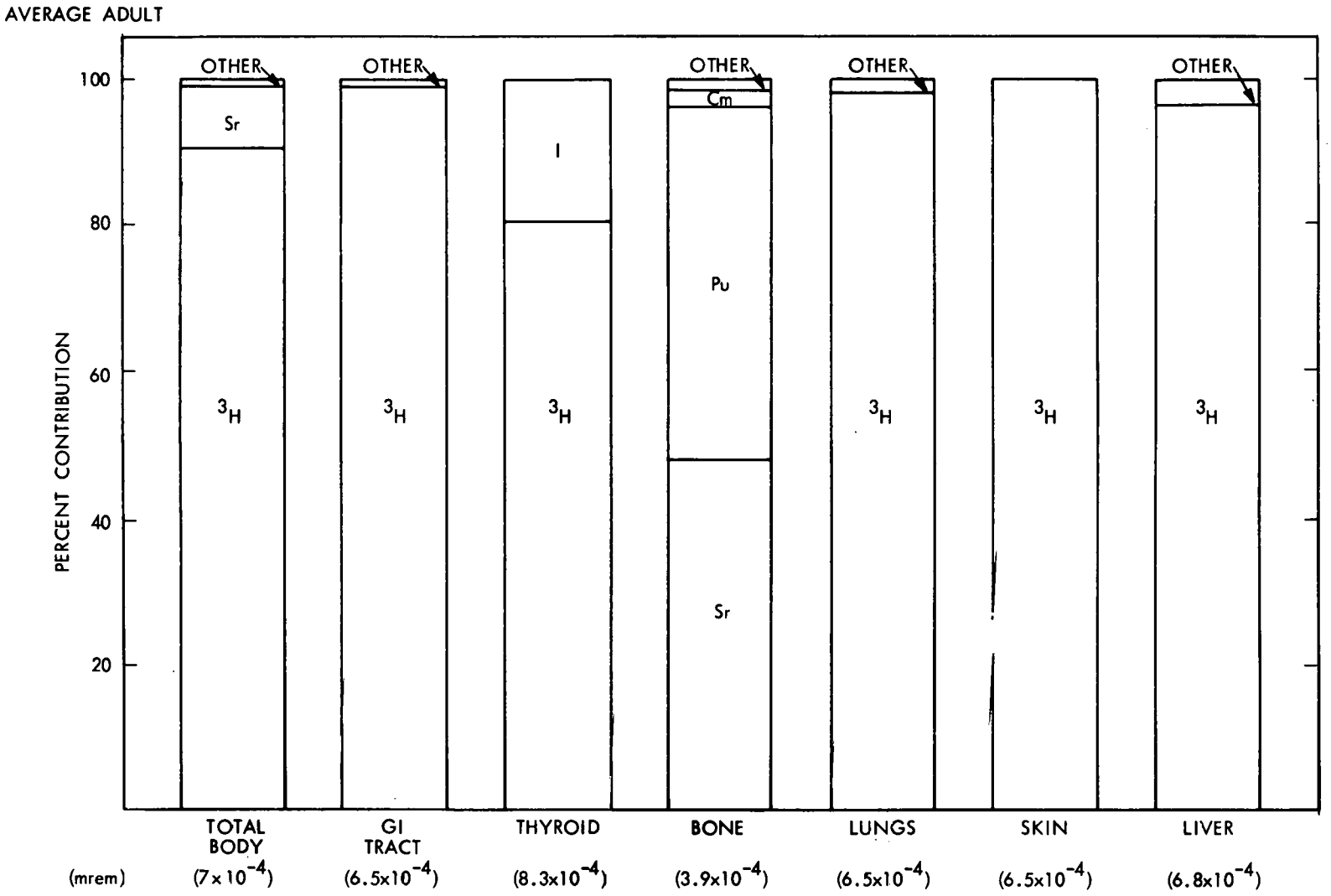


FIGURE IX-4

Nuclide Contributions to 50 Year Dose Commitment

TABLE IX-2

IODINE CONTRIBUTIONS AS A PERCENTAGE OF THE THYROID DOSE OF AN AVERAGE PERSON

Nuclide	Annual Dose, Year 2000				50-Year Commitment			
	Infant	Child	Teen	Adult	Infant	Child	Teen	Adult
^{129}I	3.9	2.7	2.9	2.5	4.3	3.3	4.	4.2
^{131}I	29.	16.	10.	8.3	31.	19.	12.	8.9
^{133}I	17.	12.	10.	9.4	18.	12.	9.4	8.3

In addition to the heavy contribution to the thyroid dose ^{133}I is calculated to contribute substantially to dose to GI tract, bone, lungs and skin.

The contribution to annual dose of two cesium isotopes, ^{134}Cs and ^{137}Cs, is mainly to bone dose. These dose contributions range from about 11% for the average infant to about 26% to the average child. The 50-year dose commitment of the cesium isotopes is calculated to be, for all age groups, less than 3%.

The isotopic contributions to dose are observed to differ among the four age groups. In many cases these differences were minor. However, for the thyroid the differences were significant. Figure IX-5 graphically portrays this point.

Pathway Composition of the Potential Regional Dose

The dose model considers ten pathways potentially leading to dose. Study results indicate that only a few of the pathways have a significant contribution to radiation dose. Those pathways and specific food types which are found to contribute to specific organ doses are given in Table IX-3.

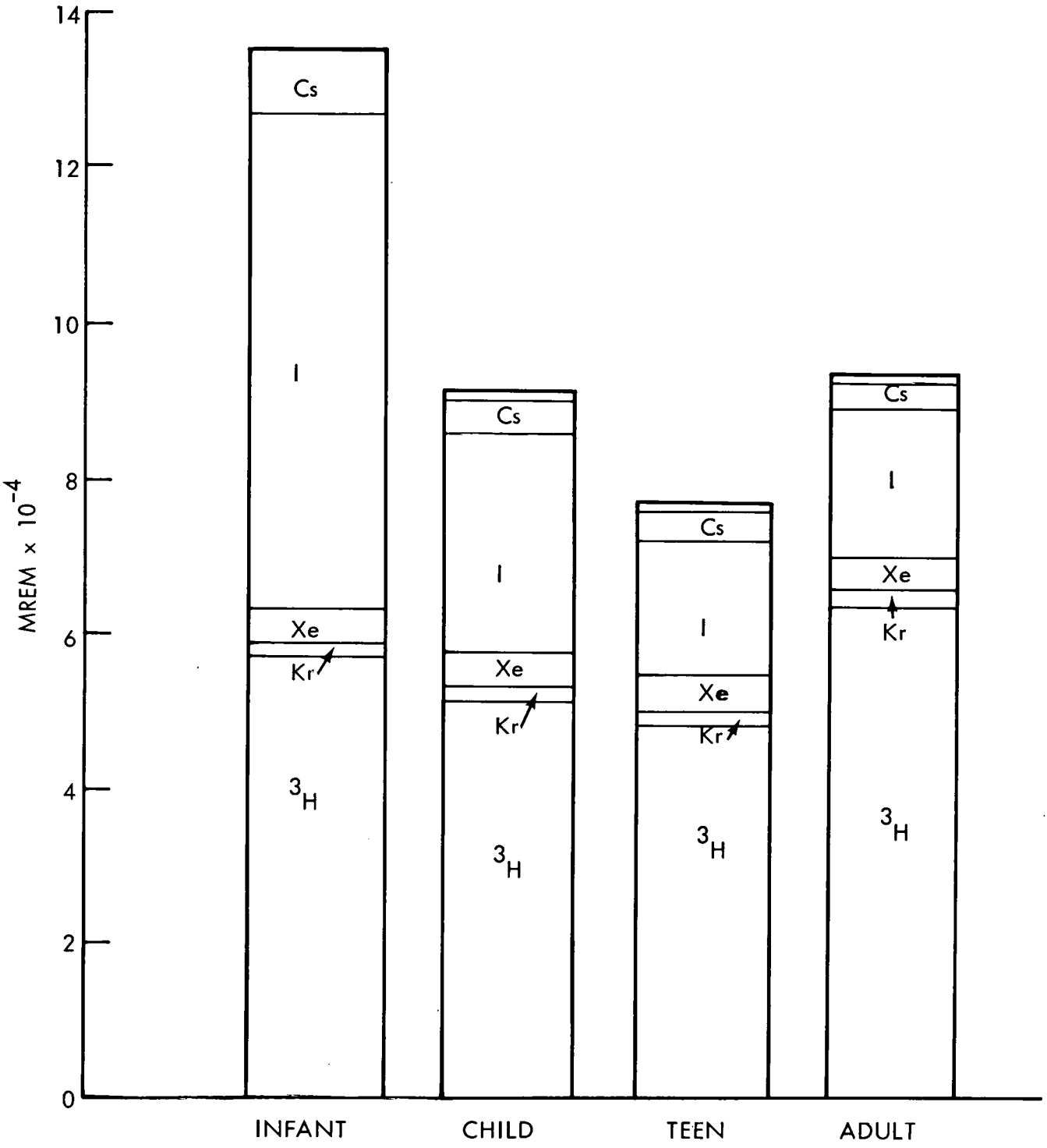


FIGURE IX-5

Age Dependence of Isotopic Contribution to Thyroid Dose
(Regional Average)

TABLE IX- 3

PATHWAYS FOUND TO CONTRIBUTE TO DOSE AND DOSE COMMITMENT

	ANNUAL DOSE							FIFTY YEAR DOSE COMMITMENT						
	Total Body	GI Tract	Thyroid	Bone	Lungs	Skin	Liver	Total Body	GI Tract	Thyroid	Bone	Lungs	Skin	Liver
Air Inhalation	X	X	X	X	X	X	X	X	X	X	X	X	X	X
^{3}H Transpiration	X	X	X		X	X	X	X	X	X	X	X	X	X
Exposure to Soil	X	X	X	X	X	X	X							
Air Submersion	X	X	X	X	X	X	X							
Drinking Water	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Foods														
Beef & Lamb	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Proc. Pork	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fresh Milk	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fresh Whole Eggs	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Dose commitment as calculated is incurred through internal pathways only. Thus, air submersion and soil exposure contribute only to the annual radiation dose.

The largest part of the potential annual dose accrues from the pathways directly associated with airborne nuclides or surface deposits from the atmosphere. Four pathways - air submersion, air inhalation, tritium transpiration, and soil exposure - contribute about 70 to 86% (age group dependent) of the total-body dose for an average person in the region. These four pathways contribute heavily to specific organ doses as well. Average contributions for an adult range from near 75% for total-body, GI tract, thyroid, lungs and liver to more than 80%-84% for bone and skin. Two of these pathways (air inhalation and tritium transpiration) contributed 70% or more of the 50-year dose commitment for the average adult.

The dose pathways that depend solely upon air transport have a strong dependence upon location of the receptor with respect to the source of the effluent and the meteorological parameters that influence diffusion and deposition. Further, for those nuclides with short half-lives the radioactive decay mechanisms may markedly affect the regional dose distribution.

The contribution to dose from drinking water has traditionally been of concern; in the earlier study of the Upper Mississippi River Basin, for example, drinking water contributed strongly to dose in several centroids, and for the area as a whole displayed contributions ranging from about 3% of the total body dose to about 25% for thyroid. In the TVR, however, the drinking water pathway was indicated to be much less important. Adult total body dose contributions from drinking water averaged about 1.4% of the total dose; dose contributions to most internal organs were about the same, although for skin and bone the contribution was markedly lower.

The small contribution of the drinking water pathway to dose in the TVR probably stems mainly from two factors:

1) In the TVR scenario for nuclear facilities, only minimal use was made of direct discharge of treated radioactive effluents to water bodies; at most types of facilities liquids after treatment were recycled through plant systems, evaporated, or solidified.
2) Streams in the TVR for the most part have high sediment loads. These sediments tend to sorb radionuclides dissolved in the water. In turn, the sediment particles tend to be trapped by settling in the reservoirs behind the many dams on the mainstream systems in the region. Although the trapped sediments may be partially removed by seasonal scouring, the trapping mechanism provides a powerful means for radionuclide dilution and decay prior to reaching points of human ingestion.

The remaining pathway of significance is that of ingestion of food. This is by far the most complex of the pathways, involving the initial uptake of radionuclides by foodstuffs, transference to edible portions of the species (and,

often, transference from vegetable to animal species), and the effects of harvest and of food preparation and transportation on radionuclide content.

Of the 35 categories of foods considered in the study (Table VIII-2), only meat foods (beef, pork, and lamb), milk, and eggs, contributed measurably to annual dose in the TVR (roughly 20% contribution to total body dose). In addition, potatoes, other vegetables, and tree fruits contributed about 15% of the 50-year dose commitment to bone. Foodstuffs in general, however, tended to contribute more to dose in the infant and child than in other age groups.

None of the recreational pathways contributed appreciably to dose. This result is consistent with the generally low radionuclide concentrations in waterways of the region and with the fact that, except for a relatively few individuals, sports fish and game birds constitute an infinitesimal part of the diet.

A summary of the pathway contributions to dose and dose commitment is shown in Figures IX-6 and IX-7. More detailed pathway contributions for selected centroids are shown in Appendix J.

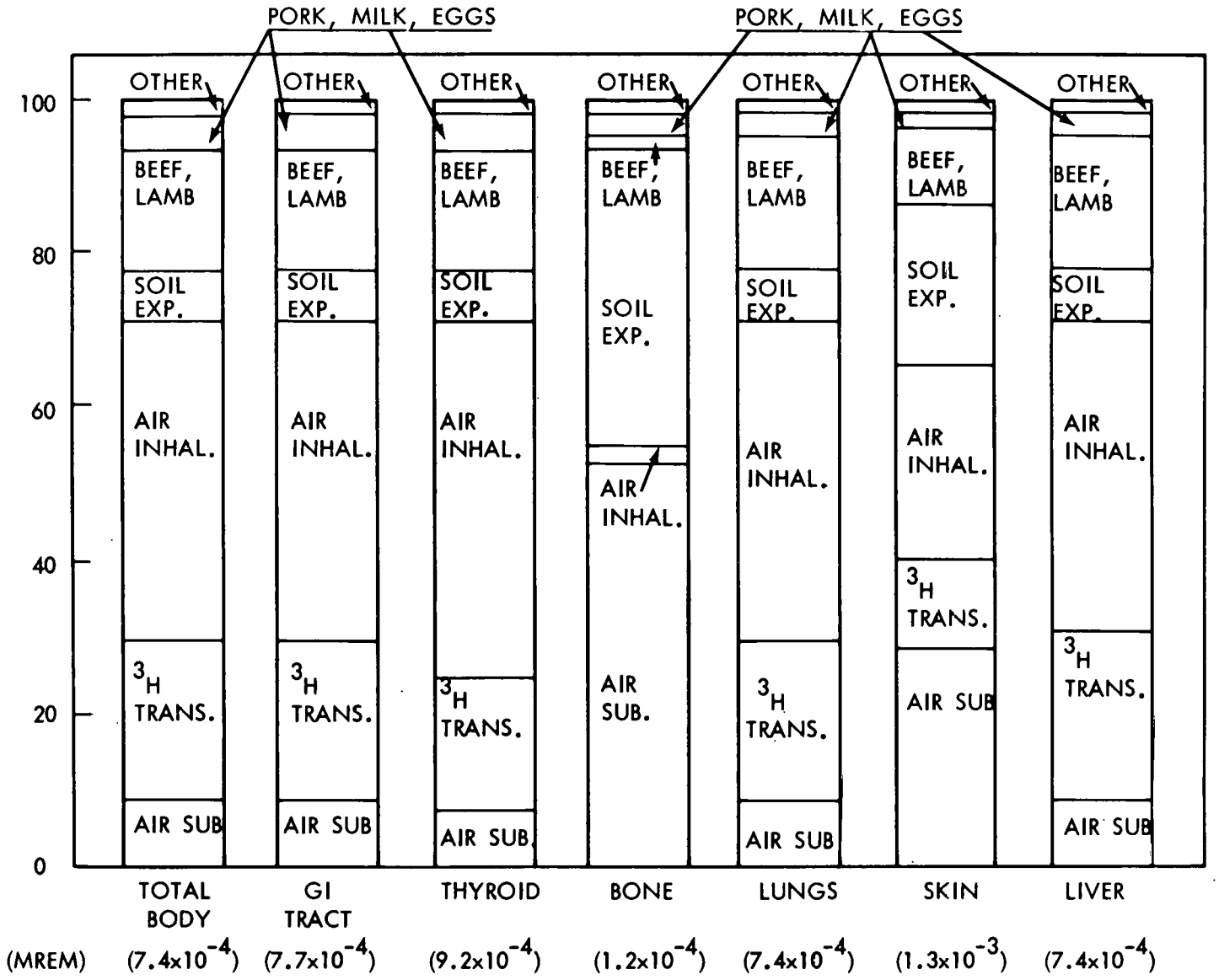


FIGURE IX-6

Pathway Contributions to Annual Dose

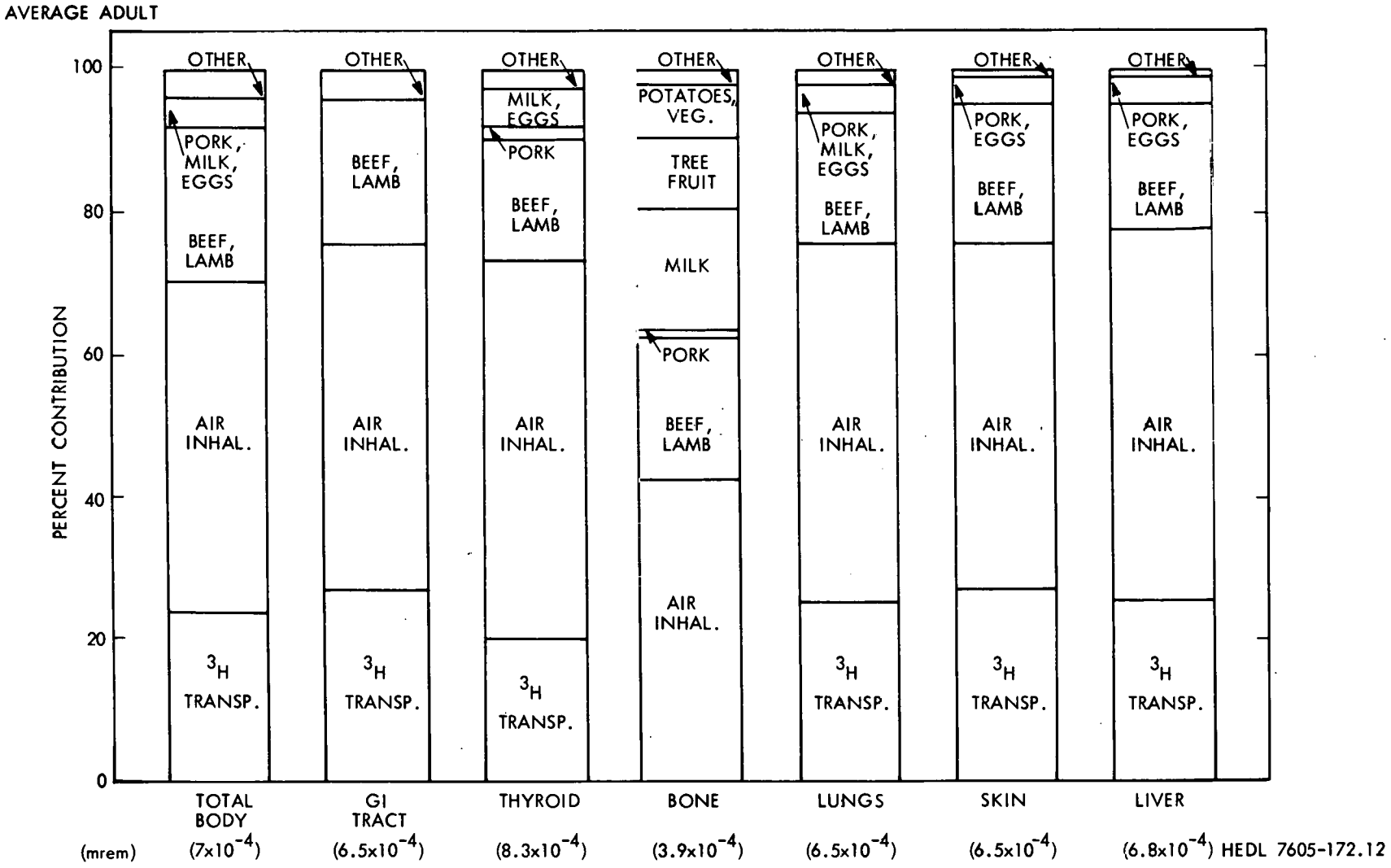


FIGURE IX-7

Pathway Contributions to 50 Year Dose Commitment

X. SENSITIVITY STUDIES:
EFFECTS OF PARAMETER VARIATIONS

The HERMES code provides a capability for estimating of radiation dose from forty-eight radionuclides and ten pathways (including the ingestion of 35 categories of foods). The particular radionuclides and pathways used in this study were selected on the basis of their potential for contribution to regional radiation dose. The results of the present study indicate that nine radionuclides and six pathways contribute nearly all of the computed radiation dose, as detailed in Chapter IX. Parameter variations have been made and analyzed to better understand the mechanisms in the model and the input data which affect the significance of various radionuclides and pathways. The sensitivity studies are designed primarily to indicate critical parts of the calculation as well as to analyze the effects of changes in the various assumptions made.

MAJOR EFFECTS ON DOSE

Most of the potential radiation dose in the region can be attributed to radioactivity transported from source to receptor via the atmosphere. Air inhalation, air submersion, tritium transpiration and exposure from radionuclides deposited on the ground from airborne effluents account for about 75% of the calculated dose. A major part of the remainder of the dose comes from ingestion of foods and drinking water. Approximately 90% of the regional dose is attributable to radionuclide releases directly associated with fuel cycle facilities, primarily reprocessing plants.

The base case calculations show that the major part of the regional dose is due to airborne radionuclide plumes from normal releases to the atmosphere. Another large portion of the dose is attributable to the radionuclide concentration

on the earth's surface resulting from deposition from the plumes. The surface-deposited radionuclides also are important contributors to dose from ingestion of foods, from drinking water, and from pathways associated with the region's waterways. The HERMES model assumes that precipitation in the area results in leaching of radionuclides from the surface. The nuclides are carried in runoff to the regional stream system, and through seepage to the root zone of the soil and to groundwater systems.

Effects of Nuclear Facilities External to the Study Area

In the TVR study, only twelve of the 50 nuclear facility sites assumed to be in operation in the year 2000 were actually located within the Tennessee-Cumberland Basin study area. The remainder were located in regions peripheral to the study area. Separate calculations were made to evaluate the relative impact of the facilities within the study area and of those external to the area. These calculations indicate that about 30% of the regional integrated total-body dose is derived from the externally-sited facilities. This "air envelope" dose contribution is virtually entirely due to tritium.

Effects of Air Deposition on River Concentrations

Radionuclides may enter regional river systems either through direct discharge from nuclear facilities or through precipitation-induced runoff from the watersheds, carrying with it portions of the radionuclide burden deposited from the air upon the ground. As was previously noted, only twelve nuclear facility sites were assumed to lie within the boundaries of the study area. Eleven of these were assumed to discharge effluents directly into rivers, although for two of these tritium is the only radionuclide discharged.

There are 77 points along the rivers at which surface-deposited material from airborne plumes were assumed to enter the river systems. Each of these points represents the cumulative drainage from one or more counties into the

river. It should be emphasized that, in the interest of being conservative, there is a double budgeting of the contribution of the surface deposited material to the calculated dose. First, all the material deposited at a centroid is assumed to contribute to the dose via all of the non-aqueous, and non-airborne pathways. Then it has been assumed that all of the surface deposited material moves to the riverways via runoff and is then available for contributing to dose by the aqueous pathways. Even with this conservatism, the contributions of these pathways to dose are small (Chapter IX).

Table X-1 is a listing of the average monthly injection rates of ten representative radionuclides for each of the two procedures discussed above. The average monthly values for runoff are much larger (again based on a very conservative assumption) than those from the facility outfalls.

It is obvious that the radionuclide contribution to the regional rivers via the overland runoff mechanism, as postulated, is the major governing factor in the potential dose attributable to the aqueous pathways.

TABLE X-1

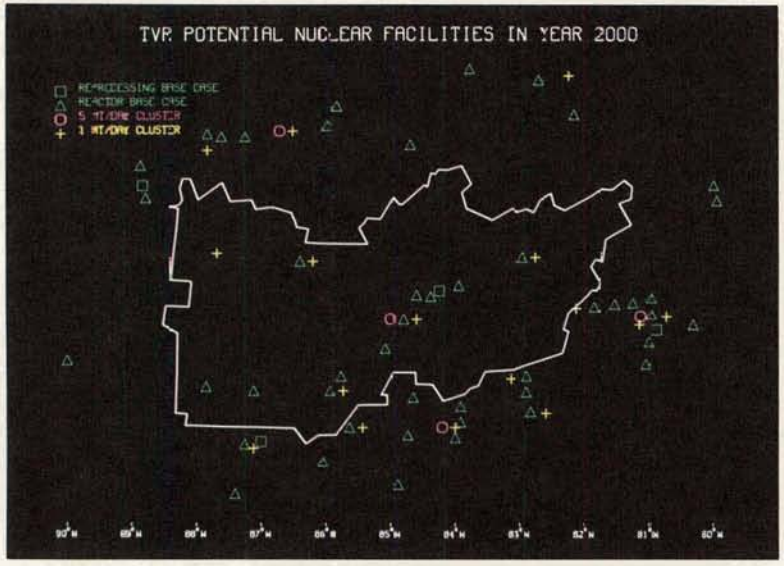
MONTHLY AVERAGE INJECTION RATES TO RIVERS

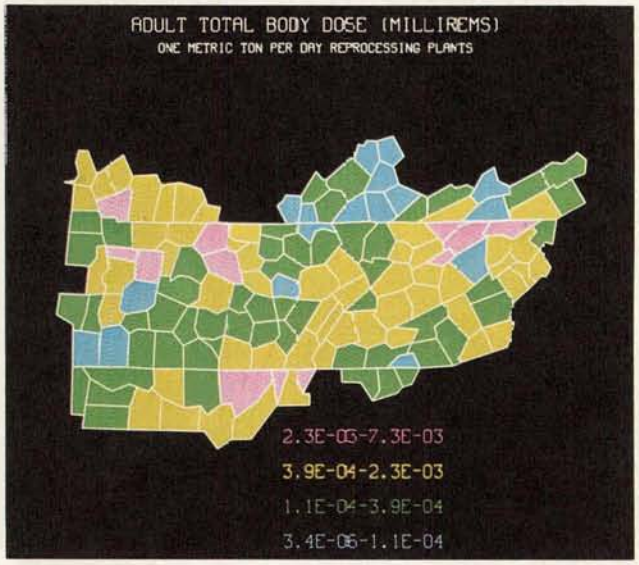
Nuclide	Direct Injection, pCi/Mo.	Overland Runoff, pCi/Mo.
^{3}H	1.5	8.4×10^{3}
^{90}Sr	1.5×10^{-7}	1.6
^{95}Zr	9.5×10^{-7}	3.9×10^{-1}
^{95}Nb	3.5×10^{-6}	4.8
^{106}Ru	6.9×10^{-11}	3.5
^{131}I	2.8×10^{-3}	3.5
^{154}Eu	2.4×10^{-8}	$1. \times 10^{-1}$
^{232}U	3.9×10^{-14}	1.5×10^{-2}
^{238}Pu	1.8×10^{-7}	9.5×10^{-2}
^{244}Cm	3.5×10^{-13}	$5. \times 10^{-2}$

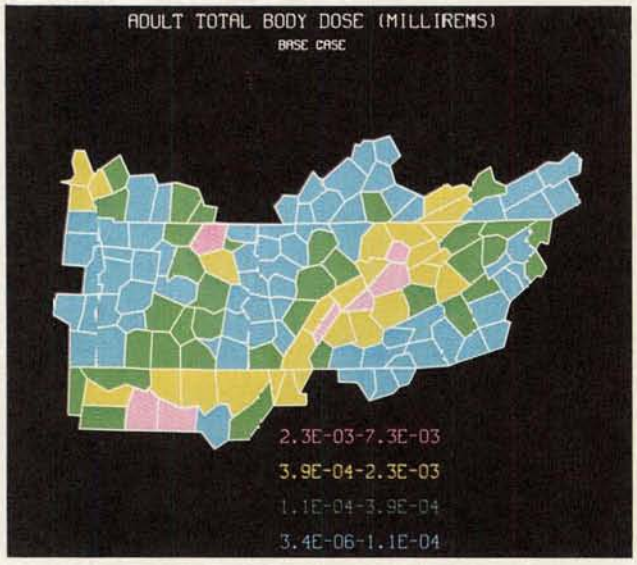
Clustering of Plants

There is a great deal of interest in the nuclear park concept. An investigation was made to determine the potential for changing the regional dose patterns of the base case for two hypothetical nuclear park concepts. In the first case all of the nuclear facilities in the base case study were grouped into six sites. Each site has a combination of nuclear power electrical production plant, fuel fabrication plant and spent fuel reprocessing facilities. For this clustering scheme each of the reprocessing facilities was assigned a plant capacity of five tons per day. The second clustering scheme assembled the nuclear facilities in the study into sixteen sites. Again, each site has representation of all nuclear facilities. The reprocessing plant capacity for this case is one ton per day. The sites assumed for these clusters are shown in Appendix B. Again, it should be emphasized that these are hypothetical sites and hypothetical nuclear facility configurations.

The fuel reprocessing facilities are the principal contributors to dose. The dose pathways that are of most concern in this regard are those dealing with material suspended in the atmosphere or deposited, from airborne plumes, onto the underlying surface. In the base case there were four reprocessing facilities, each with a 1500 ton per year capacity, in the study region and contiguous environs. The upper left presentation in Figure X-1 illustrates the three configurations. Resiting the facilities and changing the rated capacity of the reprocessing plants will obviously change the regional dose distribution. The three other illustrations in Figure X-1 show the changed patterns of adult total-body dose distribution. Figure X-2 shows the cumulative dose as a function of population fraction for the base case and the two clustering cases. Note that the cumulative total-body dose for the 16 site cluster, each containing 1 MT/day fuel reprocessing plant, is much larger for the 96-to-100-percent







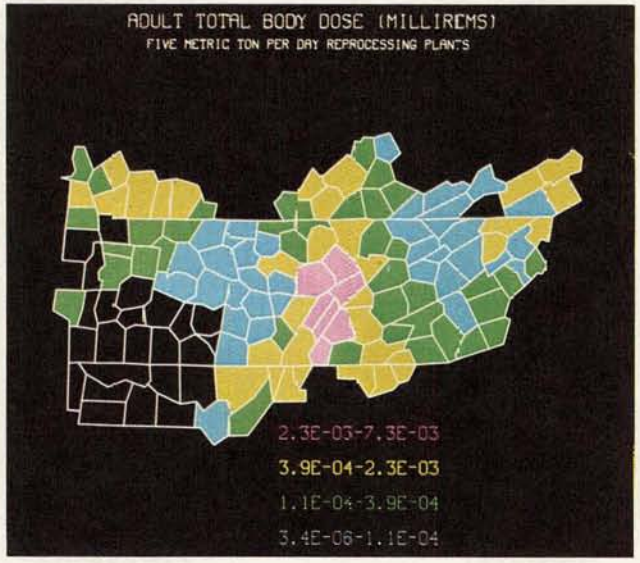


FIGURE X-1

Effect of Siting Configuration on Total Body Dose Patterns in the TVR

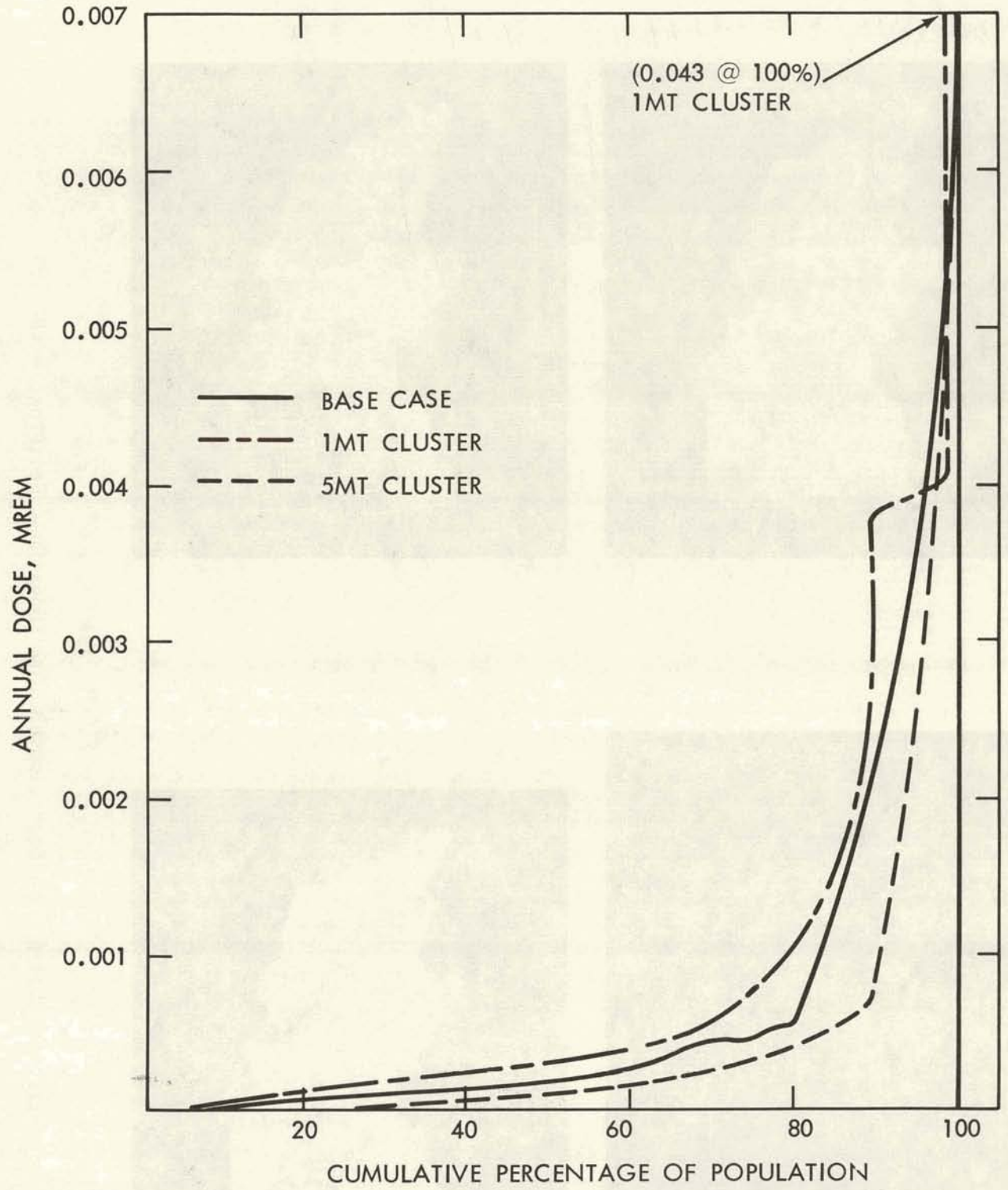


FIGURE X-2

Variation in Population Dose Distribution with Siting Assumption

population ranking. In Figure X-2, the curve for this case is terminated at the 95 percent grouping; the actual values of calculated total-body dose and pertinent data are given in Table X-2 for four counties containing clustered sites. The higher dose values that have been calculated for these four centroids point up the problem of judicious siting of fuel reprocessing plants to minimize their radiological impact.

TABLE X-2

HIGH-DOSE COUNTIES FOR 1 MT/DAY CLUSTER CASE

Nuclear Site No.	County No.	County Name	Annual Total-Body Dose (Mrem)	Latitude	Longitude
16	126	Houston, Tenn	1.56×10^{-2}	36° 19'	87° 42'
15	20	Hawkins, Tenn	1.91×10^{-2}	36° 28'	82° 51'
14	96	Sumner, Tenn	2.43×10^{-2}	36° 50'	86° 27'
13	92	Jackson, Ala	4.52×10^{-2}	34° 47'	86° 55'

RADIONUCLIDE TRANSPORT CONSIDERATIONS

Radionuclide transport and diffusion from source to receptor, culminating ultimately in a radiological dose to man, involves both coupled and uncoupled atmosphere and water mechanisms. There are implicit data assumptions involving the natural atmospheric and hydrologic parameters that affect the radionuclide transport, that have been incorporated into the pertinent HERMES code elements. In order that an appreciation of the potential effect of these assumptions may be made, a series of computations have been made wherein the major data parameters were either varied or assembled in a different form.

Variations of Air Transport Parameters

Wind Speed and Stability Categorization

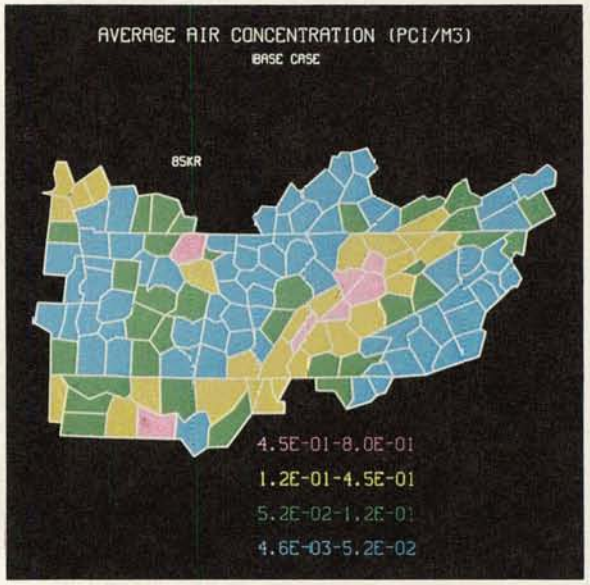
The basic meteorological data bank used in the base case is an analysis of standard U. S. Weather Service observations via a modification of the STAR[29] code. These are percent frequency of occurrence data categorized as a function of: 1) sixteen compass rose sectors, 2) six stability classes, and 3) six wind speed classes. To test their effects on nuclide concentration, these parameters were restricted in three cases to, respectively: 1) wind speed constant at five meters per second, 2) atmospheric stability class set to type "C", and 3) atmospheric stability classes restricted to two types "C" and "D". The results of these calculations are shown in Figure X-3. The four data displays in this figure show variations in ^{85}Kr concentrations for the base case for the three mentioned restrictions on atmospheric conditions.

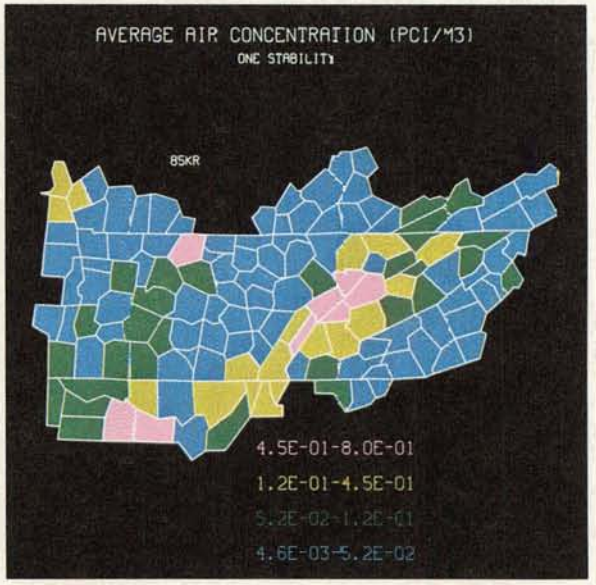
Height of Release

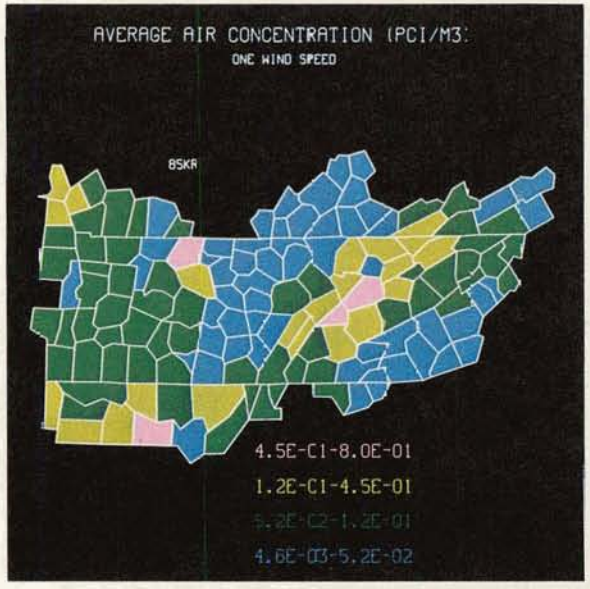
In the base case the discharge point to the atmosphere for each fuel reprocessing plant was assumed to be at a stack elevation of 100 meters. All other nuclear facilities were presumed to have the atmospheric discharge point at the surface. To test the code response to stack elevation variability two runs were made where: a) all atmospheric discharge is made at the surface, and b) all discharge to the air is at 100 meters. The reduction of the reprocessing plant stack from 100 meters to the surface has the effect of raising the air concentrations of the counties closest to the facilities. The mean tritium air concentrations over the entire study area were increased by a factor of 3.32 as a result of this action. Conversely, the arbitrary assignment of a 100 meter release point for all facilities has the effect of reducing the tritium air concentrations to about 80% of base case values.

Water Transport Parameter Variations

Data characterizing the regional waterways has been developed by (1) statistical analysis of point measurements of river flow in the region, (2) empirical







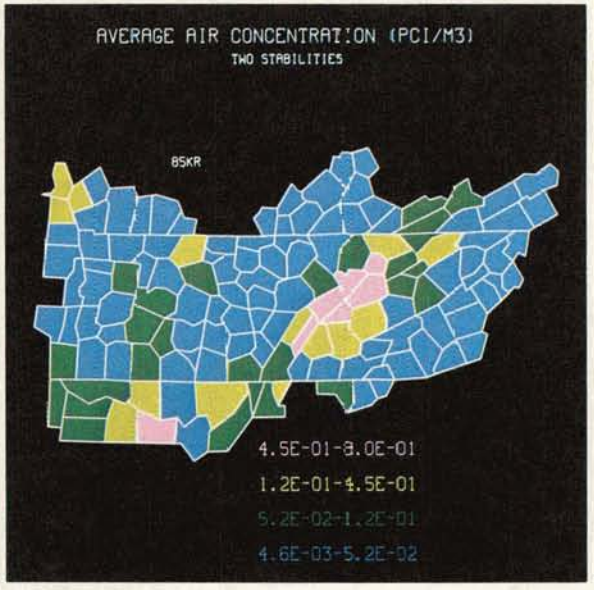


FIGURE X-3

Effect of Variation in Atmospheric Conditions on ^{85}Kr Concentration Patterns

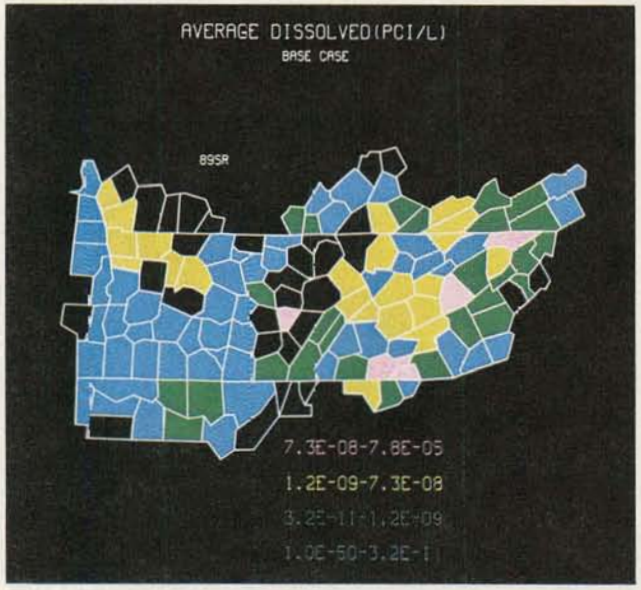
derivation of equations representing sediment loading, and (3) analysis of relatively few "grab" samples of water and of bottom sediment from river systems, to evaluate absorptive characteristics of sediments toward specific chemical elements.

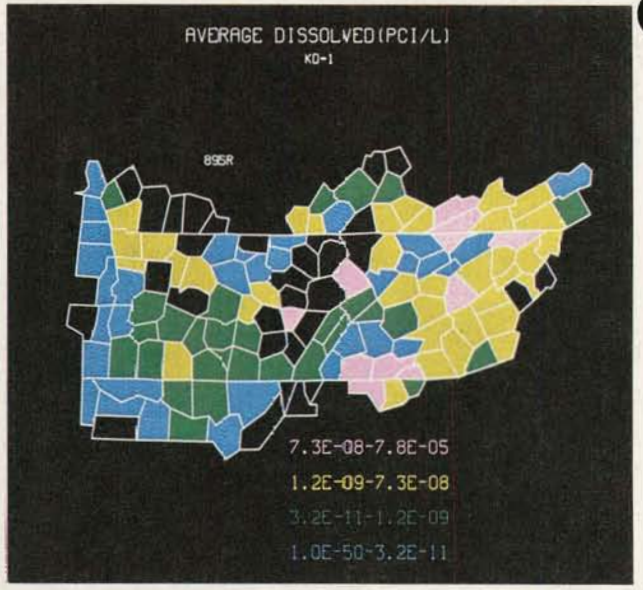
Because of lack of more definitive data, it was necessary to apply the available information on sediment characteristics rather broadly over larger regions of the study area. Furthermore, sediment behavior toward many of the radionuclides in the study was estimated on the basis of chemical similarity, again because of the lack of definitive data.

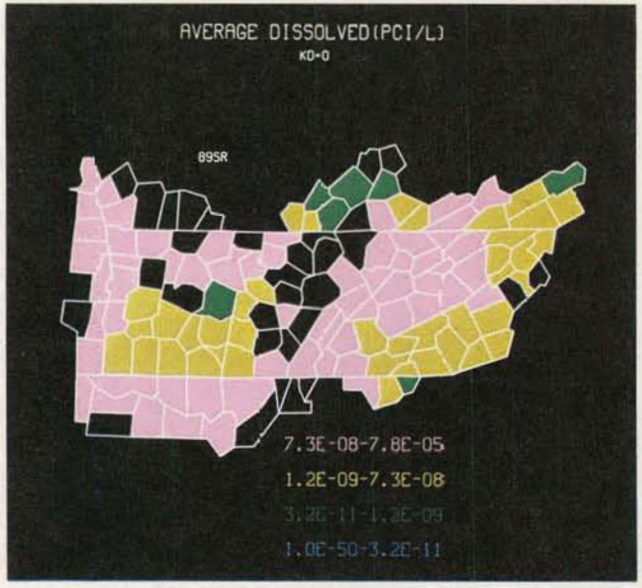
The behavior of sediment toward radionuclides is expressed as the distribution coefficient, K_d. This coefficient represents the ratio of concentration of a specific nuclide sorbed on sediment particles to the concentration remaining in solution in the water containing the sediment. Values of distribution coefficients used in the study are given in Appendix G. Because there is considerable uncertainty in these values, a series of parametric calculations were made with distribution coefficients set at arbitrary values. Results of these calculations are shown in Figures X-4 through X-7, for the radionuclides ^{89}Sr and ^{95}Zr. The strontium isotope has a relatively low distribution coefficient, with base values ranging from 80 to 280 through the study region. Zirconium, on the other hand, has a high K_D, ranging from 16,000 to 280,000 in base calculations.

The sensitivity coefficients assumed three different K_D values: zero, unity ($K_D = 1$), and 200,000. A K_D value of zero implies no sorption on sediments, with the entire nuclide burden present in dissolved form.

In the case of ^{89}Sr, the concentration in solution is not greatly changed (at most not over one order of magnitude) when the K_D is reduced from its base values to a value of unity. Further reducing the K_D to zero increases the dissolved concentrations noticeably, whereas an increase in K_D to 200,000 markedly







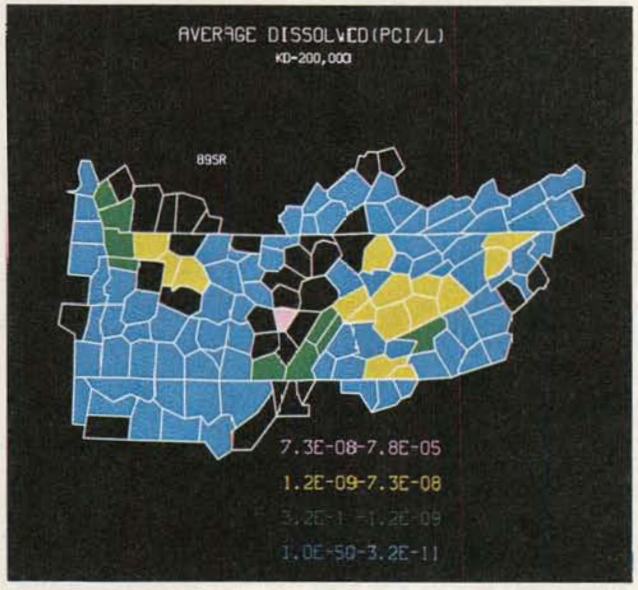
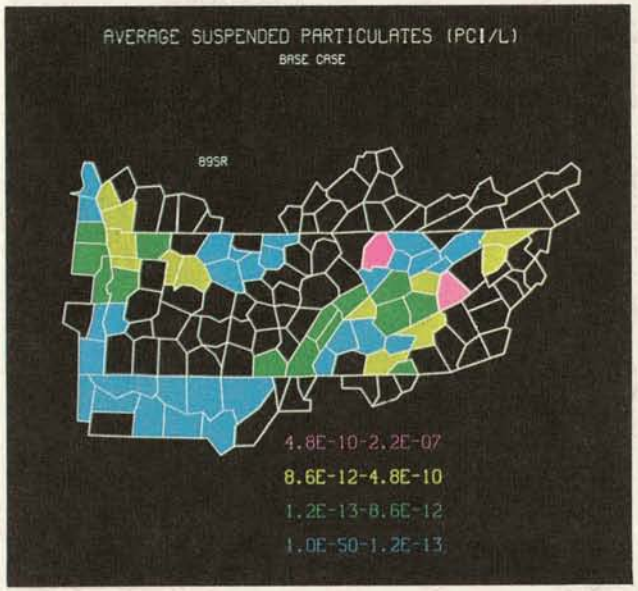
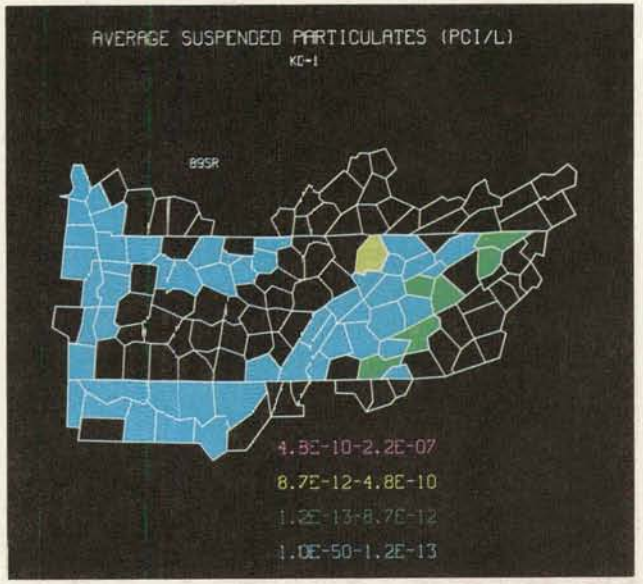


FIGURE X-4

Effects of Distribution Coefficient Value on Concentrations of Dissolved ^{89}Sr





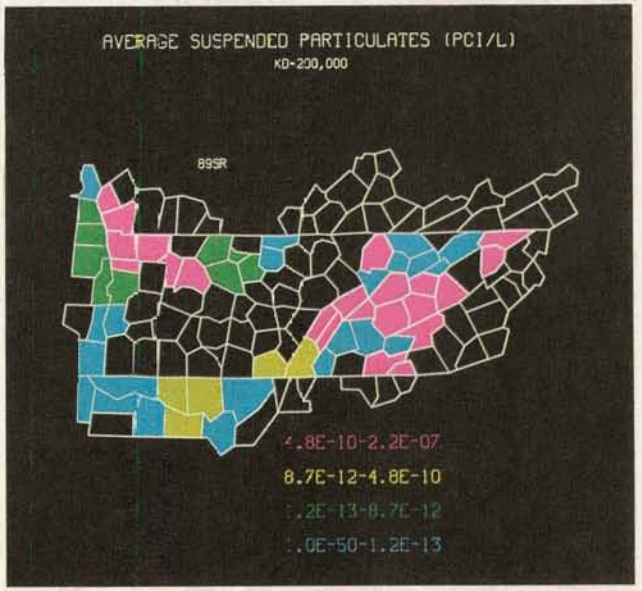


FIGURE X-5

Effects of Distribution Coefficient Value on Concentrations of ^{89}Sr in Suspended Sediments

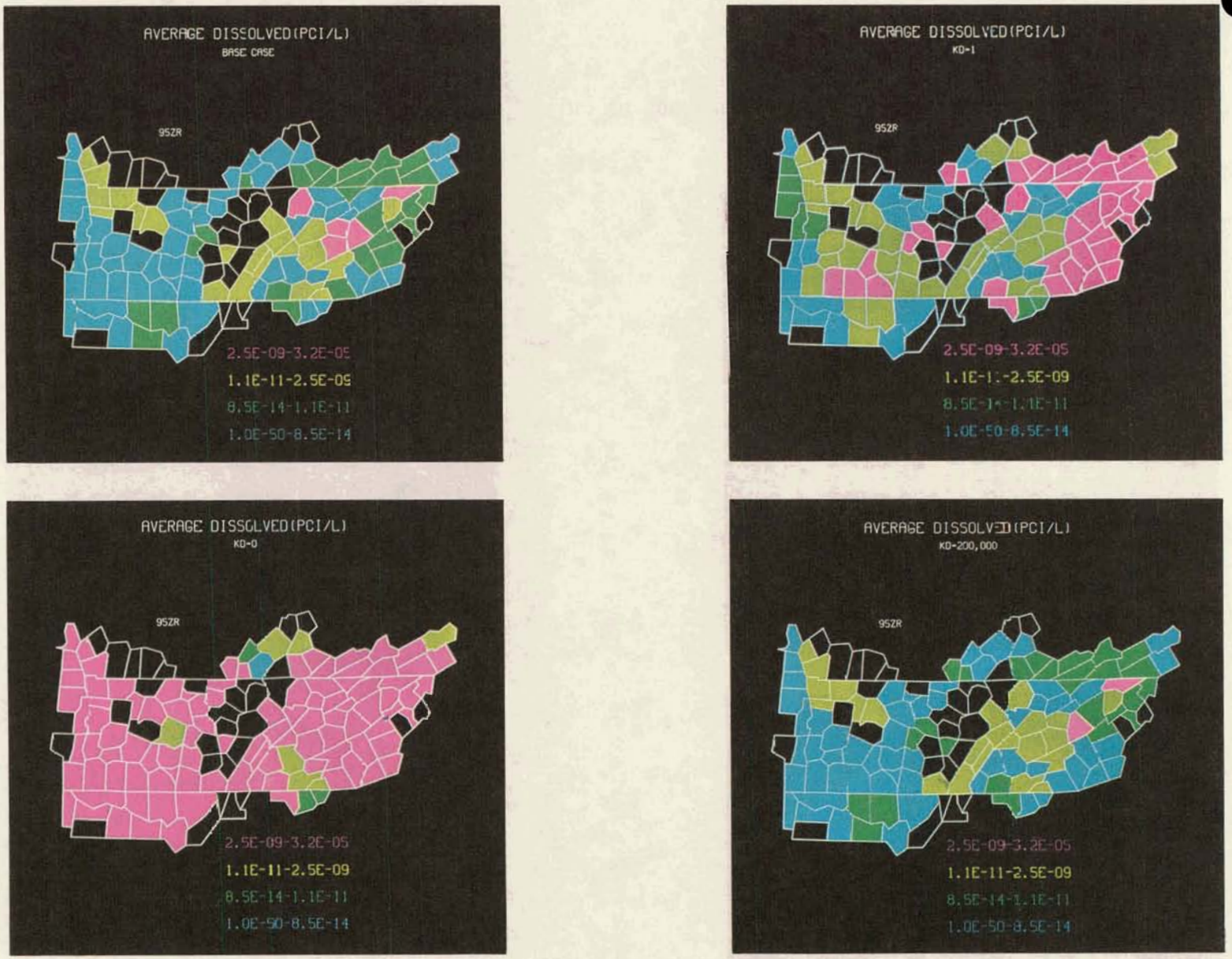
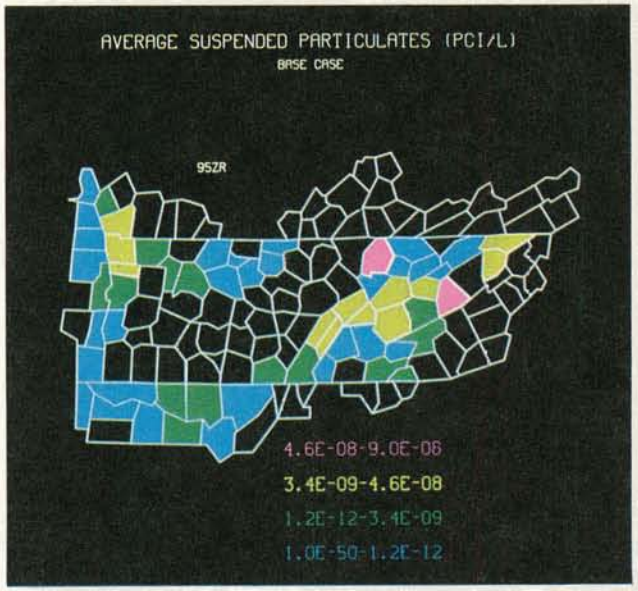
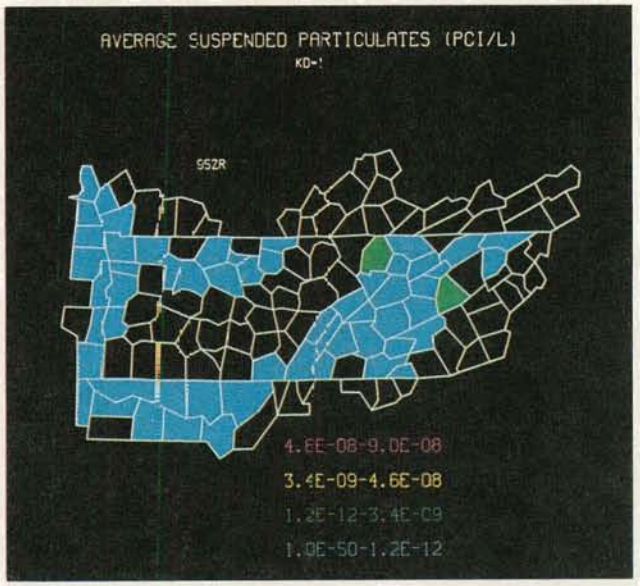


FIGURE X-6

Effects of Distribution Coefficient Value on Concentration of Dissolved ^{95}Zr





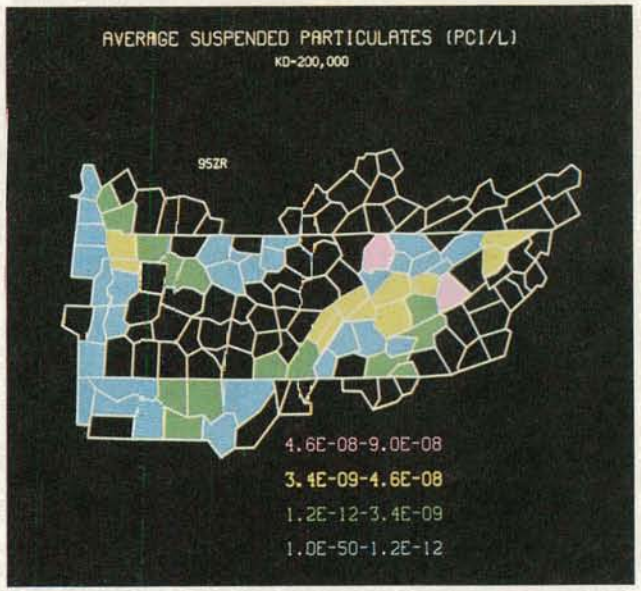


FIGURE X-7

Effects of Distribution Ccefficient Value on Concentrations of ^{95}Zr in Suspended Sediments

diminishes them. Sediment concentrations, on the other hand, appear to be rather strongly affected by either increasing or lowering K_D values. For zirconium, on the other hand, the base values for both dissolved and suspended concentrations are similar to those for the case with K_D set at 200,000. At lower K_D values dissolved concentrations are markedly increased at the expense of the sediment concentrations.

Variations in the value of the distribution coefficient not only affect the ratio between dissolved and suspended nuclide activity, but also can affect the total quantities of activity transported downstream. Sediment particles which settle to the river bed carry their proportionate loading of radionuclides with them, thus depleting the amounts transported further downstream. This radionuclide "trapping" mechanism, particularly important in sedimented reservoir systems such as exist in the Tennessee and Cumberland drainages, will have varying effect depending on the K_D values exhibited by the specific sediments. The parameterizaton studies offer insight as to the magnitude of their effects. For the present study, the contribution to dose by water-related pathways was found to be small. Hence, even large variations in K_D from the values assumed would have relatively small effect on the resulting dose to the population of the region.

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APPENDIX A

POTENTIAL NUCLEAR FACILITIES BY SITE AND ASSUMED LOCATION

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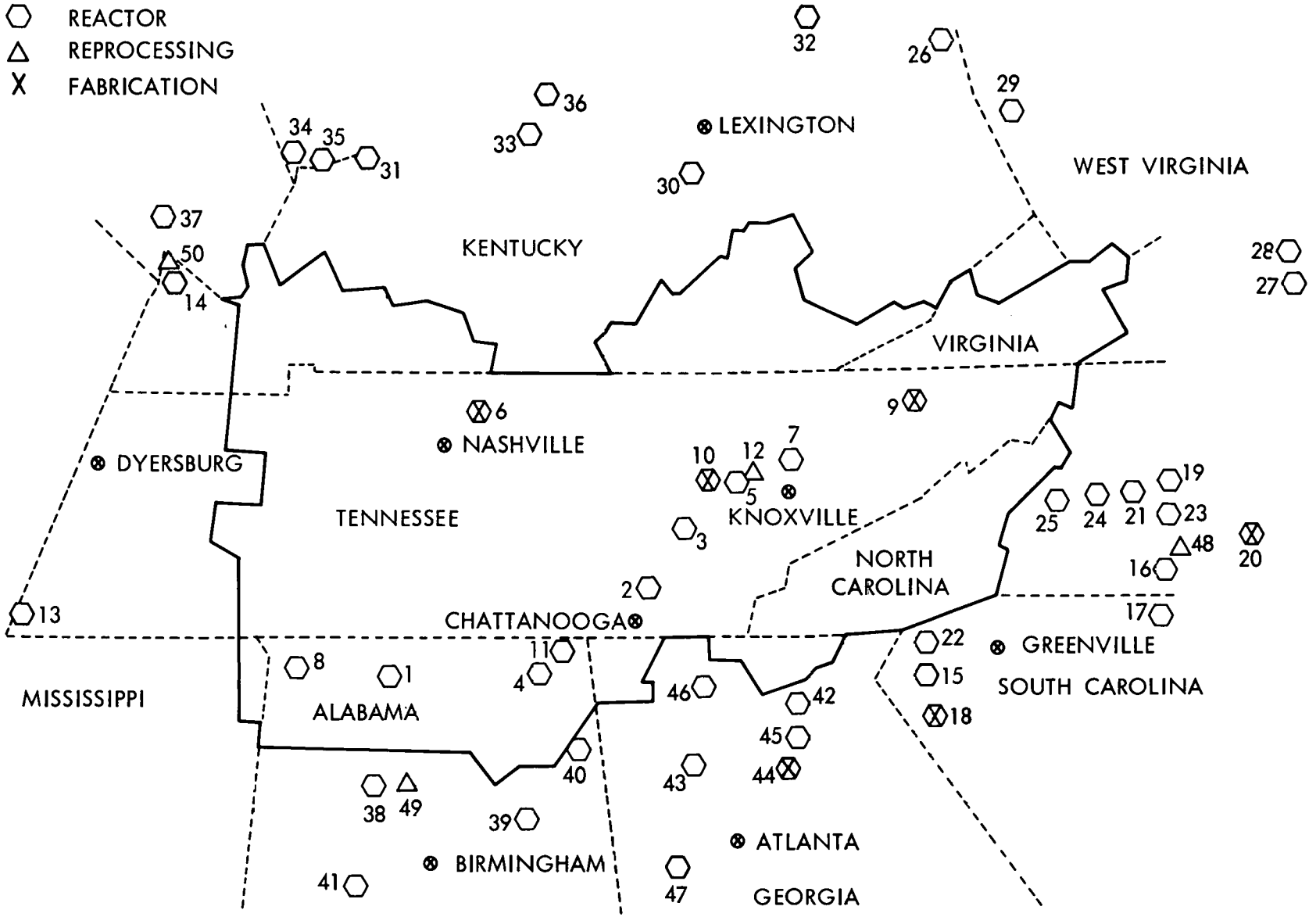

FIGURE A-1

Potential Nuclear Facility Sites in the TVR

TABLE A-1

ASSUMED NUCLEAR GENERATING PLANTS
BY SITE

Site Number	Site Name	Plant Type	Start-up Year	No. of Units	Unit Capacity, MWe
Central Region					
1	Browns Ferry	BWR	73,74,74	3	1065
2	Sequoyah	PWR	75,75	2	1125
3	Watts Bar	PWR	77,78	2	1170
4	Bellefonte	PWR	80,81	2	1175
5	Oak Ridge	LMFBR	80	1	400
6	Gallatin	BWR	81,81,82,82	4	1200
7	Bull Run	BWR HTGR	83,84 85,86	2 2	1200 1200
8	Colbert	PWR	87,88,89	3	1200
9	John Sevier	PWR	89,90,98,99	4	1200
10	Kingston	LMFBR	90,00	2	1200
11	Widows Creek	LMFBR	96,97	2	1200
Air Envelope					
13	Allen	PWR LMFBR	86,87 94,95	2 2	1200 1200
14	Shawnee	HTGR	91,92,93,94	4	1200
15	Oconee	PWR	73,73,74	3	886
16	McGuire	PWR	75,77	2	1150
17	Catawba	PWR	79,80	2	1180
18	Hartwell	PWR	81,82,83,84	4	1200
19	Long Island	BWR	83,85,86,87	4	1200
20	High Rock	HTGR	88,89,97,98	4	1200

Site Number	Site Name	Plant Type	Start-up Year	No. of Units	Unit Capacity, MWe
21	Hickory	PWR	90,92,96,97	4	1200
22	Keowee	LMFBR	93,93,99,00	4	1200
23	Terrell	PWR	95,95,96	3	1200
24	Rhodhiss	LMFBR	96,98,99,00	4	1200
25	James	BWR	98,00	2	1200
26	Russell	PWR	83,85	2	1200
27	Franklin	HTGR	87,89	2	1200
28	Smith Mountain	BWR	92,93	2	1200
29	Ranger	LMFBR	97,98	2	1200
30	Dix Dam	PWR	88,91	2	1200
31	Stanley	HTGR	94,94	2	1200
32	Maysville	LMFBR	97,98	2	1200
33	West Point	PWR	79,84,88	3	1200
34	Posey	PWR	82,86	2	1200
35	Cypress	HTGR	90,92	2	1200
36	Mill Creek	HTGR	95,96	2	1200
37	Joppa	BWR	99	1	1200
38	Falls City	PWR	80,80,81	3	1200
39	Onatchee	BWR	86,87	2	1200
40	Cedar Bluff	HTGR	90,91	2	1200
41	Black Warrior	LMFBR	96,97	2	1200
42	Sidney Lanier	PWR	79,81	2	1200
43	Allatoona	BWR	80,82	2	1200
44	Buford	PWR	84,85,89,91	4	1200
45	Chicopee	LMFBR	91,92,94,95	4	1200
46	Carters Dam	HTGR	92,93	2	1200
47	Chattahoochee	LMFBR	99,00	2	1200

TABLE A-2

ASSUMED FUEL REPROCESSING PLANTS BY SITE

Site Number	Site Name	Fuel Type(s) Processed	Start-up Year	Capacity MT/day
Central Region				
12	Oak Ridge Repro.	LWR-U	1980	5
Air Envelope				
48	Kannapolis	LWR, HTGR, LMFBR	1984	5
49	Cullman	LWR, HTGR, LMFBR	1990	5
50	Paducah	LWR, HTGR, LMFBR	1994	5

TABLE A-3

ASSUMED FUEL FABRICATION PLANTS BY SITE

Site Number	Site Name	Fuel Type Processed	Start-up Year	Capacity MT/day
Central Region				
6	Gallatin	LWR-U	1974	3
9	John Sevier	LWR-Pu	1982	3
10	Kingston	LMFBR	1990	3
Air Envelope				
18	Hartwell	LWR-Pu	1978	3
20	High Rock	HTGR	1985	1
44	Buford	LWR-U	1983	5

TABLE B-1

CLUSTER SITE LOCATIONS

CLUSTER SITES FOR REPROCESSING PLANTS HAVING 5 TONS/DAY CAPACITY

Name	Reprocessing Plant Start-Up	Contains Reactors from Sites*
Watts Bar	1984	1-15
Troutmans	1989	16-26
Forsyth	1992	27-38
Stephensport	1996	39-48

TABLE B-2

CLUSTER SITES FOR REPROCESSING PLANTS HAVING 1 TON/DAY CAPACITY

Name	Reprocessing Plant Start-Up	Contains Reactors from Sites*
Salem	1980	16, 23
Denver	1985	17, 22, 24
Savannah	1993	18, 19
Troutmans	1997	20, 21
Nepo	2000	25, 26
Glenwood	1989	27-30
Stephensport	1988	31, 33, 34, 37
Posey	1992	32, 35, 36, 38
Lewis Smith	1987	39-42
Forsyth	1985	45-46
Cedar Bluff	1992	43, 44, 47, 48
Watts Bar	1980	2, 3, 15
Bellefonte	1988	1, 4, 10
Gallatin	1984	5, 6, 12
John Sevier	1986	7, 8, 11
Cumberland	1992	9, 13, 14

* See Appendix A for site number designations.

APPENDIX B

CLUSTER SITE LOCATIONS

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Table B-2	Cluster Sites for Reprocessing Plants Having 1 Ton/Day Capacity	B-2

APPENDIX C

MONTHLY CAPACITY FACTORS

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TABLE C-1	Monthly Capacity Factors	C-2

APPENDIX C

TABLE C-1

MONTHLY CAPACITY FACTORS

YEAR 2000

Unit	Capacity Factor (%)											
	J	F	M	A	M	J	J	A	S	O	N	D
Browns Ferry 1	90	0	0	90	90	90	90	90	90	90	90	90
2	90	90	90	90	0	0	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	90	0	0
Sequoyah 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
Watts Bar 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Bellefonte 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	0	0	90	90	90	90	90	90
Gallatin 1	90	90	90	90	0	0	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
3	90	90	90	90	90	0	0	90	90	90	90	90
4	90	90	90	90	90	90	90	90	90	90	0	0
Bull Run 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	0	0	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	0	0	90
4	90	90	90	90	90	0	0	90	90	90	90	90
Oak Ridge	90	90	90	90	90	90	90	90	0	90	90	90
Allen 1	90	90	90	90	90	0	0	90	90	90	90	90
2	90	90	90	90	0	0	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	0	0	90	90
4	90	90	90	90	90	90	90	90	0	0	90	90
Colbert 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	90	0	0	90	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	0	0	90	90
John Sevier 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
3	90	90	90	90	0	0	90	90	90	90	90	90
4	90	90	90	90	90	90	90	90	0	0	90	90
Shawnee 1	90	90	90	90	90	0	0	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
3	90	90	90	90	90	90	90	90	90	90	0	0
4	90	90	90	90	90	90	90	90	90	90	0	0

TABLE C-1 (Cont'd)

Unit	Capacity Factor (%)											
	J	F	M	A	M	J	J	A	S	O	N	D
Widows Creek 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	90	0	0	90
Kingston 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Oconee 1	90	90	90	90	90	90	90	90	0	0	90	90
2	90	0	0	90	90	90	90	90	90	90	90	90
3	90	90	90	0	0	90	90	90	90	90	90	90
McGuire 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	90	0	0	90
Catawba 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	0	0	90	90	90	90	90	90	90	90	90
Hartwell 1	0	0	90	90	90	90	90	90	90	90	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	90	0	0
4	90	90	90	0	0	90	90	90	90	90	90	90
Long Island 1	90	90	90	90	90	0	0	90	90	90	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	0	0	90
4	90	90	90	0	0	90	90	90	90	90	90	90
High Rock 1	0	90	90	90	90	90	90	90	90	90	90	0
2	90	0	0	90	90	90	90	90	90	90	90	90
3	90	90	0	0	90	90	90	90	90	90	90	90
4	90	90	90	90	90	90	90	90	0	0	90	90
Hickory 1	0	90	90	90	90	90	90	90	90	90	90	0
2	90	90	90	90	90	90	90	90	90	0	0	90
3	90	0	0	90	90	90	90	90	90	90	90	90
4	90	90	90	0	0	90	90	90	90	90	90	90
James 1	90	0	0	90	90	90	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Keowee 1	0	0	90	90	90	90	90	90	90	90	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	0	0	90
4	90	90	0	0	90	90	90	90	90	90	90	90
Terrell 1	90	90	90	90	0	0	90	90	90	90	90	90
2	0	0	90	90	90	90	90	90	90	90	90	90
3	90	90	0	0	90	90	90	90	90	90	90	90

TABLE C-1 (Cont'd)

Unit	Capacity Factor (%)											
	J	F	M	A	M	J	J	A	S	O	N	D
Rhodhiss 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	0	0	90	90	90	90	90	90	90	90	90
3	90	90	90	90	90	90	90	90	90	0	0	90
4	90	90	0	0	90	90	90	90	90	90	90	90
Franklin 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	0	0	90	90	90	90	90	90
Russell 1	90	90	0	0	90	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	90	0	0	90
Ranger 1	90	0	0	90	90	90	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Smith Mountain 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
Falls City 1	90	90	90	90	0	0	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
3	90	90	0	0	90	90	90	90	90	90	90	90
Onatchee 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	0	0	90	90	90	90	90	90	90	90	90
Cedar Bluff 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	0	0	90	90	90	90	90	90	90	90
Black Warrior 1	0	90	90	90	90	90	90	90	90	90	90	0
2	90	0	0	90	90	90	90	90	90	90	90	90
Sidney Lanier 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	0	0	90	90	90	90	90	90	90	90
Allatoona 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	0	0	90	90	90	90	90	90	90	90	90
Buford 1	90	90	90	90	90	0	0	90	90	90	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
3	90	0	0	90	90	90	90	90	90	90	90	90
4	0	90	90	90	90	90	90	90	90	90	90	0
Chicopee 1	90	90	90	0	0	90	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	0	0	90	90
3	90	0	0	90	90	90	90	90	90	90	90	90
4	90	90	90	90	90	90	90	90	90	90	0	0
Carter's Dam 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	0	0	90	90	90	90	90	90	90	90

TABLE C-1 (Cont'd)

Unit	Capacity Factor (%)											
	J	F	M	A	M	J	J	A	S	O	N	D
Chattahoochee 1	0	0	90	90	90	90	90	90	90	90	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
Dix Dam 1	0	90	90	90	90	90	90	90	90	90	90	0
2	90	0	0	90	90	90	90	90	90	90	90	90
Stanley 1	90	0	0	90	90	90	90	90	90	90	90	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Maysville 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	90	0	0	90	90	90	90	90	90	90
West Point 1	90	90	90	90	0	0	90	90	90	90	90	90
2	90	90	90	90	90	90	90	90	90	0	0	90
3	90	90	0	0	90	90	90	90	90	90	90	90
Posey 1	0	90	90	90	90	90	90	90	90	90	90	0
2	90	0	0	90	90	90	90	90	90	90	90	90
Cypress 1	90	90	90	90	90	90	90	90	0	0	90	90
2	90	90	0	0	90	90	90	90	90	90	90	90
Mill Creek 1	90	90	90	90	90	90	90	90	90	0	0	90
2	90	90	90	0	0	90	90	90	90	90	90	90
Joppa	90	90	0	0	90	90	90	90	90	90	90	90

APPENDIX D

RADIONUCLIDES CONSIDERED IN STUDY

		PAGE
TABLE D-1	Radionuclides Considered in Study	D-2

		Half Life	Half Life (sec)	λ (sec^{-1})	
^{3}H	1	12.33 y	3.888×10^{8}	1.782×10^{-9}	1
^{14}C	2	5730 y	1.807×10^{11}	3.835×10^{-12}	2
^{22}Na	3	2.601 y	8.203×10^{7}	8.448×10^{-9}	3
^{39}Ar	4	269 y	8.483×10^{9}	8.169×10^{-11}	4
^{58}Co	5	71.3 d	6.160×10^{6}	1.125×10^{-7}	5
^{60}Co	6	5.272 y	1.663×10^{8}	4.167×10^{-9}	6
^{85m}Kr	7	4.48 H	1.613×10^{4}	4.296×10^{-5}	7
^{85}Kr	8	10.73 y	3.384×10^{8}	2.048×10^{-9}	8
^{87}Kr	9	76 m	4.560×10^{3}	1.520×10^{-4}	9
^{88}Kr	10	2.8 h	1.008×10^{4}	6.875×10^{-5}	10
^{89}Kr	11	3.16 m	1.896×10^{2}	3.655×10^{-3}	11
^{89}Sr	12	50.5 d	4.363×10^{6}	1.588×10^{-7}	12
^{90}Sr	13	29 y	9.145×10^{8}	7.578×10^{-10}	13
^{90}Y	14	64.0 h	2.304×10^{5}	3.008×10^{-6}	14
^{91}Y	15	58.6 d	5.063×10^{6}	1.369×10^{-7}	15
^{95}Zr	16	65.5 d	5.659×10^{6}	1.225×10^{-7}	16
^{95}Nb	17	35.1 d	3.033×10^{6}	2.285×10^{-7}	17
^{103}Ru	18	39.6 d	3.421×10^{6}	2.026×10^{-7}	18
^{106}Ru	19	369 d	3.188×10^{7}	2.174×10^{-8}	19
^{123}Sn	20	129 d	1.115×10^{7}	6.215×10^{-8}	20
^{125m}Te	21	58 d	5.011×10^{6}	1.383×10^{-7}	21
^{127}Te	22	9.4 h	3.384×10^{4}	2.048×10^{-5}	22
^{129m}Te	23	33.4 d	2.886×10^{6}	2.401×10^{-7}	23
^{132}Te	24	78 h	2.808×10^{5}	2.468×10^{-6}	24
^{129}I	25	1.59×10^{7} y	5.014×10^{14}	1.382×10^{-15}	25
^{131}I	26	8.041 d	6.947×10^{5}	9.976×10^{-7}	26
^{133}I	27	20.8 h	7.488×10^{4}	9.255×10^{-6}	27
^{133}Xe	28	5.29 d	4.570×10^{5}	1.516×10^{-6}	28
^{135m}Xe	29	15.3 m	9.180×10^{2}	7.549×10^{-4}	29
^{135}Xe	30	9.17 h	3.301×10^{4}	2.099×10^{-5}	30
^{137}Xe	31	3.84 m	2.304×10^{2}	3.008×10^{-3}	31
^{138}Xe	32	14.2 m	8.520×10^{2}	8.134×10^{-4}	32
^{134}Cs	33	2.06 y	6.496×10^{7}	1.067×10^{-8}	33
^{137}Cs	34	30.1 y	9.492×10^{8}	7.301×10^{-10}	34
^{140}Ba	35	12.79 d	1.105×10^{6}	6.271×10^{-7}	35
^{140}La	36	40.23 h	1.448×10^{5}	4.786×10^{-6}	36
^{141}Ce	37	32.53 d	2.811×10^{6}	2.465×10^{-7}	37
^{144}Ce	38	284.4 d	2.457×10^{7}	2.821×10^{-8}	38
^{154}Eu	39	8.6 y	2.712×10^{8}	2.555×10^{-9}	39
^{232}U	40	72 y	2.271×10^{9}	3.052×10^{-10}	40
^{234}U	41	2.44×10^{5} y	7.695×10^{12}	9.006×10^{-14}	41
^{238}Pu	42	87.8 y	2.769×10^{9}	2.503×10^{-10}	42
^{239}Pu	43	2.439×10^{4} y	7.692×10^{11}	9.009×10^{-13}	43
^{240}Pu	44	6540 y	2.062×10^{11}	3.361×10^{-12}	44
^{241}Pu	45	15 y	4.730×10^{8}	1.465×10^{-9}	45
^{241}Am	46	433 y	1.366×10^{10}	5.073×10^{-11}	46
^{242}Cm	47	163 d	1.408×10^{7}	4.922×10^{-8}	47
^{244}Cm	48	17.9 y	5.645×10^{8}	1.228×10^{-9}	48

TABLE D-1

RADIONUCLIDES CONSIDERED IN STUDY

APPENDIX E

POTENTIAL RADIONUCLIDE RELEASE RATES

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE
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E-2	Typical Fuel Reprocessing Plant Radionuclide Concentrations in Fuel	E-3
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E-4	Typical Fuel Fabrication Plant Radionuclide Releases	E-5

TABLE E-1

TYPICAL NUCLEAR POWER PLANTS RADIONUCLIDE RELEASES

(CURIES/YEAR)

	PWR		BWR		HTGR		LMFBR	
ISOTOPE	GASEOUS	LIQUID	GASEOUS	LIQUID	GASEOUS	LIQUID	GASEOUS	LIQUID
H3	7.79E+02	7.79E+02	3.11E+01	3.11E+01	6.66E+01	6.66E+01	5.40E+01	5.40E+01
C14	0.	0.	0.	0.	0.	0.	0.	0.
NA22	0.	0.	0.	0.	0.	0.	1.80E-06	0.
AR39	0.	0.	0.	0.	0.	0.	7.20E+01	0.
CO58	0.	4.15E-05	0.	2.09E-05	0.	0.	5.94E-09	0.
CO60	0.	0.	0.	0.	0.	0.	4.68E-11	0.
KR85M	1.06E+01	0.	1.25E+02	0.	0.	0.	2.52E-01	0.
KR85	9.05E+02	0.	7.23E+02	0.	2.55E+03	0.	3.60E-01	0.
KR87	6.93E+00	0.	1.15E+01	0.	8.64E+00	0.	3.42E-10	0.
KR88	2.01E+01	0.	1.92E+01	0.	3.82E+01	0.	4.36E-01	0.
KR89	5.74E-01	0.	5.25E+01	0.	0.	0.	0.	0.
SR89	0.	0.	0.	2.08E-05	6.57E-04	5.67E-05	9.90E-09	0.
SR90	0.	0.	0.	0.	4.50E-07	3.51E-04	1.53E-13	0.
Y90	0.	0.	0.	1.04E-05	4.86E-08	3.51E-04	1.53E-19	0.
Y91	0.	1.04E-05	0.	1.04E-05	5.13E-04	8.64E-02	1.35E-08	0.
ZR95	0.	0.	0.	0.	8.55E-08	1.35E-05	5.67E-09	0.
NB95	0.	0.	0.	0.	7.92E-08	2.70E-05	1.62E-08	0.
RU103	0.	0.	0.	0.	2.34E-08	0.	1.08E-08	0.
RU106	0.	0.	0.	0.	3.69E-10	0.	1.98E-08	0.
SN123	0.	0.	0.	0.	0.	0.	1.71E-11	0.
TE125M	0.	0.	0.	0.	0.	8.64E-05	3.96E-10	0.
TE127	0.	0.	0.	0.	4.68E-06	8.37E-05	0.	0.
TE129M	0.	1.04E-05	0.	0.	7.11E-05	8.37E-05	9.00E-09	0.
TE132	0.	1.14E-04	0.	0.	0.	0.	2.07E-14	0.
I129	0.	0.	0.	0.	0.	0.	1.80E-13	0.
I131	7.83E-03	1.84E-03	8.06E-02	7.06E-04	8.91E-06	0.	2.61E-09	0.
I133	6.44E-03	1.65E-03	4.56E-01	5.92E-04	5.76E-03	0.	0.	0.
XE133	2.99E+02	0.	3.32E+03	0.	5.81E+01	0.	2.43E-02	0.
XE135M	1.54E+00	0.	2.07E+01	0.	0.	0.	0.	0.
XE135	2.42E+01	0.	3.83E+02	0.	7.02E+00	0.	0.	0.
XE137	1.18E+00	0.	6.79E+01	0.	0.	0.	0.	0.
XE138	5.49E+00	0.	6.48E+01	0.	1.08E-01	0.	0.	0.
CS134	0.	1.25E-04	0.	5.19E-05	0.	7.56E-03	9.90E-09	0.
CS137	0.	1.04E-04	0.	4.15E-05	2.16E-06	7.56E-03	3.73E-08	0.
BA140	0.	0.	0.	3.11E-05	1.62E-05	0.	6.93E-10	0.
LA140	0.	0.	0.	2.08E-05	1.80E-06	0.	0.	0.
CE141	0.	0.	0.	0.	1.08E-07	0.	1.44E-08	0.
CE144	0.	0.	0.	0.	9.00E-09	8.10E-06	4.61E-08	0.
EU154	0.	0.	0.	0.	0.	1.62E-05	0.	0.
U232	0.	0.	0.	0.	0.	0.	0.	0.
U234	0.	0.	0.	0.	0.	0.	0.	0.
PU235	0.	0.	0.	0.	0.	0.	6.65E-10	0.
PU238	0.	0.	0.	0.	0.	0.	1.62E-10	0.
PU240	0.	0.	0.	0.	0.	0.	2.52E-10	0.
PU241	0.	0.	0.	0.	0.	0.	2.12E-04	0.
AM241	0.	0.	0.	0.	0.	0.	8.91E-11	0.
CM242	0.	0.	0.	0.	0.	0.	4.41E-09	0.
CM244	0.	0.	0.	0.	0.	0.	7.47E-11	0.

* 1220 MWE PLANTS AT 75% CAPACITY FACTOR

TABLE E-2

TYPICAL FUEL REPROCESSING PLANT RADIONUCLIDE CONCENTRATIONS IN FUEL

(CURIES/METRIC TON)

	LWR-U		LWR-PU		HTGR		LMFBR	
ISOTOPE	FUEL	WASTE	FUEL	WASTE	FUEL	WASTE	FUEL	WASTE
H3	6.92E+02	5.22E+00	9.0ME+02	6.85E+00	4.20E+03	3.05E+01	5.8CE+01	0.
C14	5.00E-01	0.	5.00E-01	C.	3.86E+01	0.	2.03E+00	0.
NA22	C.	0.	0.	0.	0.	0.	0.	0.
AR39	C.	0.	0.	0.	0.	0.	0.	0.
CO59	0.	0.	0.	0.	0.	0.	0.	0.
CO60	C.	0.	0.	0.	0.	0.	0.	0.
KR*54	C.	0.	0.	0.	0.	0.	0.	0.
KR85	1.10E+04	C.	6.85E+03	0.	6.18E+04	0.	9.34E+03	0.
KR87	0.	0.	0.	0.	0.	0.	0.	0.
KR88	C.	0.	C.	0.	0.	0.	0.	0.
KR89	C.	0.	0.	C.	0.	0.	0.	0.
SR89	9.72E+04	0.	5.77E+04	C.	5.92E+05	0.	1.70E+05	0.
SR90	7.69E+04	6.79E+04	4.54E+04	4.01E+04	2.89E+05	2.51E+05	5.30E+04	4.70E+04
Y90	7.69E+04	6.79E+04	4.54E+04	4.01E+04	2.89E+05	2.51E+05	5.31E+04	4.70E+04
Y91	1.61E+05	0.	1.19E+05	0.	7.29E+05	0.	2.93E+04	0.
ZR95	2.77E+05	C.	2.55E+05	0.	9.01E+05	0.	6.12E+05	0.
NB95	5.20E+05	0.	4.78E+05	0.	1.60E+05	0.	1.09E+06	0.
RU103	8.82E+04	0.	9.92E+04	0.	1.48E+05	0.	3.01E+05	0.
RU106	4.10E+05	1.30E+04	6.82E+05	2.17E+04	1.51E+05	3.02E+03	1.12E+06	3.79E+04
SN123	3.86E+03	1.54E-01	4.94E+03	1.97E-01	1.04E+04	1.37E-01	9.36E+03	4.43E-01
TE125M	3.20E+03	9.13E+02	5.32E+03	1.51E+03	8.18E+03	1.95E+03	1.02E+04	3.01E+03
TE127	6.15E+03	5.50E-02	7.70E+03	7.00E-02	2.70E+04	5.10E-02	1.63E+04	1.79E-01
TE129M	2.71E+03	0.	3.00E+03	C.	1.32E+04	0.	2.94E+04	0.
TE132	C.	0.	0.	0.	C.	0.	0.	0.
I129	4.04E-02	0.	4.04E-02	C.	1.25E-01	0.	5.42E-02	0.
I131	2.18E+00	0.	2.27E+00	0.	5.18E+01	0.	4.53E+01	0.
I133	0.	C.	0.	0.	0.	0.	0.	0.
XE133	0.	0.	C.	0.	5.40E-01	0.	3.98E-01	0.
XE135M	C.	0.	0.	0.	C.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.	0.
XE137	C.	0.	0.	0.	C.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.	0.
CS134	2.14E+05	3.95E+04	1.87E+05	3.44E+04	7.03E+05	1.04E+05	4.02E+04	7.98E+03
CS137	1.07E+05	9.51E+04	1.10E+05	9.78E+04	3.03E+05	2.66E+05	1.41E+05	1.26E+05
BA140	4.91E+02	0.	4.09E+02	C.	4.46E+03	0.	3.29E+03	0.
LA140	4.96E+02	C.	4.70E+02	0.	5.13E+03	0.	3.69E+03	0.
CE141	5.64E+04	0.	5.20E+04	0.	2.83E+05	0.	1.39E+05	0.
CE144	7.71E+05	8.93E+03	6.58E+05	7.63E+03	1.91E+06	1.22E+04	9.68E+05	1.21E+04
EU154	6.87E+03	5.53E+03	9.27E+03	7.46E+03	1.35E+04	1.06E+04	2.00E+03	1.65E+03
U232	C.	0.	3.00F-03	0.	2.92E+02	1.42E+00	4.43E-02	0.
U234	1.00E-02	5.00E-05	1.00E-02	5.00E-05	8.80E+01	4.40E-01	5.00E-04	2.50E-06
PU238	2.82E+03	9.95E+01	1.89E+04	1.26E+03	1.88E+04	1.80E+04	1.09E+04	3.12E+02
PU239	3.23E+02	1.62E+01	7.35E+02	3.75E+00	1.50E+01	1.50E+01	3.27E+03	1.64E+01
PU240	4.75E+02	3.48E+00	1.94E+03	7.29E+01	3.18E+01	3.26E+01	3.46E+03	2.04E+01
PU241	1.02E+05	4.04E+02	6.07E+05	2.43E+03	1.04E+04	8.20E+03	3.46E+05	1.37E+03
AM241	1.51E+02	1.56E+02	1.58E+03	1.59E+03	1.62E+01	1.01E+02	1.48E+03	1.45E+03
CM242	1.77E+04	1.48E+01	2.40E+05	2.94E+02	2.49E+03	7.39E-01	4.65E+04	1.11E+02
CM244	2.39E+03	1.97E+03	1.38E+05	1.12E+05	1.64E+03	1.32E+03	2.39E+03	1.97E+03

TABLE E-3

TYPICAL FUEL REPROCESSING PLANT RADIONUCLIDE RELEASES

(CURIES/METRIC TON)

	LWR-U		LWR-PU		HTGR		LMFBR	
ISOTOPE	FUEL	WASTE	FUEL	WASTE	FUEL	WASTE	FUEL	WASTE
H3	6.92E+02	5.22E+00	9.08E+02	6.85E+00	4.20E+03	3.05E+01	5.80E+01	0.
C14	5.00E-03	0.	5.00E-03	0.	3.86E-01	0.	2.00E-02	0.
NA22	0.	0.	0.	0.	0.	0.	0.	0.
AR39	0.	0.	0.	0.	0.	0.	0.	0.
CO59	0.	0.	0.	0.	0.	0.	0.	0.
CO60	0.	0.	0.	0.	0.	0.	0.	0.
KR85M	0.	0.	0.	0.	0.	0.	0.	0.
KR85	1.10E+02	0.	8.85E+01	0.	6.19E+02	0.	9.34E+01	0.
KR87	0.	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.	0.
SR89	9.72E-06	0.	6.77E-06	0.	5.92E-05	0.	1.70E-05	0.
SR90	7.69E-06	6.79E-06	4.54E-06	4.01E-06	2.89E-05	2.51E-05	5.30E-05	4.70E-06
Y90	7.69E-06	6.79E-06	4.54E-06	4.01E-06	2.89E-05	2.51E-05	5.31E-05	4.70E-06
Y91	1.61E-05	0.	1.19E-05	0.	7.29E-05	0.	2.93E-06	0.
ZR95	2.77E-05	0.	2.55E-05	0.	9.01E-05	0.	6.12E-05	0.
NB95	5.20E-05	0.	4.78E-05	0.	1.61E-05	0.	1.09E-04	0.
RU103	1.76E-05	0.	1.98E-05	0.	7.40E-05	0.	6.02E-05	0.
RU106	8.20E-05	6.50E-06	1.36E-04	1.09E-05	7.55E-05	1.51E-06	2.24E-04	1.90E-05
SN123	3.86E-07	1.54E-11	4.94E-07	1.97E-11	1.04E-06	1.07E-11	9.36E-07	4.43E-11
TE125M	6.40E-07	4.57E-07	1.06E-06	7.55E-07	4.09E-06	9.75E-07	2.04E-06	1.51E-06
TE127	1.23E-06	2.75E-11	1.54E-06	3.50E-11	1.35E-05	2.55E-11	3.26E-06	8.95E-11
TE129M	5.42E-07	0.	6.00E-07	0.	6.60E-06	0.	4.08E-06	0.
TE132	0.	0.	0.	0.	0.	0.	0.	0.
I129	4.04E-06	0.	4.34E-06	0.	1.25E-05	0.	5.42E-06	0.
I131	2.18E-06	0.	2.27E-06	0.	5.18E-04	0.	4.53E-05	0.
I133	0.	0.	0.	0.	0.	0.	0.	0.
XE133	0.	0.	0.	0.	5.40E-03	0.	3.98E-03	0.
XE135M	0.	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.	0.
CS134	4.28E-05	1.99E-05	3.74E-05	1.73E-05	3.55E-04	5.20E-05	8.04E-06	3.99E-06
CS137	2.14E-05	4.76E-05	2.20E-05	4.89E-05	1.52E-04	1.31E-04	2.92E-05	6.30E-05
BA140	4.31E-08	0.	4.09E-08	0.	4.46E-07	0.	3.20E-07	0.
LA140	4.98E-08	0.	4.71E-08	0.	5.13E-07	0.	3.69E-07	0.
CE141	5.64E-06	0.	5.20E-06	0.	2.83E-05	0.	1.39E-05	0.
CE144	7.71E-05	8.91E-07	6.58E-05	7.61E-07	1.91E-04	1.22E-06	9.68E-05	1.21E-06
EU154	6.87E-07	5.53E-07	9.27E-07	7.44E-07	1.35E-06	1.06E-06	2.00E-07	1.65E-07
U232	0.	0.	9.03E-09	0.	8.76E-04	1.42E-11	1.33E-07	0.
U234	3.00E-08	5.00E-15	3.00E-08	5.00E-15	2.64E-04	4.40E-11	1.50E-08	2.50E-16
PU238	8.46E-07	9.95E-09	5.67E-06	1.25E-07	5.64E-06	1.80E-05	3.27E-06	3.12E-08
PU239	9.69E-08	1.62E-10	2.21E-07	3.75E-10	4.50E-09	1.50E-09	9.81E-07	1.64E-09
PU240	1.49E-07	3.48E-10	5.92E-07	7.29E-09	9.54E-09	3.26E-09	1.16E-06	2.04E-09
PU241	3.06E-05	4.04E-09	1.82E-04	2.40E-07	3.12E-06	8.20E-07	1.04E-04	1.37E-07
AM241	1.53E-09	1.56E-08	1.58E-07	1.59E-07	1.62E-09	1.01E-08	1.48E-07	1.49E-07
CM242	1.77E-06	1.43E-09	2.40E-05	2.84E-09	2.49E-07	7.39E-11	4.65E-06	1.11E-08
CM244	2.39E-07	1.97E-07	1.36E-05	1.12E-05	1.64E-07	1.32E-07	2.39E-07	1.97E-07

TABLE E-4

TYPICAL FUEL FABRICATION PLANT RADIONUCLIDE RELEASES

(CURIES/METRIC TON)

	LWR-U		LWR-PU		HTGR		LMFBR	
ISOTOPE	GASEOUS	LIQUID	GASEOUS	LIQUID	GASEOUS	LIQUID	GASEOUS	LIQUID
H3	0.	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	5.00E-20	5.00E-18	3.86E-18	3.86E-16	2.00E-19	2.00E-17
NA22	0.	0.	0.	0.	0.	0.	0.	0.
AR39	0.	0.	0.	0.	0.	0.	0.	0.
CO58	0.	0.	0.	0.	0.	0.	0.	0.
CO60	0.	0.	0.	0.	0.	0.	0.	0.
KR85M	0.	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.	0.
SR89	0.	0.	4.74E-16	4.74E-14	4.14E-15	4.14E-13	1.19E-15	1.19E-13
SR90	0.	0.	4.49E-15	4.49E-13	2.86E-14	2.86E-12	5.25E-15	5.25E-13
Y90	0.	0.	0.	0.	0.	0.	0.	0.
Y91	0.	0.	1.12E-15	1.12E-13	6.85E-15	6.85E-13	2.75E-16	2.75E-14
ZR95	0.	0.	3.06E-15	3.06E-13	1.08E-14	1.08E-12	7.34E-15	7.34E-13
NB95	0.	0.	9.08E-16	9.08E-14	3.04E-16	3.04E-14	2.07E-15	2.07E-13
RU103	0.	0.	2.98E-16	2.98E-14	4.44E-16	4.44E-14	9.03E-16	9.03E-14
RU106	0.	0.	4.64E-14	4.64E-12	1.03E-14	1.03E-12	7.62E-14	7.62E-12
SN123	0.	0.	1.63E-16	1.63E-14	3.43E-16	3.43E-14	3.09E-16	3.09E-14
TE125M	0.	0.	4.95E-17	4.95E-15	7.61E-17	7.61E-15	9.49E-17	9.49E-15
TE127	0.	0.	0.	0.	0.	0.	0.	0.
TE129M	0.	0.	5.10E-18	5.10E-16	2.24E-17	2.24E-15	3.47E-17	3.47E-15
TE132	0.	0.	0.	0.	0.	0.	0.	0.
I129	0.	0.	4.04E-21	4.04E-19	1.25E-20	1.25E-18	5.42E-21	5.42E-19
I131	0.	0.	7.72E-29	7.72E-27	1.76E-27	1.76E-25	1.54E-27	1.54E-25
I133	0.	0.	0.	0.	0.	0.	0.	0.
XE133	0.	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.	0.
CS134	0.	0.	1.55E-14	1.55E-12	5.88E-14	5.88E-12	3.34E-15	3.34E-13
CS137	0.	0.	1.09E-14	1.09E-12	3.00E-14	3.00E-12	1.40E-14	1.40E-12
BA140	0.	0.	8.18E-22	8.18E-20	8.92E-21	8.92E-19	6.40E-21	6.40E-19
LA143	0.	0.	0.	0.	0.	0.	0.	0.
CE141	0.	0.	7.80E-17	7.80E-15	4.25E-16	4.25E-14	2.09E-16	2.09E-14
CE144	0.	0.	4.01E-14	4.01E-12	1.17E-13	1.17E-11	5.90E-14	5.90E-12
EU154	0.	0.	9.08E-16	9.08E-14	1.32E-15	1.32E-13	1.96E-16	1.96E-14
U232	0.	0.	3.00E-15	3.00E-13	2.92E-10	2.92E-08	0.	0.
U234	0.	0.	1.00E-14	1.00E-12	8.80E-11	8.80E-09	0.	0.
PU238	0.	0.	1.89E-08	1.89E-06	1.88E-08	1.88E-06	1.09E-08	1.09E-06
PU239	0.	0.	7.35E-10	7.35E-08	1.50E-11	1.50E-09	3.27E-09	3.27E-07
PU240	0.	0.	1.94E-09	1.94E-07	3.18E-11	3.18E-09	3.86E-09	3.86E-07
PU241	0.	0.	6.07E-07	6.07E-05	1.04E-08	1.04E-06	3.46E-07	3.46E-05
AM241	0.	0.	1.58E-16	1.58E-14	1.62E-16	1.62E-16	1.48E-16	1.48E-14
CM242	0.	0.	1.03E-14	1.03E-12	1.07E-16	1.07E-14	2.00E-15	2.00E-13
CM244	0.	0.	1.33E-14	1.33E-12	1.61E-16	1.61E-14	2.34E-16	2.34E-14

APPENDIX F

AIRBORNE AND AIR-DEPOSITIED CONCENTRATIONS FOR SELECTED RADIONUCLIDES

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APPENDIX F

AIRBORNE AND AIR-DEPOSITED CONCENTRATIONS FOR SELECTED RADIONUCLIDES

Typical relationships between airborne concentrations of radionuclides and the concentrations deposited on the ground are shown in Figure F-1. These relationships are depicted for selected radionuclides for eight counties representing different portions of the Tennessee Valley Region study area. The airborne concentrations are averaged over the year 2000, from monthly concentrations as calculated by the ARTRAN model. Ground concentrations are given as average monthly rates of deposition per unit area, again averaged over the year.

The rates of deposition as calculated for each month are dependent on the airborne concentration of the radionuclide in question (expressed as a time-weighted mean for the month), on the dry deposition (settling) velocity of the radionuclide particles, and on the precipitation pattern for the month. Thus, the ratio of ground deposition rate to airborne concentration is not necessarily constant, either from one radionuclide to another or from one county to another.

For many of the radionuclides included in Table F-1, very low concentrations are indicated both for air burdens and ground deposition. The significance of these concentrations may be brought into context by reference to Table F-2. That table shows the statistical specific radioactivity, in picocuries, attributable to the presence of a single atom of a radionuclide. For example, Table F-1 shows Nashville, Tennessee to experience an average year 2000 concentration for ^{95}Zr of 2.4×10^{-12} picocuries per cubic meter in air, and an average deposition rate of 3.6×10^{-7} picocuries per square meter per month. By reference to Figure F-2, these concentrations are seen to be equivalent to one atom of ^{95}Zr per 1.4 million cubic meters of air and a monthly deposition rate of one atom per 9.3 square meters of surface. These concentrations have physical significance only when averaged over large areas, such as the county areas used in this study.

TABLE F-1

COMPARISON OF AVERAGE AIRBORNE CONCENTRATIONS OF RADIONUCLIDES

AND AVERAGE MONTHLY DEPOSITION ON GROUND: SELECTED RADIONUCLIDES AND CENTROIDS

Nuclide	Asheville, NC (Buncombe County)		Franklin, NC (Macon County)		Oak Ridge, TN (Anderson County)		Albany, KY (Clinton County)	
	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.
^{3}H	1.22 E-2	7.15 E-1	1.78 E-2	7.28 E-1	0.64	49.2	3.51 E-2	1.19 E-1
^{14}C	1.95 E-6	1.35 E-5	1.68 E-6	9.40 E-6	1.86 E-5	1.42 E-4	3.35 E-6	1.67 E-7
^{22}Na	2.25 E-12	4.13 E-8	2.42 E-11	2.98 E-7	1.42 E-10	7.70 E-6	1.11 E-13	4.44 E-10
^{85}Kr	1.23 E-2	0	2.27 E-2	0	0.446	0	2.27 E-2	0
^{88}Kr	1.65 E-5	0	3.70 E-5	0	4.03 E-3	0	2.06 E-5	0
^{90}Sr	7.45 E-12	2.54 E-6	2.30 E-11	2.46 E-5	2.32 E-7	1.60 E-2	9.81 E-10	7.27 E-6
^{95}Zr	8.61 E-12	3.82 E-6	4.40 E-11	4.70 E-6	4.43 E-7	3.05 E-2	1.87 E-9	1.38 E-5
^{106}Ru	2.20 E-11	7.07 E-5	6.74 E-11	7.19 E-6	6.77 E-7	4.66 E-7	2.86 E-9	2.12 E-5
^{129}I	4.20 E-19	1.31 E-15	1.34 E-17	2.98 E-14	3.61 E-7	1.01 E-2	2.58 E-10	1.73 E-6
^{131}I	1.38 E-9	7.92 E-6	7.77 E-8	3.34 E-4	1.57 E-5	0.402	1.55 E-9	2.70 E-4
^{133}Xe	2.75 E-3	0	5.59 E-3	0	0.403	0	7.52 E-3	0
^{135}Xe	3.10 E-4	0	4.06 E-4	0	8.76 E-2	0	3.83 E-4	0
^{137}Cs	1.06 E-11	2.82 E-6	3.22 E-11	3.44 E-6	3.24 E-7	2.23 E-2	1.37 E-9	1.01 E-5
^{144}Ce	4.02 E-11	1.08 E-5	1.24 E-10	1.33 E-5	1.11 E-6	8.60 E-2	5.28 E-9	3.92 E-5
^{234}U	1.03 E-12	3.52 E-8	9.04 E-13	2.65 E-8	2.67 E-8	1.95 E-4	3.70 E-11	7.53 E-8
^{238}Pu	5.19 E-13	1.20 E-7	2.01 E-12	1.50 E-7	1.68 E-8	7.51 E-4	7.37 E-11	4.29 E-7
^{239}Pu	5.87 E-14	1.36 E-8	2.-6 E-13	1.67 E-8	1.92 E-9	1.09 E-4	8.36 E-12	4.87 E-8
^{240}Pu	8.65 E-14	2.00 E-8	3.18 E-13	2.48 E-8	2.81 E-9	1.60 E-4	1.23 E-11	7.17 E-8
^{241}Am	1.88 E-14	4.33 E-9	6.23 E-14	5.27 E-9	6.05 E-10	3.40 E-5	2.66 E-12	1.56 E-8
^{242}Cm	1.07 E-12	2.47 E-7	3.56 E-12	3.00 E-7	3.45 E-8	5.83 E-2	1.52 E-10	8.87 E-7

TABLE F-1 (continued)

COMPARISON OF AVERAGE AIRBORNE CONCENTRATIONS OF RADIONUCLIDES

AND AVERAGE MONTHLY DEPOSITION ON GROUND: SELECTED RADIONUCLIDES AND CENTROIDS

Nuclide	Chattanooga, TN (Hamilton County)		Nashville, TN (Davidson County)		Huntsville, AL (Madison County)		Cadiz, KY (Trigg County	
	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.	Avg. Airborne Concentration pCi/M^3	Avg. Monthly Deposition pCi/M^2 Mo.
^{3}H	0.296	8.62	3.74 E-2	1.2	0.182	8.13	8.02 E-2	2.16
^{14}C	9.81 E-6	6.40 E-5	1.13 E-5	3.44 E-5	3.93 E-6	2.90 E-5	5.81 E-5	6.76 E-5
^{22}Na	2.40 E-12	1.14 E-7	2.23 E-16	2.34 E-12	1.19 E-12	2.50 E-8	0	0
^{85}Kr	0.154	0	4.46 E-2	0	5.85 E-2	0	3.48 E-2	0
^{88}Kr	2.05 E-4	0	7.73 E-5	0	3.04 E-5	0	3.09 E-5	0
^{90}Sr	2.75 E-9	2.66 E-4	1.06 E-12	1.51 E-7	2.73 E-11	4.10 E-6	8.74 E-12	9.54 E-7
^{95}Zr	5.24 E-9	5.11 E-4	2.40 E-12	3.59 E-7	5.64 E-11	8.48 E-6	2.26 E-11	1.64 E-6
^{106}Ru	8.04 E-9	5.58 E-4	8.59 E-12	1.22 E-6	2.11 E-10	3.17 E-5	7.22 E-11	7.88 E-6
^{129}I	1.48 E-9	5.45 E-5	0	0	3.45 E-11	3.99 E-9	0	0
^{131}I	1.94 E-7	1.17 E-2	9.10 E-6	1.59 E-2	3.54 E-9	6.53 E-5	9.81 E-11	1.33 E-6
^{133}Xe	6.07 E-2	0	2.97 E-2	0	4.02 E-8	0	1.73 E-3	0
^{135}Xe	4.53 E-3	0	2.98 E-3	0	3.98 E-3	0	9.88 E-5	0
^{137}Cs	3.84 E-9	3.75 E-4	6.02 E-12	8.84 E-7	1.44 E-10	2.16 E-5	5.43 E-11	5.92 E-6
^{144}Ce	1.48 E-8	1.37 E-3	5.95 E-12	8.47 E-7	1.57 E-10	2.35 E-5	4.82 E-11	5.26 E-6
^{234}U	1.30 E-10	2.78 E-6	3.42 E-12	1.77 E-6	3.25 E-13	9.36 E-9	8.87 E-11	2.29 E-6
^{238}Pu	2.42 E-10	1.60 E-5	4.15 E-13	3.76 E-8	6.11 E-12	6.62 E-7	8.66 E-12	2.24 E-7
^{239}Pu	2.78 E-11	1.84 E-6	3.21 E-14	2.43 E-9	8.14 E-13	5.26 E-8	7.44 E-13	1.92 E-8
^{240}Pu	4.07 E-11	2.69 E-6	5.26 E-14	3.90 E-9	1.17 E-12	9.20 E-8	1.12 E-12	2.88 E-8
^{241}Am	8.65 E-12	5.73 E-7	1.94 E-14	7.84 E-7	1.78 E-13	2.96 E-8	3.95 E-13	1.02 E-8
^{242}Cm	4.95 E-10	3.32 E-5	1.13 E-12	7.96 E-8	1.49 E-11	2.12 E-6	1.97 E-11	5.09 E-7

TABLE F-2

EQUIVALENT LEVEL OF RADIOACTIVITY STATISTICALLY REPRESENTING ONE ATOM OF A RADIONUCLIDE

Nuclide	Equivalent Specific Activity-pCi/Atom	Nuclide	Equivalent Specific Activity-pCi/Atom
^{3}H	4.830 E-8	^{133}Xe	4.114 E-5
^{14}C	1.037 E-10	^{135}Xe	5.657 E-4
^{22}Na	2.285 E-7	^{137}Co	1.980 E-8
^{85}Kr	5.522 E-8	^{144}Ce	7.635 E-7
^{88}Kr	1.858 E-3	^{234}U	2.434 E-12
^{90}Sr	2.114 E-8	^{238}Pu	6.908 E-9
^{95}Zr	3.335 E-6	^{239}Pu	2.435 E-11
^{106}Rn	5.908 E-7	^{240}Pu	9.027 E-11
^{129}I	3.735 E-14	^{241}Am	1.297 E-9
^{131}I	2.694 E-5	^{242}Cm	1.331 E-6

APPENDIX G

VALUES OF DISTRIBUTION COEFFICIENT (K_d) USED IN TVR

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APPENDIX G

TABLE G-1

VALUES OF DISTRIBUTION COEFFICIENT (K_d) USED IN TVR

The distribution coefficient is the ratio of nuclide concentration sorbed onto water-borne sediment to the concentration dissolved in water.

$$K_d = (pCi/gm) / (pCi/l)$$

Nuclide	Eastern Mountains	Appalachian Valley	Cumberland Plateau	Highland Rim	Mississippi Embayment
^{3}H	0.	0.	0.	0.	0.
^{14}C	100.	100.	100.	100.	100.
^{22}Na	0.	0.	0.	0.	0.
^{39}Ar	*	*	*	*	*
^{58}Co	3,100	316,000	11,000	142,000	202,000
^{60}Co	3,100	316,000	11,000	142,000	202,000
^{85m}Kr	*	*	*	*	*
^{85}Kr	*	*	*	*	*
^{87}Kr	*	*	*	*	*
^{88}Kr	*	*	*	*	*
^{89}Kr	*	*	*	*	*
^{89}Sr	80	85	40	230	280
^{90}Sr	80	85	40	230	280
^{90}Y	80	85	40	230	280
^{91}Y	80	85	40	230	280
^{95}Zr	145,000	115,000	33,000	280,000	16,600
^{95}Nb	282,000	131,000	37,000	59,000	24,100
^{103}Ru	6,240	12,400	18,100	3,780	2,440
^{106}Ru	6,240	12,400	18,100	3,780	2,440
^{123}Sn	1,900	1,900	1,900	1,900	1,900
^{125m}Te	840	500	560	107	177
^{127}Te	840	500	560	107	177
^{129m}Te	840	500	560	107	177
^{132}Te	840	500	560	107	177
^{129}I	840	500	560	107	177
^{131}I	840	500	560	107	177
^{133}I	840	500	560	107	177

APPENDIX G (CONT.)

Nuclide	Eastern Mountains	Appalachian Valley	Cumberland Plateau	Highland Rim	Mississippi Embayment
^{133}Xe	*	*	*	*	*
^{135m}Xe	*	*	*	*	*
^{135}Xe	*	*	*	*	*
^{137}Xe	*	*	*	*	*
^{138}Xe	*	*	*	*	*
^{134}Cs	6,600	18,000	55,000	38,500	17,100
^{137}Cs	6,600	18,000	55,000	38,500	17,100
^{140}Ba	6,600	18,000	55,000	38,500	17,100
^{140}La	189,000	12,600	14,000	6,700	119,000
^{141}Ce	189,000	12,600	14,000	6,700	119,000
^{144}Ce	189,000	12,600	14,000	6,700	119,000
^{154}Eu	189,000	12,600	14,000	6,700	119,000
^{232}U	189,000	12,600	14,000	6,700	119,000
^{234}U	189,000	12,600	14,000	6,700	119,000
^{238}Pu	189,000	12,600	14,000	6,700	119,000
^{239}Pu	189,000	12,600	14,000	6,700	119,000
^{240}Pu	189,000	12,600	14,000	6,700	119,000
^{241}Pu	189,000	12,600	14,000	6,700	119,000
^{241}Am	189,000	12,600	14,000	6,700	119,000
^{242}Cm	189,000	12,600	14,000	6,700	119,000
^{244}Cm	189,000	12,600	14,000	6,700	119,000

Notes:

* Noble gas, not considered to be soluble in water or sorbed on sediments.

APPENDIX H

DOSE FACTORS

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TABLE H-1

SUBMERSION IN AIR DOSE FACTORS, INFANT

(MREM/HR/PER MICROCURIE/CUBIC METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.55E-03	0.
NA22	1.84E+00	1.84E+00	1.84E+00	1.84E+00	1.84E+00	2.26E+00	1.84E+00
AR39	3.28E-04	3.28E-04	3.28E-04	3.28E-04	3.28E-04	1.21E-01	3.28E-04
CO58	8.18E-01	8.18E-01	8.18E-01	8.18E-01	8.18E-01	1.06E+00	8.18E-01
CO60	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.48E+00	2.10E+00
KR85M	1.28E-01	1.28E-01	1.28E-01	1.28E-01	1.28E-01	3.25E-01	1.28E-01
KR85	2.24E-03	2.24E-03	2.24E-03	2.24E-03	2.24E-03	1.58E-01	2.24E-03
KR87	1.26E+00	1.26E+00	1.26E+00	1.26E+00	1.26E+00	2.67E+00	1.26E+00
KR88	1.49E+00	1.49E+00	1.49E+00	1.49E+00	1.49E+00	2.02E+00	1.49E+00
KR89	4.34E-01	4.34E-01	4.34E-01	4.34E-01	4.34E-01	2.91E+00	4.34E-01
SR89	2.12E-03	2.12E-03	2.12E-03	2.12E-03	2.12E-03	4.94E-01	2.12E-03
SR90	2.39E-04	2.39E-04	2.39E-04	2.39E-04	2.39E-04	1.28E-01	2.39E-04
Y90	5.77E-03	5.77E-03	5.77E-03	5.77E-03	5.77E-03	8.59E-01	5.77E-03
Y91	4.57E-01	4.57E-01	4.57E-01	4.57E-01	4.57E-01	5.63E-01	4.57E-01
ZR95	6.76E-01	6.76E-01	6.76E-01	6.76E-01	6.76E-01	8.42E-01	6.76E-01
NB95	6.38E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01	7.46E-01	6.38E-01
RU103	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.91E-01	4.07E-01
RU106	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.55E+00	1.73E-01
SN123	0.	0.	0.	0.	0.	4.60E-01	0.
TE125	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.10E-02	1.69E-03
TE127	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.58E-01	1.24E-03
TE129	9.40E-02	9.40E-02	9.40E-02	9.40E-02	9.40E-02	5.67E-01	9.40E-02
TE132	1.82E-01	1.82E-01	1.82E-01	1.82E-01	1.82E-01	2.28E-01	1.82E-01
I129	1.56E-08	1.56E-08	1.56E-08	1.56E-08	1.56E-08	3.04E-08	1.56E-08
I131	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	4.90E-01	3.11E-01
I133	4.39E-01	4.39E-01	4.39E-01	4.39E-01	4.39E-01	8.83E-01	4.39E-01
XE133	2.55E-02	2.55E-02	2.55E-02	2.55E-02	2.55E-02	6.94E-02	2.55E-02
XE135M	3.49E-02	3.49E-02	3.49E-02	3.49E-02	3.49E-02	5.00E-01	3.49E-02
XE135	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	4.90E-01	2.06E-01
XE137	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.77E+00	1.24E-01
XE138	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.74E+00	1.19E+00
CS134	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.66E+00	1.32E+00
CS137	4.67E-01	4.67E-01	4.67E-01	4.67E-01	4.67E-01	6.97E-01	4.67E-01
BA140	2.23E-01	2.23E-01	2.23E-01	2.23E-01	2.23E-01	4.45E-01	2.23E-01
LA140	1.89E+00	1.89E+00	1.89E+00	1.89E+00	1.89E+00	2.71E+00	1.89E+00
CE141	5.94E-02	5.94E-02	5.94E-02	5.94E-02	5.94E-02	1.55E-01	5.94E-02
CE144	3.96E-02	3.96E-02	3.96E-02	3.96E-02	3.96E-02	1.23E+00	3.96E-02
EU154	9.93E-01	9.93E-01	9.93E-01	9.93E-01	9.93E-01	1.29E+00	9.93E-01
U232	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	5.02E-04	2.07E-04
U234	3.76E-04	3.76E-04	3.76E-04	3.76E-04	3.76E-04	2.23E-03	3.76E-04
PU238	6.77E-05	6.77E-05	6.77E-05	6.77E-05	6.77E-05	1.75E-03	6.77E-05
PU239	5.61E-05	5.61E-05	5.61E-05	5.61E-05	5.61E-05	7.68E-04	5.61E-05
PU240	6.48E-05	6.48E-05	6.48E-05	6.48E-05	6.48E-05	1.75E-03	6.48E-05
PU241	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.36E-06	1.16E-06
AM241	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	2.71E-02	1.79E-02
CM242	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	2.08E-03	1.55E-04
CM244	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.73E-03	1.22E-04

TABLE H-2

SUBMERSION IN AIR DOSE FACTORS, CHILD

(MREM/HR PER MICROCURIE/CUBIC METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.55E-03	0.
NA22	1.84E+00	1.84E+00	1.84E+00	1.84E+00	1.84E+00	2.26E+00	1.84E+00
AR39	3.28E-04	3.28E-04	3.28E-04	3.28E-04	3.28E-04	1.21E-01	3.28E-04
CO58	8.18E-01	8.18E-01	8.18E-01	8.18E-01	8.18E-01	1.06E+00	8.18E-01
CO60	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.48E+00	2.10E+00
KR85M	1.28E-01	1.28E-01	1.28E-01	1.28E-01	1.28E-01	3.25E-01	1.28E-01
KR85	2.24E-03	2.24E-03	2.24E-03	2.24E-03	2.24E-03	1.58E-01	2.24E-03
KR87	1.26E+00	1.26E+00	1.26E+00	1.26E+00	1.26E+00	2.67E+00	1.26E+00
KR88	1.49E+00	1.49E+00	1.49E+00	1.49E+00	1.49E+00	2.02E+00	1.49E+00
KR89	4.34E-01	4.34E-01	4.34E-01	4.34E-01	4.34E-01	2.91E+00	4.34E-01
SR89	2.12E-03	2.12E-03	2.12E-03	2.12E-03	2.12E-03	4.94E-01	2.12E-03
SR90	2.39E-04	2.39E-04	2.39E-04	2.39E-04	2.39E-04	1.28E-01	2.39E-04
Y90	5.77E-03	5.77E-03	5.77E-03	5.77E-03	5.77E-03	8.59E-01	5.77E-03
Y91	4.57E-01	4.57E-01	4.57E-01	4.57E-01	4.57E-01	5.63E-01	4.57E-01
ZR95	6.76E-01	6.76E-01	6.76E-01	6.76E-01	6.76E-01	8.42E-01	6.76E-01
NB95	6.38E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01	7.46E-01	6.38E-01
RU103	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.91E-01	4.07E-01
RU106	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.55E+00	1.73E-01
SN123	0.	0.	0.	0.	0.	4.60E-01	0.
TE125	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.10E-02	1.69E-03
TE127	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.58E-01	1.24E-03
TE129	9.40E-02	9.40E-02	9.40E-02	9.40E-02	9.40E-02	5.67E-01	9.40E-02
TE132	1.82E-01	1.82E-01	1.82E-01	1.82E-01	1.82E-01	2.28E-01	1.82E-01
I129	1.56E-08	1.56E-08	1.56E-08	1.56E-08	1.56E-08	3.04E-08	1.56E-08
I131	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	4.90E-01	3.11E-01
I133	4.39E-01	4.39E-01	4.39E-01	4.39E-01	4.39E-01	8.83E-01	4.39E-01
XE133	2.55E-02	2.55E-02	2.55E-02	2.55E-02	2.55E-02	6.94E-02	2.55E-02
XE135M	3.49E-02	3.49E-02	3.49E-02	3.49E-02	3.49E-02	5.00E-01	3.49E-02
XE135	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	4.90E-01	2.06E-01
XE137	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.77E+00	1.24E-01
XE138	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.74E+00	1.19E+00
CS134	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.66E+00	1.32E+00
CS137	4.67E-01	4.67E-01	4.67E-01	4.67E-01	4.67E-01	6.97E-01	4.67E-01
BA140	2.23E-01	2.23E-01	2.23E-01	2.23E-01	2.23E-01	4.45E-01	2.23E-01
LA140	1.89E+00	1.89E+00	1.89E+00	1.89E+00	1.89E+00	2.71E+00	1.89E+00
CE141	5.94E-02	5.94E-02	5.94E-02	5.94E-02	5.94E-02	1.55E-01	5.94E-02
CE144	3.96E-02	3.96E-02	3.96E-02	3.96E-02	3.96E-02	1.23E+00	3.96E-02
EU154	9.93E-01	9.93E-01	9.93E-01	9.93E-01	9.93E-01	1.29E+00	9.93E-01
U232	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	5.02E-04	2.07E-04
U234	3.76E-04	3.76E-04	3.76E-04	3.76E-04	3.76E-04	2.23E-03	3.76E-04
PU238	6.77E-05	6.77E-05	6.77E-05	6.77E-05	6.77E-05	1.75E-03	6.77E-05
PU239	5.61E-05	5.61E-05	5.61E-05	5.61E-05	5.61E-05	7.68E-04	5.61E-05
PU240	6.48E-05	6.48E-05	6.48E-05	6.48E-05	6.48E-05	1.75E-03	6.48E-05
PU241	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.36E-06	1.16E-06
AM241	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	2.71E-02	1.79E-02
CM242	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	2.08E-03	1.55E-04
CM244	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.73E-03	1.22E-04

TABLE H-3

SUBMERSION IN AIR DOSE FACTORS, TEEN

(MREM/HR PER MICROCURIE/CUBIC METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.55E-03	0.
NA22	1.84E+00	1.84E+00	1.84E+00	1.84E+00	1.84E+00	2.26E+00	1.84E+00
AR39	3.28E-04	3.28E-04	3.28E-04	3.28E-04	3.28E-04	1.21E-01	3.28E-04
CO58	8.18E-01	8.18E-01	8.18E-01	8.18E-01	8.18E-01	1.06E+00	8.18E-01
CO60	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.48E+00	2.10E+00
KR85M	1.28E-01	1.28E-01	1.28E-01	1.28E-01	1.28E-01	3.25E-01	1.28E-01
KR85	2.24E-03	2.24E-03	2.24E-03	2.24E-03	2.24E-03	1.58E-01	2.24E-03
KR87	1.26E+00	1.26E+00	1.26E+00	1.26E+00	1.26E+00	2.67E+00	1.26E+00
KR88	1.49E+00	1.49E+00	1.49E+00	1.49E+00	1.49E+00	2.02E+00	1.49E+00
KR89	4.34E-01	4.34E-01	4.34E-01	4.34E-01	4.34E-01	2.91E+00	4.34E-01
SR89	2.12E-03	2.12E-03	2.12E-03	2.12E-03	2.12E-03	4.94E-01	2.12E-03
SR90	2.39E-04	2.39E-04	2.39E-04	2.39E-04	2.39E-04	1.28E-01	2.39E-04
Y90	5.77E-03	5.77E-03	5.77E-03	5.77E-03	5.77E-03	8.59E-01	5.77E-03
Y91	4.57E-01	4.57E-01	4.57E-01	4.57E-01	4.57E-01	5.63E-01	4.57E-01
ZR95	6.76E-01	6.76E-01	6.76E-01	6.76E-01	6.76E-01	8.42E-01	6.76E-01
NB95	6.38E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01	7.46E-01	6.38E-01
RU103	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.91E-01	4.07E-01
RU106	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.55E+00	1.73E-01
SN123	0.	0.	0.	0.	0.	4.60E-01	0.
TE125	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.10E-02	1.69E-03
TE127	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.58E-01	1.24E-03
TE129	9.40E-02	9.40E-02	9.40E-02	9.40E-02	9.40E-02	5.67E-01	9.40E-02
TE132	1.82E-01	1.82E-01	1.82E-01	1.82E-01	1.82E-01	2.28E-01	1.82E-01
I129	1.56E-08	1.56E-08	1.56E-08	1.56E-08	1.56E-08	3.04E-08	1.56E-08
I131	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	4.90E-01	3.11E-01
I133	4.39E-01	4.39E-01	4.39E-01	4.39E-01	4.39E-01	8.83E-01	4.39E-01
XE133	2.55E-02	2.55E-02	2.55E-02	2.55E-02	2.55E-02	6.94E-02	2.55E-02
XE135M	3.49E-02	3.49E-02	3.49E-02	3.49E-02	3.49E-02	5.00E-01	3.49E-02
XE135	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	4.90E-01	2.06E-01
XE137	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.77E+00	1.24E-01
XE138	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.74E+00	1.19E+00
CS134	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.66E+00	1.32E+00
CS137	4.67E-01	4.67E-01	4.67E-01	4.67E-01	4.67E-01	6.97E-01	4.67E-01
BA140	2.23E-01	2.23E-01	2.23E-01	2.23E-01	2.23E-01	4.45E-01	2.23E-01
LA140	1.89E+00	1.89E+00	1.89E+00	1.89E+00	1.89E+00	2.71E+00	1.89E+00
CE141	5.94E-02	5.94E-02	5.94E-02	5.94E-02	5.94E-02	1.55E-01	5.94E-02
CE144	3.96E-02	3.96E-02	3.96E-02	3.96E-02	3.96E-02	1.23E+00	3.96E-02
EU154	9.93E-01	9.93E-01	9.93E-01	9.93E-01	9.93E-01	1.29E+00	9.93E-01
U232	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	5.02E-04	2.07E-04
U234	3.76E-04	3.76E-04	3.76E-04	3.76E-04	3.76E-04	2.23E-03	3.76E-04
PU238	6.77E-05	6.77E-05	6.77E-05	6.77E-05	6.77E-05	1.75E-03	6.77E-05
PU239	5.61E-05	5.61E-05	5.61E-05	5.61E-05	5.61E-05	7.68E-04	5.61E-05
PU240	6.48E-05	6.48E-05	6.48E-05	6.48E-05	6.48E-05	1.75E-03	6.48E-05
PU241	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.36E-06	1.16E-06
AM241	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	2.71E-02	1.79E-02
CM242	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	2.08E-03	1.55E-04
CM244	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.73E-03	1.22E-04

TABLE H-4

SUBMERSION IN AIR DOSE FACTORS, ADULT

(MREM/HR PER MICROCURIE/CUBIC METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.55E-03	0.
NA22	1.84E+00	1.84E+00	1.84E+00	1.84E+00	1.84E+00	2.26E+00	1.84E+00
AR39	3.28E-04	3.28E-04	3.28E-04	3.28E-04	3.28E-04	1.21E-01	3.28E-04
CO58	8.18E-01	8.18E-01	8.18E-01	8.18E-01	8.18E-01	1.06E+00	8.18E-01
CO60	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.10E+00	2.48E+00	2.10E+00
KR85M	1.28E-01	1.28E-01	1.28E-01	1.28E-01	1.28E-01	3.25E-01	1.28E-01
KR85	2.24E-03	2.24E-03	2.24E-03	2.24E-03	2.24E-03	1.58E-01	2.24E-03
KR87	1.26E+00	1.26E+00	1.26E+00	1.26E+00	1.26E+00	2.67E+00	1.26E+00
KR88	1.49E+00	1.49E+00	1.49E+00	1.49E+00	1.49E+00	2.02E+00	1.49E+00
KR89	4.34E-01	4.34E-01	4.34E-01	4.34E-01	4.34E-01	2.91E+00	4.34E-01
SR89	2.12E-03	2.12E-03	2.12E-03	2.12E-03	2.12E-03	4.94E-01	2.12E-03
SR90	2.39E-04	2.39E-04	2.39E-04	2.39E-04	2.39E-04	1.28E-01	2.39E-04
Y90	5.77E-03	5.77E-03	5.77E-03	5.77E-03	5.77E-03	8.59E-01	5.77E-03
Y91	4.57E-01	4.57E-01	4.57E-01	4.57E-01	4.57E-01	5.63E-01	4.57E-01
ZR95	6.76E-01	6.76E-01	6.76E-01	6.76E-01	6.76E-01	8.42E-01	6.76E-01
NB95	6.38E-01	6.38E-01	6.38E-01	6.38E-01	6.38E-01	7.46E-01	6.38E-01
RU103	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.91E-01	4.07E-01
RU106	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.73E-01	1.55E+00	1.73E-01
SN123	0.	0.	0.	0.	0.	4.60E-01	0.
TE125	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.10E-02	1.69E-03
TE127	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.24E-03	1.58E-01	1.24E-03
TE129	9.40E-02	9.40E-02	9.40E-02	9.40E-02	9.40E-02	5.67E-01	9.40E-02
TE132	1.82E-01	1.82E-01	1.82E-01	1.82E-01	1.82E-01	2.28E-01	1.82E-01
I129	1.56E-08	1.56E-08	1.56E-08	1.56E-08	1.56E-08	3.04E-08	1.56E-08
I131	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	4.90E-01	3.11E-01
I133	4.39E-01	4.39E-01	4.39E-01	4.39E-01	4.39E-01	8.83E-01	4.39E-01
XE133	2.55E-02	2.55E-02	2.55E-02	2.55E-02	2.55E-02	6.94E-02	2.55E-02
XE135M	3.49E-02	3.49E-02	3.49E-02	3.49E-02	3.49E-02	5.00E-01	3.49E-02
XE135	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	4.90E-01	2.06E-01
XE137	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.24E-01	1.77E+00	1.24E-01
XE138	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.74E+00	1.19E+00
CS134	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.32E+00	1.66E+00	1.32E+00
CS137	4.67E-01	4.67E-01	4.67E-01	4.67E-01	4.67E-01	6.97E-01	4.67E-01
BA140	2.23E-01	2.23E-01	2.23E-01	2.23E-01	2.23E-01	4.45E-01	2.23E-01
LA140	1.89E+00	1.89E+00	1.89E+00	1.89E+00	1.89E+00	2.71E+00	1.89E+00
CE141	5.94E-02	5.94E-02	5.94E-02	5.94E-02	5.94E-02	1.55E-01	5.94E-02
CE144	3.96E-02	3.96E-02	3.96E-02	3.96E-02	3.96E-02	1.23E+00	3.96E-02
EU154	9.93E-01	9.93E-01	9.93E-01	9.93E-01	9.93E-01	1.29E+00	9.93E-01
U232	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	5.02E-04	2.07E-04
U234	3.76E-04	3.76E-04	3.76E-04	3.76E-04	3.76E-04	2.23E-03	3.76E-04
PU238	6.77E-05	6.77E-05	6.77E-05	6.77E-05	6.77E-05	1.75E-03	6.77E-05
PU239	5.61E-05	5.61E-05	5.61E-05	5.61E-05	5.61E-05	7.68E-04	5.61E-05
PU240	6.48E-05	6.48E-05	6.48E-05	6.48E-05	6.48E-05	1.75E-03	6.48E-05
PU241	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.16E-06	1.36E-06	1.16E-06
AM241	1.79E-02	1.79E-02	1.79E-02	1.79E-02	1.79E-02	2.71E-02	1.79E-02
CM242	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	2.08E-03	1.55E-04
CM244	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.73E-03	1.22E-04

TABLE H-5

INHALATION DOSE FACTORS, INFANT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.06E-01	1.06E-01	1.06E-01	0.	1.06E-01	1.06E-01	1.06E-01
C14	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01
NA22	1.76E+01	1.44E+00	1.76E+01	1.76E+01	1.76E+01	0.	1.76E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	3.49E-01	1.19E+01	0.	0.	1.71E+02	0.	2.62E-01
CO60	2.18E+00	2.94E+01	0.	0.	9.58E+02	0.	1.64E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.55E+00	4.42E+01	0.	5.40E+01	3.07E+02	0.	0.
SR90	3.10E+01	9.05E+01	0.	4.65E+02	1.83E+03	0.	0.
Y90	1.03E-02	6.79E+01	0.	3.82E-01	3.75E+01	0.	0.
Y91	2.06E+00	4.67E+01	0.	7.70E+01	3.56E+02	0.	0.
ZR95	3.69E+00	1.66E+01	0.	1.57E+01	3.20E+02	0.	5.30E+00
NB95	6.94E-01	1.10E+01	0.	2.05E+00	8.98E+01	0.	1.23E+00
RU103	1.09E-01	1.18E+01	0.	2.44E-01	9.39E+01	0.	0.
RU106	1.47E+00	1.16E+02	0.	1.16E+01	1.93E+03	0.	0.
SN123	1.36E+00	3.91E+01	7.15E-01	3.99E+01	4.88E+02	0.	8.94E-01
TE125	8.25E-02	8.85E+00	1.75E-01	6.07E-01	6.69E+01	0.	2.77E-01
TE127	5.24E-05	1.01E+01	1.68E-04	2.39E-04	1.33E+00	0.	1.08E-04
TE129	2.82E-01	4.80E+01	5.74E-01	1.75E+00	2.50E+02	0.	8.28E-01
TE132	2.76E-02	6.61E+01	3.10E-02	4.57E-02	5.67E+01	0.	3.65E-02
I129	9.03E+00	2.16E-01	3.64E+03	3.53E+00	0.	0.	2.94E+00
I131	3.44E+00	7.45E-01	1.74E+03	4.21E+00	0.	0.	5.90E+00
I133	7.84E-01	1.25E+00	4.75E+02	1.52E+00	0.	0.	2.56E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	6.73E+01	1.12E+00	0.	5.33E+01	1.59E+01	0.	1.33E+02
CS137	3.73E+01	9.60E-01	0.	6.73E+01	1.23E+01	0.	9.69E+01
BA140	4.39E-01	2.65E+00	0.	6.80E+00	2.53E+02	0.	8.37E-03
LA140	7.85E-03	5.81E+01	0.	6.02E-02	2.71E+01	0.	2.97E-02
CE141	2.54E-01	1.42E+01	0.	3.31E+00	7.20E+01	0.	2.22E+00
CE144	1.90E+01	1.05E+02	0.	3.08E+02	1.63E+03	0.	1.70E+02
EU154	2.09E+01	2.86E+01	0.	1.34E+02	8.11E+02	0.	7.43E+01
U232	3.52E+03	4.16E+01	0.	2.70E+04	3.38E+05	0.	0.
U234	6.18E+02	3.81E+01	0.	5.43E+03	7.91E+04	0.	0.
PU238	7.26E+02	4.52E+01	0.	2.90E+04	1.53E+05	0.	4.44E+03
PU239	6.83E+02	4.13E+01	0.	2.74E+04	1.44E+05	0.	4.18E+03
PU240	6.90E+02	4.13E+01	0.	2.74E+04	1.45E+05	0.	4.22E+03
PU241	6.82E-01	7.94E-02	0.	2.68E+01	9.85E+01	0.	4.09E+00
AM241	1.52E+03	4.44E+01	0.	1.90E+04	8.87E+04	0.	2.12E+04
CM242	7.02E+02	4.83E+01	0.	1.06E+04	6.30E+04	0.	1.12E+04
CM244	1.57E+03	4.60E+01	0.	2.36E+04	9.24E+04	0.	2.49E+04

NOTE - TRITIUM TRANSPIRATION DOSE FACTOR WAS TAKEN TO BE 50% OF THE INHALATION DOSE FACTOR FOR TRITIUM.

TABLE H-6

INHALATION DOSE FACTORS, CHILD

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	2.03E-01	2.03E-01	2.03E-01	0.	2.03E-01	2.03E-01	2.03E-01
C14	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00
NA22	4.42E+01	1.28E+00	4.42E+01	4.42E+01	4.42E+01	0.	4.42E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	8.62E-01	9.78E+00	0.	0.	3.03E+02	0.	4.90E-01
CO60	5.36E+00	2.53E+01	0.	0.	1.67E+03	0.	3.07E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.64E+00	4.56E+01	0.	1.61E+02	5.93E+02	0.	0.
SR90	9.26E+01	9.31E+01	0.	1.39E+03	3.53E+03	0.	0.
Y90	3.07E-02	7.43E+01	0.	1.14E+00	7.26E+01	0.	0.
Y91	6.15E+00	4.82E+01	0.	2.30E+02	6.88E+02	0.	0.
ZR95	9.36E+00	1.55E+01	0.	4.40E+01	5.73E+02	0.	1.04E+01
NB95	1.73E+00	8.96E+00	0.	5.52E+00	1.58E+02	0.	2.35E+00
RU103	2.82E-01	1.14E+01	0.	6.99E-01	1.71E+02	0.	0.
RU106	4.34E+00	1.18E+02	0.	3.47E+01	3.70E+03	0.	0.
SN123	4.06E+00	4.03E+01	2.15E+00	1.19E+02	9.44E+02	0.	2.02E+00
TE125	2.47E-01	9.13E+00	5.19E-01	1.81E+00	1.29E+02	0.	6.27E-01
TE127	1.57E-04	1.58E+01	5.03E-04	7.14E-04	2.58E+00	0.	2.44E-04
TE129	8.26E-01	4.93E+01	1.71E+00	5.21E+00	4.79E+02	0.	1.86E+00
TE132	7.13E-02	6.52E+01	8.70E-02	1.31E-01	1.03E+02	0.	7.40E-02
I129	2.63E+01	2.15E-01	4.28E+03	1.05E+01	0.	0.	6.40E+00
I131	9.27E+00	7.17E-01	4.16E+03	1.23E+01	0.	0.	1.25E+01
I133	2.15E+00	1.50E+00	1.35E+03	4.49E+00	0.	0.	5.49E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	6.02E+01	1.02E+00	0.	1.48E+02	2.84E+01	0.	2.58E+02
CS137	3.38E+01	9.22E-01	0.	1.96E+02	2.28E+01	0.	2.03E+02
BA140	1.17E+00	2.68E+00	0.	1.99E+01	4.69E+02	0.	1.74E-02
LA140	2.05E-02	6.14E+01	0.	1.75E-01	4.95E+01	0.	6.07E-02
CE141	7.33E-01	1.47E+01	0.	9.85E+00	1.38E+02	0.	4.94E+00
CE144	5.68E+01	1.08E+02	0.	9.21E+02	3.16E+03	0.	3.84E+02
EU154	5.40E+01	2.94E+01	0.	3.87E+02	1.46E+03	0.	1.54E+02
U232	1.05E+04	4.28E+01	0.	8.07E+04	6.53E+05	0.	0.
U234	1.85E+03	3.92E+01	0.	1.62E+04	1.53E+05	0.	0.
PU238	2.17E+03	4.65E+01	0.	8.68E+04	2.96E+05	0.	1.00E+04
PU239	2.04E+03	4.24E+01	0.	8.18E+04	2.78E+05	0.	9.46E+03
PU240	2.06E+03	4.24E+01	0.	8.18E+04	2.81E+05	0.	9.55E+03
PU241	2.04E+00	8.16E-02	0.	8.00E+01	1.91E+02	0.	9.27E+00
AM241	4.54E+03	4.57E+01	0.	5.68E+04	1.72E+05	0.	4.81E+04
CM242	2.10E+03	4.98E+01	0.	3.16E+04	1.22E+05	0.	2.54E+04
CM244	4.69E+03	4.73E+01	0.	7.05E+04	1.79E+05	0.	5.64E+04

NOTE - TRITIUM TRANSPIRATION DOSE FACTOR WAS TAKEN TO BE 50% OF THE INHALATION DOSE FACTOR FOR TRITIUM.

TABLE H-7

INHALATION DOSE FACTORS, TEEN

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	3.07E-01	3.07E-01	3.07E-01	0.	3.07E-01	3.07E-01	3.07E-01
C14	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00
NA22	7.53E+01	1.22E+00	7.53E+01	7.53E+01	7.53E+01	0.	7.53E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	1.43E+00	8.67E+00	0.	0.	6.26E+02	0.	1.00E+00
CO60	8.87E+00	2.34E+01	0.	0.	3.56E+03	0.	6.35E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	9.87E+00	4.85E+01	0.	3.43E+02	1.62E+03	0.	0.
SR90	1.97E+02	9.89E+01	0.	2.96E+03	9.62E+03	0.	0.
Y90	6.54E-02	8.02E+01	0.	2.43E+00	1.98E+02	0.	0.
Y91	1.31E+01	5.12E+01	0.	4.90E+02	1.88E+03	0.	0.
ZR95	1.61E+01	1.01E+01	0.	8.93E+01	1.30E+03	0.	2.28E+01
NB95	2.90E+00	8.67E+00	0.	1.10E+01	3.42E+02	0.	4.93E+00
RU103	5.01E-01	1.13E+01	0.	1.45E+00	4.04E+02	0.	0.
RU106	9.13E+00	1.26E+02	0.	7.38E+01	1.00E+04	0.	0.
SN123	8.66E+00	4.28E+01	5.37E+00	2.54E+02	2.57E+03	0.	5.37E+00
TE125	5.25E-01	9.71E+00	1.30E+00	3.86E+00	3.53E+02	0.	1.66E+00
TE127	3.34E-04	1.87E+01	1.26E-03	1.52E-03	7.03E+00	0.	6.47E-04
TE129	1.72E+00	5.23E+01	4.27E+00	1.11E+01	1.29E+03	0.	4.86E+00
TE132	1.28E-01	6.68E+01	2.04E-01	2.73E-01	2.48E+02	0.	1.73E-01
I129	5.36E+01	2.23E-01	1.04E+04	2.23E+01	0.	0.	1.62E+01
I131	1.75E+01	7.66E-01	1.01E+04	2.59E+01	0.	0.	3.05E+01
I133	4.14E+00	1.63E+00	3.30E+03	9.48E+00	0.	0.	1.37E+01
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	5.23E+01	9.80E-01	0.	3.03E+02	6.38E+01	0.	5.64E+02
CS137	3.15E+01	9.45E-01	0.	4.12E+02	5.67E+01	0.	4.91E+02
BA140	2.16E+00	2.77E+00	0.	4.18E+01	1.17E+03	0.	4.22E-02
LA140	3.73E-02	6.43E+01	0.	3.66E-01	1.21E+02	0.	1.45E-01
CE141	1.51E+00	1.47E+01	0.	2.09E+01	3.70E+02	0.	1.29E+01
CE144	1.21E+02	1.15E+02	0.	1.96E+03	8.61E+03	0.	1.02E+03
EU154	9.62E+01	2.95E+01	0.	8.08E+02	3.49E+03	0.	3.59E+02
U232	2.24E+04	4.55E+01	0.	1.72E+05	1.78E+06	0.	0.
U234	3.93E+03	4.16E+01	0.	3.46E+04	4.17E+05	0.	0.
PU238	4.62E+03	4.95E+01	0.	1.85E+05	8.07E+05	0.	2.66E+04
PU239	4.35E+03	4.51E+01	0.	1.74E+05	7.59E+05	0.	2.51E+04
PU240	4.39E+03	4.51E+01	0.	1.74E+05	7.66E+05	0.	2.53E+04
PU241	4.34E+00	8.68E-02	0.	1.70E+02	5.20E+02	0.	2.46E+01
AM241	9.68E+03	4.86E+01	0.	1.21E+05	4.68E+05	0.	1.27E+05
CM242	4.46E+03	5.29E+01	0.	6.72E+04	3.32E+05	0.	6.72E+04
CM244	9.98E+03	5.03E+01	0.	1.50E+05	4.87E+05	0.	1.49E+05

NOTE - TRITIUM TRANSPIRATION DOSE FACTOR WAS TAKEN TO BE 50% OF THE INHALATION DOSE FACTOR FOR TRITIUM.

TABLE H-8

INHALATION DOSE FACTORS, ADULT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.05E-01	1.05E-01	1.05E-01	0.	1.05E-01	1.05E-01	1.05E-01
C14	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01
NA22	1.30E+01	1.63E+00	1.30E+01	1.30E+01	1.30E+01	0.	1.30E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	2.58E-01	1.33E+01	0.	0.	1.16E+02	0.	1.97E-01
CO60	1.64E+00	3.56E+01	0.	0.	6.68E+02	0.	1.27E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.07E+00	4.37E+01	0.	3.72E+01	1.75E+02	0.	0.
SR90	2.17E+01	9.05E+01	0.	3.23E+02	1.06E+03	0.	0.
Y90	7.02E-03	6.33E+01	0.	2.62E-01	2.13E+01	0.	0.
Y91	1.49E+00	4.81E+01	0.	5.57E+01	2.13E+02	0.	0.
ZR95	2.79E+00	1.88E+01	0.	1.28E+01	2.21E+02	0.	4.15E+00
NB95	5.25E-01	1.30E+01	0.	1.75E+00	6.32E+01	0.	9.75E-01
RU103	8.23E-02	1.38E+01	0.	1.91E-01	6.32E+01	0.	0.
RU106	1.02E+00	1.14E+01	0.	8.01E+00	1.10E+03	0.	0.
SN123	9.52E-01	3.92E+01	5.37E-01	2.79E+01	2.83E+02	0.	6.31E-01
TE125	5.83E-02	8.83E+00	1.31E-01	4.26E-01	3.92E+01	0.	1.97E-01
TE127	3.87E-05	7.18E+00	1.32E-04	1.76E-04	8.15E-01	0.	8.03E-05
TE129	1.98E-01	4.79E+01	4.30E-01	1.22E+00	1.45E+02	0.	5.84E-01
TE132	2.01E-02	6.37E+01	2.36E-02	3.25E-02	3.60E+01	0.	2.68E-02
I129	6.36E+00	2.22E-01	5.11E+03	2.48E+00	0.	0.	2.11E+00
I131	2.56E+00	7.85E-01	1.49E+03	3.15E+00	0.	0.	4.47E+00
I133	5.68E-01	1.09E+00	3.66E+02	1.08E+00	0.	0.	1.86E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	8.37E+01	1.30E+00	0.	4.13E+01	1.07E+01	0.	1.01E+02
CS137	4.78E+01	1.05E+00	0.	5.04E+01	7.90E+00	0.	7.31E+01
BA140	3.21E-01	2.73E+01	0.	4.89E+00	1.59E+02	0.	6.15E-03
LA140	5.74E-03	5.74E+01	0.	4.31E-02	1.71E+01	0.	2.17E-02
CE141	1.91E-01	1.50E+01	0.	2.49E+00	4.52E+01	0.	1.68E+00
CE144	1.30E+01	1.02E+02	0.	2.10E+02	9.25E+02	0.	1.17E+02
EU154	1.54E+01	3.40E+01	0.	1.00E+02	5.19E+02	0.	5.71E+01
U232	2.46E+03	4.16E+01	0.	1.89E+04	1.96E+05	0.	0.
U234	4.33E+02	3.81E+01	0.	3.80E+03	4.59E+04	0.	0.
PU238	5.08E+02	4.52E+01	0.	2.03E+04	8.88E+04	0.	3.13E+03
PU239	4.78E+02	4.13E+01	0.	1.92E+04	8.34E+04	0.	2.95E+03
PU240	4.79E+02	4.21E+01	0.	1.92E+04	8.36E+04	0.	2.95E+03
PU241	2.04E+01	8.65E-01	0.	9.52E+02	7.94E+01	0.	5.55E+01
AM241	1.06E+03	4.60E+01	0.	1.33E+04	5.15E+04	0.	1.50E+04
CM242	4.90E+02	4.91E+01	0.	7.42E+03	3.65E+04	0.	7.89E+03
CM244	1.10E+03	4.68E+01	0.	1.65E+04	5.36E+04	0.	1.76E+04

NOTE - TRITIUM TRANSPIRATION DOSE FACTOR WAS TAKEN TO BE 50% OF THE INHALATION DOSE FACTOR FOR TRITIUM.

TABLE H-9

SOIL EXPOSURE DOSE FACTORS, INFANT
(MREM/HR PER MICROCURIE/SQUARE METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	0.	0.
NA22	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	7.90E-02	2.00E-02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	9.70E-03	9.70E-03	9.70E-03	9.70E-03	9.70E-03	1.50E-02	9.70E-03
CO60	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.80E-02	2.00E-02
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.60E-01	1.10E-04
SR90	4.40E-06	4.40E-06	4.40E-06	4.40E-06	4.40E-06	5.80E-02	4.40E-06
Y90	5.30E-05	5.30E-05	5.30E-05	5.30E-05	5.30E-05	1.80E-01	5.30E-05
Y91	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	1.70E-01	6.90E-05
ZR95	7.40E-03	7.40E-03	7.40E-03	7.40E-03	7.40E-03	2.10E-02	7.40E-03
NB95	7.80E-03	7.80E-03	7.80E-03	7.80E-03	7.80E-03	9.80E-03	7.80E-03
RU103	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	8.00E-03	5.00E-03
RU106	2.20E-03	2.20E-03	2.20E-03	2.20E-03	2.20E-03	1.80E-01	2.20E-03
SN123	0.	0.	0.	0.	0.	1.60E-01	0.
TE125	5.10E-05	5.10E-05	5.10E-05	5.10E-05	5.10E-05	7.80E-05	5.10E-05
TE127	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.60E-05	6.90E-02	1.60E-05
TE129	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.50E-01	1.20E-03
TE132	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.70E-03	2.30E-03
I129	6.51E-04	6.51E-04	6.51E-04	6.51E-04	6.51E-04	1.00E-03	6.51E-04
I131	3.90E-03	3.90E-03	3.90E-03	3.90E-03	3.90E-03	4.80E-02	3.90E-03
I133	5.30E-03	5.30E-03	5.30E-03	5.30E-03	5.30E-03	1.40E-01	5.30E-03
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	5.90E-02	1.60E-02
CS137	5.80E-03	5.80E-03	5.80E-03	5.80E-03	5.80E-03	4.00E-02	5.80E-03
BA140	2.70E-03	2.70E-03	2.70E-03	2.70E-03	2.70E-03	7.80E-02	2.70E-03
LA140	1.80E-02	1.80E-02	1.80E-02	1.80E-02	1.80E-02	1.90E-01	1.80E-02
CE141	7.60E-04	7.60E-04	7.60E-04	7.60E-04	7.60E-04	2.70E-02	7.60E-04
CE144	1.80E-04	1.80E-04	1.80E-04	1.80E-04	1.80E-04	3.70E-03	1.80E-04
EU154	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	7.50E-03	1.10E-02
U232	3.10E-07	3.10E-07	3.10E-07	3.10E-07	3.10E-07	1.10E-06	3.10E-07
U234	1.31E-06	1.31E-06	1.31E-06	1.31E-06	1.31E-06	2.97E-04	1.31E-06
PU238	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.50E-04	2.00E-06
PU239	1.50E-06	1.50E-06	1.50E-06	1.50E-06	1.50E-06	1.20E-04	1.50E-06
PU240	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.60E-06	2.10E-06
PU241	1.91E-08	1.91E-08	1.91E-08	1.91E-08	1.91E-08	2.19E-08	1.91E-08
AM241	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	1.20E-03	3.00E-04
CM242	8.40E-06	8.40E-06	8.40E-06	8.40E-06	8.40E-06	2.50E-04	8.40E-06
CM244	6.80E-06	6.80E-06	6.80E-06	6.80E-06	6.80E-06	2.10E-04	6.80E-06

TABLE H-10

SOIL EXPOSURE DOSE FACTORS, CHILD

(MREM/HR PER MICROCURIE/SQUARE METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	0.	0.
NA22	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	7.90E-02	2.00E-02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	9.70E-03	9.70E-03	9.70E-03	9.70E-03	9.70E-03	1.50E-02	9.70E-03
CO60	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.80E-02	2.00E-02
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.10E-04	1.60E-01	1.10E-04
SR90	4.40E-06	4.40E-06	4.40E-06	4.40E-06	4.40E-06	5.80E-02	4.40E-06
Y90	5.30E-05	5.30E-05	5.30E-05	5.30E-05	5.30E-05	1.80E-01	5.30E-05
Y91	6.90E-05	6.90E-05	6.90E-05	6.90E-05	6.90E-05	1.70E-01	6.90E-05
ZR95	7.40E-03	7.40E-03	7.40E-03	7.40E-03	7.40E-03	2.10E-02	7.40E-03
NB95	7.80E-03	7.80E-03	7.80E-03	7.80E-03	7.80E-03	9.80E-03	7.80E-03
RU103	5.00E-03	5.00E-03	5.00E-03	5.00E-03	5.00E-03	8.00E-03	5.00E-03
RU106	2.20E-03	2.20E-03	2.20E-03	2.20E-03	2.20E-03	1.80E-01	2.20E-03
SN123	0.	0.	0.	0.	0.	1.60E-01	0.
TE125	5.10E-05	5.10E-05	5.10E-05	5.10E-05	5.10E-05	7.80E-05	5.10E-05
TE127	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.60E-05	6.90E-02	1.60E-05
TE129	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03	1.50E-01	1.20E-03
TE132	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.30E-03	2.70E-03	2.30E-03
I129	6.51E-04	6.51E-04	6.51E-04	6.51E-04	6.51E-04	1.00E-03	6.51E-04
I131	3.90E-03	3.90E-03	3.90E-03	3.90E-03	3.90E-03	4.80E-02	3.90E-03
I133	5.30E-03	5.30E-03	5.30E-03	5.30E-03	5.30E-03	1.40E-01	5.30E-03
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	5.90E-02	1.60E-02
CS137	5.80E-03	5.80E-03	5.80E-03	5.80E-03	5.80E-03	4.00E-02	5.80E-03
BA140	2.70E-03	2.70E-03	2.70E-03	2.70E-03	2.70E-03	7.80E-02	2.70E-03
LA140	1.80E-02	1.80E-02	1.80E-02	1.80E-02	1.80E-02	1.90E-01	1.80E-02
CE141	7.60E-04	7.60E-04	7.60E-04	7.60E-04	7.60E-04	2.70E-02	7.60E-04
CE144	1.80E-04	1.80E-04	1.80E-04	1.80E-04	1.80E-04	3.70E-03	1.80E-04
EU154	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	7.50E-03	1.10E-02
U232	3.10E-07	3.10E-07	3.10E-07	3.10E-07	3.10E-07	1.10E-06	3.10E-07
U234	1.31E-06	1.31E-06	1.31E-06	1.31E-06	1.31E-06	2.97E-04	1.31E-06
PU238	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.00E-06	2.50E-04	2.00E-06
PU239	1.50E-06	1.50E-06	1.50E-06	1.50E-06	1.50E-06	1.20E-04	1.50E-06
PU240	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.10E-06	2.60E-06	2.10E-06
PU241	1.91E-08	1.91E-08	1.91E-08	1.91E-08	1.91E-08	2.19E-08	1.91E-08
AM241	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	1.20E-03	3.00E-04
CM242	8.40E-06	8.40E-06	8.40E-06	8.40E-06	8.40E-06	2.50E-04	8.40E-06
CM244	6.80E-06	6.80E-06	6.80E-06	6.80E-06	6.80E-06	2.10E-04	6.80E-06

TABLE H-11

SOIL EXPOSURE DOSE FACTORS, TEEN

(MREM/HR PER MICROCURIE/SQUARE METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	0.	0.
NA22	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	2.30E-02	1.60E-02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	8.00E-03	8.00E-03	8.00E-03	8.00E-03	8.00E-03	9.30E-03	8.00E-03
CO60	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.90E-02	1.70E-02
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	9.10E-05	9.10E-05	9.10E-05	9.10E-05	9.10E-05	6.00E-02	9.10E-05
SR90	3.40E-06	3.40E-06	3.40E-06	3.40E-06	3.40E-06	2.50E-03	3.40E-06
Y90	4.50E-05	4.50E-05	4.50E-05	4.50E-05	4.50E-05	9.60E-02	4.50E-05
Y91	5.60E-05	5.60E-05	5.60E-05	5.60E-05	5.60E-05	6.60E-02	5.60E-05
ZR95	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	7.30E-03	5.90E-03
NB95	6.30E-03	6.30E-03	6.30E-03	6.30E-03	6.30E-03	7.50E-03	6.30E-03
RU103	4.10E-03	4.10E-03	4.10E-03	4.10E-03	4.10E-03	4.90E-03	4.10E-03
RU106	1.70E-03	1.70E-03	1.70E-03	1.70E-03	1.70E-03	1.40E-01	1.70E-03
SN123	0.	0.	0.	0.	0.	5.50E-02	0.
TE125	3.80E-05	3.80E-05	3.80E-05	3.80E-05	3.80E-05	6.20E-05	3.80E-05
TE127	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	4.60E-03	1.30E-05
TE129	9.70E-04	9.70E-04	9.70E-04	9.70E-04	9.70E-04	5.50E-02	9.70E-04
TE132	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	2.20E-03	1.90E-03
I129	4.50E-04	4.50E-04	4.50E-04	4.50E-04	4.50E-04	7.51E-04	4.50E-04
I131	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.20E-03	5.70E-03	3.20E-03
I133	4.40E-03	4.40E-03	4.40E-03	4.40E-03	4.40E-03	4.80E-02	4.40E-03
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.80E-02	1.30E-02
CS137	4.60E-03	4.60E-03	4.60E-03	4.60E-03	4.60E-03	8.90E-03	4.60E-03
BA140	2.20E-03	2.20E-03	2.20E-03	2.20E-03	2.20E-03	1.70E-02	2.20E-03
LA140	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	8.20E-02	1.50E-02
CE141	6.30E-04	6.30E-04	6.30E-04	6.30E-04	6.30E-04	1.30E-03	6.30E-04
CE144	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.70E-04	1.50E-04
EU154	8.80E-03	8.80E-03	8.80E-03	8.80E-03	8.80E-03	2.40E-02	8.80E-03
U232	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	6.80E-07	2.60E-07
U234	6.32E-07	6.32E-07	6.32E-07	6.32E-07	6.32E-07	1.59E-04	6.32E-07
PU238	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.40E-04	1.20E-06
PU239	9.90E-07	9.90E-07	9.90E-07	9.90E-07	9.90E-07	6.30E-05	9.90E-07
PU240	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.40E-06	1.20E-06
PU241	1.75E-08	1.75E-08	1.75E-08	1.75E-08	1.75E-08	1.86E-08	1.75E-08
AM241	2.40E-06	2.40E-06	2.40E-06	2.40E-06	2.40E-06	7.40E-06	2.40E-06
CM242	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	1.40E-04	4.10E-06
CM244	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06	1.10E-04	3.00E-06

TABLE H-12

SOIL EXPOSURE DOSE FACTORS, ADULT
(MREM/HR PER MICROCURIE/SQUARE METER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	0.	0.
NA22	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	2.30E-02	1.60E-02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	8.00E-03	8.00E-03	8.00E-03	8.00E-03	8.00E-03	9.30E-03	8.00E-03
CO60	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.90E-02	1.70E-02
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	9.10E-05	9.10E-05	9.10E-05	9.10E-05	9.10E-05	6.00E-02	9.10E-05
SR90	3.40E-06	3.40E-06	3.40E-06	3.40E-06	3.40E-06	2.50E-03	3.40E-06
Y90	4.50E-05	4.50E-05	4.50E-05	4.50E-05	4.50E-05	9.60E-02	4.50E-05
Y91	5.60E-05	5.60E-05	5.60E-05	5.60E-05	5.60E-05	6.60E-02	5.60E-05
ZR95	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	7.30E-03	5.90E-03
NB95	6.30E-03	6.30E-03	6.30E-03	6.30E-03	6.30E-03	7.50E-03	6.30E-03
RU103	4.10E-03	4.10E-03	4.10E-03	4.10E-03	4.10E-03	4.90E-03	4.10E-03
RU106	1.70E-03	1.70E-03	1.70E-03	1.70E-03	1.70E-03	1.40E-01	1.70E-03
SN123	0.	0.	0.	0.	0.	5.50E-02	0.
TE125	3.80E-05	3.80E-05	3.80E-05	3.80E-05	3.80E-05	6.20E-05	3.80E-05
TE127	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	4.60E-03	1.30E-05
TE129	9.70E-04	9.70E-04	9.70E-04	9.70E-04	9.70E-04	5.50E-02	9.70E-04
TE132	1.90E-03	1.90E-03	1.90E-03	1.90E-03	1.90E-03	2.20E-03	1.90E-03
I129	4.50E-04	4.50E-04	4.50E-04	4.50E-04	4.50E-04	7.51E-04	4.50E-04
I131	3.20E-03	3.20E-03	3.20E-03	3.20E-03	3.20E-03	5.70E-03	3.20E-03
I133	4.40E-03	4.40E-03	4.40E-03	4.40E-03	4.40E-03	4.80E-02	4.40E-03
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.30E-02	1.80E-02	1.30E-02
CS137	4.60E-03	4.60E-03	4.60E-03	4.60E-03	4.60E-03	8.90E-03	4.60E-03
BA140	2.20E-03	2.20E-03	2.20E-03	2.20E-03	2.20E-03	1.70E-02	2.20E-03
LA140	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	8.20E-02	1.50E-02
CE141	6.30E-04	6.30E-04	6.30E-04	6.30E-04	6.30E-04	1.30E-03	6.30E-04
CE144	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.70E-04	1.50E-04
EU154	8.80E-03	8.80E-03	8.80E-03	8.80E-03	8.80E-03	2.40E-02	8.80E-03
U232	2.60E-07	2.60E-07	2.60E-07	2.60E-07	2.60E-07	6.80E-07	2.60E-07
U234	6.32E-07	6.32E-07	6.32E-07	6.32E-07	6.32E-07	1.59E-04	6.32E-07
PU238	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.40E-04	1.20E-06
PU239	9.90E-07	9.90E-07	9.90E-07	9.90E-07	9.90E-07	6.30E-05	9.90E-07
PU240	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.20E-06	1.40E-06	1.20E-06
PU241	1.75E-08	1.75E-08	1.75E-08	1.75E-08	1.75E-08	1.86E-08	1.75E-08
AM241	2.40E-06	2.40E-06	2.40E-06	2.40E-06	2.40E-06	7.40E-06	2.40E-06
CM242	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	1.40E-04	4.10E-06
CM244	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06	1.10E-04	3.00E-06

TABLE H-13

IMMERSION IN WATER DOSE FACTORS, INFANT

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.83E-03	0.
NA22	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.81E+00	4.03E+00
AR39	6.18E-04	6.18E-04	6.18E-04	6.18E-04	6.18E-04	1.33E-01	6.18E-04
CO58	1.78E+00	1.78E+00	1.78E+00	1.78E+00	1.78E+00	2.33E+00	1.78E+00
CO60	4.58E+00	4.58E+00	4.58E+00	4.58E+00	4.58E+00	5.36E+00	4.58E+00
KR85M	2.79E-01	2.79E-01	2.79E-01	2.79E-01	2.79E-01	5.14E-01	2.79E-01
KR85	4.69E-03	4.69E-03	4.69E-03	4.69E-03	4.69E-03	1.75E-01	4.69E-03
KR87	2.75E+00	2.75E+00	2.75E+00	2.75E+00	2.75E+00	4.64E+00	2.75E+00
KR88	3.26E+00	3.26E+00	3.26E+00	3.26E+00	3.26E+00	4.05E+00	3.26E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	5.43E-01	4.64E-03
SR90	5.37E-04	5.37E-04	5.37E-04	5.37E-04	5.37E-04	1.48E-01	5.37E-04
Y90	1.26E-02	1.26E-02	1.26E-02	1.26E-02	1.26E-02	9.46E-01	1.26E-02
Y91	9.97E-01	9.97E-01	9.97E-01	9.97E-01	9.97E-01	1.20E+00	9.97E-01
ZR95	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.78E+00	1.48E+00
NB95	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.63E+00	1.39E+00
RU103	8.90E-01	8.90E-01	8.90E-01	8.90E-01	8.90E-01	1.06E+00	8.90E-01
RU106	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.77E-01	1.91E+00	3.77E-01
SN123	0.	0.	0.	0.	0.	5.03E-01	0.
TE125	3.62E-03	3.62E-03	3.62E-03	3.62E-03	3.62E-03	1.52E-02	3.62E-03
TE127	2.73E-03	2.73E-03	2.73E-03	2.73E-03	2.73E-03	1.75E-01	2.73E-03
TE129	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	7.41E-01	2.06E-01
TE132	3.96E-01	3.96E-01	3.96E-01	3.96E-01	3.96E-01	4.79E-01	3.96E-01
I129	8.58E-08	8.58E-08	8.58E-08	8.58E-08	8.58E-08	1.53E-07	8.58E-08
I131	6.79E-01	6.79E-01	6.79E-01	6.79E-01	6.79E-01	9.34E-01	6.79E-01
I133	9.58E-01	9.58E-01	9.58E-01	9.58E-01	9.58E-01	1.53E+00	9.58E-01
XE133	5.67E-02	5.67E-02	5.67E-02	5.67E-02	5.67E-02	1.08E-01	5.67E-02
XE135M	7.63E-01	7.63E-01	7.63E-01	7.63E-01	7.63E-01	9.96E-01	7.63E-01
XE135	4.49E-01	4.49E-01	4.49E-01	4.49E-01	4.49E-01	7.94E-01	4.49E-01
XE137	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.09E+00	2.71E-01
XE138	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00	3.38E+00	2.60E+00
CS134	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.90E+00	3.50E+00	2.90E+00
CS137	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.36E+00	1.02E+00
BA140	4.86E-01	4.86E-01	4.86E-01	4.86E-01	4.86E-01	7.63E-01	4.86E-01
LA140	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	5.34E+00	4.11E+00
CE141	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	2.44E-01	1.30E+00
CE144	8.65E-02	8.65E-02	8.65E-02	8.65E-02	8.65E-02	1.39E+00	8.65E-02
EU154	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.66E+00	2.17E+00
U232	4.56E-04	4.56E-04	4.56E-04	4.56E-04	4.56E-04	1.11E-03	4.56E-04
U234	8.50E-04	8.50E-04	8.50E-04	8.50E-04	8.50E-04	5.28E-03	8.50E-04
PU238	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	4.05E-03	1.48E-04
PU239	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.75E-03	1.22E-04
PU240	1.41E-04	1.41E-04	1.41E-04	1.41E-04	1.41E-04	4.03E-03	1.41E-04
PU241	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.98E-06	2.53E-06
AM241	3.92E-02	3.92E-02	3.92E-02	3.92E-02	3.92E-02	6.13E-02	3.92E-02
CM242	3.39E-04	3.39E-04	3.39E-04	3.39E-04	3.39E-04	4.73E-03	3.39E-04
CM244	2.64E-04	2.64E-04	2.64E-04	2.64E-04	2.64E-04	3.94E-03	2.64E-04

TABLE H-14

IMMERSION IN WATER DOSE FACTORS, CHILD

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.83E-03	0.
NA22	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.81E+00	4.03E+00
AR39	6.18E-04	6.18E-04	6.18E-04	6.18E-04	6.18E-04	1.33E-01	6.18E-04
CO58	1.78E+00	1.78E+00	1.78E+00	1.78E+00	1.78E+00	2.30E+00	1.78E+00
CO60	4.58E+00	4.58E+00	4.58E+00	4.58E+00	4.58E+00	5.36E+00	4.58E+00
KR85M	2.79E-01	2.79E-01	2.79E-01	2.79E-01	2.79E-01	5.14E-01	2.79E-01
KR85	4.69E-03	4.69E-03	4.69E-03	4.69E-03	4.69E-03	1.75E-01	4.69E-03
KR87	2.75E+00	2.75E+00	2.75E+00	2.75E+00	2.75E+00	4.64E+00	2.75E+00
KR88	3.26E+00	3.26E+00	3.26E+00	3.26E+00	3.26E+00	4.05E+00	3.26E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	5.43E-01	4.64E-03
SR90	5.37E-04	5.37E-04	5.37E-04	5.37E-04	5.37E-04	1.48E-01	5.37E-04
Y90	1.26E-02	1.26E-02	1.26E-02	1.26E-02	1.26E-02	9.46E-01	1.26E-02
Y91	9.97E-01	9.97E-01	9.97E-01	9.97E-01	9.97E-01	1.20E+00	9.97E-01
ZR95	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.78E+00	1.48E+00
NB95	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.63E+00	1.39E+00
RU103	8.90E-01	8.90E-01	8.90E-01	8.90E-01	8.90E-01	1.06E+00	8.90E-01
RU106	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.77E-01	1.91E+00	3.77E-01
SN123	0.	0.	0.	0.	0.	5.03E-01	0.
TE125	3.62E-03	3.62E-03	3.62E-03	3.62E-03	3.62E-03	1.52E-02	3.62E-03
TE127	2.73E-03	2.73E-03	2.73E-03	2.73E-03	2.73E-03	1.75E-01	2.73E-03
TE129	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	7.41E-01	2.06E-01
TE132	3.96E-01	3.96E-01	3.96E-01	3.96E-01	3.96E-01	4.79E-01	3.96E-01
I129	8.58E-08	8.58E-08	8.58E-08	8.58E-08	8.58E-08	1.53E-07	8.58E-08
I131	6.79E-01	6.79E-01	6.79E-01	6.79E-01	6.79E-01	9.34E-01	6.79E-01
I133	9.58E-01	9.58E-01	9.58E-01	9.58E-01	9.58E-01	1.53E+00	9.58E-01
XE133	5.67E-02	5.67E-02	5.67E-02	5.67E-02	5.67E-02	1.08E-01	5.67E-02
XE135M	7.63E-01	7.63E-01	7.63E-01	7.63E-01	7.63E-01	9.96E-01	7.63E-01
XE135	4.49E-01	4.49E-01	4.49E-01	4.49E-01	4.49E-01	7.94E-01	4.49E-01
XE137	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.09E+00	2.71E-01
XE138	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00	3.38E+00	2.60E+00
CS134	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.90E+00	3.50E+00	2.90E+00
CS137	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.36E+00	1.02E+00
BA140	4.86E-01	4.86E-01	4.86E-01	4.86E-01	4.86E-01	7.63E-01	4.86E-01
LA140	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	5.34E+00	4.11E+00
CE141	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	2.44E-01	1.30E+00
CE144	8.65E-02	8.65E-02	8.65E-02	8.65E-02	8.65E-02	1.39E+00	8.65E-02
EU154	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.66E+00	2.17E+00
U232	4.56E-04	4.56E-04	4.56E-04	4.56E-04	4.56E-04	1.11E-03	4.56E-04
U234	8.50E-04	8.50E-04	8.50E-04	8.50E-04	8.50E-04	5.28E-03	8.50E-04
PU238	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	4.05E-03	1.48E-04
PU239	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.75E-03	1.22E-04
PU240	1.41E-04	1.41E-04	1.41E-04	1.41E-04	1.41E-04	4.03E-03	1.41E-04
PU241	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.98E-06	2.53E-06
AM241	3.92E-02	3.92E-02	3.92E-02	3.92E-02	3.92E-02	6.13E-02	3.92E-02
CM242	3.39E-04	3.39E-04	3.39E-04	3.39E-04	3.39E-04	4.73E-03	3.39E-04
CM244	2.64E-04	2.64E-04	2.64E-04	2.64E-04	2.64E-04	3.94E-03	2.64E-04

TABLE H-15

IMMERSION IN WATER DOSE FACTORS, TEEN

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.83E-03	0.
NA22	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.81E+00	4.03E+00
AR39	6.18E-04	6.18E-04	6.18E-04	6.18E-04	6.18E-04	1.33E-01	6.18E-04
CO58	1.78E+00	1.78E+00	1.78E+00	1.78E+00	1.78E+00	2.30E+00	1.78E+00
CO60	4.58E+00	4.58E+00	4.58E+00	4.58E+00	4.58E+00	5.36E+00	4.58E+00
KR85M	2.79E-01	2.79E-01	2.79E-01	2.79E-01	2.79E-01	5.14E-01	2.79E-01
KR85	4.69E-03	4.69E-03	4.69E-03	4.69E-03	4.69E-03	1.75E-01	4.69E-03
KR87	2.75E+00	2.75E+00	2.75E+00	2.75E+00	2.75E+00	4.64E+00	2.75E+00
KR88	3.26E+00	3.26E+00	3.26E+00	3.26E+00	3.26E+00	4.05E+00	3.26E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	5.43E-01	4.64E-03
SR90	5.37E-04	5.37E-04	5.37E-04	5.37E-04	5.37E-04	1.48E-01	5.37E-04
Y90	1.26E-02	1.26E-02	1.26E-02	1.26E-02	1.26E-02	9.46E-01	1.26E-02
Y91	9.97E-01	9.97E-01	9.97E-01	9.97E-01	9.97E-01	1.20E+00	9.97E-01
ZR95	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.78E+00	1.48E+00
NB95	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.63E+00	1.39E+00
RU103	8.90E-01	8.90E-01	8.90E-01	8.90E-01	8.90E-01	1.06E+00	8.90E-01
RU106	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.77E-01	1.91E+00	3.77E-01
SN123	0.	0.	0.	0.	0.	5.03E-01	0.
TE125	3.62E-03	3.62E-03	3.62E-03	3.62E-03	3.62E-03	1.52E-02	3.62E-03
TE127	2.73E-03	2.73E-03	2.73E-03	2.73E-03	2.73E-03	1.75E-01	2.73E-03
TE129	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	7.41E-01	2.06E-01
TE132	3.96E-01	3.96E-01	3.96E-01	3.96E-01	3.96E-01	4.79E-01	3.96E-01
I129	8.58E-08	8.58E-08	8.58E-08	8.58E-08	8.58E-08	1.53E-07	8.58E-08
I131	6.79E-01	6.79E-01	6.79E-01	6.79E-01	6.79E-01	9.34E-01	6.79E-01
I133	9.58E-01	9.58E-01	9.58E-01	9.58E-01	9.58E-01	1.53E+00	9.58E-01
XE133	5.67E-02	5.67E-02	5.67E-02	5.67E-02	5.67E-02	1.08E-01	5.67E-02
XE135M	7.63E-01	7.63E-01	7.63E-01	7.63E-01	7.63E-01	9.96E-01	7.63E-01
XE135	4.49E-01	4.49E-01	4.49E-01	4.49E-01	4.49E-01	7.94E-01	4.49E-01
XE137	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.09E+00	2.71E-01
XE138	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00	3.38E+00	2.60E+00
CS134	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.90E+00	3.50E+00	2.90E+00
CS137	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.36E+00	1.02E+00
BA140	4.86E-01	4.86E-01	4.86E-01	4.86E-01	4.86E-01	7.63E-01	4.86E-01
LA140	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	5.34E+00	4.11E+00
CE141	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	2.44E-01	1.30E+00
CE144	8.65E-02	8.65E-02	8.65E-02	8.65E-02	8.65E-02	1.39E+00	8.65E-02
EU154	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.66E+00	2.17E+00
U232	4.56E-04	4.56E-04	4.56E-04	4.56E-04	4.56E-04	1.11E-03	4.56E-04
U234	8.50E-04	8.50E-04	8.50E-04	8.50E-04	8.50E-04	5.28E-03	8.50E-04
PU238	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	4.05E-03	1.48E-04
PU239	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.75E-03	1.22E-04
PU240	1.41E-04	1.41E-04	1.41E-04	1.41E-04	1.41E-04	4.03E-03	1.41E-04
PU241	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.98E-06	2.53E-06
AM241	3.92E-02	3.92E-02	3.92E-02	3.92E-02	3.92E-02	6.13E-02	3.92E-02
CM242	3.39E-04	3.39E-04	3.39E-04	3.39E-04	3.39E-04	4.73E-03	3.39E-04
CM244	2.64E-04	2.64E-04	2.64E-04	2.64E-04	2.64E-04	3.94E-03	2.64E-04

TABLE H-16

IMMERSION IN WATER DOSE FACTORS, ADULT

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	3.83E-03	0.
NA22	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.03E+00	4.81E+00	4.03E+00
AR39	6.18E-04	6.18E-04	6.18E-04	6.18E-04	6.18E-04	1.33E-01	6.18E-04
CO58	1.78E+00	1.78E+00	1.78E+00	1.78E+00	1.78E+00	2.30E+00	1.78E+00
CO60	4.58E+00	4.58E+00	4.58E+00	4.58E+00	4.58E+00	5.36E+00	4.58E+00
KR85M	2.79E-01	2.79E-01	2.79E-01	2.79E-01	2.79E-01	5.14E-01	2.79E-01
KR85	4.69E-03	4.69E-03	4.69E-03	4.69E-03	4.69E-03	1.75E-01	4.69E-03
KR87	2.75E+00	2.75E+00	2.75E+00	2.75E+00	2.75E+00	4.64E+00	2.75E+00
KR88	3.26E+00	3.26E+00	3.26E+00	3.26E+00	3.26E+00	4.05E+00	3.26E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.64E-03	4.64E-03	4.64E-03	4.64E-03	4.64E-03	5.43E-01	4.64E-03
SR90	5.37E-04	5.37E-04	5.37E-04	5.37E-04	5.37E-04	1.48E-01	5.37E-04
Y90	1.26E-02	1.26E-02	1.26E-02	1.26E-02	1.26E-02	9.46E-01	1.26E-02
Y91	9.97E-01	9.97E-01	9.97E-01	9.97E-01	9.97E-01	1.20E+00	9.97E-01
ZR95	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.48E+00	1.78E+00	1.48E+00
NB95	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.39E+00	1.63E+00	1.39E+00
RU103	8.90E-01	8.90E-01	8.90E-01	8.90E-01	8.90E-01	1.06E+00	8.90E-01
RU106	3.77E-01	3.77E-01	3.77E-01	3.77E-01	3.77E-01	1.91E+00	3.77E-01
SN123	0.	0.	0.	0.	0.	5.03E-01	0.
TE125	3.62E-03	3.62E-03	3.62E-03	3.62E-03	3.62E-03	1.52E-02	3.62E-03
TE127	2.73E-03	2.73E-03	2.73E-03	2.73E-03	2.73E-03	1.75E-01	2.73E-03
TE129	2.06E-01	2.06E-01	2.06E-01	2.06E-01	2.06E-01	7.41E-01	2.06E-01
TE132	3.96E-01	3.96E-01	3.96E-01	3.96E-01	3.96E-01	4.79E-01	3.96E-01
I129	8.58E-08	8.58E-08	8.58E-08	8.58E-08	8.58E-08	1.53E-07	8.58E-08
I131	6.79E-01	6.79E-01	6.79E-01	6.79E-01	6.79E-01	9.34E-01	6.79E-01
I133	9.58E-01	9.58E-01	9.58E-01	9.58E-01	9.58E-01	1.53E+00	9.58E-01
XE133	5.67E-02	5.67E-02	5.67E-02	5.67E-02	5.67E-02	1.08E-01	5.67E-02
XE135M	7.63E-01	7.63E-01	7.63E-01	7.63E-01	7.63E-01	9.96E-01	7.63E-01
XE135	4.49E-01	4.49E-01	4.49E-01	4.49E-01	4.49E-01	7.94E-01	4.49E-01
XE137	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.71E-01	2.09E+00	2.71E-01
XE138	2.60E+00	2.60E+00	2.60E+00	2.60E+00	2.60E+00	3.38E+00	2.60E+00
CS134	2.90E+00	2.90E+00	2.90E+00	2.90E+00	2.90E+00	3.50E+00	2.90E+00
CS137	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.02E+00	1.36E+00	1.02E+00
BA140	4.86E-01	4.86E-01	4.86E-01	4.86E-01	4.86E-01	7.63E-01	4.86E-01
LA140	4.11E+00	4.11E+00	4.11E+00	4.11E+00	4.11E+00	5.34E+00	4.11E+00
CE141	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	2.44E-01	1.30E+00
CE144	8.65E-02	8.65E-02	8.65E-02	8.65E-02	8.65E-02	1.39E+00	8.65E-02
EU154	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.17E+00	2.66E+00	2.17E+00
U232	4.56E-04	4.56E-04	4.56E-04	4.56E-04	4.56E-04	1.11E-03	4.56E-04
U234	8.50E-04	8.50E-04	8.50E-04	8.50E-04	8.50E-04	5.28E-03	8.50E-04
PU238	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.48E-04	4.05E-03	1.48E-04
PU239	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.22E-04	1.75E-03	1.22E-04
PU240	1.41E-04	1.41E-04	1.41E-04	1.41E-04	1.41E-04	4.03E-03	1.41E-04
PU241	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.53E-06	2.98E-06	2.53E-06
AM241	3.92E-02	3.92E-02	3.92E-02	3.92E-02	3.92E-02	6.13E-02	3.92E-02
CM242	3.39E-04	3.39E-04	3.39E-04	3.39E-04	3.39E-04	4.73E-03	3.39E-04
CM244	2.64E-04	2.64E-04	2.64E-04	2.64E-04	2.64E-04	3.94E-03	2.64E-04

TABLE H-17

INGESTION DOSE FACTORS, INFANT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	3.07E-01	3.07E-01	3.07E-01	0.	3.07E-01	3.07E-01	3.07E-01
C14	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00
NA22	1.00E+02	2.45E+00	1.00E+02	1.00E+02	1.00E+02	0.	1.00E+02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	9.26E+00	9.73E+00	0.	0.	0.	0.	3.78E+00
CO60	2.56E+01	2.64E+01	0.	0.	0.	0.	1.07E+01
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	8.13E+01	5.48E+01	0.	2.83E+03	0.	0.	0.
SR90	8.14E+02	2.43E+02	0.	3.05E+03	0.	0.	0.
Y90	2.41E-03	1.29E+02	0.	8.97E-02	0.	0.	0.
Y91	3.27E-02	8.26E+01	0.	1.23E+00	0.	0.	0.
ZR95	3.76E-02	2.38E+01	0.	2.09E-01	0.	0.	5.30E-02
NB95	1.03E-02	1.40E+01	0.	3.90E-02	0.	0.	1.75E-02
RU103	4.85E-01	1.76E+01	0.	1.41E+00	0.	0.	0.
RU106	3.12E+00	1.97E+02	0.	2.54E+01	0.	0.	0.
SN123	6.90E+00	6.91E+01	4.37E+00	2.79E+02	0.	0.	4.37E+00
TE125	3.24E+00	1.17E+01	8.00E+00	2.43E+01	0.	0.	8.19E+00
TE127	2.06E-01	2.27E+01	7.75E-01	9.58E-01	0.	0.	3.19E-01
TE129	1.59E+01	6.33E+01	3.93E+01	1.04E+02	0.	0.	3.58E+01
TE132	9.76E+00	8.08E+01	1.55E+01	2.13E+01	0.	0.	1.05E+01
I129	7.15E+01	4.46E-01	1.36E+04	2.95E+01	0.	0.	2.16E+01
I131	2.33E+01	1.53E+03	1.31E+04	3.42E+01	0.	0.	4.07E+01
I133	5.52E+00	3.27E+00	4.31E+03	1.25E+01	0.	0.	1.83E+01
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	6.97E+01	1.96E+00	0.	4.05E+02	8.33E+01	0.	7.89E+02
CS137	4.20E+01	1.89E+00	0.	5.49E+02	7.40E+01	0.	6.88E+02
BA140	8.99E+00	4.43E+00	0.	1.74E+02	1.07E-01	0.	1.75E-01
LA140	2.17E-03	1.04E+02	0.	2.13E-02	0.	0.	8.42E-03
CE141	5.67E-03	2.38E+01	0.	7.88E-02	0.	0.	4.84E-02
CE144	1.79E-01	1.85E+02	0.	2.97E+00	0.	0.	1.47E+00
EU154	1.28E-01	4.76E+01	0.	1.10E+00	0.	0.	4.15E-01
U232	2.47E+03	7.34E+01	0.	2.16E+04	0.	0.	0.
U234	4.33E+02	6.72E+01	0.	4.34E+03	0.	0.	0.
PU238	3.99E+00	7.98E+01	0.	1.60E+02	0.	0.	2.30E+01
PU239	3.75E+00	7.28E+01	0.	1.50E+02	0.	0.	2.16E+01
PU240	3.78E+00	7.28E+01	0.	1.50E+02	0.	0.	2.18E+01
PU241	3.77E-03	1.40E-01	0.	1.48E-01	0.	0.	2.13E-02
AM241	1.33E+01	7.84E+01	0.	1.66E+02	0.	0.	1.74E+02
CM242	7.51E+00	8.53E+01	0.	1.13E+02	0.	0.	1.13E+02
CM244	1.38E+01	8.12E+01	0.	2.07E+02	0.	0.	2.04E+02

TABLE H-18

INGESTION DOSE FACTORS, CHILD

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	2.03E-01	2.03E-01	2.03E-01	0.	2.03E-01	2.03E-01	2.03E-01
C14	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00
NA22	5.89E+01	2.57E+00	5.89E+01	5.89E+01	5.89E+01	0.	5.89E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	5.58E+00	1.10E+01	0.	0.	0.	0.	1.85E+00
CO60	1.55E+01	2.86E+01	0.	0.	0.	0.	5.17E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	3.82E+01	5.15E+01	0.	1.33E+03	0.	0.	0.
SR90	3.82E+02	2.29E+02	0.	1.43E+03	0.	0.	0.
Y90	1.13E-03	1.20E+02	0.	4.21E-02	0.	0.	0.
Y91	1.54E-02	7.77E+01	0.	5.75E-01	0.	0.	0.
ZR95	2.18E-02	2.50E+01	0.	1.03E-01	0.	0.	2.41E-02
NB95	6.13E-03	1.44E+01	0.	1.96E-02	0.	0.	8.34E-03
RU103	2.74E-01	1.78E+01	0.	6.78E-01	0.	0.	0.
RU106	1.48E+00	1.85E+02	0.	1.19E+01	0.	0.	0.
SN123	3.24E+00	6.50E+01	1.75E+00	1.31E+02	0.	0.	1.65E+00
TE125	1.52E+00	1.10E+01	3.20E+00	1.14E+01	0.	0.	3.09E+00
TE127	9.65E-02	1.92E+01	3.10E-01	4.50E-01	0.	0.	1.20E-01
TE129	7.60E+00	5.96E+01	1.58E+01	4.90E+01	0.	0.	1.37E+01
TE132	5.42E+00	7.89E+01	6.62E+00	1.02E+01	0.	0.	4.50E+00
I129	3.50E+01	4.29E-01	5.58E+03	1.39E+01	0.	0.	8.54E+00
I131	1.24E+01	1.43E+00	5.42E+03	1.63E+01	0.	0.	1.67E+01
I133	2.86E+00	2.99E+00	1.76E+03	5.93E+00	0.	0.	7.32E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	8.03E+01	2.04E+00	0.	1.97E+02	3.70E+01	0.	3.61E+02
CS137	4.50E+01	1.84E+00	0.	2.62E+02	2.97E+01	0.	2.84E+02
BA140	4.85E+00	4.21E+00	0.	8.26E+01	4.32E-02	0.	7.25E-02
LA140	1.19E-03	1.00E+02	0.	1.02E-02	0.	0.	3.54E-03
CE141	2.76E-03	2.36E+01	0.	3.71E-02	0.	0.	1.86E-02
CE144	8.43E-02	1.74E+02	0.	1.40E+00	0.	0.	5.54E-01
EU154	7.16E-02	4.74E+01	0.	5.27E-01	0.	0.	1.78E-01
U232	1.16E+03	6.91E+01	0.	1.01E+04	0.	0.	0.
U234	2.03E+02	6.32E+01	0.	2.04E+03	0.	0.	0.
PU238	1.87E+00	7.50E+01	0.	7.49E+01	0.	0.	8.67E+00
PU239	1.76E+00	6.85E+01	0.	7.05E+01	0.	0.	8.15E+00
PU240	1.78E+00	6.85E+01	0.	7.05E+01	0.	0.	8.23E+00
PU241	1.77E-03	1.32E-01	0.	6.95E-02	0.	0.	8.04E-03
AM241	6.23E+00	7.37E+01	0.	7.80E+01	0.	0.	6.55E+01
CM242	3.53E+00	8.03E+01	0.	5.31E+01	0.	0.	4.25E+01
CM244	6.46E+00	7.64E+01	0.	9.72E+01	0.	0.	7.71E+01

TABLE H-19

INGESTION DOSE FACTORS, TEEN

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.06E-01	1.06E-01	1.06E-01	0.	1.06E-01	1.06E-01	1.06E-01
C14	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01
NA22	2.35E+01	2.88E+00	2.35E+01	2.35E+01	2.35E+01	0.	2.35E+01
AS39	0.	0.	0.	0.	0.	0.	0.
CO58	2.26E+00	1.34E+01	0.	0.	0.	0.	9.92E-01
CO60	6.30E+00	3.31E+01	0.	0.	0.	0.	2.76E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.28E+01	4.99E+01	0.	4.44E+02	0.	0.	0.
SR90	1.28E+02	2.20E+02	0.	4.80E+02	0.	0.	0.
Y90	3.79E-04	1.09E+02	0.	1.41E-02	0.	0.	0.
Y91	5.15E-03	7.53E+01	0.	1.93E-01	0.	0.	0.
ZR95	8.62E-03	2.68E+01	0.	3.68E-02	0.	0.	1.23E-02
NB95	2.46E-03	1.78E+01	0.	7.25E-03	0.	0.	4.37E-03
RU103	1.06E-01	1.85E+01	0.	2.37E-01	0.	0.	0.
RU106	5.03E-01	1.81E+02	0.	4.00E+00	0.	0.	0.
SN123	1.09E+00	6.31E+01	5.82E-01	4.39E+01	0.	0.	7.28E-01
TE125	5.08E-01	1.07E+01	1.08E+00	3.83E+00	0.	0.	1.37E+00
TE127	3.23E-02	1.22E+01	1.03E-01	1.51E-01	0.	0.	5.32E-02
TE129	2.59E+00	5.80E+01	5.28E+00	1.64E+01	0.	0.	6.09E+00
TE132	2.10E+00	8.00E+01	2.36E+00	3.55E+00	0.	0.	2.22E+00
I129	1.20E+01	4.31E-01	4.74E+03	4.66E+00	0.	0.	3.92E+00
I131	4.59E+00	1.49E+00	2.27E+03	5.56E+00	0.	0.	7.86E+00
I133	1.04E+00	2.50E+00	6.19E+02	2.01E+00	0.	0.	3.41E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	8.97E+01	2.24E+00	0.	7.11E+01	2.07E+01	0.	1.86E+02
CS137	4.97E+01	1.92E+00	0.	8.97E+01	1.60E+01	0.	1.36E+02
BA140	1.82E+00	4.14E+00	0.	2.83E+01	2.33E-02	0.	3.48E-02
LA140	4.58E-04	9.49E+01	0.	3.51E-03	0.	0.	1.73E-03
CE141	9.56E-04	2.29E+01	0.	1.24E-02	0.	0.	8.34E-03
CE144	2.82E-02	1.70E+02	0.	4.67E-01	0.	0.	2.45E-01
EU154	2.77E-02	5.12E+01	0.	1.83E-01	0.	0.	8.60E-02
U232	3.88E+02	6.72E+01	0.	3.39E+03	0.	0.	0.
U234	6.81E+01	6.14E+01	0.	6.81E+02	0.	0.	0.
PU238	6.27E-01	7.30E+01	0.	2.51E+01	0.	0.	3.83E+00
PU239	5.89E-01	6.66E+01	0.	2.36E+01	0.	0.	3.60E+00
PU240	5.95E-01	6.66E+01	0.	2.36E+01	0.	0.	3.63E+00
PU241	5.92E-04	1.28E-01	0.	2.33E-02	0.	0.	3.55E-03
AM241	2.09E+00	7.17E+01	0.	2.61E+01	0.	0.	2.89E+01
CM242	1.18E+00	7.80E+01	0.	1.78E+01	0.	0.	1.88E+01
CM244	2.16E+00	7.42E+01	0.	3.25E+01	0.	0.	3.41E+01

TABLE H-20

INGESTION DOSE FACTORS, ADULT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.05E-01	1.05E-01	1.05E-01	0.	1.05E-01	1.05E-01	1.05E-01
C14	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01
NA22	1.74E+01	3.26E+00	1.74E+01	1.74E+01	1.74E+01	0.	1.74E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	1.67E+00	1.51E+01	0.	0.	0.	0.	7.46E-01
CO60	4.74E+00	4.02E+01	0.	0.	0.	0.	2.15E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	8.80E+00	4.94E+01	0.	3.07E+02	0.	0.	0.
SR90	8.95E+01	1.02E+02	0.	3.34E+02	0.	0.	0.
Y90	2.59E-04	1.02E+02	0.	9.65E-03	0.	0.	0.
Y91	3.73E-03	7.76E+01	0.	1.39E-01	0.	0.	0.
ZR95	6.51E-03	3.03E+01	0.	2.99E-02	0.	0.	9.66E-03
NB95	1.86E-03	2.10E+01	0.	6.22E-03	0.	0.	3.46E-03
RU103	7.98E-02	2.16E+01	0.	1.85E-01	0.	0.	0.
RU106	3.47E-01	1.79E+02	0.	2.75E+00	0.	0.	0.
SN123	7.60E-01	6.33E+01	4.37E-01	3.07E+01	0.	0.	5.14E-01
TE125	3.59E-01	1.07E+01	8.07E-01	2.68E+00	0.	0.	9.73E-01
TE127	2.38E-02	8.68E+00	8.17E-02	1.11E-01	0.	0.	3.96E-02
TE129	1.82E+00	5.79E+01	3.95E+00	1.15E+01	0.	0.	4.30E+00
TE132	1.53E+00	7.71E+01	1.80E+00	2.52E+00	0.	0.	1.63E+00
I129	8.48E+00	4.44E-01	6.66E+03	3.27E+00	0.	0.	2.81E+00
I131	3.41E+00	1.57E+00	1.95E+03	4.16E+00	0.	0.	5.96E+00
I133	7.57E-01	2.18E+00	4.77E+02	1.43E+00	0.	0.	2.48E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.12E+02	2.59E+00	0.	5.51E+01	1.40E+01	0.	1.42E+02
CS137	6.37E+01	2.11E+00	0.	6.72E+01	1.03E+01	0.	1.02E+02
BA140	1.33E+00	4.18E+01	0.	2.03E+01	1.47E-02	0.	2.56E-02
LA140	3.35E-04	9.25E+01	0.	2.51E-03	0.	0.	1.27E-03
CE141	7.18E-04	2.42E+01	0.	9.36E-03	0.	0.	6.33E-03
CE144	1.93E-02	1.65E+02	0.	3.19E-01	0.	0.	1.69E-01
EU154	2.05E-02	5.48E+01	0.	1.36E-01	0.	0.	6.62E-02
U232	2.72E+02	6.72E+01	0.	2.37E+03	0.	0.	0.
U234	4.77E+01	6.14E+01	0.	4.77E+02	0.	0.	0.
PU238	4.39E-01	7.30E+01	0.	1.75E+01	0.	0.	2.70E+00
PU239	4.12E-01	6.66E+01	0.	1.65E+01	0.	0.	2.54E+00
PU240	4.13E-01	6.78E+01	0.	1.65E+01	0.	0.	2.55E+00
PU241	1.77E-02	1.40E+00	0.	8.26E-01	0.	0.	4.82E-02
AM241	1.46E+00	7.42E+01	0.	1.83E+01	0.	0.	2.04E+01
CM242	8.25E-01	7.92E+01	0.	1.25E+01	0.	0.	1.32E+01
CM244	1.51E+00	7.55E+01	0.	2.28E+01	0.	0.	2.40E+01

TABLE H-21

SURFACE WATER EXPOSURE DOSE FACTORS, INFANT

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	1.92E-03	0.
NA22	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.41E+00	2.01E+00
AR39	3.09E-04	3.09E-04	3.09E-04	3.09E-04	3.09E-04	6.65E-02	3.09E-04
CO58	8.92E-01	8.92E-01	8.92E-01	8.92E-01	8.92E-01	1.15E+00	8.92E-01
CO60	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.68E+00	2.29E+00
KR85M	1.40E-01	1.40E-01	1.40E-01	1.40E-01	1.40E-01	2.57E-01	1.40E-01
KR85	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	8.77E-02	2.34E-03
KR87	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00	2.32E+00	1.37E+00
KR88	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	2.03E+00	1.63E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.72E-01	2.32E-03
SR90	2.68E-04	2.68E-04	2.68E-04	2.68E-04	2.68E-04	7.42E-02	2.68E-04
Y90	6.28E-03	6.28E-03	6.28E-03	6.28E-03	6.28E-03	4.73E-01	6.28E-03
Y91	4.98E-01	4.98E-01	4.98E-01	4.98E-01	4.98E-01	6.01E-01	4.98E-01
ZR95	7.38E-01	7.38E-01	7.38E-01	7.38E-01	7.38E-01	8.91E-01	7.38E-01
NB95	6.97E-01	6.97E-01	6.97E-01	6.97E-01	6.97E-01	8.15E-01	6.97E-01
RU103	4.45E-01	4.45E-01	4.45E-01	4.45E-01	4.45E-01	5.29E-01	4.45E-01
RU106	1.89E-01	1.89E-01	1.89E-01	1.89E-01	1.89E-01	9.55E-01	1.89E-01
SN123	0.	0.	0.	0.	0.	2.51E-01	0.
TE125	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03	7.61E-03	1.81E-03
TE127	1.36E-03	1.36E-03	1.36E-03	1.36E-03	1.36E-03	8.73E-02	1.36E-03
TE129	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	3.71E-01	1.03E-01
TE132	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	2.40E-01	1.98E-01
I129	4.29E-08	4.29E-08	4.29E-08	4.29E-08	4.29E-08	7.65E-08	4.29E-08
I131	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	4.67E-01	3.40E-01
I133	4.79E-01	4.79E-01	4.79E-01	4.79E-01	4.79E-01	7.66E-01	4.79E-01
XE133	2.83E-02	2.83E-02	2.83E-02	2.83E-02	2.83E-02	5.40E-02	2.83E-02
XE135M	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.81E-01	4.98E-01	3.81E-01
XE135	2.25E-01	2.25E-01	2.25E-01	2.25E-01	2.25E-01	3.97E-01	2.25E-01
XE137	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.04E+00	1.35E-01
XE138	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.69E+00	1.30E+00
CS134	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.75E+00	1.45E+00
CS137	5.10E-01	5.10E-01	5.10E-01	5.10E-01	5.10E-01	6.81E-01	5.10E-01
BA140	2.43E-01	2.43E-01	2.43E-01	2.43E-01	2.43E-01	3.81E-01	2.43E-01
LA140	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.67E+00	2.06E+00
CE141	6.49E-01	6.49E-01	6.49E-01	6.49E-01	6.49E-01	1.22E-01	6.49E-01
CE144	4.32E-02	4.32E-02	4.32E-02	4.32E-02	4.32E-02	6.94E-01	4.32E-02
EU154	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.33E+00	1.09E+00
U232	2.28E-04	2.28E-04	2.28E-04	2.28E-04	2.28E-04	5.53E-04	2.28E-04
U234	4.25E-04	4.25E-04	4.25E-04	4.25E-04	4.25E-04	2.64E-03	4.25E-04
PU238	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.38E-05	2.02E-03	7.38E-05
PU239	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	8.74E-04	6.12E-05
PU240	7.07E-05	7.07E-05	7.07E-05	7.07E-05	7.07E-05	2.01E-03	7.07E-05
PU241	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.49E-06	1.27E-06
AM241	1.96E-02	1.96E-02	1.96E-02	1.96E-02	1.96E-02	3.07E-02	1.96E-02
CM242	1.69E-04	1.69E-04	1.69E-04	1.69E-04	1.69E-04	2.36E-03	1.69E-04
CM244	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.97E-03	1.32E-04

TABLE H-22

SURFACE WATER EXPOSURE DOSE FACTORS, CHILD

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	1.92E-03	0.
NA22	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.41E+00	2.01E+00
AR39	3.09E-04	3.09E-04	3.09E-04	3.09E-04	3.09E-04	6.65E-02	3.09E-04
CO58	8.92E-01	8.92E-01	8.92E-01	8.92E-01	8.92E-01	1.15E+00	8.92E-01
CO60	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.68E+00	2.29E+00
KR85M	1.40E-01	1.40E-01	1.40E-01	1.40E-01	1.40E-01	2.57E-01	1.40E-01
KR85	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	8.77E-02	2.34E-03
KR87	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00	2.32E+00	1.37E+00
KR88	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	2.03E+00	1.63E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.72E-01	2.32E-03
SR90	2.68E-04	2.68E-04	2.68E-04	2.68E-04	2.68E-04	7.42E-02	2.68E-04
Y90	6.28E-03	6.28E-03	6.28E-03	6.28E-03	6.28E-03	4.73E-01	6.28E-03
Y91	4.98E-01	4.98E-01	4.98E-01	4.98E-01	4.98E-01	6.01E-01	4.98E-01
ZR95	7.38E-01	7.38E-01	7.38E-01	7.38E-01	7.38E-01	8.91E-01	7.38E-01
NB95	6.97E-01	6.97E-01	6.97E-01	6.97E-01	6.97E-01	8.15E-01	6.97E-01
RU103	4.45E-01	4.45E-01	4.45E-01	4.45E-01	4.45E-01	5.29E-01	4.45E-01
RU106	1.89E-01	1.89E-01	1.89E-01	1.89E-01	1.89E-01	9.55E-01	1.89E-01
SN123	0.	0.	0.	0.	0.	2.51E-01	0.
TE125	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03	7.61E-03	1.81E-03
TE127	1.36E-03	1.36E-03	1.36E-03	1.36E-03	1.36E-03	8.73E-02	1.36E-03
TE129	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	3.71E-01	1.03E-01
TE132	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	2.40E-01	1.98E-01
I129	4.29E-08	4.29E-08	4.29E-08	4.29E-08	4.29E-08	7.65E-08	4.29E-08
I131	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	4.67E-01	3.40E-01
I133	4.79E-01	4.79E-01	4.79E-01	4.79E-01	4.79E-01	7.66E-01	4.79E-01
XE133	2.83E-02	2.83E-02	2.83E-02	2.83E-02	2.83E-02	5.40E-02	2.83E-02
XE135M	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.81E-01	4.98E-01	3.81E-01
XE135	2.25E-01	2.25E-01	2.25E-01	2.25E-01	2.25E-01	3.97E-01	2.25E-01
XE137	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.04E+00	1.35E-01
XE138	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.69E+00	1.30E+00
CS134	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.75E+00	1.45E+00
CS137	5.10E-01	5.10E-01	5.10E-01	5.10E-01	5.10E-01	6.81E-01	5.10E-01
BA140	2.43E-01	2.43E-01	2.43E-01	2.43E-01	2.43E-01	3.81E-01	2.43E-01
LA140	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.67E+00	2.06E+00
CE141	6.49E-01	6.49E-01	6.49E-01	6.49E-01	6.49E-01	1.22E-01	6.49E-01
CE144	4.32E-02	4.32E-02	4.32E-02	4.32E-02	4.32E-02	6.94E-01	4.32E-02
EU154	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.33E+00	1.09E+00
U232	2.28E-04	2.28E-04	2.28E-04	2.28E-04	2.28E-04	5.53E-04	2.28E-04
U234	4.25E-04	4.25E-04	4.25E-04	4.25E-04	4.25E-04	2.64E-03	4.25E-04
PU238	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.38E-05	2.02E-03	7.38E-05
PU239	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	8.74E-04	6.12E-05
PU240	7.07E-05	7.07E-05	7.07E-05	7.07E-05	7.07E-05	2.01E-03	7.07E-05
PU241	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.49E-06	1.27E-06
AM241	1.96E-02	1.96E-02	1.96E-02	1.96E-02	1.96E-02	3.07E-02	1.96E-02
CM242	1.69E-04	1.69E-04	1.69E-04	1.69E-04	1.69E-04	2.36E-03	1.69E-04
CM244	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.97E-03	1.32E-04

TABLE H-23

SURFACE WATER EXPOSURE DOSE FACTORS, TEEN

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	1.92E-03	0.
NA22	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.41E+00	2.01E+00
AR39	3.09E-04	3.09E-04	3.09E-04	3.09E-04	3.09E-04	6.65E-02	3.09E-04
CO58	8.92E-01	8.92E-01	8.92E-01	8.92E-01	8.92E-01	1.15E+00	8.92E-01
CO60	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.68E+00	2.29E+00
KR85M	1.40E-01	1.40E-01	1.40E-01	1.40E-01	1.40E-01	2.57E-01	1.40E-01
KR85	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	8.77E-02	2.34E-03
KR87	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00	2.32E+00	1.37E+00
KR88	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	2.03E+00	1.63E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.72E-01	2.32E-03
SR90	2.68E-04	2.68E-04	2.68E-04	2.68E-04	2.68E-04	7.42E-02	2.68E-04
Y90	6.28E-03	6.28E-03	6.28E-03	6.28E-03	6.28E-03	4.73E-01	6.28E-03
Y91	4.98E-01	4.98E-01	4.98E-01	4.98E-01	4.98E-01	6.01E-01	4.98E-01
ZR95	7.38E-01	7.38E-01	7.38E-01	7.38E-01	7.38E-01	8.91E-01	7.38E-01
NB95	6.97E-01	6.97E-01	6.97E-01	6.97E-01	6.97E-01	8.15E-01	6.97E-01
RU103	4.45E-01	4.45E-01	4.45E-01	4.45E-01	4.45E-01	5.29E-01	4.45E-01
RU106	1.89E-01	1.89E-01	1.89E-01	1.89E-01	1.89E-01	9.55E-01	1.89E-01
SN123	0.	0.	0.	0.	0.	2.51E-01	0.
TE125	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03	7.61E-03	1.81E-03
TE127	1.36E-03	1.36E-03	1.36E-03	1.36E-03	1.36E-03	8.73E-02	1.36E-03
TE129	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	3.71E-01	1.03E-01
TE132	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	2.40E-01	1.98E-01
I129	4.29E-08	4.29E-08	4.29E-08	4.29E-08	4.29E-08	7.65E-08	4.29E-08
I131	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	4.67E-01	3.40E-01
I133	4.79E-01	4.79E-01	4.79E-01	4.79E-01	4.79E-01	7.66E-01	4.79E-01
XE133	2.83E-02	2.83E-02	2.83E-02	2.83E-02	2.83E-02	5.40E-02	2.83E-02
XE135M	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.81E-01	4.98E-01	3.81E-01
XE135	2.25E-01	2.25E-01	2.25E-01	2.25E-01	2.25E-01	3.97E-01	2.25E-01
XE137	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.04E+00	1.35E-01
XE138	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.69E+00	1.30E+00
CS134	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.75E+00	1.45E+00
CS137	5.10E-01	5.10E-01	5.10E-01	5.10E-01	5.10E-01	6.81E-01	5.10E-01
BA140	2.43E-01	2.43E-01	2.43E-01	2.43E-01	2.43E-01	3.81E-01	2.43E-01
LA140	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.67E+00	2.06E+00
CE141	6.49E-01	6.49E-01	6.49E-01	6.49E-01	6.49E-01	1.22E-01	6.49E-01
CE144	4.32E-02	4.32E-02	4.32E-02	4.32E-02	4.32E-02	6.94E-01	4.32E-02
EU154	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.33E+00	1.09E+00
U232	2.28E-04	2.28E-04	2.28E-04	2.28E-04	2.28E-04	5.53E-04	2.28E-04
U234	4.25E-04	4.25E-04	4.25E-04	4.25E-04	4.25E-04	2.64E-03	4.25E-04
PU238	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.38E-05	2.02E-03	7.38E-05
PU239	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	8.74E-04	6.12E-05
PU240	7.07E-05	7.07E-05	7.07E-05	7.07E-05	7.07E-05	2.01E-03	7.07E-05
PU241	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.49E-06	1.27E-06
AM241	1.96E-02	1.96E-02	1.96E-02	1.96E-02	1.96E-02	3.07E-02	1.96E-02
CM242	1.69E-04	1.69E-04	1.69E-04	1.69E-04	1.69E-04	2.36E-03	1.69E-04
CM244	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.97E-03	1.32E-04

TABLE H-24

SURFACE WATER EXPOSURE DOSE FACTORS, ADULT

(MREM/HR PER MICROCURIE/LITER)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	0.	0.	0.	0.	0.	0.	0.
C14	0.	0.	0.	0.	0.	1.92E-03	0.
NA22	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.01E+00	2.41E+00	2.01E+00
AR39	3.09E-04	3.09E-04	3.09E-04	3.09E-04	3.09E-04	6.65E-02	3.09E-04
CO58	8.92E-01	8.92E-01	8.92E-01	8.92E-01	8.92E-01	1.15E+00	8.92E-01
CO60	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.29E+00	2.68E+00	2.29E+00
KR85M	1.40E-01	1.40E-01	1.40E-01	1.40E-01	1.40E-01	2.57E-01	1.40E-01
KR85	2.34E-03	2.34E-03	2.34E-03	2.34E-03	2.34E-03	8.77E-02	2.34E-03
KR87	1.37E+00	1.37E+00	1.37E+00	1.37E+00	1.37E+00	2.32E+00	1.37E+00
KR88	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	2.03E+00	1.63E+00
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.32E-03	2.72E-01	2.32E-03
SR90	2.68E-04	2.68E-04	2.68E-04	2.68E-04	2.68E-04	7.42E-02	2.68E-04
Y90	6.28E-03	6.28E-03	6.28E-03	6.28E-03	6.28E-03	4.73E-01	6.28E-03
Y91	4.98E-01	4.98E-01	4.98E-01	4.98E-01	4.98E-01	6.01E-01	4.98E-01
ZR95	7.38E-01	7.38E-01	7.38E-01	7.38E-01	7.38E-01	8.91E-01	7.38E-01
NB95	6.97E-01	6.97E-01	6.97E-01	6.97E-01	6.97E-01	8.15E-01	6.97E-01
RU103	4.45E-01	4.45E-01	4.45E-01	4.45E-01	4.45E-01	5.29E-01	4.45E-01
RU106	1.89E-01	1.89E-01	1.89E-01	1.89E-01	1.89E-01	9.55E-01	1.89E-01
SN123	0.	0.	0.	0.	0.	2.51E-01	0.
TE125	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03	7.61E-03	1.81E-03
TE127	1.36E-03	1.36E-03	1.36E-03	1.36E-03	1.36E-03	8.73E-02	1.36E-03
TE129	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	3.71E-01	1.03E-01
TE132	1.98E-01	1.98E-01	1.98E-01	1.98E-01	1.98E-01	2.40E-01	1.98E-01
I129	4.29E-08	4.29E-08	4.29E-08	4.29E-08	4.29E-08	7.65E-08	4.29E-08
I131	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	4.67E-01	3.40E-01
I133	4.79E-01	4.79E-01	4.79E-01	4.79E-01	4.79E-01	7.66E-01	4.79E-01
XE133	2.83E-02	2.83E-02	2.83E-02	2.83E-02	2.83E-02	5.40E-02	2.83E-02
XE135M	3.81E-01	3.81E-01	3.81E-01	3.81E-01	3.81E-01	4.98E-01	3.81E-01
XE135	2.25E-01	2.25E-01	2.25E-01	2.25E-01	2.25E-01	3.97E-01	2.25E-01
XE137	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.04E+00	1.35E-01
XE138	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.30E+00	1.69E+00	1.30E+00
CS134	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.45E+00	1.75E+00	1.45E+00
CS137	5.10E-01	5.10E-01	5.10E-01	5.10E-01	5.10E-01	6.81E-01	5.10E-01
BA140	2.43E-01	2.43E-01	2.43E-01	2.43E-01	2.43E-01	3.81E-01	2.43E-01
LA140	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.06E+00	2.67E+00	2.06E+00
CE141	6.49E-01	6.49E-01	6.49E-01	6.49E-01	6.49E-01	1.22E-01	6.49E-01
CE144	4.32E-02	4.32E-02	4.32E-02	4.32E-02	4.32E-02	6.94E-01	4.32E-02
EU154	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.09E+00	1.33E+00	1.09E+00
U232	2.28E-04	2.28E-04	2.28E-04	2.28E-04	2.28E-04	5.53E-04	2.28E-04
U234	4.25E-04	4.25E-04	4.25E-04	4.25E-04	4.25E-04	2.64E-03	4.25E-04
PU238	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.38E-05	2.02E-03	7.38E-05
PU239	6.12E-05	6.12E-05	6.12E-05	6.12E-05	6.12E-05	8.74E-04	6.12E-05
PU240	7.07E-05	7.07E-05	7.07E-05	7.07E-05	7.07E-05	2.01E-03	7.07E-05
PU241	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.27E-06	1.49E-06	1.27E-06
AM241	1.96E-02	1.96E-02	1.96E-02	1.96E-02	1.96E-02	3.07E-02	1.96E-02
CM242	1.69E-04	1.69E-04	1.69E-04	1.69E-04	1.69E-04	2.36E-03	1.69E-04
CM244	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.97E-03	1.32E-04

TABLE H-25

INHALATION DOSE COMMITMENT FACTORS, INFANT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	3.07E-01	3.07E-01	3.07E-01	0.	3.07E-01	3.07E-01	3.07E-01
C14	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00	3.60E+00
NA22	7.53E+01	1.22E+00	7.53E+01	7.53E+01	7.53E+01	0.	7.53E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	1.43E+00	3.67E+00	0.	0.	5.27E+02	0.	1.00E+00
CO60	9.52E+00	2.34E+01	0.	0.	3.76E+03	0.	6.72E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	9.88E+00	4.85E+01	0.	3.44E+02	1.62E+03	0.	0.
SR90	3.46E+02	9.89E+01	0.	5.24E+03	1.01E+04	0.	0.
Y90	5.54E-02	8.02E+01	0.	2.43E+00	1.98E+02	0.	0.
Y91	1.31E+01	5.12E+01	0.	4.90E+02	1.88E+03	0.	0.
ZR95	1.62E+01	1.01E+01	0.	8.94E+01	1.30E+03	0.	2.28E+01
NB95	2.90E+00	8.67E+00	0.	1.10E+01	3.42E+02	0.	4.93E+00
RU103	5.01E-01	1.13E+01	0.	1.45E+00	4.04E+02	0.	0.
RU106	9.42E+00	1.26E+02	0.	7.61E+01	1.03E+04	0.	0.
SN123	8.73E+00	4.28E+01	5.40E+00	2.56E+02	2.59E+03	0.	5.40E+00
TE125	5.26E-01	9.71E+00	1.30E+00	3.86E+00	3.53E+02	0.	1.66E+00
TE127	3.34E-04	1.87E+01	1.26E-03	1.52E-03	7.03E+00	0.	6.47E-04
TE129	1.72E+00	5.23E+01	4.27E+00	1.11E+01	1.29E+03	0.	4.86E+00
TE132	1.28E-01	5.63E+01	2.04E-01	2.73E-01	2.48E+02	0.	1.73E-01
I129	5.59E+01	2.23E-01	1.04E+04	2.23E+01	0.	0.	1.62E+01
I131	1.75E+01	7.65E-01	1.01E+04	2.59E+01	0.	0.	3.05E+01
I133	4.14E+00	1.53E+00	3.30E+03	9.48E+00	0.	0.	1.37E+01
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	5.23E+01	9.80E-01	0.	3.23E+02	5.76E+01	0.	5.75E+02
CS137	3.15E+01	9.45E-01	0.	4.49E+02	5.11E+01	0.	5.04E+02
BA140	2.16E+00	2.77E+00	0.	4.18E+01	1.17E+03	0.	4.22E-02
LA140	3.73E-02	5.43E+01	0.	3.66E-01	1.21E+02	0.	1.45E-01
CE141	1.51E+00	1.47E+01	0.	2.09E+01	3.70E+02	0.	1.29E+01
CE144	1.26E+02	1.15E+02	0.	2.05E+03	8.77E+03	0.	1.05E+03
EU154	1.21E+02	2.95E+01	0.	1.10E+03	3.67E+03	0.	3.85E+02
U232	2.43E+04	4.55E+01	0.	1.98E+05	1.87E+06	0.	0.
U234	4.27E+03	4.16E+01	0.	4.00E+04	4.38E+05	0.	0.
PU238	3.59E+04	4.95E+01	0.	1.44E+06	1.10E+06	0.	1.69E+05
PU239	3.52E+04	4.51E+01	0.	1.41E+06	1.04E+06	0.	1.66E+05
PU240	3.55E+04	4.51E+01	0.	1.41E+06	1.05E+06	0.	1.67E+05
PU241	2.80E+01	8.68E-02	0.	1.10E+03	5.94E+02	0.	1.30E+02
AM241	1.81E+04	4.86E+01	0.	2.31E+05	4.91E+05	0.	1.98E+05
CM242	4.55E+03	5.29E+01	0.	6.85E+04	3.35E+05	0.	6.82E+04
CM244	1.72E+04	5.03E+01	0.	2.62E+05	5.11E+05	0.	2.15E+05

NOTE - TRITIUM TRANSPIRATION DOSE COMMITMENT WAS TAKEN TO BE 50% OF THE INHALATION DOSE COMMITMENT FOR TRITIUM.

TABLE H-26

INHALATION DOSE COMMITMENT FACTORS, CHILD

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	2.03E-01	2.03E-01	2.03E-01	0.	2.03E-01	2.03E-01	2.03E-01
C14	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00	1.69E+00
NA22	4.42E+01	1.28E+00	4.42E+01	4.42E+01	4.42E+01	0.	4.42E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	3.66E-01	9.78E+00	0.	0.	3.04E+02	0.	4.92E-01
CO60	5.07E+00	2.53E+01	0.	0.	1.87E+03	0.	3.47E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	4.73E+00	4.56E+01	0.	1.65E+02	5.93E+02	0.	0.
SR90	1.25E+03	9.31E+01	0.	1.92E+04	4.00E+03	0.	0.
Y90	3.07E-02	7.43E+01	0.	1.14E+00	7.26E+01	0.	0.
Y91	5.38E+00	4.82E+01	0.	2.39E+02	5.89E+02	0.	0.
ZR95	9.74E+00	1.55E+01	0.	4.62E+01	5.74E+02	0.	1.07E+01
NB95	1.73E+00	8.96E+00	0.	5.53E+00	1.58E+02	0.	2.36E+00
RU103	2.82E-01	1.14E+01	0.	6.99E-01	1.71E+02	0.	0.
RU106	4.65E+00	1.18E+02	0.	3.74E+01	3.94E+03	0.	0.
SN123	4.19E+00	4.03E+01	2.27E+00	1.29E+02	9.61E+02	0.	2.14E+00
TE125	2.47E-01	9.13E+00	5.20E-01	1.82E+00	1.30E+02	0.	6.29E-01
TE127	1.57E-04	1.58E+01	5.03E-04	7.14E-04	2.58E+00	0.	2.44E-04
TE129	3.26E-01	4.93E+01	1.71E+00	5.21E+00	4.79E+02	0.	1.85E+00
TE132	7.13E-02	5.52E+01	8.70E-02	1.31E-01	1.03E+02	0.	7.40E-02
I129	2.86E+01	2.15E-01	4.28E+03	1.05E+01	0.	0.	6.40E+00
I131	9.27E+00	7.17E-01	4.16E+03	1.23E+01	0.	0.	1.25E+01
I133	2.15E+00	1.50E+00	1.35E+03	4.49E+00	0.	0.	5.49E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	5.02E+01	1.02E+00	0.	1.68E+02	3.21E+01	0.	2.69E+02
CS137	3.38E+01	9.22E-01	0.	2.34E+02	2.71E+01	0.	2.16E+02
BA140	1.17E+00	2.68E+00	0.	1.99E+01	4.69E+02	0.	1.74E-02
LA140	2.05E-02	5.14E+01	0.	1.75E-01	4.95E+01	0.	6.07E-02
CE141	7.34E-01	1.47E+01	0.	9.87E+00	1.38E+02	0.	4.95E+00
CE144	1.00E+02	1.08E+02	0.	1.88E+03	3.32E+03	0.	5.88E+02
EU154	2.24E+02	2.94E+01	0.	2.61E+03	1.64E+03	0.	2.45E+02
U232	1.56E+04	4.28E+01	0.	2.19E+05	7.43E+05	0.	0.
U234	2.76E+03	3.92E+01	0.	4.46E+04	1.74E+05	0.	0.
PU238	5.31E+04	4.65E+01	0.	2.53E+06	5.87E+05	0.	2.87E+05
PU239	5.17E+04	4.24E+01	0.	2.48E+06	5.56E+05	0.	2.81E+05
PU240	5.23E+04	4.24E+01	0.	2.48E+06	5.61E+05	0.	2.83E+05
PU241	4.95E+01	8.16E-02	0.	1.94E+03	3.65E+02	0.	2.21E+02
AM241	5.97E+04	4.57E+01	0.	9.07E+05	1.95E+05	0.	5.78E+05
CM242	3.21E+03	4.98E+01	0.	4.84E+04	1.25E+05	0.	3.73E+04
CM244	5.17E+04	4.73E+01	0.	9.55E+05	2.02E+05	0.	5.63E+05

NOTE - TRITIUM TRANSPIRATION DOSE COMMITMENT WAS TAKEN TO BE 50% OF THE INHALATION DOSE COMMITMENT FOR TRITIUM.

TABLE H-27

INHALATION DOSE COMMITMENT FACTORS, TEEN

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.06E-01	1.06E-01	1.06E-01	0.	1.06E-01	1.06E-01	1.06E-01
C14	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01	5.66E-01
NA22	1.76E+01	1.44E+00	1.76E+01	1.76E+01	1.76E+01	0.	1.76E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	3.51E-01	1.19E+01	0.	0.	1.71E+02	0.	2.64E-01
CO60	2.47E+00	2.94E+01	0.	0.	1.07E+03	0.	1.85E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.58E+00	4.42E+01	0.	5.51E+01	3.07E+02	0.	0.
SR90	2.64E+02	9.05E+01	0.	4.01E+03	2.07E+03	0.	0.
Y90	1.03E-02	5.79E+01	0.	3.82E-01	3.75E+01	0.	0.
Y91	2.14E+00	4.67E+01	0.	7.99E+01	3.56E+02	0.	0.
ZR95	3.84E+00	1.65E+01	0.	1.65E+01	3.21E+02	0.	5.49E+00
NB95	5.96E-01	1.10E+01	0.	2.05E+00	8.98E+01	0.	1.24E+00
RU103	1.10E-01	1.18E+01	0.	2.44E-01	9.39E+01	0.	0.
RU106	1.58E+00	1.15E+02	0.	1.25E+01	2.05E+03	0.	0.
SN123	1.40E+00	3.91E+01	7.56E-01	4.31E+01	4.97E+02	0.	9.44E-01
TE125	3.27E-02	8.85E+00	1.75E-01	6.09E-01	5.70E+01	0.	2.73E-01
TE127	5.24E-05	1.01E+01	1.68E-04	2.39E-04	1.33E+00	0.	1.08E-04
TE129	2.82E-01	4.80E+01	5.74E-01	1.79E+00	2.50E+02	0.	8.28E-01
TE132	2.76E-02	6.61E+01	3.10E-02	4.57E-02	5.67E+01	0.	3.65E-02
I129	9.81E+00	2.16E-01	3.65E+03	3.53E+00	0.	0.	2.94E+00
I131	3.44E+00	7.45E-01	1.74E+03	4.21E+00	0.	0.	5.90E+00
I133	7.84E-01	1.25E+00	4.75E+02	1.52E+00	0.	0.	2.55E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	5.80E+01	1.12E+00	0.	6.04E+01	1.80E+01	0.	1.39E+02
CS137	3.79E+01	9.60E-01	0.	8.02E+01	1.46E+01	0.	1.03E+02
BA140	4.39E-01	2.65E+00	0.	6.80E+00	2.53E+02	0.	8.37E-03
LA140	7.85E-03	5.81E+01	0.	6.02E-02	2.71E+01	0.	2.97E-02
CE141	2.54E-01	1.42E+01	0.	3.31E+00	7.20E+01	0.	2.22E+00
CE144	3.35E+01	1.05E+02	0.	6.26E+02	1.72E+03	0.	2.60E+02
EU154	3.12E+01	2.86E+01	0.	7.43E+02	9.13E+02	0.	1.18E+02
U232	5.24E+03	4.16E+01	0.	7.27E+04	3.84E+05	0.	0.
U234	9.24E+02	3.81E+01	0.	1.48E+04	9.00E+04	0.	0.
PU238	1.25E+04	4.52E+01	0.	5.00E+05	3.02E+05	0.	7.52E+04
PU239	1.22E+04	4.13E+01	0.	4.89E+05	2.96E+05	0.	7.34E+04
PU240	1.23E+04	4.13E+01	0.	4.89E+05	2.89E+05	0.	7.40E+04
PU241	2.45E+01	7.94E-02	0.	1.08E+03	1.88E+02	0.	9.59E+01
AM241	1.39E+04	4.44E+01	0.	1.78E+05	1.01E+05	0.	1.69E+05
CM242	1.07E+03	4.83E+01	0.	1.62E+04	5.47E+04	0.	1.67E+04
CM244	1.31E+04	4.60E+01	0.	2.01E+05	1.09E+05	0.	1.73E+05

NOTE - TRITIUM TRANSPIRATION DOSE COMMITMENT WAS TAKEN TO BE 50% OF THE INHALATION DOSE COMMITMENT FOR TRITIUM.

TABLE H-28

INHALATION DOSE COMMITMENT FACTORS, ADULT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.05E-01	1.05E-01	1.05E-01	0.	1.05E-01	1.05E-01	1.05E-01
C14	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01	4.27E-01
NA22	1.30E+01	1.63E+00	1.30E+01	1.30E+01	1.30E+01	0.	1.30E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	2.59E-01	1.33E+01	0.	0.	1.16E+02	0.	1.98E-01
CO60	1.86E+00	3.55E+01	0.	0.	7.47E+02	0.	1.44E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.09E+00	4.37E+01	0.	3.80E+01	1.75E+02	0.	0.
SR90	7.67E+02	9.05E+01	0.	1.25E+04	1.20E+03	0.	0.
Y90	7.02E-03	5.33E+01	0.	2.62E-01	2.13E+01	0.	0.
Y91	1.55E+00	4.81E+01	0.	5.78E+01	2.13E+02	0.	0.
ZR95	2.90E+00	1.88E+01	0.	1.34E+01	2.22E+02	0.	4.30E+00
NB95	5.26E-01	1.30E+01	0.	1.76E+00	5.32E+01	0.	9.77E-01
RU103	8.23E-02	1.38E+01	0.	1.91E-01	5.32E+01	0.	0.
RU106	1.09E+00	1.14E+01	0.	8.65E+00	1.17E+03	0.	0.
SN123	3.82E-01	3.92E+01	5.67E-01	3.01E+01	2.88E+02	0.	6.67E-01
TE125	5.84E-02	8.83E+00	1.31E-01	4.27E-01	3.92E+01	0.	1.98E-01
TE127	3.87E-05	7.18E+00	1.32E-04	1.76E-04	8.15E-01	0.	8.03E-05
TE129	1.98E-01	4.79E+01	4.30E-01	1.22E+00	1.45E+02	0.	5.84E-01
TE132	2.01E-02	5.37E+01	2.36E-02	3.25E-02	3.60E+01	0.	2.68E-02
I129	5.91E+00	2.22E-01	5.55E+03	2.46E+00	0.	0.	2.11E+00
I131	2.56E+00	7.85E-01	1.49E+03	3.15E+00	0.	0.	4.47E+00
I133	5.58E-01	1.09E+00	3.65E+02	1.08E+00	0.	0.	1.85E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	9.09E+01	1.30E+00	0.	4.68E+01	1.22E+01	0.	1.05E+02
CS137	5.36E+01	1.05E+00	0.	6.01E+01	9.41E+00	0.	7.77E+01
BA140	3.21E-01	2.73E+01	0.	4.89E+00	1.59E+02	0.	6.15E-03
LA140	5.74E-03	5.74E+01	0.	4.31E-02	1.71E+01	0.	2.17E-02
CE141	1.91E-01	1.50E+01	0.	2.49E+00	4.52E+01	0.	1.69E+00
CE144	2.29E+01	1.02E+02	0.	4.28E+02	9.74E+02	0.	1.79E+02
EU154	5.48E+01	3.40E+01	0.	7.43E+02	5.85E+02	0.	9.10E+01
U232	3.66E+03	4.16E+01	0.	5.14E+04	2.23E+05	0.	0.
U234	5.46E+02	3.81E+01	0.	1.04E+04	5.22E+04	0.	0.
PU238	5.71E+04	4.52E+01	0.	2.71E+06	1.76E+05	0.	3.75E+05
PU239	7.50E+04	4.13E+01	0.	3.03E+06	1.67E+05	0.	4.23E+05
PU240	7.50E+04	4.21E+01	0.	3.07E+06	1.67E+05	0.	4.23E+05
PU241	1.29E+03	9.65E-01	0.	6.06E+04	1.52E+02	0.	3.29E+03
AM241	5.52E+04	4.60E+01	0.	1.00E+06	5.86E+04	0.	3.47E+05
CM242	7.50E+02	4.91E+01	0.	1.14E+04	3.74E+04	0.	1.18E+04
CM244	3.52E+04	4.68E+01	0.	5.92E+05	5.07E+04	0.	2.54E+05

NOTE - TRITIUM TRANSPIRATION DOSE COMMITMENT WAS TAKEN TO BE 50%
OF THE INHALATION DOSE COMMITMENT FOR TRITIUM.

TABLE H-29

INGESTION DOSE COMMITMENT FACTORS, INFANT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	3.07E-01	3.07E-01	3.07E-01	0.	3.07E-01	3.07E-01	3.07E-01
C14	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00	4.81E+00
NA22	1.00E+02	2.45E+00	1.00E+02	1.00E+02	1.00E+02	0.	1.00E+02
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	9.26E+00	9.79E+00	0.	0.	0.	0.	3.78E+00
CO60	2.56E+01	2.64E+01	0.	0.	0.	0.	1.07E+01
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	8.15E+01	5.48E+01	0.	2.84E+03	0.	0.	0.
SR90	5.04E+03	2.43E+02	0.	1.93E+04	0.	0.	0.
Y90	2.41E-03	1.29E+02	0.	8.97E-02	0.	0.	0.
Y91	3.29E-02	8.26E+01	0.	1.23E+00	0.	0.	0.
ZR95	3.79E-02	2.38E+01	0.	2.11E-01	0.	0.	5.32E-02
NB95	1.03E-02	1.40E+01	0.	3.90E-02	0.	0.	1.75E-02
RU103	4.85E-01	1.76E+01	0.	1.41E+00	0.	0.	0.
RU106	3.12E+00	1.97E+02	0.	2.54E+01	0.	0.	0.
SN123	6.91E+00	6.91E+01	4.37E+00	2.81E+02	0.	0.	4.37E+00
TE125	3.24E+00	1.17E+01	8.00E+00	2.43E+01	0.	0.	8.19E+00
TE127	2.06E-01	2.27E+01	7.75E-01	9.58E-01	0.	0.	3.19E-01
TE129	1.59E+01	6.33E+01	3.93E+01	1.04E+02	0.	0.	3.58E+01
TE132	9.76E+00	8.08E+01	1.55E+01	2.13E+01	0.	0.	1.05E+01
I129	7.45E+01	4.46E-01	1.36E+04	2.95E+01	0.	0.	2.16E+01
I131	2.33E+01	1.53E+00	1.31E+04	3.42E+01	0.	0.	4.07E+01
I133	5.52E+00	3.27E+00	4.31E+03	1.25E+01	0.	0.	1.83E+01
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	6.97E+01	1.96E+00	0.	4.31E+02	8.82E+01	0.	8.05E+02
CS137	4.20E+01	1.89E+00	0.	5.99E+02	7.97E+01	0.	7.05E+02
BA140	8.99E+00	4.43E+00	0.	1.74E+02	1.07E-01	0.	1.75E-01
LA140	2.17E-03	1.04E+02	0.	2.13E-02	0.	0.	8.42E-03
CE141	5.67E-03	2.38E+01	0.	7.88E-02	0.	0.	4.84E-02
CE144	2.09E-01	1.85E+02	0.	3.71E+00	0.	0.	1.58E+00
EU154	2.44E-01	4.76E+01	0.	2.86E+00	0.	0.	4.41E-01
U232	2.57E+03	7.34E+01	0.	2.91E+04	0.	0.	0.
U234	4.51E+02	6.72E+01	0.	5.87E+03	0.	0.	0.
PU238	3.46E+01	7.98E+01	0.	1.39E+03	0.	0.	1.73E+02
PU239	3.63E+01	7.28E+01	0.	1.46E+03	0.	0.	1.82E+02
PU240	3.65E+01	7.28E+01	0.	1.46E+03	0.	0.	1.83E+02
PU241	1.44E-01	1.40E-01	0.	6.66E+00	0.	0.	3.91E-01
AM241	1.12E+02	7.84E+01	0.	1.59E+03	0.	0.	7.57E+02
CM242	8.45E+00	8.53E+01	0.	1.27E+02	0.	0.	1.23E+02
CM244	8.12E+01	8.12E+01	0.	1.30E+03	0.	0.	6.86E+02

TABLE H-30

INGESTION DOSE COMMITMENT FACTORS, CHILD

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	2.03E-01	2.03E-01	2.03E-01	0.	2.03E-01	2.03E-01	2.03E-01
C14	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00	2.26E+00
NA22	5.89E+01	2.57E+00	5.89E+01	5.89E+01	5.89E+01	0.	5.89E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	5.58E+00	1.10E+01	0.	0.	0.	0.	1.85E+00
CO60	1.55E+01	2.86E+01	0.	0.	0.	0.	5.17E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	3.84E+01	5.15E+01	0.	1.34E+03	0.	0.	0.
SR90	4.43E+03	2.29E+02	0.	1.75E+04	0.	0.	0.
Y90	1.13E-03	1.20E+02	0.	4.21E-02	0.	0.	0.
Y91	1.56E-02	7.77E+01	0.	5.83E-01	0.	0.	0.
ZR95	2.21E-02	2.50E+01	0.	1.05E-01	0.	0.	2.43E-02
NB95	6.13E-03	1.44E+01	0.	1.96E-02	0.	0.	8.34E-03
RU103	2.74E-01	1.78E+01	0.	6.78E-01	0.	0.	0.
RU106	1.48E+00	1.85E+02	0.	1.19E+01	0.	0.	0.
SN123	3.24E+00	6.50E+01	1.75E+00	1.33E+02	0.	0.	1.65E+00
TE125	1.52E+00	1.10E+01	3.20E+00	1.14E+01	0.	0.	3.09E+00
TE127	9.65E-02	1.92E+01	3.10E-01	4.50E-01	0.	0.	1.20E-01
TE129	7.60E+00	5.96E+01	1.58E+01	4.90E+01	0.	0.	1.37E+01
TE132	5.42E+00	7.89E+01	6.62E+00	1.02E+01	0.	0.	4.50E+00
I129	3.81E+01	4.29E-01	5.58E+03	1.39E+01	0.	0.	8.54E+00
I131	1.24E+01	1.43E+00	5.42E+03	1.63E+01	0.	0.	1.67E+01
I133	2.86E+00	2.99E+00	1.76E+03	5.93E+00	0.	0.	7.32E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	8.03E+01	2.04E+00	0.	2.24E+02	4.19E+01	0.	3.77E+02
CS137	4.50E+01	1.84E+00	0.	3.12E+02	3.54E+01	0.	3.12E+02
BA140	4.85E+00	4.21E+00	0.	8.26E+01	4.32E-02	0.	7.25E-02
LA140	1.19E-03	1.00E+02	0.	1.02E-02	0.	0.	3.54E-03
CE141	2.76E-03	2.36E+01	0.	3.71E-02	0.	0.	1.86E-02
CE144	1.14E-01	1.74E+02	0.	2.14E+00	0.	0.	6.70E-01
EU154	1.87E-01	4.74E+01	0.	2.26E+00	0.	0.	2.04E-01
U232	1.26E+03	6.91E+01	0.	1.77E+04	0.	0.	0.
U234	2.21E+02	6.32E+01	0.	3.57E+03	0.	0.	0.
PU238	3.12E+01	7.50E+01	0.	1.26E+03	0.	0.	1.54E+02
PU239	3.30E+01	6.85E+01	0.	1.33E+03	0.	0.	1.64E+02
PU240	3.32E+01	6.85E+01	0.	1.33E+03	0.	0.	1.65E+02
PU241	1.49E-01	1.32E-01	0.	6.92E+00	0.	0.	3.94E-01
AM241	1.01E+02	7.37E+01	0.	1.44E+03	0.	0.	6.29E+02
CM242	4.46E+00	8.03E+01	0.	6.74E+01	0.	0.	5.28E+01
CM244	7.09E+01	7.64E+01	0.	1.14E+03	0.	0.	5.45E+02

TABLE H-31

INGESTION DOSE COMMITMENT FACTORS, TEEN

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.06E-01	1.06E-01	1.06E-01	0.	1.06E-01	1.06E-01	1.06E-01
C14	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01	7.55E-01
NA22	2.35E+01	2.88E+00	2.35E+01	2.35E+01	2.35E+01	0.	2.35E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	2.26E+00	1.34E+01	0.	0.	0.	0.	9.92E-01
CO60	6.30E+00	3.31E+01	0.	0.	0.	0.	2.76E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	1.29E+01	4.99E+01	0.	4.47E+02	0.	0.	0.
SR90	2.08E+03	2.20E+02	0.	8.42E+03	0.	0.	0.
Y90	3.79E-04	1.09E+02	0.	1.41E-02	0.	0.	0.
Y91	5.22E-03	7.53E+01	0.	1.95E-01	0.	0.	0.
ZR95	8.72E-03	2.68E+01	0.	3.74E-02	0.	0.	1.25E-02
NB95	2.46E-03	1.78E+01	0.	7.26E-03	0.	0.	4.38E-03
RU103	1.06E-01	1.85E+01	0.	2.37E-01	0.	0.	0.
RU106	5.03E-01	1.81E+02	0.	4.00E+00	0.	0.	0.
SN123	1.09E+00	6.31E+01	5.84E-01	4.44E+01	0.	0.	7.30E-01
TE125	5.08E-01	1.07E+01	1.08E+00	3.83E+00	0.	0.	1.37E+00
TE127	3.23E-02	1.22E+01	1.03E-01	1.51E-01	0.	0.	5.32E-02
TE129	2.59E+00	5.80E+01	5.28E+00	1.64E+01	0.	0.	6.09E+00
TE132	2.10E+00	8.00E+01	2.36E+00	3.55E+00	0.	0.	2.22E+00
I129	1.31E+01	4.31E-01	4.77E+03	4.66E+00	0.	0.	3.92E+00
I131	4.59E+00	1.49E+00	2.27E+03	5.56E+00	0.	0.	7.86E+00
I133	1.04E+00	2.50E+00	6.19E+02	2.01E+00	0.	0.	3.41E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	9.06E+01	2.24E+00	0.	8.06E+01	2.35E+01	0.	1.94E+02
CS137	5.05E+01	1.92E+00	0.	1.07E+02	1.91E+01	0.	1.44E+02
BA140	1.82E+00	4.14E+00	0.	2.83E+01	2.33E-02	0.	3.48E-02
LA140	4.58E-04	9.49E+01	0.	3.51E-03	0.	0.	1.73E-03
CE141	9.56E-04	2.29E+01	0.	1.25E-02	0.	0.	8.34E-03
CE144	3.82E-02	1.70E+02	0.	7.15E-01	0.	0.	2.96E-01
EU154	7.18E-02	5.12E+01	0.	7.81E-01	0.	0.	9.84E-02
U232	4.21E+02	6.72E+01	0.	5.90E+03	0.	0.	0.
U234	7.40E+01	6.14E+01	0.	1.19E+03	0.	0.	0.
PU238	1.78E+01	7.30E+01	0.	7.17E+02	0.	0.	9.96E+01
PU239	1.98E+01	6.66E+01	0.	8.02E+02	0.	0.	1.10E+02
PU240	1.98E+01	6.66E+01	0.	8.00E+02	0.	0.	1.10E+02
PU241	2.42E-01	1.28E-01	0.	1.14E+01	0.	0.	6.12E-01
AM241	5.62E+01	7.17E+01	0.	8.55E+02	0.	0.	3.21E+02
CM242	1.49E+00	7.80E+01	0.	2.25E+01	0.	0.	2.33E+01
CM244	3.23E+01	7.42E+01	0.	5.37E+02	0.	0.	2.52E+02

TABLE H-32

INGESTION DOSE COMMITMENT FACTORS, ADULT

(MREM/MICROCURIE)

NUCLIDE	T BODY	GI-LLI	THYROID	BONE	LUNGS	SKIN	LIVER
H3	1.05E-01	1.05E-01	1.05E-01	0.	1.05E-01	1.05E-01	1.05E-01
C14	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01	5.69E-01
NA22	1.74E+01	3.26E+00	1.74E+01	1.74E+01	1.74E+01	0.	1.74E+01
AR39	0.	0.	0.	0.	0.	0.	0.
CO58	1.67E+00	1.51E+01	0.	0.	0.	0.	7.46E-01
CO60	4.74E+00	4.02E+01	0.	0.	0.	0.	2.15E+00
KR85M	0.	0.	0.	0.	0.	0.	0.
KR85	0.	0.	0.	0.	0.	0.	0.
KR87	0.	0.	0.	0.	0.	0.	0.
KR88	0.	0.	0.	0.	0.	0.	0.
KR89	0.	0.	0.	0.	0.	0.	0.
SR89	8.85E+00	4.94E+01	0.	3.09E+02	0.	0.	0.
SR90	1.87E+03	1.02E+02	0.	7.62E+03	0.	0.	0.
Y90	2.59E-04	1.02E+02	0.	9.65E-03	0.	0.	0.
Y91	3.78E-03	7.76E+01	0.	1.41E-01	0.	0.	0.
ZR95	6.59E-03	3.03E+01	0.	3.04E-02	0.	0.	9.76E-03
NB95	1.86E-03	2.10E+01	0.	6.23E-03	0.	0.	3.46E-03
RU103	7.98E-02	2.15E+01	0.	1.85E-01	0.	0.	0.
RU106	3.47E-01	1.79E+02	0.	2.75E+00	0.	0.	0.
SN123	7.60E-01	6.33E+01	4.38E-01	3.11E+01	0.	0.	5.16E-01
TE125	3.59E-01	1.07E+01	8.07E-01	2.68E+00	0.	0.	9.73E-01
TE127	2.38E-02	8.68E+00	8.17E-02	1.11E-01	0.	0.	3.96E-02
TE129	1.82E+00	5.79E+01	3.95E+00	1.15E+01	0.	0.	4.30E+00
TE132	1.53E+00	7.71E+01	1.80E+00	2.52E+00	0.	0.	1.63E+00
I129	9.22E+00	4.44E-01	7.24E+03	3.27E+00	0.	0.	2.81E+00
I131	3.41E+00	1.57E+00	1.95E+03	4.16E+00	0.	0.	5.96E+00
I133	7.57E-01	2.18E+00	4.77E+02	1.43E+00	0.	0.	2.48E+00
XE133	0.	0.	0.	0.	0.	0.	0.
XE135M	0.	0.	0.	0.	0.	0.	0.
XE135	0.	0.	0.	0.	0.	0.	0.
XE137	0.	0.	0.	0.	0.	0.	0.
XE138	0.	0.	0.	0.	0.	0.	0.
CS134	1.21E+02	2.59E+00	0.	6.24E+01	1.59E+01	0.	1.48E+02
CS137	7.15E+01	2.11E+00	0.	8.01E+01	1.23E+01	0.	1.09E+02
BA140	1.33E+00	4.18E+01	0.	2.03E+01	1.47E-02	0.	2.56E-02
LA140	3.35E-04	9.25E+01	0.	2.51E-03	0.	0.	1.27E-03
CE141	7.18E-04	2.42E+01	0.	9.36E-03	0.	0.	6.34E-03
CE144	2.61E-02	1.65E+02	0.	4.88E-01	0.	0.	2.04E-01
EU154	5.39E-02	5.48E+01	0.	6.18E-01	0.	0.	7.57E-02
U232	2.95E+02	6.72E+01	0.	4.14E+03	0.	0.	0.
U234	5.18E+01	6.14E+01	0.	8.37E+02	0.	0.	0.
PU238	1.67E+01	7.30E+01	0.	6.73E+02	0.	0.	9.31E+01
PU239	1.88E+01	6.66E+01	0.	7.60E+02	0.	0.	1.04E+02
PU240	1.88E+01	6.78E+01	0.	7.58E+02	0.	0.	1.04E+02
PU241	3.32E-01	1.40E+00	0.	1.56E+01	0.	0.	8.47E-01
AM241	5.26E+01	7.42E+01	0.	8.09E+02	0.	0.	2.78E+02
CM242	1.04E+00	7.92E+01	0.	1.58E+01	0.	0.	1.64E+01
CM244	2.88E+01	7.55E+01	0.	4.85E+02	0.	0.	2.07E+02

APPENDIX I

NUCLIDE CONTRIBUTION TO DOSE

FIGURE NUMBER	TITLE	PAGE
I-1	Nuclide Contribution to Infant Dose (Asheville, NC)	I-2
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I-5	Nuclide Contribution to Infant Dose (Oak Ridge, TN)	I-6
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I-9	Nuclide Contribution to Infant Dose (Nashville, TN)	I-10
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I-15	Nuclide Contribution to Teen Dose (Huntsville, AL)	I-16
I-16	Nuclide Contribution to Adult Dose (Huntsville, AL)	I-17

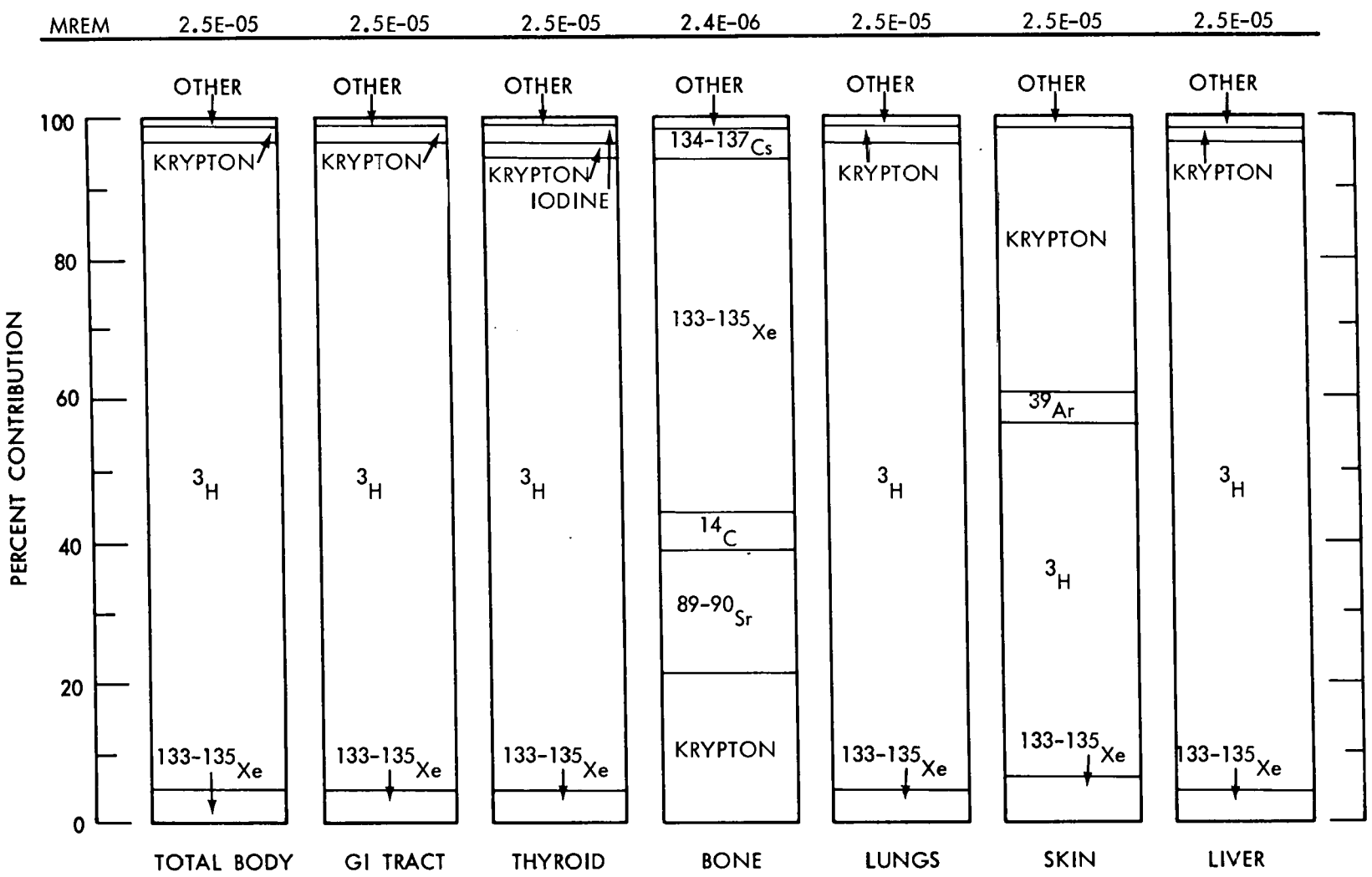

FIGURE I-1

Nuclide Contribution To Infant Dose (Asheville, NC)

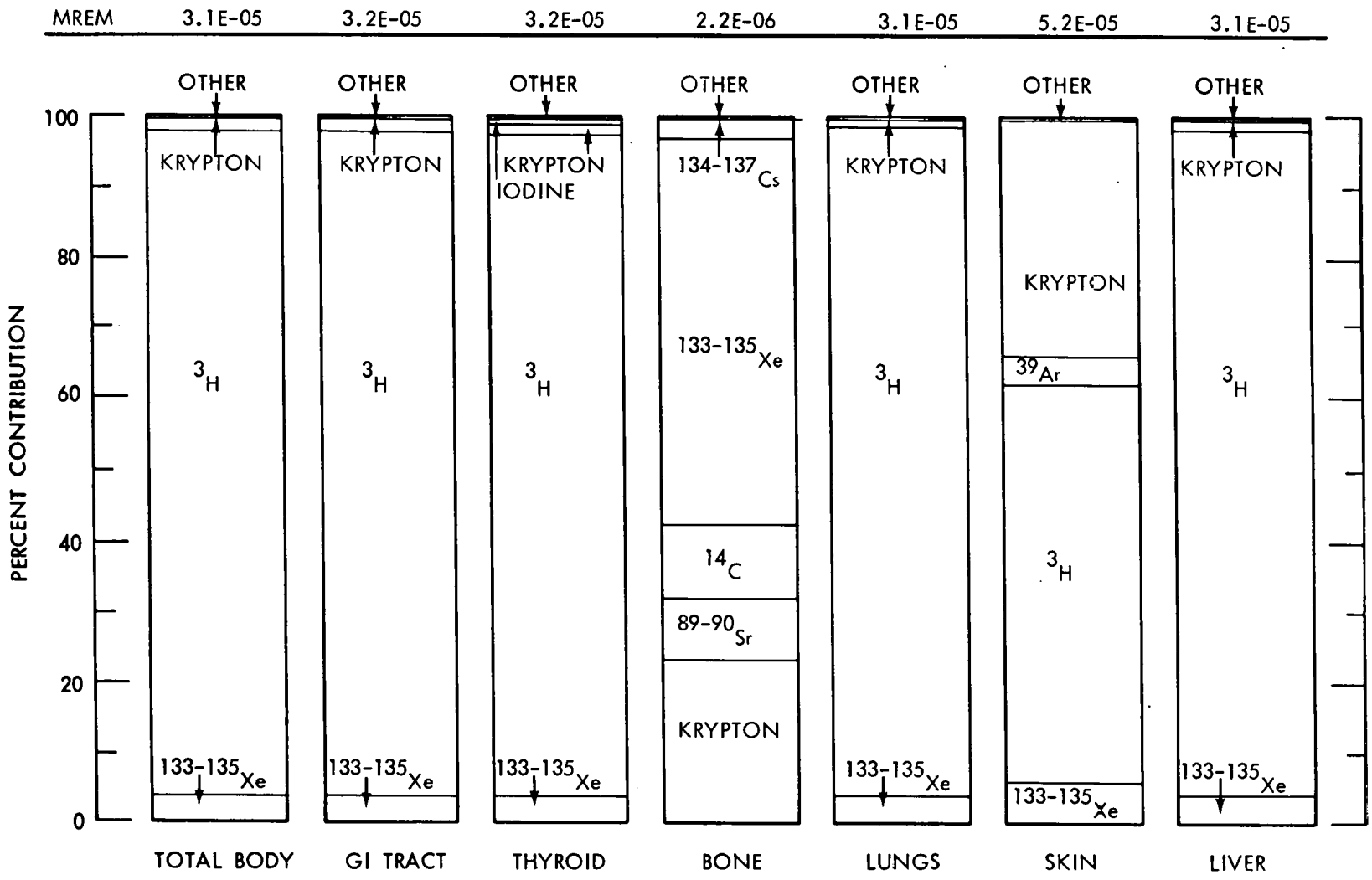

FIGURE I-2

Nuclide Contribution to Child Dose (Asheville, NC)

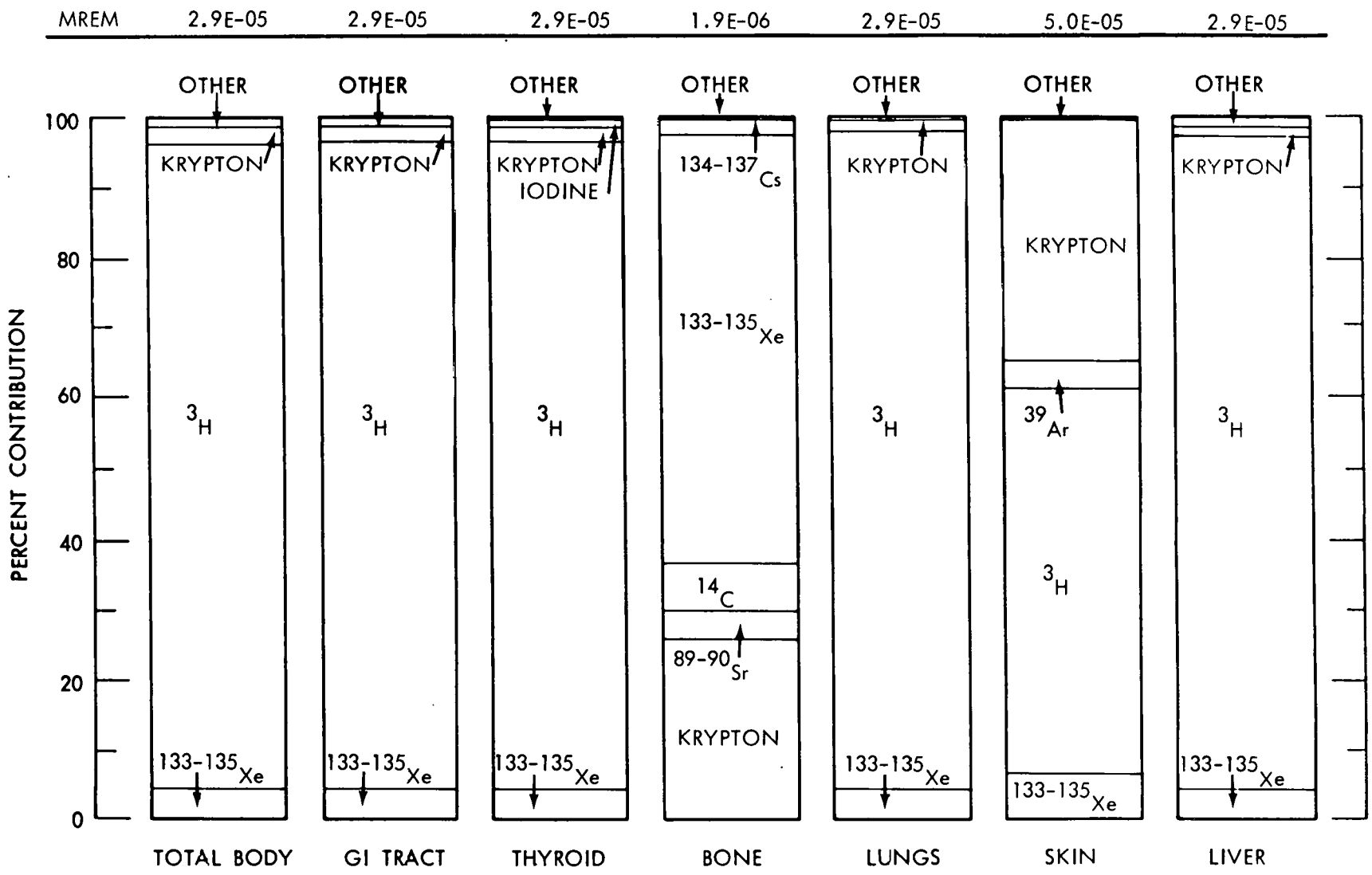

FIGURE I-3

Nuclide Contribution for Teen Dose (Asheville, NC)

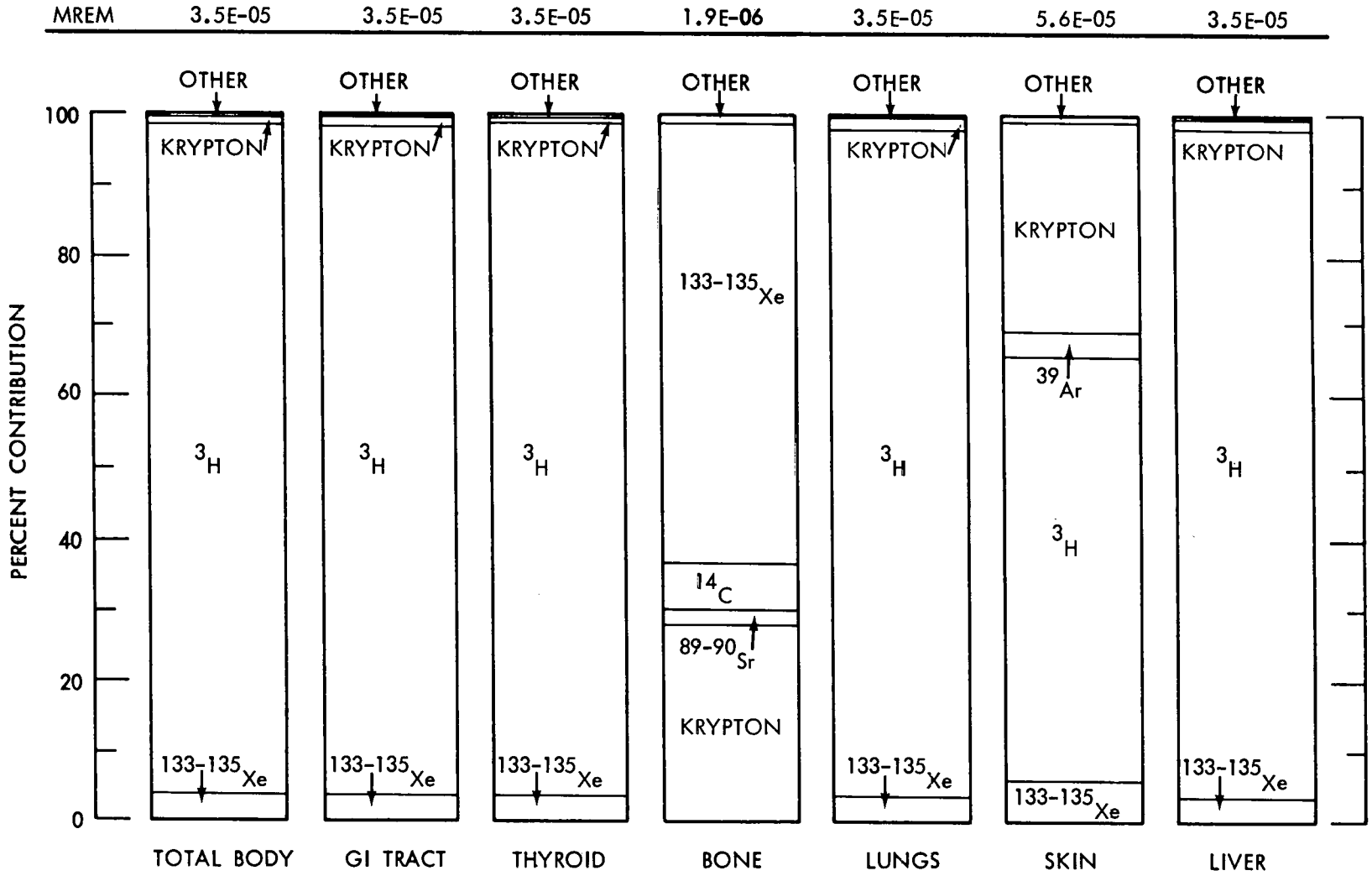

FIGURE I-4

Nuclide Contribution for Adulat Dose (Asheville, NC)

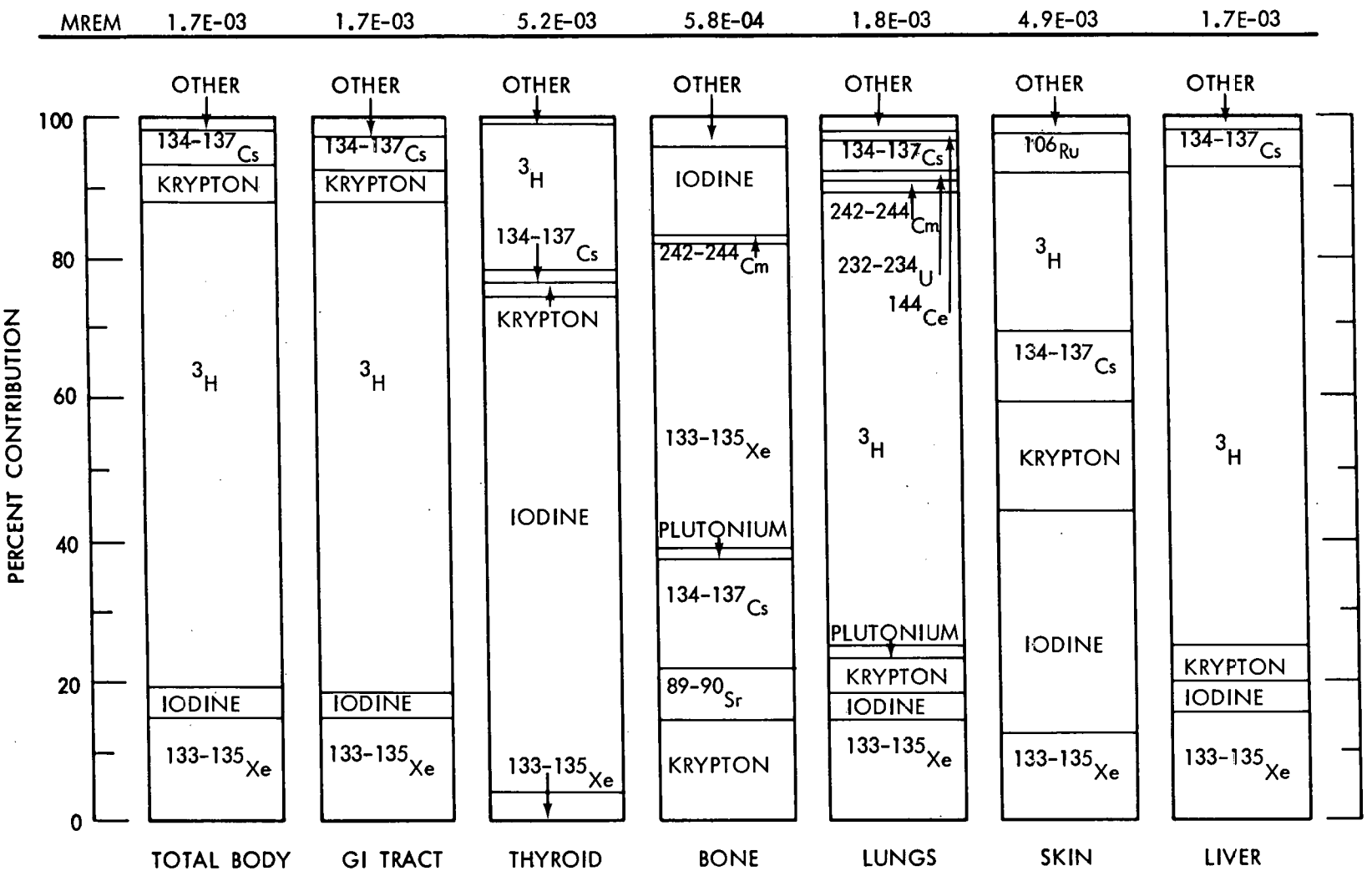

FIGURE I-5

Nuclide Contribution to Infant Dose (Oak Ridge, TN)

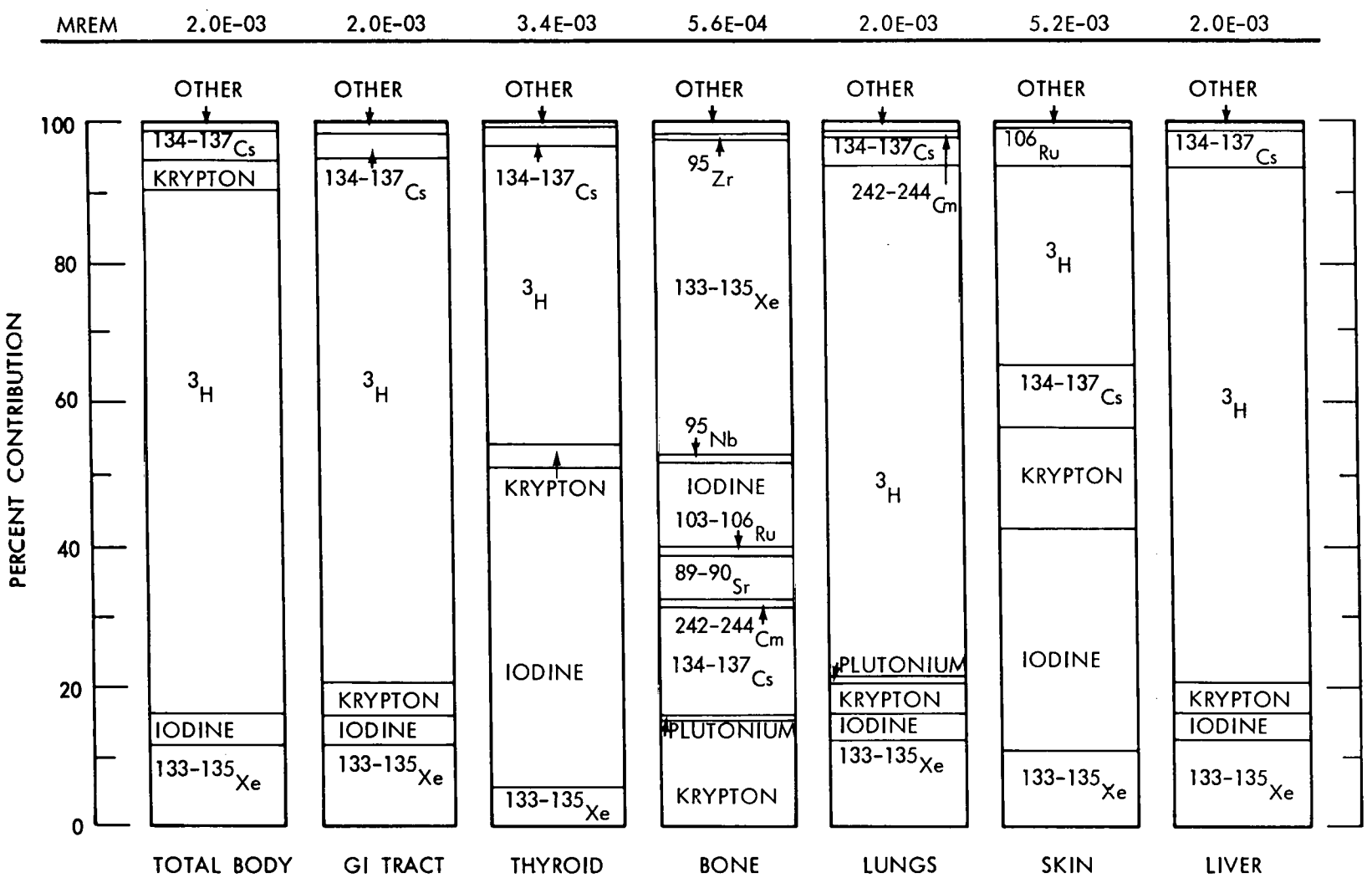

FIGURE I-6

Nuclide Contribution to Child Dose (Oak Ridge, TN)

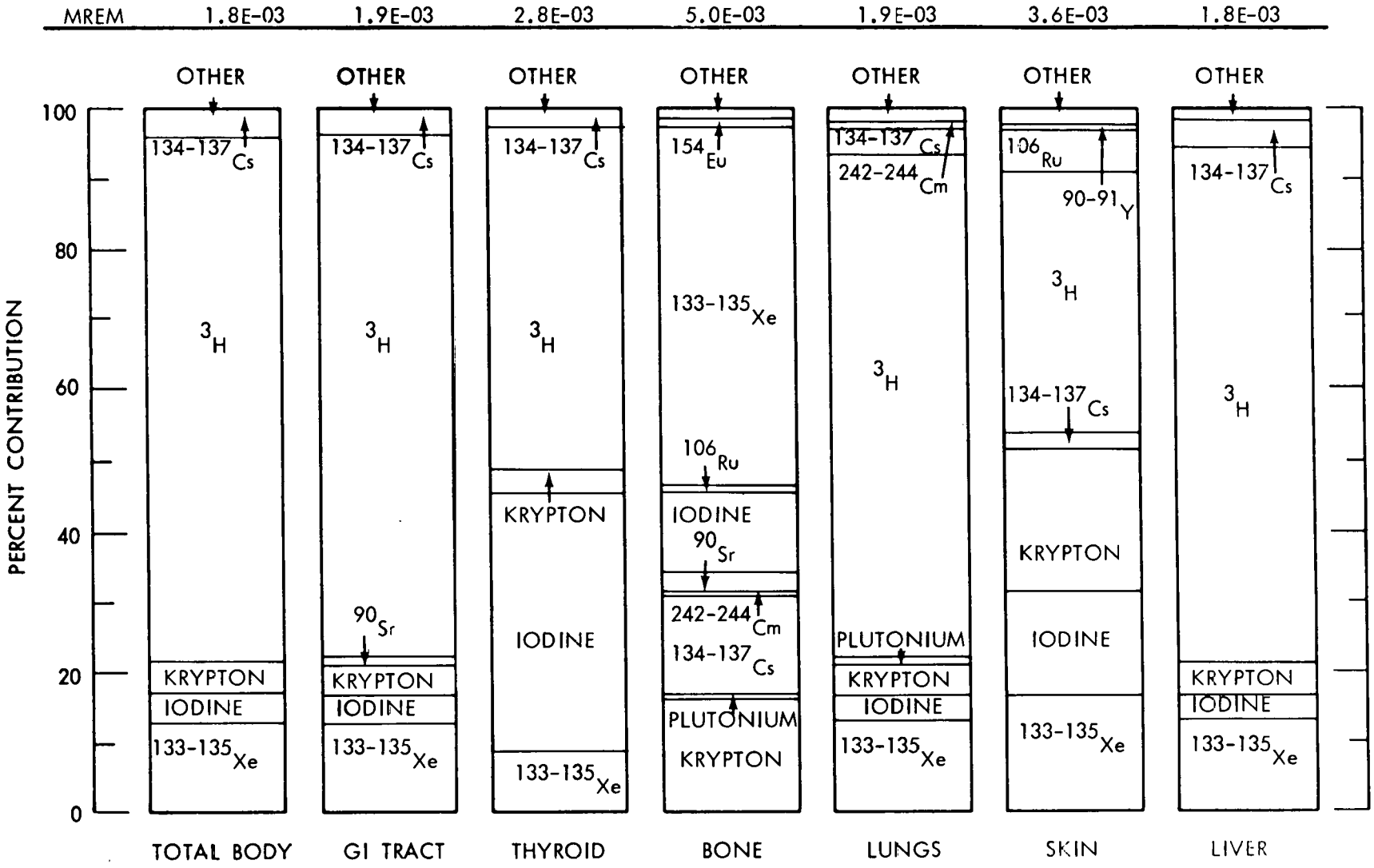

FIGURE I-7

Nuclide Contribution to Teen Dose (Oak Ridge, TN)

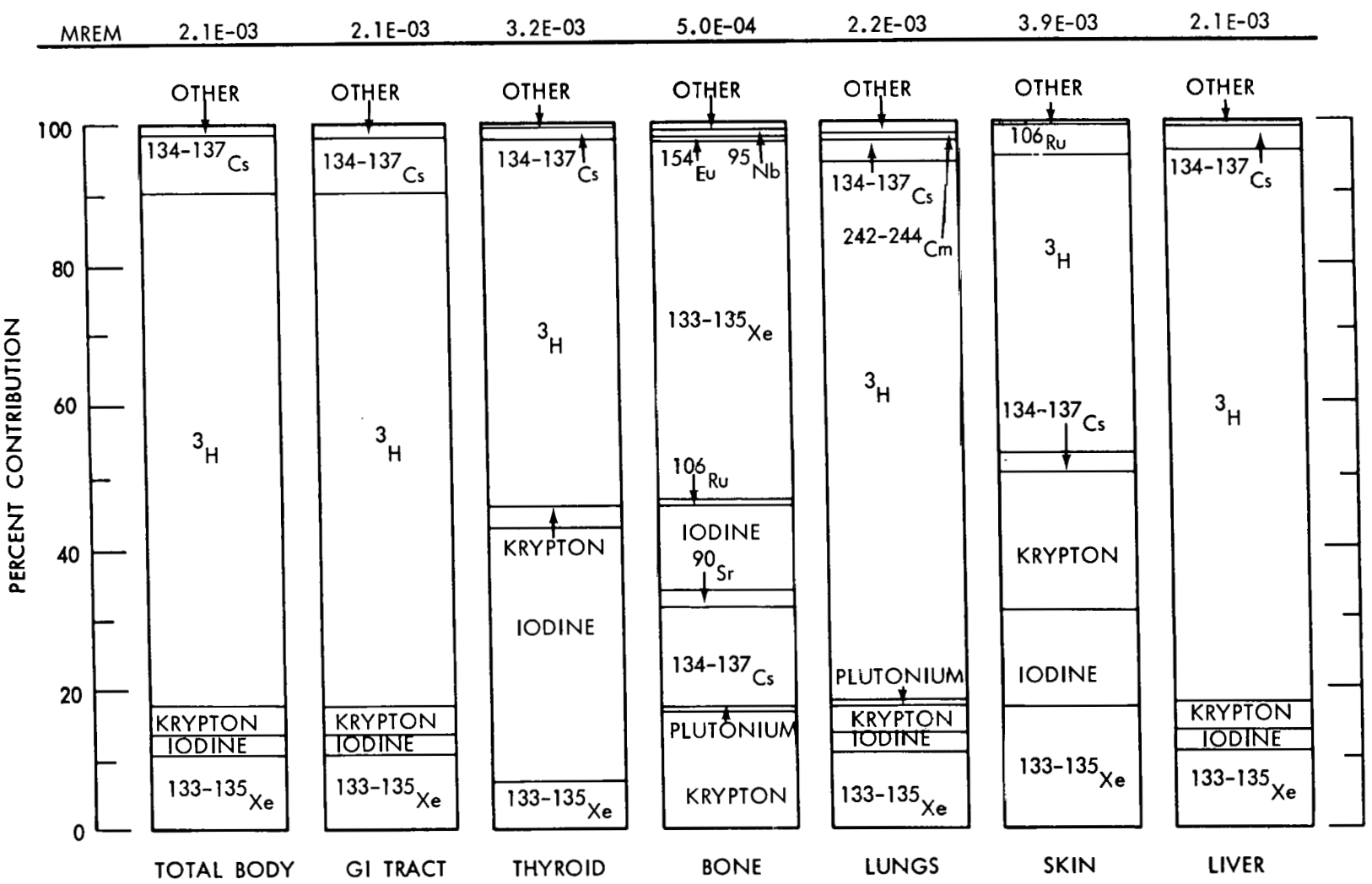

FIGURE I-8

Nuclide Contribution to Adult Dose (Oak Ridge, TN)

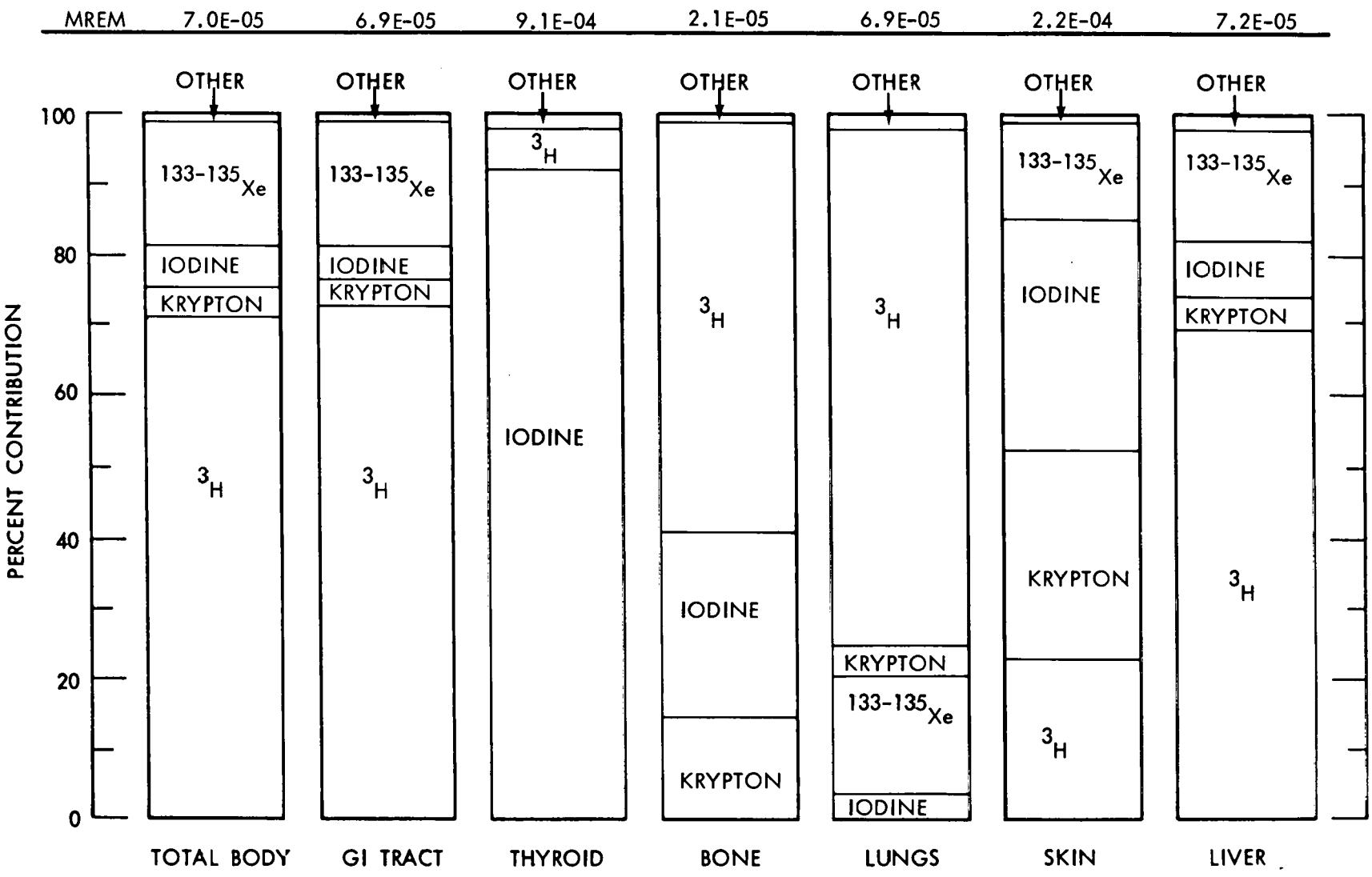

FIGURE I-9

Nuclide Contribution to Infant Dose (Nashville, TN)

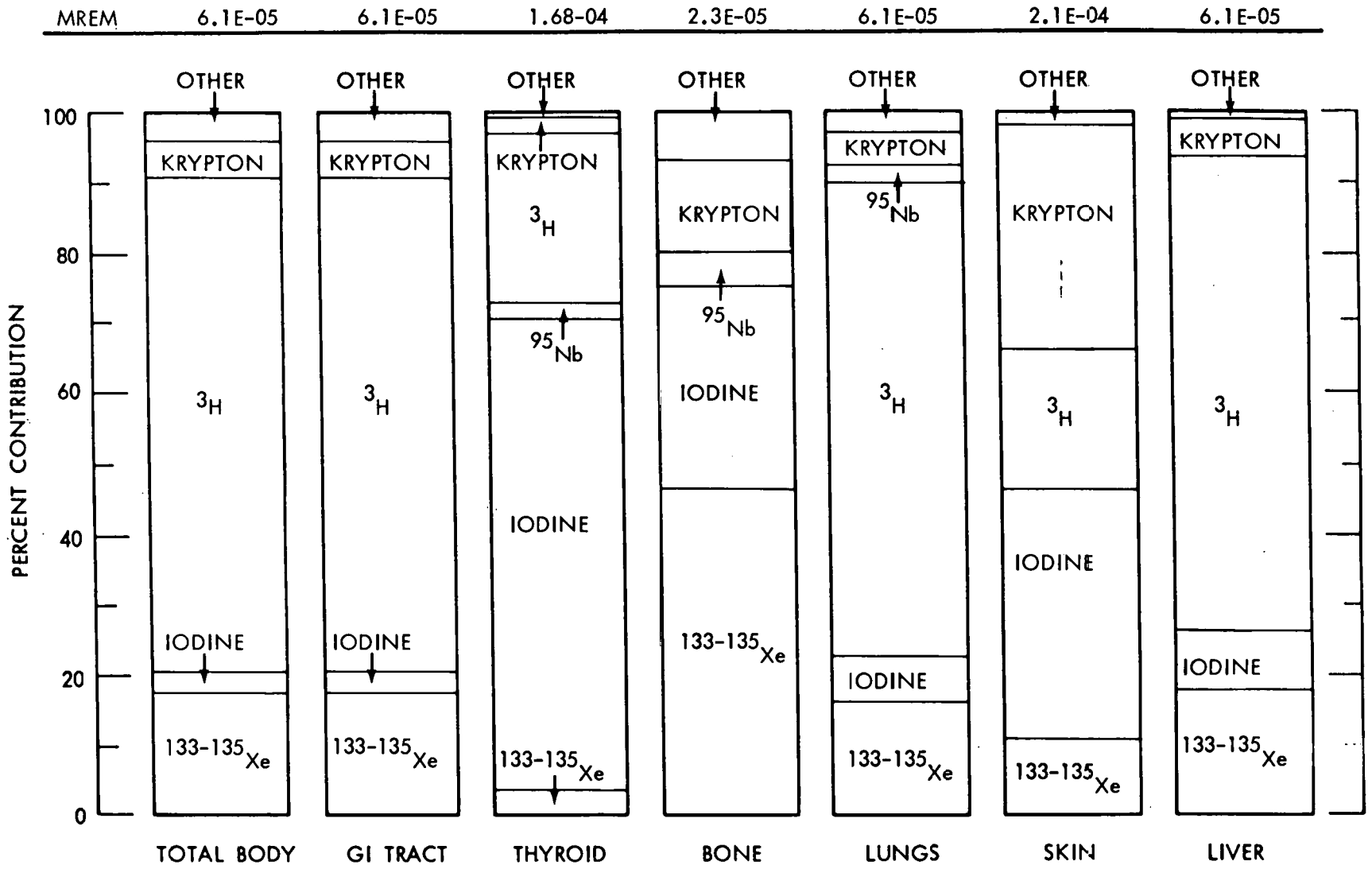

FIGURE I-10

Nuclide Contribution to Child Dose (Nashville, TN)

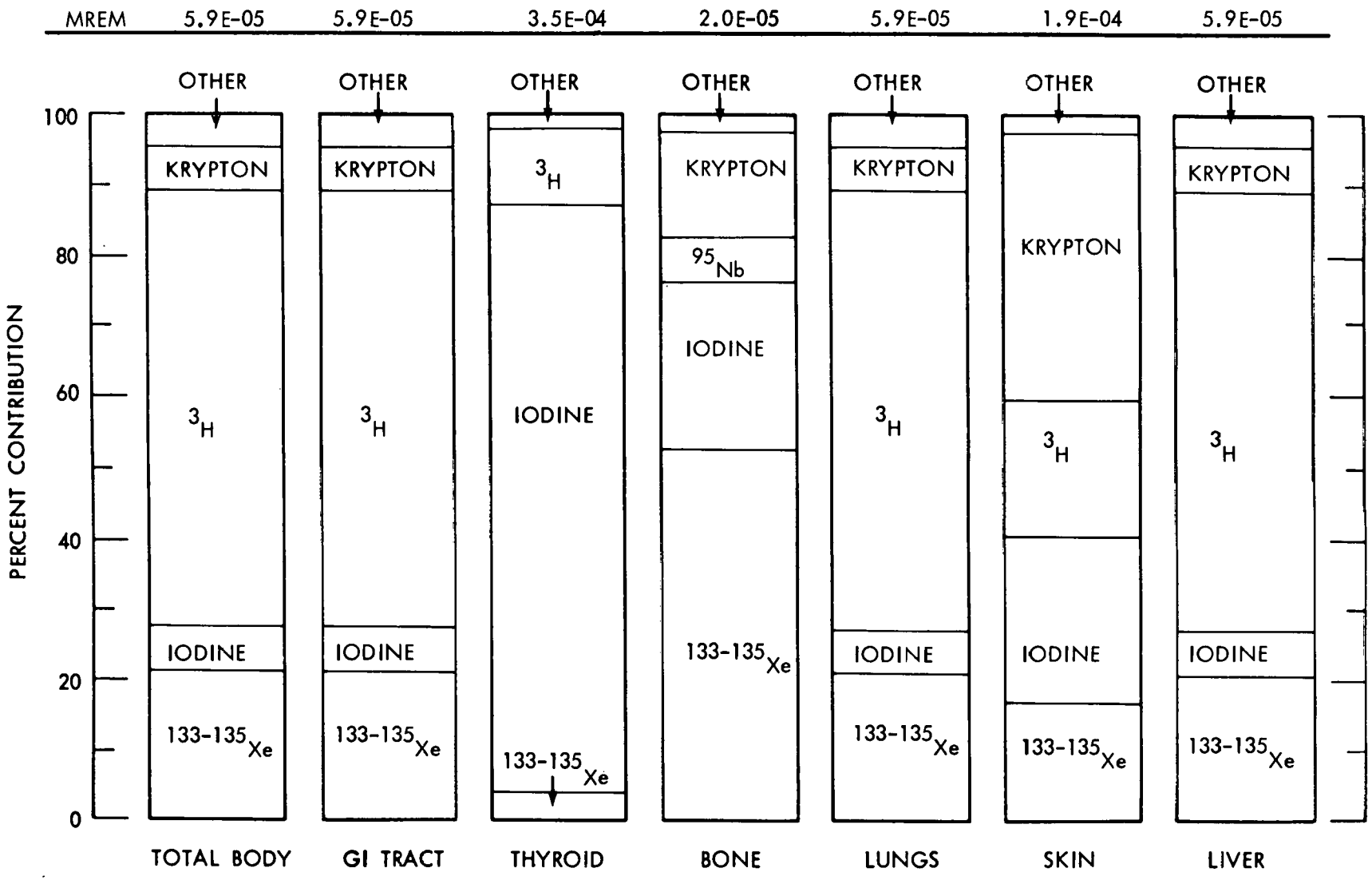

FIGURE I-11

Nuclide Contribution to Teen Dose (Nashville, TN)

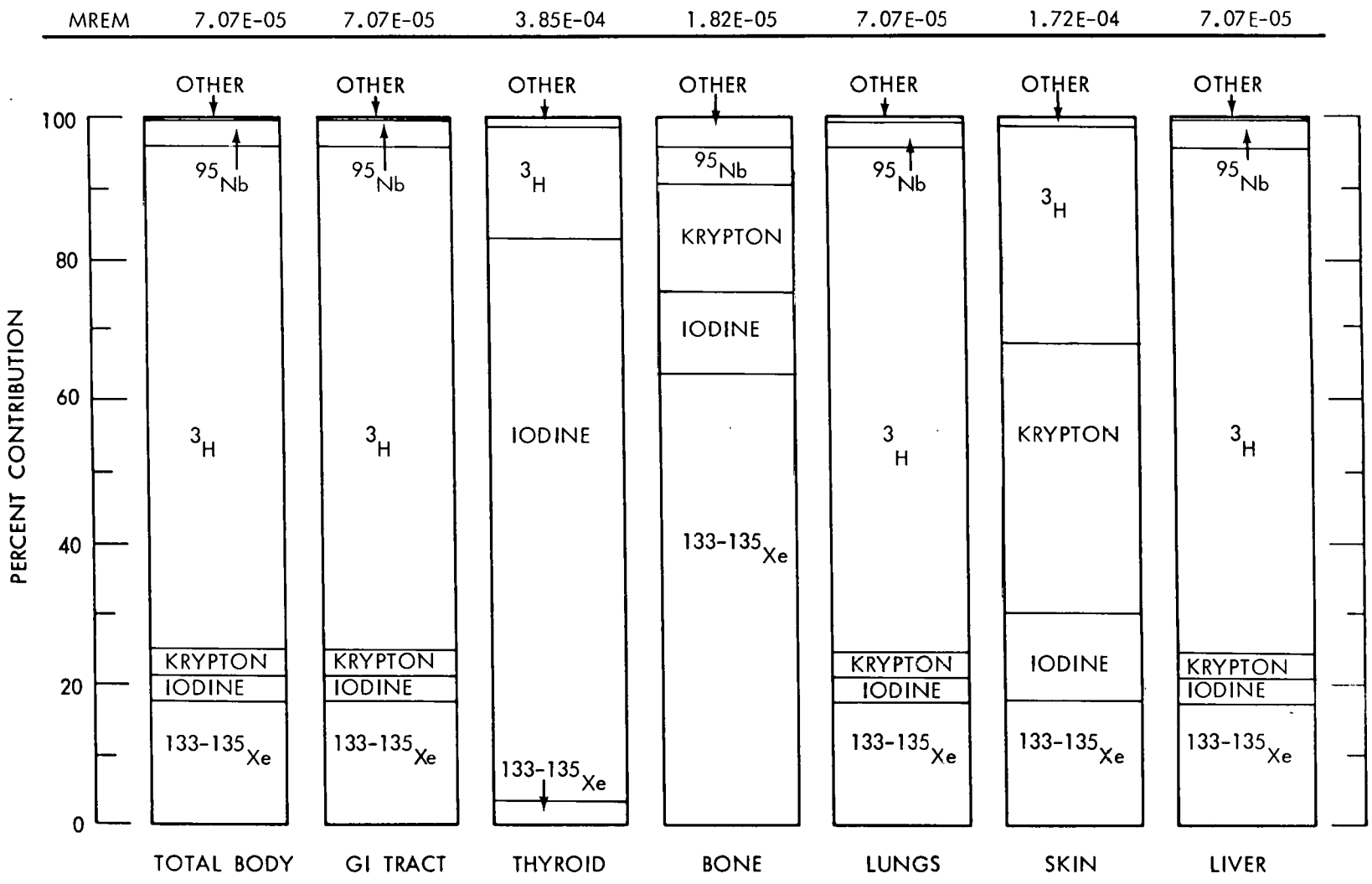

FIGURE I-12

Nuclide Contribution to Adult Dose (Nashville, TN)

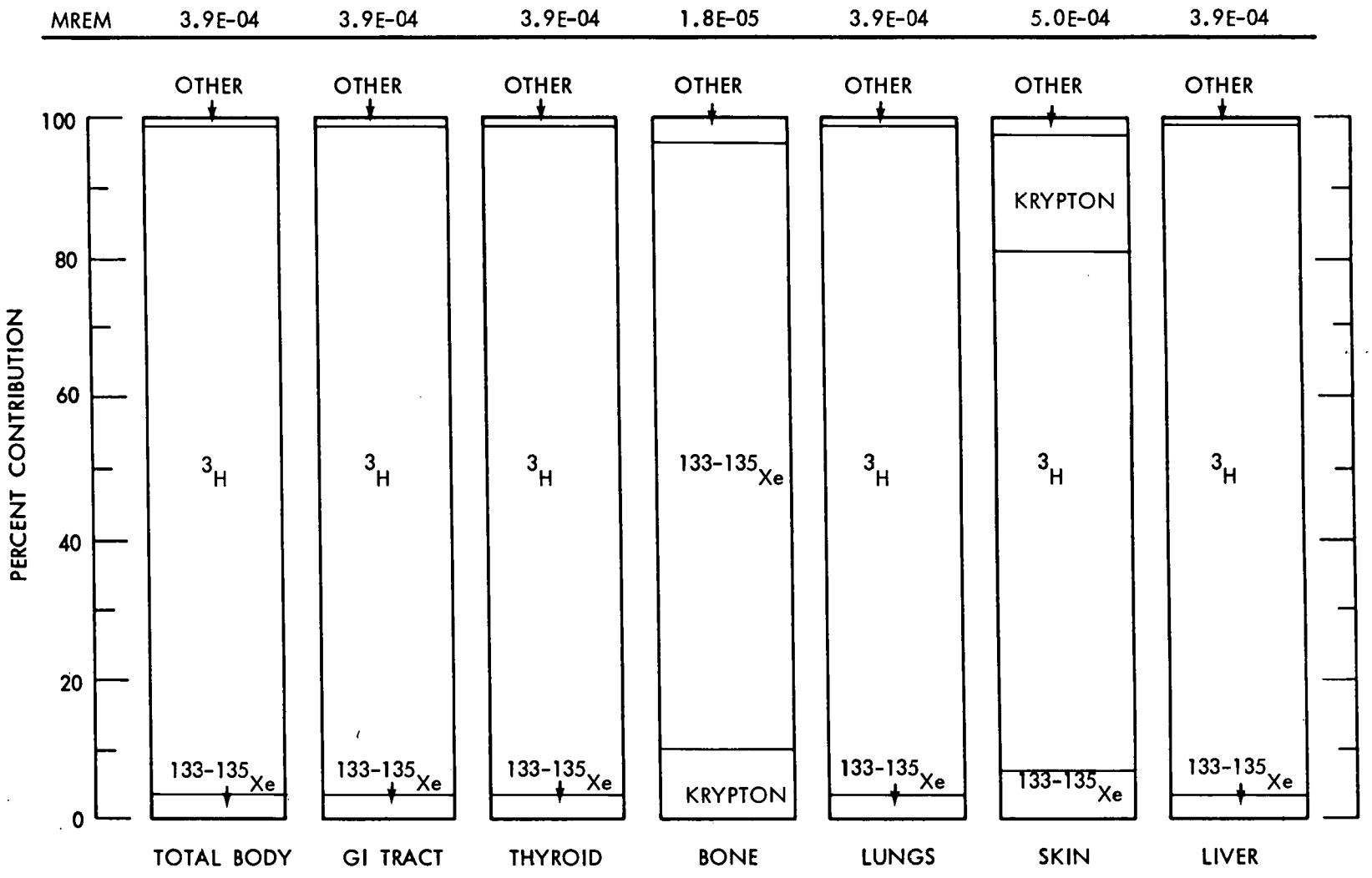

FIGURE I-13

Nuclide Contribution to Infant Dose (Huntsville, AL)

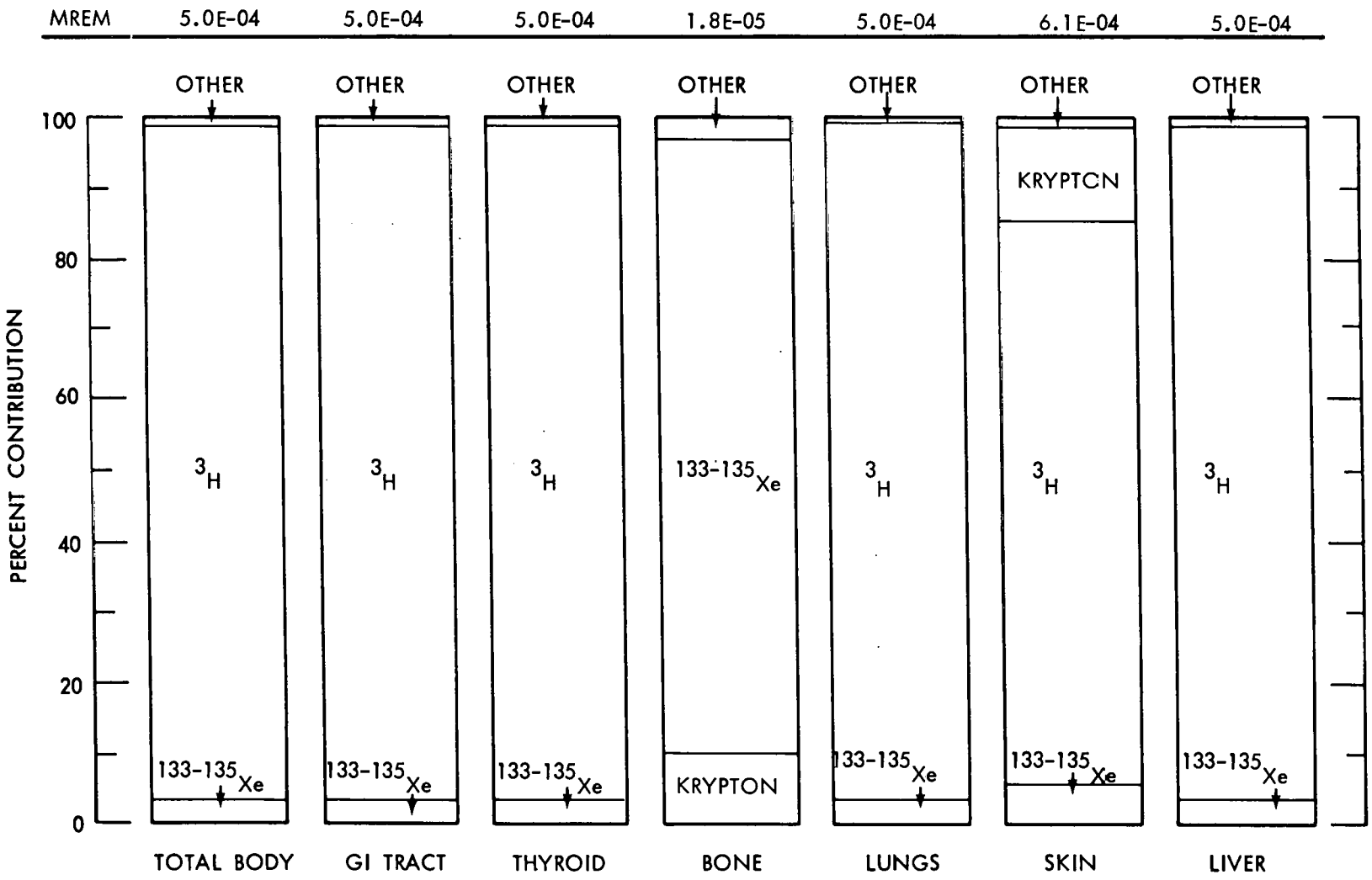

FIGURE I-14

Nuclide Contribution to Child Dose (Huntsville, AL)

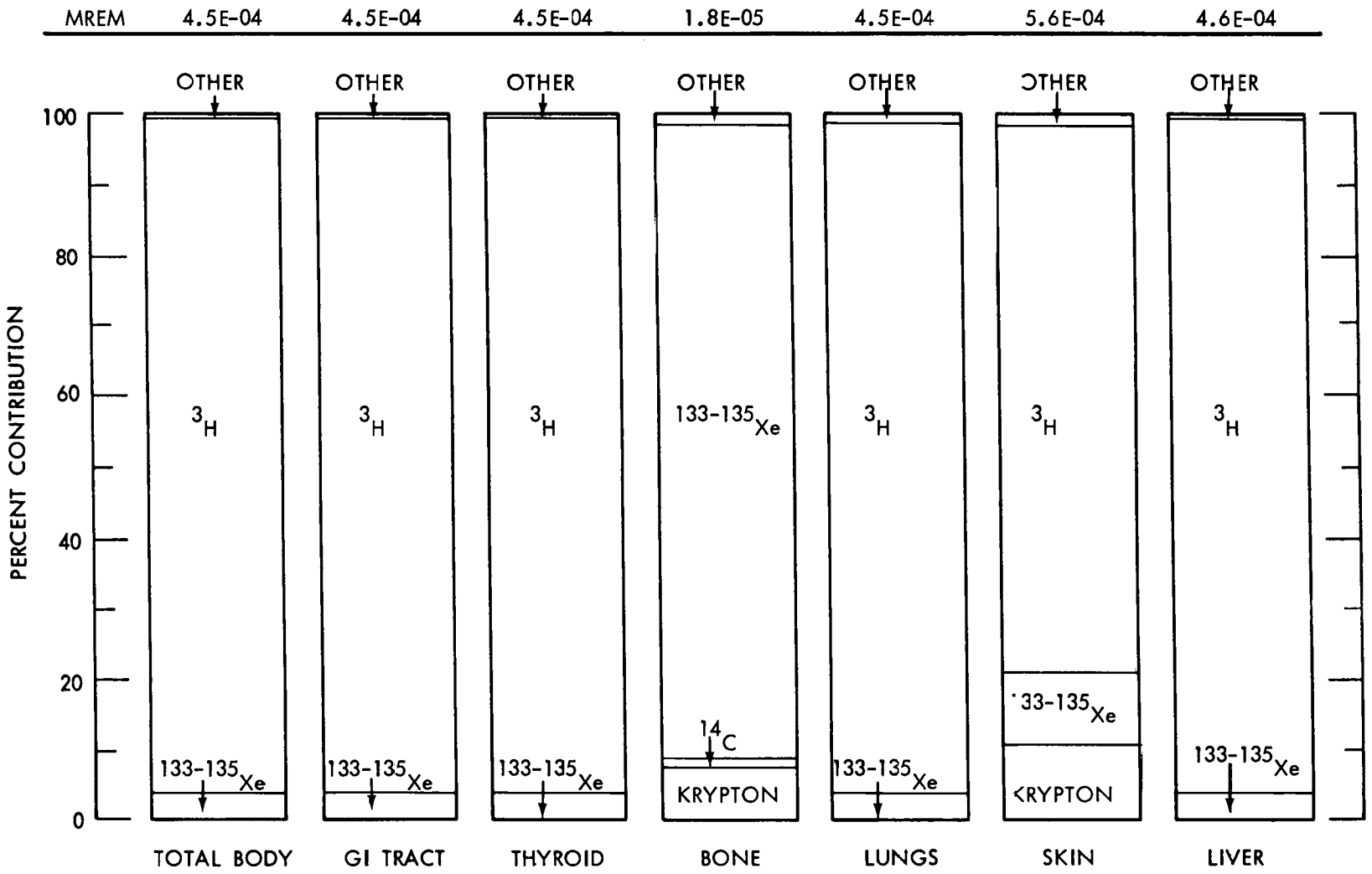

FIGURE I-15

Nuclide Contribution to Teen Dose (Huntsville, AL)

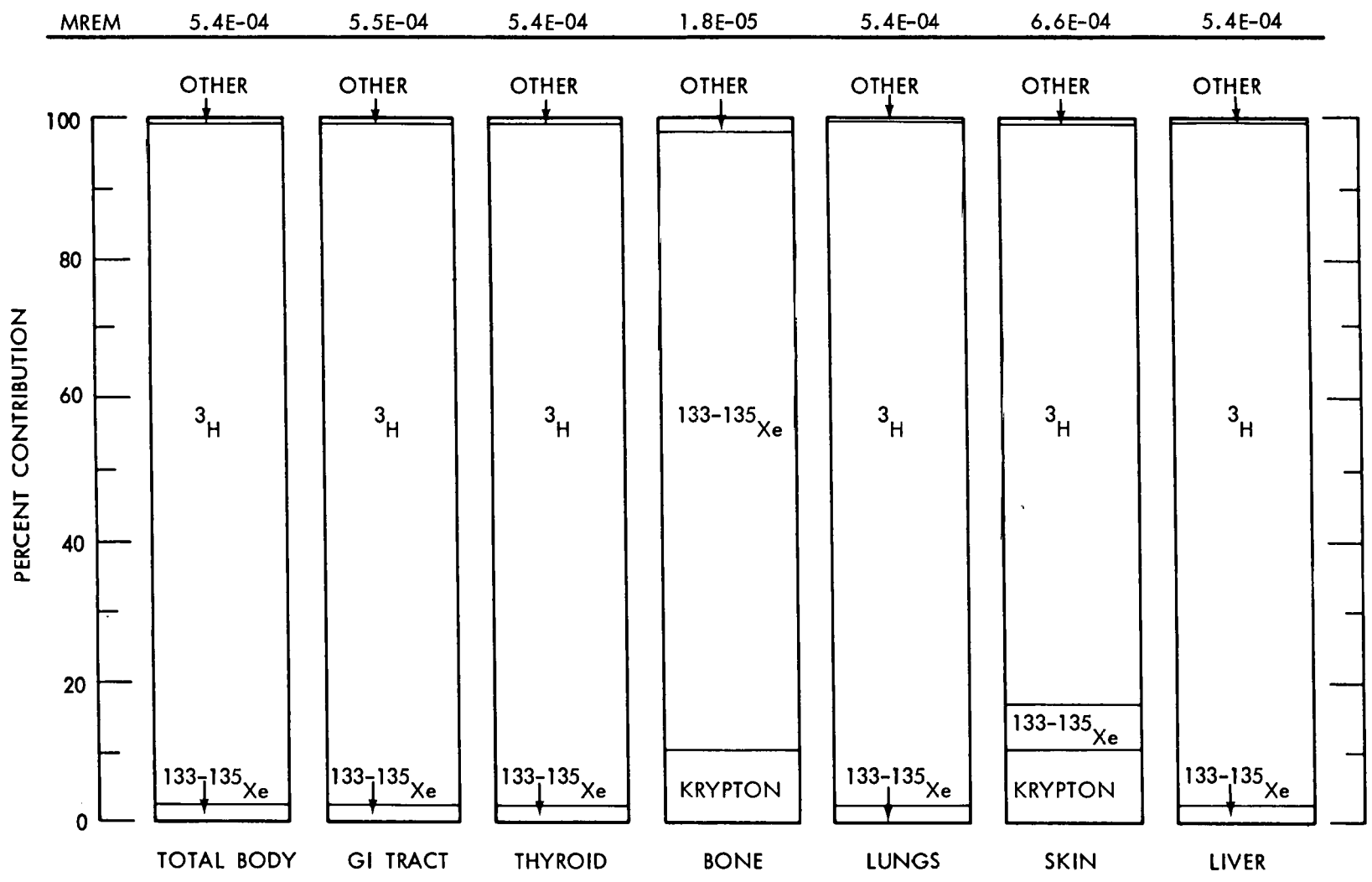

FIGURE I-16

Nuclide Contribtuion to Adult Dose (Huntsville, AL)

APPENDIX J

PATHWAY CONTRIBUTIONS TO DOSE

LIST OF FIGURES

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J-15	Pathway Contribution to Teen Dose (Huntsville, AL)	J-16
J-16	Pathway Contribution to Adult Dose (Huntsville, AL)	J-17

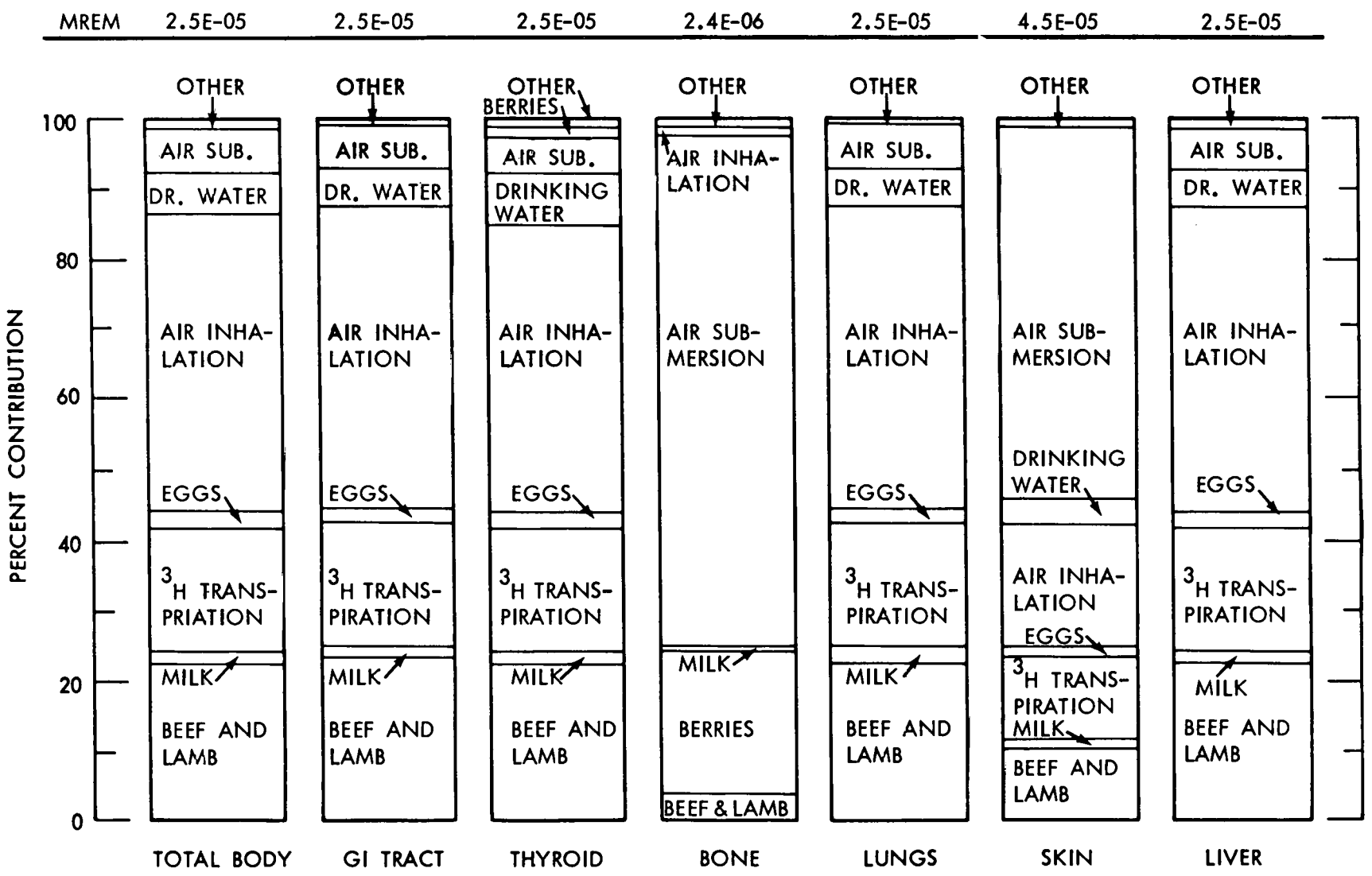

FIGURE J-1

Pathway Contribution to Infant Dose (Asheville, NC)

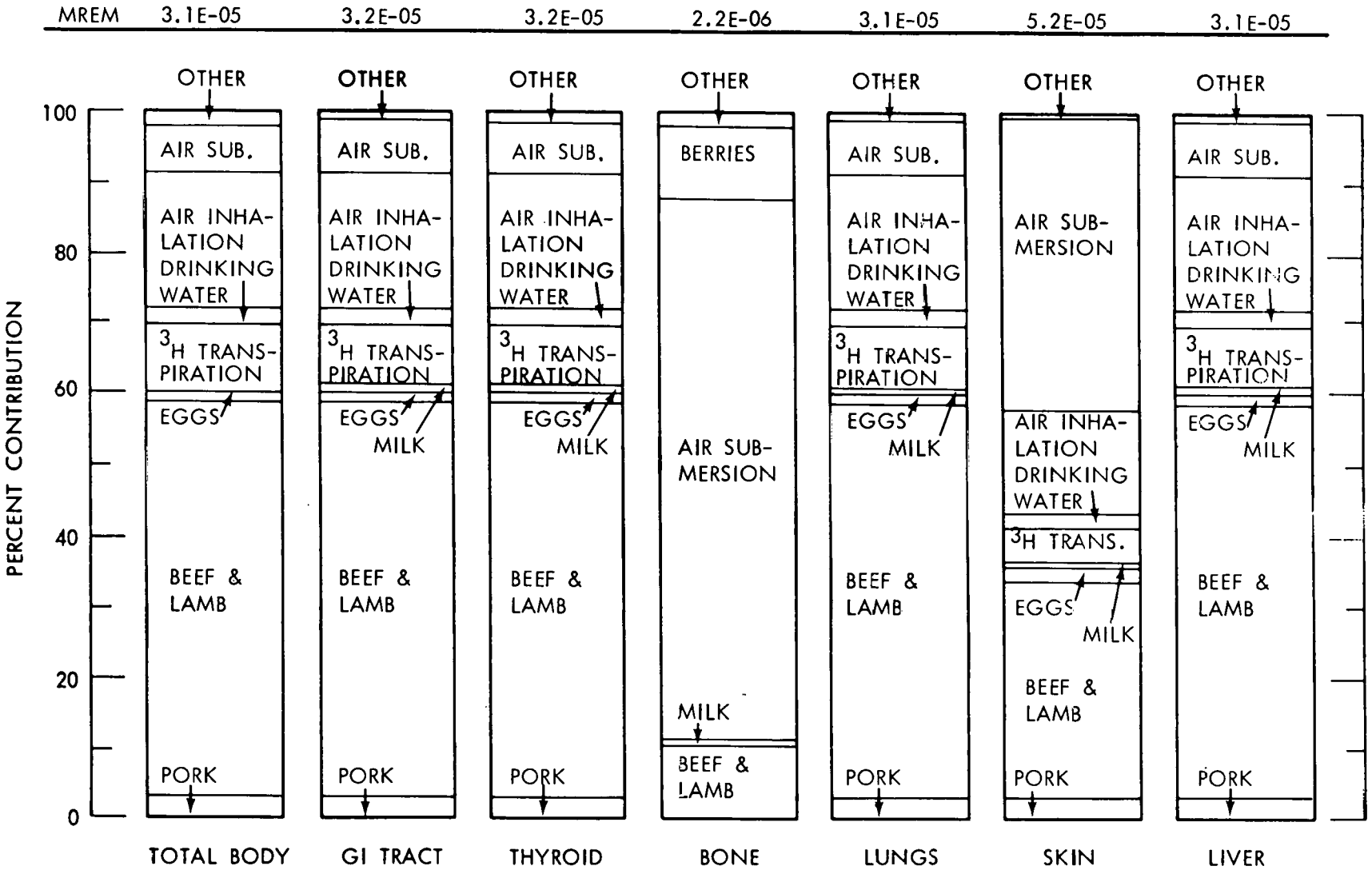

FIGURE J-2

Pathway Contribution to Child Dose (Asheville, NC)

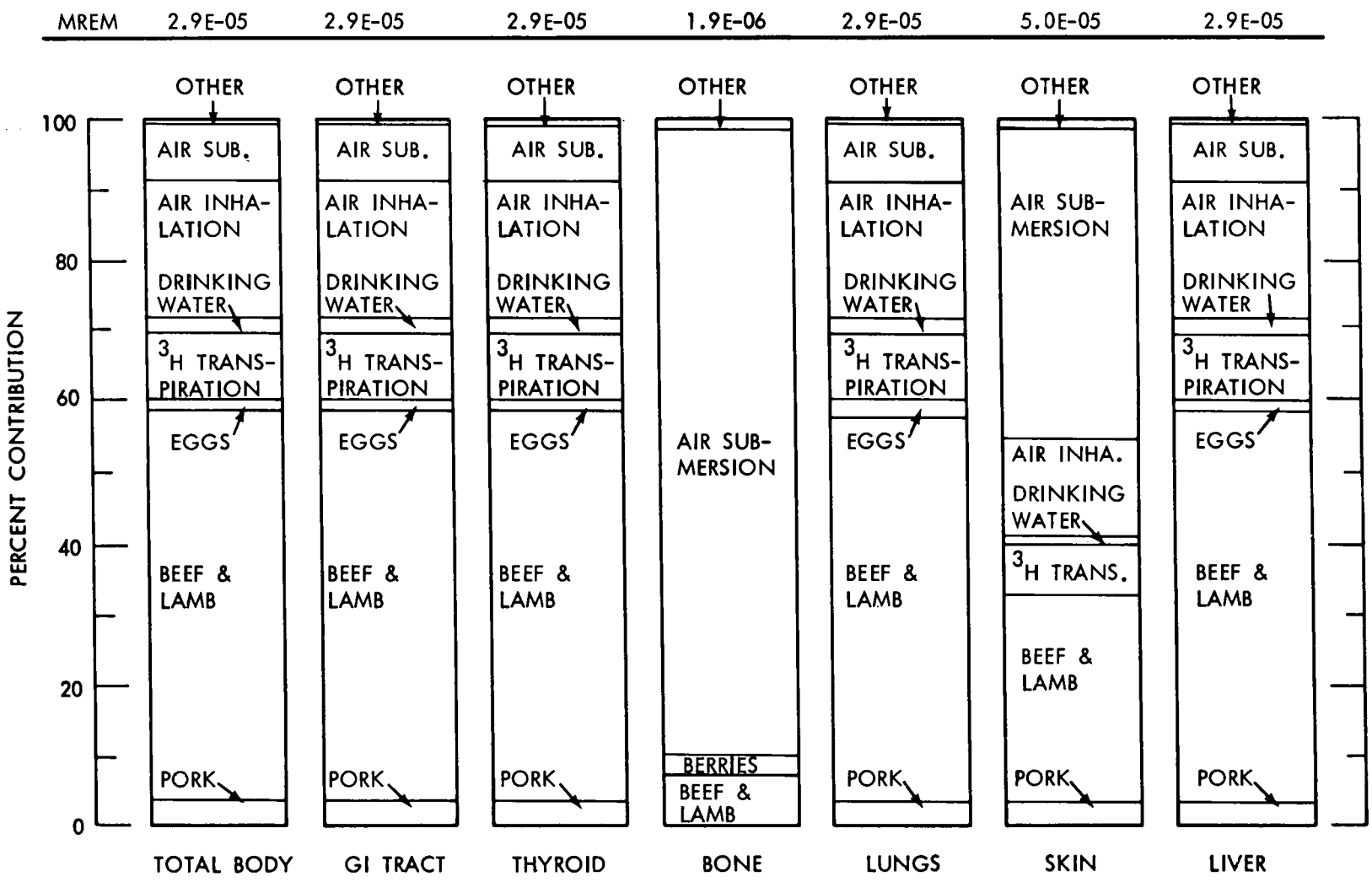

FIGURE J-3

Pathway Contribution to Teen Dose (Asheville, NC)

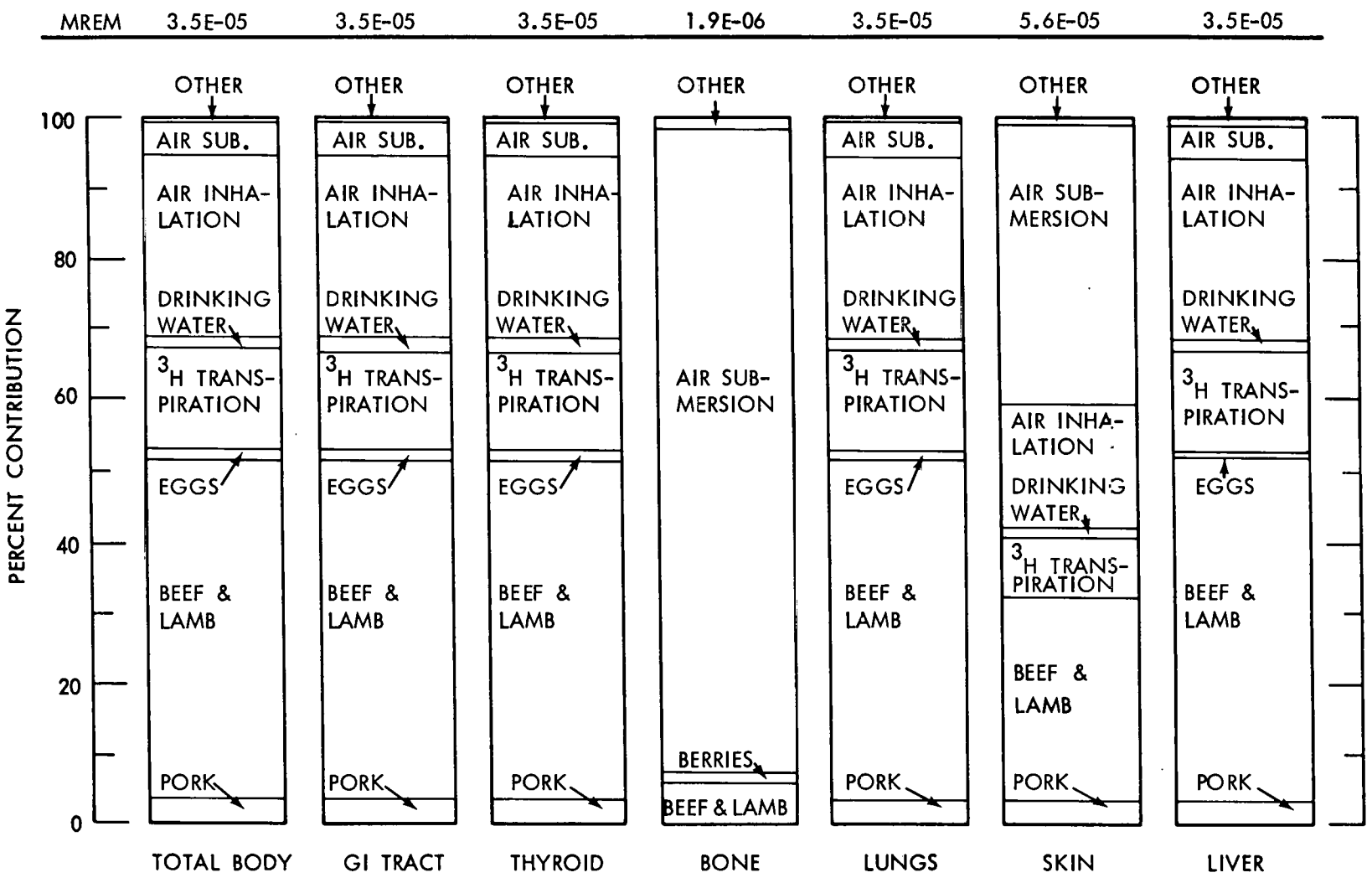

FIGURE J-4

Pathway Contribution to Adult Dose (Asheville, SC)

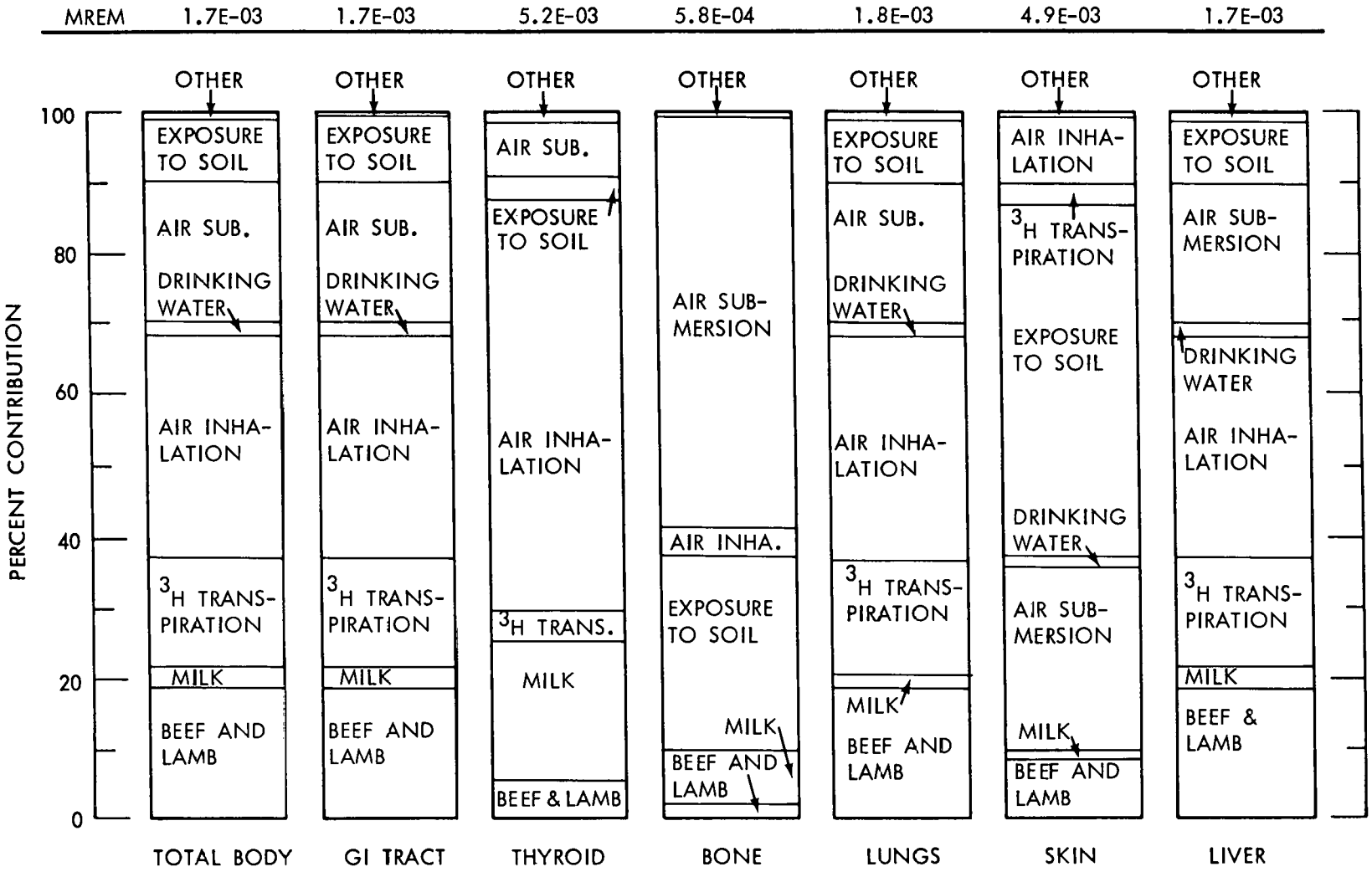

FIGURE J-5

Pathway Contribution to Infant Dose (Oak Ridge, TN)

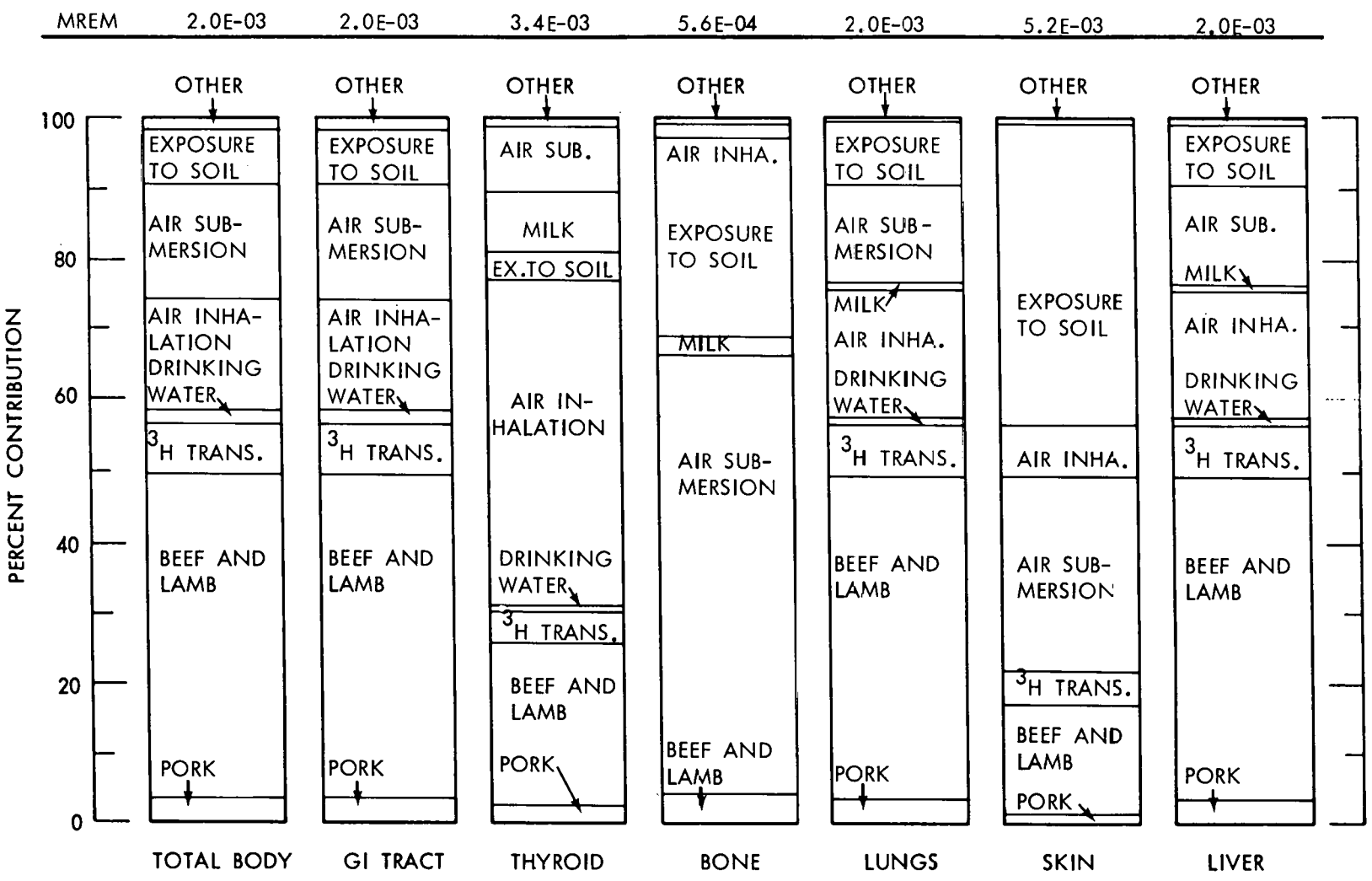

FIGURE J-6

Pathway Contribution to Child Dose (Oak Ridge, TN)

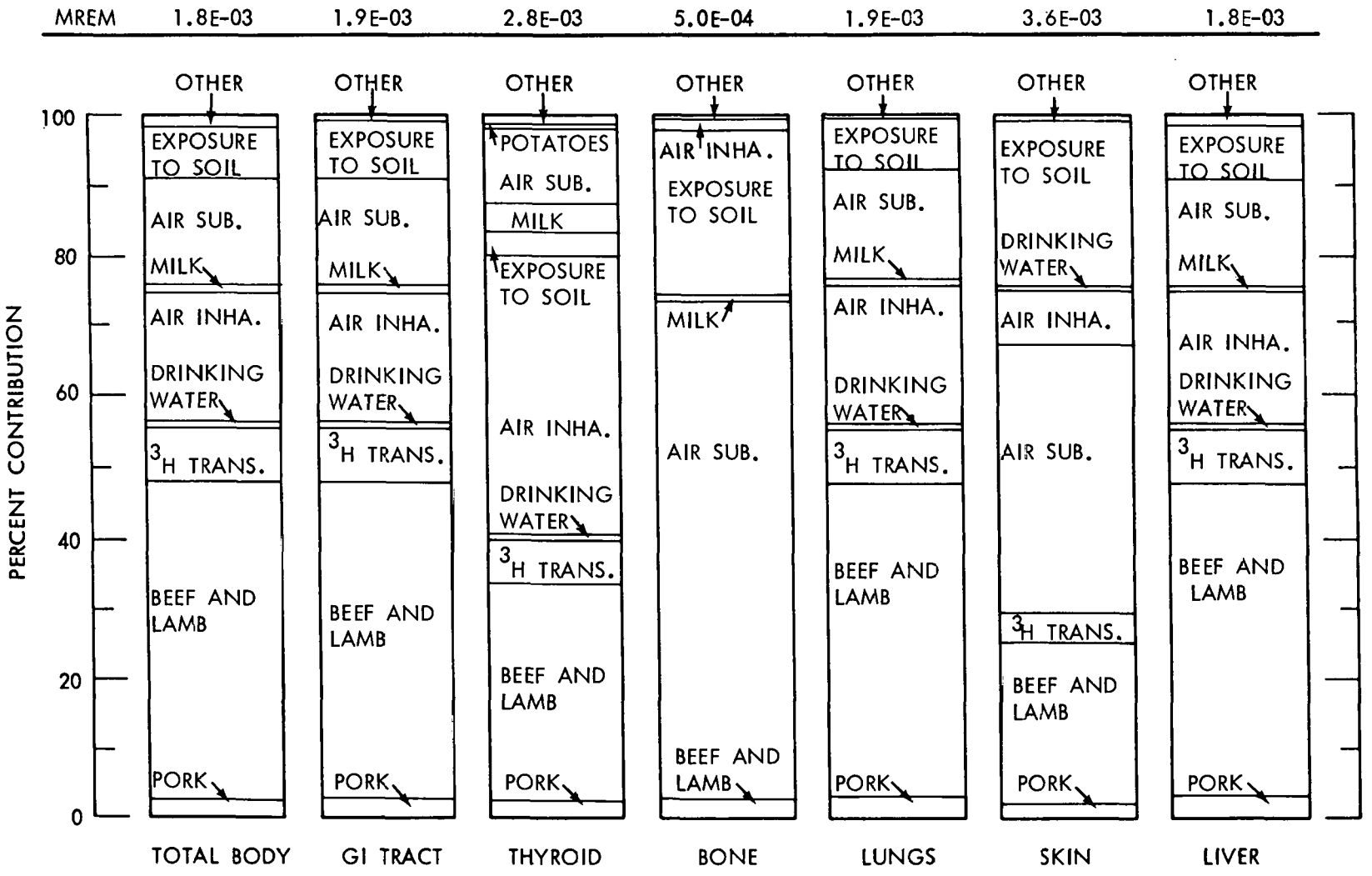

FIGURE J-7

Pathway Contribution to Teen Dose (Oak Ridge, TN)

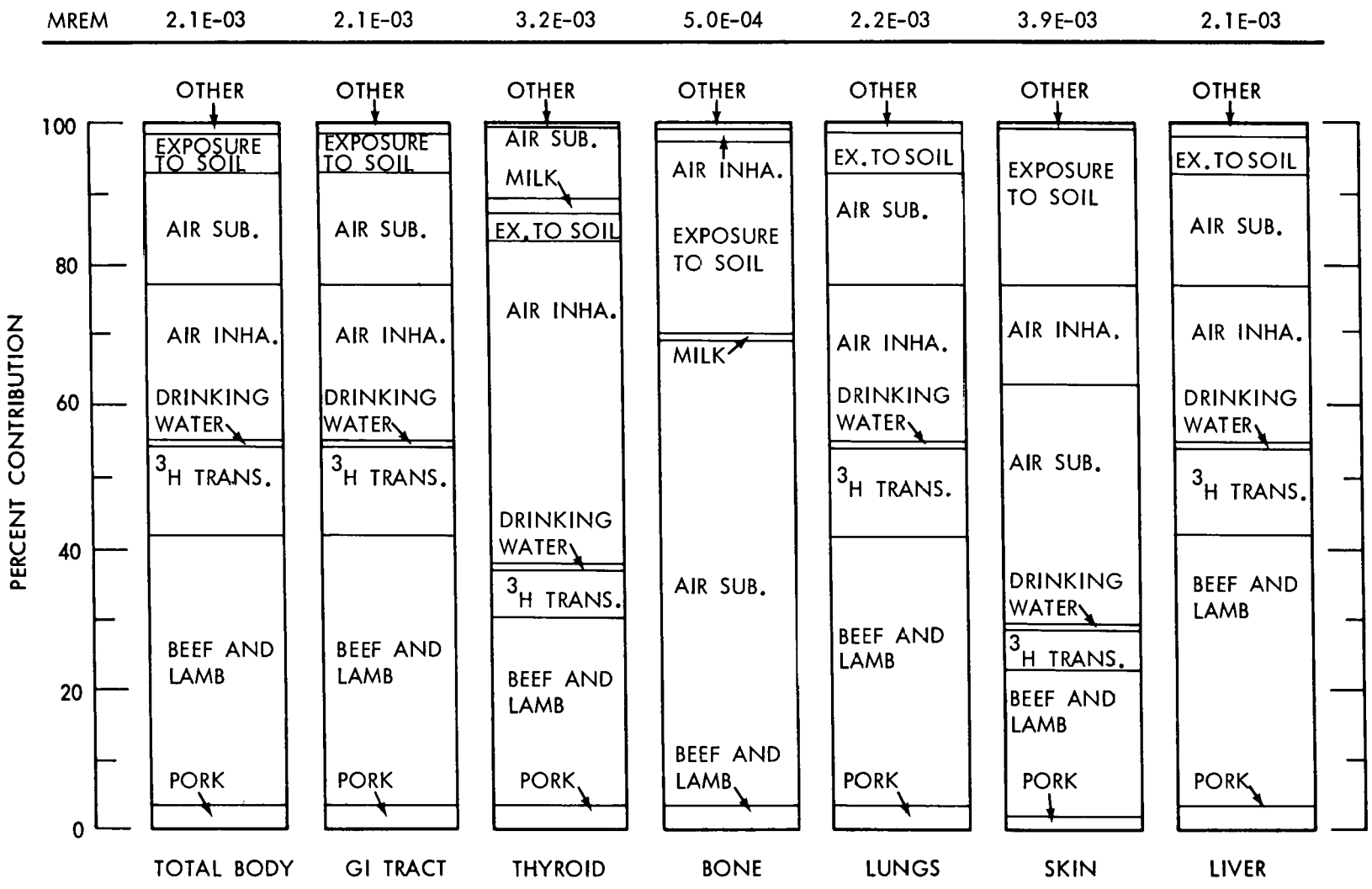

FIGURE J-8

Pathway Contribution to Adult Dose (Oak Ridge, TN)

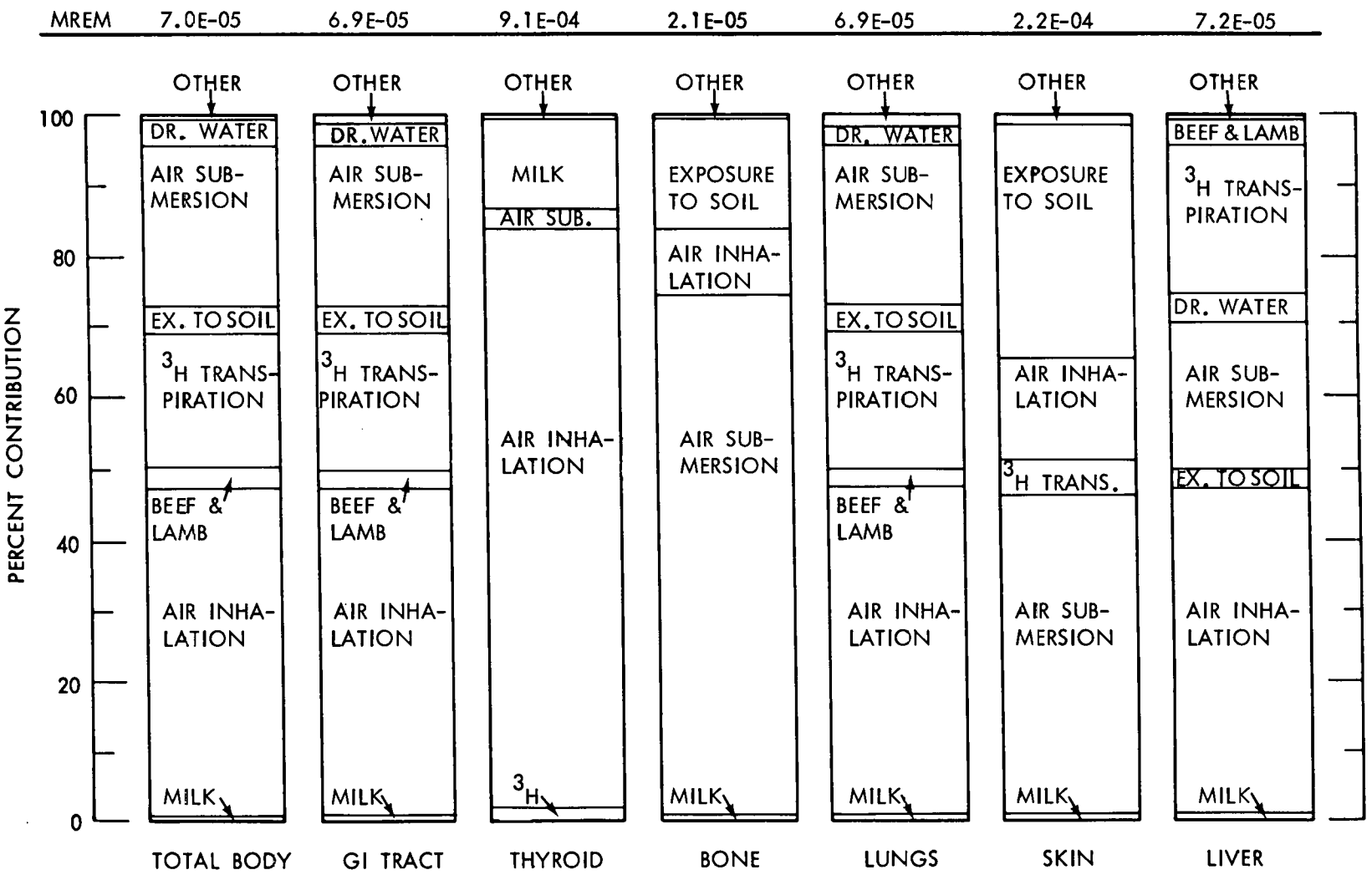

FIGURE J-9

Pathway Contribution to Infant Dose (Nashville, TN)

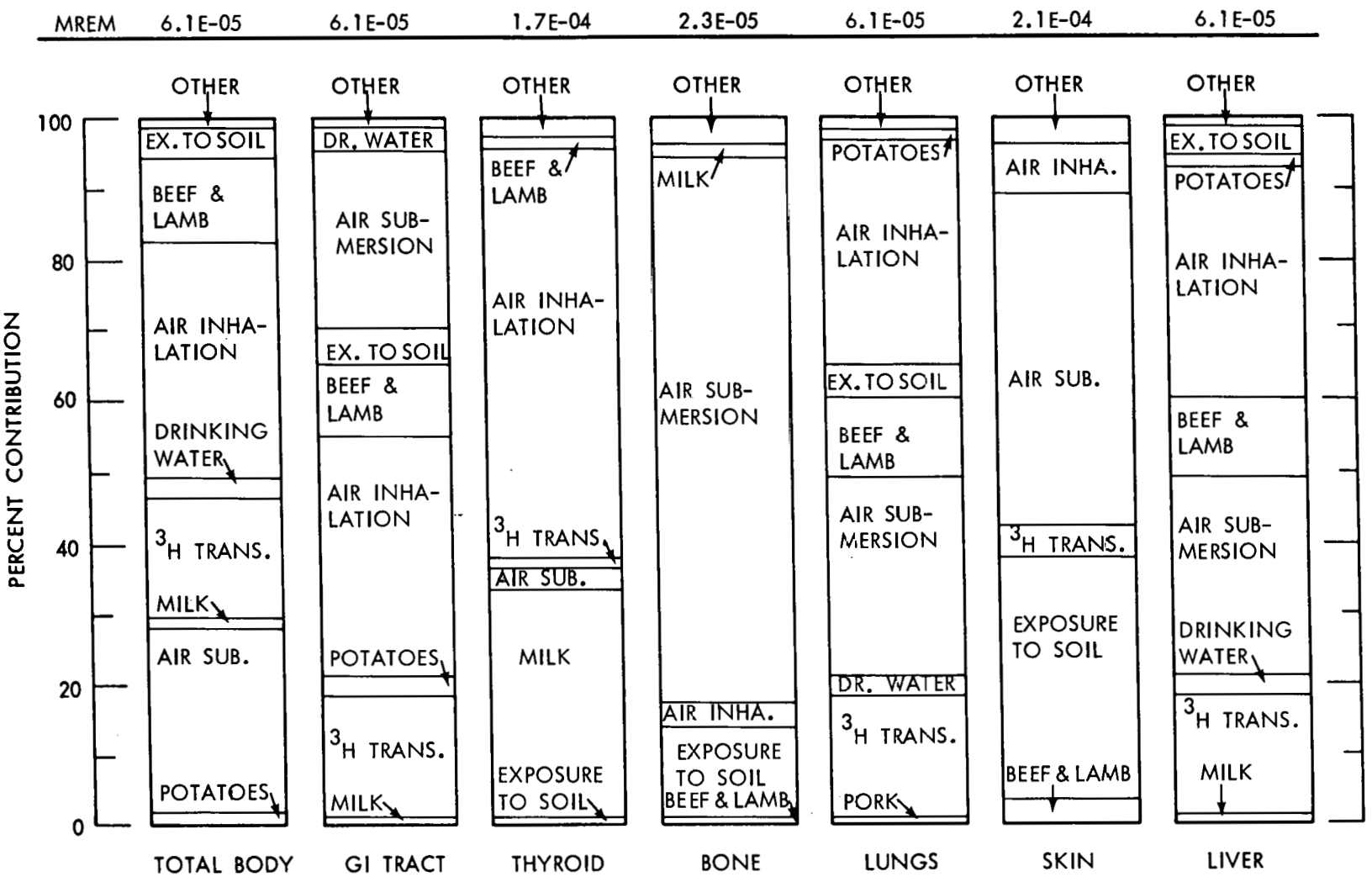

FIGURE J-10

Pathway Contribution to Child Dose (Nashville, TN)

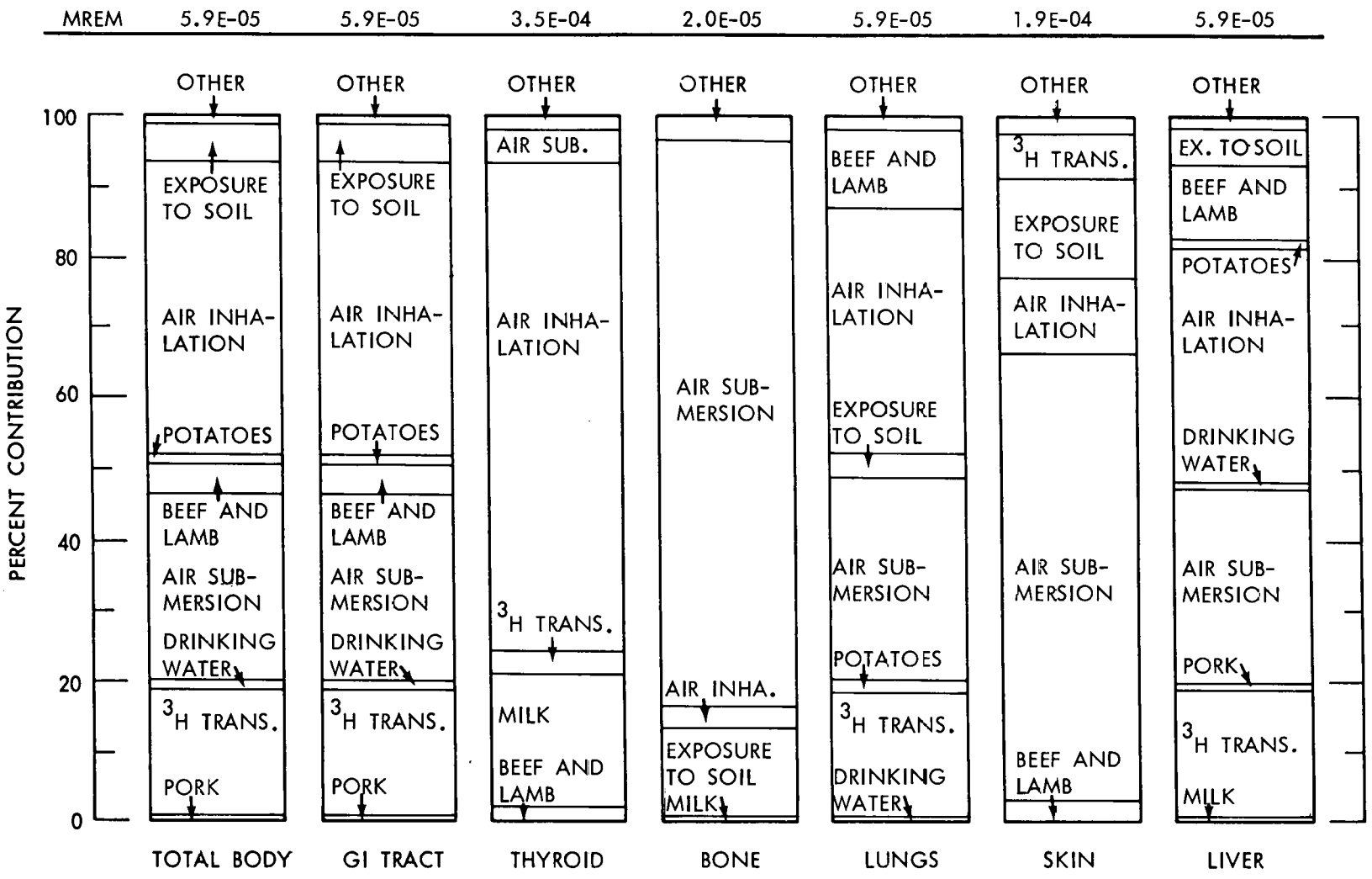

FIGURE J-11

Pathway Contribution to Teen Dose (Nashville, TN)

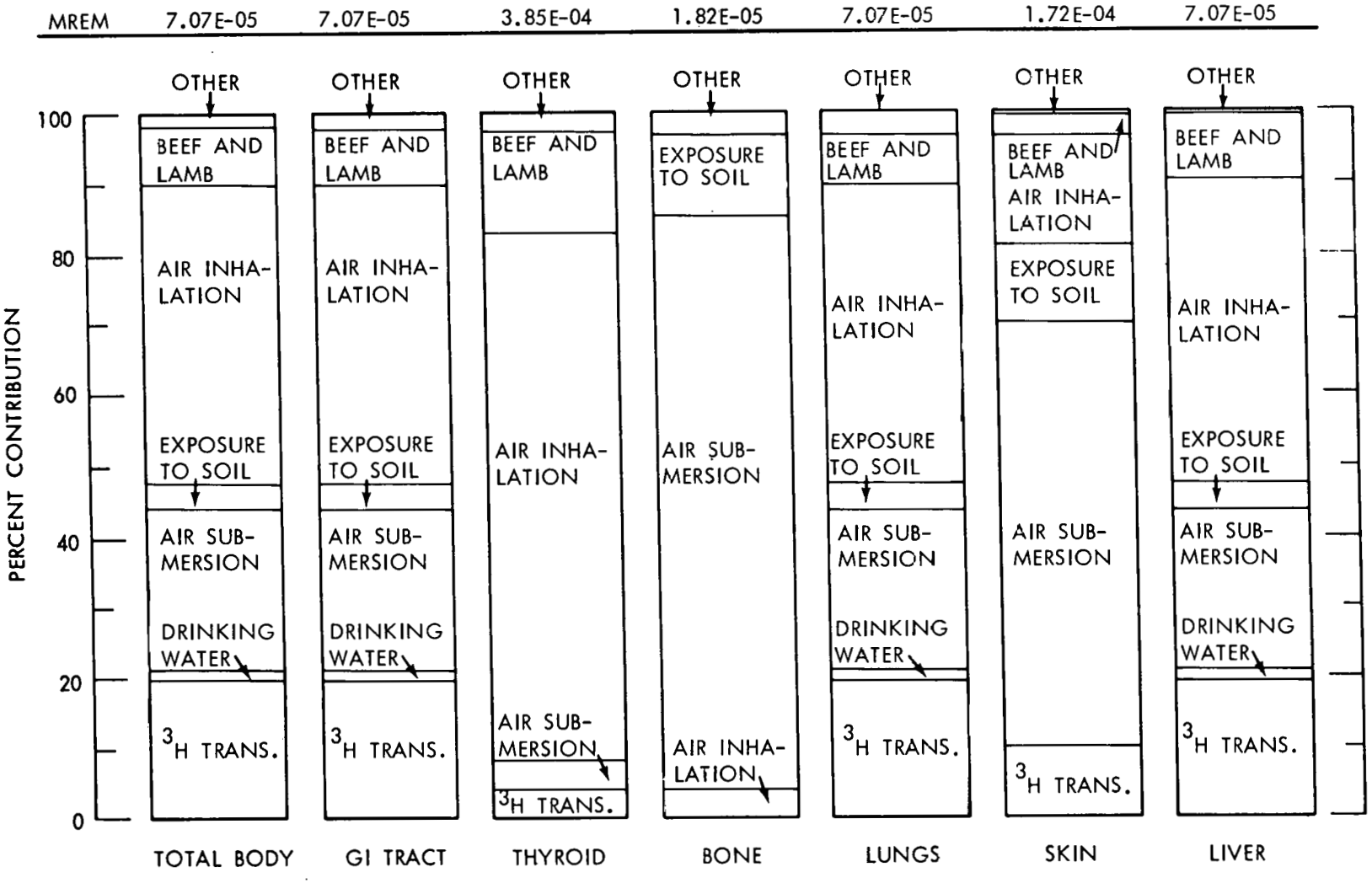

FIGURE J-12

Pathway Contribution to Adult Dose (Nashville, TN)

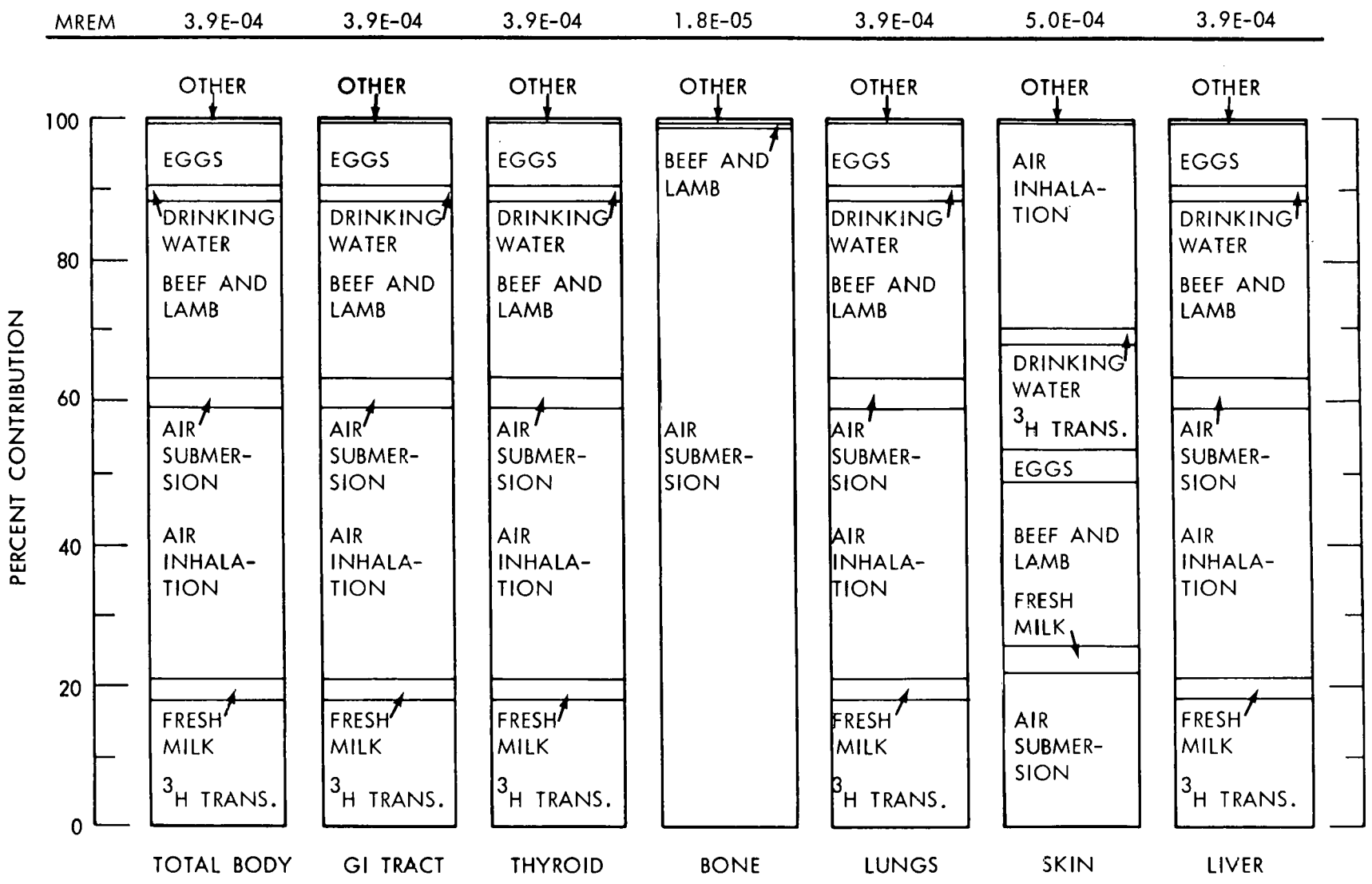

FIGURE J-13

Pathway Contribution to Infant Dose (Huntsville, AL)

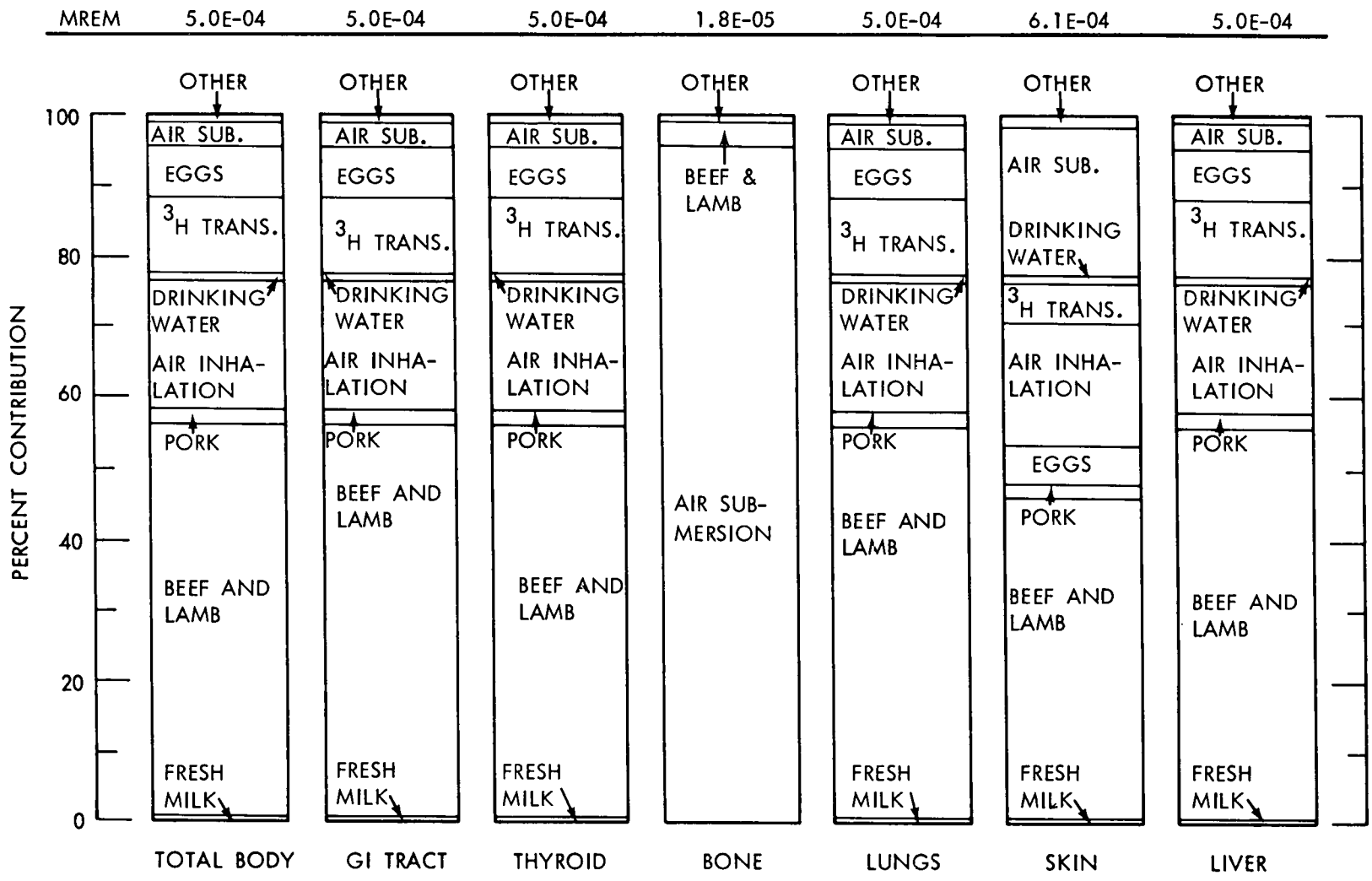

FIGURE J-14

Pathway Contribution to Child Dose (Huntsville, AL)

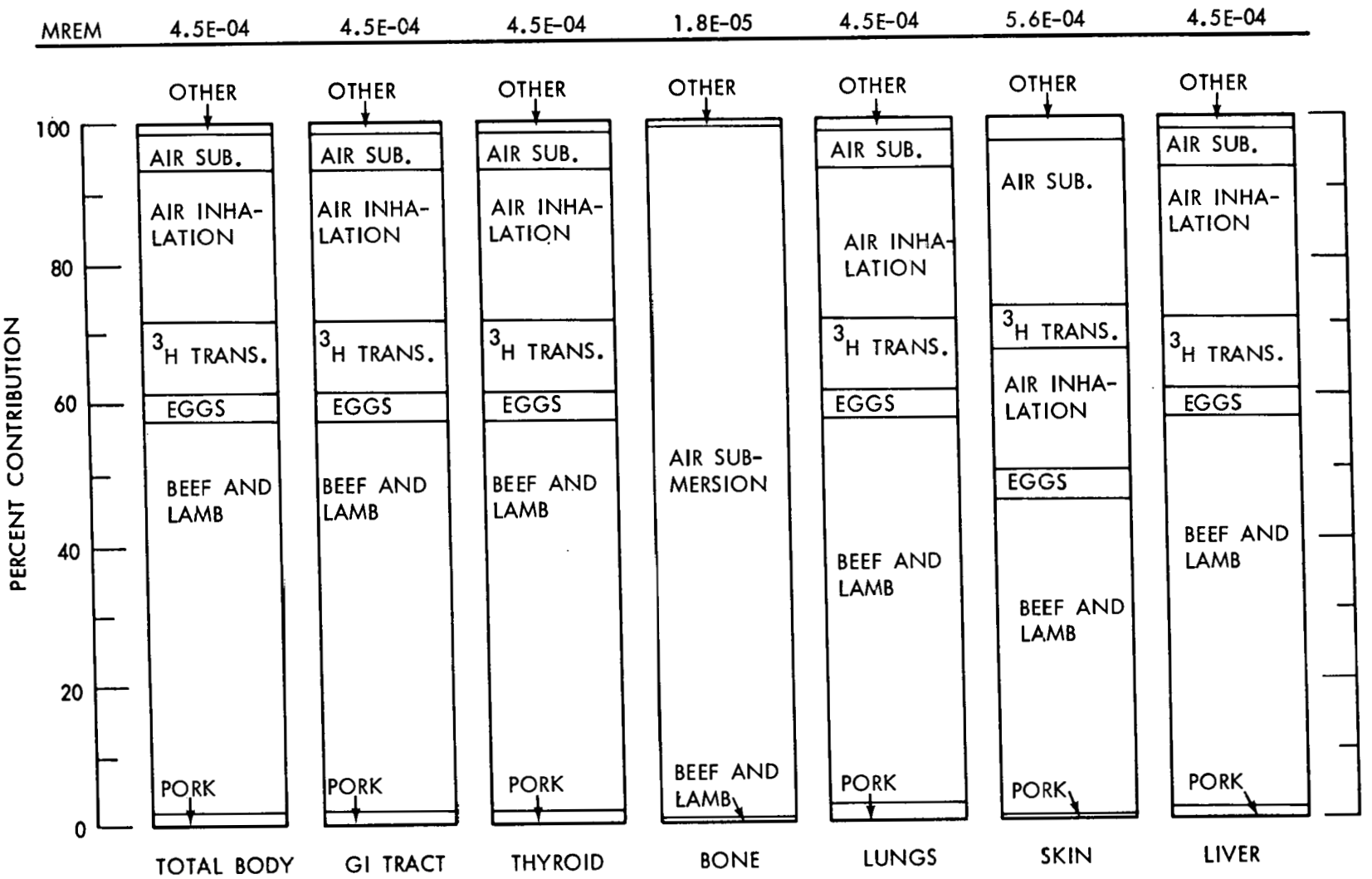

FIGURE J-15

Pathway Contribution to Teen Dose (Huntsville, AL)

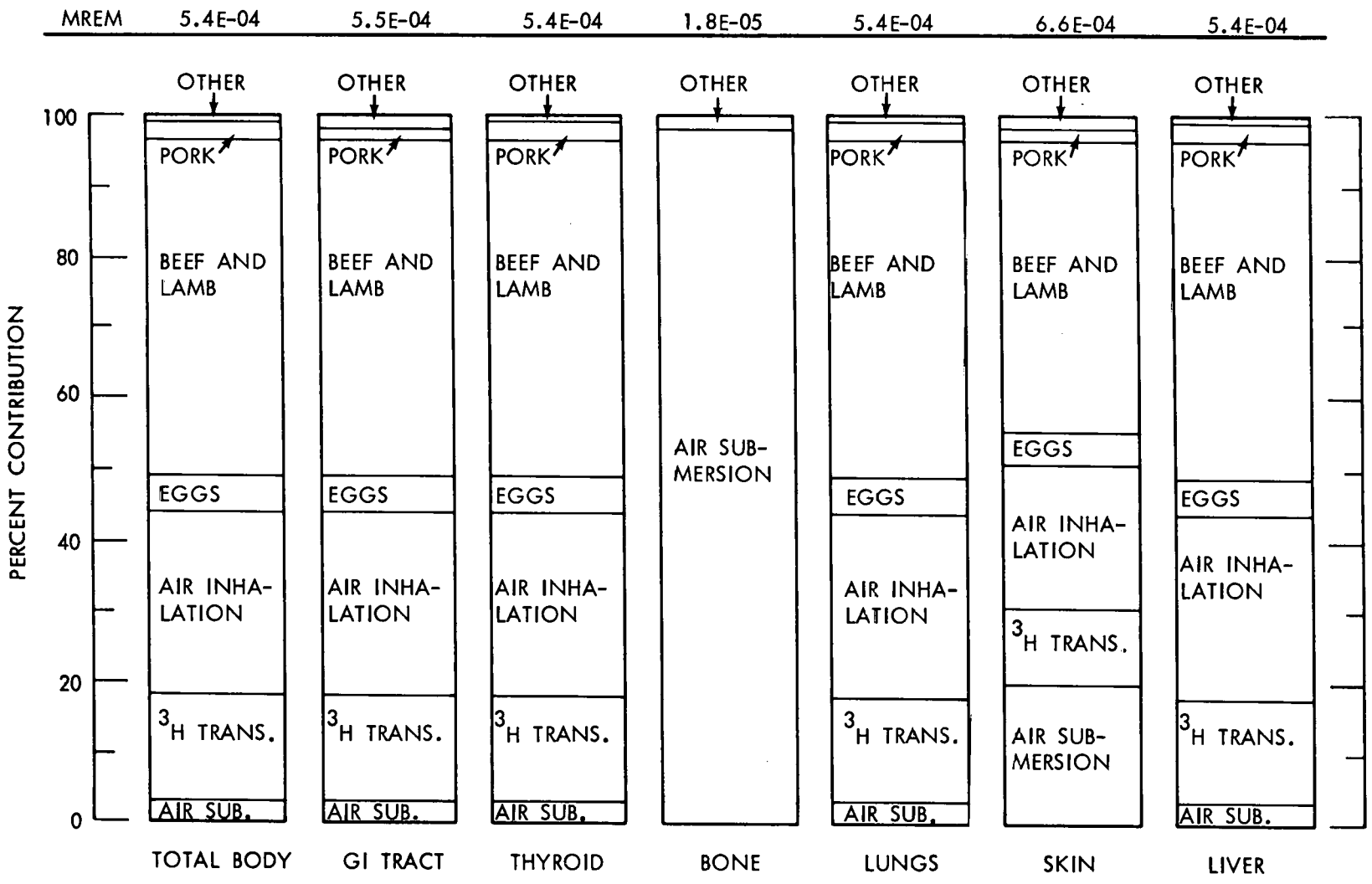

FIGURE J-16

Pathway Contribution to Adult Dose (Huntsville, AL)

APPENDIX K

GLOSSARY OF TERMS

APPENDIX K

GLOSSARY OF TERMS

Absorbed Dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad equals 100 ergs per gram.

Absorption: (1) The process by which radiation imparts some or all of its energy to any material through which it passes. (2) The entrapment of gases or liquids in the internal structure of solid bodies with which they are in contact. For example, a sponge absorbs water.

Absorption Coefficient: Fractional decrease in the intensity of a beam of X or gamma radiation per unit thickness (linear absorption coefficient), per unit mass (mass absorption coefficient) of absorber, due to deposition of energy in the absorber.

Activation Product: An unstable isotope of an element formed in a nuclear reactor by processes other than fission.

Activity: The number of nuclear transformations occurring in a given quality of material per unit time. (See Curie).

Adsorption: The adhesion in an extremely thin layer of gases, dissolved substances, or liquids to the surfaces of solid bodies which they contact.

Air Envelope: Radioactivity released in the zone is allowed to travel into the study area via air transport to minimize isolation effects on the regional dose calculation.

Atmosphere Stability: A characterization scheme that describes the turbulent nature of the atmosphere (in this report specifically the vertical component of turbulence) within certain preset criteria.

Aquifer: A geological formation containing groundwater.

Average Adult (teen, child): A person whose dietary habits represent the average of his age group at his centroid of residence and whose recreation habits similarly represent the average of the habits for his age group at his centroid.

Background: Radioactivity found in the environment which emanates from sources other than nuclear reactors or fuel cycle facilities.

Base-Loaded Plant: A power plant operated at a high plant factor for much of its life to meet the relatively constant portion of the energy demand.

Beta Particle: Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.

Boating: Recreational activity that includes water skiing, sailing, canoeing, boating, and fishing from a boat or barge.

Body Burden: A particular amount of radioactivity retained within the body of an individual.

BWRA: An advanced BWR (as used in this study) featuring increased linear heat rate.

Centroid: A designation used in this evaluation whereby a county or group of counties is represented by a single point. The entire population of the area and its characteristics are represented by typical individuals and their activities referenced to that point.

Close-In Dose: The radiation dose received by people living within a few miles of a nuclear facility.

Cold Trapping System: The coolant cleanup system assumed used in reducing radionuclide concentrations in LMFBR systems. Such a system removes impurities from the sodium coolant by reducing the temperature of a small stream of coolant. Impurities less soluble at the lower temperature are thus removed.

Curie: A unit of radioactivity. One curie equals 3.700×10^{10} nuclear transformations per second. (Abbreviated Ci.) Several fractions of the curie are in common usage.

- Microcurie: One-millionth of a curie (3.7×10^{4} disintegrations per sec.) (Abbreviated μCi.)
- Millicurie: One-thousandth of a curie (3.7×10^{7} disintegrations per sec.) (Abbreviated mCi.)
- Picocurie: One-millionth of a microcurie (3.7×10^{-2} disintegrations per second or 2.22 disintegrations per minute). (Abbreviated pCi; replaces the term μμC.)

Daughter: Synonym for decay product.

Decay, Radioactive: Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

Decay Constant: (See Disintegration Constant.)

Decay Product: A nuclide resulting from the radioactive disintegration of a radionuclide, formed either directly or as the result of successive transformations in a radioactive series. A decay product may be either radioactive or stable.

Decontamination Factor: The ratio of the amount of undesired radioactive material initially present to the amount remaining after a suitable processing step has been completed. Decontamination factors may refer to the reduction of some particular species of radionuclide, or to the gross measurable radioactivity.

Disintegration Constant: The number which characterizes the rate of decay of a radionuclide (λ in the equation $N = N_0 e^{-\lambda}$, where N_0 is the initial number of atoms present, and N is the number of atoms present after some time, t).

Disintegration, Nuclear: A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

Distribution Coefficient: For any dissolved substance, the ratio of concentrations adsorbed on soils or suspended sediments in contact with water to the concentration of the substance in solution.

Dose: A general term denoting the quantity of radiation or energy absorbed. For special purposes it may be appropriately qualified. In this report, it is generally used synonomously with Dose Equivalent.

Dose Commitment: The dose received during a specified time (e.g., 50 years) following intake of a quantity of a radionuclide, caused by retention of that radionuclide in the body. As used in this report, dose commitment is calculated for radionuclide intake in the year 2000 only, and does not include previous or subsequent intake of radionuclides.

Dose Commitment Factor: A number which can be used to calculate the radiation dose received over a long period of time from an intake of a radionuclide. In this report, the dose commitment factor has units of mrem/50 yrs per pCi/yr intake and the dose commitment calculated is the dose

received in the ensuing 50 years from the first year's intake. No external dose commitment factors have been used in this report.

Dose Equivalent: A quantity used in radiation protection. It expresses all radiations on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose in rads and certain modifying factors denoting the biological effectiveness for the particular type and energy of radiation involved. (The unit of dose equivalent is the rem.)

Dose Factor: A number which can be used to calculate radiation dose to a person (or organ) from the intake of radionuclide (internal dose factor) or from exposure to given concentration of radionuclides in environmental media (external dose factor). In this report, internal dose factors have units of mrem/yr per unit intake of radionuclide and the dose calculated represents the dose in the first year from the first year intake. External dose factors have units of mrem/unit concentration of a radionuclide in air (pCi/m^3), water (pCi/liter), or on the ground (pCi/m^2). The value calculated represents dose rates received during time of exposure.

Dose Rate: Absorbed dose delivered per unit time.

Dry Deposition: The depletion of an airborne contaminant plume by interaction process at the ground-air interface (i.e., gravitational settling, impaction, chemical interaction, etc., with surface-based material).

Effective Energy: In this report, a term used to denote the actual energy deposited at the point of interest per disintegration of a nuclide. It is found by summing the products obtained by multiplying the average energy of the beta particle (or gamma photon) emitted, the fraction of disintegrations which give rise to that particular beta particle (or photon), and the fraction of the initially released energy which is absorbed at the place of interest.

Effective Radius: The radius of a hypothetical spherical organ, used for calculational simplicity, in which the absorbed fraction of the gamma rays emitted from a point source in the center is the same as the absorbed fraction of the gamma rays emitted by the same quantity of a radionuclide uniformly distributed throughout the volume of the real organ. For such a sphere, the absorbed fraction is equal to $(1-e^{-\mu x})$ where x is the effective radius in cm, and μ is the Absorption Coefficient in cm^{-1}.

Equilibrium, Radioactive: In a radioactive series, the state which prevails when the ratio between the amounts of successive members of the series remains constant.

Exposure: A measure of the ionization produced in air by X or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen. In this report, exposure has been used synonomously with dose and dose equivalent, especially when received from external sources.

Exposure Pathway: The means by which a person becomes exposed to, and receives a radiation dose from, radionuclides released to the environment. Generally, the pathway followed by the radionuclide between the time of release and the time of exposure.

Exposure Rate: Exposure delivered per unit time.

External Dose: A radiation dose received by a person (or organ) which is delivered by radiation originating outside of the person.

Fabrication Plant: A plant devoted to the manufacture of fuel assemblies for nuclear reactors.

Fishing: Recreational activity that includes, in this study, fishing from the bank only.

Fission, Nuclear: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

Fission Product: An unstable isotope formed during the fissioning process.

Fission Yield: The percentage of fissions leading to a particular nuclide.

Food Deficit: Excess of food consumption over production for a given food type (within a centroid).

Food Surplus: Excess of food production over consumption for a given food type (within a centroid).

Fuel Burnup: A measure of the degree to which a nuclear fuel is consumed before replacement with new fuel, commonly expressed in megawatt days per metric ton of fuel.

Gamma Ray: Short wave length electromagnetic radiation of nuclear origin (range of energy from 10 KeV to 9 MeV) emitted from the nucleus.

Generating Plant Mix: The mix of nuclear and fossil plants which produce electric power for the study area.

Gigawatt-Electrical (GW_e): One billion watts of electrical energy (often used as a unit of electric generating capacity).

Groundwater: Water residing below the surface of the land in formations saturated with water. The "water table" is the upper surface of groundwater.

Half-Life, Biological: The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination. Approximately the same for both stable and radioactive isotopes of a particular element.

Half-Life, Effective: Time required for the radioactive element in the body to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$T_{eff} = \frac{T_B \times T_R}{T_B + T_R}$$

T_{eff} = Effective half-life
T_B = Biological half-life
T_R = Radiological half-life

Half-Life, Radioactive: Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

HTGR: A helium cooled reactor system, operating on the thorium - ^{234}U cycle, assumed to be in operation in the TVR scenario.

Induced Radioactivity: Radioactivity produced in a substance after bombardment with neutrons or other particles.

Integrated-Dose: The summation of all the products of each particular dose level times the number of people exposed at each particular dose level.

Internal Dose: A dose received by a person (or organ) from radiation originating from material contained within the person.

Ion: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

Ion Exchange: A chemical process involving the reversible interchange of ions between a solution and a particular solid material such as an ion exchange resin consisting of a matrix of insoluble materials interspersed with fixed ions of the same charge but of different species.

Ionization: The process by which a neutral atom or molecule acquires a positive or negative charge.

(LWR) Light Water Reactor: A general designation applied to thermal reactors using normal water as a coolant and moderator, and including both pressurized (PWR) and boiling (BWR) water reactors.

Linear Heat Rate: The quantity of heat produced in unit length of reactor fuel rod.

Linear Programming: A mathematical technique that finds the solution to a set of simultaneous linear equations which results in the maximum (or minimum) value of a particular linear function which is designated as the objective function.

LMFBR (Liquid Metal Fast Breeder Reactor): A nuclear reactor type, using liquid metal coolant (usually sodium) designed to operate with an unmoderated ("fast") neutron spectrum and to "breed" more nuclear fuel materials than it consumes.

Living Pattern: Observable features that characterize an individual, i.e., where he lives, water he drinks, food he eats, air he breathes and his recreational habits.

Load-Following Plant: A power plant whose output is varied to enable a power system to meet changes in demand.

Maximum Adult (teen, child): A person whose dietary and recreation habits tend to maximize the radiation dose which he (or she) receives. In this report, the maximum individual is assumed to reside at the same location within the centroid as does the average person. For this reason, doses higher than those calculated for the maximum person can be postulated, e.g., the air submersion dose from full-time residence close to the site boundary of a nuclear facility.

Man-Rem Dose: A number expressing the total integrated total-body dose received by a large population. It is obtained by multiplying the average dose received by a given subgroup of the population by the number of persons in that subgroup and then summing over all subgroups (see Integrated Dose).

Megawatt-Electrical (MWe): One million watts of electrical energy (often used as an electric generating station capacity unit).

Micron: Unit of length equal to 10^{-6} meters. (Symbol: μ or more recently μm).

Millirem (mrem): A submultiple of the Rem, equal to one one-thousandth of a Rem. (See Rem).

Mixing Depth: The depth of that portion of the atmosphere immediate contiguous with the earth in which vertical motion is not signficantly inhibited.

Monitoring: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region.

Noble gas: A member of the family of inert gases (helium and its chemical homologues), whose orbital electron configurations cause them to have little tendency to react chemically with other materials. For most purposes they can be assumed to be totally non-reactive or inert chemically, although they can be affected by essentially physical processes (e.g., adsorption).

Nuclide: A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons (Z), number of neutrons (N), and energy content; or, alternatively, by the atomic number (Z), mass number A = (N + Z), and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time. Thus, nuclear isomers are separate nuclides, whereas promptly decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

Organ: Group of tissues which together perform one or more definite functions in a living body.

Parent: A radionuclide which, upon disintegration, yields a specified nuclide - either directly or as a later member of a radioactive series. (See also Daughter).

Pathway: An environmental mechanism or series of mechanisms by which radionuclides are transported from a source to a receptor.

Plant Factor: The ratio of the actual energy output in the period of time considered to the energy output which would have occurred if the plant had been operating at its full rating throughout the total time in the period.

Poison: Material of high absorption cross section which absorbs neutrons unproductively and reduces the reactivity of a reactor.

PWR (Pressurized Water Reactor): A water-cooled reactor in which the coolant is pressurized to the extent that boiling in the reactor core is inhibited. Steam is generated in a secondary system, using a separate heat exchanger.

Rad: The unit of absorbed dose equal to 0.01 Joule/Kg (100 ergs per gram) in any medium (see Absorbed Dose). (Written: rad.)

Radionuclide: Any isotope (of one of the chemical elements) which undergoes radioactive decay.

Radwaste: Radioactive waste.

Radwaste System: A combination of process equipment components used in a nuclear facility to clean up the reactor coolant and other liquid and gas streams before reuse, storage, or discharge.

Receptor: An individual for whom a radiation dose is calculated.

Rem (roentgen equivalent man): A biological dose unit defined by the amount of energy absorbed from a radiation source times the relative biological effectiveness of the particular type of radiation.

Release Fraction: The fraction of a fission product generated in the fuel which is released from the fuel matrix. This fraction is released to the coolant in failed fuel rods.

Reprocessing Plant: Chemical processing plant which separates useful isotopes from waste products in spent nuclear fuel.

Roentgen (R): The special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air. (See Exposure.)

Rural Non-Farm Area: A centroid designation used for areas outside of urban localities but without a farm operator.

Rural Area: A centroid designation used for areas outside of urban localities with a farm operator.

Sensitivity Study: The part of the overall examination of a technical problem where evaluations are made of the effect of changes in particular parameters of interest on the behavior of the system being examined.

Source: A point of discharge for radioactive materials to the environment.

Source Map: A compilation of all regional sources of radioactive releases from nuclear facilities.

Spent Fuel: The depleted nuclear fuel which must be discharged from nuclear reactors periodically to be replaced by fresh fuel.

Surface Water: Water on the surface of the land.

Total Body: The whole body taken as an organ for purposes of computing a radiation dose.

Transpiration: The absorption of water vapor through the skin; thus, tritium transpiration is the absorption of tritated water vapor (HTO).

Transuranium Isotope: An isotope with an atomic number greater than that of uranium.

Turbulent Diffusion: The diffusion of an airborne contaminant by eddies in a turbulent flow.

Urban Area: Localities with at least 2500 inhabitants and in closely settled fringe areas surrounding cities of 50,000 or more inhabitants.

Voloxidizer: A system to oxidize and volatilize components of spent fuel prior to dissolution in a reprocessing plant to permit more effective trapping of the volatile effluents.

Wet Deposition: The depletion of an airborne contaminant plume by precipitation (rainfall, etc.).