Appendix A

CDC and NCI Responses to Key NAS Recommendations

The National Academy of Sciences Committee to Review the CDC-NCI Feasibility Study of the Health Consequences from Nuclear Weapon Test was asked by CDC to address the following specific questions:

1. Are the methods and sources of information used in the technical report to estimate radiation doses and health effects from fallout appropriate for this study?
2. Are the methods and results clearly presented in the main text of the technical report?
3. Are the findings presented in the report supported by the data and analyses provided?
4. Do the Options for Future Work presented in Chapter 6 represent an appropriate range of options for public health activities that could be pursued as a result of this study?

The Committee made the following comments and recommendations to CDC and NCI. The CDC/NCI responses to these recommendations are also provided.

Estimates of dose from Nevada Test Site and global fallout

Recommendation: The committee recommends that changes be made in the draft report to clarify the assumptions, methods, and uncertainties related to dose estimation. Tables should be used to lay out the sources of uncertainty in the dosimetry and in the estimation of risk. The basis of a "credibility interval" of a factor of 3 for dose estimates should be described in the text in a manner analogous to description of the credibility interval for the risk estimation (given some dose).

CDC/NCI Response:
The main assumptions and the methods related to dose estimation have been clarified in the body of the report. In addition, the Appendices D, E, F, and G where the methods are

explained in detail are referred to as many times as judged appropriate. However, it was considered that a systematic assessment of the uncertainties associated with the dose estimates was not within the scope of this feasibility report. It was subjectively estimated that the 90% credibility interval for dose extends from a factor of about 3 below the dose estimate to a factor of about 3 above the estimate. It is emphasized that this quantitative estimate of uncertainty was provided for illustration only. In fact, the uncertainties in the dose estimates vary according to the type of dose that is considered, the conditions of exposure, and the lifestyle and dietary habits of the population groups or individuals that are considered. A much more detailed dose estimation process would be needed in order to derive the uncertainties with a reasonable degree of reliability. It would be carried out if the decision is made to exercise Option 5.

Recommendation: CDC and NCI should consider performing a reanalysis of the ^{131}I exposures to the American public that would incorporate new dosimetry-related information from Chernobyl and elsewhere, the contribution of global fallout, a more comprehensive uncertainty analysis, and correction of acknowledged errors in the previous dosimetry. However, the committee does not recommend an expanded study of exposure to radionuclides other than ^{131}I inasmuch as the human doses were much lower than those of ^{131}I, they confer essentially non-detectable increases in individual risk, and the risks are of little public-health significance.

CDC/NCI Response: CDC and NCI acknowledge that the feasibility report incorporates data available through Fall 2001, and that should future research efforts be undertaken by either agency these should include the topics addressed in this recommendation. It should be noted that these analyses, particularly the estimation of the contribution of global fallout to the ^{131}I exposures of the American public and the preparation of a more comprehensive uncertainty analysis, will require a substantial effort and, although these updates might affect the estimated doses, they would not change the report's conclusions regarding the feasibility of a study.

Document location and retrieval

Recommendation: The committee recommends an effort to retrieve and archive additional relevant information about the nuclear-weapons testing program. That means collecting data preserved in various repositories that have not been cataloged and may be in danger of imminent destruction. CDC should also:

- Continue its search for documents not held by governmental agencies and take steps necessary to ensure their preservation.
- Enroll other government agencies, especially the Department of Defense, in the effort to identify, preserve, and publish information.
- Make copies of key documents, the data derived from them, and relevant computer codes or other calculation tools and make them all publicly available, including archiving and providing public access to all the databases and spreadsheets generated by the feasibility study and mentioned in it and its appendices, together with inputs and calculation tools used for other studies performed for NCI and CDC.

CDC/NCI Response: CDC has a long history of conducting similar projects, and will undertake this particular effort if resources are identified. NCI will continue to process unique and unpublished fallout data sets obtained by means of direct contact with fallout specialists.

Recommendation: The committee also recommends that CDC urge Congress to declare a government-wide moratorium on the destruction of documents that are potentially pertinent to measuring fallout in the United States and to mandate declassification of historical fallout-related records.

CDC/NCI Response: CDC will explore methods to communicate this information to Congress and other stakeholders.

Estimates of cancer and non-cancer risks

Recommendation: The committee recommends that more emphasis be placed on levels of individual risk and the associated uncertainty and less on population risk from collective dose. Although collective dose and population risk may have some public health utility if the doses are significant in the context of doses and risks from other sources, they fail to show the size of the risk that individuals are likely to experience, which is the key consideration for concerned citizens and for most public-health implications. It is also important that the executive summary and text compare putative lifetime risks posed by fallout with risks posed by natural background irradiation and with natural lifetime risks. Such comparisons will help to provide a perspective for the general public to better understand the risks related to fallout.

CDC/NCI Response:
Although qualitative statements are made in the report on the levels of individual risk and of their associated uncertainties, it was considered that quantitative estimates were beyond the scope of this feasibility report.

With regard to the comparison of fallout and natural background radiation, a section was added in Chapter 3 to describe the components of natural background radiation exposure; this section includes a presentation of the geographic variation of natural background exposures in the continental U.S. in the form of maps, which allow a comparison with the doses from fallout to be made. The corresponding risks are considered in section 4.

Recommendation: The potential that the dose-response association might have a substantial upward quadratic component or a threshold should be considered in modeling the risk of leukemia posed by fallout radiation.

CDC/NCI Response:
The potential that the dose-response association might have a substantial upward quadratic component or a threshold was mentioned in the discussion of the risk estimates. The implications of dose-response curves other than linear, however, were not assessed quantitatively in the absence of refined dose estimates.

Recommendation: There is no evidence that radiation doses of the magnitude sustained from NTS or global fallout cause any of the major non-cancer diseases (cardiovascular, respiratory, digestive or genitourinary). A conclusion to this effect would therefore be appropriate.

CDC/NCI Response:
It was clearly indicated in the report that, other than thyroid cancer and leukemia, there is no epidemiological evidence that fallout caused any other major disease.

Communication with the public about exposure and cancer risk

Recommendation: CDC/NCI should develop a detailed public summary and a communication plan for its distribution. The public summary should provide information that can be readily understood by the lay public, including comparison of background radiation with the radiation doses discussed in the report of the feasibility study and a description of the important uncertainties (related to dose and risk) that apply to the feasibility study.

CDC/NCI Response: CDC has developed a public summary, which will be posted on its website (http://www.cdc.gov/nceh/radiation/fallout/default.htm) and linked with NCI's ^{131}I/Nevada Test Site website materials. The public summary discusses comparison with background radiation as well as the importance of uncertainties in dose and risk estimates that apply to the feasibility study.

Recommendation: The agencies should phase information from the feasibility study into the ^{131}I/Nevada Test Site Communication Plan in a timely fashion to give interested American citizens a more complete picture of their exposure to NTS and global fallout with appropriate explanations of relative health risks.

CDC/NCI Response: A public summary providing information from the feasibility study will be linked with the ^{131}I/Nevada Test Site Communication Plan on the NCI website. If additional information becomes available through further research, CDC will ensure that it is also added into these linked websites in a timely fashion.

Recommendation: If Option 5 is adopted and important new scientific work develops, CDC/NCI should produce a timely major educational effort that builds on the efforts of the communication plan for the ^{131}I/Nevada Test Site study.

CDC/NCI Response: If additional information were found that would have significant impact on the data and/or conclusions in this feasibility report, CDC and NCI could produce appropriate materials building on the existing communication efforts related to the ^{131}I/Nevada Test Site.

Recommendation: CDC and NCI should make studies on radiation exposure of US citizens transparent and accessible to interested individuals. The committee recommends that interested citizens take part in the study process and, with scientific and social science experts, serve as members of advisory boards for such studies.

CDC/NCI Response: Communication of study results to interested individuals and the general public are important aspects of CDC and NCI policy, and will continue to be emphasized in the areas of radiation exposure and associated health effects, as well as others. We will also continue to provide opportunities for interested members of the public to participate in the study process and to serve on study advisory boards.

Recommendation: CDC and NCI should hold a follow-up conference, similar to the one sponsored by NCI on risk communication (January 2000), as part of the continuing CDC effort to develop effective guidelines for communicating radiation risk to the American public.

CDC/NCI Response: CDC has held several meetings and roundtables in which radiation risk communications has been a key topic. We will continue to seek opportunities to add to the body of knowledge about this important topic.

Appendix B

Summary of the National Cancer Institute Report

Contents: *This appendix provides a summary of the NCI report on* ^{131}*I doses and risks to the American people as a result of fallout from nuclear weapons testing at the Nevada Test Site. It also includes a brief summary of the review of that report by the Institute of Medicine.*

B.1 The National Cancer Institute Report

In response to a Congressional mandate, the National Cancer Institute published in 1997 a report (NCI 1997) which provides estimates of human exposure to and thyroid radiation doses from ^{131}I resulting from individual nuclear tests conducted at the Nevada Test Site (NTS). The report is available in printed form and on the internet at http://rex.nci.nih.gov/massmedia/Fallout/index.html. The legislation also called for the assessment of the risk of thyroid cancer associated with radiation thyroid doses due to ^{131}I. Other studies address this requirement; they are summarized in this chapter for the sake of completeness. Most of what follows is based on a recently published summary of the NCI report (Bouville et al. 1999).

Low-yield nuclear tests were conducted at the NTS between 1951 and 1992. From January 1951 through October 1958, 119 tests were conducted, most of them above ground. Nuclear testing was discontinued between November 1958 and September 1961, but from September 1961 until September 1992 more than 800 tests were conducted. With very few exceptions, these tests were detonated underground, under conditions that were designed for containment of radioactive debris. Only 38 of these underground tests resulted in the detection off-site of radioactive materials; the last occurrence of substantial radioactive contamination of the environment took place in December 1970. On 2 October 1992, the United States entered into another moratorium on nuclear weapons testing (DOE 1994).

Ninety of the nuclear tests released almost 99% of the total ^{131}I entering the atmosphere from all bomb tests conducted at the NTS. These ninety tests released about 6 x 10^{18} Bq of ^{131}I, mainly in the years 1952, 1953, and 1957. Some radioiodine was deposited everywhere in the United States; highest deposition densities were immediately downwind of the NTS and lowest deposition densities were on the West Coast. In the eastern part of the country, most of the deposited ^{131}I was associated with rain, while in the more arid west, dry deposition prevailed. Because ^{131}I decays with an 8-day half-life, exposure from the released ^{131}I occurred primarily during the first month following a test.

B.2 Estimating Exposures and Thyroid Doses

For most people, the major exposure route was the ingestion of cows' milk contaminated as the result of ^{131}I deposited on pasture grasses; other exposure routes such as the inhalation of contaminated air and the ingestion of contaminated leafy vegetables, goats' milk, cottage cheese, and eggs also were considered. Historical measurements of the amounts of radioactivity deposited and of daily rainfall were used as the basis for the dose calculations whenever feasible. Nationwide deposition data were available for all but nine of the ninety tests that were studied in detail; for those nine tests, a mathematical model was used to estimate the atmospheric transport and ground deposition of the ^{131}I.

Data on the transfer to milk of ^{131}I deposited on pasture and on regional pasture consumption by cows were used to estimate concentrations of ^{131}I in milk fresh from cows. These concentrations, together with milk distribution patterns in the 1950s, were used to estimate local concentrations of ^{131}I in the cows' milk available for human consumption throughout the country. The categories of fresh cows' milk that were considered include the milk obtained directly from dairy farms, milk purchased in stores, either provided from local or from distant farms, and milk obtained from family cows. Finally, cows' milk consumption rates, based upon diet surveys, were used to estimate the amounts of ^{131}I ingested by humans by age group and by gender. The transfer of ^{131}I to people through other exposure routes (ingestion of leafy vegetables, goats' milk, mother's milk, eggs, and cottage cheese contaminated by ^{131}I, as well as inhalation of air contaminated by ^{131}I) was similarly analyzed.

Thyroid doses from ^{131}I were estimated for 13 age groups, including the fetus, and adults of both genders, in each county of the contiguous United States and for all periods of exposure. The overall average thyroid dose to the approximately 160 million people in the country during the 1950s was 20 mGy. The uncertainty in this per capita dose is estimated to be a factor of 2; that is, the overall average thyroid dose may have been as small as 10 mGy or as large as 40 mGy, but 20 mGy is the best estimate. The study also demonstrated that there were large variations in thyroid dose from one individual to another. The primary factors contributing to this variation are county of residence, age at the time of exposure, and milk consumption patterns.

B.2.1 Geography

The geographical location where people lived is very important. In counties east of the NTS in Nevada and Utah, and in some counties in Idaho, Montana, New Mexico, Colorado, and Missouri, the estimated per capita thyroid doses from all tests were highest, in the range of 50 to 160 mGy. In many counties on or near the West Coast, the border with Mexico, and parts of Texas and Florida, the estimated per capita thyroid doses were lowest, in the range of 0.01 to 5 mGy. Intermediate values were obtained in the remainder of the country.

B.2.2 Age

The thyroid doses to individuals at a particular location were strongly dependent upon age at the time of exposure. Thyroid dose estimates resulting from milk consumption were uniformly higher for young children than for adults, assuming that individuals consumed milk at average rates for each age group from the same source. At any particular time, the average thyroid doses resulting from milk consumption for children between 3 months and 5 years of age exceeded the thyroid doses received by adults by at least a factor of ten.

The date of birth and geographic residence of individuals also are strong determinants of the cumulative dose received from all tests (from 1951 to 1970). The variation in cumulative thyroid doses to individuals born at different times, each of whom lived in a single county and consumed cows' milk from local sources at average rates, is illustrated in Table A.1. This can be considered a dose table for six typical families located in the identified cities throughout the testing period. The factors affecting the doses to parents are approximately independent of birth dates up to 1930; doses to adult men and women born prior to this time were nearly the same. Thyroid doses to children born about six months prior to the three major test series (1952, 1953, and 1957) were substantially higher than the adult doses, as shown in the three central columns. The last column shows doses to children born in 1958, which is the year when the last test series in the atmosphere took place at the NTS. Cumulative thyroid doses to most of the children born in later years are estimated to be less than 1 mGy.

Table B.1 Example calculations showing the variation of the thyroid dose according to date of birth and place of residence of the individual considered.

Place of residence	Thyroid dose estimates (mGy)					
	Father, born 9/15/27	Mother, born 10/10/29	Child, born 10/1/51	Child, born 9/15/52	Child, born 11/28/56	Child, born 9/5/58
Los Angeles, CA	0.3	0.4	3	0.8	0.2	0
Salt Lake City, UT	17	18	130	96	56	1
Denver, CO	15	16	120	100	65	2
Chicago, IL	6	7	76	62	20	0.3
Tampa, FL	3	4	18	19	22	0.03
New York, NY	8	9	73	49	21	0.1

B.2.3 Diet, particularly milk consumption

For individuals within a particular age range, milk consumption can vary substantially. For example, surveys have shown that 10-20% of children between ages 1 and 5 do not consume cows' milk. Their doses were only about one-tenth of those received by children who consumed milk at average rates for their age. Conversely, the milk consumption of 5 to 10% of individuals in the same age range was 2-3 times greater than the average and their thyroid doses were therefore proportionally larger. The type of milk consumed also is important. It is estimated that about 20,000 individuals in the United States population consumed goats’ milk during the time of the bomb tests. Thyroid doses to those individuals could have been 10 to 20 times greater than those to other residents of the same county who were the same age and gender and drank the same amount of cows' milk. On the other hand, thyroid doses received during infancy (0 to 1 y) were much smaller for the infants who consumed mother’s milk or formula than for the infants who consumed cows’ milk.

B.2.4 Estimating thyroid doses for specific individuals

The foregoing examples illustrate that the thyroid dose received by any particular individual depends on his/her source of milk and dietary habits and thus may differ considerably from the group dose estimates. Furthermore, the person's total thyroid dose from all tests depends upon place of residence and age at the time of each test. Because of the very large number of variations in residence location, age, and dietary habits, it is not feasible to provide estimates of cumulative doses for specific individuals. However, detailed instructions and examples are provided in the report to permit individuals to estimate their cumulative dose using personal residence and dietary data. In addition, the information available on the internet enables the reader to enter a date and county of birth, as well as gender, in order to obtain estimates of thyroid dose applicable to the individuals with those characteristics for each test series and for all tests for a range of milk consumption rates and for various types of milk (including mother’s milk, cow’s milk, and goat's milk). In these calculations, it is assumed that the individuals did not change their dietary habits or their county of residence during the time period when atmospheric weapons testing took place at the Nevada Test Site.

B.2.5 Uncertainties and model validation

There are large uncertainties in the estimated thyroid doses given in the NCI report because it is impossible to know all the information needed to determine exact doses. These uncertainties were assessed in two ways. First, calculated concentrations of ^{131}I were compared with historical measurements of ^{131}I in people and the environment. Second, the uncertainties in the historical measurements and in each of the factors used to estimate the transfer of ^{131}I to people's thyroids through the various exposure routes yielded an estimate of the total uncertainty. The uncertainty in the thyroid dose estimated for an individual is greater than the uncertainty in the overall average thyroid to the entire United States population. Under the best circumstances, the uncertainty of an individual's thyroid dose from NTS ^{131}I is about a factor of 3; e.g., if the thyroid dose estimate for an individual is 30 mGy, it will likely lie between 10 and 90 mGy, compared with a factor of 2 for the entire United States population.

B.3 Estimating Risks

Thyroid cancer risk associated with external irradiation by gamma rays and x rays is well quantified. However, information is limited regarding the risk associated with thyroid exposure from ingested or inhaled ^{131}I and precise dose-response estimates are not available. To estimate the thyroid cancer risk from the ^{131}I exposure, it was necessary to extrapolate from what is known about external radiation, taking into account an appropriate value for the relative biological effectiveness (RBE) of ^{131}I compared to gamma rays or x rays. RBE values ranging from 0.1 to 1.0 have been suggested based on experimental data (Lee et al. 1982; NCRP 1985; Walinder 1972) or a comparison of animal and human data (Laird 1987).

The risk of induction of thyroid cancer following external irradiation by gamma rays or x-rays is derived from studies of the Hiroshima-Nagasaki survivors and of several medically exposed populations. Findings are summarized in a pooled analysis of seven studies (Ron et al. 1995). The evidence for a radiation-related risk is strong for childhood exposure, and weak or non-existent for adult exposure. The pooled analysis also demonstrated a linear dose-response relationship with no significant difference in risk by gender. The excess relative risk (ERR) decreased sharply with increasing age at exposure. The age-specific excess relative risks are shown in Table A.2. Ron et al. (1995) estimated an ERR of 7.7 per Gy (95% confidence interval = 2.1-28.7), for childhood exposure at ages younger than 15. The radiation-associated risk persisted for at least four decades and although there was evidence of variation in radiation-related relative risk over time following exposure, there was no evidence of a trend.

Table B.2 Excess relative risk by age at exposure (Ron et al. 1995).

Age at exposure, y	ERR at 1 Gy
0 – 4	9.0
5 – 9	5.4
10 - 14	1.8

Land (1997) estimated the lifetime excess thyroid cancer cases based on the following assumptions: (a) there is a significant excess risk following exposure before age 20 years, but no risk after age 20 years; (b) there is a linear dose response with age-specific risk coefficients estimated from modifying factors provided in Ron et al (1995); (c) ERR remains constant over lifetime; (d) ERR is the same for males and females; (e) RBE could range from 0.1 to 1.0; and (f) the estimated lifetime risk of developing thyroid cancer is 0.25% for males and 0.64% for females (SEER 1973-92). Land's estimates and 95% uncertainty intervals are given in Table A.3 for various assumed values of RBE. Assuming that the RBE is 0.66, an estimate of 49,000 lifetime excess cases is predicted, with a 95% uncertainty interval ranging from 11,300 to 212,000.

Table B.3 Estimated numbers of lifetime excess thyroid cancer cases for a range of RBE values (Land 1997).

Assumed RBE	Estimated number of lifetime excess cancer cases	95% uncertainty interval
1.0	75,000	17,000 – 324,000
0.66	49,000	11,300 – 212,000
0.3	22,000	5,100 – 95,000
0.1	7,500	1,700 – 32,000

Hoffman (1997) used a somewhat different method to predict lifetime risk. A probabilistic distribution of RBE values was selected, with discrete values of 1.0, 0.66, 0.5, 0.33, and 0.2 assigned with probabilities of 35%, 40%, 15%, 7%, and 3%, respectively. The uncertainty associated with the Ron et al. (1995) risk coefficient was also taken into account. A central estimate of 46,000 lifetime excess thyroid cancer cases, with 95% uncertainty limits from 8,000 to 208,000, was obtained by means of a Monte-Carlo simulation analysis (Table A.4).

Table B.4 Predicted numbers of excess thyroid cancer cases, by gender (Hoffman 1997). The lower and upper limits correspond to a subjective 95% confidence interval.

Gender	Lower limit	Central value	Upper limit
Females	6,700	37,000	184,000
Males	1,200	7,400	38,000
Total	8,000	46,000	208,000

B.4 Subsequent Activities

In order to ensure that the results presented in the NCI report are credible, that the predicted lifetime excess thyroid cancer cases are reasonable, and that their public health implications are understood, the NCI requested the National Academy of Sciences – Institute of Medicine (IOM) to assess the soundness of the dose reconstruction, to provide a preliminary assessment of the public health implications, and to provide guidance to the Department of Health and Human Services for educating and informing members of the public and the medical profession about public health issues related to the thyroid dose estimated which was presented in the NCI report. Regarding the estimation of the thyroid doses, the conclusions of the IOM report (IOM 1999) were that "the NCI report reflects an intensive effort to collect or generate the data needed for a complicated series of analyses, although documentation of methods, analyses, or results was insufficient in a few places. The committee concluded that the NCI was unlikely to have grossly over- or underestimated the collective I-131 dose, but it was less confident that the NCI had realistically determined the uncertainty associated with the estimate." With respect to the NCI estimates of cancer risk, it is indicated in the IOM report (1999) that "the committee considered the NCI approach to developing estimates of excess cancer cases due to ^{131}I exposure generally reasonable, but the committee did raise questions about certain assumptions. In particular, it noted that there is disagreement within the scientific community about the assumption of dose-response linearity, that is, the assumption that the smallest dose of ^{131}I to the thyroid results in some excess risk of cancer. Most exposure to ^{131}I following the Nevada tests was low-level exposure for which evidence of cancer risk is very limited."

References

Bouville A, Wachholz BW, Ron E. Nevada Atmospheric Nuclear Bomb Tests: Estimation of the Thyroid Doses and Health Effects Resulting from the Iodine-131 Releases. "Nevada atmospheric nuclear bomb tests: estimation of the thyroid doses and health effects resulting from the Iodine-131 releases". Radiation and Thyroid Cancer (eds. G. Thomas, A. Karaoglou and E.D. Williams). Publication no. EUR 18552 EN of the European Commission; pp. 21-28. World Scientific Publishing, 1999.

DOE – United States Department of Energy. United States Nuclear Tests, July 1945 through September 1992. Report DOE/NV-209 (rev. 14); 1994

Hoffman FO. Calculation of the Estimated Lifetime Risk of Radiation-Related Thyroid Cancer in the United States from Nevada Test Site Fallout. *Report prepared for NAS/IOM committee* 1997.

IOM – Institute of Medicine. Exposure to American People to Iodine-131 from Nevada Nuclear Bomb Tests. Washington, DC: National Academy Press; 1999.

Laird NM. (1987) Thyroid Cancer Risk from Exposure to Ionizing Radiation: A Case Study in the Comparative Potency Model. *Risk Analysis* 1987; **7**: 299-309.

Land, C. Calculation of the Estimated Lifetime Risk of Radiation-Related Thyroid Cancer in the United States from Nevada Test Site Fallout. *Report prepared for NCI* 1997.

Lee W, Chiacchierini RP, Shleien B, Telles NC (1982), Thyroid tumors following I-131 or localized X-irradiation to the thyroid and pituitary glands in rats. *Radiat. Res*. 1982; 92: 307.

NCI - National Cancer Institute. Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests. U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute, 1997.

NCRP - National Council on Radiation Protection and Measurements. Induction of Thyroid Cancer by Ionizing Radiation. Report No.80. Bethesda, NCRP, 1985.

Ron E, Lubin JH, Shore RE, Mabuchi K, Modan B, Pottern LM, Schneider AB, Tucker MA, Boice JD, Jr. Thyroid cancer following exposure to external radiation: a pooled analysis of seven studies. *Radiat Res* 1995; 141: 255-273.

Ries LAG, Kosary CL, Hankey BF, Harras A, Miller BA, Edwards BK (eds). SEER Cancer Statistics Review, 1973-1993: Tables and Graphs, National Cancer Institute. Bethesda, MD, 1996.

Walinder G. Late effects of irradiation on the thyroid gland in mice. I. Irradiation of adult mice. *Acta Radiol. Ther. Phys. Biol.* 1972; 11: 433

Appendix C

ACERER Issues

***Contents**: This section provides a list of recommendations made by the Advisory Committee on Energy-Related Epidemiologic Research and the status of the Department of Health and Human Services' response to those recommendations. (Note: The charter for this committee has expired and it no longer exists.)*

In the fall of 1998, the Advisory Committee on Energy-Related Epidemiologic Research (ACERER) provided a set of formal recommendations to Department of Health and Human Services (DHHS) concerning its research into the occupational and public health consequences of the nation's nuclear weapons production and testing activities. These recommendations (and the status of our response actions) are as follows (ACERER 1998)[1]:

- **"Fulfill the legislative intent of Public Law 97-414."**

  The NCI (NIH 2000) has recently updated the Radioepidemiological Tables that were published in 1985 (NIH 1985). This revision required developing risk models for more than 20 specific cancers, including those organs and tissues that are of interest following exposures to radioactive fallout. Although the tables are being developed to estimate the "probability of causation" (the probability that a cancer that has been diagnosed in an individual is the result of some previous exposure to radiation), the models could be used to estimate the lifetime risk of developing cancer, which is a more useful quantity for those exposed to fallout and who as yet have no observable health effects. Additionally, the NCI is developing the ^{131}I/NTS Communications Plan, which will provide the American public and the nation's health care providers with accurate, yet understandable, information regarding the potential risks of thyroid disease associated with exposure to ^{131}I released during nuclear bomb tests in the 1950s and 1960s at the NTS.

- **"Complete a comprehensive dose reconstruction project for NTS fallout."**

  This feasibility report provides DHHS's initial work to provide dose estimates beyond ^{131}I to include all of the biologically significant radionuclides from NTS and

[1] Advisory Committee for Energy-Related Epidemiologic Research (ACERER), (1998). Resolution containing six recommendations concerning the Department of Health and Human Service's Follow-up to the NCI study, October, 1998.

global testing. The options for future work discussed in Chapter 6 address this ACERER recommendation.

- **"Notify Americans of the factors that might help them to determine whether they received significant radiation doses from NTS fallout."**

NCI has taken the lead in communicating information to people exposed to ^{131}I fallout from the Nevada Test Site as well as the potential health implications of these exposures. The communications plan developed by NCI for the ^{131}I/NTS Communications Campaign may prove to be a useful model for communicating information about exposure and risk from *other* radionuclides from NTS as well as global fallout. If a detailed study is conducted and sufficient resources are provided, a comprehensive, nationwide public awareness and provider education campaign could be implemented.

- **"Create a public and health care provider information service on NTS exposures and resulting public health concerns."**

A major component of the communications and education approach discussed in this feasibility report calls for the development of education strategies, plans and resources to guide health care practitioners through patient education, diagnosis, treatment, and the surveillance of illness in persons exposed to radioactive fallout. This report also discusses the need to explore and evaluate existing inconsistent health care recommendations and guidelines in order to develop consistent messages for health care providers. Also, the establishment of a national resource center to provide information and education to both concerned public and health care providers is outlined as a potential mechanism for addressing the public's needs and concerns.

- **"Support archival projects to document experiences of exposed peoples."**

CDC agrees with ACERER that the citizen input they have received throughout their energy-related work at nuclear weapons production sites can provide helpful information on records recovery, past exposures and exposure pathways. In the communications and education approach presented in this feasibility report, archival projects are discussed as a useful source to not only measure the level of public awareness, concern, and familiarity with the issues, but also as potential partners during the planning and implementation phases of a communications effort to assist in defining target audiences and disseminating information. If additional fallout-related work is funded, it may be possible to assist national, regional and local efforts devoted to recording and preserving the histories of peoples exposed to radiation from nuclear testing and nuclear weapons materials production. It would be important to identify and protect existing data archives (such as, historical reports, monitoring data, institutional memories, etc.) in order to facilitate any future scientific work.

- **"Further evaluate screening opportunities for thyroid cancer. It is urgent, in the meantime, to evaluate the advisability and feasibility of screening for other (noncancerous) thyroid and parathyroid diseases, with a priority to evaluate this service for those at highest risk due to their exposures."**

ACERER, with planning and logistical support from NCI and CDC, held a discussion of screening issues with invited experts on June 8, 2000. This is a very complex public health issue that has been considered by the Institute of Medicine and others. Though ACERER has not made formal recommendations to DHHS regarding targeted screening of higher exposure groups, DHHS has been proactive in investigating current thyroid screening recommendations by groups such as the Preventive Services Task Force and the American Thyroid Association. Additionally, it has explored existing coverage of thyroid disease screening procedures by programs under its purview, such as Medicare and the Indian Health Service.

Since ACERER first submitted these recommendations to DHHS, they have been updated on the progress of NCI and CDC on both the ^{131}I/NTS Communications Project and the work being conducted to complete this feasibility report. Specifically, ACERER and other members of the public have been able to review and provide advice and comment on:

- The agenda and draft materials for the ^{131}I/NTS Communications Project January 2000 Workshop;
- The outline of the ^{131}I /NCI Communications Plan;
- Monthly progress reports on the Communications Project's activities;
- Progress reports on CDC and NCI's work to examine the scientific feasibility of estimating the doses and potential risks to the American publics resulting from other radionuclide exposure from NTS fallout and global nuclear weapons testing and the subsequent nationwide communication of this research; and
- They will be provided a draft copy of this feasibility report and they will have an opportunity to comment.

The agencies and DHHS will continue to work with their advisory committee as work progresses on these fallout-related projects.

References

NIH. National Institutes of Health. NIH Publication No. 85-2748. Report of the National Institutes of Health Ad Hoc Working Group to develop radioepidemiological tables. Bethesda, MD; 1985.

NIH. National Institutes of Health. Draft report of the NCI-CDC working group to revise the 1985 NIH radioepidemiological tables. Bethesda, MD; 2000.

Appendix D

Document Preservation and Retrieval: Current and Potential Future Activities

Contents: *Any additional fallout-related work will require an extensive review of fallout monitoring programs. This section describes some of these programs and the need for document identification and preservation.*

D.1 The Need for Original Data

In over ten years of dose reconstructions, the Centers for Disease Control and Prevention (CDC) has always tried to locate and use original data whenever possible in order to reduce calculation errors and loss of accuracy. In many cases, this has led to substantial revisions to previous release data. For example, at the Savannah River Site and Fernald, CDC's estimates more than doubled the previously reported amounts of some released radioisotopes, and at Hanford CDC determined that the amount of ^{131}I should be increased by 70%. These results were obtained simply by careful evaluations of known sources and activity at those sites, without discovering any previously unknown activities or releases.

In conducting this feasibility study, CDC discovered extensive repositories of data that could be used in this study. However, some of these data have already been destroyed. Some are being preserved in various repositories, and they may or may not be catalogued. An unknown amount exists in undocumented collections at different government facilities or in private hands. The people who conducted the research and who understand the data will not be available much longer, due to retirement or death. If there is ever going to be a study of the health effects of all nuclear weapons tests using original data, the information collection phase must be done soon.

D.2 Past Research

Measurements and evaluations of fallout dispersal and deposition during the era of nuclear testing were, in the aggregate, probably the largest environmental monitoring program ever undertaken by the United States and other countries. Most of the monitoring programs were classified at the time, and many still are. Future studies will require access to and declassification of documents by the Departments of Energy (DOE) and Defense (DOD). In addition to the specific and extensive monitoring conducted with each test, there were many national or international monitoring programs. For example, the United States Public Health Service (PHS) maintained a nationwide network of gummed film collecting stations and conducted a nationwide milk-sampling program (Devore and Terrill 1982). The United States Atomic Energy Commission's Health and Safety Laboratory in New York City, later renamed the Environmental Measurements Laboratory, also maintained a nationwide sampling program including atmospheric samples, soil samples, and gummed film samples (Bouville and Beck 2000; Friend 1961; Harley 1976; Salter 1965). The Applied Fisheries Laboratory at the University of Washington collected extensive seawater and marine biology samples (Hines 1962).

In addition to the efforts of the PHS and the Atomic Energy Commission, many state agencies, universities, other government agencies, and even some corporations conducted their own monitoring programs. The DOD had its own set of sampling programs that remain classified to this day. Eastman Kodak conducted fallout measurements because fallout was exposing newly manufactured film.

Every nation that conducted atmospheric nuclear weapons tests took similar measurements, and many other nations had significant fallout measurement programs during this period. Japan and India monitored and analyzed Chinese fallout data. New Zealand and Australia collected data on French tests in the South Pacific and British tests in Australia. Finland, Sweden, and Norway collected and analyzed fallout from Russian atmospheric tests on Novaya Zemlya. The United Kingdom conducted an extensive program of atmospheric ^{137}Cs and ^{90}Sr monitoring. There were also some international programs under the auspices of the United Nations.

Since the end of nuclear testing, the United States, several foreign governments, the United Nations, and various non-governmental organizations have conducted studies of the health effects of fallout in various regions of the world. For example, the International Atomic Energy Agency (IAEA) conducted a dose reconstruction on Fangataufa and Mururoa after the French tests there. The United States and the Republic of the Marshall Islands jointly conducted a radiological survey of the Marshall Islands after testing by the United States in the Pacific Ocean. The governments of the countries of the former Soviet Union are conducting epidemiological and radiological studies around Soviet test sites, and making their data available internationally. The Scientific Committee on Problems of the Environment (SCOPE), part of the International Committee for Science, recently completed an assessment of the environmental and human impacts of nuclear test explosions (Kirchmann 2000).

D.3 Current Status of Document Preservation

Ten years ago the DOE declared a moratorium on the destruction of all energy-related documents of epidemiological significance. Since that time, DOE documents shipped to a Federal Records Center or the National Archives have indefinite destruction dates if they are in a group of records covered under the moratorium. Many of these records, particularly the older ones, are not cataloged in any detail. A researcher may be able to determine that there are 60 cubic feet of documents about nuclear weapons testing at the Federal Records Center in Maryland, but it is necessary to actually visit the Center and open boxes to determine what the documents are and whether they are needed. Since these records are in a safe place, this effort may be deferred for the time being.

In 1978, the DOE launched a comprehensive effort to gather as much information about United States nuclear weapons testing as possible. This information is held at the Coordination and Information Center (CIC) in Las Vegas, NV. This information is very well catalogued, and researchers can search for documents by title, DOE number, author, or key words via the Internet (http://www.osti.gov/waisgate/opennet.new.html). As long as CIC's funding remains stable, these documents will remain available for researchers.

The DOE has an Internet site listing sites that contain relevant documents (http://tis.eh.doe.gov/workstation/homerep.html). However, this Internet site does not provide enough information for a researcher to determine what is available without an actual visit to the facility. If these documents are to be useful for future research, someone should visit each site and catalog documents actually useful for fallout research. The documents are protected, however, so this could be deferred.

Other agencies in addition to the DOE conducted their own research or measurements programs, such as the PHS (Devore and Terrill 1982) or Department of Defense. These documents are not covered by DOE's moratorium and could be destroyed at any time if they have not already been destroyed or lost. The documents at these sites should be copied and catalogued as soon as possible.

Many nations sent reports of their fallout measurements to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in Vienna, Austria, beginning in 1958. Many of these research reports are out of print and the copy at UNSCEAR may be the only surviving copy. Since submission of reports to UNSCEAR was voluntary, none of their report series are complete. However, UNSCEAR documents may be useful in two ways. First, the research reports themselves may provide useful scientific data (even if incomplete); and second, it is possible to use UNSCEAR's records to identify countries and laboratories where measurements were made. UNSCEAR has stated they intend to preserve these records indefinitely. CDC has made copies of all the UNSCEAR records relevant to fallout listed in past UNSCEAR Annual Reports, and archived them in Atlanta.

Many scientists with years of experience on fallout studies have unique data in their own offices. Others working for universities, the government, or other organizations took their data with them when they retired. These data are the most fragile of all. They are not catalogued, covered by a moratorium, or available to future researchers. For example, one retired scientist had several thousand measurements of radioactive iodine in animal thyroids from all over the world. Some of the information was contained in hand-written notebooks and some of it was stored on antiquated IBM tapes. CDC was able to find a contractor capable of reading old data tapes, retrieved the data, and now has it in a modern database format. NCI and its contractors are having the remaining notebooks entered into a database and appended to the existing data. The government should mount an aggressive effort to identify, copy, and preserve information like this as soon as possible if this information is ever to be used in a new study.

The DOD has never declared a moratorium on destruction of records of epidemiological significance, and they are not under any obligation to share whatever relevant data they may have with the Department of Health and Human Services (DHHS). The Navy was in charge of early weapons testing in the Pacific, including radiological measurements; and the Air Force has been conducting atmospheric measurements for many years. Most of this information remains classified. Immediate steps should be taken to identify, catalogue, protect, and declassify this material (in that order). This requires giving DHHS staff with the appropriate security clearances access to the material, but it will not be necessary to declassify any documents until the time comes to use them.

CDC has not visited any foreign repositories for fallout-related information except the UNSCEAR headquarters in Vienna, Austria. CDC's staff knows with a fairly high degree of confidence what laboratories have conducted measurements, but we do not know what data are still available or how long they will be available. DHHS could identify what kind of data are required from foreign laboratories to fill the holes in available data for calculating health effects on residents of the United States from global fallout and begin negotiating with foreign governments for permission to review, copy, and use their data as necessary.

In the United States, CDC has visited 15 sites to evaluate documents for their relevance to this fallout study. There has been no attempt to catalog these documents, and only a few copies were made as examples of what was there.

- The information at some sites was not useful for future fallout studies. CDC noted that fact and will take no further action.
- Some of the DOE information at Federal Records Centers was useful. This information was covered by the moratorium, so it will not be destroyed. However, it was not very clearly described, so it will eventually be necessary to visit these Centers, open boxes, and enter abstracts of the useful documents into a database if this information is to be useful to future researchers.
- Some of the DOD information at Federal Records Centers was useful. Some of this information is not covered by the moratorium and will be destroyed in the next few years if no action is taken. CDC has not done anything with this material, and will not without funding for this purpose.

- Some of the DOD information was not made available to CDC, so it is impossible to tell whether it is useful or not.
- There are large quantities of useful information at national laboratories. This information is often scattered all over the laboratory, not catalogued in any way. While this information fits the description of material covered by the moratorium, the administration of the moratorium covers only groups of boxes in archives, not individual records, so there is no guarantee the material will be preserved. Under a different appropriation and for a different project, CDC is busy searching, copying, and cataloguing relevant documents at the Los Alamos National Laboratory. The purpose of this effort is to identify documents which would be useful in a dose reconstruction of that laboratory, but the contractors have been instructed to note any documents they encounter which would be useful in a future fallout study. There are no document retrieval and assessment activities underway at any other national laboratory at this time for the purpose of studying fallout, due to lack of funding or a mandate to do so.

The Environmental Measurements Laboratory (EML) in New York City is an important source of fallout data. Some of this information is very well preserved and readily available, such as the soil sampling data posted on the Internet. In addition to their own research, the EML has collected published reports about fallout measurements from all over the country or the world. Many of these are out of print. Since they are not DOE reports, but copies of old journal reports, they are not covered by the moratorium, and CDC discovered that EML staff was preparing to destroy these reports in order to reduce required office space and save money. Other information, such as gummed film data, was to be stored uncatalogued in boxes in the basement of the building. While this material would not have been lost, it would not be available to future researchers because no one would be aware of the existence of the material. CDC made two more visits to EML, where they separated out fallout-relevant material and made arrangements with EML staff to retain that material. NCI is working with EML to have the printed gummed film records entered into spreadsheets.

In 1978, the PHS combed its own archives and collected about 11,000 documents about fallout. The 1979 report Effects of Nuclear Weapons Testing on Health: Report of the Panel of Experts (Hulley 1979) describes the contents of this archive. In Hulley (1979), the panel concluded that the PHS archive contained enough information to assess the health effects of fallout. CDC has a copy of this report. All of the documents from the original archive are on microfilm at the DOE's Coordination and Information Center (CIC) in Las Vegas.

During the years of nuclear weapons testing, Congress held many hearings on the health effects of fallout and the need for further nuclear weapons testing. The published hearings are out of print now, but CDC has found extensive collections of these hearings in several locations – CIC, university libraries, and the Environmental Measurements Laboratory, to name a few. CDC has a copy of the Hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, 85th Congress First Session on the Nature of Radioactive Fallout and its Effects on Man 1957 and will use others as the need arises. These hearings are valuable in two ways. They contain useful information themselves, and they point to locations where more information may be found. As with other documents cited above, DHHS needs to identify Congressional hearings relevant to the fallout study which are not already stored at CIC, find and copy them, and ensure they are stored in a protected archive.

D.4 Possible Future Actions

There is a fundamental need for DHHS to continue the past efforts of itself and other agencies to ensure the preservation and continuing availability of data necessary for future fallout research. Priorities should be:

- Enroll other US government agencies, especially the DOD, in the effort to identify, preserve and publish information.
- Continue the US search for documents not held by a U.S. Government agency; copy them, catalog them, and take steps to ensure their preservation.

Specific actions that could be done in the near future:

- Find PHS gummed film and milk data.
- Extend the moratorium to DOD data.
- Review DOD data, especially data on post-test fission product ratios.
- Catalog the reports at the EML and establish a reading room or library for them.
- Visit 44 facilities identified by DOE that contain fallout relevant material, and protect and catalog the material if necessary.
- Assemble a list of Congressional hearings relevant to fallout and ensure that a complete collection is preserved somewhere.

References

Bouville, A. and H. L. Beck. The HASL Gummed-Film Network And Its Use In The Reconstruction Of Doses Resulting From Nuclear Weapons Tests, Technology 7:355-362; 2000.

DeVore, R. and Terrill, J.G. The Role of the U.S. Public Health Service in Radiological Health: 1946 – 1969 (FDA/NCDRH-83/20) Public Health Service, Rockville, MD, September 1982

Friend, J.P. (ed.). The High-Altitude Sampling Program, . DASA-1300, Defense Atomic Support Agency, August 31, 1961.

Harley, J. A Brief History of Long-Range Fallout. Environmental Quarterly, (HASL 306), Health and Safety Laboratory, July 1, 1976, pp I-3 to I-19

Hines, Neal O., Proving Ground: An Account of the Radiobiological Studies in the Pacific, 1`946 – 1961 University of Washington Press, 1962

Hulley, S.B. and W. Winkelstein, Effects of Nuclear Weapons Testing on Health: Report of the Panel of Experts on the Public Health Service Archive of Documents (2 volumes), U.S. Department of Health, Education, and Welfare, April 18, 1979

Kirchmann, R.J.C. and F. Warner, Nuclear Test Explosions: Environmental and Human Impacts (SCOPE 59), John Wiley and Sons, 2000

Salter, L.P. Stratospheric Air Concentrations of Plutonium Isotopes and Strontium-90, October 1964 - February 1965. HASL Technical Memorandum 65-10. New York, June 11, 1965.

Appendix E

External Dose Estimates from NTS Fallout

External Radiation Exposure to the Population of the Continental U.S. from Nevada Weapons Tests and Estimates of Deposition Density of Radionuclides That Could Significantly Contribute to Internal Radiation Exposure via Ingestion

Harold L. Beck

Report to the National Cancer Institute in fulfillment of
P.O. #263-MQ-909853

June 30, 1999 (revised Nov. 1, 1999)

Abstract

This report provides estimates of the external radiation exposure and whole-body effective dose received by residents of the continental U.S. during the period 1951-1962 from weapons tests carried out at the Nevada Test Site (NTS). Estimates are given on a county- by-county basis for each test and for each year of testing. The average committed population dose from all NTS tests was about 0.5 mSv, about equivalent to 1-2 years of external radiation exposure from natural background. Residents of the counties immediately downwind from the NTS incurred much higher doses, in excess of 3 mSv, while the residents of the Far West, Pacific Northwest and Southeast received lower than average exposures. The tests and radionuclides that contributed the most exposure are discussed, as well as the dependence on fallout time of arrival. The most exposed individuals were outdoor workers; the least exposed were persons who spent most of their time indoors in heavily constructed buildings.

The deposition of radionuclides that contribute to internal radiation exposure via the ingestion pathway was also calculated on a county-by-county and test-by-test basis. The general pattern of deposition, tests contributing the most to the deposition, deposition density versus distance from the NTS, and the differences in deposition between radionuclides are discussed. In general the deposition of long-lived radionuclides such as Sr-90 and Cs-137 was about a factor of 20 less than that from “global fallout” from high-yield weapons tests carried out in the Pacific and Soviet Union. However, the deposition of short-lived isotopes such as I-131 was greater than from “global fallout.”

Introduction

In response to a request by Congress to the CDC and NCI to investigate the impact on the U.S. population from weapons tests, the NCI contracted with the author of this report to:

"Prepare crude estimates of the doses *from external irradiation* received by the American people as a result of the above-ground tests carried out *at the Nevada Test Site.* These dose estimates would be:

- based on a review of the readily available open literature and information; it is not expected that sophisticated computer models should be developed or used for this purpose. For the purposes of this assessment, the extensive database of Iodine-131 that was prepared by NCI in the framework of the nationwide NTS fallout study could be used;
- averaged over large regions of the continental U.S., with indications on how the high-risk populations would be identified. However, if feasible, primary calculations should be carried out on a county-by-county basis, and averaged only for presentation purposes;
- calculated separately for the most important radionuclides produced in nuclear weapons tests. Those would include, but would not be limited to Te-I-132, Ba-La-140, Zr-Nb-95, Cs-137, and Np-239;
- provided in terms of average whole-body dose for gamma irradiation and of dose to the skin for beta irradiation.
- calculated by year and summed over all NTS tests, with a comparison to the published UNSCEAR latitudinal averages for all tests.

2. Provide a list of references regarding: (1) the history of nuclear weapons testing at the NTS; (2) the production of important radionuclides during those tests; (3) the networks of fallout measurements; (4) the assessment of the activities deposited on the ground; (5) the vertical migration of fallout radionuclides into deeper layers of soil; and (6) the assessment of the doses from external irradiation.

3. Identify reports that could be declassified. Examples of such reports are those that would provide the fission and total yields, and those that would greatly facilitate the estimation of doses due to the plutonium isotopes."

This report, along with an associated electronic database, is presented in fulfillment of the above scope of work.

As per the scope of work, this report relies heavily on previous studies of NTS fallout, e.g., NCI (1997); Hicks (1982, 1990); Church et al. (1990); Beck et al. (1990, 1996). Exposure rates and deposition densities were calculated for about 60 of the approximately 100 atmospheric tests conducted at the NTS. These 60 tests accounted for over 95% of the total I-131 produced (NCI, 1997) and corresponded to the majority of tests for which total I-131 deposition was estimated by the NCI (1997) in their study of I-131 exposure to the American people from NTS fallout. A few tests considered in the NTS study for which only local fallout estimates were estimated were not treated in this study. The tests considered in this report are listed in Table 1. Table 1 also gives some specific information about each test that was used in the calculations described later in this report.

The basic starting point for the estimates in this report were the daily I-131 deposition density estimates and associated uncertainty estimates from NCI (1997). All calculations for this report were carried out separately for each county (and sub-county as defined in NCI (1997), Appendix 2, and then summed to provide estimates on a test-by-test, annual, and total NTS basis. The total exposure and deposition density for other nuclides was calculated from the NTS I-131 deposition densities by using the relationships calculated by Hicks (1981) for each NTS shot. Besides the total free-in-air exposure rate from gamma emitters, provided by the Hicks data, estimates were also made of the annual whole body effective dose, the beta-ray dose to the skin from radionuclides in the surface soil, and the 50y committed effective dose. The radionuclides that contributed most to both gamma and beta-ray exposure were identified.

Deposition densities were estimated on a county-by-county basis for each test for the radionuclides listed in Table 2. These radionuclides were determined by Ng et al. (1990) to account for over 90% of the potential dose from ingestion in the ORERP (Church et al., 1990) study. A database (in Excel) containing the estimated deposition density of each radionuclide listed for each test on a county-by-county basis was provided to NCI earlier in partial fulfillment of this contract. The database containing these deposition density estimates and associated uncertainty estimates will be used by the NCI to estimate internal radiation doses due to ingestion of contaminated food. The patterns of total deposition for some of the longer-lived nuclides are discussed in this report and the total deposition of various radionuclides is compared to that from the "global” fallout resulting from the high-yield tests carried out in the Pacific and in the USSR.

In addition to the references provided in the text of this report, an additional reading list is provided in fulfillment of item 2 of the scope of work. A list of data that is presently classified but if unclassified would be useful in improving the estimates made in this report and allowing similar estimates to be made for weapons tests conducted outside the U.S. is also included in fulfillment of item 3.

The next section of this report describes in detail the methodology used to calculate exposure and deposition densities.

Table 1: Tests considered in this study

Test	Test Date	yield (kT)	Type	Cs-137/ Sr-90	% Cs-137 from Pu*	Pu-240/ Pu-239	Pu-241/ Pu-239	Cs-137/ Pu*
BAKER-1	1/28/51	8	air	1.79	72%	0.027	0.0006	5
Baker-2	2/2/51	8	air	1.79	72%	0.026	0.0005	5
BAKER	10/28/51	4	air	2.50	100%	0.033	0.0011	4
CHARLIE	10/30/51	14	air	1.16	18%	0.028	0.0010	20
DOG	11/1/51	21	air	1.27	31%	0.028	0.0010	12
EASY	11/5/51	31	air	1.24	28%	0.036	0.0011	13
SUGAR	11/19/51	1	surface	1.06	3%	0.001	0.0000	316
UNCLE	11/29/51	1	crater	1.06	3%	0.001	0.0000	299
ABLE	4/1/52	1	air	1.06	3%	0.001		142
BAKER	4/15/52	1	air	1.06	3%	0.001		144
CHARLIE	4/22/52	31	air	1.27	31%	0.051	0.0028	11
DOG	5/1/52	19	air	1.28	32%	0.035	0.0012	11
EASY	5/7/52	12	tower	1.27	31%	0.024	0.0005	24
FOX	5/25/52	11	tower	1.27	31%	0.024	0.0006	24
GEORGE	6/1/52	15	tower	1.27	31%	0.026	0.0015	24
HOW	6/5/52	14	tower	1.26	30%	0.027	0.0005	24
ANNIE	3/17/53	16	tower	1.28	32%	0.025	0.0010	23
NANCY	3/24/53	24	tower	1.27	31%	0.028	0.0012	23
RUTH	3/31/53	0	tower	1.06	3%	0.000		306
DIXIE	4/6/53	11	air	1.27	31%	0.022	0.0006	12
RAY	4/11/53	0	tower	1.06	3%	0.000		292
BADGER	4/18/53	23	tower	1.34	38%	0.034	0.0011	19
SIMON	4/25/53	43	tower	1.12	12%	0.027	0.0006	60
ENCORE	5/8/53	27	air	1.16	17%	0.052	0.0028	20
HARRY	5/19/53	32	tower	1.21	24%	0.038	0.0018	29
GRABLE	5/25/53	15	air	1.04	0%	0.001		833
CLIMAX	6/4/53	61	air	1.11	11%	0.034	0.0009	33
WASP	2/18/55	1	air	1.77	71%	0.055	0.0036	5
MOTH	2/22/55	2	tower	1.77	70%	0.078	0.0065	9

Test	Test Date	yield (kT)	Type	Cs/Sr	% Cs-137 fromPu*	Pu-240/239	Pu-241/239	Cs/Pu*
TESLA	3/1/55	7	tower	2.42	98%	0.019	0.0003	8
TURK	3/7/55	43	tower	1.20	23%	0.033	0.0008	32
HORNET	3/12/55	4	tower	1.38	43%	0.058	0.0036	16
BEE/ESS	3/22/55	9	tower/crater	1.42	46%	0.085	0.0071	13
APPLE/WASP'	3/29/55	17	tower/air	1.16	18%	0.025	0.0006	40
POST	4/9/55	2	tower	2.47	99%	0.019	0.0005	8
MET	4/15/55	22	tower	1.03	-1%	0.007	0.0001	10000
APPLE2	5/5/55	29	tower	1.06	4%	0.031	0.0008	186
ZUCCHINI	5/15/55	28	tower	1.11	10%	0.032	0.0008	69
BOLTZMANN	5/28/57	12	tower	1.51	53%	0.079	0.0060	12
WILSON	6/18/57	10	balloon	1.29	33%	0.082	0.0065	9
PRISCILLA	6/24/57	37	balloon	1.07	5%	0.011		74
HOOD	7/5/57	74	balloon	1.12	12%	0.067		27
DIABLO	7/15/57	17	tower	1.22	26%	0.062		26
KEPLER	7/24/57	10	tower	2.37	96%	0.072	0.0054	7
OWENS	7/25/57	10	balloon	2.44	98%	0.070	0.0047	3
SHASTA	8/18/57	17	tower	1.19	22%	0.057		30
DOPPLER	8/23/57	11	balloon	1.26	30%	0.070	0.0046	11
SMOKY	8/31/57	44	tower	1.08	6%	0.006		136
GALILEO	9/2/57	11	tower	2.19	90%	0.075	0.0050	7
WHEELER/ (+COULOMB)	9/6/57	1	balloon/ surface	1.04	0%	0.038		785
LAPLACE	9/8/57	1	balloon	1.07	6%	0.000		72
FIZEAU	9/14/57	11	tower	1.43	47%	0.063	0.0040	14
NEWTON	9/15/57	12	balloon	2.46	99%	0.072	0.0058	3
WHITNEY	9/23/57	19	tower	1.41	45%	0.073		14
CHARLESTON	9/28/57	12	balloon	1.29	33%	0.074		10
MORGAN	10/7/57	8	balloon	1.23	26%	0.077	0.0063	12
SEDAN	7/6/62	104	crater	2.44	98%	0.063		8
SMALLBOY	7/14/62	20	surf tower	2.51	100%	0.065	0.0056	8

**Estimated-see text*

Table 2: Radionuclides for which deposition densities were calculated

Nuclide	Half life (parent), d
Sr-89	52
Sr-90,Y-90*	10400
Sr-91	0.4
Y-91m (=0.65 * Sr-91)	*
Y-91	59
Y-93	0.4
Zr-97, Nb-97*	0.7
Zr-95, Nb-95*	64
Nb-97m (=0.96 * Zr-97)	*
Mo-99	2.8
Tc-99m (=0.96 * Mo-99)	*
Tc-99	7.8E7
Ru-103, Rh103m*	39
Ru-105, Rh-105m*	0.2
Rh-105	1.5
Ru-106, Rh-106*	368
I-131 (from NCI, 1997)	8
Te-132	3.3
I-132 (=1.03 * Te-132)	*
I-133	0.9
I-135	0.3
Cs-136	13
Cs-137	11000
Ba-140	13
La-140	1.7
Ce-141`	32.5
Ce-143	1.4
Pr-143	14
Ce-144, Pr-144*	284
Nd-147	11
Pm-147	956
Np-239	2.36
Pu-239	24131 y
Pu-240	6569 y
Pu-241	14.4 y
Am-241	430 y

** in equilibrium with parent*

Methodology

Deposition Densities

The deposition densities of the nuclides listed in Table 2 were calculated from the corresponding NCI estimates of I-131 deposition density. The daily geometric mean (GM) I-131 deposition densities and corresponding geometric standard deviations (GSD) were decay corrected back to H+12 hours. The ratio of the H+12 h I-131 value, which includes the I-131 that grew in from precursors (NCI, 1997), to the ratio of each of the radionuclides in Table 2, as a function of fallout arrival time, was calculated using Hicks (1981). The H+12 h I-131 value for each day of fallout was then multiplied by the appropriate ratio for a time of arrival corresponding to that day to obtain the respective deposition density.

Because the fallout estimates based on gummed-film data were decay corrected to the midpoint of the day of sampling and the test detonations were generally near the beginning of the sampling period (Beck, 1984), fallout arriving on the same day as sampling was assumed to have a time of arrival of 0.5 d, on the second day 1.5 d, etc. Generally, only about 10 days of data had to be considered for a given shot, although a few shots produced significant fallout for periods of up to two weeks. Daily deposition densities were calculated only for short-lived nuclides (half lives less than 30 d). For longer-lived nuclides, the ratio to H+12 h I-131 did not vary significantly over the first several weeks of fallout and thus their total test deposition could be calculated directly from the sum of the daily I-131 depositions.

The daily deposition densities were then summed to obtain a total test deposition density. Since the I-131 deposition densities were given as geometric means with a GSD, it was necessary to first transform the GM to a mean and the GSD to a variance before summing, using standard transformations as discussed in NCI (1997). After the means and variances were summed, the results were transformed back to geometric means and GSDs, assuming the sum of lognormally-distributed distributions is itself approximately lognormally-distributed (see NCI, 1997). The Excel spreadsheet database which accompanies this report contains both the mean values and the GM values. For the long-lived radionuclides, the deposition densities were calculated by multiplying the summed I-131 deposition density by the appropriate ratio for that test from Hicks' data. No additional uncertainty was assumed due to use of the Hick's calculated isotope ratios. Because of the large GSDs associated with the I-131 deposition data, any small additional error in Hicks' data would have a negligible effect on the error in the deposition densities.

Besides, the individual test values, the deposition densities for each test series (year of testing) and for all NTS tests were obtained by summing the individual test results in a similar manner. The short-lived nuclide deposition densities for radionuclides that did not contribute significantly to external dose were not summed to obtain annual or total values. It was assumed that for these short-lived nuclides, the exact week of deposition would be required to make reasonable estimates of ingestion dose. If annual sums are desired for these radionuclides, it is a fairly simple task to obtain them since the GM to mean transformed values are provided in the accompanying database.

A detailed example of the calculation of the deposition density of Cs-137 and Ba-140 for a representative county for a representative test is given in Appendix 1.

Plutonium isotopes were also contained in the fallout from Nevada weapons tests. Pu isotopes do not contribute to external exposure and contribute in only a minor way to ingestion exposure. The main hazard from Pu is generally via the inhalation pathway. However, the inhalation pathway has been shown to not have been a significant contributor to population exposure from NTS testing (Church et al., 1990). Because of the generally high degree of interest by the public in Pu contamination, deposition densities of Pu-239, 240 and 241, and of Am-241 which is a decay product of Pu-241 are also estimated in this report. However, only crude estimates can be made for individual tests since Hicks does not provide any estimates of relative Pu deposition. The ratios of Pu to Cs-137, Sr-90, etc. are still classified (see Appendix 3). The reason for the classification still being in place is that knowledge of such ratios would allow one to estimate the fission efficiency of individual tests. However, one can still roughly estimate Pu deposition densities for individual tests by assuming an average ratio of Pu/Cs-137 deposition density from Pu fission based on observed environmental measurements, if one can estimate the relative amounts of fission due to Pu-239 versus U-235 for each test.

In Table 1, we list the ratio of Cs-137/Sr-90 activity (Hicks, 1981) and the Pu-240/239 and Pu-241/239 atom ratios for each test (Hicks and Barr, 1984). Table 3 presents the fission yields for Pu and U-235 for a fission neutron spectrum and for a thermal neutron spectrum.

Table 3: Fission yields for Cs-137 and Sr-90 (England and Ryder, 1994)

Nuclide	U-235$_f$	U-235$_{th}$	Pu-239$_f$	Pu-239$_{th}$
Cs-137	6.22	6.19	6.58	5.50
Sr-90	5.46	5.78	2.05	2.10
Cs/Sr (atom)	1.14	1.07	3.21	2.62
Cs/Sr (activity)	1.06	1.00	3.00	2.44
Observed ratio	1.04		2.5	

Note that the Cs/Sr ratios in Table 1 range from a value of 1.04 to 2.5. Based on the fission yields in Table 3, one can infer that the Cs/Sr ratio of 1.04 represents shots where the fission was entirely from U-235, while the ratio of 2.5 represents fission entirely from Pu-239. It is assumed that for these low-yield tests essentially none of the fission was from high-energy neutrons and that for at least most of the tests, no other fissionable material was used. As can be seen, both U-235 and Pu-239 fueled most of the tests[1]. Based on Hick's calculations, the tests inferred to be all U-235 also correspond to those that produced no Am-241 (Hicks, 1981) and exhibited very low Pu-240/239 atom ratios and little Pu-241 (Table 1), consistent with a pure U-235 weapon. (A small amount of Pu will be produced from Np-239 decay even in a pure uranium device since Np-239 is produced by the activation of U-238). Assuming only a mixture of Pu and U-235 as fuel, one can then derive equation 1) for the fraction f of Cs-137 activity that resulted from Pu-239 fission for each shot:

$$f = 1.71 * (x – 1.04) / x$$ where x is the Cs/Sr activity ratio from Table 1. (1)

Using the Cs/Sr activity ratios from Hicks, given in Table 1, one can then estimate the fraction of the Cs-137 produced that was from Pu-239 fission for each shot from Equation 1, above. This fraction is given in the fifth column of Table 1.

Since these were tests, it is expected that the fission efficiency, and thus the ratio of Cs-137 to Pu-239 from Pu fission probably varied considerably from shot to shot. However, if we choose a reasonable estimate for the mean for all tests and assign a conservative error estimate, we can make rough estimates of Pu deposition which, while possibly significantly in error for a given shot, should provide reasonable total deposition values when summed over all shots. A Cs/Pu ratio of 4 was thus adopted for tests where all the fission was from Pu. Using this ratio then results in the crude estimates of total Cs/Pu for each test shown in the last column of Table 1. The choice of this particular ratio is somewhat arbitrary but seems to provide estimates of Cs/Pu reasonably consistent with measurements of Cs-137/Pu-239+240 in NTS fallout (Krey and Beck, 1981).

An uncertainty corresponding to a GSD of 1.5 was assigned to reflect the large uncertainty in this mean efficiency estimate and the likely large variability from test to test. Using this formulation, Pu-239+240 and Pu-241 deposition densities in fallout were estimated for each test, test series, and for all NTS fallout. (Note that for tower and surface shots, since Pu is a refractory material, according to Hicks (1982, 1990) only ½ of the Pu from tower and surface shots would be deposited outside the immediate vicinity of the NTS. Thus the Pu deposition estimates for these shots were multiplied by ½). Because of the large uncertainty, the Pu deposition estimated for a particular county for any particular test has a large uncertainty (GSD ≅ 2- 4), resulting both from the large uncertainty in the NCI I-131 deposition density estimates as well as the large uncertainty in fission efficiency. However, the sums over all tests have smaller uncertainty (GSD ≅ 1.5-2.0) and are believed to present a reasonable exposition of the total Pu deposition

[1] (The very low Np-239 values given by Hicks for some shots that apparently used very little Pu, suggests that U-233 may have been used in a few tests.)

across the U.S. from NTS testing.[2] Accurate estimates of Pu deposition from particular tests will only be possible if additional information on the Cs/Pu ratios for particular tests is eventually unclassified and thus the Pu results presented in this report should be treated as only preliminary crude estimates.

Some additional Pu-239 is generated from the decay of Np-239. Np-239 is formed by the activation of U-238, present in all U fueled weapons and possibly also in Pu-fueled devices as a tamper. Hicks (1981) provides estimates of Np-239 for each shot and these were used to estimate the Pu-239 that would remain after the Np-239 had decayed. This Pu-239 contribution is included in the estimates of Pu-239 in this report. For devices partially or totally fueled by Pu, this contribution is small. However, for U fueled devices it is the only source of Pu in the fallout. Np-239 is also a significant contributor to external radiation exposure rates during the first few days after detonation.

Pu-241 was also estimated from the Pu-239+240 estimate and the reported 241/239 atom ratios. At this time most of the Pu-241 deposited has decayed into Am-241 with a resultant Am-241 activity equal to the ratio of Pu-241/Am-241 half-lives (see Table 2).

External Radiation Exposure

Hicks (1981) calculated the relative exposure rate versus time for each NTS test using deposition to exposure rate conversion factors published by Beck (1980). The conversion factors used by Hicks assume the radioactivity was distributed in the soil with a relaxation length of about 0.1 cm for all times (the relaxation length is defined as the depth at which an exponentially decreasing activity falls to 1/e of the value at the surface). This value was chosen since even fresh fallout is attenuated somewhat as a result of surface roughness (Jacob et al., 1986; Eckerman and Ryman,1993). However, it is well established (UNSCEAR, 1993, NCRP, 1999, Miller et al., 1990; Gale et al., 1964) that radionuclides penetrate deeper into the soil with time. Data from the Chernobyl accident indicates that that even after a few weeks, a relaxation length of 1 cm is not uncommon (Likhtariov et al., 1996; UNSCEAR, 1993), particularly in areas with typical rainfall levels. After a few months, measurements have generally shown that the distribution reaches about a 3-cm relaxation length before the penetration begins to slow and asymptote (Beck, 1966; UNSCEAR, 1988; Miller and Helfer, 1985). However, for heavily watered areas, relaxation lengths of up to 6-7 cm have been observed (Miller et al., 1990; Beck and Krey. 1980).

Because, as will be shown later, most of the radiation exposure occurred during the first few weeks, the use of a 0.1-cm relaxation length by Hicks (1981) for all time intervals had only a small impact on the total integral exposure. However, in this report, an attempt was made to use a somewhat more realistic model. The 0.1 cm relaxation length used by

[2] Note that the county Pu deposition-density estimates for a particular are correlated since the uncertainty in Cs/Pu (or I-131/Pu) is the same for all counties for a given test. Thus the uncertainty in the Pu deposited in the U.S. from a given test will have minimum uncertainty of GSD=1.5. This correlation was accounted for in calculating the total Pu deposition for the U.S. discussed later in this report.

Hicks was maintained for the first 20 d after detonation, but from 20 d to 200 d, a relaxation length of 1 cm was used, while for times greater than 200 days, a relaxation length of 3 cm was used. The corresponding deposition-density to exposure conversion factors for each of these relaxation lengths are from Beck (1980). Although a gradually increasing relaxation length would be more physically realistic, the fact that most of the exposure occurs in the first 20 d, did not warrant the considerable effort that would be entailed in calculating dose rates using a continuously-variable relaxation length.

Since the penetration into the soil would be slower in more arid regions, maintaining the 0.1 cm relaxation length for the first 20 d provides a slightly conservative estimate of the exposure for sites with greater precipitation and early fallout arrival times. Table 4 illustrates the dependence of the exposure rate in air on the various relaxation lengths. Note that the exposure rate is reduced by about 1/3 as the activity penetrates to a relaxation length of 1 cm and about ½ as the activity penetrates to a relaxation length of 3 cm from 0.1 cm. This accentuates the importance of the first few weeks after a test with respect to total external radiation exposure to an even greater degree than previous calculations based only on radionuclide decay.

Table 4: Exposure rate (: R/h per mCi/km^2) versus relaxation length for selected fission products (Beck, 1980)

Nuclide	Relaxation length (cm)		
	0.1	1	3
Zr-95	1.20E-02	7.94E-03	5.63E-03
Ru-103	7.85E-03	5.25E-03	3.58E-03
Rh-106	3.37E-03	2.25E-03	1.56E-03
Te-132	3.38E-03	2.29E-03	1.54E-03
Cs-137	9.29E-03	6.15E-03	4.32E-03
Ce-141	1.09E-03	7.25E-04	4.92E-04
Ce-144	2.53E-04	1.70E-04	1.16E-04
Np-239	2.56E-03	1.75E-03	1.17E-03

Since Hicks already calculated exposure rate versus time for the first 0-20 days using a relaxation length of 0.1 cm, his results for 0.5-20 d were adopted directly and fit to a function of the form at^{-x}. This function was then integrated to obtain the total exposure from TOA to 20 d, where TOA is the time of arrival in days. In all cases the correlation coefficient for the fit over the period 0.5-20 d was greater than 0.99. The variation in the exponent from shot to shot also turned out to be quite low ($x = 1.109$ ∀ 0.022). To obtain the integral from 20 d to the end of the year, the subsequent year, and to 50y, the Hicks' data for nuclides that contribute to the exposure at those times were entered into a spreadsheet. The variation with time from 20 d on was calculated directly from the appropriate Bateman equations that account for ingrowth of precursors and radioactive decay. By using the appropriate analytical formulae normalized to Hicks' data at 20 d, it was possible to integrate analytically over the various intervals of interest. Note that due to the change in depth profile at 200 d, integration had to be done by first integrating from 20 d to 200 d (or to the end of the first year if less than 200 d) and then from 200 d to the end of the year.

Thus for each test, the total exposure was obtained for the year of the test, the next year, and finally for a total period from fallout time-of-arrival to 50 y. Hicks' calculations were normalized to unit exposure rate at H+12 h, which corresponds to a particular value of effective I-131 deposition density at H+12 h. Thus the ratio of the effective I-131 deposition for each day calculated by the NCI (1997) was multiplied by the appropriate normalized exposure integral to obtain the actual exposure for that interval and time-of-arrival. The individual daily estimates were then summed to obtain annual and 50y committed exposure estimates for each test, test series, and for all NTS tests. Again, no additional uncertainty was assigned for the exposure estimates since the error in the deposition density estimate dwarfs the estimated error in exposure rate estimates. The uncertainty in normalized integral exposure for a particular day is estimated to be at most 10-20%, due primarily to variations in the depth profile from site to site. The errors in the conversion factors themselves are thought to be less than 5% (Beck, 1980).

A detailed example of the calculation of total exposure for a representative county for a representative test is given in Appendix 1.

Because the NCI deposition data are given for a particular day, the exposure estimates for sites where the fallout arrived very early (less than 12 h) are underestimated in this report. The exposure rate falls very rapidly during the first few hours (see Table 5) and thus the integral is very sensitive to arrival time for short arrival times. For this report it was assumed that the fallout that occurred on the day of the test occurred at H+12 h (H + 0.25 h for the 1952 tests due to a different gummed-film sample interval). Thus, for those sites where significant fallout occurred prior to H+12 h, the data presented here may be significantly in error (up to 50% too low). This is illustrated by Table 5, which gives the exposure rate and integral exposure versus time for a typical test. However, the exposure rates and external doses for close-in sites have been calculated in great detail for each community (Anspaugh and Church, 1990; Henderson and Smale, 1990; Thompson et al., 1990) and these dose estimates should be used in lieu of those in this report.

Table 5 also gives the fraction of the exposure occurring in various time intervals. One can see that that the exposure rate falls off rapidly with time and that over 80% of the exposure occurs in the first 20 d for an arrival time of 12 h. Thus only a small fraction of the total exposure (about 1% as shown later) is incurred in the year(s) after the test occurred unless the tests were very late in the year, particularly for locations where the fallout arrived within a day or two. The drop-off in exposure rate was of course accentuated by the penetration of the activity into the soil with time. Previous calculations that did not take this penetration into consideration overestimated the total exposure. Note that the common assumption of a $t^{-1,2}$ decay rate and no penetration would imply only about 50% of the dose being incurred in the first 20 d!. The difference results not as much from the greater penetration with time but more to the fact that the exposure rate drops off much more rapidly than $t^{-1.2}$ after 20 d (Hicks, 1981).

Table 5: Relative Exposure rate and total exposure versus time of arrival (TOA)*

TOA, d	Exposure rate, mR/h	Total Exposure (50 y), mR
0.25	2.1	53
0.5	1.0	45
1.5	0.30	33
2.5	0.17	27
3.5	0.12	24
5.5	0.071	20
10.5	0.035	14
20	0.015	6

**values are for shot HARRY but are similar for all tests.*

The exposures calculated in this report are generally based on estimates or measurements of radionuclide deposition densities and conversion factors from deposition density to exposure rate. Very few actual measurements of exposure were made outside the immediate vicinity of the NTS. However, for states immediately downwind from the NTS, all available data was used to estimate deposition densities including actual exposure rate measurements if any (Beck and Anspaugh, 1991; Beck, 1996). The conversion factors relating deposition density to exposure rate in air have been validated in many studies and as mentioned previously are believed to be accurate to better than 5% for a given depth distribution (NCRP, 1999).

Whole Body Effective Dose

In order to calculate the whole-body dose from the free-in-air exposure data, one must first convert exposure to dose in air by multiplying by a factor of 0.875 rad/R. Then, to convert to dose in tissue and account for shielding by the body, one must convert from rads in air to rem (or in S.I. units, Gy to Sv). In this report we chose to follow the ICRP guidelines (ICRP, 1991) and estimate the effective whole body dose that weights the effects on various organs in a proscribed manner. The UNSCEAR (1993) recommends a factor of 0.75 ± 0.05 to convert from Gy to Sv for adults. This is similar to average values recommended by the ICRP and others (NCRP, 1999). This factor of course varies with the energy of the radiation and the orientation with respect to radiation incidence (NCRP, 1999, Eckerman and Ryman, 1993). However, a value of 0.75 is a reasonable average for fission products (NCRP, 1999). The net conversion from exposure in air to effective dose is thus about $0.875 * 0.75 = 0.66$ for adults. Calculations using computer phantoms have indicated that the effective dose to young children is about 30% higher (NCRP, 1999).

Thus the dose to adults exposed outdoors is about 2/3 of the outdoor exposure. However, most people spend most of their time indoors and thus their exposure is reduced greatly

due to attenuation of the radiation by building materials. The amount of shielding (i.e. the shielding factor) will depend on the type of structure. In general, based on a review of the available literature, it is estimated that heavily constructed buildings made of brick or concrete will provide a shielding factor of about 0.2 ± 20% (1 s,d,) while lightly constructed buildings will provide a shielding factor of about 0.4. ± 20% (NCRP, 1999). These estimates are fairly conservative and allow for a small amount of radioactivity that may be tracked into the home from contamination of shoes, etc. Assuming that on average most persons spend about 80% of their time indoors (UNSCEAR, 1993; NCRP, 1999) with an average shielding factor of 0.3, their whole body effective dose would be 0.66 * (0.2 + 0.8 * 0.3) = 0.29 x Outdoor exposure. However, the UNSCEAR estimated that persons who work outdoor spend on average only 40% of their time indoors and the most exposed outdoor worker spends only about 30% of his/her time indoors. The NRC (1977) made a similar estimate of 40% of time spent indoors for the maximum exposed individual. Assuming only 30% indoors in a lightly shielded structure for the maximum exposed outdoor worker, the dose to the most exposed individuals would be
0.66 * (0.7 + 0.3 * 0.4) = 0.54 x Outdoor exposure or almost twice that of the average exposure. Conversely, the UNSCEAR (1993) estimated indoor workers spend only about 10% of their time outdoors while other estimates indicate some individuals spend even less time outdoors. Assuming 5% as a reasonable estimate for the least exposed individual living in a well shielded house and/or working in a well shielded building, the minimum exposed individual would receive a dose of about 0.66 * (0.05 + 0.95 * 0.2) = 0.16 x outdoor exposure, or about ½ that of the average dose.

Thus the actual dose to any individual can range by about a factor of four depending on the amount of time spent outdoors and the type of structure the individual lives and works in. The dose to children could be about 30% higher than that for adults for the same fraction of time outdoors. In this report, all calculations of dose are based on the average exposure given above and estimates for any individual should be adjusted up or down based on the above discussion.

Note that no additional uncertainty has been incorporated in the dose estimates in this report above that for the uncertainty in the underlying deposition density estimates that were used to estimate exposure. However, using a S.D of ± 20% for the shielding factors, ± 0.05 for the conversion from rad to rem, and 0.8 ± 0.05 for the fraction of time spent indoors by an average individual implies that the uncertainty (one S.D.) in the average conversion from exposure to dose of 0.3 is about 0.04, or about 10%. Even for the sum over all tests, the uncertainty (GSD) in the outdoor exposure in a given county averages about 1.3 (GSD). Thus, this additional uncertainty in converting to dose can be ignored provided one adjusts their individual dose estimate for time spent outdoors on average, particularly during the first few weeks after each test.

Beta Skin Dose

All of the exposures and doses discussed above refer to exposure to gamma radiation from the fission products deposited onto the ground. However almost all of the gamma emitting radionuclides also emit beta rays and a number of fission products emit beta rays but no gamma rays. Because of their low penetrating power, beta rays are attenuated rapidly in soil and even in air and thus contribute little to whole-body radiation exposure (Eckerman and Ryman, 1993; NCRP, 1999). However beta rays can contribute to the dose to skin, particularly in the days immediately following fallout before the activity has penetrated more deeply into the soil. Because the beta radiation is so sensitive to the actual depth distribution in the soil, only a very crude estimate can be made of the dose. Thus the beta skin dose has been estimated only for a single test, HARRY. The variation in beta dose from test to test is expected to be negligible compared to the variation due to variations in depth distribution (penetration rate) in the soil.

Besides the beta radiation itself, the beta rays produce a small amount of gamma radiation via bremsstrahlung (Eckerman and Ryman, 1993). This gamma radiation, although only a small fraction of the energy of the beta ray itself, can produce a small whole-body exposure and add to skin dose. Furthermore, it is generally the only way a beta emitter can irradiate body organs other than the skin. In order to account for both beta radiation itself as well as the accompanying bremsstrahlung, we have used the dose factors calculated by Eckerman and Ryman (1993) to estimate doses to skin for the deposition densities of the various fission products reported in Hicks (1991). Unfortunately, however, Eckerman and Ryman (1993) do not separate out beta and gamma dose contributions in their tabulated results and also did not calculate values for exponentially decreasing concentrations in soil. Thus the beta dose for beta-gamma emitters for a 1 cm slab source was inferred by plotting their doses for pure beta emitters versus their total energy of emitted betas and using this curve to estimate the beta doses from beta-gamma emitters. The dose for a source with a 0.1-cm relaxation length, corresponding to the distribution used for gamma rays for the first 20 days, was then estimated. For this estimate, it was assumed that all the activity is contained in a 0.144 cm thick slab, corresponding to the mean depth of a 0.1 cm relaxation length exponential distribution and that any activity from depths greater than that would not contribute significantly due to attenuation. Thus the skin dose values from Eckerman and Ryman (1993) for a 1-cm slab with 1 Bq/cm^3 were multiplied by a factor of 5.3 to correspond to the concentration in a 0.144-cm slab for a deposition density of 1 nCi/m^2 with a 0.1 cm relaxation length.

The beta skin dose from fallout distributed with a 0.1-cm relaxation length was then calculated to be about 25-50% of that from a plane source on the soil surface, depending on the age of the fallout. The early fallout contains a greater fraction of higher energy beta rays and thus the attenuation in soil is lower. The results of these calculations are presented in the next section and compared to the gamma ray exposure results.

Results

Fallout Deposition

The total deposition density of Cs-137 from all NTS tests examined through 1962 is shown in Figure 1. The pattern of deposition is similar to that for I-131, shown in Figure 2 (from NCI, 1997) although, due to its long half life, the drop-off in activity in the eastern U.S. is less than that for I-131. Deposition densities range from less than 5 mCI/km^2 in the western and northwestern states to over 20 near the NTS. As for the I-131 deposition, the regional and local variations are due to variations in precipitation, which is the main fallout mechanism at distances remote from the test site. The well documented elevated region in northern New York State was due to heavy thunderstorm activity during passage of the cloud from shot SIMON in April, 1953 (NCI, 1997; Beck et al., 1990). The deposition density patterns for most of the other radionuclides covered in this report were in general intermediate to the patterns for Cs and I, with any differences reflected by the differences in respective half lives.

The deposition density data for each test for all covered nuclides is contained in the database accompanying this report. However, the patterns for Sr-90 and Pu-239+240 vary somewhat from those for Cs-137 and I-131due to the differences in Sr and Pu production as a function of the device fuel. Figure 3 shows the ratio of total Cs-137 to total Sr-90..Figure 4 is for the ratio of Cs-137 to Pu-239+240. Note that the Cs to Sr ratio varies from about 0.8 to 1.9 with relatively low Sr deposition in Idaho, western Montana, western Nevada and the S.E. states and relatively higher Sr deposition relative to Cs in areas of the Midwest. The differences, of course, reflect the fact that the fallout in different regions resulted from different test(s). The Cs/Pu ratios, shown in Figure 3 vary from 3 to over 50. The highest relative Pu deposition was in counties near the NTS. However, areas in the mountain states, eastern NM and the Midwest exhibited generally low relative Pu deposition. For most of the country, the Cs to Pu activity ratio was about 10-20. As discussed previously, the Pu estimates in this report for any particular county are very uncertain and should be viewed only as illustrative of the variations across the country due to the varying tracks of Pu-fueled tests versus U-235-fueled tests. The number of counties within each range is shown in parenthesis in the figure captions.

Figure 5 shows the fraction of the total Cs-137 deposition in the continental U.S. resulting from each test series. The 1957 Plumbbob series deposited 35% of the total Cs followed by the 1953 Upshot Knothole series (23%). Of course the fraction of the total deposition in a particular year for any particular county will differ from this distribution due to the varying fallout tracks during different years. (The maps shown later of external exposure versus year reflect the relative annual depositions of fission products in each area). The ten tests depositing the most Cs in the continental U.S. are shown in Figure 6, while Figure 7 shows comparable data for the population-weighted deposition density.

Two tests from the 1953 UPSHOT-KNOTHOLE series deposited the most Cs-137 (SIMON and HARRY). HARRY also deposited the most I-131 (NCI, 1997). The comparable plot for the tests resulting in the highest population-weighted deposition density differs somewhat from the total deposition. Foe example, HARRY's impact on a population-weighted basis was much less than for total deposition, reflecting the fact that the fallout tracks and deposition patterns for each test differed, sometimes significantly (NCI, 1997; Beck et al., 1990).

The total amount of Cs-137 deposited in the continental U.S. from all tests was 62500 Ci. The total deposition for a number of other selected radionuclides is shown in Table 6.

The total deposition density was calculated for several radionuclides in order to compare with the deposition from "global" fallout as reported by UNSCEAR (1993). For this purpose, the calculated values for each county were weighted by population and then summed. Because of the sharp gradations in deposition from west to east, and the higher populations in the eastern U.S., these population-weighted values are slightly less than the mean unweighted deposition obtained by dividing the total deposition by the total area of the continental U.S. However, they are a fairer indicator of the impact the deposition had with respect to both external and internal population doses. The resulting population-weighted deposition densities for the U.S. are given in Table 6 and compared with corresponding estimates by UNSCEAR for the 40-50 degree latitude band of the northern hemisphere

Table 6: Total deposition and population-weighted mean deposition density of selected radionuclides for NTS fallout and "global" fallout.

Nuclide	Total Deposition (kCi)	Population weighted Deposition density ($nCi\ m^2$)	
	NTS	NTS	"global fallout"**
Cs-137	62.5	6.9	140
Sr-90	49.2	5.3	87
Zr-95	5900	680	1030
Ru-103	11500	1240	760
Ba-140	37600	3900	620
Ce-141	13500	1460	570
Ce-144	1070	123	1300
Ru-106	635	71	650
Sr-89	9000	980	540
I-131	40100	5200	513
Pu-239+240	3.6#	~0.42	1.6
Pu-241	14.6	~1.6	20

**f*or 40-50 degree latitude band, # About 5% of total is from the decay of Np-239.*

Thus for the long-lived radionuclides, NTS fallout contributed only about 5% of the total deposition. The deposition of short-lived radionuclides such as Sr-89, Ba-140 and I-131 was several times that of "global" fallout. These results are consistent with the fact that although the total fission yield of NTS tests was only about 1 MT, compared to about 150 MT for tests outside the U.S., most of the debris from the large thermonuclear tests outside the U.S. was injected into the stratosphere. According to the UNSCEAR (1993), the average residence time for this stratospheric debris before re-entering the troposphere and depositing is about 1 y. This delay in fallout coupled with a more uniform deposition over the entire globe accounts for the reduced impact of global fallout and in particular the very much-reduced short-lived activity relative to the amounts produced.

Another factor contributing to the greater deposition per unit yield in the continental U.S. of NTS tests is the fact that tests detonated near the ground, either on the surface or from relatively low towers, deposit a large fraction of their debris locally and regionally compared to tests detonated higher in the atmosphere. Figure 8 compares the cumulative Cs-137 deposition versus distance from the NTS as a fraction of that produced for various types of tests. Figure 9 compares the deposition as a fraction of the total deposited in the U.S. From Figure 8, one sees that less than 10% of the activity produced in an air burst deposits within 4,400 km (or within the continental U.S.) compared to about 45% for tower and surface shots. Balloon-borne devices deposited 30% in the U.S., less than tower shots but much more than air bursts. (The height of detonation for balloon shots was generally on the order of 500 m compared to ~100-200 m for tower shots (Beck, 1984)). For all NTS tests, 34% of the Cs-137 produced deposited in the continental U.S. In terms of the total deposited in the U.S., all types of tests deposited the same approximate fraction of their total U.S. deposition at distances greater than 2,000 km. However, tower shots, as expected, deposited a greater fraction very close to the NTS, while air bursts seemed to deposit a greater fraction from 1,500-2,500 km.

Overall, air bursts deposited only about 8% of the total activity produced within the continental U.S., consistent with the UNSCEAR estimate of an average tropospheric residence time of 30 d. assuming a cross-country transit time of about 4 d on average.

The estimates of total deposition and fractional deposition discussed above of course rely upon the accuracy of the underlying I-131 deposition densities calculated by interpolating a relatively small number of gummed film measurements and weighting interpolated values by measured precipitation (NCI, 1997). However, most of the random uncertainty in total deposition is averaged out when summing over a large number of tests, days per test, and counties. The calculated propagated uncertainty in total deposition is less than 5% (GSD < 1.05). This assumes of course that there is no large systematic error and that the daily deposition estimates are not correlated. The values for a particular day are correlated with values for nearby counties since that is the basis of the kriging method used (see NCI, 1997), however, results from one day to another and one test to another should not be correlated.

Exposure and Dose

The geographical distribution of total whole-body effective dose from all NTS tests for a typically exposed individual (80% indoors, 0.3 shielding factor) is shown in Figure 10. The specific mean and GM free-in-air exposures for each county for each test, year, and total NTS are included in the database that accompanies this report. The interested reader can estimate his/her exposure and dose by multiplying by the appropriate indoor/outdoor and shielding factor correction factor as discussed in the previous section. As expected, the dose pattern is similar to the I-131 deposition pattern presented in NCI (1997) since the exposure rate is closely related to the deposition of short-lived radionuclides. The most exposed were individuals who lived in states immediately downwind from the NTS. However, pockets of higher and lower exposures occurred throughout the U.S. as a result of the uneven deposition of fallout and the variation in tracks of the many tests that contributed. The geographical distribution of doses varied significantly from year to year as shown in Figures 11-16. As can be seen, the 1952 TUMBLER-SNAPPER series impacted areas to the north of the NTS more than did the tests in other years, while the fallout from the 1955 TEAPOT series was concentrated in the center of the U.S. The 1957 Plumbbob series accounted for much of the exposure to residents of ND, MN and surrounding areas.

The relative impact of various test series was investigated by calculating the population exposure, i.e. the product of the exposure for a given county multiplied by its population, and then summing over all counties. The population exposure versus year of exposure is given in Table 7.

Table 7: Population exposure and per capita exposure versus year of exposure.

Year	Annual	50 y Committed	per capita
	-------10^6 person-R----------		mR
1951	2180	2250	13
1952	5040	5310	31
1953	6320	6630	39
1954*	56		0.34
1955	3930	4170	24
1956*	37		0.23
1957	6730	7530	41
1958*	275		1.7
1962	1570	1640	9.7
Total NTS	26400	27900	162 (49 mrem), 171 committed

**From previous years fallout.*

The uncertainty in the above calculated population exposures was less than 1.1 (GSD) for all years except 1951 and 1962. The GSD for 1951 was 1.2 due to the large uncertainty in the I-131 deposition density estimates for some of the early Ranger series tests. The GSD for the 1962 fallout, which was due mainly to the SEDAN cratering shot, is very large, 1.8, again due to very uncertain estimates of I-131 deposition. The population exposure for each year includes that from fallout in that year plus from fallout in the previous year, if any. The per capita exposure of 162 mR corresponds to an average whole body effective dose of about 0.5 mSv (50 mrem), for the years of testing, about what an average person would receive from natural background radiation in 1-2 years depending on the area of the country. Residents of some counties near the NTS received doses in excess of 3 mSv (300 mrem) while residents of the extreme Western and Northwestern states and some Midwestern counties received average doses less than 0.25 mSv (25 mrem). The committed (50 y) dose from all NTS tests is about 5 % higher than the dose received during the testing years. In contrast, the UNSCEAR, 1993, has estimated the population-weighted per capita dose from external radiation from “global” fallout in the latitude band 40-50 degrees to be about 1 mSv. Twenty-five tests accounted for over 80% of the population exposure but no single test accounted for greater than 7%. The ten top contributors that account for about 50% of the population exposure are shown in Figure 17. Again, the impact of the SEDAN shot is very uncertain (GSD = 1.8) while the GSD of the population exposures for the other 9 tests are all in the range 1.1-1.3.

A large number of fission products are produced in a nuclear explosion. However, only a relatively few account for most of the external exposure. Different radionuclides contribute significantly to the exposure rate at different times and thus determination of the most important radionuclides with respect to total exposure depends on the time of arrival of the fallout. Table 8 shows the largest contributors to total integrated exposure (% of total integrated exposure from nuclide and decay products) for several different times of fallout arrival. The data are for shot HARRY but vary only slightly from shot to shot with volatile nuclide contribution being greater for tower and surface shots as opposed to air bursts. However, as shown earlier, the surface and tower shots account for most of the radiation exposure to the population of the continental U.S. As can be seen, at early arrival times the short-lived iodine isotopes contribute relatively more to the exposure while after a few days, I-132, Ba-140, Zr-Nb-95 and Ru-103 dominate. I-132 is a major contributor even for later arrival times. Note that by contrast, most of the external dose from “global” fallout was due to the longer-lived nuclides, with Cs-137 accounting for about 50% of the exposure and Ru-103, Ru-106, Ce-Pr-144 and Zr-Nb-95 most of the remainder (UNSCEAR, 1993). In contrast, these nuclides contribute only small amounts to the integral dose from NTS fallout.

Figures 18 through 22 show the fraction of the total dose from all NTS tests that resulted from Te-I-132, Ba-La-140, Zr-Nb-95, Np-239, and Ru-103, respectively. Note that as expected from the dependence on arrival time shown in Table 8, the shorter-lived nuclides such as Np-239 (2.4 d) have a larger impact close to the NTS while the relative contribution of nuclides with relatively long half lives such as Zr-95 (64 d) is much greater at large distances from the NTS. Because of this strong dependence on time of fallout arrival, the radionuclide composition accounting for the total exposure varies significantly with distance from the NTS.

Table 8: Percentage of total integral exposure contributed by various fission products as a function of fallout arrival time

TOA= Nuclide	0.5 d (%)	2.5d (%)	5d (%)
Te-I-132	23	27	20
Ba-La-140	21	35	43
I-133	13	3	<1
Np-239	6	6	4
Zr-Nb-95	6	10	14
Zr-Nb-97, 97m	6	1	<1
I-135	5	<1	<1
Ru-103	3	6	7
I-131	3	4	4

The doses discussed above are from gamma irradiation. Table 9 presents the estimates of the ratio of beta skin dose to whole body gamma dose outdoors for shot HARRY as a function of time of arrival of fallout. This ratio is about 2 for fallout shortly after the test but falls to about 1.0 after a few days. The ratio of dose rates is about 5 at early times and falls to about 1 at about 5d. Note that it has been assumed that the beta dose can be neglected after 20 days. The activity is then assumed to be distributed with a relaxation length of 1 cm, deep enough to reduce the beta-ray flux to a negligible level. The beta dose estimates determined here are in reasonable agreement with previous results. For example the ICRU (1977) estimated the beta skin dose rate from a plane source of fission products to be about 8-16 times the total effective dose. The ratio of dose rates for a 0.1 cm relaxation length for early arrival times is about 3-5 from Table 9. Dose rate ratios calculated for a plane source for the same beta spectrum (HARRY) ranged from about 7-11 over the first 2-3 days, with the higher value, that likely corresponds better to the beta ray spectrum assumed by the ICRU, corresponding to earlier arrival times. Only a relatively few nuclides emitting higher energy beta rays contribute significantly to the dose: Rb-88, Sr-91, Y-92, Y-93, Sb-128, Te-129, I-132. I-133, I-135, Ce-143, and Pr-145. The relative contributions of each to the total dose depended on fallout time-of -arrival.

The actual impact of beta exposure is of course even less than the ratios in Table 9. The average individual would be exposed to beta radiation only for the 20% of time spent outdoors, resulting in an actual beta skin dose to gamma whole body dose ratio of about 0.2-0.4. Furthermore, since the radio-sensitivity of the skin is generally accepted to be much lower than for other organs, even the beta dose to the most exposed individuals who spend up to 70% of their time outdoors can be considered insignificant compared to their whole-body gamma exposure.

Two sources of beta radiation exposure might be significant in some cases. One is the direct deposition of radioactivity onto the skin during cloud passage. The second is contamination to the skin from children playing in contaminated soil, both from soil adhering to the skin as well as due to a closer proximity to the source. The former case is only of significance to individuals living close to the test site and was considered by Henderson and Smale (1990), in the ORERP study. Neglecting the dose from soil adhering to the skin, the dose to a child playing on the ground would probably be about a factor of two higher than that to a standing adult due to the closer proximity to the source plane. However, this would still probably not constitute a significant exposure. A more significant exposure route would likely be direct ingestion of soil (NCRP, 1999).

Table 9: Beta ray skin dose divided by whole body gamma dose as a function of fallout time of arrival-shot HARRY

Time of arrival, d	dose rate ratio	integrated dose ratio*
0.5	4.8	1.9
1.5	3.0	1.3
2.5	1.5	1.1
5.5	1.1	0.8
10.0	0.7	0.4

**100% outdoors*

Summary and Conclusions

Fallout from atmospheric tests at the NTS resulted in an average external radiation exposure of about 0.5 mSv to the population of the U.S., about half of that incurred from “global” fallout from the large-scale testing outside the U.S. However, residents in the states immediately downwind from the NTS received much higher exposures while the exposures in the Western and Northwestern U.S. and some areas of the Midwest and Southeast were much less than the average. Most of this exposure occurred with the first 3 weeks of each test and was due to relatively short-lived radionuclides. In contrast, the exposure from “global” fallout occurred over a much greater span of time (1952-62) and primarily from a few long-lived radionuclides. Thus the dose rate was more uniform with time. Almost the entire whole-body effective dose to the population was from gamma rays emitted by fission products deposited on the ground. The actual dose received by any individual depended on the fraction of time he/she spent outdoors during the first few weeks after fallout and the degree of shielding provided by his/her dwelling. The most exposed individuals at any particular location would have been outdoor workers or others who spent most of their day outdoors. Beta radiation from fission products in the surface soil did result in additional dose to the skin when outdoors. However, this contribution was not large enough to be considered an important component of total fallout radiation exposure except perhaps for children who played in the soil for significant intervals of time.

The deposition of fission products contributed to internal radiation exposure via ingestion as well as external exposure. The deposition densities of all nuclides that could contribute significantly to ingestion doses were calculated for this study although the internal doses via ingestion will be treated in a separate report. It is noteworthy that the deposition of long-lived nuclides was much less than from global fallout, while the deposition of short-lived radionuclides was generally higher. About 1/3 of the fission products produced by the roughly 1 MT of NTS explosions was deposited within the continental U.S. Surface shots and shots conducted on towers produced much more fallout in the U.S. per unit yield than air bursts.

The annex to this report, in the form of Excel spreadsheet files, gives the calculated deposition densities of all the radionuclides considered for each test for each county of the U.S. The free-in-air exposure resulting from each test and test series is also tabulated for each county. By accessing the data for their particular county of residence for any given year(s) and applying the appropriate correction factor to convert from exposure to dose by adjusting for the actual fraction of time spent outdoors, the interested reader can estimate his/her whole body dose from NTS fallout.

Three appendices follow. Appendix 1 provides a detailed example of the calculation of deposition density and exposure for a representative county to illustrate the calculational procedure. The other two appendices are included to satisfy the scope of work given in the introduction of this report. The first is a bibliography of additional references on weapons testing in Nevada and assessments thereof. The second discusses the need for declassification of documents that might improve our ability to assess the impact of fallout from weapons testing, both within the U.S. and outside the U.S., on the American population.

References

Anspaugh, L.R. and Church, B.W. Historical estimates of external gamma exposure and collective external gamma exposure from testing at the Nevada test site. 1.Test Series through Hardtack II, 1958. Health Physics **51**:35-51; 1986.

Beck, H.L., Environmental gamma radiation from deposited fission products, 1960-1964. Health Physics **12**:313-322, 1966.

Beck, H.L. Exposure rate conversion factors for radionuclides deposited on the ground. US Dept. of Energy report EML-378. NTIS, Springfield, VA, 1980.

Beck, H.L. Estimates of fallout from Nevada weapons testing in the western United States based on gummed-film monitoring data. U.S. Department of Energy report EML-433. Environmental Measurements Laboratory, New York, October 1984.

Beck, H.L. and Krey, P.W. Cesium-137 inventories in undisturbed Utah soils-interim report on radionuclides in soils of populated areas. . U.S. Department of Energy report EML-375. . Environmental Measurements Laboratory, New York, June 1980.

Beck, H.L., I.K. Helfer, A. Bouville, and M. Dreicer. Estimates of fallout in the western U.S. from Nevada weapons testing based on gummed-film monitoring data. Health Phys. **59**(5): 565-570; 1990.

Beck, H.L. Reconstructing source terms from environmental data. Proceedings of the Thirty-First Annual Meeting of the National Council on Radiation Protection and Measurements. Proceedings No. 17, pp. 79-91. NCRP, Bethesda, MD, 1996.

Beck, H.L. and L.R. Anspaugh. Development of the County Data Base: Estimates of exposure rates and times of arrival of fallout in the ORERP Phase-II area. Comparison with cumulative deposition-density estimates based on analyses of retrospective and historical soil samples. U.S. Department of Energy report DOE/NV-320; 1991.

Church, B.W.; Wheeler, D.L.; Campbell, C.M.; Nutley, R.V.; Anspaugh, L.R. Overview of the Department of Energy's Off-Site Radiation Exposure Review Project (ORERP). Health Phys. **59**:503-510; 1990.

Eckerman, K. and Ryman, J.C. Dose Coefficients for external exposure to radionuclides distributed in air, water and soil, Federal Guidance report 12. USEPA, Washington; 1993.

England, T.R. and Ryder, B.F., Evaluation and Compilation of Fission Product Yields, 1993. Las Alamos National Laboratory report LA-UR-94-3106 (ENDF-349); 1994.

Gale, H.J., Humphrey's, D.L.O., and Fisher, E.M.R. The weathering of caesium 137 in Soil. Nature **201**, 257.;1964.

Henderson, R.W.; Smale, R.F. External exposure estimates for individuals near the Nevada Test Site. Health Phys. **59**(5):715-721; 1990.

Hicks, H.G. Results of calculations of external radiation exposure rates from fallout and the related radionuclide composition. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-53152, parts 1-8; 1981.

Hicks, H.G. Calculation of the concentration of any radionuclide deposited on the ground by off-site fallout from a nuclear detonation. Health Phys. 42:585-600; 1982.

Hicks, H.G., Report on Plutonium Isotopic Ratios, Reporters transcript of ninth dose assessment Advisory group Meeting, Feb. 17, 1984, Vol II, USDOE Nevada Operations Office, 1984 (CIC #41989); 1984.

Hicks, H.G. Additional calculations of radionuclide production following nuclear explosions and Pu isotopic ratios for Nevada Test Site events. Health Phys. **59**(5):515-523; 1990.

Hicks, H.G.and D.W.Barr. Nevada Test Site atom ratios: 240Pu/239Pu and 241Pu/239Pu, Univ. CA Radiation Laboratory, UCRL-53499/1; Feb. 1984.

ICRP. International Commission on Radiological Protection., 1990 Recommendations of the International Commission on radiological protection, ICRP Pub. 60, Annals of the ICRP **21**, Pergamon Press, Elmsford, NY; 1991.

ICRU. Dosimetry of External Beta Rays for Radiation Protection. Report of the International Commission on Radiation Units and Measurements, ICRU-56. ICRU, Bethesda, MD;1997.

Jacob,P., Paretzke, H.G., Rosenbaum, H. and Zankl, M. "Effective dose equivalent for photon exposures from plane sources on the ground", Radiat. Prot. Dos. **14** (4), 299-310; 1986.

Krey, P.W. and Beck, H.L. The distribution throughout Utah of 137Cs and 239+240Pu from Nevada Test Site detonations. USDOE report EML-400. NTIS; 1981.

Likhtariov, I, Kovgan, L.,Novak, D., Vavilov. S, Jacob, P, and Paretzke, H.G.. Effective doses due to external radiation from the Chernobyl accident for different population groups of Ukraine. Health Physics **70**. 87-98; 1996.

Miller, K.M. and Helfer, I.H.. In situ measurements of Cs-137 inventory in natural terrain, p 243-252 in Environmental Radiation '85, Proceedings of the 18^{th} topical Symposium of the Health Physics Society. Health Physics Society, McLean, Va.; 1985.

Miller, K.M., Kuiper, J.L. and Helfer, I.K. Cs-137 fallout depth distributions in forest versus field sites-implications for eternal gamma dose rates, J. Env. Radio. **12**, 23, 1990.

National Cancer Institute. Estimated exposures and thyroid doses received by the American people from Iodine-131 in fallout following Nevada atmospheric nuclear bomb tests; October 1997.

NCRP. Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies. National Council on Radiation Protection and Measurements report. #129. NCRP, Bethesda, MD; 1999.

Ng, Y.C.; Anspaugh, L.R.; Cederwall, R.T. ORERP internal dose estimates for individuals. Health Phys. **59**:693-713; 1990.

NRC. US Nuclear Regulatory Commission. Calculation of Annual Doses from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I. Regulatory Guide 1.109, rev. 1. USNRC, Washington; 1977.

Thompson, C.B.; McArthur, R.D.; Hutchinson, S.W. Development of the Town Data Base: Estimates of Exposure Rates and Times of Fallout Arrival Near the Nevada Test Site. Springfield, VA: National Technical Information Service; DOE/NVO-374; 1994.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly. United Nations report. E.88.IX.7. United Nations. New York; 1988.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. 1993 Report to the General Assembly, with scientific annexes. UN pub. E.94.IX.2. United Nations, New York; 1993.

Appendix 1: Example of Calculation Procedure

In this appendix, the calculation of the deposition density of Ba-140 and of Cs-137 for a particular arbitrarily chosen county, St. Louis (FIPS=29189), from shot HARRY, 5/19/53, is shown in detail. The calculation of the total external exposure for St. Louis County resulting from shot HARRY is also illustrated.

DEPOSITION DENSITY

All calculations start with the measured effective I-131 reported by the NCI (1997). These measured I-131 values (mCi/km^2) for St. Louis County for various days after the detonation (TOA) are shown in the second column of Table A1. As discussed in the text a TOA of 1.5 d refers to fallout on the second day after the detonation or in this case on 5/20/53, etc. The corresponding GSD reported in NCI (1997) is given in column 3. The effective I-131, denoted as I-131*, is just the measured value decayed back to H+12 h (column 5). The effective I-131 includes the contributions of I-131 that will subsequently grow in from Te-131 and Te-131m since these contributions are included in the reported measured I-131 (NCI, 1997).

In order to calculate the corresponding Ba-140 and Cs-137 for each day with I-131 deposition it is necessary to know the ratios of Ba-140/I-131* for each of these days. These values, from Hicks (1981) are given in columns 5 and 6, respectively. Note that the values in the Hicks Tables (Ci/km^2) for all nuclides are normalized to a unit exposure rate of 1 mR/h at H+12 h. In each case the value of Ba-140 or Cs-137 for the particular TOA was obtained from the Hicks (1981) Table for test HARRY and divided by the corresponding I-131* H+12 h value from Hicks for test HARRY, .819 mCi/km^2. The latter value was obtained from the tabulated values for test HARRY for I-131, Te-131, Te-131m at H+12 h (I-131* =[I-131 *193 h + Te-131m * 30 h + Te-131 * 0.417 h] / 193h) and represents the total I-131 at H+12h plus the I-131 that will subsequently grow in from Te-131 and Te-131m.

Table A1: Measured I-131 deposition density (mCi/km^2), ratios of Ba-140 and Cs-137 to I-131*, and calculated Ba-140 and Cs-137 deposition densities (mCi/km^2).

TOA, d	I-131	GSD	I-131*	Ba-140/I*	Ba-140	Cs-137/I*	Cs-137
0.25	0			0.85		0.00121	
0.5	0			0.83		0.00121	
1.5	20	2	21.8	0.78	17.0	0.00121	0.026
2.5	16	2	19.0	0.74	14.1	0.00121	0.023
3.5	50	2.5	64.8	0.70	45.3	0.00121	0.078
4.5	8	2	11.3	0.66	7.5	0.00121	0.014
5.5	16	1.5	24.6	0.63	15.5	0.00121	0.030
6.5	16	1.5	26.8	0.59	15.8	0.00121	0.032
7.5	0			0.57		0.00121	
8.5	0			0.54		0.00121	
9.5	0			0.51		0.00121	
10.5	0			0.48		0.00121	

Multiplying the Ba-140/I-131* and Cs-137/I-131* by the measured I-131* provides the estimated GM deposition densities of Ba-140 and Cs-137 for each day of fallout. Since the uncertainty in the Hicks (1981) ratios of deposition densities is assumed to be minor compared to the larger uncertainty in the measured deposition densities, the GSD for Ba-140 and Cs-137 are assumed to be the same as that for the corresponding measured I-131.

In order to calculate the total Ba-140 and Cs-137 deposition densities for this county from shot HARRY, one must sum the daily values. However, one cannot sum GM values so one must first convert each daily GM to the corresponding mean. As discussed in NCI (1997), the conversion is given by mean, $m = GM * \exp(0.5 * s^{2)}$ where $s^2 = \ln(GSD)$. The corresponding variance, $var = m^2 = [\exp(s^2) - 1]$. Table A2 gives the calculated means and variances for the days with fallout.

Table A2: mean and total deposition densities (mCi/km^2).

	Ba-140			Cs-137		
TOA	GM	mean	var	GM	mean	var
1.5	17.0	21.6	288.4	0.0264	0.0335	0.000694
2.5	14.1	17.9	197.4	0.0230	0.0292	0.000528
3.5	45.3	69.0	6258	0.0784	0.119	0.0187
4.5	7.45	9.48	55.4	0.0137	0.0174	0.000186
5.5	15.5	16.8	50.7	0.0298	0.0323	0.000187
6.5	15.8	17.2	52.8	0.0325	0.0353	0.000222
SUM:		152	6903		0.267	0.0205
GM =		134			0.235	
GSD =		1.7			1.7	

The mean of the total deposition density of Ba-140 is thus 152 mCi/km^2 with a variance of 6003. As discussed in NCI (1997), the sum of lognormally-distributed distributions can themselves be assumed to be approximately lognormally distributed with a GM given by GM = m / SQRT [1 + var / m^2] and a GSD given by GSD = exp [SQRT (ln {1 + var / m^2)}. Using these equations, the GM Ba-140 deposition density for this county for shot HARRY is thus 134 mCi/km^2 with a GSD of 1.7. The corresponding Cs-137 deposition density is 0.235 with a GSD of also 1.7.

In a similar manner, the deposition densities resulting from all other tests conducted in 1953 were calculated and the total Ba-140 and Cs-137 deposition densities from all 1953 (UPSHOT-KNOTHOLE) tests obtained by summing the **means and variances** of the individual test results. To obtain the total deposition density from all NTS tests, the means and variances calculated for each test series were summed. These sums are provided in the database that accompanies this report along with the calculated conversions to GM and GSD for each test, test series, and NTS totals.

Exposure

The calculation of free-in-air exposure again starts with the measured I-131* values and the I-131* value per mR/h at H+12 h (= 819 mCi/km^2) for HARRY given in Hicks (1981). The exposure rate at any time t is given by the deposition density at time t in mCi/km^2 multiplied by a dose rate conversion factor :R / h per mCi /km^2 taken from Beck (1980). As discussed in the text, these conversion factors are a function of the assumed depth distribution. For t < 20 d, a depth distribution with a relaxation length of 0.1 cm was assumed. This was the value used in Hicks (1981) for all times. For t > 20 d < 200 d, a relaxation length of 1 cm was assumed in this report, and for > 200 d, a relaxation length of 3 cm. The conversion factors for Ba-140, La-140 and Cs-137 for each relaxation length are given below:

Table A3: Conversion factors from deposition density to exposure rate, :R / h per mCi /km^2

Nuclide	RL =0.1 cm	RL- 1 cm	RL = 3 cm
Ba-140	2.41E-03	1.62E-03	1.10E-03
La-140	3.33E-02	2.28E-02	1.60E-02
Cs-137	9.28E-03	6.15E-03	4.32E-03

In order to calculate the total exposure rate as a function of time from TOA to the end of the year, and to 50 y after detonation for a particular test, it is necessary to sum the exposure rates per unit I-131* from each of a large number of radionuclides contributing to the total exposure rate at any particular time, multiply this total by the measured I-131* deposition density, and then integrate the total from all nuclides over the period of interest. For the first 20 d after detonation, a very large number of nuclides contribute to the exposure rate (>100). Since Hicks already calculated the total exposure rate per unit I-131* for this period for a range of t, it was not necessary to attempt to recalculate and tabulate the individual radionuclide exposure rates for this period. They can be obtained directly from the Hicks (1981) tables if desired. The exposure rates versus time per unit I-

131* for the first 20 d as reported in Hicks (1981) for shot Harry are given below (The reported exposure rates have been normalized to unit deposition density of I-131* by dividing by 819.

Table A4: Exposure rate versus time of arrival for test HARRY per mCi /km^2 I-131*

TOA (h)	mR/h
18	7.84E-04
21	6.57E-04
24	5.54E-04
48	2.50E-04
120	9.83E-05
240	4.54E-05
480	1.81E-05

In order to calculate the total exposure from any particular time of arrival (TOA) to 20 d after detonation, the exposure rates in Table A4 were fit to a function of the form a t^{-b} for the period 12 h to 20 d (480 h). The results of this fit for test HARRY was a = 5.62E-04; b=-1.0958 with a correlation coefficient r^2 of 0.9995. The integral from any time TOA to 20 d is then Ia t^{-b} dt = [0.4602/ (0.0958)] [$TOA^{-0.0958}$ –$20^{-0.0958}$]. The resultant total integral exposures from TOA to 20 d for various TOA are given in the second column of Table A5 below. Note that this formulation actually assumes a 0.1-cm relaxation length for times TOA to 20 d rather than for a period totaling 20 d after deposition. This is reasonable, however. As the time of arrival of fallout increases due to increasing distance of the fallout cloud from the NTS, a greater fraction of the deposition is due to washout from precipitation (NCI, 1997). This wet deposition resulted in greater penetration into the soil than that from the dry deposition that occurred near the NTS at early arrival times.

The exposure rate from 20 d post detonation to 200 d could not be taken from the Hicks (1981) tables directly since we use an exposure rate conversion factor that assumes a 1-cm relaxation length. However, the number of radionuclides contributing significantly to the total exposure during this period is much smaller (about 24). It was thus possible to use the actual time variation of the deposition density for each of these radionuclides multiplied by the appropriate dose rate factor from Beck (1980) to calculate the integral exposure for each for the desired interval. For example: the exposure rate for Cs-137 for the period 20 d to 200 d is given by:

I (t) :R/d = Cs(20 d) mCi /km^2 * 6.15E-03 :R / h per mCi /km^2 * 24 h/d * exp(-λ * (t-20 d)),

where Cs(20 d) is the deposition density of Cs-137 (per unit I-131*) at 20 d after detonation, from Hicks (1981) and λ = ln (2) / $T_{1/2}$.

The integral from 20 d to 200 d is thus:

I (mR) = Cs (20 d) * 6.15E-03 * 24 * 1/λ * [1 –exp (-180 * λ)]/ 1000.

The half life of Cs-137 is 11000 d (Table 2). The exposure rates of the other radionuclides contributing to the exposure rate during this period were calculated in a similar manner. Note that for a few radionuclides that grow in from precursors (e.g. Nb-95 from Zr-95), the activity versus time is a function of the parent activity and the analytical relationship is sometimes more complicated than that for a single radionuclide. The daughter to parent activity for these nuclides is given by $D/P = \square\ (T_{1/2\ p})/(T_{1/2p} - T_{1/2\ d}) * [1 - \exp(-\square_d - \square_p)\ t]$, where $\square$ is the number of daughter atoms produced per parent decay and the subscripts p and d stand for parent and daughter, respectively. This equation is easily integrated to provide the integral exposure of the daughter activity in a manner similar to that for the parent as described above. (If the daughter half life is short compared to that of the parent the activity of the daughter is approximately equal to that of the parent at all times, and the exposure rate is just the parent activity multiplied by the exposure rate conversion factor for the daughter).

Since HARRY was detonated on the 139^{th} day of the year (May 23), there were 226 d remaining in the year 1953. The total exposure for the year from a deposit on day TOA was thus the sum of the exposures from TOA-20 d, 20-200d and 200-226 d. For the last 26 days, the calculation was similar to that for 20-200 d except that the integration was from 200 d to 226 d and the deposition densities from 200-226 d were multiplied by the exposure rate conversion factors for a 3 cm relaxation length, rather than for a 1-cm relaxation length. For the year 1954, and for the remainder of the 50 y period for which the exposure was calculated, only a few radionuclides contributed to the exposure. Again, the integrated doses were calculated individually for each as shown above for Cs-137, integrating over the appropriate time interval.

Table A5 gives the final integrated exposure for each of the time intervals of interest, TOA-20 d, 20-200 d, the entire year (1953), 1954, 1955 – 50 Y, and the total = TOA - 50 Y. By multiplying each of these normalized exposure values by the corresponding measured I-131* for each day with fallout (from Table A1), one obtains the mean and GM exposures for St. Louis County for test HARRY shown in Table A6, along with the corresponding variances and GSDs. Again, the means are calculated from the measured GM, as described previously for the deposition density calculations, and then summed to obtain the total exposure resulting from all days of fallout. The total exposure from all tests in the year 1953, and from all NTS tests, was calculated in a similar manner by summing the mean exposures from each test.

Table A5: Integral exposure from time of arrival to 20 d, 20 d to end of year, 1953, 1954, TOA-50 y, per unit I-131* deposition density (mR per mCi/km2)

TOA	TOA-20 d	20 d- 226 d	1953	1954	1955-50Y	TOA-50 Y
0.25	0.0551	0.008108	0.0632	0.000404	0.001255	0.0649
0.5	0.0448	0.008108	0.0529	0.000404	0.001255	0.0545
1.5	0.0297	0.008108	0.0379	0.000404	0.001255	0.0395
2.5	0.0233	0.008108	0.0314	0.000404	0.001255	0.0330
3.5	0.0192	0.008108	0.0273	0.000404	0.001255	0.0290
4.5	0.0162	0.008108	0.0243	0.000404	0.001255	0.0260
5.5	0.0139	0.008108	0.0220	0.000404	0.001255	0.0237
6.5	0.0120	0.008108	0.0201	0.000404	0.001255	0.0218
7.5	0.0104	0.008108	0.0185	0.000404	0.001255	0.0202
8.5	0.0090	0.008108	0.0171	0.000404	0.001255	0.0188
9.5	0.0078	0.008108	0.0159	0.000404	0.001255	0.0176
10.5	0.0067	0.008108	0.0148	0.000404	0.001255	0.0165

Table A6: Total exposure from HARRY for St. Louis County, mR

	------------- For 1953--------------			--------- -TOA - 50 Y ---------------		
TOA	GM	mean	var	GM	mean	var
1.5	0.83	1.05	0.68	0.86	1.10	0.74
2.5	0.60	0.76	0.36	0.63	0.80	0.39
3.5	1.77	2.69	9.52	1.88	2.85	10.71
4.5	0.27	0.35	0.08	0.29	0.37	0.09
5.5	0.54	0.59	0.06	0.58	0.63	0.07
6.5	0.54	0.59	0.06	0.58	0.63	0.07
SUM:		6.02	10.75		6.39	12.07
GM =		5.28			5.68	
GSD =		1.7			1.7	

Although the exposure contribution from each radionuclide was not estimated separately in the database accompanying this report, the exposure from all tests for a few specific radionuclides was calculated from the corresponding deposition densities and used to prepare the data shown in Figures 18 through 22. These figures illustrate the fraction of the total exposure from these particular radionuclides. The mean deposition densities of each radionuclide for each test and test series is provided in the database and can be used to estimate exposures for a particular year from any particular radionuclide by multiplying by an appropriate dose rate conversion factor from Beck (1980).

Appendix 2: Additional Reading

(1) The history of nuclear weapons testing at the NTS:

Anders R.M., Holl, J.M., Buck, A.L. and Dean, P.C., The United States nuclear weapons program. A summary history. US Dept. of Energy report. DOE/E5-0005 (draft), March, 1983.

Frieson, H.N. A perspective on atmospheric nuclear tests in Nevada. Nevada Operations Office report. NVO-296; Aug. 1985.

Joint Committee on Atomic Energy. The nature of radioactive fallout and its effects on man, Congressional hearings transcript; 1997.

Joint Committee on Atomic Energy. Fallout from nuclear weapons tests, Congressional Hearings transcript; May, 1959)

U.S. Dept. of Energy. Announced United States Nuclear Tests, July 1945 through December, 1987. Nevada Operations Office report. NVO-209, Rev. 8; 1988.

(2) The production of important radionuclides during those tests:

Environmental Contamination from Weapons Tests. USAEC report. HASL-42; 1958.

Hicks, H.G. Radiochemical data collected on events from which radioactivity escaped beyond the borders of the Nevada test range complex. Lawrence Livermore National Laboratory report. UCRL-52934; Feb. 1981.

Radiological Health Data. U.S. Dept of Health, Education and Welfare, Public Health Service. Monthly reports, 1958+

Public Health Service. “Tabulation of findings, radiation surveillance network,” available from CIC, Las Vegas.

Schoengold, C.R., DeMarre, M.E., McDowell, E.M., Radiological effluents released from announced U.S. continental tests: 1961 through 1988. U.S. Dept. of Energy Nevada Operations Office report. DOE/NV-317; May, 1990.

USAEC, Health and Safety Laboratory Fallout Quarterly Reports, 1958-.

(3) The networks of fallout measurements:

Bouville, A. and Beck, H.L. The HASL gummed-film network and its use in the reconstruction of doses resulting from nuclear weapons tests. Environ. Intl; in press.

Eisenbud, M. An Environmental Odyssey. People, Pollution, and Politics in the Life of a Practical Scientist, University of Washington Press, Seattle and Washington, 1990.

Harley, John H., A Brief History of Long-Range Fallout, in Health and Safety Laboratory report HASL-306, Environmental Quarterly, July 1, 1976, pp I-3 to I-1.

(4) The assessment of the activities deposited on the ground:

Bouville, A., M. Dreicer, H.L. Beck, W.H. Hoecker, and B.W. Wachholz. Models of radioiodine transport to populations within the continental U.S. Health Phys. **59**(5): 659-668; 1990.

Bouville, A. Reconstructing doses to downwinders from fallout. Proceedings of the Thirty-First Annual Meeting of the National Council on Radiation Protection and Measurements. Proceedings No. 17, pp. 171-189. NCRP, Bethesda, MD, 1996.

Whicker, F.W. Environmental pathway analysis in dose reconstruction. Proceedings of the Thirty-First Annual Meeting of the National Council on Radiation Protection and Measurements. Proceedings No. 17, pp. 93-106,. NCRP, Bethesda, MD, 1996.

(5) The vertical migration of fallout radionuclides into deeper layers of soil:

See references in text.

(6) The assessment of the doses from external irradiation:

Beck, H.L.; Krey, P.W. Radiation exposure in Utah from Nevada nuclear tests. Science **220**:18-24; 1983.

Lloyd, R.D.; Gren, D.C.; Simon, S.L.; Wrenn, M.E.; Hawthorne, H.A.; Lotz, T.M.; Stevens, W.; Till, J.E. Individual external exposures from Nevada Test Site fallout for Utah leukemia cases and controls. Health Phys. **59**(5):723-737; 1990.

Simon, S.L.; Till, J.E.; Lloyd, R.D.; Kerber, R.L.; Thomas, D.C.; Preston-Martin, S.; Lyon, J.L.; Stevens, W. The Utah leukemia case-control study: dosimetry methodology and results. Health Phys. **68**(4):460-471; 1995.

Haskell, E.H., I.K. Balliff, G.H. Kenner, P.L. Kaipa, and M.E. Wrenn. Thermoluminescent measurements of gamma-ray doses attributable to fallout from the Nevada Test Site using building bricks as natural dosimeters. Health Physics **66**, 380-391; 1994.

Appendix 3: Classified Data That Could be of Use in Assessing Fallout Impact on U.S. Population

The ability to estimate fallout deposition from NTS shots was made possible by the calculations of Hick based on cloud measurements of the relative production of the various fission products from each test. The composition of debris is very dependent on the spectrum of neutrons produced in the device and the composition of the fuel. Similar data for tests carried out by the U.S. and U.K. in the Pacific as well as for tests carried out in the Soviet Union will be required to allow comparable estimates of fallout deposition to be made for tests carried out outside the U.S. Such data, if available, is classified. Also classified is the fraction of the total yield of individual shots that resulted from fission versus fusion. Again, this information will be needed to make reasonable estimates of deposition and resultant doses from tests held outside the U.S. In some cases, even the exact value of the total yield is classified. Since tritium is a byproduct of fusion, any information on the amount of tritium released from a particular test is probably also classified.

For the NTS tests, the efficiencies of fission are classified as well as any information that would allow one to infer those efficiencies, such as ratios of Cs-137/Pu activity. Thus the amounts of residual (unfissioned) Pu in the fallout had to be inferred as discussed in this report. The resultant crude estimates of Pu deposition thus have relatively large uncertainty compared to the deposition of fission products.

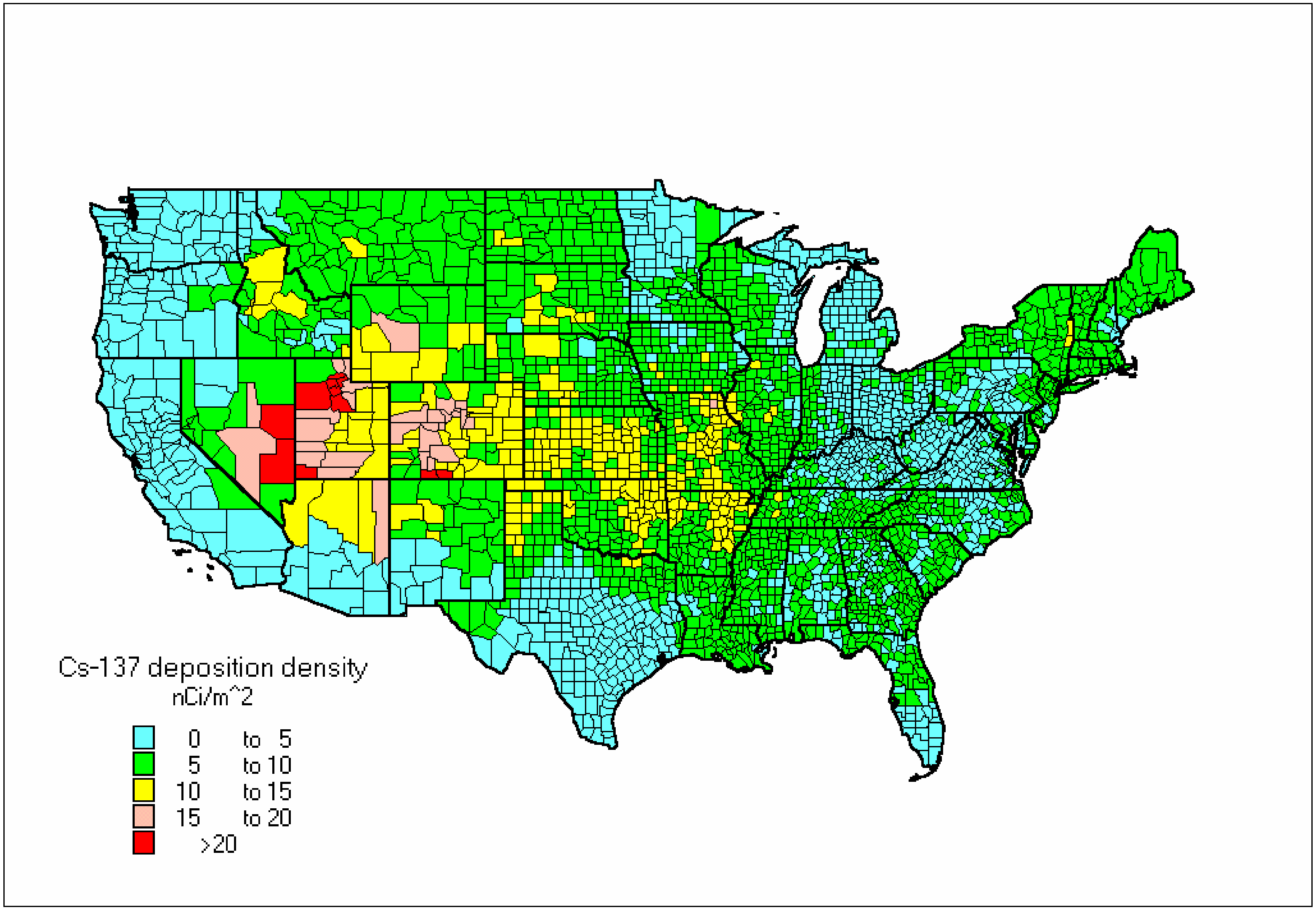


Figure 1. Cs-137 deposition density due to all NTS tests.

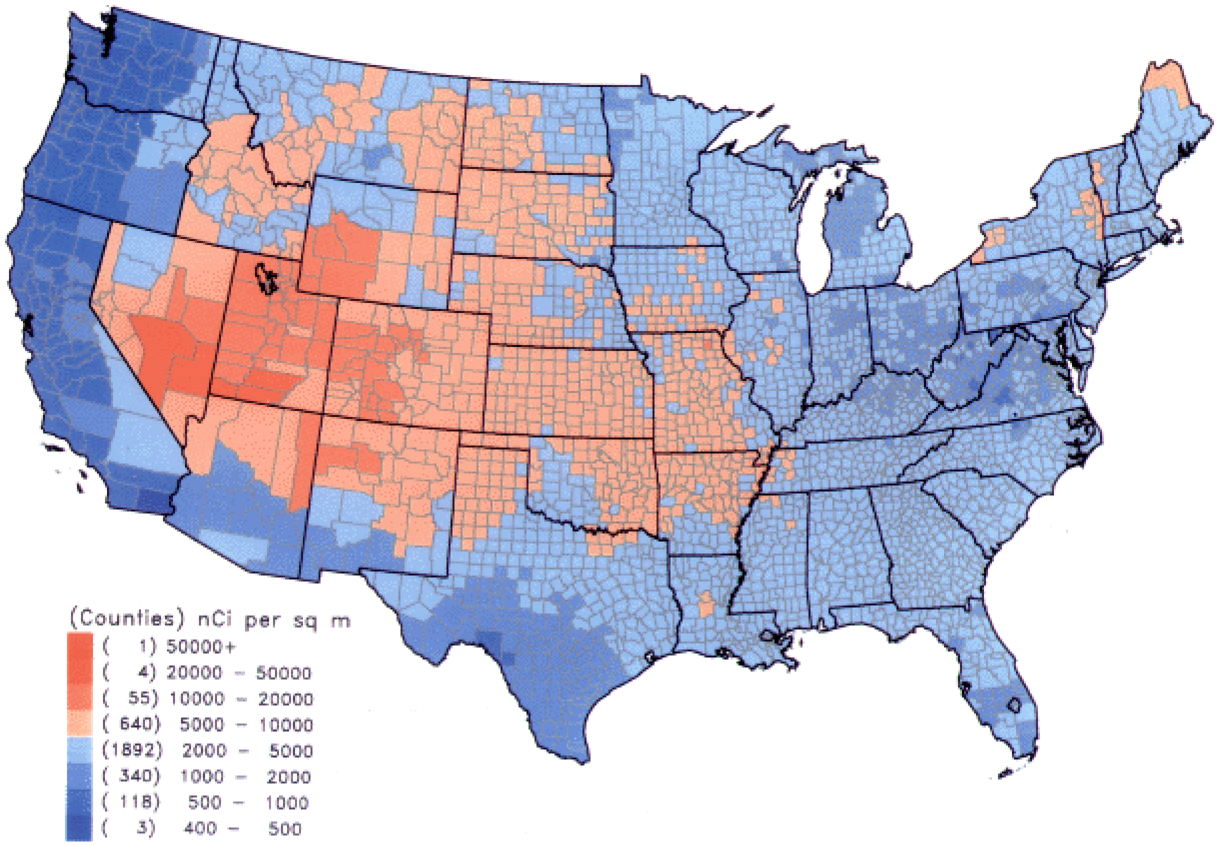


Figure 2. I-131 deposition density due to all NTS tests.

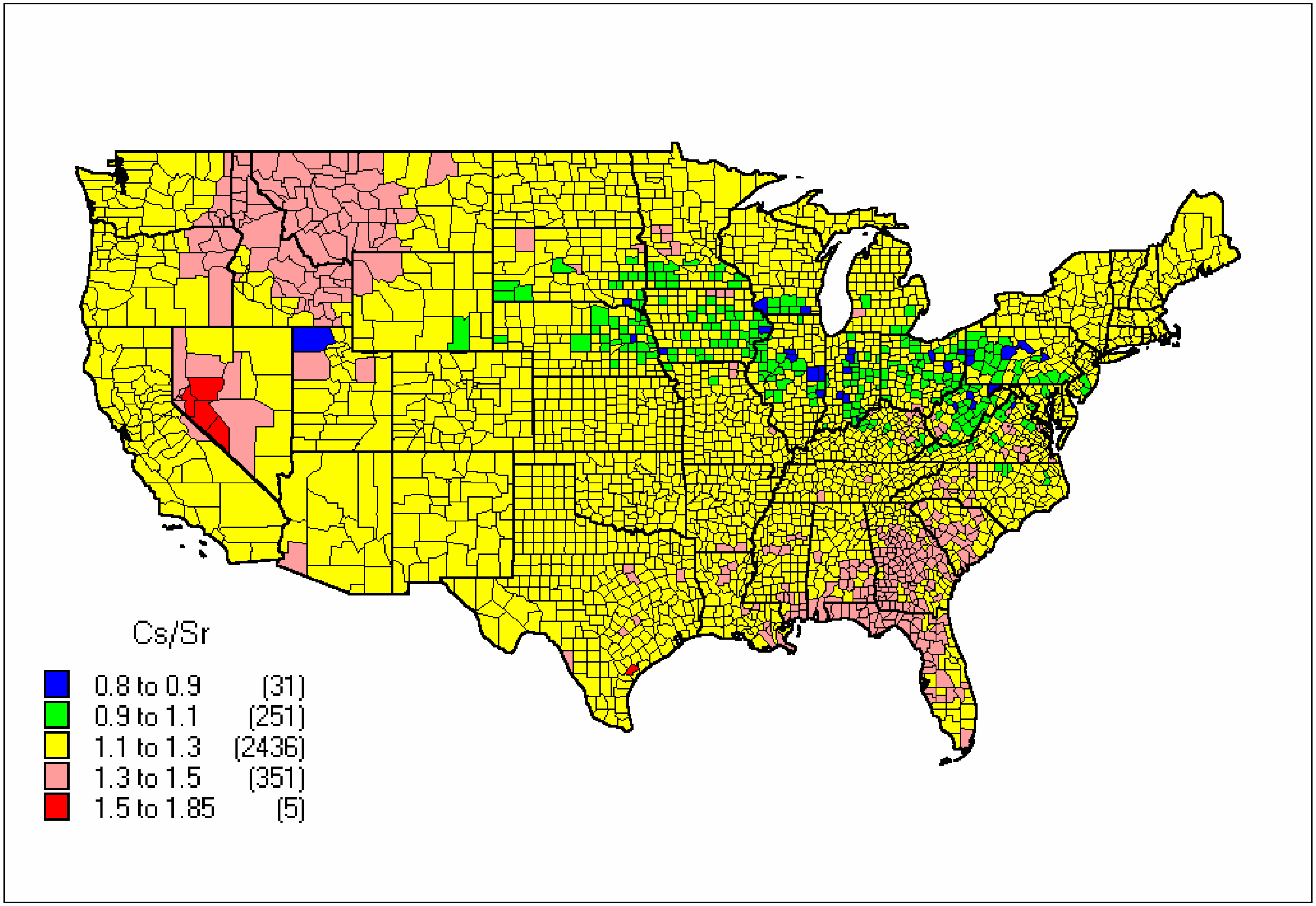


Figure 3. Ratio of Cs-137 to Sr-90 deposition density from all tests. Number of counties in each group shown in parenthesis.

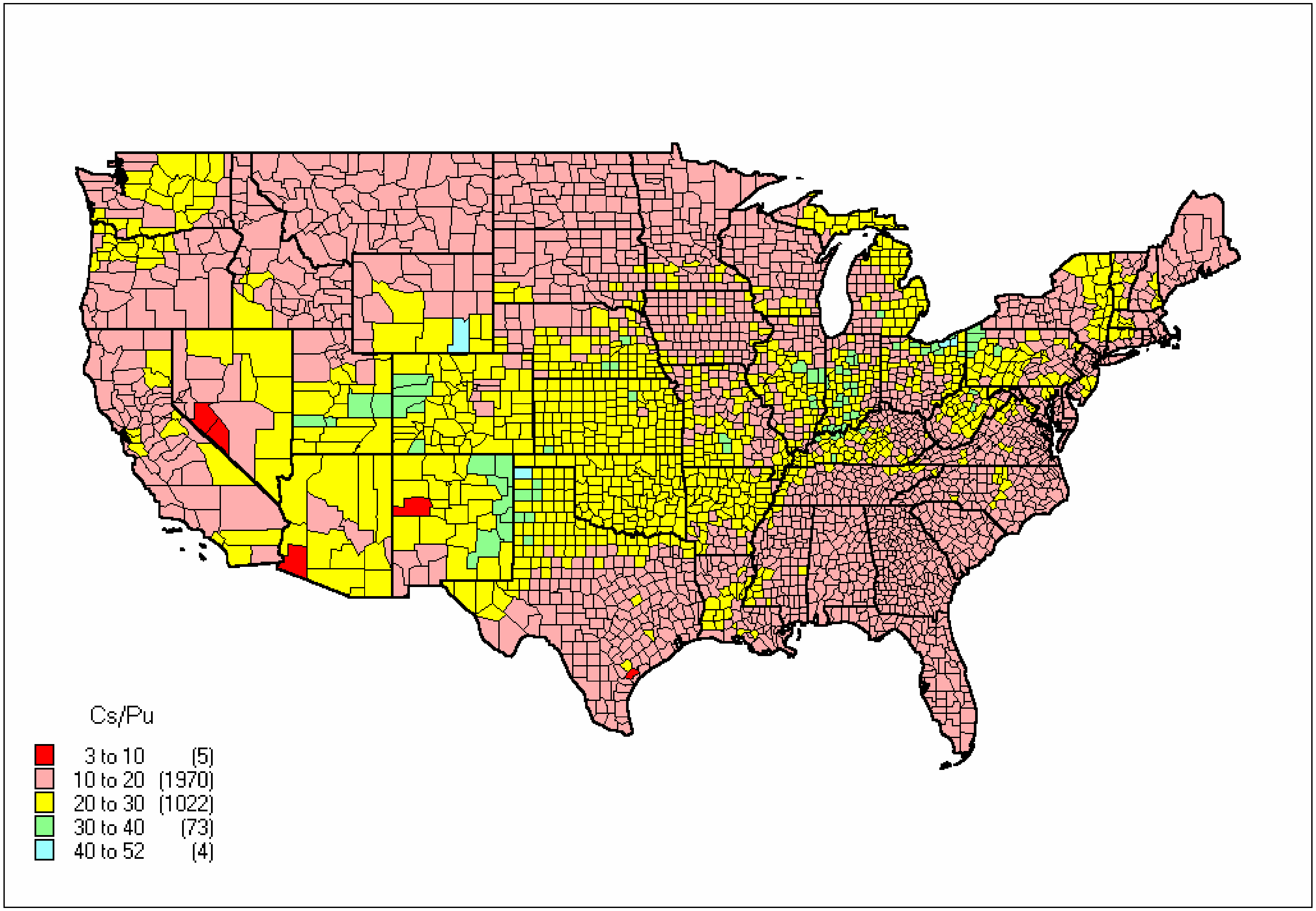


Figure 4. Estimated ratio of Cs-137 to Pu-239+249 deposition density. Number of counties in each group shown in parenthesis.

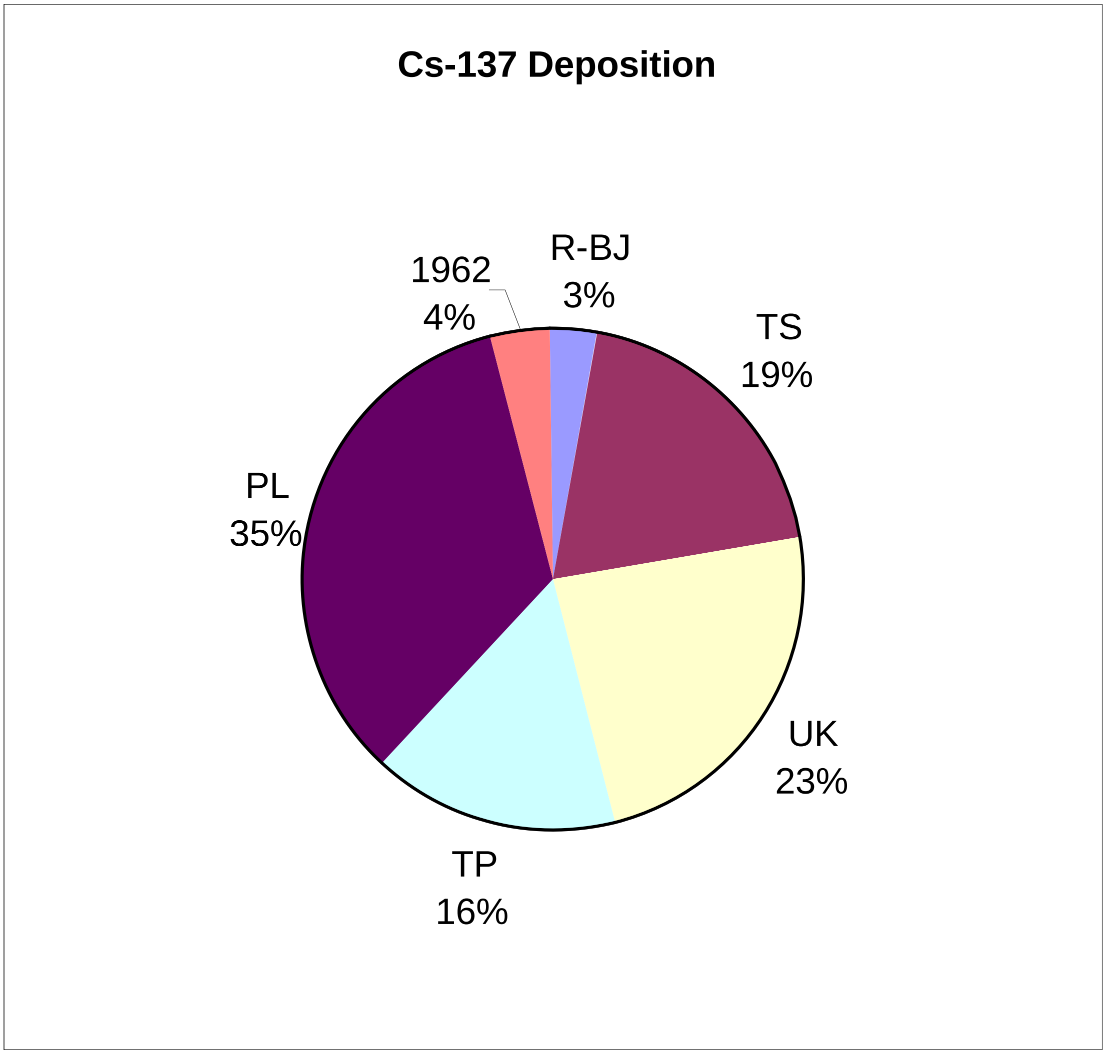


Figure 5. Fraction of total Cs-137 deposition from each test series.

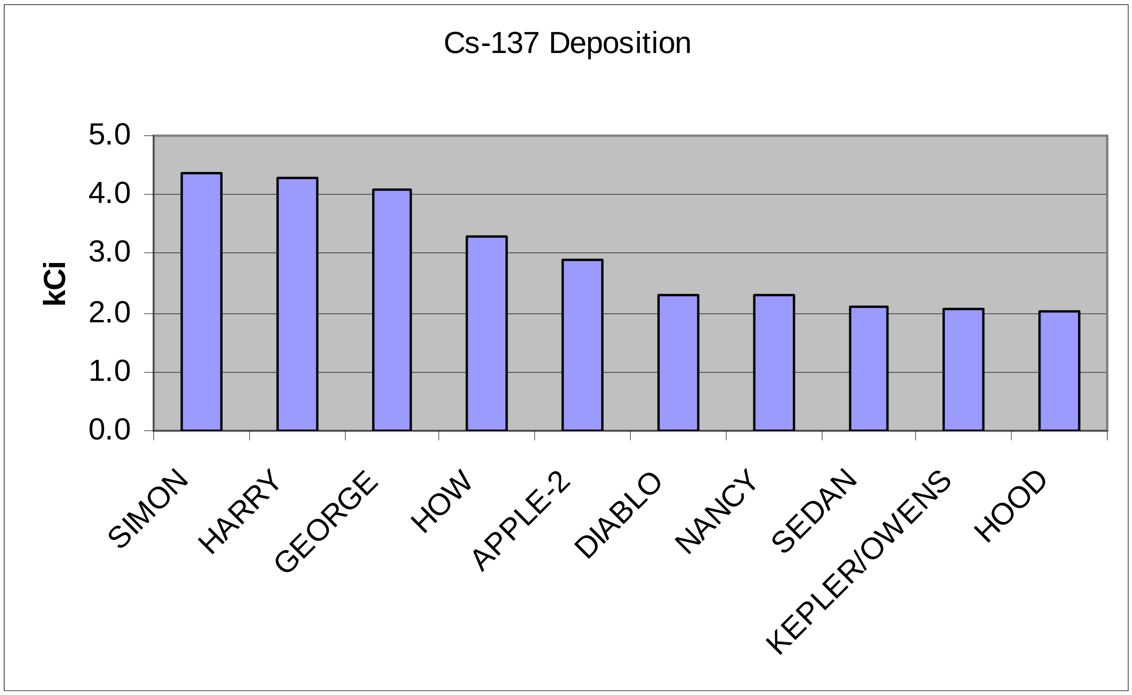


Figure 6. Ten tests depositing the greatest amounts of Cs-137 in the continental U.S.

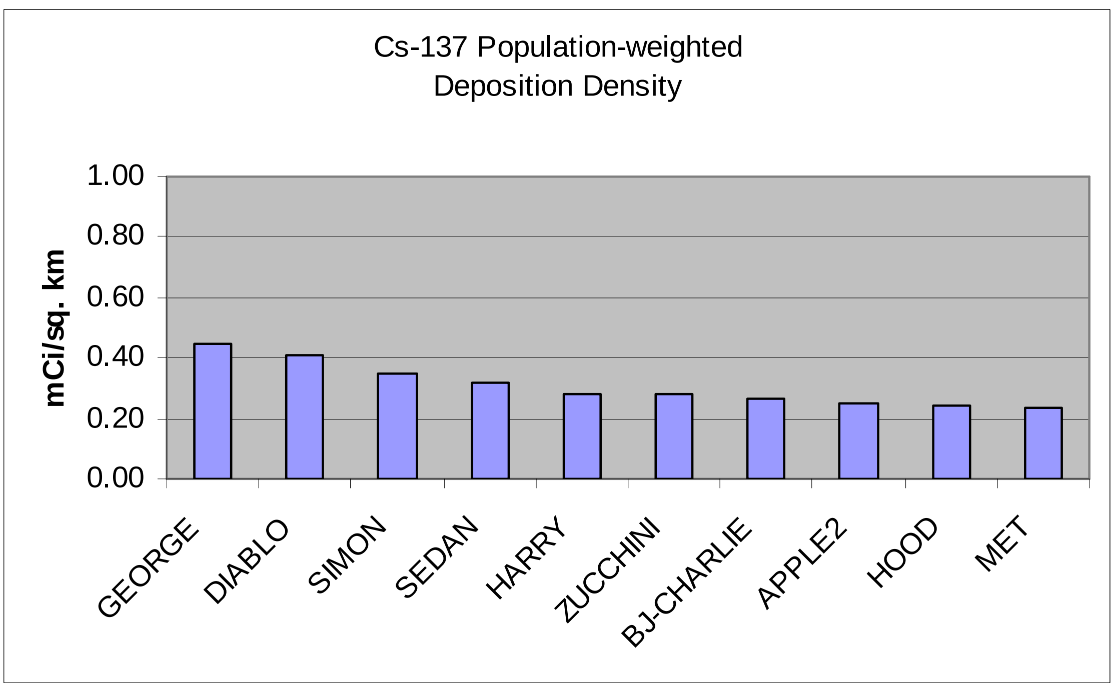


Figure 7. Ten tests producing the greatest population-weighted Cs-137 deposition density.

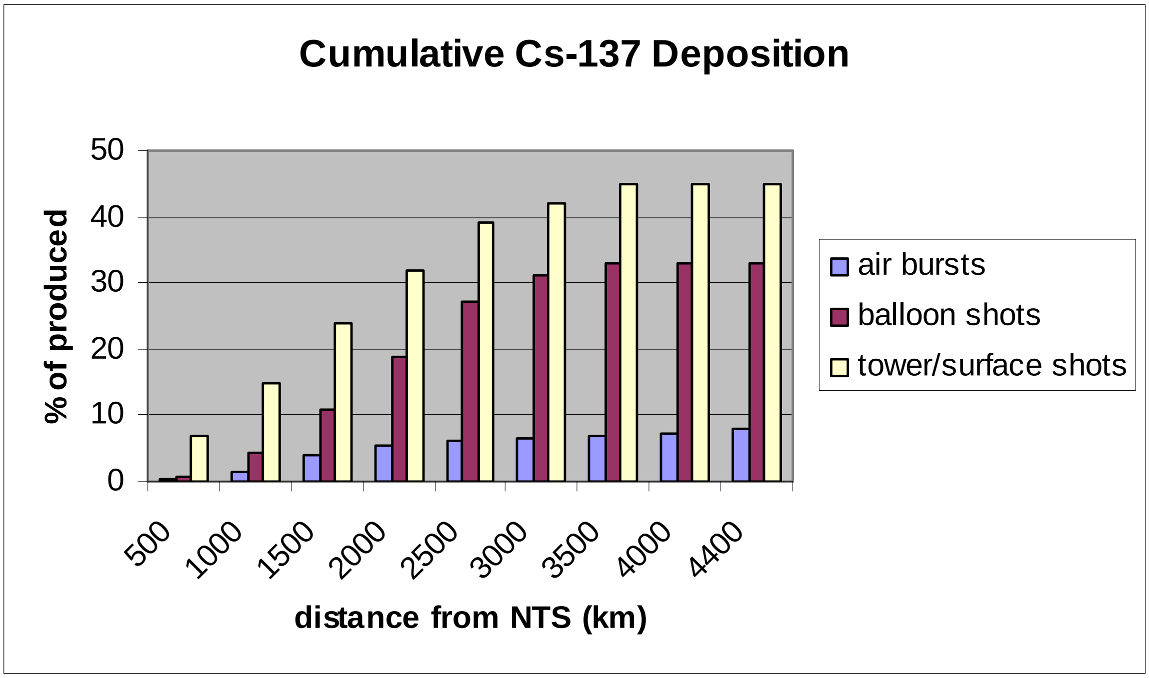


Figure 8. Cumulative Cs-137 deposition relative to total produced versus distance from the NTS.

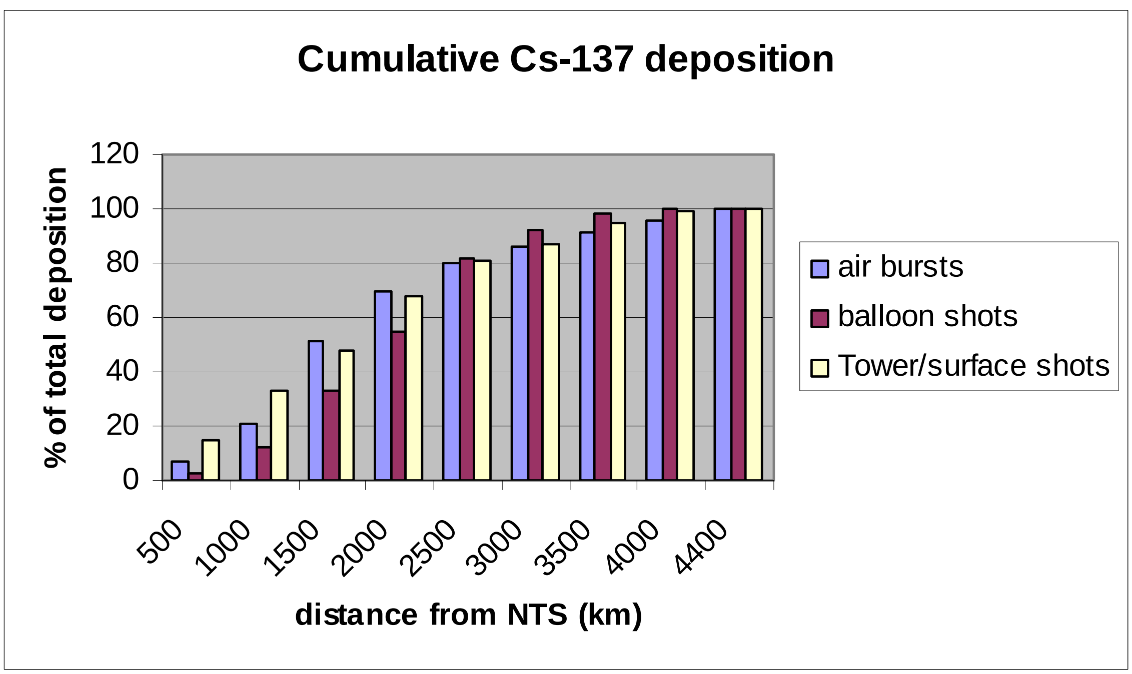


Figure 9: Cumulative Cs-137 deposition relative to total deposited in the U.S. versus distance from the NTS.

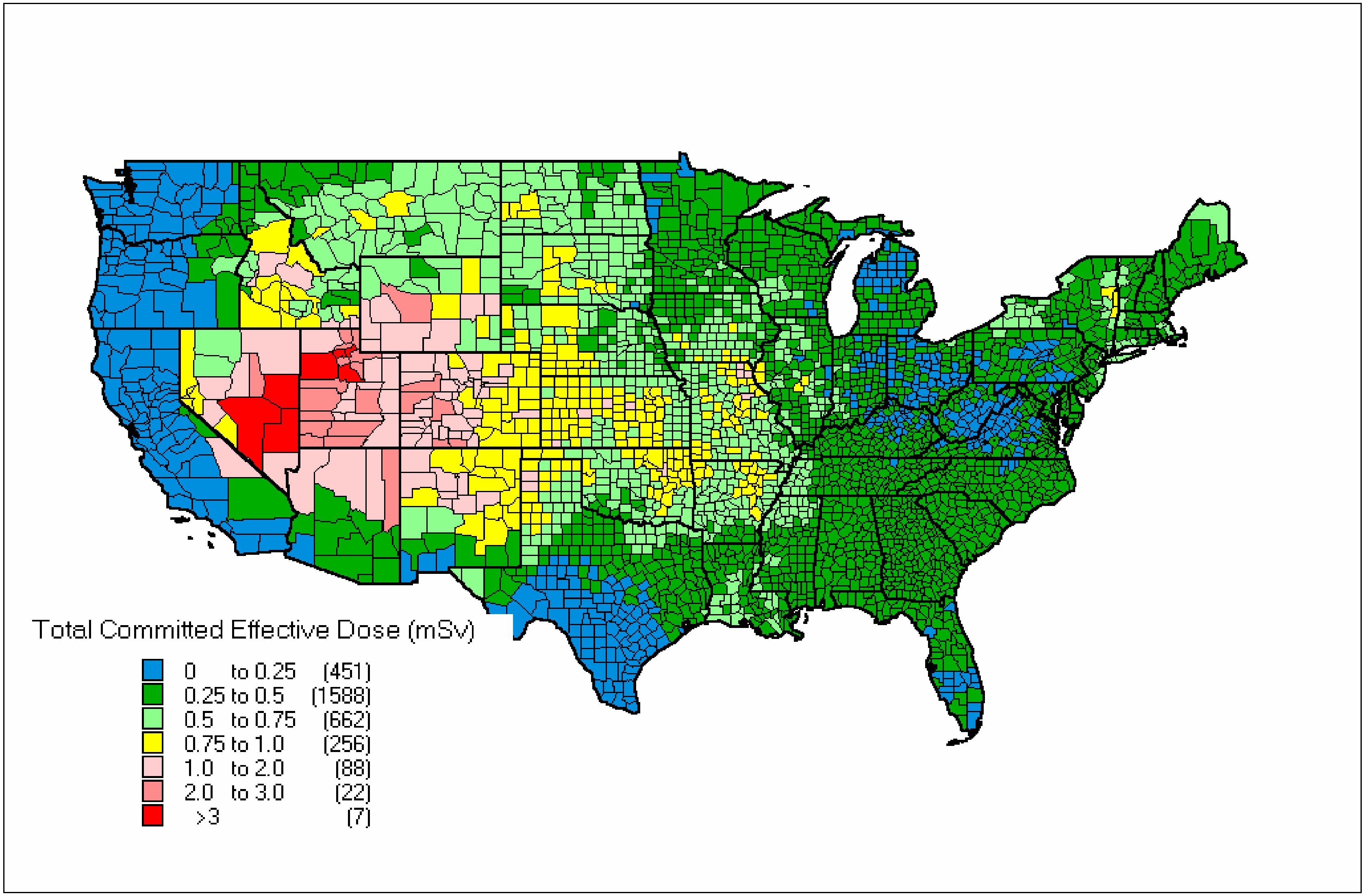


Figure 10: Total dose to average exposed individual from all tests. Number of counties in each group shown in parenthesis.

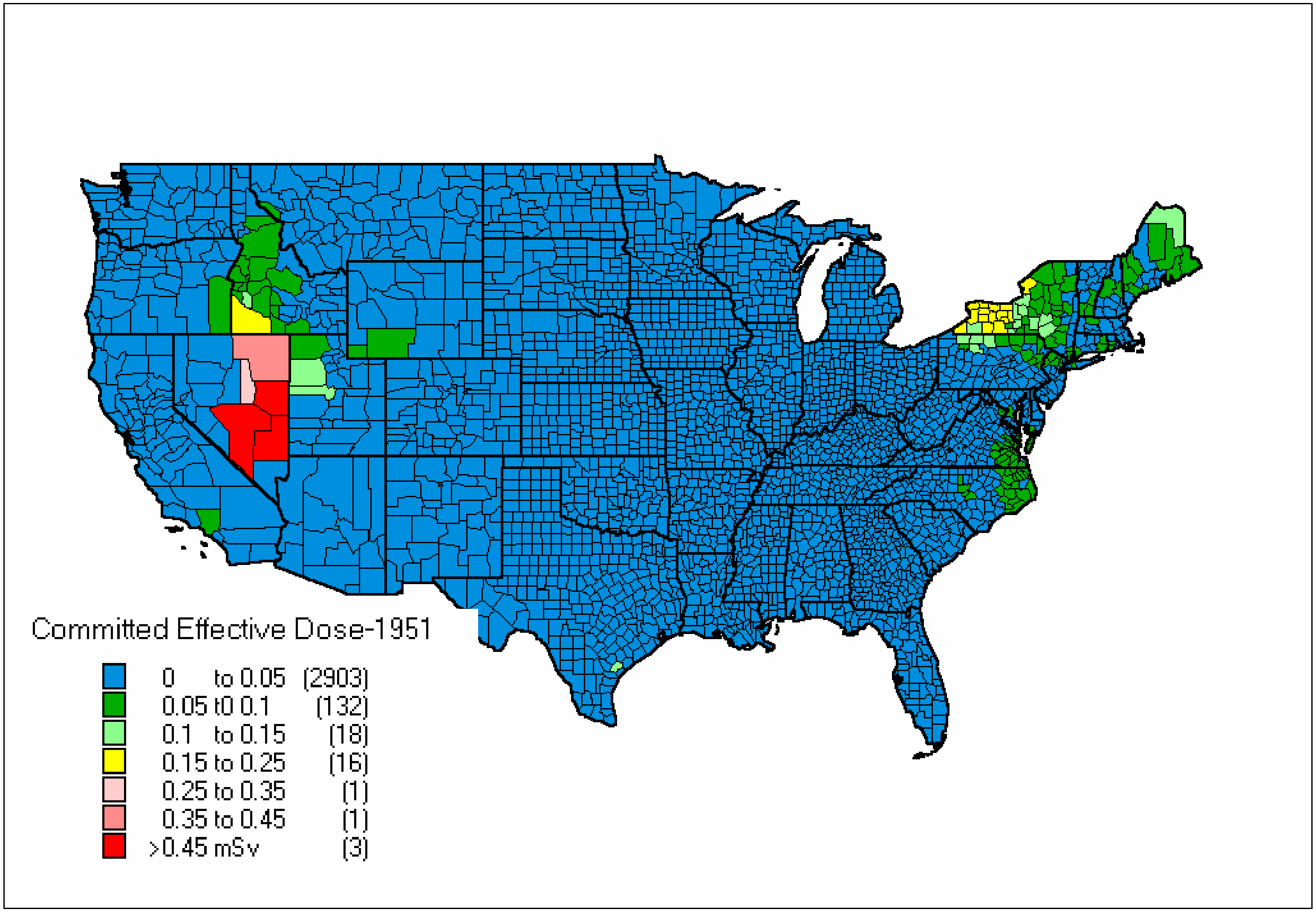


Figure 11. Dose to average exposed individual from tests in 1951. Number of counties in each group shown in parenthesis.

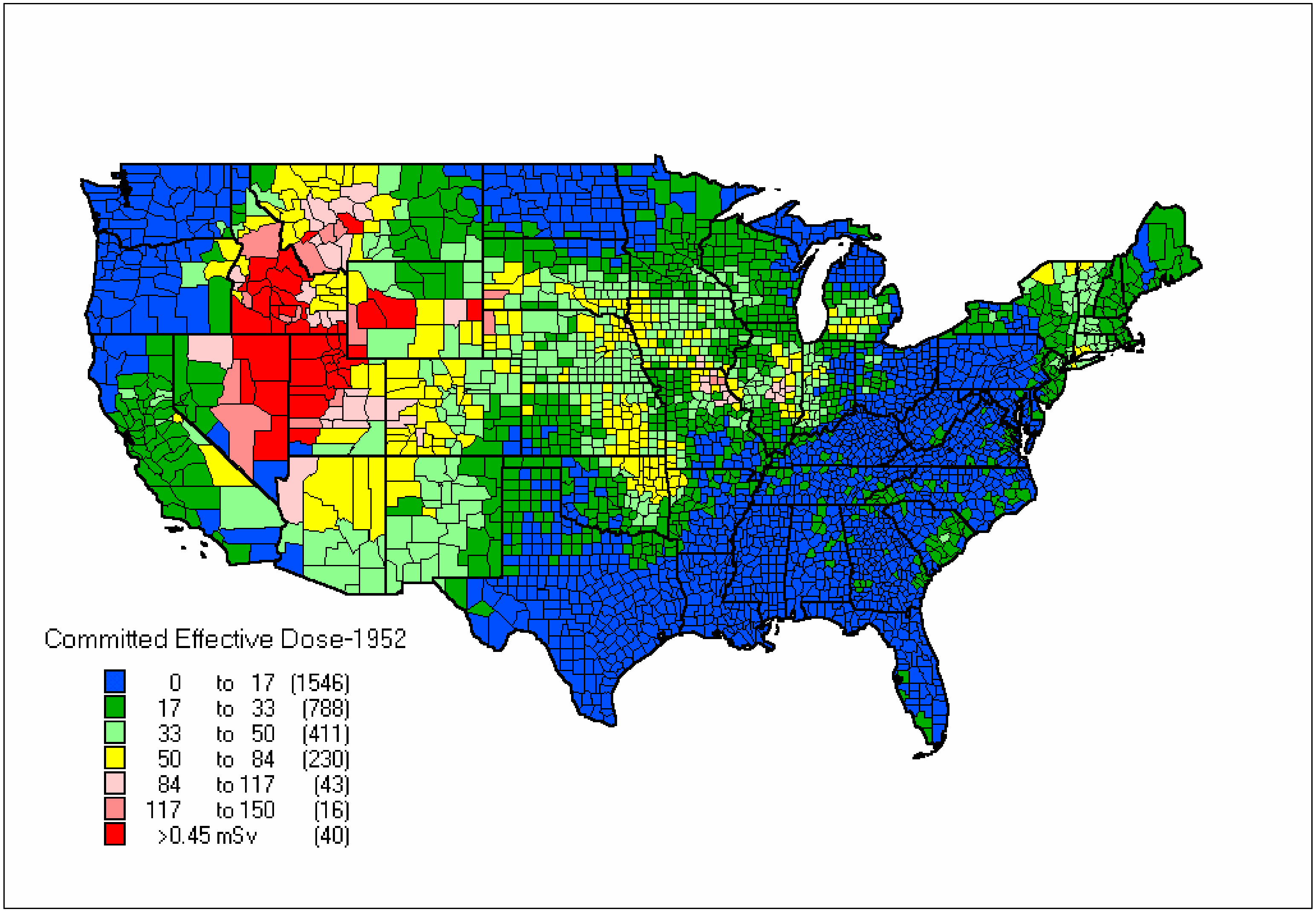


Figure 12. Dose to average exposed individual from tests in 1952. Number of counties in each group shown in parenthesis.

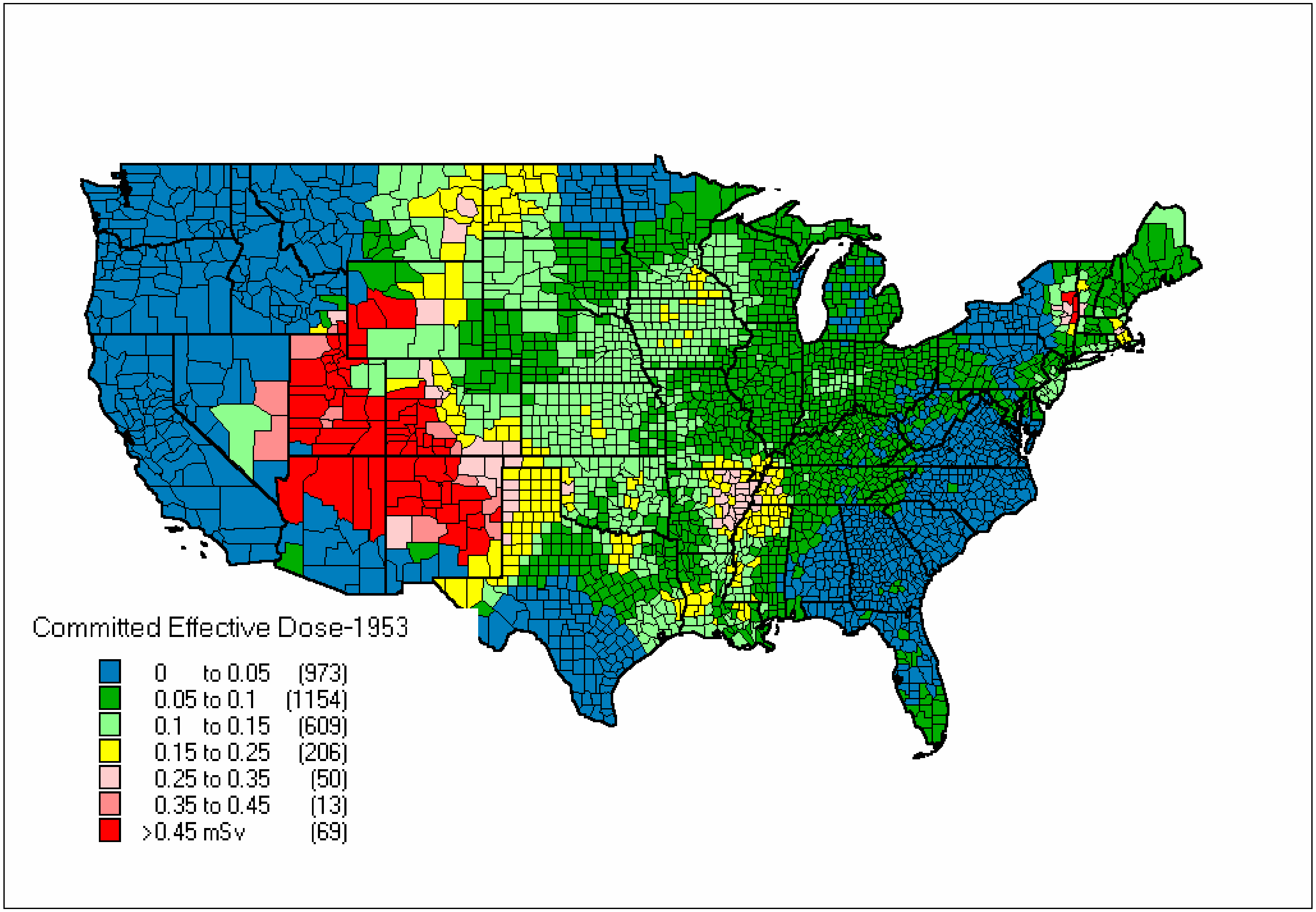


Figure 13. Dose to average exposed individual from tests in 1953. Number of counties in each group shown in parenthesis.

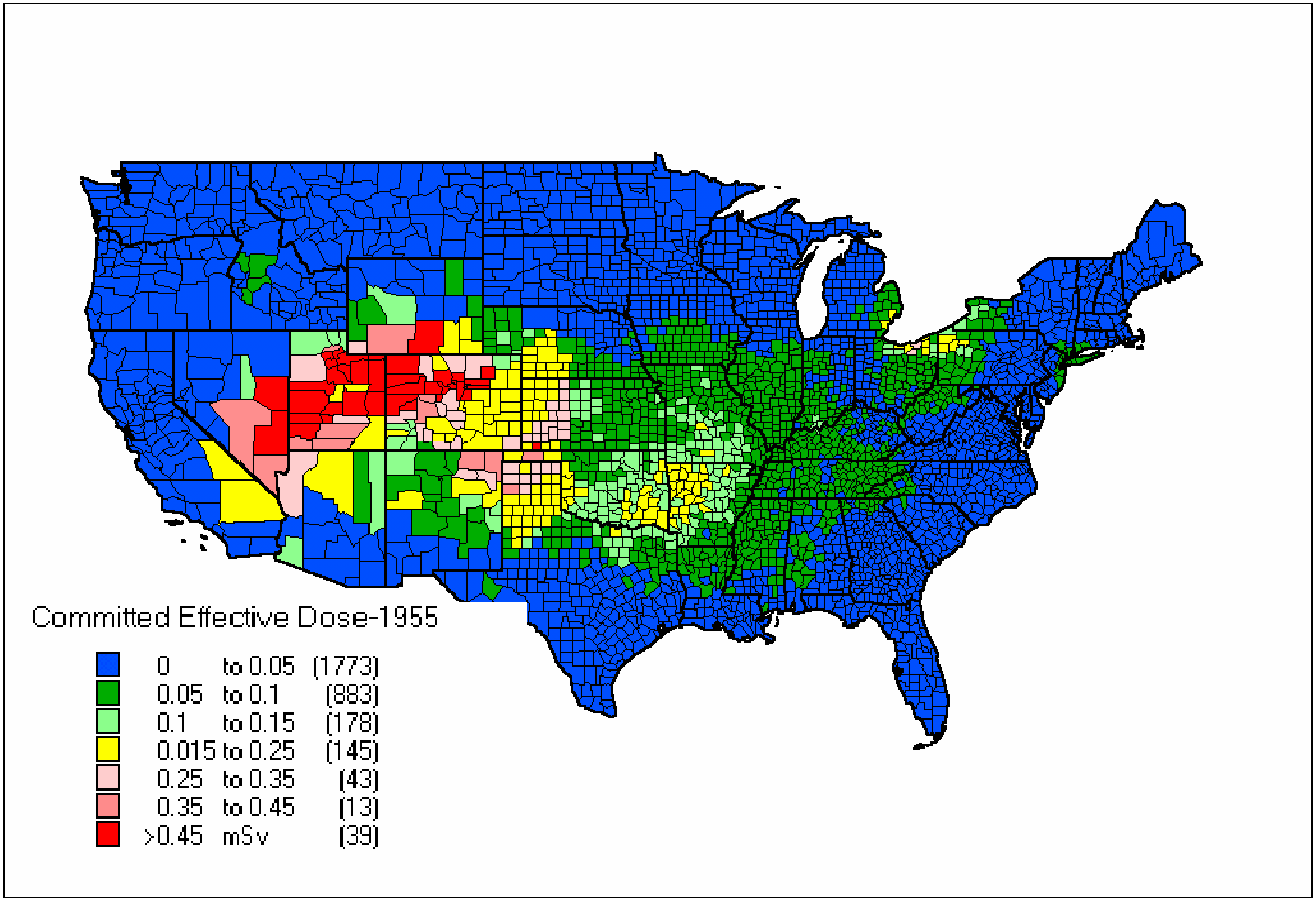


Figure 14. Dose to average exposed individual from tests in 1955. Number of counties in each group shown in parenthesis.

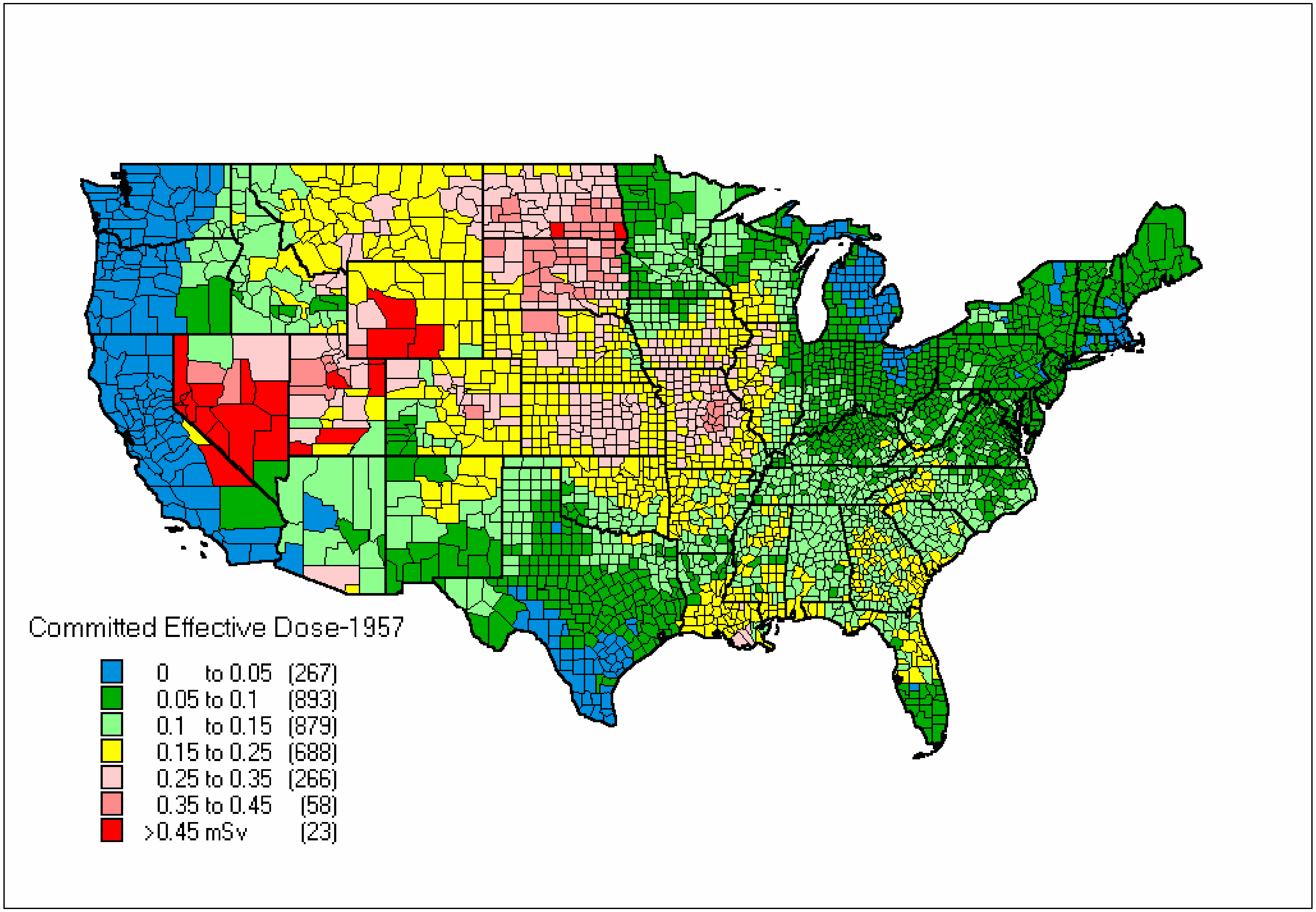


Figure 15. Dose to average exposed individual from tests in 1957. Number of counties in each group shown in parenthesis.

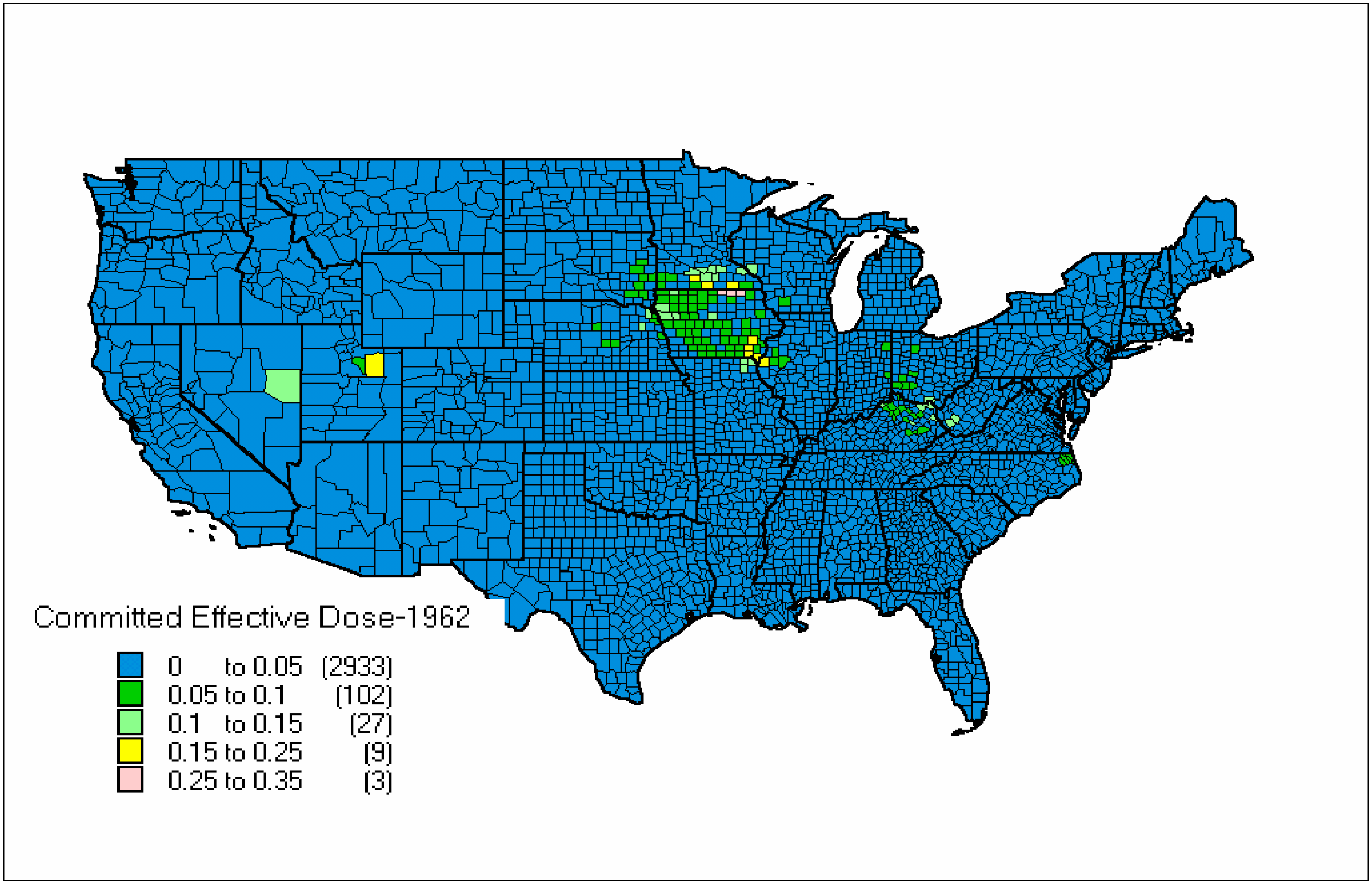


Figure 16. Dose to average exposed individual from SEDAN and Smallboy. Number of counties in each group shown in parenthesis.

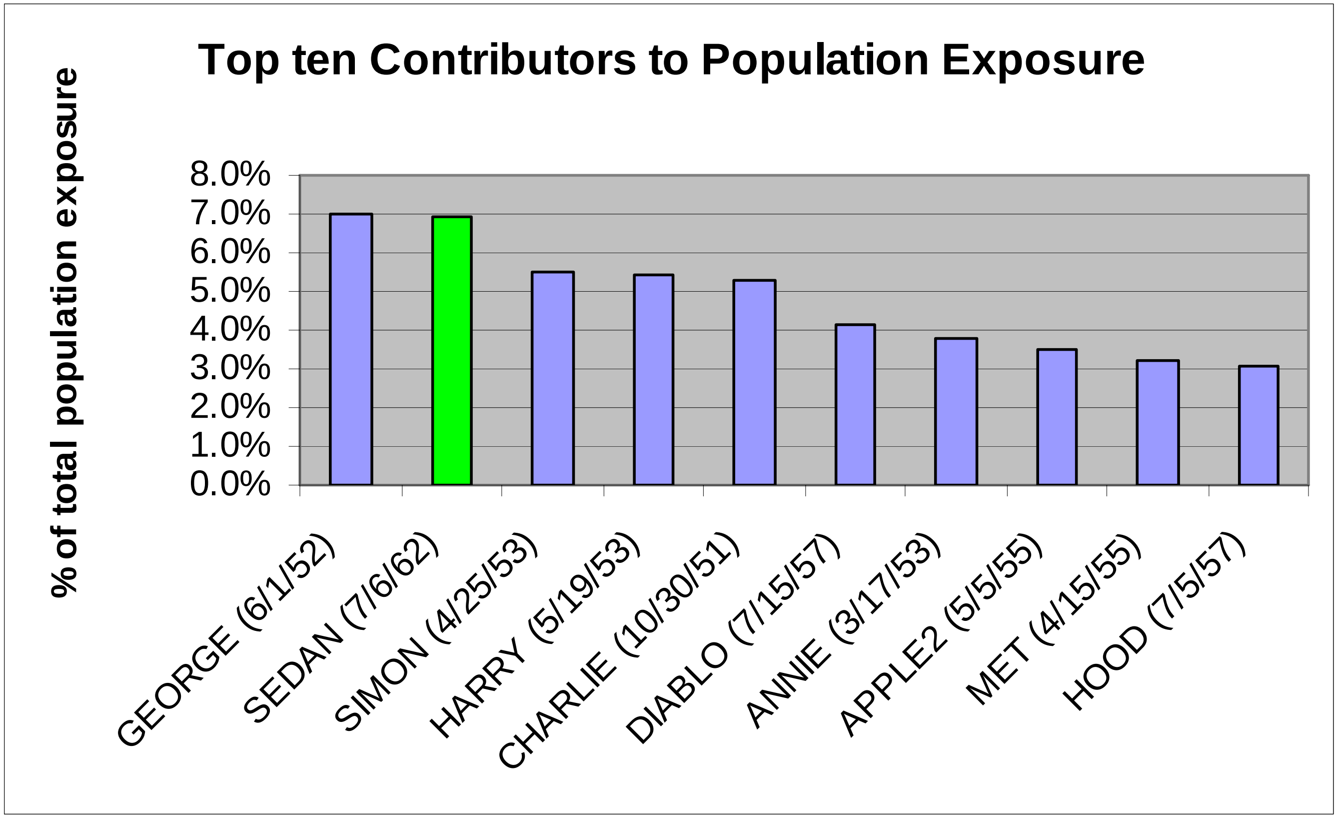


Figure 17. Ten tests with the greatest contributions to total population exposure. The value for SEDAN is much more uncertain than that for the other tests.

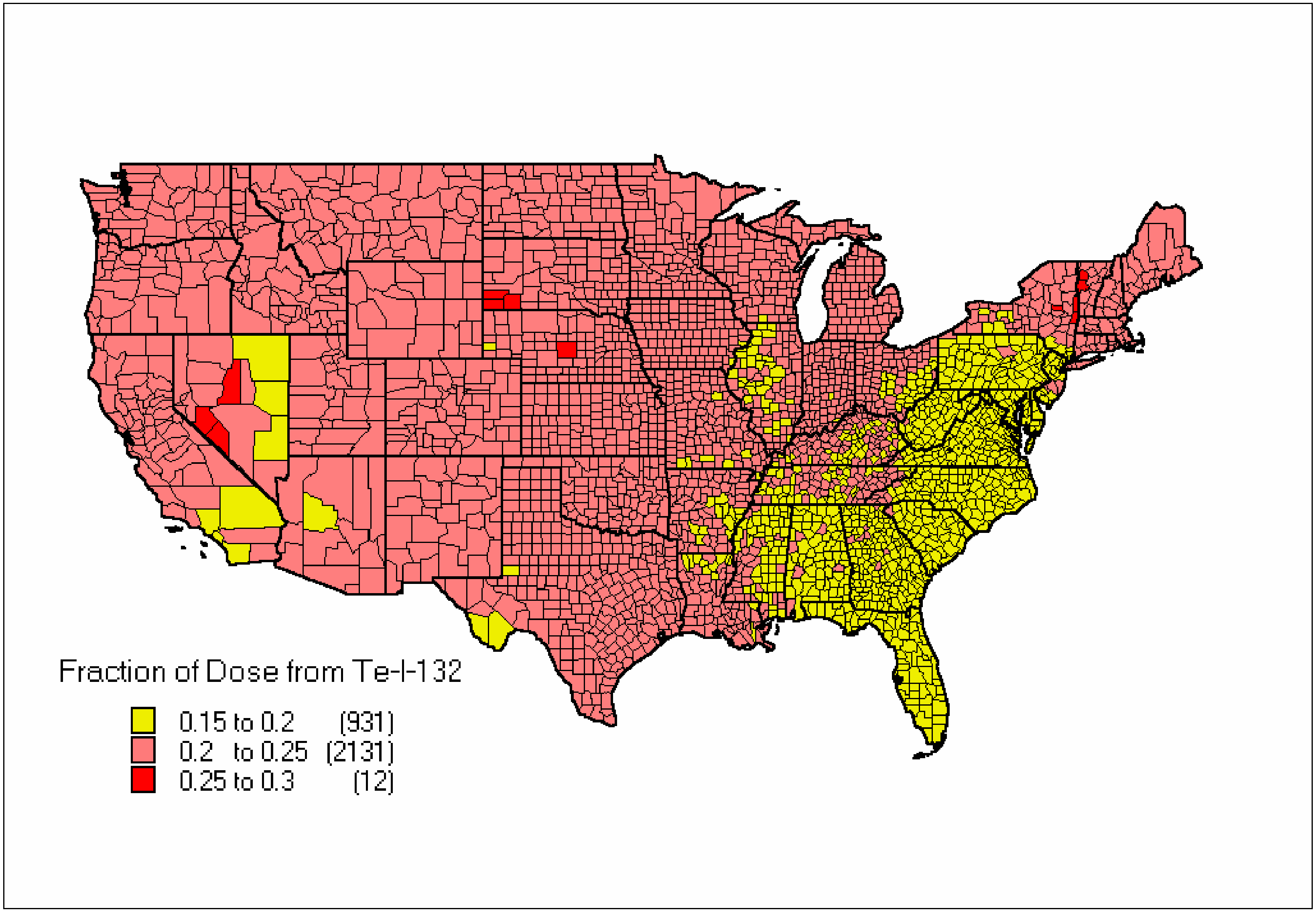


Figure 18. Fraction of total dose from Te-I-132. The number of counties in each group is shown in parenthesis.

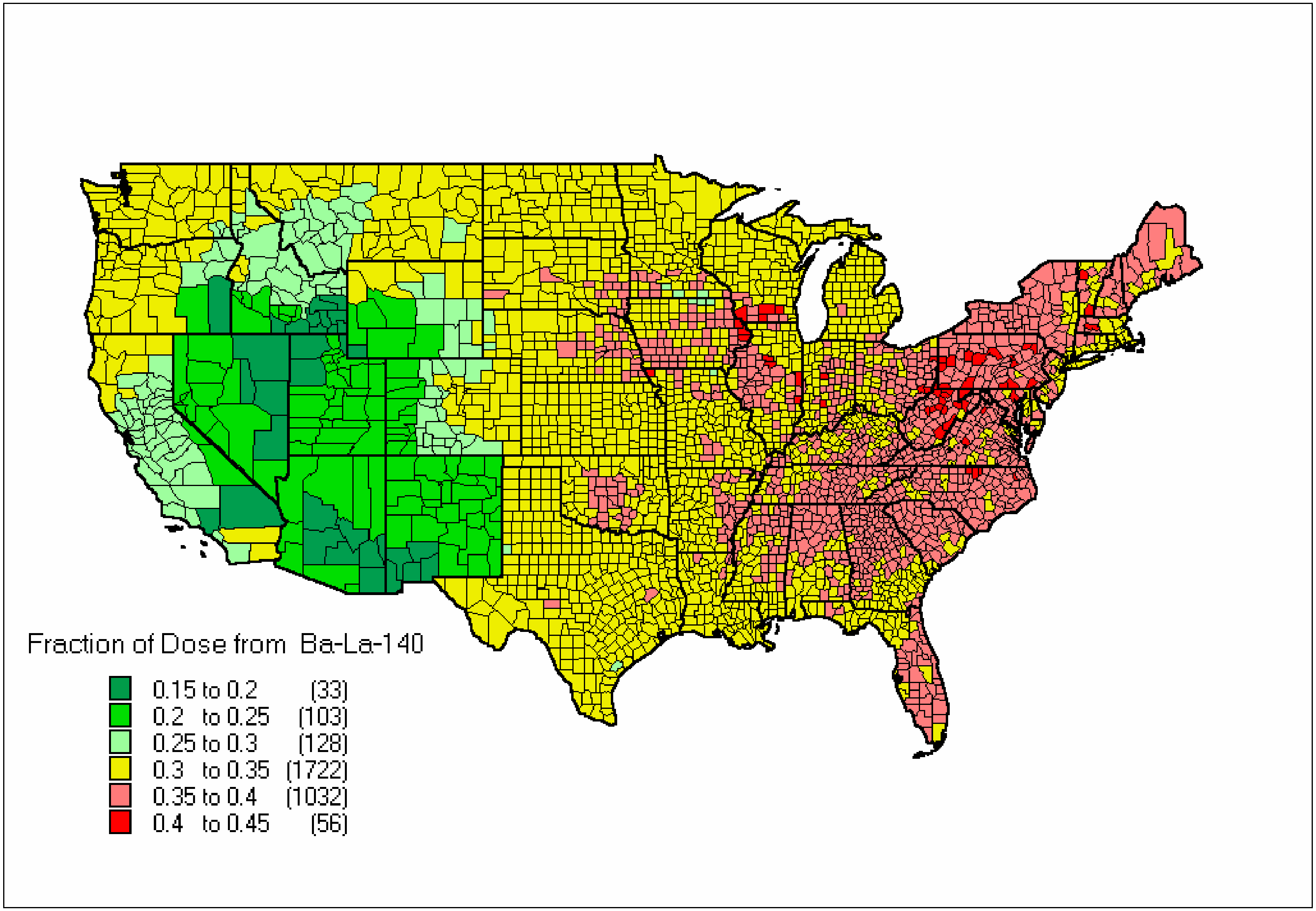


Figure 19. Fraction of total dose from Ba-La-140. The number of counties in each group is shown in parenthesis.

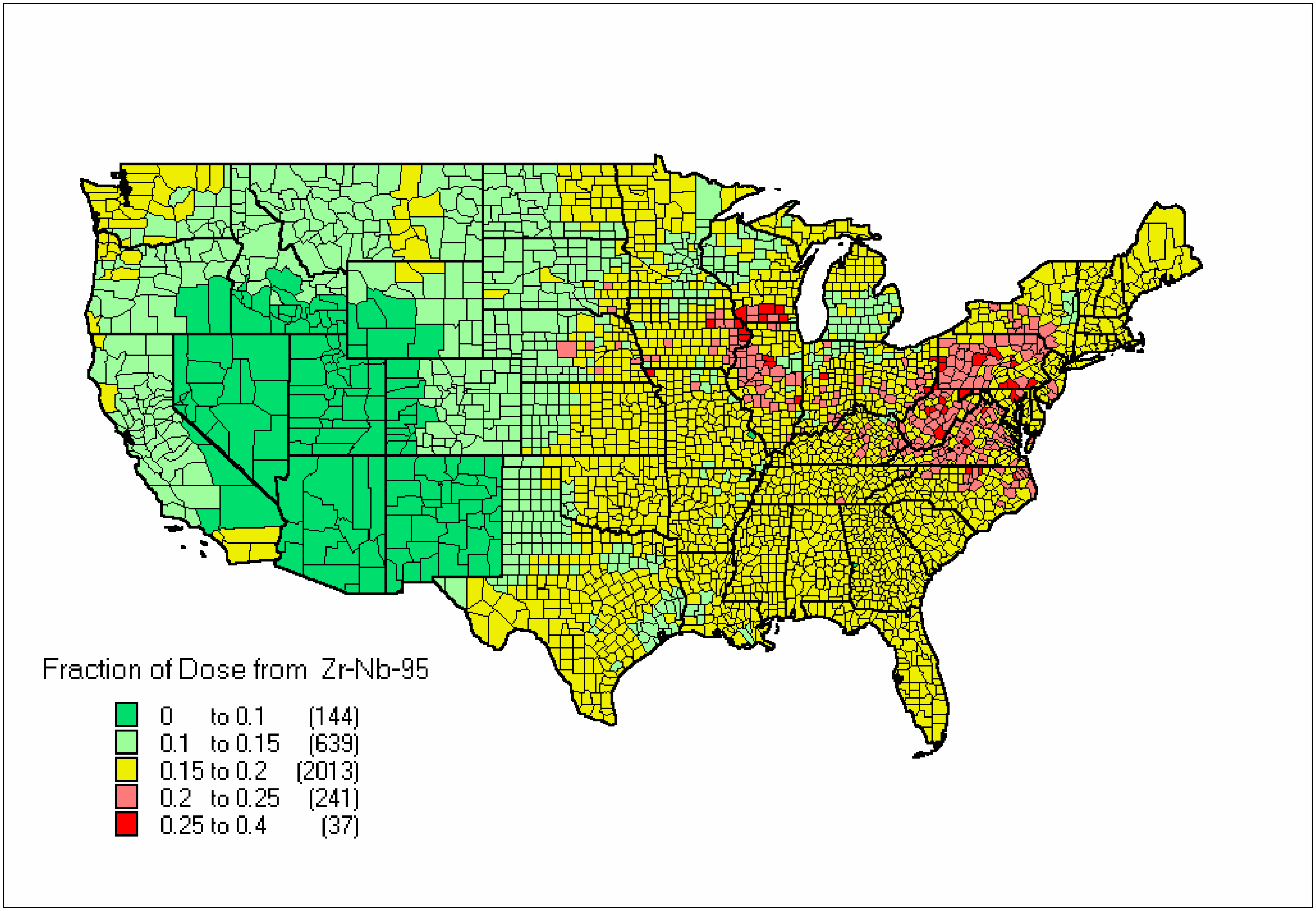


Figure 20. Fraction of total dose from Zr-Nb-95. The number of counties in each group is shown in parenthesis.

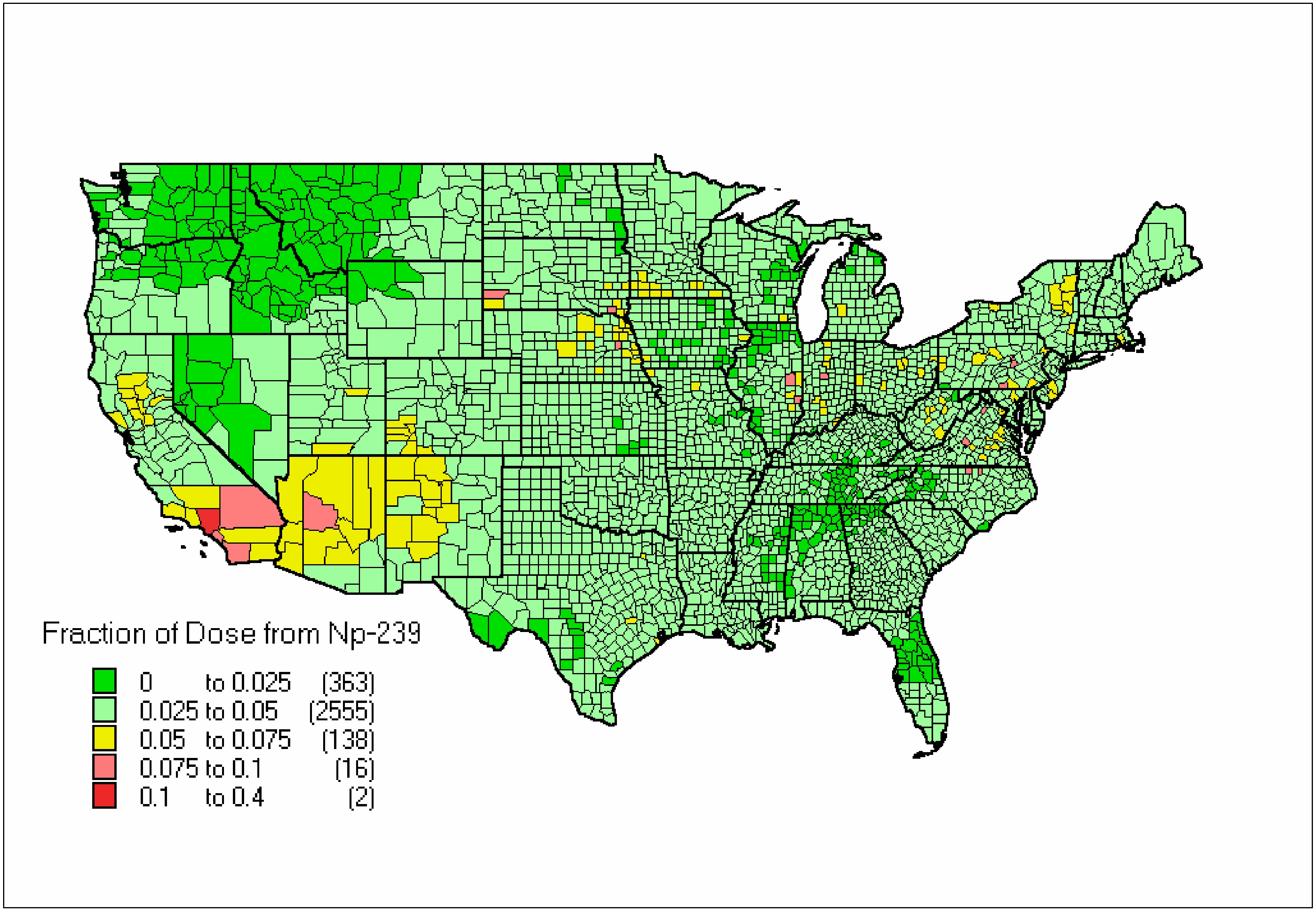


Figure 21. Fraction of total dose from Np-239. The number of counties in each group is shown in parenthesis.

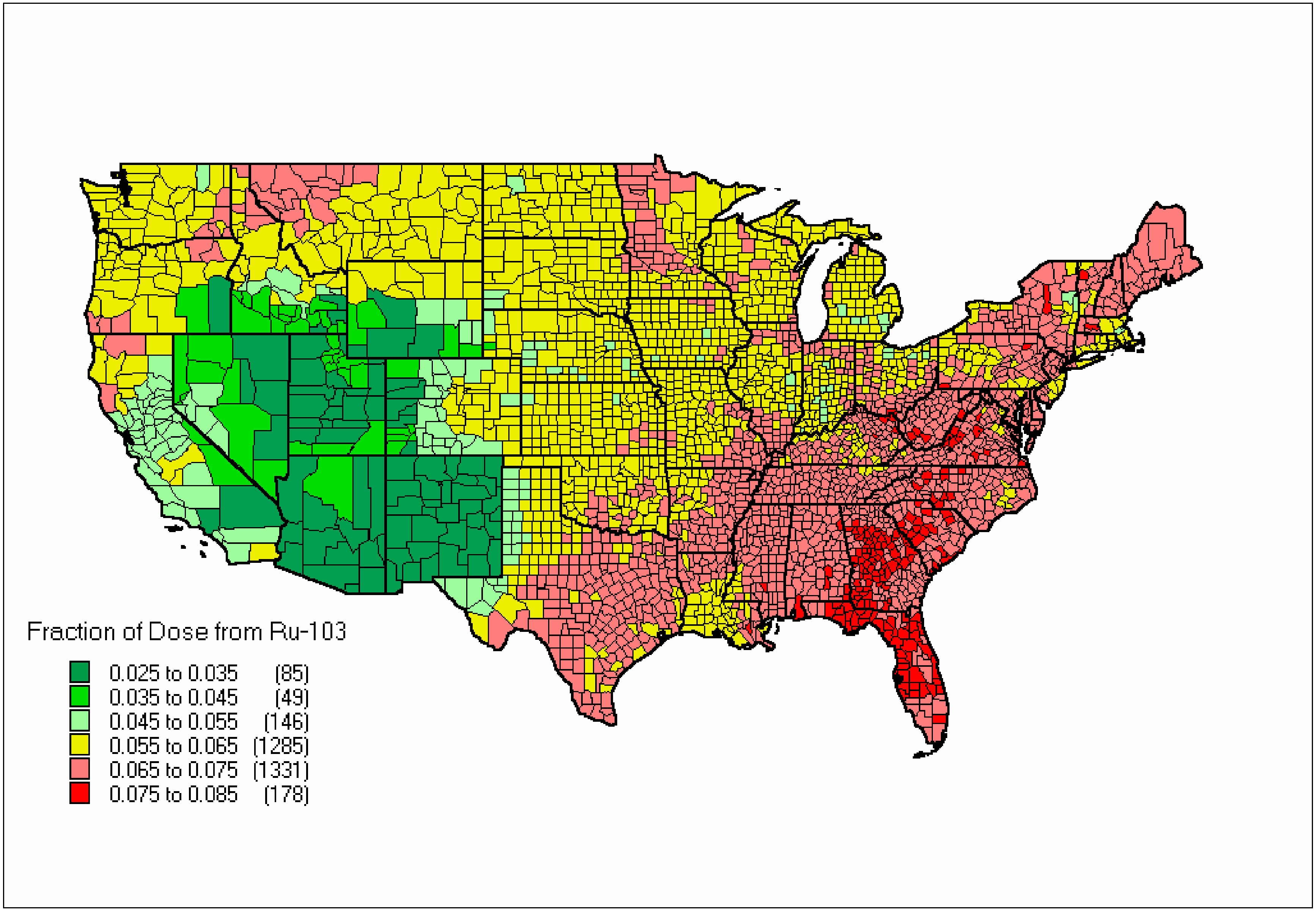


Figure 22. Fraction of total dose from Ru-103. The number of counties in each group is shown in parenthesis.

Appendix F

Internal Dose Estimates from NTS Fallout

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from Nuclear Tests at the Nevada Test Site

Final Report

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-912901

February 4, 2000
(Revised May 30, 2000)

TABLE OF CONTENTS

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from Nuclear Tests at the Nevada Test Site

Part I. Estimates of Dose

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-912901

ABSTRACT

According to a Congressional request to the Department of Health and Human Services, a feasibility study has been conducted to determine if doses to the American public from radionuclides other than ^{131}I can be calculated for the tests of nuclear weapons and related devices conducted at the Nevada Test Site (NTS). Results of this feasibility study on doses received via the ingestion of contaminated foods indicate that doses from other radionuclides can be calculated, as have the doses from ^{131}I that were reported earlier by the NCI. The methods of calculation are based upon the methods developed and used earlier by the Off-Site Radiation Exposure Review Project; these methods employed seasonally adjusted values of radioecological transfer of radionuclides to humans.

Doses were calculated for 61 of the more significant events that occurred at the NTS during 1951, 1952, 1953, 1955, 1957, and 1962. Detailed results are provided in two CDs that accompany this report. Summary results in the form of coded maps for each of the above years and for the total time period are also provided. The total estimated collective effective committed dose from the ingestion of contaminated foods is 110,000±14,000 Sv; the total estimated per caput effective committed dose is 680±90 µSv. The larger fractions of dose resulted from the tests of Operation Plumbbob conducted in 1957, Operation Tumbler-Snapper in 1952, and Operation Upshot-Knothole in 1953. The largest contribution from any single event is estimated to have been from Project Sedan, a cratering experiment in 1962, although the uncertainty in dose calculated for this event is unusually large due to the absence of information regarding its fission yield and other factors; there is also concern about the validity of the input data for this event. The radionuclide ^{131}I was by far the most important contributor to collective effective dose and accounted for nearly 90% of the total age-corrected collective effective dose. The thyroid is estimated to have received by far the largest collective organ dose of 2,000,000±280,000 person Sv. Most organs received a collective dose of about 15,000 person Sv; other than the thyroid, the organs receiving the higher doses were the colon (56,000±8400 person Sv) and the bone surface (31,000±4000 person Sv).

The per caput dose calculated here is almost the same as the 670 µSv effective dose committed from the consumption of contaminated food over a comparable time period of 50 years from global fallout, as inferred from the work of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). However, the more important contributors to dose from the NTS were short-lived radionuclides (^{131}I, ^{89}Sr, and ^{140}Ba), whereas for global fallout the more important contributors were long-lived radionuclides (^{137}Cs ^{90}Sr, and ^{14}C). While the per caput doses from the two sources are about the same, doses from the NTS vary from county-to-county by a maximum factor of nearly 300; it is expected that the doses from global fallout would have been much more even due to the nature of the processes involved. Doses from the two sources also would have been received at different times—during the 1950s for NTS fallout and during 1963–1965 for global fallout. The dose from inhalation has not been calculated explicitly; rather, the relative contribution of inhalation compared to ingestion has been estimated for the ten more important radionuclides and for $^{239+240}$Pu. For the ten more important radionuclides, the relative contribution varies from about one-third to much less. For $^{239+240}$Pu the relative contribution via inhalation is calculated to be about 2.6 times that from ingestion; however the total contribution of dose from $^{239+240}$Pu is small.

INTRODUCTION

Congress has asked the Department of Health and Human Services (HHS) to study the health consequences to the American people of nuclear weapons tests. Within that framework a purchase order has been received to assist in the determination of radiation dose to the American people from the weapons tests conducted in Nevada.

The primary work to be performed is to "prepare crude estimates of the doses of internal radiation received by the American people as a result of the aboveground tests carried out at the Nevada Test Site (NTS)." These estimates are to be:

- Based upon a review of the readily available open literature and information; it is not expected that sophisticated computer models should be developed or used for this purpose;
- Based upon an electronic data base of radionuclide-deposition densities prepared by Beck (1999);
- Averaged over large regions of the continental United States with indications of how the high-risk populations could be identified. However, primary calculations should be carried out on a county-by-county basis and averaged only for presentation purposes;
- Calculated separately for the more important radionuclides produced in nuclear weapons tests of the types carried out at the Nevada Test Site. Radionuclides should include ^{90}Sr, ^{137}Cs, and ^{106}Ru; if sufficient information is available from Beck and other sources doses from additional radionuclides should be calculated.
- Provided in terms of absorbed dose for some of the more radiosensitive organs and tissues (red bone marrow, gastrointestinal tract, etc.);
- Calculated by year of testing (1951, 1952, 1953, 1955, 1957, and 1962) and summed over all tests at the Nevada Test Site (NTS) with a comparison to the published latitudinal average doses (UNSCEAR 1993) for all tests; and
- Provided both in written form and in an electronic version.

Additional work to be performed included the provision of a list of references regarding (1) networks performing measurements of fallout radionuclides in air and foodstuffs and (2) the assessment of doses from internal radiation. The funds made available to accomplish this work consisted of $25,000. Thus, it was necessary to find very efficient means to accomplish this complex task.

The purpose of this report is to describe the results of the study outlined above. Based upon the deposition-density values provided by Beck (1999), dose commitments to internal organs that originated from the ingestion of contaminated food have been estimated for adults in each of approximately 3,100 counties in the continental United States. Estimates are made for 20 parent radionuclides from 61 events that took place at the NTS from 1951 through 1962. For this feasibility study not all organs have been considered; rather, effective doses have been calculated and organ doses have been considered only in those cases where the organ-dose coefficient for a particular radionuclide is more than twice the dose coefficient for effective dose. According to this criterion, organ doses are estimated for bone surface, colon, kidneys, liver, red marrow, and thyroid. Results of the calculations are summarized for each county by year of test (1951, 1952, 1953, 1955, 1957, and 1962) and for the total series. Collective effective dose commitments are calculated for each year and for the total. These summary results are presented in the main report in the form of maps and tables. The attachments to this report provide results for other tasks.

The detailed results of the calculations by county for each test and with yearly and total summaries by county are attached in the form of spreadsheets on two compact discs (CDs).

METHODS

Nuclear events of interest

There were 100 nuclear events conducted in the atmosphere at the NTS (DOE 1994). These tests ranged in yield from extremely small (<1 t) to a maximum of 74 kt (Shot Hood on 5 July 1957). In addition there were "cratering" events that released significant amounts of debris; the most notable was the 104-kt Project Sedan detonated on 6 July 1962. Not all of these events produced fallout that was measured or measurable beyond the confines of the NTS; thus Beck's and this investigation have focused on those more meaningful events in terms of releases to the offsite environment. Beck (1999) has reported results for a total of 61 events: eight in 1951, eight in 1952, 11 in 1953, 13 in 1955, 19 in 1957, and two in 1962 (including Sedan). Some of these events were detonated so close together in time that it has been impossible to distinguish the debris. Thus, results for Bee and Ess (both fired on 22 March 1955); Apple and Wasp (both fired on 29 March 1955); Kepler (24 July 1957) and Owens (25 July 1957); and Wheeler (6 September 1957), Coulomb (6 September 1957), and Laplace (8 September 1957) were combined in Beck (1999). Results are thus reported here for 56 calculations. A complete list of these events with dates and yields is given in Table 1.

General system of dose calculation

The method of calculation used for this report was derived from that used for the Off-Site Radiation Exposure and Review Project (ORERP), which was performed during the time period of approximately 1979 through 1987 (Church et al. 1990).* The ORERP study was designed to calculate external and internal doses from the tests of nuclear weapons at the NTS, but the focus was on populations living in the near downwind regions. Originally, the assessment domain consisted of several counties in Nevada and one county in Utah that were known to have received higher depositions. Eventually, the assessment domain was expanded to include the entire states of Nevada, Utah, Arizona, and New Mexico, and portions of several additional states [western Colorado, southwestern Wyoming, southern Idaho, southeastern Oregon,

* The author of the current report was the Scientific Director of the ORERP.

Table 1. A list and some parameters of the nuclear explosions at the Nevada Test Site that are included in this assessment of dose from the ingestion of food contaminated by these events. Some events were so close together in time that they were considered together for the estimates of deposition densities tabulated by Beck (1999).

Calculation number	Operation	Test	Type	Date	Yield, kt
1	Ranger	Baker	Airdrop	28-Jan-51	8
2		Baker-2	Airdrop	2-Feb-51	8
3	Buster	Baker	Airdrop	28-Oct-51	3.5
4		Charlie	Airdrop	30-Oct-51	14
5		Dog	Airdrop	1-Nov-51	21
6		Easy	Airdrop	5-Nov-51	31
7	Jangle	Sugar	Surface	19-Nov-51	1.2
8		Uncle	Crater	29-Nov-51	1.2
9	Tumbler-	Able	Airdrop	1-Apr-52	1
10	Snapper	Baker	Airdrop	15-Apr-52	1
11		Charlie	Airdrop	22-Apr-52	31
12		Dog	Airdrop	1-May-52	19
13		Easy	Tower	7-May-52	12
14		Fox	Tower	25-May-52	11
15		George	Tower	1-Jun-52	15
16		How	Tower	5-Jun-52	14
17	Upshot-	Annie	Tower	17-Mar-53	16
18	Knothole	Nancy	Tower	24-Mar-53	24
19		Ruth	Tower	31-Mar-53	0.2
20		Dixie	Airdrop	6-Apr-53	11
21		Ray	Tower	11-Apr-53	0.2
22		Badger	Tower	18-Apr-53	23
23		Simon	Tower	25-Apr-53	43
24		Encore	Airdrop	8-May-53	27
25		Harry	Tower	19-May-53	32
26		Grable	Airburst	25-May-53	15
27		Climax	Airdrop	4-Jun-53	61
28	Teapot	Wasp	Airdrop	18-Feb-55	1
29		Moth	Tower	22-Feb-55	2
30		Tesla	Tower	1-Mar-55	7
31		Turk	Tower	7-Mar-55	43
32		Hornet	Tower	12-Mar-55	4
33		Bee}Ess			
		Bee	Tower	22-Mar-55	8
		Ess	Crater	23-Mar-55	1

Table 1. (concluded).

Calculation number	Operation	Test	Type	Date	Yield, kt
34		Apple}Wasp'			
		Apple-1	Tower	29-Mar-55	14
		Wasp'	Airdrop	29-Mar-55	3
35		Post	Tower	9-Apr-55	2
36		Met	Tower	15-Apr-55	22
37		Apple-2	Tower	5-May-55	29
38		Zucchini	Tower	15-May-55	28
39	Plumbbob	Boltzmann	Tower	28-May-57	12
40		Wilson	Balloon	18-Jun-57	10
41		Priscilla	Balloon	24-Jun-57	37
42		Hood	Balloon	5-Jul-57	74
43		Diablo	Tower	15-Jul-57	17
44		Kepler}Owens			
		Kepler	Tower	24-Jul-57	10
		Owens	Balloon	25-Jul-57	9.7
45		Shasta	Tower	18-Aug-57	17
46		Doppler	Balloon	23-Aug-57	11
47		Smoky	Tower	31-Aug-57	44
48		Galileo	Tower	2-Sep-57	11
49		WCL			
		Wheeler	Balloon	6-Sep-57	0.197
		Coulomb-B	Surface	6-Sep-57	0.3
		Laplace	Balloon	8-Sep-57	1
50		Fizeau	Tower	14-Sep-57	11
51		Newton	Balloon	16-Sep-57	12
52		Whitney	Tower	23-Sep-57	19
53		Charleston	Balloon	28-Sep-57	12
54		Morgan	Balloon	7-Oct-57	8
55	Storax	Sedan	Crater	6-Jul-62	104
56		Small Boy	Tower	14-Jul-62	Low

and nearby areas of California (including Los Angeles)]. Given that appropriate input data are available, it is a logical extension to apply the ORERP methodology to a broader assessment domain.

The general ORERP methodology for calculating internal dose from the consumption of contaminated foods has been described by Whicker and Kirchner (1987), Breshears et al. (1989), Whicker et al. (1990, 1996), Ng et al. (1990), and Kirchner et al. (1996). A modular system[†] was developed that depended upon three things:

[†] The modular system was necessitated by the fact that many different organizations at several locations had responsibilities for the conduct of the project.

- Estimating the deposition per unit area of individual radionuclides on the ground. This was done either through evaluation of exposure-rate measurements with conversion to radionuclide deposition (Beck 1980; Hicks 1982, 1990), or through inference of the deposition of one or more of the important radionuclides (Beck and Anspaugh 1991).
- Estimating the total amount of an individual radionuclide that might be ingested by humans of differing ages. This simple statement covers a very complex undertaking of estimating the dynamics of radionuclide contamination of foods and age-dependent human-consumption rates of food (Whicker and Kirchner 1987).
- Estimating the amount of age-dependent dose that would be received by a member of the public from the ingestion of a unit activity of a particular radionuclide. When the ORERP work was started, the International Commission on Radiological Protection (ICRP) had not yet published their work on this subject, and such calculations were performed within the project (Ng et al. 1990; Kirchner et al. 1996).

Thus, the modular system used can be written as a simple equation:

$$D = P \times I \times F_g \,, \qquad (1)$$

where D = Absorbed dose, Gy, or equivalent/effective dose, Sv;
P = Deposition density of the radionuclide of interest at time of fallout arrival, Bq m^{-2};
I = Integrated intake by ingestion of the radionuclide per unit deposition, Bq per Bq m^{-2}; and
F_g = Ingestion-dose coefficient for the radionuclide, Gy Bq^{-1} or Sv Bq^{-1}.

Equivalent and effective doses were not calculated for the ORERP, but such calculations are performed and reported here for this task. This requires additional specification of the values and units for F_g and subsequently for D.

Radionuclides of interest

A great many fission-product radionuclides are created by a nuclear explosion. Due to the extremely short reaction time, long-lived radionuclides do not accumulate as they do during the operation of a nuclear reactor. Thus, much of the dose from small nuclear weapons tests (<100 kt) in the atmosphere arises from fairly short-lived radionuclides. The situation is rather different for the large U.S. tests that were conducted in the Pacific or for the large Russian tests conducted near the Arctic Circle. Those tests were powerful enough to inject most of their debris into the stratosphere from which it devolved with a half time of at least one year. Thus, most of the short-lived radionuclides had already decayed by the time this global fallout was deposited. In addition, the large nuclear explosions were mainly of fusion devices with a rather small fission trigger (and with perhaps a tertiary fission stage); these kinds of devices produced and/or spilled large amounts of ^{3}H. The intense flux of neutrons from these devices also produced large amounts of ^{14}C through the reaction $^{14}N(n,p)^{14}C$. The amount of ^{14}C produced by the fusion explosions is so large that this radionuclide produces the largest portion of dose commitment from the ingestion of foods contaminated by global[‡] fallout (UNSCEAR 1993).

[‡] Debris injected into the high troposphere or the stratosphere circulates in a latitudinal band around the entire globe and eventually deposits on the earth. Hence, the term "global" fallout.

At the NTS the atmospheric tests were small in comparison; the debris from the tests was not injected into the stratosphere to a significant extent; and the amounts of ^{3}H and ^{14}C released were sufficiently small that the resulting doses from these two radionuclides were trivial in comparison to doses from other radionuclides.

For the ORERP, screening calculations (Ng et al. 1990) were performed for more than 100 radionuclides in order to focus on the more important. Beck (1999) has generally followed the results of this procedure and has provided estimates of the deposition per unit area for this same group of radionuclides. The radionuclides for which it is possible to estimate internal doses without undertaking significant new work are ^{89}Sr, ^{90}Sr, ^{91}Sr, ^{97}Zr, ^{99}Mo, ^{103}Ru, ^{105}Rh, ^{106}Ru, ^{131}I, ^{132}Te, ^{133}I, ^{135}I, ^{136}Cs, ^{137}Cs, ^{140}Ba, ^{143}Ce, ^{144}Ce, ^{147}Nd, ^{239}Np, $^{239+240}Pu$, and ^{241}Pu.[§] Based upon the screening calculations performed for ORERP for its assessment domain, this group of radionuclides accounts for at least 95% of the dose to each organ through ingestion of contaminated foods. Due to the fact that the current assessment domain is much larger and the average travel time of the debris is longer, the importance of some of the shorter lived radionuclides (e.g., ^{91}Sr, ^{97}Zr, ^{133}I, ^{135}I, and ^{143}Ce) is less than it was for the ORERP assessment domain. For this work dose calculations were performed for 19 of the 21 radionuclides listed above; ^{135}I and ^{239}Np were not included, as deposition densities were not reported in Beck (1999).

In addition to the parent radionuclides listed in the above paragraph, doses from decay products were also included in the calculation to the extent that the product arises from the decay of the parent radionuclide after it has entered the body. For example, the decay product of ^{132}Te is ^{132}I, which has a half life of 2.30 h (ICRP 1983). Any ^{132}I that originates in the body from the decay of ^{132}Te is included in the dose calculation; but any ^{132}I on food at the time of consumption is not included. Additional parent-progeny pairs are $^{90}Sr(^{90}Y)$, $^{97}Zr(^{97}Nb)$, $^{103}Ru(^{103m}Rh)$, $^{106}Ru(^{106}Rh)$, $^{137}Cs(^{137m}Ba)$, $^{140}Ba(^{140}La)$, and $^{144}Ce(^{144}Pr)$.

Estimates of deposition per unit area (deposition density)

The first parameter in eqn (1) is P, the deposition per unit area. For the radionuclides indicated above as being included in this assessment, Beck (1999) has provided estimates of the deposition densities of each radionuclide in each of the approximately 3,100 counties in the contiguous United States. Nearby the NTS where some of the larger counties experienced considerable gradations in deposition, counties have been broken into subparts. In all, estimates are provided for 3,094 geographic units (counties or subparts of counties). These estimates of deposition are based primarily on measurements made at the time and reported by the "gummed-film" network operated by the Department of Energy's (DOE's) Environmental Measurements Laboratory (EML), which was then known as the Atomic Energy Commission's (AEC's) Health and Safety Laboratory (HASL). As the measurements occurred at a finite number (which varied from year to year) of locations and the amount of fallout within a small geographic area could be influenced significantly by rainfall, the measured data were analyzed through a complex process known as "kriging." This process is an unbiased interpolator that is capable of correlating with other data such as rainfall rate; the latter data were available on essentially a county-by-county basis. This complex process has been described in general by Beck et al. (1990) and Beck

[§] Plutonium-241 was not included in the ORERP calculations, but deposition densities were provided in Beck (1999); ^{241}Pu was assumed to have the same value of *I* as does $^{239+240}Pu$.

(1999), and for the important radionuclide, ^{131}I, by the NCI (1997). In some cases additional data, such as the experimentally measured residual levels of ^{137}Cs in the soil column, have been used to validate results or to provide additional information (Beck et al. 1990; Beck and Anspaugh 1991). Estimates of radionuclide-deposition density are provided in Beck (1999) as geometric mean estimates along with the estimated geometric standard deviations.

Age groups to be considered

The detailed calculations of dose were performed for adults only. This choice was necessitated by the limited resources available for this study and because adults constitute by far the largest segment of the population. Suggestions are provided below for how an interested reader might convert the doses reported here for adults to doses for other age groups. The specific situation of age differences in doses to the thyroid from ^{131}I has been treated extensively by the NCI (1997). In addition, some calculations presented below of per caput and collective dose commitment have been adjusted for the effect of age.

Estimates of integrated intake

For the radionuclides listed above, seasonally-dependent values of *I*, the integrated intake per unit deposition, have been published by Whicker and Kirchner (1987) based on their development of the PATHWAY model for the ORERP. "Integrated intake" is an estimate of the normalized (to deposition density) total amount of a radionuclide that will enter a person's mouth over time subsequent to the initial deposition of the radionuclide. Thus, the units of *I* are Bq per Bq m^{-2}. This is a very complex function that includes the two major components of 1) seasonally dependent rate of radioecological transfer of radionuclides through food chains and 2) the age-dependent rates of consumption of differing types of food. These estimates are also equivalent to geometric means (Breshears et al. 1989), and estimates of geometric standard deviations have been published by Breshears et al. (1989). Values of both geometric means and geometric standard deviations vary according to a radionuclide's chemical characteristics, including half life, and the season. As milk is generally a critical pathway, a key factor that varies with season is whether cows are grazing on fresh pasture (or being fed green chop) or are being fed stored feed.

For this assessment, the values published in Whicker and Kirchner (1987) were used. In their Table 9, values of integrated intakes by adults for 20 radionuclides are given for eight nuclear shots that occurred over a range of seasonal times. Based upon these published values for the eight times, values for other times were interpolated or extrapolated. Examples of input data for four of the more significant radionuclides are shown in Fig. 1.

Plots of the actual data used in this assessment for 19 radionuclides are shown in Figs. 2 through 19. Each point in the plots of Figs. 2 through 19 represents one of the "calculation numbers" indicated in Table 1. Estimates of the geometric standard deviations that accompany these values were taken from Table 5 of Breshears et al. (1989); these values are reproduced here as Table 2.

The radioecological component of PATHWAY is complex and includes many factors:

- Initial retention of radionuclides by vegetation;

- Loss of radionuclides from vegetation;
- Dilution of radionuclide concentration in fresh vegetation by plant growth;
- Movement through several soil compartments;
- Uptake of a radionuclide through the soil-root system; and
- Recontamination of plant surfaces by resuspension and redeposition and by rain splash.

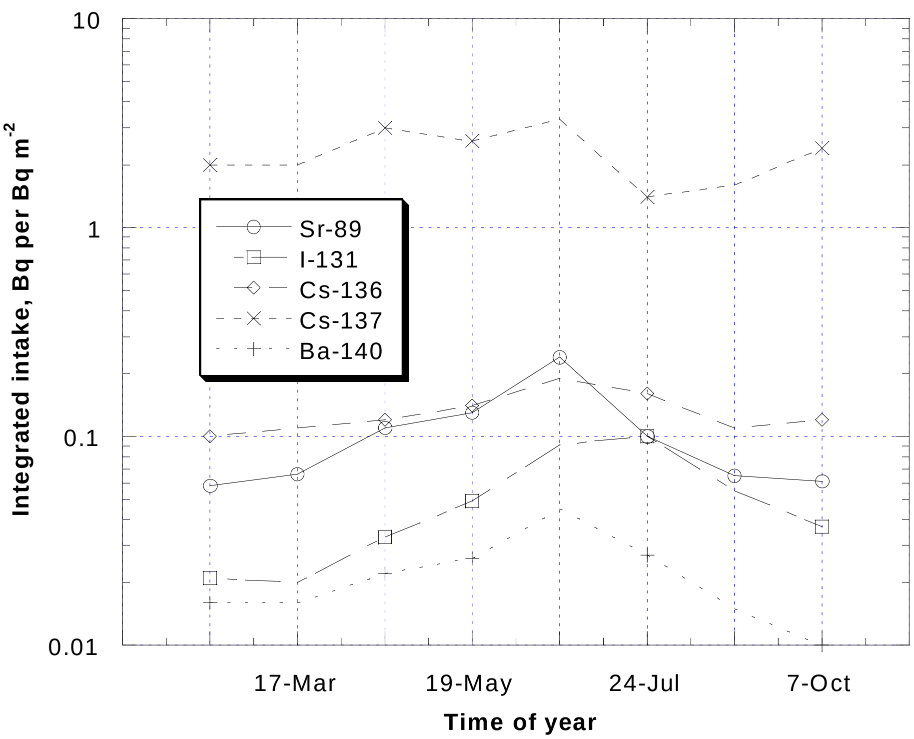


Fig. 1. Examples of the seasonally dependent values of integrated intake reported by Whicker and Kirchner (1987) for four of the more important radionuclides.

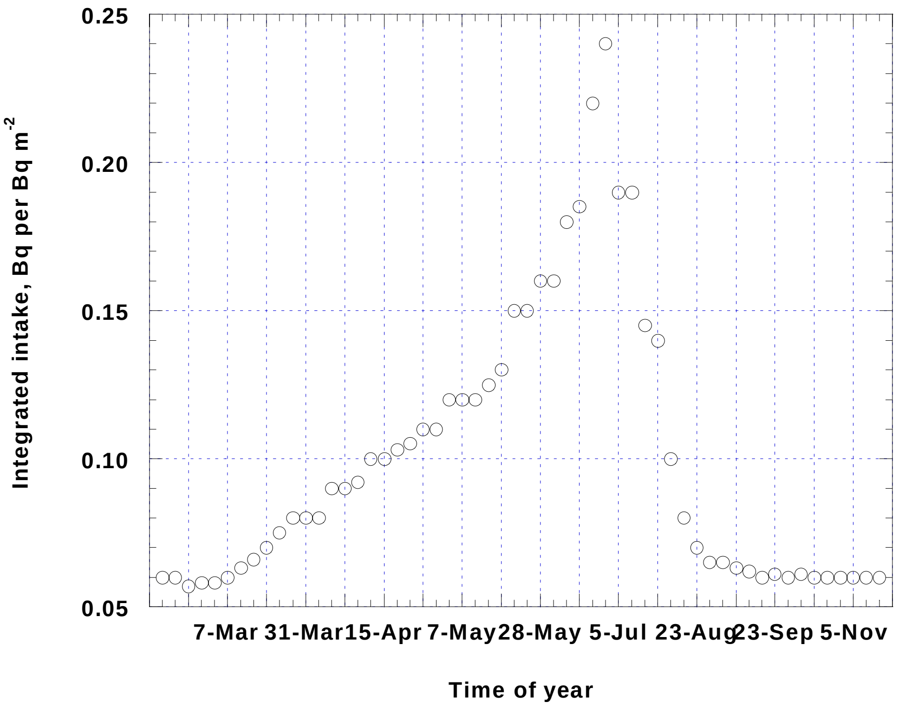


Fig. 2. Values for integrated intake used for ^{89}Sr.

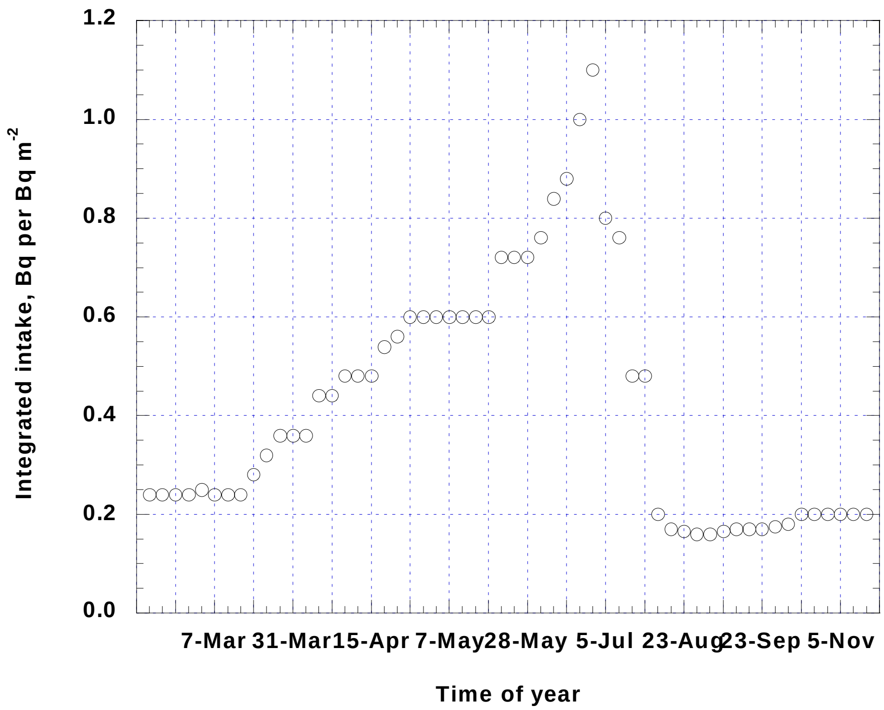


Fig. 3. Values for integrated intake used for ^{90}Sr.

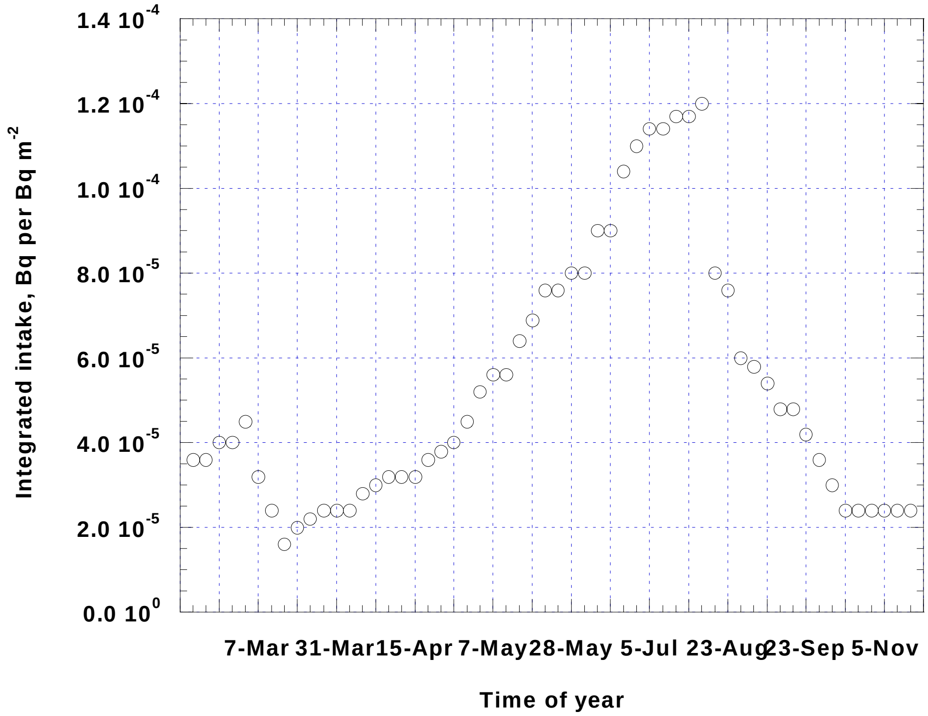


Fig. 4. Values for integrated intake used for ^{91}Sr.

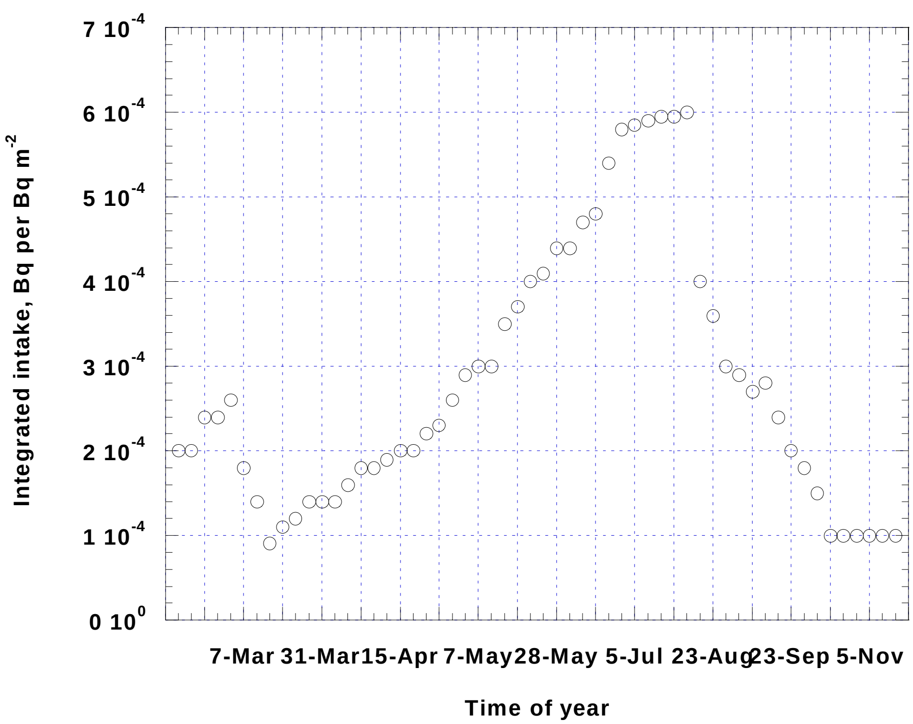


Fig. 5. Values for integrated intake used for ^{97}Zr.

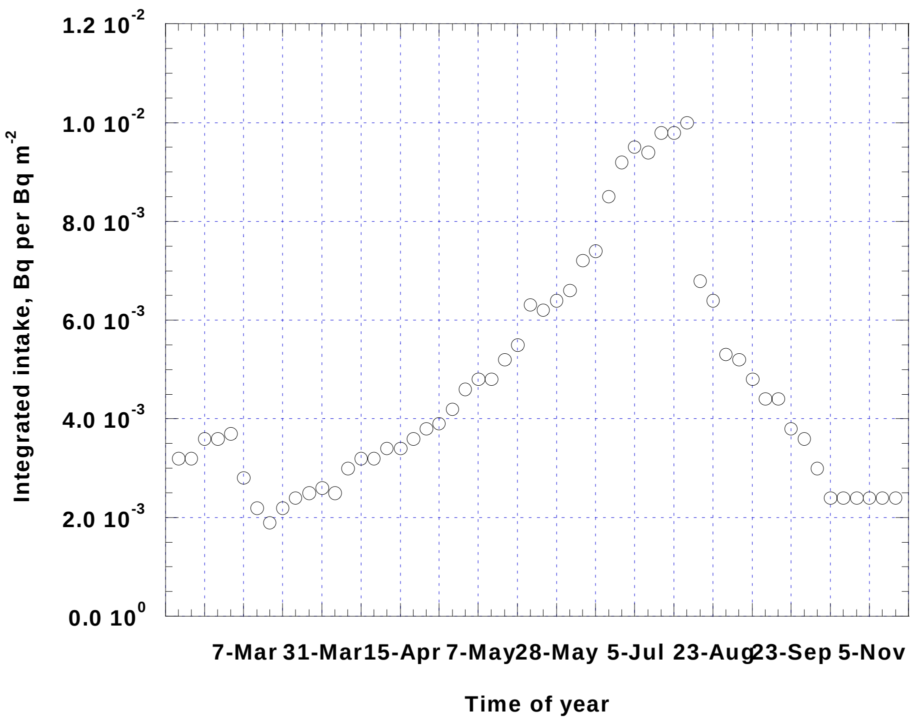


Fig. 6. Values for integrated intake used for ^{99}Mo.

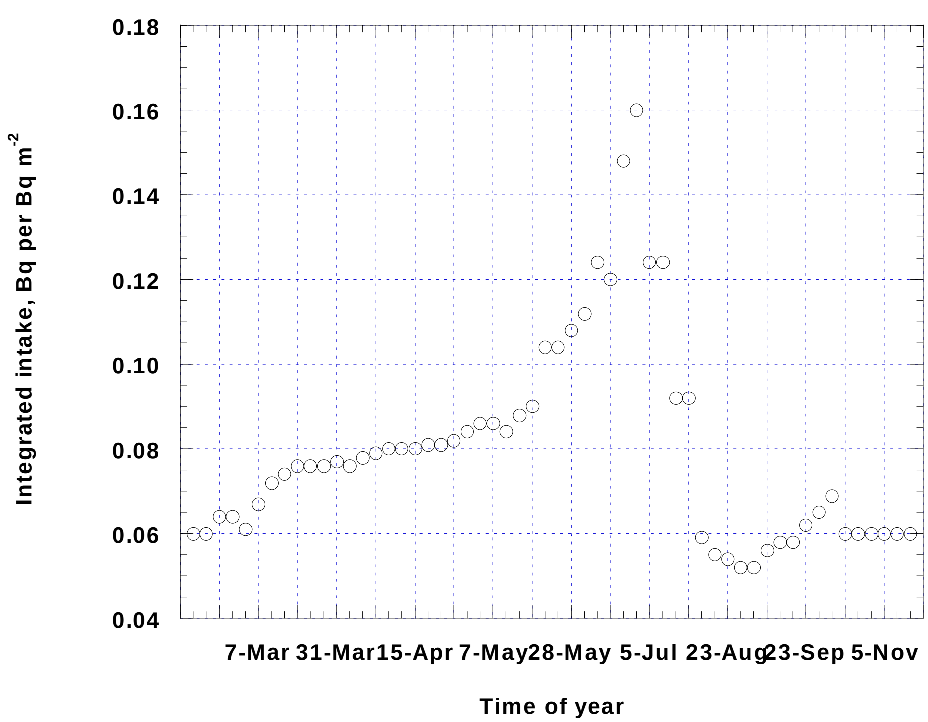


Fig. 7. Values for integrated intake used for ^{103}Ru.

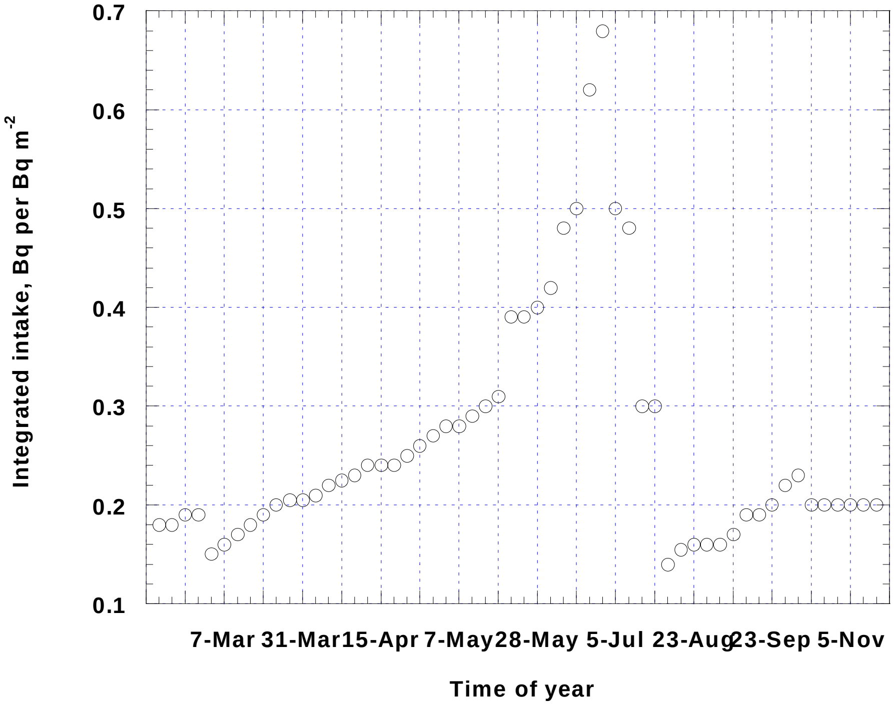


Fig. 8. Values for integrated intake used for ^{106}Ru.

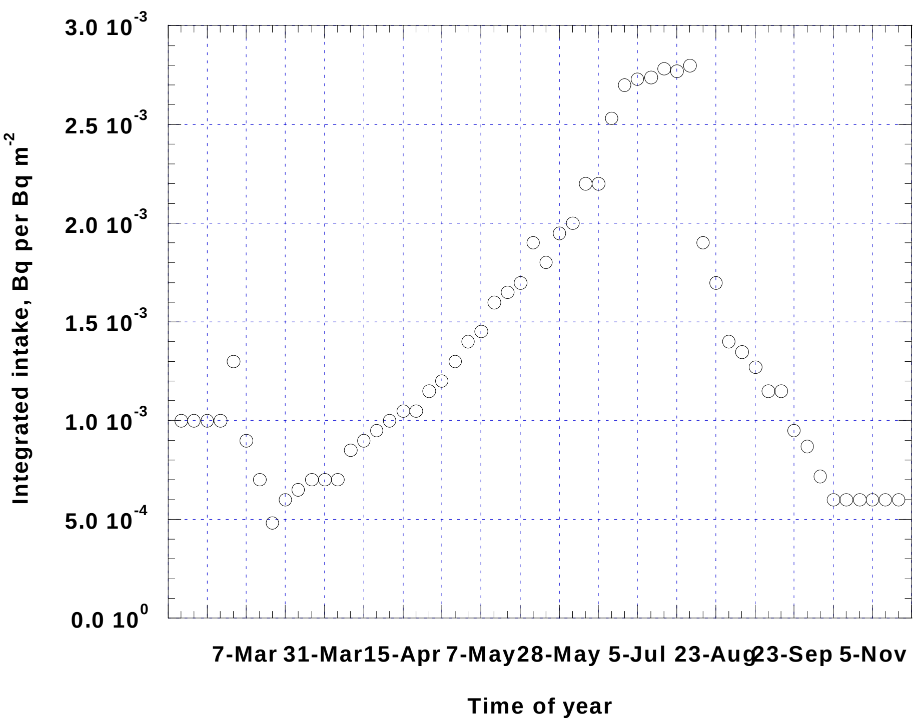


Fig. 9. Values for integrated intake used for ^{105}Rh.

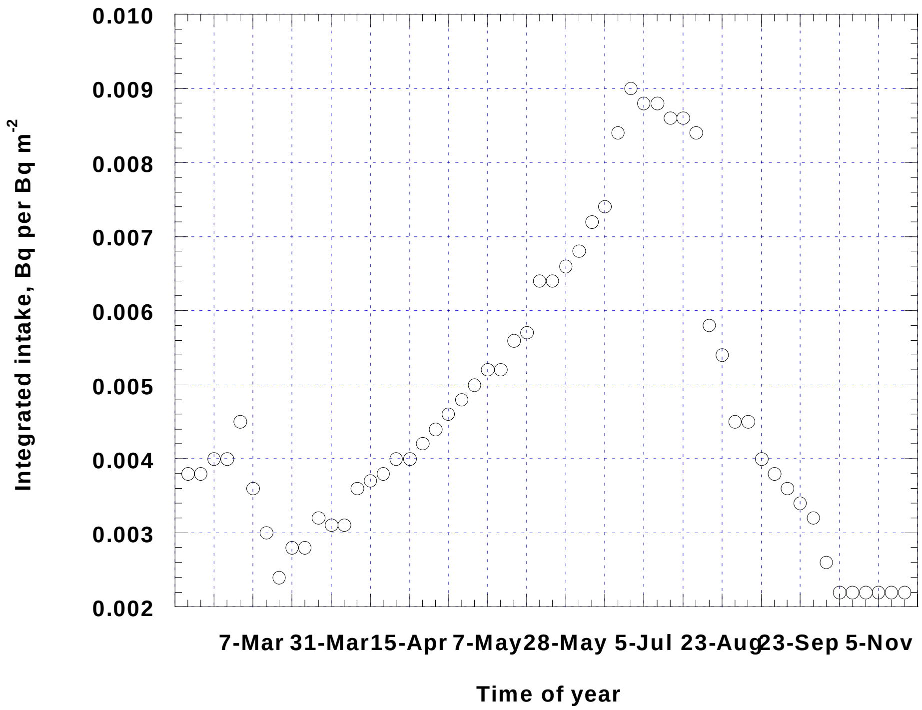


Fig. 10. Values for integrated intake used for ^{132}Te.

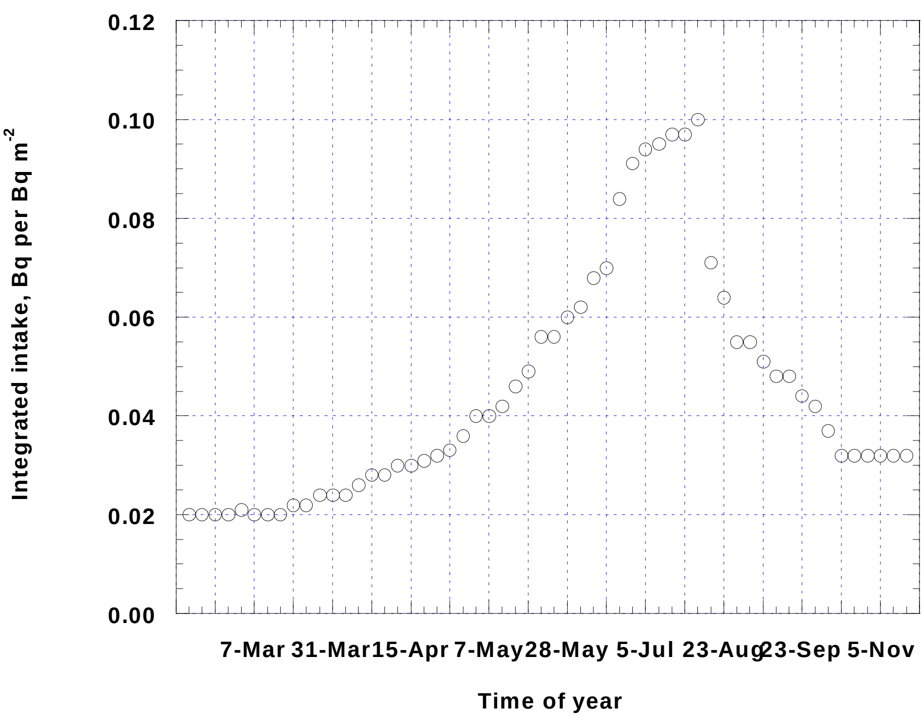


Fig. 11. Values for integrated intake used for ^{131}I.

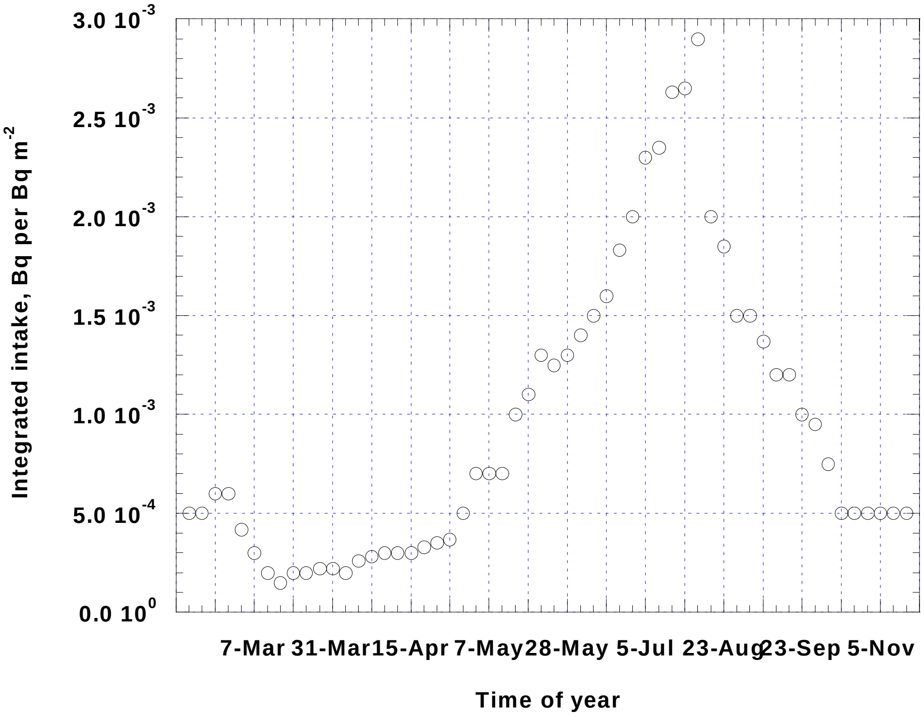


Fig. 12. Values for integrated intake used for ^{133}I.

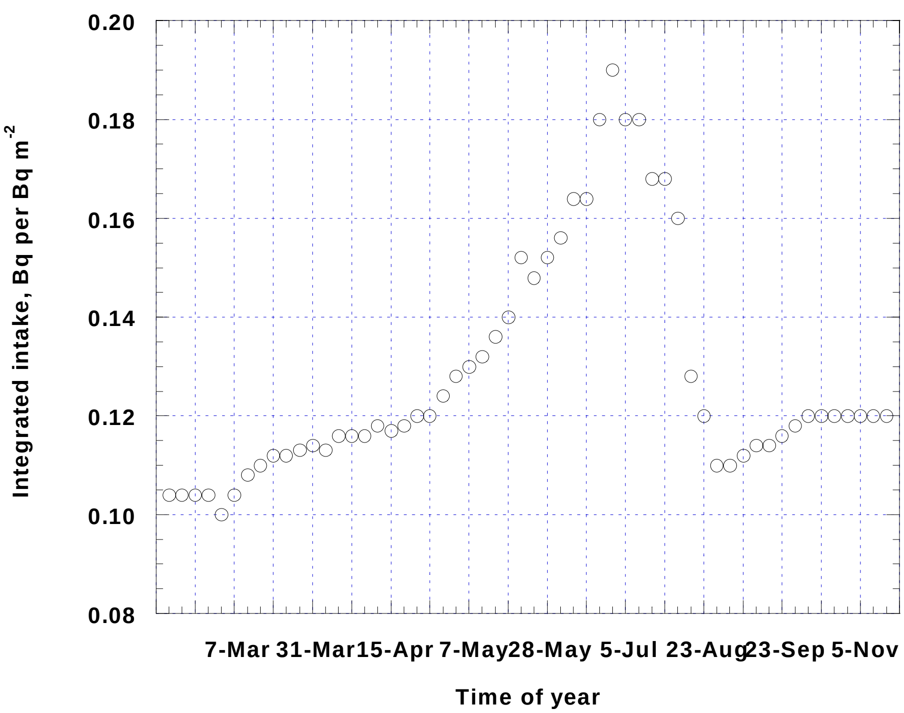


Fig. 13. Values for integrated intake used for ^{136}Cs.

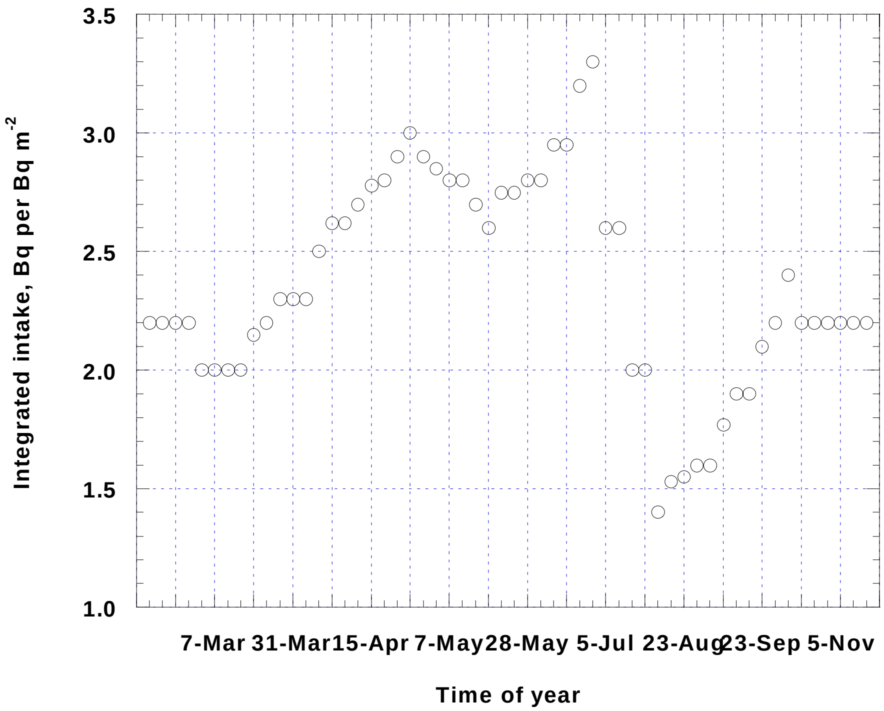


Fig. 14. Values for integrated intake used for ^{137}Cs.

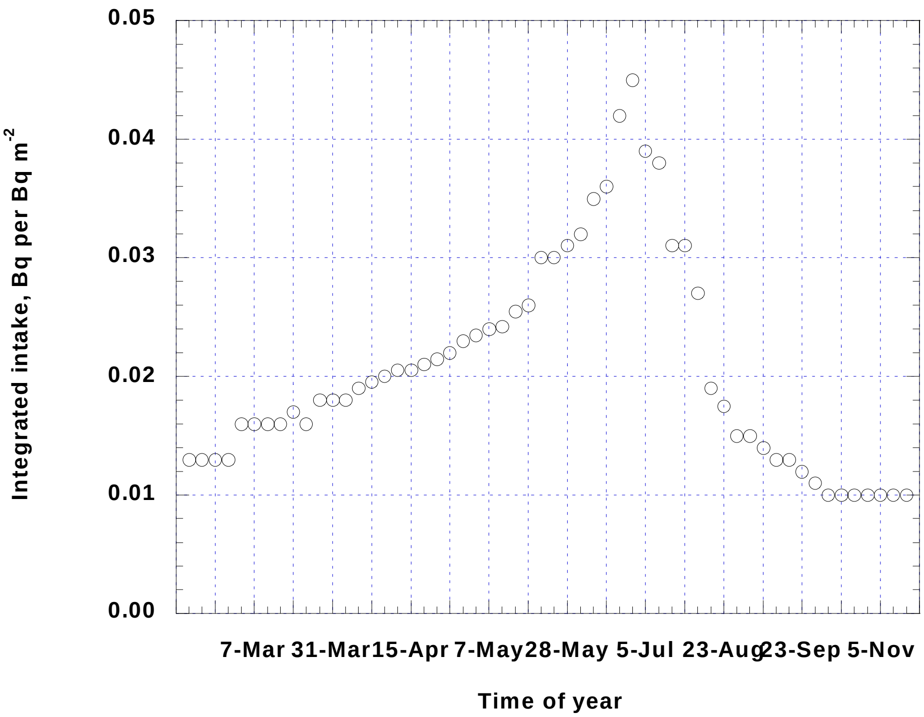


Fig. 15. Values for integrated intake used for ^{140}Ba.

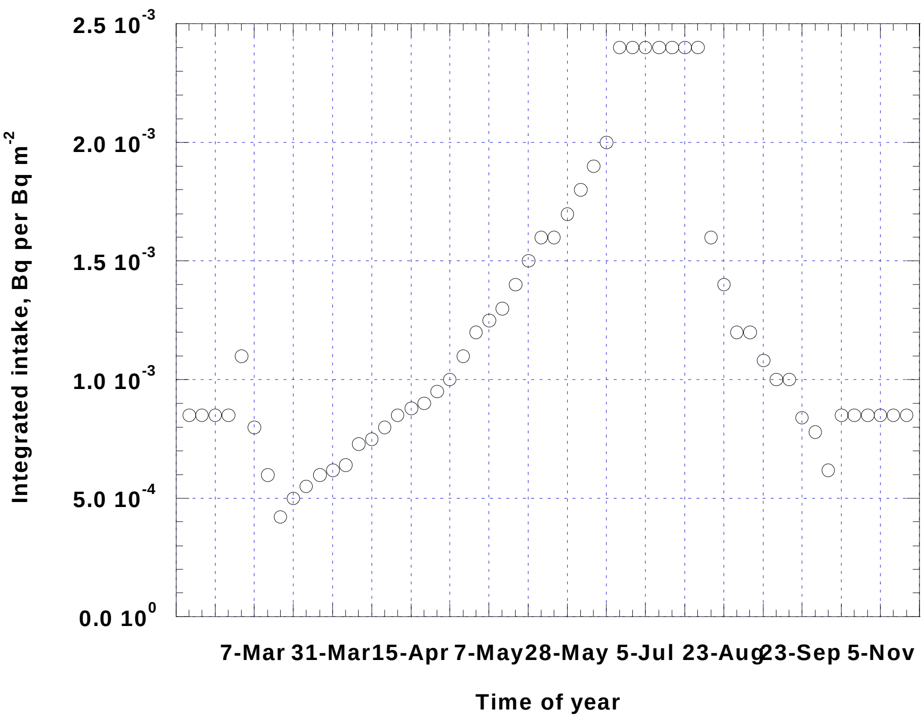


Fig. 16. Values for integrated intake used for ^{143}Ce.

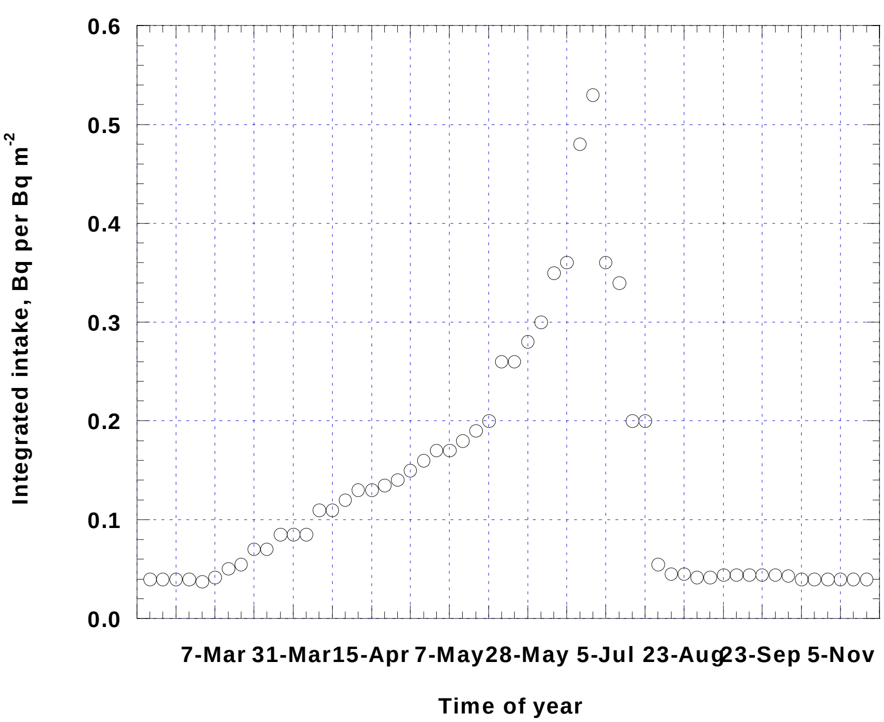


Fig. 17. Values for integrated intake used for ^{144}Ce.

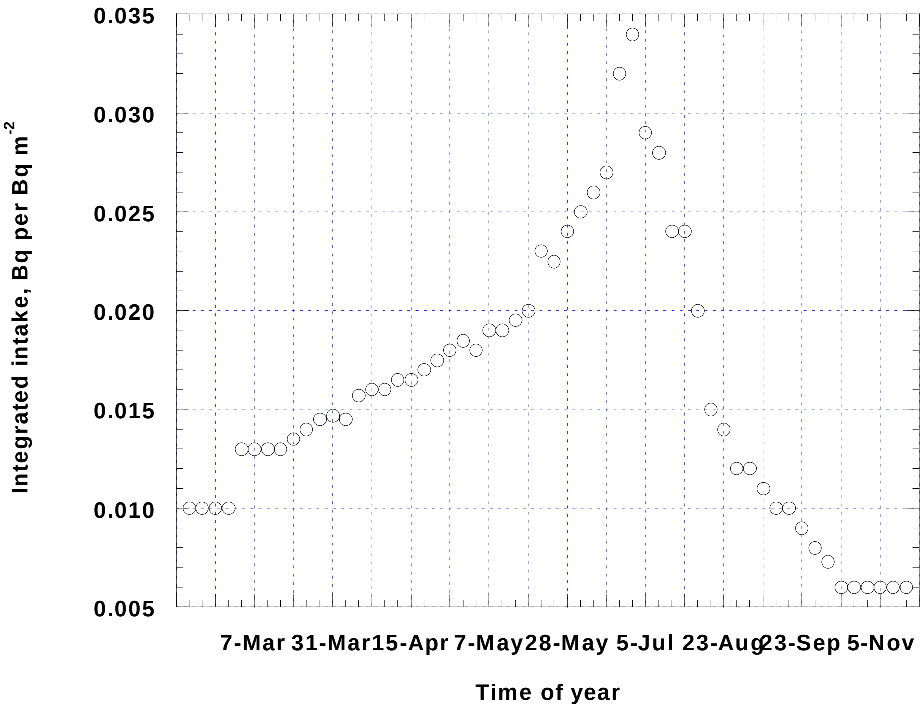


Fig. 18. Values for integrated intake used for ^{147}Nd.

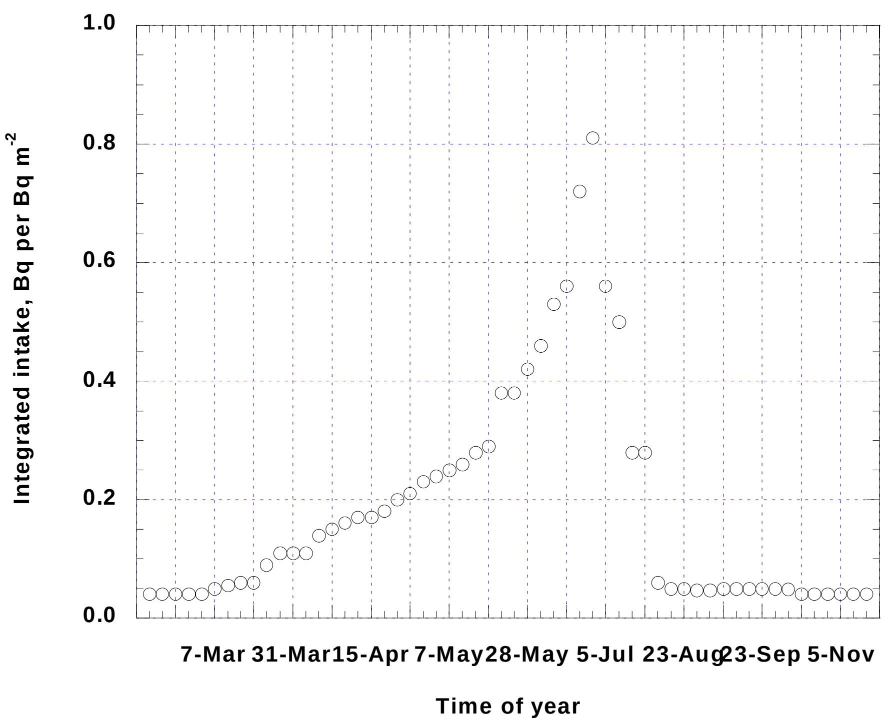


Fig. 19. Values for integrated intake used for $^{239+240}$Pu and ^{241}Pu.

Table 2. Values of geometric standard deviation associated with the values of the geometric means of integrated deposition shown in Figs. 2–19. Values are from table 5 of Breshears et al. (1989).

Month of fallout deposition	Physical half life		
	<30 d	30–500 d	>500 d
January	1.7	1.9	2.1
February	1.7	1.9	2.1
March	1.7	1.9	2.1
April	1.9	2.0	2.1
May	2.3	2.2	2.1
June	2.1	2.1	2.1
July	2.1	2.1	2.1
August	2.1	2.1	2.0
September	2.7	2.3	2.0
October	1.7	1.8	1.9
November	1.7	1.8	1.9
December	1.7	1.8	1.9

One of the critical factors that is known to vary substantially is the initial retention of fallout by fresh vegetation, particularly when deposition occurs with precipitation (Anspaugh 1987; NCI 1997). The value used for this parameter in PATHWAY is 0.39 m^2 kg^{-1}. The value of this parameter is known to vary with particle size (and distance from the site of detonation) for dry deposition and with rainfall rate for wet deposition. In addition, values vary substantially for reasons that are not yet explicable. Thus, uncertainty in this parameter contributes substantially to the uncertainty in the estimates of internal dose. Some reduction in uncertainty might be achieved, if the county-by-county estimates of rainfall for each day following each shot were retrieved and used to adjust this value, as was done in NCI (1997) for dose from ^{131}I. This effort was beyond the scope of the present study, and it is not clear from the data in NCI (1997) that this laborious process resulted in a substantial reduction in uncertainty.

Thus, while the discussed values of integrated intake were originally derived for dry deposition in the semi-arid western areas of the U.S. nearby the NTS, this same value has been used for the entire study performed here. Based upon the experimental data reported by Hoffman et al. (1989), the value of 0.39 m^2 kg^{-1} is actually a reasonable value for retention during rainfall, except during conditions of very light rainfall when higher values have been observed.

Dose coefficients

The ICRP (1989, 1993, 1995, 1996) has provided compilations of dose coefficients, F_g, for ingestion of radionuclides by members of the general public. These published values, however, are incomplete in the sense that dose coefficients are not listed for all organs for all age groups. Recently, the ICRP (1998) has made available a CD-ROM system that allows the calculation of equivalent and effective doses for all organs for the six age groups** considered by the ICRP. The dose values provided by the ICRP represent the dose from a given intake that will occur over the next 50 years for adults or until age 70 y for the younger age groups.

The ICRP-tabulated values are the basic source of dose coefficients used for this dose assessment. As for previously performed assessments (Ng et al. 1990), the ICRP dose coefficients have been considered to be average values (or arithmetic means). Thus, in order to be consistent and to allow for the analytical propagation of error, the ICRP values have been converted to geometric means, $\bar{x}_g$, by the use of eqn (2):

$$\bar{x}_g = \exp[(\ln(\bar{x}) - \ln^2(\sigma_g)], \tag{2}$$

where $\bar{x}$ is the arithmetic mean (from the ICRP tabulation) and σ_g is the estimated geometric standard deviation. The latter values have been taken from Kirchner et al. (1996). The estimated values of σ_g for adults are 1.6 for ^{89}Sr and ^{91}Sr, 1.4 for ^{90}Sr, 1.5 for ^{136}Cs, 1.3 for ^{137}Cs, and 1.8 for all other radionuclides. These values were used for all target organs and for effective dose.

The dose coefficients actually used for this study are shown in Table 3 along with the original values taken from ICRP (1998).

Organs of interest

In principle, doses can be calculated for the 22 organs considered by the ICRP and dose coefficients are available (ICRP 1998). However, experience from ORERP (Ng et al. 1990) is that only the thyroid would be expected to receive a higher dose from the ingestion of fallout compared to the dose received from external exposure to the same fallout. For this and reasons of efficiency, calculations are provided here in terms of effective dose. In addition, if the dose to any organ for any radionuclide is more than twice that of the effective dose, calculations for those organs are also provided. For example, for ^{137}Cs, which is distributed throughout the body, calculations are provided only for effective dose. On the other hand, for plutonium radionuclides doses are also provided for the bone surface and the liver, which are organs where plutonium concentrates. An approximation of the dose to any organ from all of the radionuclides considered would be to sum doses for all radionuclides for which that organ is specifically listed and to add the effective dose for any radionuclide for which calculations for a specific organ have not been provided. Alternatively, a more accurate calculation for a specific situation could be done by using a ratio of the dose coefficients found in ICRP (1998).

As the effective dose is a weighted sum of the dose to all organs, where the weights represent the estimated probability of the occurrence of a “stochastic” effect in that organ, the effective dose is the most efficient choice of an input parameter for the estimation of health

** The six age groups considered by the ICRP are 1) three months [0 to 12 months], 2) one y [from 1 y to 2 y], 3) five y [>2 y to 7 y], 4) 10 y [>7 y to 12 y], 5) 15 y [>12 y to 17 y], and 6) adult [>17 y].

Table 3. Dose coefficients used in this study. The arithmetic mean values ($\bar{x}$) are taken from ICRP (1998), the geometric standard deviations (σ_g) are from Kirchner et al. (1996), and the geometric means ($\bar{x}_g$) are calculated according to eqn (2).

Radionuclide	Organ	Dose coefficient		
		$\bar{x}$, Sv Bq^{-1}	σ_g	$\bar{x}_g$, Sv Bq^{-1}
^{89}Sr	Effective	2.6×10^{-9}	1.4	2.5×10^{-9}
	Bone surface	5.9×10^{-9}	1.4	5.6×10^{-9}
	Colon	1.4×10^{-8}	1.4	1.3×10^{-8}
^{90}Sr	Effective	2.8×10^{-8}	1.3	2.7×10^{-8}
	Bone surface	4.1×10^{-7}	1.3	4.0×10^{-7}
	Red marrow	1.8×10^{-7}	1.3	1.7×10^{-7}
^{91}Sr	Effective	6.5×10^{-10}	1.8	5.5×10^{-10}
	Colon	3.8×10^{-9}	1.8	3.2×10^{-9}
^{97}Zr	Effective	2.1×10^{-9}	1.8	1.8×10^{-9}
	Colon	1.5×10^{-8}	1.8	1.3×10^{-8}
^{99}Mo	Effective	6.0×10^{-10}	1.8	5.0×10^{-10}
	Kidneys	3.1×10^{-9}	1.8	2.6×10^{-9}
	Liver	2.8×10^{-9}	1.8	2.4×10^{-9}
^{103}Ru	Effective	7.3×10^{-10}	1.8	6.1×10^{-10}
	Colon	4.3×10^{-9}	1.8	3.6×10^{-9}
^{106}Ru	Effective	7.0×10^{-9}	1.8	5.9×10^{-9}
	Colon	4.5×10^{-8}	1.8	3.8×10^{-8}
^{105}Rh	Effective	3.7×10^{-10}	1.8	3.1×10^{-10}
	Colon	2.7×10^{-9}	1.8	2.3×10^{-9}
^{132}Te	Effective	3.8×10^{-9}	1.8	3.2×10^{-9}
	Colon	1.3×10^{-8}	1.8	1.1×10^{-8}
	Thyroid	3.1×10^{-8}	1.8	2.6×10^{-8}
^{131}I	Effective	2.2×10^{-8}	1.8	1.9×10^{-8}
	Thyroid	4.3×10^{-7}	1.8	3.6×10^{-7}
^{133}I	Effective	4.3×10^{-9}	1.8	3.6×10^{-9}
	Thyroid	8.2×10^{-8}	1.8	6.9×10^{-8}
^{136} Cs	Effective	3.0×10^{-9}	1.4	2.8×10^{-9}
^{137}Cs	Effective	1.3×10^{-8}	1.3	1.3×10^{-8}
^{140}Ba	Effective	2.6×10^{-9}	1.8	2.2×10^{-9}
	Colon	1.7×10^{-8}	1.8	1.4×10^{-8}
^{143}Ce	Effective	1.1×10^{-9}	1.8	9.3×10^{-10}
	Colon	8.3×10^{-9}	1.8	7.0×10^{-9}
^{144}Ce	Effective	5.2×10^{-9}	1.8	4.4×10^{-9}
	Colon	4.2×10^{-8}	1.8	3.5×10^{-8}
^{147}Nd	Effective	1.1×10^{-9}	1.8	9.3×10^{-10}
	Colon	8.2×10^{-9}	1.8	6.9×10^{-9}

Table 3. (concluded).

Radionuclide	Organ	Dose coefficient		
		$\bar{x}$, Sv Bq^{-1}	σ_g	$\bar{x}_g$, Sv Bq^{-1}
$^{239+240}$Pu	Effective	2.5×10^{-7}	1.8	2.1×10^{-7}
	Bone surface	8.2×10^{-6}	1.8	6.9×10^{-6}
	Liver	1.7×10^{-6}	1.8	1.4×10^{-6}
^{241}Pu	Effective	4.8×10^{-9}	1.8	4.0×10^{-9}
	Bone surface	1.6×10^{-7}	1.8	1.3×10^{-7}
	Liver	3.4×10^{-8}	1.8	2.9×10^{-8}

effects to the U.S. population from the radionuclides released by the Nevada tests. As noted in the paragraph above, past experience has shown the thyroid is the only organ anticipated to receive a dose from the ingestion of contaminated foods that would exceed the dose from external exposure.

In Table 3, dose coefficients are given for the colon, and this corresponds to the values given in ICRP (1998). This represents a change in the usual practice of the ICRP, which was not to give dose coefficients for the colon but for the Upper Large Intestine (ULI) and the Lower Large Intestine (LLI) separately. This new procedure is more consistent with the practice of the ICRP in assigning a weighting factor (for the purpose of calculating effective dose) to the colon. In practice the LLI had been used for this, and the ULI had been considered a “remainder” organ. Now the colon dose is considered as the mass average of the equivalent dose in the walls of the upper and lower large intestine (ICRP 1995). Thus, with *H* representing equivalent dose, the dose coefficient for the colon is defined in terms of the dose coefficients for the ULI and LLI as

$$H_{\text{colon}} \equiv 0.57 H_{\text{ULI}} + 0.43 H_{\text{LLI}} \; . \tag{3}$$

Periods of summation

For each county (or part of a county) the dose commitments for a given radionuclide received within the years of major testing have been summed for those tests that took place in the years of 1951, 1952, 1953, 1955, 1957, or 1962. In order to achieve this summation, the individual estimates of geometric mean dose and geometric standard deviation for each test during the year have been converted to arithmetic means and variances, summed, and then reconverted to estimates of geometric mean and geometric standard deviation. The equations used for this purpose are as given in Ng et al. (1990).

The sum of effective doses from all radionuclides for each geographical unit has also been calculated for each test, for each year, and for the total time period by use of the same methodology as indicated in the paragraph above.

Collective dose

Estimates of collective dose to the entire contiguous U.S. were calculated by multiplying the arithmetic mean dose for each county by its estimated 1954 population and summing over all counties. The sums of collective effective doses for all radionuclides have been calculated for each test and summed for each year of testing. For the total summary over all years, additional tabulations of collective dose were calculated by summing collective effective dose and the collective dose to each organ indicated in Table 3. If the organ dose had not been calculated for a particular radionuclide, the effective dose for that radionuclide was included instead. This procedure overestimates the actual collective organ dose, and some corrections to this overestimation are considered and presented in the results discussed below. This correction is useful, as the great majority of effective dose is contributed by the dose from ^{131}I to the thyroid. Even though the tissue-weighting factor for the thyroid is only 0.05, the dose to many organs is less than 0.001 of that of the thyroid.

RESULTS AND DISCUSSION

The results of the basic calculations made for this project are provided on two CDs that accompany this report. Information on the CDs is organized with a folder containing all data for each year of significant tests at the NTS: 1951, 1952, 1953, and 1955 on the first CD; and 1957 and 1962 on the second CD. Within the folder for each year is a workbook for each event shown in Table 1. Each workbook contains two spreadsheets: "S1" contains data on geometric means and geometric standard deviations, and "S2" contains data on arithmetic means and arithmetic variances and collective effective dose. The data available for each event are indicated in Table 4. In addition, there is a summary workbook for each year that includes three spreadsheets. Spreadsheet "AM" contains the sum of doses for each geographic unit by arithmetic means and arithmetic standard deviations, whereas spreadsheet "GM" contains similar data according to geometric means and geometric standard deviations. These values of dose and effective dose are in units of mSv. The third spreadsheet, "Coll," contains information on the collective dose for each geographic unit summed over all events that took place during that year. Units for the third spreadsheet are person Sv. At the bottom of the latter spreadsheet is the sum of collective effective dose over all geographic units.

Information on these spreadsheets is coded according to the geographic location. An explanation of these codes is provided in the "FIPS" spreadsheet found on the first CD. In addition to providing the name of the county, the area of the county in km^2 and the estimated population in 1954 are given. The FIPS spreadsheet was provided by Beck (1999) and is reproduced from that report.

A final workbook is provided on the second CD that is labeled "TotalSummary." This contains three spreadsheets as for the yearly summaries. In addition, the total collective dose for effective dose and for each organ for all tests is summarized at the bottom of the "Coll" spreadsheet.

Table 4. Dose calculations provided for every significant nuclear test at the NTS. For each indicated calculation, data are provided on the geometric mean estimate, the geometric standard deviation, the arithmetic mean, and the arithmetic standard deviation. Effective doses are calculated for all radionuclides. In cases where the dose coefficient for an organ was more than twice that for effective dose, an additional calculation was made for that organ.

Radionuclide	Doses calculated
^{89}Sr	Effective, bone surface, colon
^{90}Sr	Effective, bone surface, red marrow
^{91}Sr	Effective, colon
^{97}Zr	Effective, colon
^{99}Mo	Effective, kidneys, liver
^{103}Ru	Effective, colon
^{106}Ru	Effective, colon
^{105}Rh	Effective, colon
^{132}Te	Effective, colon, thyroid
^{131}I	Effective, thyroid
^{133}I	Effective, thyroid
^{136}Cs	Effective
^{137}Cs	Effective
^{140}Ba	Effective, colon
^{143}Ce	Effective, colon
^{144}Ce	Effective, colon
^{147}Nd	Effective, colon
$^{239+240}Pu$	Effective, bone surface, liver
^{241}Pu	Effective, bone surface, liver
All	Effective
All	Collective effective

Effective dose commitments for individuals

Such large amounts of data are more easily summarized graphically. Figs. 20 through 25 consist of color-coded maps that provide information on the effective dose summed over all radionuclides for each year of testing. Fig. 26 is a summary over all years. For these plots the best estimator of effective dose is considered to be the geometric means, as tabulated in the spreadsheets contained in the CDs. Some dose was estimated to have occurred in every county considered; the highest total dose (3.0 mSv) occurred in part of Nye County, Nevada, and the lowest (0.011 mSv) in Wahkiakum County, Washington. Data for the 80 counties or parts of counties with higher estimates of total individual effective dose are given in Table 5. It is not surprising to see a large representation from Nevada (11) and Utah (31), but 21 counties from Colorado also appear on the list. This is apparently due to two reasons: These locations are downwind from many fallout tracks that passed over Utah, and there was enhanced deposition with rain after some clouds passed over the Rocky Mountains (see Beck 1984).

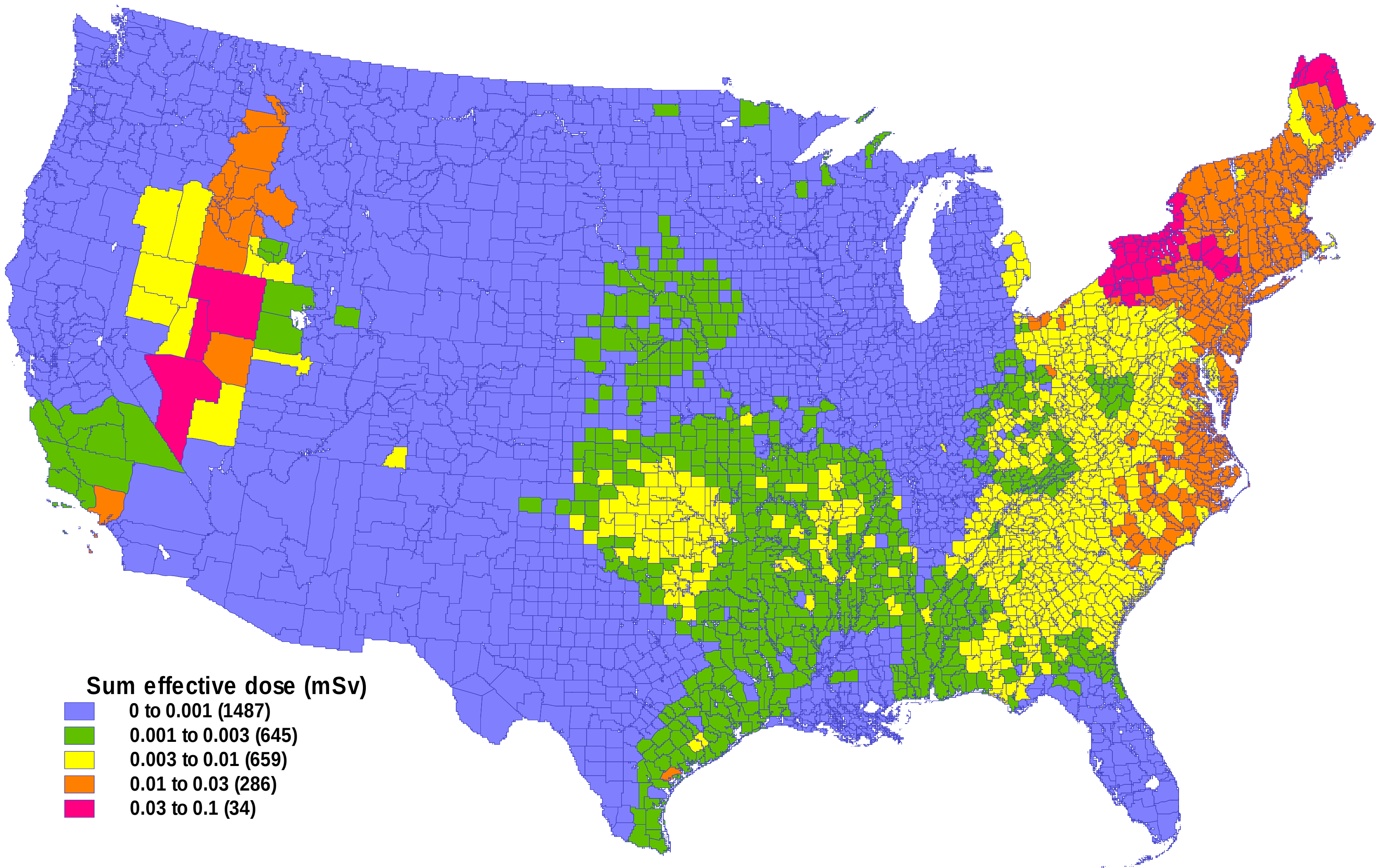


Fig. 20. Map of the effective dose by geographical area for the tests conducted in the year 1951.

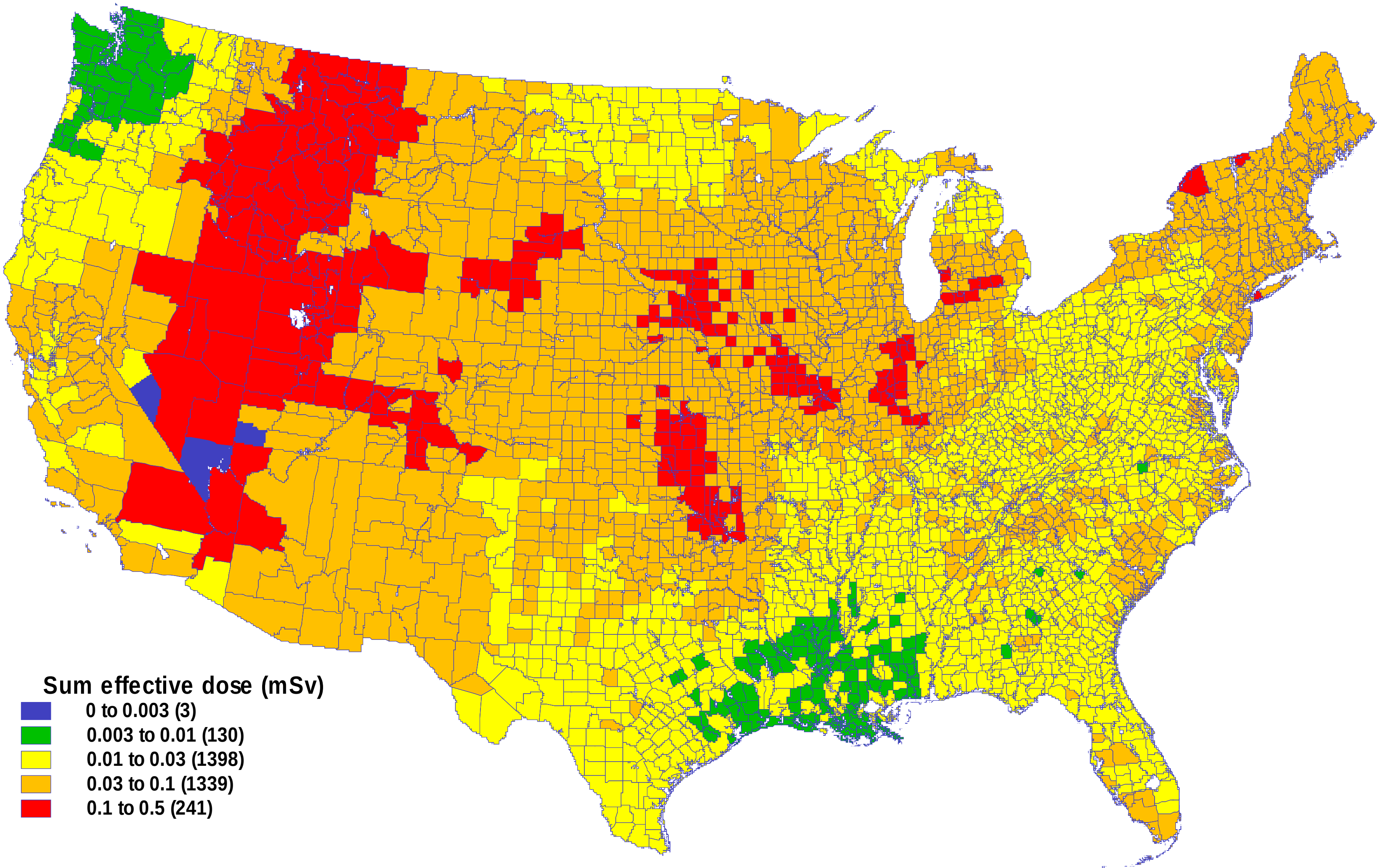


Fig. 21. Map of the effective dose by geographical area for the tests conducted in the year 1952.

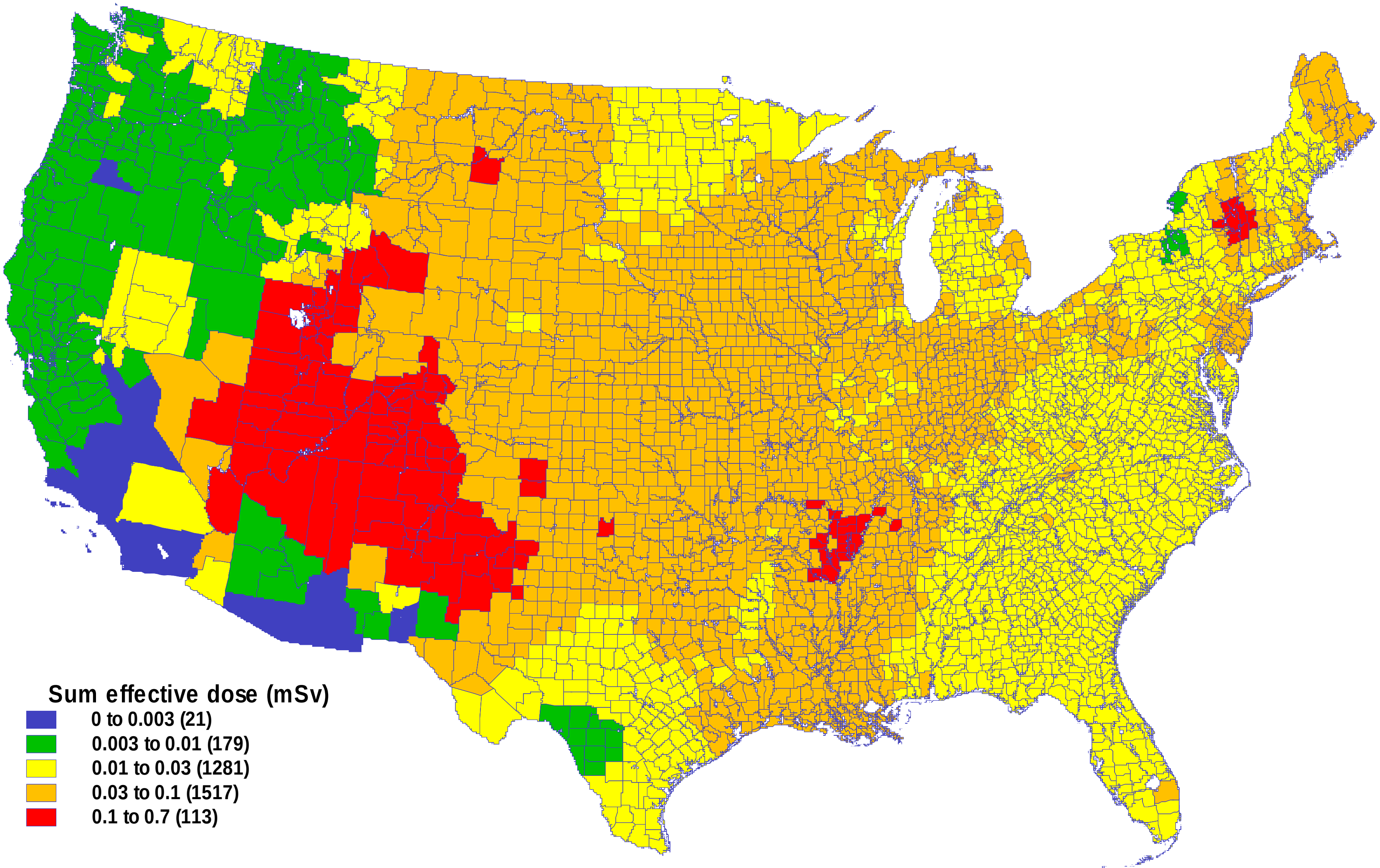


Fig. 22. Map of the effective dose by geographical area for the tests conducted in the year 1953.

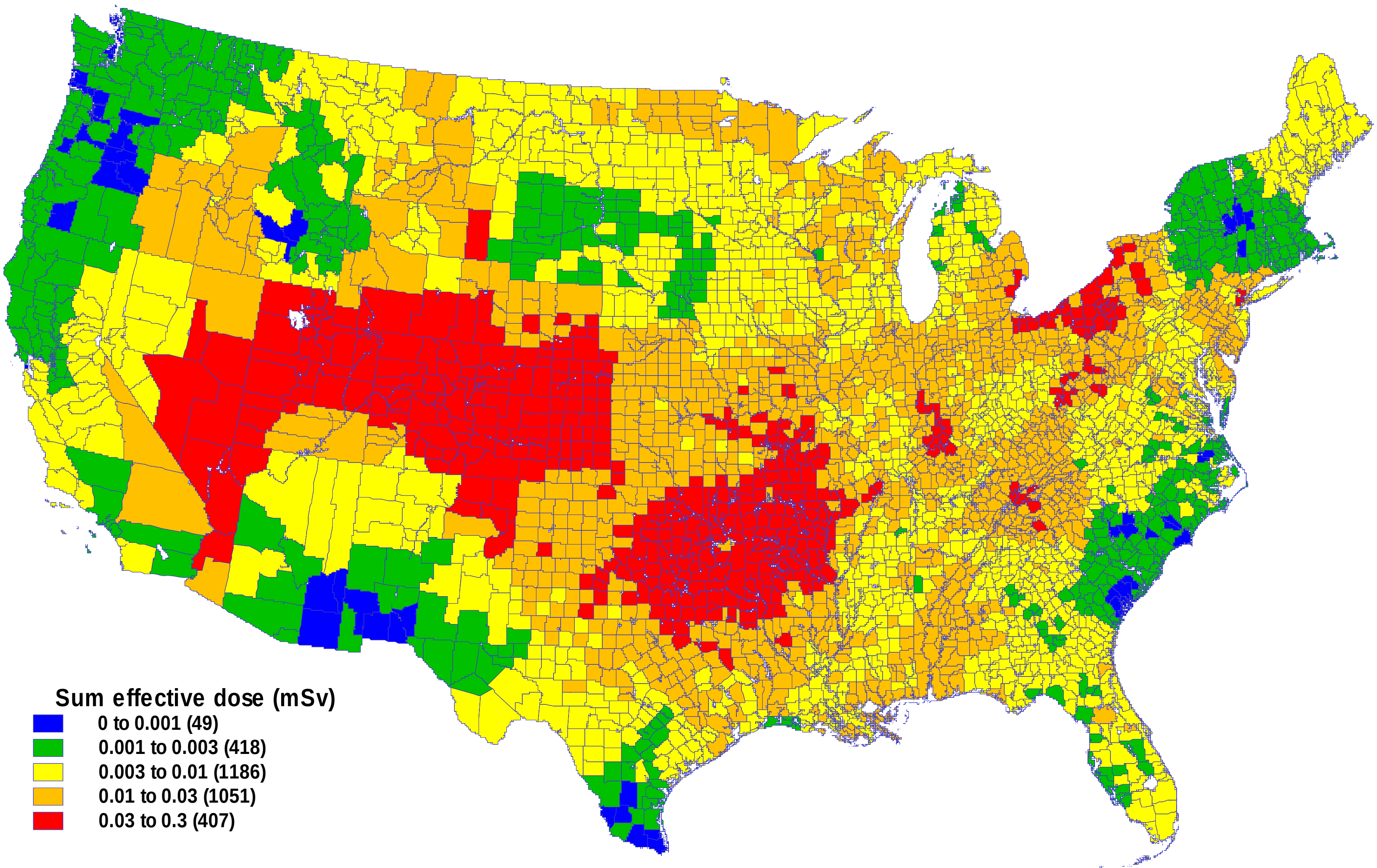


Fig. 23. Map of the effective dose by geographical area for the tests conducted in the year 1955.

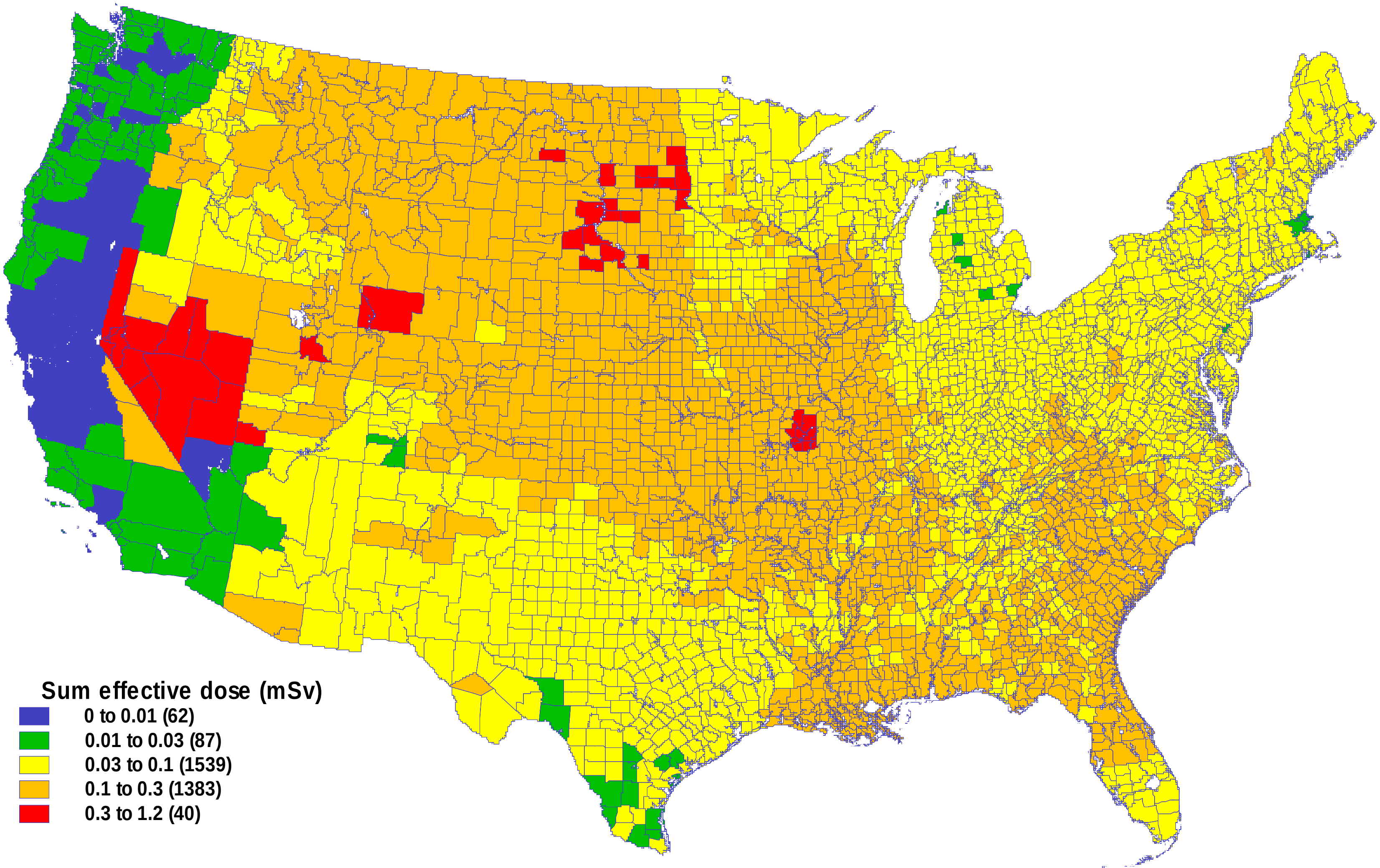


Fig. 24. Map of the effective dose by geographical area for the tests conducted in the year 1957.

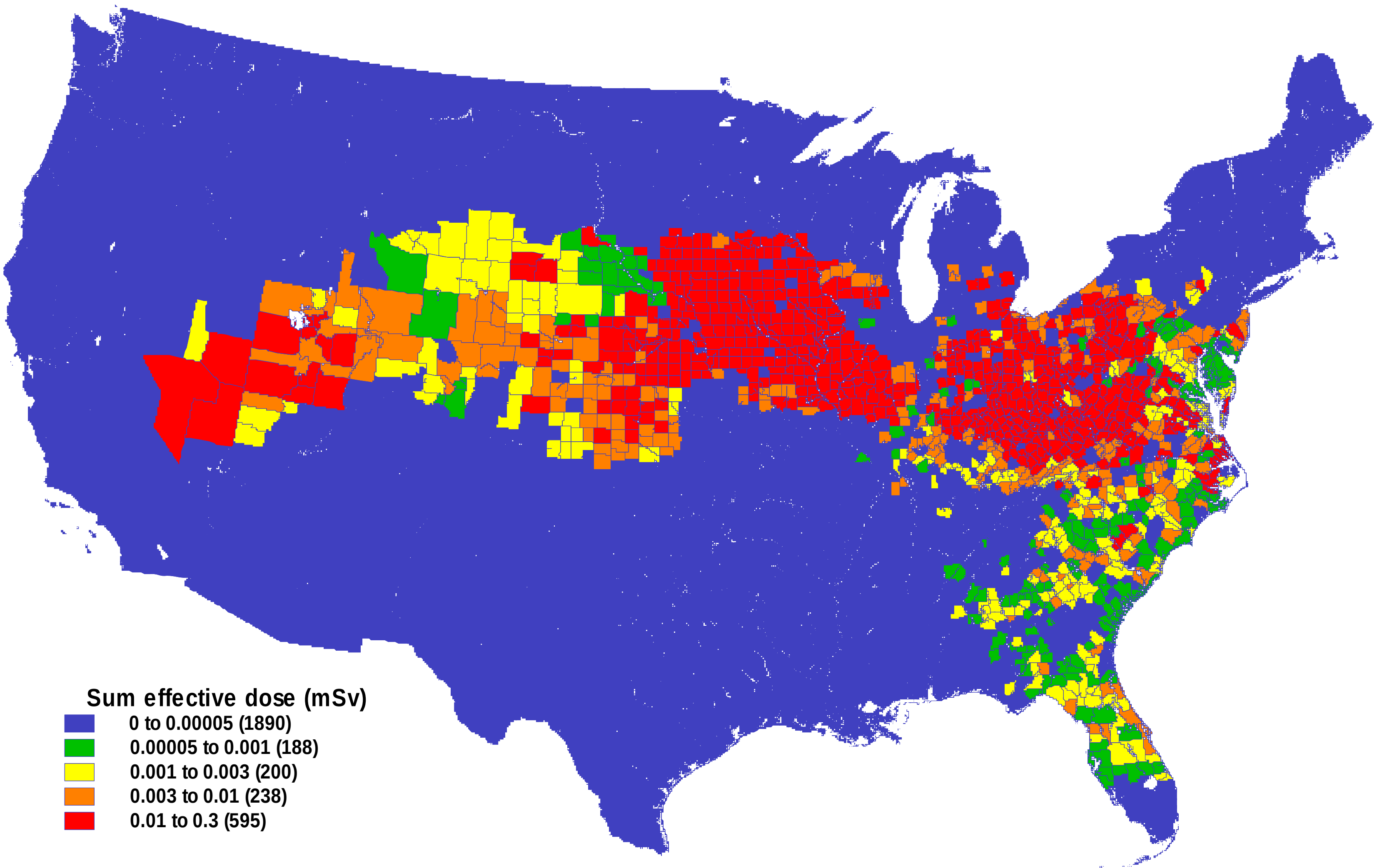


Fig. 25. Map of the effective dose by geographical area for the tests conducted in the year 1962.

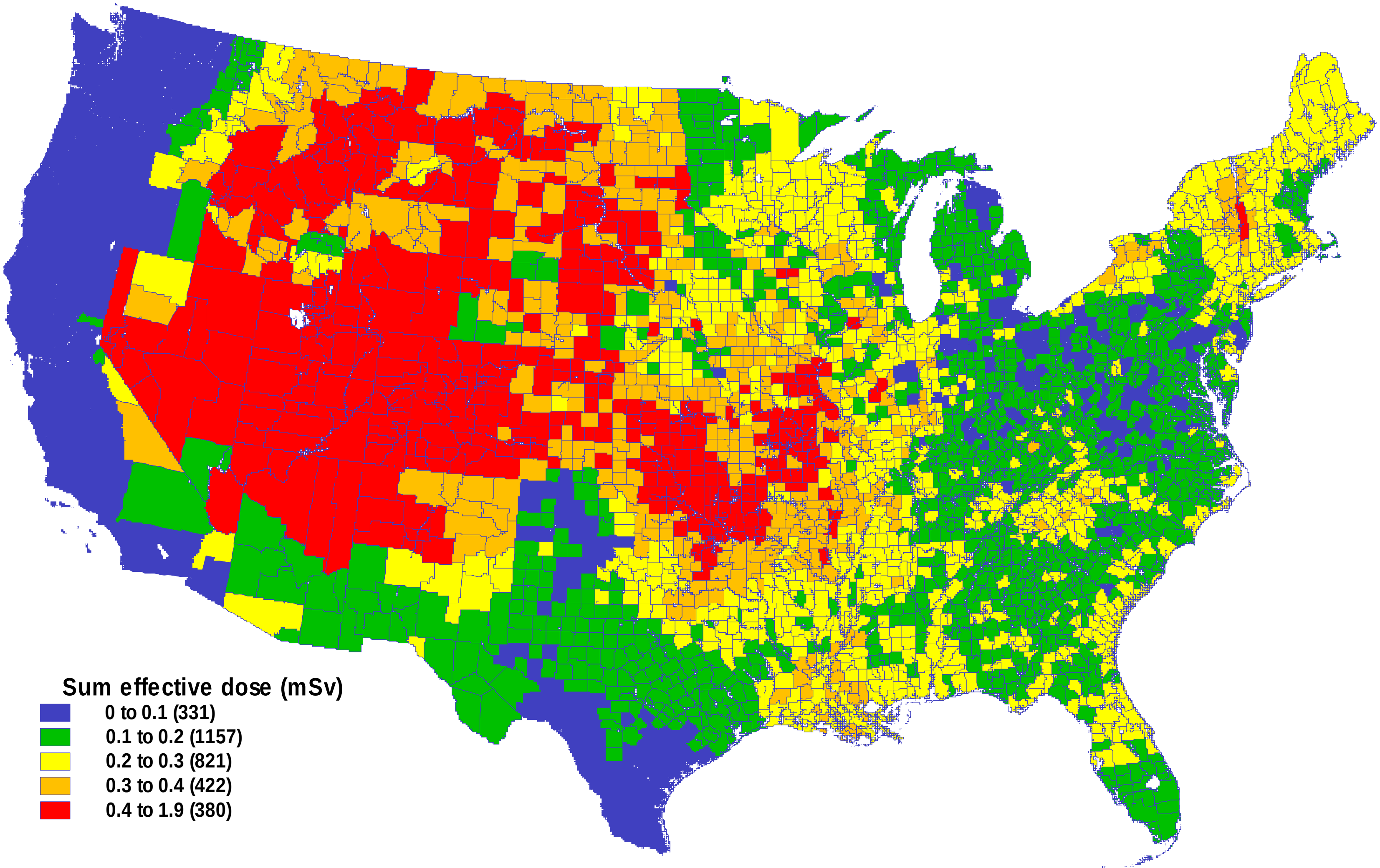


Fig. 26. Map of the effective dose by geographical area for the tests conducted from 1951 through 1962.

Table 5. Counties or subcounties with higher estimates of total individual effective dose.

State	County	$\bar{x}_g$, mSv	σ_g	State	County	$\bar{x}_g$, mSv	σ_g
NV	Nye 2	3.0	1.5	UT	Box Elder 2	0.72	1.5
NV	White Pine 2	1.8	1.5	CO	Eagle	0.71	2.1
NV	Lincoln 1	1.4	1.8	CO	Lake	0.71	2.3
NV	White Pine 3	1.4	1.5	UT	Rich	0.71	1.5
UT	Utah	1.2	1.5	UT	Garfield	0.71	2.4
AZ	Mohave 2	1.2	1.8	CO	Saguache	0.70	2.2
NV	White Pine 1	1.1	1.5	NV	Lander 2	0.70	1.8
UT	Washington 3	1.1	1.7	UT	Sanpete	0.70	1.6
CA	Inyo 3	1.1	2.0	CO	Clear Creek	0.70	1.8
UT	Wasatch	1.0	1.5	UT	Uintah	0.70	1.6
UT	Tooele 1	0.99	1.7	UT	Beaver	0.69	1.6
NV	Eureka	0.99	1.7	WY	Sweetwater	0.69	1.7
UT	Millard	0.97	1.5	MO	Audrain	0.69	2.5
UT	Washington 2	0.97	1.7	UT	Grand	0.68	1.6
UT	Kane 2	0.93	2.3	UT	Cache	0.67	1.5
UT	Tooele 2	0.91	1.5	NV	Lincoln 2	0.67	3.9
CO	Conejos	0.91	3.2	UT	Iron 2	0.66	2.3
UT	Davis	0.90	1.5	NV	Mineral	0.66	1.9
UT	Morgan	0.89	1.5	CO	Rio Blanco	0.66	1.5
UT	Washington 1	0.88	2.3	NV	Elko	0.66	1.6
UT	Juab	0.88	1.5	CO	Delta	0.65	1.6
UT	Weber	0.88	1.5	CO	Montrose	0.65	1.8
UT	Salt Lake	0.87	1.4	NM	McKinley	0.64	1.7
UT	Iron 1	0.86	2.1	UT	Dagget	0.64	1.6
CO	Archuleta	0.86	2.8	CO	Pitkin	0.64	2.9
UT	Summit	0.84	1.4	ID	Custer	0.63	3.7
CO	Hinsdale	0.82	2.7	WY	Carbon	0.63	1.4
AZ	Mohave 1	0.81	2.2	UT	Iron 3	0.62	2.6
CO	Gunnison	0.80	3.7	CO	Rio Grande	0.62	2.8
CO	Mineral	0.80	2.7	SD	Haakon	0.62	2.0
UT	Kane 1	0.80	2.4	CO	Douglas	0.62	1.9
WY	Fremont	0.79	1.5	WY	Uinta	0.62	1.5
AZ	Coconino 2	0.77	1.7	CO	Summit	0.61	2.5
NV	Washoe	0.76	1.6	UT	Sevier	0.61	1.5
CO	Garfield	0.76	1.5	CO	Grand	0.61	2.6
CO	Mesa	0.75	1.6	CO	Gilpin	0.60	1.8
AZ	Apache	0.75	1.7	MT	Meagher	0.60	2.7
UT	Duchesne	0.74	1.6	CO	Boulder	0.60	2.0
MO	Knox	0.73	3.4	WY	Sublette	0.60	1.5
UT	Emery	0.72	1.6	ID	Gem	0.59	3.8

Collective dose commitments

The collective effective dose commitments and the per caput[6] effective dose commitments for all years are summarized in Table 6, where the internal doses are compared to the recent calculations of Beck (1999) for external dose commitments. As considered in more detail later, the values for internal dose in the middle column of Table 6 are dominated by the value of effective dose from ^{131}I, which in turn is dominated by the dose from ^{131}I to the thyroid. The dose from ^{131}I to the thyroid also varies strongly with age with the larger doses being received by infants and young children. Thus, even though infants and young children make up a small fraction of the population, their contribution to the total collective dose can be proportionally much higher. Therefore, it is appropriate to consider an age correction to the collective doses for the contribution from ^{131}I. (It would be appropriate to consider such an age correction for all radionuclides; this was not done for this feasibility study for radionuclides other than ^{131}I, as the age-correction effects for other radionuclides are known to be much smaller.) The details of the age-correction calculation for ^{131}I are shown in Table 7, where data are shown for each year of age group from <1 through age 20 y and for ≥21 y. The year-by year population values are from the U.S. 1960 census; the dose coefficients (without modification to geometric means) are from ICRP (1998), and the integrated intakes represent average ratios of age-adjusted intakes from Whicker and Kirchner (1987) multiplied by the average seasonally-adjusted intakes used for this study. The results are that the age-corrected collective doses from ^{131}I would be 2.52 times higher for thyroid dose and 2.45 times higher for effective dose compared to the values calculated for adults only. The age-corrected values of collective dose and per caput dose are shown in the last column of Table 6.

As shown in Table 6, the age-corrected values of collective effective dose and per caput dose are somewhat larger for internal dose than for external dose. This follows from the fact that the effective dose is dominated by the dose to the thyroid from ^{131}I. As will be shown later, the dose to all organs except for the thyroid is much lower than the effective dose.

Table 6. Total collective effective doses and per caput doses from all tests.

Parameter	Value	Age corrected value[a]
Internal dose commitment		
Collective effective dose, person Sv	53,000 ± 5,900	110,000 ± 14,000
Per caput dose, µSv	320 ± 40	680 ± 90
External dose commitment (Beck 1999)		
Collective effective dose, person Sv	84,000	
Per caput dose, µSv	520	

[a] For the contribution from ^{131}I.

[6] The per caput dose is the collective dose divided by the number of persons in the population considered. The value of the population for this report is the estimated 1954 population of 163 million.

Table 7. Derivation of an age correction for collective dose from ^{131}I.

Age	Fraction of 1960 population	Thyroid F_g, Sv Bq^{-1}	Effective F_g, Sv Bq^{-1}	Average integrated intake, Bq Bq^{-1} m^2	Thyroid product, Sv m^2 Bq^{-1}	Effective product, Sv m^2 Bq^{-1}
<1	0.0229	$3.70 \times 10^{-}$	$1.80 \times 10^{-}$	0.0645	5.47×10^{-9}	2.66×10^{-10}
1	0.0229	$3.60 \times 10^{-}$	$1.80 \times 10^{-}$	0.0548	4.52×10^{-9}	2.26×10^{-10}
2	0.0229	$3.60 \times 10^{-}$	$1.80 \times 10^{-}$	0.0548	4.51×10^{-9}	2.25×10^{-10}
3	0.0224	$2.10 \times 10^{-}$	$1.00 \times 10^{-}$	0.0548	2.58×10^{-9}	1.23×10^{-10}
4	0.0222	$2.10 \times 10^{-}$	$1.00 \times 10^{-}$	0.0548	2.56×10^{-9}	1.22×10^{-10}
5	0.0220	$2.10 \times 10^{-}$	$1.00 \times 10^{-}$	0.0548	2.54×10^{-9}	1.21×10^{-10}
6	0.0213	$2.10 \times 10^{-}$	$1.00 \times 10^{-}$	0.0548	2.45×10^{-9}	1.17×10^{-10}
7	0.0211	$2.10 \times 10^{-}$	$1.00 \times 10^{-}$	0.0548	2.43×10^{-9}	1.16×10^{-10}
8	0.0204	$1.00 \times 10^{-}$	$5.20 \times 10^{-}$	0.0548	1.11×10^{-9}	5.80×10^{-11}
9	0.0194	$1.00 \times 10^{-}$	$5.20 \times 10^{-}$	0.0548	1.06×10^{-9}	5.53×10^{-11}
10	0.0194	$1.00 \times 10^{-}$	$5.20 \times 10^{-}$	0.0548	1.06×10^{-9}	5.53×10^{-11}
11	0.0194	$1.00 \times 10^{-}$	$5.20 \times 10^{-}$	0.0548	1.06×10^{-9}	5.52×10^{-11}
12	0.0199	$1.00 \times 10^{-}$	$5.20 \times 10^{-}$	0.0623	1.24×10^{-9}	6.46×10^{-11}
13	0.0196	$6.80 \times 10^{-}$	$3.40 \times 10^{-}$	0.0623	8.29×10^{-10}	4.14×10^{-11}
14	0.0153	$6.80 \times 10^{-}$	$3.40 \times 10^{-}$	0.0623	6.47×10^{-10}	3.24×10^{-11}
15	0.0154	$6.80 \times 10^{-}$	$3.40 \times 10^{-}$	0.0623	6.52×10^{-10}	3.26×10^{-11}
16	0.0156	$6.80 \times 10^{-}$	$3.40 \times 10^{-}$	0.0623	6.61×10^{-10}	3.31×10^{-11}
17	0.0160	$6.80 \times 10^{-}$	$3.40 \times 10^{-}$	0.0623	6.76×10^{-10}	3.38×10^{-11}
18	0.0141	$4.30 \times 10^{-}$	$2.20 \times 10^{-}$	0.0623	3.78×10^{-10}	1.93×10^{-11}
19	0.0127	$4.30 \times 10^{-}$	$2.20 \times 10^{-}$	0.0447	2.44×10^{-10}	1.25×10^{-11}
20	0.0122	$4.30 \times 10^{-}$	$2.20 \times 10^{-}$	0.0447	2.35×10^{-10}	1.20×10^{-11}
≥21	0.6030	$4.30 \times 10^{-}$	$2.20 \times 10^{-}$	0.0447	1.16×10^{-8}	5.93×10^{-10}
Weighted sum	1.00				4.85×10^{-8}	2.41×10^{-9}
Ratio of weighted sum-to-adult value					2.52	2.45

As a consequence, the doses to organs except for the thyroid are substantially higher from external exposure than from internal dose.

Collective effective dose by year of testing. The collective effective dose commitments by year of testing are shown in Table 8. Age corrections have not been made in this table, as the primary goal is to indicate the contributions by year only in a relative sense. The highest contribution occurred in 1957 during the 16 explosions of Operation Plumbbob. The second and third higher contributions occurred in 1952 during the eight events of Operation Tumbler-Snapper and in 1953 during the 11 events of Operation Upshot-Knothole.

Table 8. Collective effective dose commitments from ingestion by year of testing. Values are not corrected for age.

Year of testing	Collective effective dose commitment, person Sv
1951	1,900 ± 310
1952	10,000 ± 700
1953	7,900 ± 560
1955	5,900 ± 1,600
1957	20,000 ± 1,300
1962	6,600 ± 5,400
Total	53,000 ± 5,900

A surprisingly large contribution is attributed to the two explosions that occurred in 1962 during Operation Storax; almost all of the later was due to Project Sedan, a large cratering experiment.[7] The relative ranking of contributions by year is not the same as for external dose (Beck 1999), although the largest contribution for both was from tests conducted in 1957. The reason for differences in order is primarily due to the seasonal dependence for the contribution from dose via ingestion. As shown in Figs. 3 through 19, the seasonal dependence is quite strong for many radionuclides with a peak typically occurring in June–July. The relative ranking by year is the same as noted for the dose to the thyroid from ^{131}I only as reported in NCI (1997).

Collective effective dose by event. The collective effective dose commitments for the 16 events contributing at least 1000 person Sv are indicated in Table 9 in descending order of dose. As for Table 8, these values have not been age-corrected. It was not anticipated that Project Sedan[8] would head this list, but there are several notable factors for this event. First, the uncertainty associated with the deposition for this event is very large; this and the additional uncertainties involved in the dose calculation result in a very large uncertainty for the associated dose from this event—in fact, the uncertainty is nearly as large as the estimated dose. Another important factor is that this event took place during a time of year when the integrated intake function is at a maximum. And finally, the yield for the Project Sedan was the largest of those listed in Table 1. However, the yield for this event is presumed to have been mostly fusion, although the fractional fission yield is not available; the fact that the fission yield is unavailable is a major contributor to the uncertainty in the calculated deposition values for Project Sedan. The other events listed in Table 9 are generally known to have been major contributors to off-site dose, and they typically occurred during the time of year when radioecological transfer would have been high.

[7] See the following footnote concerning Sedan.

[8] This illogical prominence of the estimated dose from Sedan prompted a re-evaluation of the deposition values by Beck (personal communication 2000) for this event. The conclusion is that the original ^{131}I-deposition values taken from the NCI data base used for NCI (1997) are seriously in error for Sedan: The calculated total deposition across the U.S. is thirty times higher than the amount of ^{131}I stated to have been released by this event. The error is apparently associated with the meteorological model used to calculate deposition for Sedan. As this model was also used for Ranger Baker, Ranger Baker-2, and Storax Small Boy, similar errors may have occurred for these three events. This major discrepancy for Sedan and questions about the other events must be resolved, if this dose-reconstruction project evolves beyond the current feasibility phase.

Table 9. Collective effective dose commitments from ingestion for the 16 nuclear explosions that are estimated to have resulted in more than 1000 person Sv. Values are not corrected for age.

Event	Date	Collective effective dose commitment, person-Sv
Storax Sedan	6 July 1962	6200 ± 5400
Tumbler-Snapper George	1 June 1952	4400 ± 540
Plumbbob Diablo	15 July 1957	4100 ±850
Upshot-Knothole Harry	19 May 1953	2800 ±280
Plumbbob Kepler}Owens	24–25 July 1957	2600 ± 380
Plumbbob Hood	5 July 1957	2600 ±340
Tumbler-Snapper How	5 June 1952	2100 ±240
Tumbler-Snapper Simon	25 April 1953	1900 ±280
Plumbbob Priscilla	24 June 1957	1900 ± 460
Teapot Zucchini	15 May 1955	1700 ± 510
Plumbbob Galileo	2 September 1957	1600 ± 250
Teapot Apple 2	5 May 1955	1600 ± 180
Tumbler-Snapper Fox	25 May 1952	1500 ± 250
Plumbbob Doppler	23 August 1957	1400 ± 480
Plumbbob Wilson	18 June 1957	1300 ± 150
Buster Charlie	30 October 1951	1100 ± 180
Sum of the above		39,000 ± 5,600

Together, these 16 events account for 73% of the total non-age-corrected estimated dose.

Collective effective dose by radionuclide. The collective effective dose commitments (not corrected for age) for all tests according to the ten radionuclides contributing more than 98% of the estimated dose are shown in Table 10 arranged in descending order of dose. Iodine-131 alone accounts for 76% of the non-age-corrected collective effective dose. Of the ten more important radionuclides only ^{90}Sr and ^{137}Cs are long lived. Plutonium radionuclides accounted for only 0.4% of the estimated total dose. As noted above, the potentially important radionuclide ^{239}Np has not been included in this feasibility study.

Collective dose by organ. As indicated above, doses were also calculated for each radionuclide for any organ that had a dose coefficient more than twice that of the dose coefficient for effective dose. Total collective organ doses were then calculated by summing the dose by organ, but if a dose had not been calculated separately for that organ for a radionuclide, then the effective dose for that radionuclide was added to the sum. This procedure is only approximate, but was used for this feasibility study in order to derive some estimate of the organs receiving the more significant doses. The results for the organs listed in Table 4 are given in the middle column of Table 11 and indicate that the bone surface and colon are of potential interest.

Table 10. Collective effective dose commitments for all tests according to radionuclide. The ten radionuclides in the table account for more than 98% of the total dose from ingestion calculated for all 20 radionuclides. Doses from ^{239}Np were not considered in this feasibility study.

Radionuclide	Collective effective dose commitment, person-Sv
^{131}I	40,000 ± 5,700[a]
^{89}Sr	2800 ± 150
^{140}Ba	1900 ± 180
^{137}Cs	1700 ± 120
^{132}Te	1300 ± 160
^{106}Ru	1200 ± 250
^{144}Ce	860 ± 69
^{103}Ru	620 ± 87
^{90}Sr	600 ± 37
^{136}Cs	580 ± 210
Sum of above	52,000 ± 5,900

[a] The age-corrected value is 99,000±14,000.

Table 11. Collective dose commitments for all tests according to organ.
If an organ dose had not been calculated separately for a given radionuclide, the effective dose for that radionuclide was added to the organ total; this resulted in a substantial overestimate. The last column is corrected to remove the overestimate due to ^{131}I effective dose. Doses are based on calculations for adults.

Organ	Collective organ dose commitment, person-Sv	Corrected[a] collective organ dose commitment, person-Sv
Effective	53,000 ± 5,900	110,000 ± 14,000
Bone surface	71,000 ± 7,000	31,000 ± 4,000
Colon	96,000 ± 10,000	56,000 ± 8,400
Kidneys	53,000 ± 5,900	13,000 ± 1,600
Liver	54,000 ± 5,900	14,000 ± 1,600
Red marrow	56,000 ± 5,900	16,000 ± 1,600
Thyroid	820,000 ± 110,000	2,000,000 ± 280,000

[a] Excess contribution from ^{131}I effective dose eliminated and age corrections made for effective and thyroid dose.

However, as the doses to the bone surface and colon were not calculated specifically for ^{131}I, it is also clear from the results in Table 10 that the effective dose from ^{131}I accounts for most of the estimated dose to the bone surface and colon shown in the middle column of Table

11. The ICRP (1998) dose coefficients for the organs considered here and for effective dose are reproduced in Table 12. The thyroid has a very high dose coefficient compared to the other organs, and, even though its tissue weighting factor is only 0.05, it accounts for essentially all of the effective dose coefficient; the dose coefficients for the other organs are at least 100 times smaller than that for the effective dose. Therefore, the collective organ doses shown in the middle column of Table 11 were corrected by subtracting the effective dose from ^{131}I and adding back the dose for that organ. Operationally, this was done by the following calculation:

$$S_{\text{Organ,corrected}} = S_{\text{Organ}} - S_{\text{Effective,131}} \cdot \left(1 - \frac{DC_{\text{Organ,131}}}{DC_{\text{Effective,131}}}\right), \quad (4)$$

where *S* is collective dose and *DC* is dose coefficient. The estimates of effective dose and thyroid dose are also age corrected, as explained above and according to the values derived in Table 7. The results of these estimates of corrected collective organ dose commitments are shown in the last column of Table 11. Practically, the net result was the subtraction of 40,000 person Sv from the collective dose for all organs, except thyroid. Compared to the corrected collective doses for most other organs (thyroid being a notable exception), the collective doses to the bone surface and colon are significantly higher.

About two thirds of the corrected collective dose commitment to the bone surface is contributed by three radionuclides: ^{90}Sr, $^{239+240}$Pu, and ^{89}Sr in that order. For the colon, three-fourths of the corrected dose is contributed by four radionuclides: ^{89}Sr, ^{140}Ba, ^{106}Ru, and ^{144}Ce in that order (^{239}Np was not considered during this feasibility study). It is also useful to note that these collective organ doses are less than the collective dose received from external radiation, as inferred from Table 6. (The collective dose to the bone surface from external exposure would be larger than the collective effective dose from external exposure.) Thus, the only organ that has received a substantially higher collective dose from the ingestion of contaminated foods as compared to the dose from external exposure

Table 12. ICRP (1998) dose coefficients for ^{131}I for effective dose and for the organs considered in this study.

Organ	Dose coefficient, Sv Bq^{-1}
Effective	2.2×10^{-8}
Bone surface	1.3×10^{-10}
Colon	1.2×10^{-10}
Kidneys	4.6×10^{-11}
Liver	4.9×10^{-11}
Red marrow	1.0×10^{-10}
Thyroid	4.3×10^{-7}

is the thyroid, which is estimated to have received a collective dose about 24 times higher than that due to external exposure.

Comparison to dose estimates from global fallout

One of the requirements for this project was to compare the doses calculated above to the latitudinal average doses published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1993). The latter doses are for "global fallout" from the large explosions conducted by the U.S. in the Pacific Region and by Russia near the Arctic Circle, whereas the doses calculated here are for local and regional fallout from the relatively small tests at the NTS. The nature of the UNSCEAR calculations is basically the same as that conducted for this study: Calculated doses are per caput doses for adults and focus on effective dose commitments with the only age correction having been made for doses from ^{131}I. A comparison of dose commitments arising from the ingestion of contaminated foods is shown in Table 13. The UNSCEAR values listed here are for averages over the 40°–50° latitude band of the north temperate zone, which would cover much, but not all, of the contiguous United States.

As discussed above, the small nuclear tests conducted in the atmosphere at the NTS would not have created significant amounts of ^{3}H and ^{14}C in comparison to the large amounts that were produced by the much larger tests of fusion devices in the atmosphere conducted by the U.S. in the Pacific Region and by Russia near the Arctic Circle. Thus, these two radionuclides have not been included in the current assessment of doses from the NTS, but the two radionuclides are noted to be significant contributors to dose from global fallout.

The method used by the UNSCEAR (1993) to calculate dose commitment from ^{14}C also deserves some comment. The value in UNSCEAR (1993) for the effective dose commitment from ^{14}C is 2600 μSv, but this commitment extends over infinite time for a radionuclide with a half life of 5730 years and which remains widely distributed in the atmosphere and hydrosphere over very long times. Thus, the per caput dose commitment calculated by the UNSCEAR is intergenerational. According to UNSCEAR (1993) 5% of this dose would be delivered during the first 100 years; therefore, in order to compare more reasonably with the dose commitments from the NTS the value of 2600 μSv has been reduced by multiplying by 0.03; this modified result is given in Table 13.

In general, the effective dose commitment from the NTS is dominated by short-lived radionuclides, such as ^{131}I, ^{89}Sr, and ^{140}Ba. In contrast, the estimates of dose commitment from global fallout are dominated by long-lived radionuclides, such as ^{137}Cs and ^{90}Sr. This is consistent with the mechanisms that produced the deposition of fallout from the two sources.

Another feature of global fallout was that the debris was injected into the upper troposphere and stratosphere and circulated around the globe with relatively little mixing across latitude bands; debris was removed from these regions of the upper atmosphere with a half life of about one year. Thus, if rainfall had been equal at all locations within a latitude band, then the deposition of radionuclides from global fallout should have been essentially constant within latitude bands. Of course, rainfall was not equal at all locations, and the amount of yearly rainfall correlates strongly with the amount of fallout deposition.

Table 13. Comparison of fallout dose commitments from NTS and from global sources.

Radionuclide	Per caput effective dose commitment, μSv This project Nevada Test Site (NTS)	 UNSCEAR (1993) Global fallout
^{3}H	-	48
^{14}C	-	78[a]
^{55}Fe		14
^{89}Sr	17	2.3
^{90}Sr	3.7	170
^{91}Sr	0.0065	
^{97}Zr	0.15	
^{99}Mo	1.0	
^{103}Ru	3.8	
^{106}Ru	7.2	
^{105}Rh	0.086	
^{132}Te	7.8	
^{131}I	610[b]	79
^{133}I	1.9	
^{136}Cs	3.6	
^{137}Cs	10	280
^{140}Ba	12	0.42
^{143}Ce	0.40	
^{144}Ce	5.3	
^{147}Nd	1.1	
^{238}Pu		0.0009
$^{239+240}Pu$	1.2	0.50
^{241}Pu	0.087	0.004
^{241}Am		1.5
Sum	680[b]	670[a]

[a] The UNSCEAR (1993) value of 2600 μSv was multiplied by a factor of 0.03, the portion estimated to be delivered in 50 y.

[b] Age corrected.

Debris from the NTS originated from relatively small explosions, and much of the debris remained within the lower regions of the atmosphere. Thus, a much greater fraction of NTS debris was deposited within the U.S. during the first few days following the explosions. Rainfall was also an important determining feature of the amount of NTS fallout deposited at a given location, but also important was the distance from the NTS. Thus, the variation in the amount of NTS fallout deposition is expected to be larger than for global fallout. As mentioned earlier, the maximum amount (averaged over a county-size area) of non-age-corrected dose commitment from NTS fallout summed over all years was 3000 μSv and the minimum was 11 μSv—a ratio of nearly 300. Although the per caput dose commitments shown in Table 13 indicate that dose from global fallout was about the same as the value from NTS fallout, at any specific location the true ratio can vary substantially. The timing of deposition also varied for NTS versus global fallout. While most of the NTS fallout occurred in the 1950's, most of the global fallout occurred in 1963–1965 (UNSCEAR 1993).

Dose from inhalation

For this feasibility study, dose has not been estimated for inhalation. The primary reason is that estimates of integrated air concentration were not available. When the gummed-film network was being operated, substantial numbers of measurements were made of concentrations of radionuclides in air. If these measurements should be used in the future for calculations of dose from inhalation, it would be necessary to go through a similar process of kriging with consideration of rainfall to produce estimates on a county-by-county basis. In the case of air concentration, rainfall should be inversely correlated with integrated air concentration, whereas the reverse is true for deposition.

Past experience (Ng et al. 1990; UNSCEAR 1993) indicates that dose from inhalation is much less important than the dose received from external exposure or the ingestion of contaminated foods. In general, dose via inhalation only becomes of some importance for those radionuclides that have an extremely low rate of absorption across the gut wall, but remain in the lung for a long time when inhaled. Such a radionuclide is $^{239+240}Pu$.

Another approach to providing crude estimates of dose from inhalation is to base the calculation upon a deposition density and to assume that there is a relationship between deposition density, *P*, and integrated air concentration, *IAC*, that is given by a deposition velocity, v_g. This approach is only approximate, as this relationship is influenced very strongly by rainfall amount; and rainfall is an important vector producing deposition of fallout. Such an approach has been used by the UNSCEAR (1993) and is based upon long-term observations of the relationship between *IAC* and *P* at New York City. According to the UNSCEAR, an average value of v_g is 1.76 cm s^{-1}. Thus, given *P*, the dose from inhalation can be calculated by

$$D_h = \mathrm{K} \times R \times P \times \frac{1}{v_g} \times B \times F_h \ , \tag{5}$$

where K is a units-conversion factor, *R* is a reduction factor associated with indoor occupancy, *B* is breathing rate, and F_h is the dose coefficient for intake via inhalation. According to NCI (1997) a reasonable derivation of *R* is to assume that adults spend 80% of their time indoors where the concentration of radionuclides in air is 0.3 of that in outdoor air. A commonly used value by the ICRP for *B* is 22 m^3 day^{-1}; values of F_h are available for all organs in ICRP (1998).

For the purpose here it is more convenient to calculate the ratio of dose from inhalation to the dose from ingestion for a particular radionuclide for a particular event:

$$\frac{D_h}{D_g} = \frac{\mathrm{K'} \times R \times B \times F_h}{v_g \times I \times F_g} \ . \tag{6}$$

For illustrative purposes, the event (Project Sedan) estimated to have produced the largest dose is used and values have been calculated for the ten radionuclides of greater impact (Table 10) plus $^{239+240}$Pu. The results are presented in Table 14. For these conditions the only radionuclide whose dose via inhalation would have exceeded the dose via ingestion is $^{239+24}$Pu. However, $^{239+240}$Pu did not account for a significant amount of the total dose from the tests. For the other radionuclides, the estimated ratio is generally a third or much less. These values are biased toward the low side by the date of Project Sedan, which occurred when radioecological transfer was high. The values are biased toward the high side due to the fact that most of the deposition occurred during rainstorms. Better estimates could be made in the future of doses via inhalation, but kriged or otherwise derived values of integrated air concentration would be necessary.

Comparison of results with those from NCI (1997)

NCI (1997) presents the results of a very detailed, multi-year study of the dose to residents of the U.S. The study considers only ^{131}I and the dose to the thyroid. The bottom line result from NCI (1997) is a collective thyroid dose of 4,000,000 person Sv, whereas a comparable number estimated from this work (Table 11) is 2,000,000 Sv. Further, the distribution of individual dose on a county-by-county basis appears to be somewhat different with the NCI (1997) values appearing to be higher in Idaho, Montana, and the Midwest.

Table 14. Calculated ratios of dose from inhalation-to-dose from ingestion for the conditions of Project Sedan.

Radionuclide	$\frac{D_h}{D_g}$
^{131}I	0.022
^{89}Sr	0.079
^{140}Ba	0.33
^{137}Cs	0.00087
^{132}Te	0.38
^{106}Ru	0.053
^{144}Ce	0.13
^{103}Ru	0.17
^{90}Sr	0.011
^{136}Cs	0.014
$^{239+240}$Pu	2.6

Differences most likely result from the different treatments for the critical factor of the amount of fallout retained by vegetation. For this study a constant value was used, whereas NCI (1997) used a value that varied depending upon the amount of rainfall. A similar treatment (which would require the input data on the daily amounts of rainfall for each county) could be used, if the assessment of dose from other radionuclides is to move beyond this feasibility phase. However, there is still large uncertainty in the rainfall-rate dependent values of this parameter, and it might be useful to undertake once again a review of the data that can be used to derive such factors and the uncertainties in such values. For lower amounts of rainfall and high standing biomasses the NCI (1997) procedure results in estimates of the retention of fallout by vegetation of essentially 100%, which is not consistent with several experimental observations [Hoffman et al. (1989) and as reviewed by Anspaugh (1987)].

CONCLUSIONS

The main objective of this work was to determine whether it is feasible to reconstruct the doses from radionuclides other than ^{131}I to the population of the United States that resulted from the tests of nuclear weapons at the Nevada Test Site. The results provided here establish that such a reconstruction is feasible, provided that estimates of deposition density for a particular radionuclide are available. As it was demonstrated many years ago for the ORERP project that there is a definable relationship for the ratio of one radionuclide to another for all radionuclides of interest (Hicks 1982, 1990), this conclusion is not surprising.

What is more of a surprise is the extent to which the dose from ^{131}I dominates the dose received by the American public from tests at the NTS. Other than the doses from ^{131}I to the thyroid (and how this effects the effective dose), doses to other organs are much smaller and are less than the dose that was estimated by Beck (1999) to have resulted from external exposure.

The effective dose received by the U.S. population from releases from the NTS is about the same as the dose received from global fallout. However, large deviations from the average are expected, and the two sources resulted in doses delivered during two different time periods.

This study and the deposition values calculated by Beck for 20 different radionuclides are based upon the NCI (1997) data base of county-by-county ^{131}I-deposition values for each test. A review of these values for Project Sedan has revealed a major discrepancy of a factor of 30 between the total calculated deposition within the U.S. and the amount stated to have been produced by the Sedan event. This error is believed to have resulted from the meteorological model used for Sedan and a few other events. Correction of these values was beyond the scope of the current feasibility study, but should be an item of importance for any follow-on study.

Deposition values of ^{239}Np were not provided as input data for this study. Any follow-on study should include this important radionuclide, as it can contribute a substantial fraction of dose to the colon.

REFERENCES

Anspaugh, L. R. Retention by vegetation of radionuclides deposited in rainfall—A literature summary. Livermore: Lawrence Livermore National Laboratory, Livermore; UCRL-53810; 1987.

Beck, H. L. Exposure rate conversion factors for radionuclides deposited on the ground. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-378; 1980.

Beck, H. L. Estimates of fallout from Nevada weapons testing in the western United States based on gummed-film monitoring data. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-433; 1984.

Beck, H. L. External radiation exposure to the population of the continental U.S. from Nevada weapons tests and estimates of deposition density of radionuclides that could significantly contribute to internal radiation exposure via ingestion. New York: Report to the National Cancer Institute, P.O. #263-MQ-909853; 1999.

Beck, H. L.; Anspaugh, L. R. Development of the County Database: Estimates of exposure rates and times of arrival of fallout in the ORERP Phase-II area. Las Vegas: United States Department of Energy Nevada Field Office; DOE/NV-320; 1991.

Beck, H. L.; Helfer, I. K.; Bouville, A.; Dreicer, M. Estimates of fallout in the continental U.S. from Nevada weapons testing based on gummed-film monitoring data. Health Phys. 59:565–576; 1990.

Breshears, D. D.; Kirchner, T. B.; Otis, M. D.; Whicker, F. W. Uncertainty in predictions of fallout radionuclides in foods and of subsequent ingestion. Health Phys. 57:943–953; 1989.

Church, B. W.; Wheeler, D. L.; Campbell, C. M.; Nutley, R. V.; Anspaugh, L. R. Overview of the Department of Energy's Off-Site Radiation Exposure Review Project (ORERP). Health Phys. 59:503–510; 1990.

Department of Energy. United States nuclear tests. July 1945 through September 1992. Las Vegas: U.S. DOE Nevada Operations Office; Report DOE/NV-209 (Rev. 14); 1994.

Hicks, H. G. Calculation of the concentration of any radionuclide deposited on the ground by off-site fallout from a nuclear detonation. Health Phys. 42:585–600; 1982.

Hicks, H. G. Additional calculations of radionuclide production following nuclear explosions and Pu isotopic ratios for Nevada Test Site events. Health Phys. 59:515–523; 1990.

Hoffman, F. O.; Frank, M. L.; Blaylock, B. G.; von Bernuth, R. D.; Deming, E. J.; Graham, R. V.; Mohrbacher, D. A.; Water, A. E. Pasture grass interception and retention of ^{131}I, ^{7}Be, and insoluble microspheres deposited in rain. Oak Ridge: Oak Ridge National Laboratory; ORNL-6542; 1989.

International Commission on Radiological Protection. Radionuclide transformations. Energy and intensity of emissions. Annals ICRP 11–13. Oxford: Pergamon Press; Publication 38; 1983.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 1. Annals ICRP 20(2). Oxford: Pergamon Press; Publication 56; 1989.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 2: Ingestion dose coefficients. Annals ICRP 23(3/4). Oxford: Pergamon Press; Publication 67; 1993.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 3: Ingestion dose coefficients. Annals ICRP 25(1). Oxford: Pergamon Press; Publication 69; 1995.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 5: Compilation of ingestion and inhalation dose coefficients. Annals ICRP 26(1). Oxford: Pergamon Press; Publication 72; 1996.

International Commission on Radiological Protection. The ICRP database of dose coefficients: Workers and members of the public. Oxford: Pergamon Press; Version 1.0 on CD-ROM; 1998.

Kirchner, T. B.; Whicker, F. W.; Anspaugh, L. R.; Ng, Y. C. Estimating internal dose due to ingestion of radionuclides from Nevada Test Site fallout. Health Phys. 74:487–501; 1996.

National Cancer Institute. Estimated exposures and thyroid doses received by the American people from Iodine-131 in fallout following Nevada atmospheric nuclear bomb tests. Washington: NCI Report; 1997.

Ng, Y. C.; Anspaugh, L. R.; Cederwall, R. T. ORERP internal dose estimates for individuals. Health Phys. 59:693–713; 1990.

United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York: United Nations; Sales No. E.94.IX.2; 1993.

Whicker, F. W.; Kirchner, T. B. PATHWAY: A dynamic food-chain model to predict radionuclide ingestion after fallout deposition. Health Phys. 52:717–737; 1987.

Whicker, F. W.; Kirchner, T. B.; Breshears, D. D.; Otis, M. D. Estimation of radionuclide ingestion: The "PATHWAY" food-chain model. Health Phys. 59:645–657; 1990.

Whicker, F. W.; Kirchner, T. B.; Anspaugh, L. R.; Ng, Y. C. Ingestion of Nevada Test Site fallout: Internal dose estimates. Health Phys. 71:477–486; 1996.

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from Nuclear Tests at the Nevada Test Site

Part II. Reference and Subsidiary Information Pertaining to Exposure and Doses to the American Publics from Nuclear-Weapons Related Tests Conducted at the Nevada Test Site (NTS)

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-912901

LIST OF DOCUMENTS

Trinity Event

Before the Trinity event took place, Fermi and others had performed calculations and were aware that fallout might be a problem (Hoddeson et al. 1993). Thus, monitors were ready to evacuate people, if necessary, and did follow the cloud across New Mexico and into Colorado (Hoffman 1947). It is reported that residents of one farm received exposures of up to 60 R (Hacker 1987). A source term (Hicks 1985) for Trinity was calculated and a fallout pattern (Quinn 1987) was reconstructed on behalf of the ORERP. However, doses from this event have not been reconstructed, due primarily to scarcity of data. It is known that photographic film was fogged due to packing in strawboard that was contaminated by Trinity debris that was deposited in Indiana (Webb 1949).

Hacker, B. C. The dragon's tail. Radiation safety in the Manhattan Project, 1942–1946. Berkeley: University of California Press; 1987.

Hicks, H. G. Results of calculations of external gamma radiation exposure rates from local fallout and the related radionuclide compositions—the TRINITY event. Livermore: Lawrence Livermore National Laboratory; UCRL-53075; 1985.

Hoddeson, L.; Henriksen, P. W.; Meade, R. A.; Westfall, C. Critical assembly. A technical history of Los Alamos during the Oppenheimer years, 1943–1945. Cambridge: Cambridge University Press; 1993.

Hoffman, J. G. Nuclear explosion 16 July 1945 health physics report on radioactive contamination throughout New Mexico following the nuclear explosion. Los Alamos: Los Alamos National Laboratory; LA-626; 1947.

Olafson, J. H.; Nishita, H.; Larson, K. H. The distribution of plutonium in the soils of central and northeastern New Mexico as a result of the atomic bomb test of July 16, 1945. Los Angeles: University of California; UCLA 406; 1957.

Quinn, V. E. Analysis of nuclear test Trinity radiological and meteorological data. Las Vegas: U.S. Department of Energy Nevada Operations Office; NVO-313; 1987.

Webb, J. H. The fogging of photographic film by radioactive contaminants in cardboard packaging materials. Phys. Rev. 76:375–380; 1949.

Nuclear explosions at the Nevada Test Site

Carter, M. W.; Moghissi, A. A. Three decades of nuclear testing. Health Phys. 33:55–71; 1977.

U.S. Department of Energy. United States nuclear tests. Las Vegas: Nevada Operations Office; DOE/NV-209, Rev. 14; 1994.

Congressional Hearings

Over the years Congress has held several hearing on fallout, and the records of the major hearings listed below are major sources of information on fallout. Most of the material is concerned with global fallout, but significant amounts of information pertaining to the Nevada Test Site are also included, particularly in the 1957, 1959, and 1963 hearings.

U.S. Congress. The nature of radioactive fallout and its effects on man. Washington: U.S. Government Printing Office; Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy; 85th Congress; 1957.

U.S. Congress. Fallout from nuclear weapons tests. Washington: U.S. Government Printing Office; Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy; 86th Congress; 1959.

U.S. Congress. Radiation standards, including fallout. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy; 87th Congress; 1962.

U.S. Congress. Fallout, radiation standards, and countermeasures. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy; 88th Congress; 1963.

U.S. Congress. Low-level radiation effects on health. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Oversight and Investigations, Committee on Interstate and Foreign Commerce, House of Representatives; 96th Congress; 1979.

Reports of organized off-site monitoring activities (Military, National Laboratory, Public Health Service, Environmental Protection Agency, Atomic Energy Commission, University of California at Los Angeles, U.S. Weather Service)

Based upon the experience with the Trinity test and the test series conducted in the Pacific during 1946 and 1948, the potential exposure of workers and the public to fallout were known and appreciated. Beginning with the first test in Nevada monitoring of the nearby region was performed by members of the military, the Los Alamos National Laboratory, and the on-site contractor. In addition, the then Atomic Energy Commission undertook monitoring across the United States through its then Health and Safety Laboratory in New York. On-site radioecological studies were also conducted by a team from the University of California at Los Angeles.

Over the years these monitoring activities became increasingly sophisticated. For the 1955 test series at the NTS responsibility for the monitoring of the nearby off-site area was assumed by the U.S. Public Health Service, and a laboratory for this purpose was established in Las Vegas. The name of this laboratory has changed several times over the years, but their responsibility for off-site monitoring continued until the end of testing.

The U.S. Public Health Service also undertook the creation and management of nationwide networks to monitor activity in air, milk, and water. The earliest measurements on a nationwide basis occurred in 1954; the importance of milk as a vector for ^{131}I had been postulated but was not known clearly until 1962. Prior to 1962 there was more interest in milk as a vector for the transmission of ^{90}Sr and ^{137}Cs from global fallout. Early results of the nationwide networks are reviewed by Terrill (1963); the nationwide monitoring networks that existed in 1961 are summarized in the first issue of *Radiological Health Data and Reports*.

Andrews, V. E.; Vandervort, J. C. Fruit and vegetable radioactivity survey, Nevada Test Site environs. Las Vegas: U.S. Environmental Protection Agency; EMSL-LV-0539-13; 1978.

Andrews, V. E.; Vandervort, J. C. Fruit and vegetable radioactivity survey follow-on, Nevada Test Site environs. Las Vegas: U.S. Environmental Protection Agency;LV-VL-0539-19; 1978.

Atomic Energy Commission. 11th Semiannual report to Congress. Washington: U.S. Department of Energy; 1952.

Atomic Energy Commission. 13th Semiannual report to Congress. Washington: U.S. Department of Energy; 1953.

Atomic Energy Commission. 14th Semiannual report to Congress. Washington: U.S. Department of Energy; 1953.

Barth, D. S.; Engel, R. E.; Black, S. C.; Shimoda, W. Dairy farm radioiodine studies following the Pin Stripe event of April 25, 1966. Las Vegas: U.S. Environmental Protection Agency; SWRHL-41r; 1969.

Baurmash, L.; Neel, J. W.; Vance, W. K.; Mork, H. M.; Larson, K. H. Distribution and characterization of fallout and airborne activity from 10 to 160 miles from ground zero. Spring 1955. Los Angeles: University of California; WT-1178; 1955.

Beck, H. L. Estimates of fallout from Nevada weapons testing in the western United States based on gummed-film monitoring data. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-433; 1984.

Beck, H. L. Results of reanalyses for ^{137}Cs, ^{90}Sr, and plutonium of continental U.S. soil samples collected in the 1950s. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-544; 1992.

Black, S. C.; Douglas, R. L.; Barth, D. S. Gaseous radioiodine transport in the air-forage-cow-milk system. Las Vegas: U.S. Environmental Protection Agency; EMSL-LV-539-2; 1976.

Black, S. C.; McNelis, D. N.; Bretthauer, E. W. Radionuclide studies in dairy cows following Project Schooner. Las Vegas: U.S. Environmental Protection Agency; SWRHL-112r; 1972.

Bliss, W. A.; Jakubowski, F. M. Plutonium distribution in the environs of the Nevada Test Site—Status report. In: White, M. G.; Dunaway, P. B., eds., The radioecology of plutonium and other transuranics in desert environments. Las Vegas: U.S. Department of Energy Nevada Operations Office; NVO-153; 1975:237–250.

Bouton, E. H.; Hardin, L. M.; Wilsey, E. F.; Showers, R. L.; Tompkins, R. C.; Egerland, W. O.; Dombeck, N. J. Operation Sun Beam. Shots Little Feller I, II, Johnie Boy, and Small Boy. Projects Officers Report—Project 2.8. Radiological Surveys. Edgewood Arsenal: U.S. Army Nuclear Defense Laboratory; POR-2266; 1964.

Collison, T. D. Operation Upshot-Knothole, Nevada Proving Grounds, March-June 1953. Radiological Safety Operation. Albuquerque: Field Command, Armed Forces Special Weapons Project; WT-702 (Ref.); 1953.

Coogan, J. S.; Bliss, W. A. Protective action taken at Schofield's dairy, Hiko, Nevada, following an accident release of radioactivity from the Nevada Test Site. Las Vegas: U.S. Environmental Protection Agency; SWRHL-56r; 1972.

Dunning, G. M. Fallout from nuclear tests at the Nevada Test Site. Washington: U.S. Department of Energy; TID-5551; 1959.

Dunning, G. M. Nuclear safety in fallout situations. Nucl. Safety 4(3):69–77, 81; 1963.

Eisenbud, M.; Harley, J. H. Radioactive dust from nuclear detonations. Science 117:141–147; 1953.

Eisenbud, M.; Harley, J. H. Radioactive fallout in the United States. Science 121:677–680; 1955.

Eisenbud, M.; Harley, J. H. Radioactive fallout through September 1955. Science 124:251–255; 1956.

Environmental Monitoring and Support Laboratory. Environmental monitoring report for the Nevada Test Site and other test areas used for underground nuclear detonations. January through December 1975. Las Vegas: U.S. Environmental Protection Agency; EMSL-LV-539-4; 1976.

Garrett, J. R. A study of the milk distribution system in Nevada. Reno: University of Nevada; 1984.

Grossman, R. F.; Black, S. C.; Dye, R. E.; Smith, D. D.; Thomé, D. J.; Mullen, A. A. Off-site environmental monitoring report. Radiation monitoring around United States nuclear test areas, calendar year 1985. Las Vegas: U.S. Environmental Protection Agency; EPA/600/4-86-022; 1985.

Gwynn, P. S. Operation Tumbler-Snapper radiological safety report to the test manager. Washington: Armed Forces Special Weapons Project; WT-558 (DEL); 1952.

Harley, J. H.; Hallden, N. A.; Ong, L. D. Y. Summary of gummed film results through December, 1959. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-93; 1960.

Health and Safety Laboratory. Survey of fallout of radioactive material following the Las Vegas, Nevada, test explosions. New York: U.S. Department of Energy Environmental Measurements Laboratory; unpublished report; 1951.

Health and Safety Laboratory. Radioactive debris from Operations Buster and Jangle, observations beyond 200 miles from the test site. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-1576 (del.); 1952.

Health and Safety Laboratory. Radioactive debris from Operations Tumbler and Snapper, Part I. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4505 (del.); 1953.

Health and Safety Laboratory. Radioactive debris from Operations Upshot and Knothole. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4552 (del.); 1954.

Johnson, W. S.; Hyatt, E. C.; Schulte, H. F. Report of the advisory personnel to the Air-Sampling Program, Operation Tumbler-Snapper. Los Alamos: Los Alamos National Laboratory; WT-566; 1953.

Johnson, W. S.; McClelland, J.; Skillern, C. P. Monitoring of cow's milk for fresh fission products following an atomic detonation. Los Alamos: Los Alamos National Laboratory; LA-1597; 1953.

Johnston, R. W. Utilization of telemetering techniques in evaluating residual radioactive contamination. Washington: U.S. Department of Energy; WT-1182; 1956.

Larson, K. H.; Neel, J. W.; Hawthorne, H. A.; Mork, H. M.; Rowland, R. H.; Baurmash, L.; Lindberg, R. G.; Olafson, J. H.; Kowalewsky, B. W. Distribution, characteristics, and biotic availability of fallout, Operation Plumbbob. Los Angeles: University of California; WT-1488; 1966.

Larson, K. H.; Olafson, J. H.; Mork, H. M.; Howton, D. R. Field observations and preliminary field data obtained by the UCLA survey group, Operation Jangle, November 1951. Los Angeles: University of California; UCLA-182; 1952.

LeVine, H. D.; Graveson, R. T. Measurement of off-site fallout by automatic monitoring stations. New York: U.S. Department of Energy Environmental Measurements Laboratory; WT-1186; 1956.

Lindberg, R. G.; Romney, E. M.; Olafson, J. H.; Larson, K. H. Factors influencing the biological fate and persistence of radioactive fallout. Los Angeles: University of California; WT-1177; 1959.

Lindberg, R. G.; Scanlan, J. T.; Watson, J. C.; Rhoads, W. A.; Larson, K. H. Environmental and biological fate of fall-out from nuclear detonations in areas adjacent to the Nevada Proving Grounds. Los Angeles: University of California; WT-812; 1954.

List, R. J. Radioactive debris from Operations Tumbler and Snapper, Part II. Washington: Weather Bureau; NYO-4512 (del.); 1953.

List, R. J. The transport of atomic debris from Operation Upshot-Knothole. Washington: Weather Bureau; NYO-4602 (del.); 1954.

List, R. J. Radioactive fallout in North America from Operation Teapot. Washington: Weather Bureau; NYO-4696 (del.); 1956.

Martin, W. E. Loss of I^{131} from fallout-contaminated vegetation. Health Phys. 9:1141–1148; 1963.

Martin, W. E. Interception and retention of fallout by desert shrubs. Health Phys. 11:1341–1354; 1965.

Mork, H. M.; Larson, K. H.; Kowalewsky, B. W.; Wood, R. A.; Paglia, D. E.; Rhoads, W. A.; Guillou, R. B. Project Sedan. Part I. Characteristics of fallout from a deeply buried nuclear detonation from 7 to 70 miles from Ground Zero. Part II. Aerial radiometric survey. Los Angeles: University of California at Los Angeles; PNE-225F; 1967.

Nagler, K. M.; Telegadas, K. The distribution of significant fallout from Nevada tests. Silver Spring: U.S. Weather Bureau; 1956.

National Environmental Research Center. Environmental monitoring report for the Nevada Test Site. January–December 1971. Las Vegas: U.S. Environmental Protection Agency; NERC-LV-539-1; 1972.

National Environmental Research Center. Off-site surveillance activities of the National Environmental Research Center from July through December 1970. Las Vegas: U.S. Environmental Protection Agency; NERC-LV-539-17; 1974.

Olafson, J. H.; Larson, K. H. Plutonium, its biology and environmental persistence. Los Angeles: University of California; UCLA 501; 1961.

Paas, H. J. Radioactive particle fallout in the Hanford environs from Nevada nuclear explosions, Spring 1953. Richland: Pacific Northwest National Laboratory; HW-28925; 1953.

Pan, V.; Stevenson, K. A. Temporal variation analysis of plutonium baseline concentration in surface air from selected sites in the continental U.S. J. Environ. Radioact.32:239–257; 1996.

Placak, O. R. Final off-site report of the Project Sedan event, July 6, 1962. Las Vegas: U.S. Environmental Protection Agency; PNE-200F; 1963.

Placak, O. R.; Carter, M. W.; Gilmore, R. A.; Goeke, R. H.; Weaver, C. I. Operation Plumbbob off-site radiological safety report. Las Vegas: U.S. Environmental Protection Agency; OTO-57-3; 1957.

Placak, O. R.; Seal, M. S.; McBride, J. R.; Gilmore, R. A.; Elder, R. L.; Silhanek, J. S.. Operation Hardtack—Phase II. Off-site radiological safety report, Nevada Test Site, 1958. Las Vegas: U.S. Environmental Protection Agency; OTO-58-6; 1957.

Rainey, C. T.; Neel. J. W.; Mork, H. M.; Larson, K. H. Distribution and characteristics of fallout at distances greater than 10 miles from ground zero, March and April 1953. Los Angeles: University of California; WT-811; 1954.

Rehm, F. R. Aerial-monitoring operations development. Battle Creek: Office of Civil and Defense Mobilization; WT-1485; 1962.

Romney, E. M.; Lindberg, R. G.; Hawthorne, H. A.; Bystrom, B. G.; Larson, K. H. Contamination of plant foliage with radioactive fallout. Ecology 44:343–349; 1963.

Romney, E. M.; Lindberg, R. G.; Kinnear, J. E.; Wood, R. A. Persistence of ^{90}Sr and ^{137}Cs in fallout areas of southern Nevada and Utah. Los Angeles: University of California; UCLA 12-1308; 1981.

Sanders, J. B.; Placak, O. R.; Carter, M. W. Report of off-site radiological safety activities, Operation Teapot. Las Vegas: U.S. Environmental Protection Agency; M-7001; 1955.

Schoengold, C. R.; DeMarre, M. E.; McDowell, E. M. Radiological effluents released from announced U.S. continental tests. 1961 through 1988. Las Vegas: U.S. Department of Energy Nevada Operations Office; DOE/NV-317; 1990.

Seal, M. S.; Fountain, E. L. Iodine inhalation study for Project Sedan, July 6, 1962. Las Vegas: U.S. Environmental Protection Agency; SWRHL-2r; 1964.

Shelton, A. V.; Goeke, R. H.; Kennedy, W. R.; Larson, K. H.; Nagler, K. M.; Placak, O. R. Exposures prior to 1960. Report of the Test Manager's Committee to establish fallout doses to communities near the Nevada Test Site. unpublished report. Reproduced as Appendix A in Anspaugh and Church (1985).

Shipman, T. L. Operation Buster-Jangle radiological safety. Los Alamos: Los Alamos National Laboratory; WT-425; 1953.

Sigoloff, S. C.; Borella, H. M. Remote radiological monitoring. Washington: U.S. Department of Energy; WT-1509; 1958.

Skillern, C. P.; Johnson, W. S.; Schulte, H. P. Some observations on air sampling techniques used at the Nevada Proving Ground. Los Alamos: Los Alamos National Laboratory; LA-1685; 1955.

Smith, D. D.; Andrews, V. E. Selected radioisotopes in animal tissues in Nevada: ^{90}Sr and ^{137}Cs measurements from 1956 to 1977. Las Vegas: U.S. Environmental Protection Agency; EPA-600/3-71-027; 1981.

Smith, D. D.; Black, S. C.; Giles, K. R.; Moghissi, A. A. Report of animal investigation program activities for the Baneberry event. Las Vegas: U.S. Environmental Protection Agency; NERC-LV-539-10; 1975.

Smith, D. D.; Coogan, J. S. Population distribution around the Nevada Test Site—1984. Las Vegas: U.S. Environmental Protection Agency; EPA-600/4-84-067; 1984.

Southwestern Radiological Health Laboratory. Final report of off-site surveillance for Operation Nougat, September 15, 1961, to June 30, 1962. Las Vegas: U.S. Environmental Protection Agency; SWRHL-1r; 1964.

Southwestern Radiological Health Laboratory. Final report of off-site surveillance for Operation Dominic II. Las Vegas: U.S. Environmental Protection Agency; SWRHL-3r; 1965.

Southwestern Radiological Health Laboratory. Final report of off-site surveillance for Operation Storax. Las Vegas: U.S. Environmental Protection Agency; SWRHL-4r; 1965.

Southwestern Radiological Health Laboratory. Final report of off-site surveillance for Operation Niblick. Las Vegas: U.S. Environmental Protection Agency; SWRHL-12r; 1966.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1964. Las Vegas: U.S. Environmental Protection Agency; SWRHL-20r; 1966.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1964. Las Vegas: U.S. Environmental Protection Agency; SWRHL-22r; 1968.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1965. Las Vegas: U.S. Environmental Protection Agency; SWRHL-23r; 1966.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1965. Las Vegas: U.S. Environmental Protection Agency; SWRHL-24r; 1966.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1966. Las Vegas: U.S. Environmental Protection Agency; SWRHL-37r; 1970.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1966. Las Vegas: U.S. Environmental Protection Agency; SWRHL-38r; 1968.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1967. Las Vegas: U.S. Environmental Protection Agency; SWRHL-47r; 1970.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1967. Las Vegas: U.S. Environmental Protection Agency; SWRHL-64r; 1970.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1968. Las Vegas: U.S. Environmental Protection Agency; SWRHL-83r; 1971.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1969. Las Vegas: U.S. Environmental Protection Agency; SWRHL-97r; 1971.

Southwestern Radiological Health Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from July through December 1969. Las Vegas: U.S. Environmental Protection Agency; SWRHL-98r; 1971.

Tami, T. M.; Gibson, R. A., Jr.; Prindle, A. L. Project Schooner, far-out fallout collection program. Livermore: Army Corps of Engineers Nuclear Cratering Group; PNE-527; 1971.

Taplin, G. V.; Meredith, O. V.; Kade, H. Evaluation of the acute inhalation hazard from radioactive fallout material by analysis of results from field operations and controlled inhalation studies in the laboratory. Los Angeles: University of California; WT-1172; 1958.

Telegadas, K. Letter to Gene Quinn with tabulated fallout data. unpublished data. Reproduced as Appendices B and C in Anspaugh and Church (1985).

Terrill, J. G., Jr. Review of radionuclides in the food chain. In: U.S. Congress (1963), Vol. 1:71–201.

Thompson, G. D. C. Utah’s experience with radioactive milk. Salt Lake City: Utah State Department of Health and Salt Lake City Department of Health; 1962.

U.S. Atomic Energy Commission. Off-site environmental contamination from nuclear explosives at the Nevada Test Site. September 15, 1961–September 15, 1962. Washington: U.S. Department of Energy; TID-18892; 1963.

U.S. Public Health Service. Report of Public Health Service activities in the off-site monitoring program. Nevada Proving Ground—Spring 1953. Las Vegas: U.S. Environmental Protection Agency; 1955.

U.S. Public Health Service. Radiological health data. A series of monthly reports published from April 1960 through December 1974. Washington: U.S. Government Printing Office. (Later names of this journal were “Radiological Health Data and Reports” and “Radiation Data and Reports.”)

Weiss, M. M. A study of the airborne radioactivity at Brookhaven National laboratory from the Nevada tests, March through June 1953; Upton: Brookhaven National laboratory; BNL-252; 1953.

Western Environmental Research Laboratory. Final report of off-site surveillance for Project Schooner, December 8, 1968. Las Vegas: U.S. Environmental Protection Agency; PNE-524; 1971.

Western Environmental Research Laboratory. Final report of off-site surveillance for the Pin Stripe event, April 25, 1966. Las Vegas: U.S. Environmental Protection Agency; SWRHL-59r; 1972.

Western Environmental Research Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1968. Las Vegas: U.S. Environmental Protection Agency; SWRHL-81r; 1972.

Western Environmental Research Laboratory. Final report of off-site surveillance for the Baneberry event, December 18, 1970. Las Vegas: U.S. Environmental Protection Agency; SWRHL-107r; 1972.

Western Environmental Research Laboratory. Off-site surveillance activities of the Southwestern Radiological Health Laboratory from January through June 1970. Las Vegas: U.S. Environmental Protection Agency; SWRHL-108r; 1972.

Wilsey, E. F. Residual gamma radiation patterns from the SUNBEAM and SEDAN nuclear detonations. Edgewood: U.S. Army Nuclear Defense Laboratory; NDL-TR-77 (DEL); 1966.

Reports from the Off-Site Radiation Exposure Review Project on dose reconstruction (including reports of supporting studies made by the Environmental Measurements Laboratory)

Anspaugh, L. R.; Church, B. W. Historical estimates of external gamma exposure and collective external gamma exposure from testing at the Nevada Test Site. I. Test series through Hardtack II, 1958. Las Vegas: U.S. Department of Energy Nevada Operations Office; NVO-226; 1985.

Anspaugh, L. R.; Church, B. W. Historical estimates of external gamma exposure and collective external gamma exposure from testing at the Nevada Test Site. I. Test series through Hardtack II, 1958. Health Phys. 51:35–51; 1986.

Anspaugh, L. R.; Ricker, Y. E.; Black, S. C.; Grossman, R. F.; Wheeler, D. L.; Church, B. W.; Quinn, V. E. Historical estimates of external gamma exposure and collective external gamma exposure from testing at the Nevada Test Site. II. Test Series after Hardtack II, 1958, and summary. Health Phys. 59:525–532; 1990.

Beck, H. L.; Anspaugh, L. R. Development of the County Database: Estimates of exposure rates and times of arrival of fallout in the ORERP Phase-II Area: Comparison with cumulative deposition-density estimates based on analyses of retrospective and historical soil samples. Las Vegas: United States Department of Energy Nevada Operations Office; DOE/NV-320; 1991.

Beck, H. L.; Krey, P. W. Cesium-137 inventories in undisturbed soils—Interim report on radionuclides in soils of populated areas. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-375; 1980.

Beck, H. L.; Krey, P. W. External radiation exposure of the population of Utah from Nevada Weapons Tests. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-401; 1982.

Beck, H. L.; Krey, P. W. Radiation exposures in Utah from Nevada nuclear tests. Science 220:18–24; 1983.

Breshears, D. D.; Kirchner, T. B.; Whicker, F. W. Contaminant transport through agroecosystems: Assessing relative importance of environmental, physiological, and management factors. Ecological Applications 2:285–297; 1992.

Cederwall, R. T.; Peterson, K. R. Meteorological modeling of arrival and deposition of fallout at intermediate distances downwind of the Nevada Test Site. Health Phys. 59:593–601; 1990.

Cederwall, R. T.; Ricker, Y. E.; Cederwall, P. L.; Homan, D. N.; Anspaugh, L. R. Ground-based air-sampling measurements near the Nevada Test Site after atmospheric nuclear tests. Health Phys. 59:533–540; 1990.

Church, B. W.; Wheeler, D. L.; Campbell, C. M.; Nutley, R. V.; Anspaugh, L. R. Overview of the Department of Energy's Off-Site Radiation Exposure Review Project (ORERP). Health Phys. 59:503–510; 1990.

Dose Assessment Advisory Group. Transcript of proceedings. Las Vegas: U.S. Department of Energy Coordination and Information Center; Multiple Proceedings in Multiple Volumes; 1980–1987.

Dose Assessment Advisory Group. Final report. Las Vegas: U.S. Department of Energy Coordination and Information Center; 1987.

Grossman, R. F.; Thompson, C. B. Creation of a data base of survey meter readings in the western United States after nuclear tests. Las Vegas: U.S. Environmental Protection Agency; EPA/600/R-93/034; 1993.

Henderson, R. W.; Smale, R. F. External exposure estimates for individuals near the Nevada Test Site. Health Phys. 59:715–721; 1990.

Hicks, H. G. Radiochemical data collected on events from which radioactivity escaped beyond the borders of the Nevada Test Range Complex. Livermore: Lawrence Livermore National Laboratory; UCRL-52934; 1981.

Hicks, H. G. Results of calculations of external radiation exposure rates from fallout and the related radionuclide compositions. Livermore: Lawrence Livermore National Laboratory; UCRL-53152, parts 1–8; 1981.

Hicks, H. G. Calculation of the concentration of any radionuclide deposited on the ground by off-site fallout from a nuclear detonation. Health Phys. 42:585–600; 1982.

Hicks, H. G. Results of calculations of external radiation exposure rates from local fallout and the related radionuclide compositions of selected U.S. Pacific tests. Livermore: Lawrence Livermore National Laboratory; UCRL-53505; 1984.

Hicks, H. G. Results of calculations of external radiation exposure rates from fallout and the related radionuclide composition from the SIMON event of Operation Upshot-Knothole, 1953. Livermore: Lawrence Livermore National Laboratory; UCRL-53529; 1984.

Hicks, H. G. Results of calculations of external radiation exposure rates from local fallout and the related radionuclide compositions of two hypothetical 1-Mt nuclear bursts. Livermore: Lawrence Livermore National Laboratory; UCRL-53569; 1984.

Hicks, H. G. Additional calculations of radionuclide production following nuclear explosions and Pu isotopic ratios for Nevada Test Site events. Health Phys. 59:515–523; 1990.

Hicks, H. G.; Barr, D. W. Nevada Test Site atom ratios: ^{240}Pu/^{239}Pu and ^{241}Pu/^{239}Pu. Livermore: Lawrence Livermore National Laboratory; UCRL-53499/1; 1984.

Kirchner, T. B.; Whicker, F. W. Validation of PATHWAY, a simulation model of the transport of radionuclides through agroecosystems. Ecol. Modelling 22:21–44; 1983.

Kirchner, T. B.; Whicker, F. W.; Anspaugh, L. R.; Ng, Y. C. Estimating internal dose due to ingestion of radionuclides from Nevada Test Site fallout. Health Phys. 71:487–501; 1996.

Krey, P. W.; Beck, H. L. The distribution throughout Utah of ^{137}Cs and $^{239+240}$Pu from Nevada Test Site detonations. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-400; 1981.

Krey, P. W.; Hardy, E. P.; Heit, M. Nevada Test Site fallout in the area of Enterprise, Utah. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-386; 1980.

Krey, P. W.; Heit, M.; Miller, K. M. Radioactive fallout reconstruction from contemporary measurements of reservoir sediments. Health Phys. 59:541–554; 1990.

McArthur, R. D.; Miller, F. L. Offsite Radiation Exposure Review Project Phase-II soil program. Las Vegas: U.S. Department of Energy Nevada Operations Office; DOE/NV/10384-23RE; 1989.

Miller, K. M.; Gogolak, C. V.; Tanabe, H. Natural background radiation and ^{137}Cs inventories in southern Nevada—Preliminary report on fallout. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-386; 1980.

Ng, Y. C.; Anspaugh, L. R.;. Cederwall, R. T. ORERP internal dose estimates for individuals. Health Phys. 59:693–713; 1990.

Phillips, W. G.; Sherman, S.; Young, R. User's guide for survey meter and film badge dosimetry data bases. Las Vegas: U.S. Environmental Protection Agency; EPA-600/4-81-035; 1981.

Potter, G. B. Film-badge and survey-meter data bases for historical off-site radiation exposures around the Nevada Test Site. Health Phys. 50:424; 1986.

Quinn, V. E. Analysis of Operation Upshot-Knothole nuclear test BADGER radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-299; 1986.

Quinn, V. E. Analysis of Operation Teapot nuclear test BEE radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-304; 1986.

Quinn, V. E. Analysis of Operation Teapot nuclear test ZUCCHINI radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-307; 1987.

Quinn, V. E. Analysis of meteorological and radiological data for selected fallout episodes. Health Phys. 59:577–592; 1990.

Quinn, V. E.; Kennedy, N. C. Fallout particle trajectory computations and fallout particle arrival time calculations. Las Vegas: Weather Service Nuclear Support Office; NVO-318; 1989.

Quinn, V. E.; Kennedy, N. C.; Steadman, C. R., Jr. Analysis of Operation Dominic II SMALL BOY radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-285; 1984.

Quinn, V. E.; Kennedy, N. C.; Urban, V. D. Analysis of Operation Plumbbob SMOKY radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-249; 1982.

Quinn, V. E.; Urban, V. D.; Kennedy, N. C. Analysis of Upshot-Knothole 9 (HARRY) radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-233; 1981.

Quinn, V. E.; Urban, V. D.; Kennedy, N. C. Analysis of Operation Tumbler-Snapper nuclear test EASY radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-297; 1986.

Steadman, C. R., Jr. Analysis of Operation Upshot-Knothole nuclear test SIMON radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-315; 1987.

Steadman, C. R., Jr.; Kennedy, N. E.; Quinn, V. E. Analysis of Upshot-Knothole 1 (ANNIE) radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-254; 1983.

Steadman, C. R., Jr.; Kennedy, N. E.; Quinn, V. E. Analysis of Operation Plumbbob nuclear test SMOKY aerial radiological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-275; 1984.

Steadman, C. R., Jr.; Kennedy, N. E.; Quinn, V. E. Analysis of Operation Upshot-Knothole nuclear test NANCY radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-282; 1984.

Steadman, C. R., Jr.; Kennedy, N. E.; Quinn, V. E. Analysis of Operation Plumbbob BOLTZMANN radiological and meteorological data. Las Vegas: U.S. Weather Service Nuclear Support Office; NVO-285; 1984.

Thompson, C. B. Estimates of exposure rates and fallout arrival times near the Nevada Test Site. Health Phys. 59:555–563; 1990.

Thompson, C. B.; McArthur, R. D.; Hutchinson, S. W. Development of the Town Database: Estimates of exposure rates and times of fallout arrival near the Nevada Test Site. Las Vegas: U.S. Department of Energy Nevada Operations Office; DOE/NV-374; 1994.

Ward, G. M.; Whicker, F. W. Milk production and distribution in nine western states in the 1950s. Livermore: Lawrence Livermore National Laboratory; UCRL-15907; 1987.

Ward, G. M.; Whicker, F. W. Milk distribution and feeding practice data for the PATHWAY model. Health Phys. 59:637–643; 1990.

Whicker, F. W.; Kirchner, T. B. PATHWAY: A dynamic food-chain model to predict radionuclide ingestion after fallout deposition. Health Phys. 52:717–737; 1987.

Whicker, F. W.; Kirchner, T. B.; Breshears, D. D.; Otis, M. D. Estimation of radionuclide ingestion: The "PATHWAY" food-chain model. Health Phys. 59:645–657; 1990.

Whicker, F. W.; Kirchner, T. B. Final report on the pathway analysis task. Fort Collins: Colorado State University; 1993.

Whicker, F. W.; Kirchner, T. B.; Anspaugh, L. R.; Ng, Y. C. Ingestion of Nevada Test Site fallout: Internal dose estimates. Health Phys. 71:477–486; 1996.

University of Utah studies

Church, B. W.; Lloyd, R. d.; Pendleton, R. C.; Mays, C. W. Evidence for radioruthenium in milk. Nature 207:775–776; 1965.

Gren, D. C.; Hawthorne, H. A.; Crockett, R. A.; Lloyd, R. D.; Simon, S. L.; Till, J. E.; Stevens, W. Feeding of dairy livestock and milk distribution for the Thyroid Cohort Study. Salt Lake City: University of Utah; 1988.

Kerber, R. A.; Till, J. E.; Simon, S.; Lyon, J. L.; Thomas, D. C.; Preston-Martin, S.; Rallison, M. L.; Lloyd, R. D.; Stevens, W. A cohort study of thyroid disease in relation to fallout from nuclear weapons testing. J. Am. Med. Assoc. 270:2076–2082; 1993.

Lloyd, R. D.; Gren, D. C.; Simon, S. L.; Wrenn, M. E.; Hawthorne, H. A.; Lotz, T. M.; Stevens, W.; Till, J. E. Individual external exposures from Nevada Test Site fallout for Utah leukemia cases and controls. Health Phys. 59:723–737; 1990.

Lloyd, R. D.; Mays, C. W.; Pendleton, R. C.; Clark, D. O. A comparison of the cesium-137 content of milk and people from 19 dairy farms in Utah. Radiol. Health Data Repts. 10:427–433; 1969.

Lloyd, R. D.; Pendleton, R. C.; Clark, D. O.; Mays, C. W.; Goates, G. B. Cesium-137 in humans: A relationship to milk ^{137}Cs content. Health Phys. 24:23–36; 1973.

Mays, C. W. Radioactive fallout measurements in air and people. Salt Lake City: University of Utah; AECU-4112; 1958.

Mays, C. W. Thyroid irradiation in Utah infants exposed to iodine-131. Scientist and Citizen August 1966:3–9.

Pendleton, R. C.; Koranda, J. J.; Wagner, W. W.; Phelps, P. L.; Lloyd, R. D.; Anspaugh, L. R.; Chapman, W. H. Radioecological studies in Utah subsequent to the Baneberry Event. In: Nelson, D. J., ed., Radionuclides in ecosystems. Springfield: National Technical Information Services; 1971:150–169.

Pendleton, R. C.; Lloyd, R. D. Environmental levels of radioactivity in Utah following Operation Pinstripe. Radiol. Health Data Repts. 11:65–67; 1970.

Pendleton, R. C.; Lloyd, R. D.; Mays, C. W. Iodine-131 in Utah during July and August 1962. Science 141:640–642; 1963.

Pendleton, R. C.; Mays, C. W.; Lloyd, R. D.; Brooks, A. L. Differential accumulation of iodine-131 from local fallout in people and milk. Health Phys. 9:1253–1262; 1963.

Pendleton, R. C.; Mays, C. W.; Lloyd, R. D.; Church, B. W. A trophic level effect on ^{137}Cs concentration. Health Phys. 11:1503–1510; 1965.

Simon, S. L. An analysis of vegetation interception data pertaining to close-in weapons test fallout. Health Phys. 59:619–626; 1990.

Simon, S. L.; Lloyd, R. D.; Till, J. e.; Hawthorne, H. A.; Gren, D. C.; Rallison, M. L.; Stevens, W. Development of a method to estimate dose from fallout radioiodine in a thyroid cohort study. Health Phys. 59:669–691; 1990.

Stevens, W. Till, J. E.; Thomas, D. C.; Lyon, J. L.; Kerber, R. A.; Preston-Martin, S.; Simon, S. L.; Rallison, M. L.; Lloyd, R. D. Assessment of leukemia and thyroid disease in relation to fallout in Utah, report of a cohort study of thyroid disease and radioactive fallout from the Nevada Test Site. Salt Lake City: University of Utah; 1992.

Till, J. E.; Simon, S. L.; Kerber, R.; Lloyd, R. D.; Stevens, W.; Thomas, D. C.; Lyon, J. L.; Preston-Martin, S. The Utah Thyroid Cohort Study: Analysis of the dosimetry results. Health Phys. 68:472–483; 1995.

Walters, J. L.; Plowman, R. D.; Mickelsen, C. H.; Zaugg, N. L. Dairy production and pasture utilization by dairy cows in Utah between 1952 and 1961. Logan: Utah State University; 1985.

National Cancer Institute Studies

Beck, H. L.; Helfer, I. K.; Bouville, A.; Dreicer, M. Estimates of fallout in the continental U.S. from Nevada weapons testing based on gummed-film monitoring data. Health Phys. 59:565–576; 1990.

Bouville, A.; Dreicer, M.; Beck, H. L.; Hoecker, W. H.; Wachholz, B. W. Models of radioiodine transport to populations within the continental U. S. Health Phys. 59:659–668; 1990.

Dreicer, M.; Bouville, A.; Wachholz, B. W. Pasture practices, milk distribution, and consumption in the continental U.S. in the 1950s. Health Phys. 59:627–636; 1990.

Hoecker, W. H.; Machta, L. Meteorological modeling of radioiodine transport and deposition within the continental United States. Health Phys. 59:603–617; 1990.

National Cancer Institute. Estimated exposures and thyroid doses received by the American people from Iodine-131 in fallout following Nevada atmospheric nuclear bomb tests. Washington: NCI Report; 1997.

Other studies containing calculations of internal dose resulting from NTS tests

Knapp, H. A. Iodine-131 in fresh milk and human thyroids following a single deposition of nuclear test fallout. Washington: U.S. Department of Energy; TID-19266; 1963.

Lapp, R. E. Nevada test fallout and radioiodine in milk. Science 137:756–757; 1962.

Perez, L. J.; Robinson, P. B. Estimates of iodine-131 thyroid doses from gross beta radioactivity in milk samples collected at St. George, Utah, 1953. Rockville: National Center for Radiological Health, Public Health Service; 1967.

Reiss, E. Statement and papers presented to Congress on behalf of the Greater St. Louis Citizens' Committee for Nuclear Information. In: U.S. Congress (1963), Vol. 2:601–658.

Tamplin, A. R.; Fisher, H. L. Estimation of dosage to thyroids of children in the U.S. from nuclear tests conducted in Nevada during 1952 through 1955. Livermore: Lawrence Livermore National Laboratory; UCRL-14707; 1966.

Other pertinent publications

Åberg, B.; Hungate, F. P. Radioecological concentration processes. Proceedings of an international symposium held in Stockholm 25–29 April 1966. New York: Pergamon Press; 1967.

Anspaugh, L. R. Retention by vegetation of radionuclides deposited in rainfall: A literature summary. Livermore: Lawrence Livermore National Laboratory; UCRL-53810; 1972.

Anspaugh, L. R. Technical basis for dose reconstruction. In: Environmental dose reconstruction and risk implications, Till, J., ed. Bethesda: National Council on Radiation Protection and Measurements; Proceedings No. 17; 1996:25–48.

Barry, P. J.; Chamberlain, A. C. Deposition of iodine onto plant leaves from air. Health Phys. 9:1149–1157; 1963.

Beierwaltes, W. H.; Crane, H. R.; Wegst, A.; Spafford, N. R.; Carr, E. A., Jr. Radioactive iodine concentration in the fetal human thyroid gland from fall-out. J. Am. Med. Assoc. 173:1895–1902; 1960.

Beierwaltes, W. H.; Hilger, M. T. J.; Wegst, A. Radioiodine concentration in fetal human thyroid from fallout. Health Phys. 9:1263–1266; 1963.

Clark, H. M. The occurrence of an unusually high-level radioactive rainout in the area of Troy, N. Y. Science 119:619–622; 1954.

Cohn, S. H.; Gusmano, E. A. Uptake and transfer of fallout I^{131} in pregnant women. Heath Phys. 9:1267–1269; 1963.

Dunning, G. M. Two ways to estimate thyroid dose from radioiodine in fallout. Nucleonics 14(2):38–44; 1956.

Dunning, G. M. Criteria for evaluating gamma radiation exposures from fallout following nuclear detonations. Radiology 66:585–594; 1956.

Dunning, G. M. Criteria for establishing short term permissible ingestion of fallout material. Am. Ind. Hyg. Assoc. J. 19:111–120; 1958.

Garner, R. J. A mathematical analysis of the transfer of fission products to cows' milk. Health Phys. 13:205–212; 1967.

Koranda, J. J. Agricultural factors affecting the daily intake of fresh fallout by dairy cows. Livermore: Lawrence Livermore National Laboratory; UCRL-12479; 1965.

Koranda, J. J.; Phelps, P. L.; Anspaugh, L. R.; Potter, G. B.; Chapman, W.; Hamby, K. O.; Peterson, K. R.; Crawford, T. V.; Pendleton, R. C. Radioecological studies related to the BANEBERRY Event. Livermore: Lawrence Livermore National Laboratory; UCRL-51027; 1991.

Meinke, W. W. Observations on radioactive snows at Ann Arbor, Michigan. Science 113:545–546; 1951.

Rupp, E. M. Age dependent values of dietary intake for assessing human exposure to environmental pollutants. Health Phys. 39:151−163;1980.

Stannard, J. N. Radioactivity and health. A history. Springfield, VA: National Technical Information Service; 1988.

Ward, G. M.; Johnson, J. E. Forage-milk relationships of ^{137}Cs, ^{131}I and ^{90}Sr in one herd of cows. J. Dairy Sci. 46:644−647; 1963.

Weaver, J. C.; Kamm, M. L.; Dobson, R. L. Excretion of radioiodine in human milk. J. Am. Med. Assoc. 173:872−875; 1960.

CLASSIFIED REPORTS

One of the tasks for this work was "To identify classified reports that could be declassified for the purposes of this study, including those that would greatly facilitate the estimation of doses from internal irradiation that are due to the plutonium isotopes."

For many years it has been the policy of the U.S. Government not to identify in unclassified documents the titles of classified reports, and the author presumes that is still the case. However, it can be noted that there is a classified version of the Hicks and Barr (1984) report [see above reference] that would be extremely useful in allowing for a more accurate and consistent calculation of doses from the plutonium radionuclides.

Also, there is a specific problem in dealing with the Sedan event that is caused by the fact that the fission yield of the Sedan event is still classified. The present author cannot identify a specific report in which this fission yield is listed, but such a report obviously exists.

Other than the reports noted above that would be useful in defining the releases of plutonium in general and the fission yield of a few events [beyond the feasibility study, the fission yields of other events, such as Schooner, Buggy, Palanquin, etc., might be needed in order to perform a complete assessment], the author does not know of any reports that would be useful in general in defining the dose from the consumption of contaminated foods. Some isolated classified reports on this subject might exist, but it is doubtful that classified information of a generally useful nature exists.

HIGH-RISK POPULATIONS

Another task was to identify how high-risk populations might be identified. On a geographic basis the areas with the higher estimated doses are shown in Figs. 20–26, and the 80 county or sub-county areas with the higher doses for adults are listed in Table 5. As the most important radionuclide is ^{131}I, young children are also at higher risk (see Table 7). In addition, it is known that children drinking goats' milk would receive doses that are approximately ten times higher than those drinking cows' milk. Thus, the higher risk populations would be young children living in the 80 county or sub-county areas shown in Table 5. The highest risk population would be young children drinking goats' milk in the 80 county or sub-county areas.

Appendix G

External Dose Estimates from Global Fallout

External Radiation Exposure to the Population of the Continental U.S. from High Yield Weapons Tests Conducted by the U.S., U.K. and U.S.S.R. between 1952 and 1963

Harold L. Beck

Report to the National Cancer Institute in fulfillment of
P.O. #263-MQ-003539

March 15, 2000

Abstract

This report provides estimates of the external radiation exposure and whole body effective dose received by residents of the continental U.S. during the period 1953-2000 from nuclear weapons tests. Doses were calculated for tests carried out in the Pacific by the U.S. and U.K. and by the U.S.S.R. at various sites in the former Soviet Union during the years 1952-62. Estimates are given on a county by county basis for each month from 1953-1972.

The average population dose from the fallout from all of these tests was about 0.7 mSv, about equivalent to 2-3 years of external radiation exposure from natural background. In contrast to the fallout from tests at the Nevada Test site, the variation in exposure across the country from "global" fallout was relatively small, reflecting primarily variations in annual rainfall. Precipitation was the main mechanism for the deposition of fallout from these mostly high-yield thermonuclear tests that injected most of their debris into the stratosphere. Thus residents of counties in the eastern and Midwestern U.S. that received above average rainfall were impacted more than residents of the more arid Southwestern states. Since the states downwind from the NTS that were impacted most by the NTS fallout are in general more arid than the eastern U.S., the areas most impacted by NTS fallout were in general least impacted by "global" fallout.

In contrast to fallout from the NTS where most of the exposure was due to the short-lived radionuclides (primarily I-Te-132 and Ba-La-140), Zr-Nb-95 was the major contributor to external dose from "global" fallout during the years of testing. The total dose through 2000 was dominated by the long-lived Cs-137. Cs-137 present in soil continues to result in a small radiation exposure to the public even at the present time. As was the case for NTS fallout, the most exposed individuals were outdoor workers, the least exposed, persons who spent most of their time indoors in heavily constructed buildings.

The deposition of all radionuclides that contribute significantly to external exposure, as well as a few that contributed significantly (Sr-89, Sr-90) to internal radiation exposure via the ingestion pathway, were calculated on a county by county and test by test basis. The general pattern of deposition is discussed. In general the population-weighted total deposition of long-lived radionuclides such as Sr-90 and Cs-137 was about a factor of about 10-15 greater than that from NTS fallout. However, the population-weighted deposition of short-lived isotopes such as I-131 was generally much less than from NTS fallout.

Introduction

In response to a request by Congress to the CDC and NCI to investigate the impact on the U.S. population from weapons tests, the NCI contracted with the author of this report to:

1. Prepare crude estimates of the doses *from external irradiation* received by the American people as a result of the above-ground tests carried out in the 1950s and early 1960s *by the U.S. in the Pacific and by the USSR in Kazakhstan and on Arctic Islands*. These dose estimates would be:
   - based on a review of the readily available open literature and information. It is not expected that sophisticated computer models should be developed or used for this purpose nor that a formal uncertainty analysis be carried out;
   - averaged over states or groups of states of the continental U.S., with indications on how the high-risk populations would be identified. However, if feasible, primary dose estimates should be made on a county-by-county basis, and averaged only for presentation purposes;
   - calculated separately for the most important radionuclides produced in these nuclear weapons tests with respect to external irradiation of the U.S. population. Those would include, but would not be limited to Cs-137, Zr-Nb-95, Mn-54, Sb-125, and Ba-La-140;
   - provided in terms of average whole-body dose for gamma irradiation. The dose to the skin for beta irradiation should also be indicated, however, since this dose is expected to be small compared to the gamma dose, it is not expected that detailed beta dose calculations will be made for each geographical area and month/year of fallout; calculated by year of fallout and summed over all tests, with a comparison to the results previously obtained for the NTS tests. If feasible, calculations should be carried out by month of fallout.

2. Provide an electronic database with the deposition densities and estimated doses of the important fallout radionuclides, by month of fallout and geographical area (county, state or group of states). From the point of view of external irradiation, the important radionuclides include those listed above. In addition, the deposition densities of Sr-90, Sr-89, I-131, Fe-55, and Pu-239 should be estimated, as they are important from the point of view of internal irradiation.

3. Indicate whether it would be feasible to improve the dose and deposition density estimates provided in this assessment. If so, discuss briefly how it could be done and estimate the level of effort, in terms of man-months, that would be needed.

This report along with an associated electronic database is presented in fulfillment of the above scope of work.

In a previous report (Beck, 1999), this author estimated the external exposure of the population of the continental U.S. from Nevada Weapons Tests. The mostly low-yield (<100 kT) weapons tests conducted at the NTS injected almost all of their debris into the troposphere where it was deposited mostly within the continental U.S.A. (Beck, 1999). In contrast, the mostly high-yield (thermonuclear tests with yields greater than 1 MT accounted for over 90% of the fission products produced) tests carried out by the U.S., UK and USSR in the Pacific and at various sites in the USSR injected most of their debris into the stratosphere (UNSCEAR, 1982,1993). The total fission yield of these tests was about 150 MT (see Table 1) compared to about 1 MT for NTS tests. However, because of the long residence times for the transfer of air between the stratosphere and troposphere (on the order of 1 year), the fallout from these high yield tests was relatively depleted of short-lived radionuclides. Thus the total deposition in the continental U.S.A. of short-lived radionuclides such as I-131 was considerably lower than that from NTS tests.

The debris from these high-yield tests was dispersed throughout the atmosphere resulting in “global” fallout as opposed to the local and regional fallout from the NTS tests. This resulted in even the deposition of long-lived radionuclides such as Cs-137 and Sr-90 in the continental U.S. being only about 10-15 times that from NTS fallout. The deposition from this “global” fallout was also much more evenly distributed across the U.S. than the fallout from NTS tests. Thus even the deposition density for I-131 may have been comparable to the deposition of I-131 from NTS tests at some sites in the eastern U.S. with high average annual precipitation. Unfortunately, however, in this preliminary study, it was not feasible to estimate the deposition of I-131 from “global” fallout in any particular county with a reasonable degree of confidence.

While much of the fallout from NTS tests, particularly in areas close to the NTS, was dry deposition, most of the debris from this “global” fallout was deposited by precipitation scavenging of debris which had reentered the troposphere from the stratosphere or was originally injected into the high troposphere. Thus the deposition of fallout at any site tended to reflect whether or not, and how frequently, rain occurred at that site, particularly during the months of peak atmospheric fission product concentrations. While separate estimates were made for each NTS test, the estimates in the present report cannot easily be attributed to any particular test due to the frequency of the tests and the difference in the mechanism of fallout deposition. During the periods of testing, tests were often held on a daily basis and sometimes multiple tests occurred on the same day at separate sites. Fig.1 shows the estimated FY on a monthly basis and illustrates that the debris was released over a few relatively intense intervals of testing, primarily in 1954, 1956, 1958 and 1961-62. Since most of the debris from these tests was injected into the stratosphere, the activity in stratospheric air at any time generally represented a complex mixture of contributions from a large number of tests. Since most if not all of the subsequent fallout was from this stratospheric reservoir, it is impossible to attribute the deposition at any particular time to a particular test. However, one can assume that the relative contribution of USSR tests to the total U.S. fallout is roughly proportional to the relative fission yield of Soviet versus U.S. and UK tests. About 84 MT of the total estimated fission yield of 150 MT is estimated to be from tests carried out in the USSR (see Table 1).

A huge body of literature exists regarding fallout from nuclear weapons tests. However, the only widespread continuous monitoring of fallout deposition were the global networks of gummed-film samplers and later precipitation collectors (stainless-steel pots and ion exchange columns) operated by the USAEC's Health and Safety Laboratory (HASL) and the network of air sampling stations along the 80th meridian operated prior to 1963 by the Naval Research Laboratory and after 1963 by HASL (Harley, 1976; Lockhart et al., 1965). The Public Health Service monitored radioactivity in milk at a number of U.S. cities beginning in 1958 and also total beta activity in air and precipitation at a number of sites in the U.S. beginning in 1957 (Rad. Health Data, 1958-; PHS, 1958-). A large amount of other scattered sources of data are available in reports by investigators at National Labs, Universities and State and Local Agencies. The HASL, in conjunction with the USDA, also carried out extensive soil sample surveys in 1956, 1958 and 1964-66 (Alexander et al., 1961; Meyer et al., 1968; Hardy et al., 1968). These soil data provide estimates of the geographical variation in the cumulative deposition estimates of long-lived radionuclides such as Cs-137 and Sr-90. The HASL also carried out nationwide surveys of external exposure rate levels in 1962-64, using in situ gamma-ray spectrometry to identify the contribution of fallout to the total exposure rate in air (Beck et al., 1964,1966; Lowder et al., 1964). These exposure rate measurements also provide confirmation of the exposure and dose estimates in this report.

The basic starting point for the estimates in this report were the monthly Sr-90 deposition density measurements reported by the HASL for about 30 sites across the U.S. (HASL, 1958-72, USERDA, 1977}. These data were supplemented by scattered data from the literature (Collins and Hallden, 1958; Collins et al., 1961; Kuroda et al., 1965). The deposition of Sr-90 (and for some sites also Sr-89) was measured by collecting precipitation using steel pots and/or ion exchange columns. Figure 2 shows the location of HASL monitoring sites in operation in 1962. The number of monitoring sites varied from year to year with the maximum number in operation during 1962-1965. Except for one or two sites (i.e. New York City) continuous measurements were not carried out extensively prior to 1958. Thus little or no data exist for years prior to 1958. The HASL did monitor total beta deposition at about 50 sites from 1952 through 1960 using gummed film (see Beck, 1999, Beck et al., 1990). However, only the data for years of NTS testing has been reevaluated and thus these data were unavailable for use in this analysis.

Monthly deposition densities were estimated for the radionuclides listed in Table 2. The expected production rates of each radionuclide per MT fission are also listed based on estimates of the fission yield from thermonuclear tests (UNSCEAR, 1993) and reported estimates of radionuclide production relative to Sr-90 for selected Pacific tests (Hicks, 1984). Because of the delay in transfer of debris from the stratosphere to the troposphere discussed above, the relative fission yields shown in Table 1 and production ratios shown in Table 2 are not necessarily reflective of the relative deposition density of particular radionuclides or the variation in deposition with time. However, the deposition of nuclides with similar half-life can be expected to track reasonably well. Note that with the agreement of the contracting officer, detailed estimates have not been made in this preliminary report for a few of the radionuclides listed in the scope of work (e.g., Fe-55, Pu-239). Pu deposition was generally proportional to Sr-90 deposition (UNSCEAR,

1993) and as a first approximation can be estimated from the reported Sr-90 estimates. Fe-55, an activation product, is a minor contributor to ingestion dose and does not contribute to external dose. Because the production of Fe-55 from any particular test may have varied considerably, it was decided not to attempt to estimate Fe-55 deposition for this preliminary feasibility study.

The patterns of total deposition for some of the longer-lived nuclides are discussed in this report and the total deposition of various radionuclides is compared to that from the fallout from the NTS previously reported by this author (Beck, 1999). The general validity of the deposition density estimates and dose estimates are indicated by comparisons with measurements of Sr-90 in soil samples and in situ gamma-ray measurements of exposure rate that were made during the peak fallout years (1963-65).

All calculations for this report were carried out separately for each county in the Continental U.S. using a relatively crude model. Fallout in Hawaii and Alaska has not been considered in this study. Estimates were made of deposition density for each nuclide contributing significantly to the external exposure for the years 1953-72, as well as for Sr-90, which is a major contributor to internal exposure. These deposition density estimates and the resultant external exposure estimates for each nuclide are included in the electronic database that accompanies this report. A portion of this database containing the estimated deposition density on a monthly and county by county basis for Sr-90 and Cs-137 was provided to NCI earlier in partial fulfillment of this contract. The database containing these deposition density estimates will be used by the NCI to estimate internal radiation doses due to ingestion of contaminated food.

The monthly results for individual nuclides were summed to provide annual and total estimates of deposition density and doses for each county as well as population weighted estimates for the continental U.S. Besides the total free-in-air exposure rate from gamma emitters, estimates were also made of the annual whole-body effective dose. The beta-ray dose to the skin from radionuclides in the surface soil is also discussed and the radionuclides that contributed most to both gamma and beta-ray exposures were identified.

The results presented in this report are not intended to be definitive estimates of the geographical and temporal variations in “global” fallout across the U.S. They are preliminary estimates intended to demonstrate the feasibility of making such estimates given sufficient data and the resources to develop more sophisticated models than the crude models used here. The present results are believed to reasonably indicate the overall geographical and temporal variations in fallout, particularly for the years of greatest fallout (1961-65). However, the specific county estimates or estimates for years prior to 1958 and for any particular month and county at any time may be quite uncertain and should be used with discretion. This is particularly true for the short-lived radionuclides for which little or no actual data was available upon which to base estimates. Possible improvements in the methodology are discussed later in this report, as are additional data requirements. Recommendations are made on how to improve the estimates in this preliminary feasibility study and to estimate the uncertainty in the individual monthly or annual dose estimates for residents of any particular county.

The next section of this report describes in detail the methodology used to calculate exposure and deposition densities.

Table 1: Estimated Fission Yields*- MT

Year	US, UK	USSR
1952	6.0	0
1953	0	0.04
1954	31	0.1
1955	0.0	1
1956	8.6	1
1957	1.5	2.4
1958	18.5	8.5
1959	0	0
1960	0	0
1961	0	18
1962	53	19

*Total yields were reported in DOE (1994) and VNIEF (1996). Because the fission yield of individual tests are still classified, assumptions were made to estimate the values of the fission yields. For purposes of providing values for Table 1, all tests smaller than 0.1 Mt total yield were assumed to be due only to fission. For tests in the range 0.5-5 Mt, fission yields averaging about 50% have been assumed here. For tests in the range 0.1-0.5 MT, a fission yield of 67% was assumed. There were 17 tests in the range 5-25 Mt. With no other indications available, fission yields of 33% were assumed for those tests. However, the fission yields of the U.S. tests were arbitrarily adjusted to agree with the reported total fission yields for the years 1952, 1954 and 1958 (USDOE, 1999). Note: tests carried out at the NTS are not included in Table 1.

Table 2: Radionuclides for which deposition densities and external exposures were calculated

Nuclide	**Half life (parent), d**	**FY(%) (a)**	**PBq/MT**
Mn-54	313	activation product	b)
Sr-89	51	3.2 (c)	731
Sr-90,Y-90*	28.6 y	3.5	3.9
Zr-95,	64	5.1	922
Nb-95	35	0	0 (d)
Ru-103, Rh103m*	39	5.2	1540
Ru-106, Rh-106*	372	2.4	76.4
Sb-125	2.73 y	0.4	4.66 (e)
I-131	8	2.9	4200
Cs-137	30.14 y	5.6	5.9
Ba-140, La-140*	13	5.2	4730
Ce-141	33	4.6	1640
Ce-144, Pr-144*	285	4.7	191

- In equilibrium with parent

a) Fission yields from UNSCEAR, 1993.
b) approx. 15.9 PBq/MT fusion (UNSCEAR, 1993)
c) Based on reported ratio to Sr-90 for US Pacific tests (Hicks, 1984).
d) Nb-95 is a decay product of Zr-95. The deposition of Nb-95 will depend on the age of the fallout as will the amount of Nb-95 present in soil at any time.
e) Some additional Sb-125 (as well as Sb-124) was also produced by activation of Sb-123 in some of the very high yield tests carried out by the USSR in 1962 (UNSCEAR, 1993).

Methodology

General

The basic model used to estimate the deposition of various fallout radionuclides from the "global" fallout produced by the generally high yield tests described in the introduction was as follows.

a) The average precipitation for each month for each county of the continental U.S. was estimated from U.S. Weather Service records.

b) Based on available deposition data and soil analysis results, a crude model was developed to describe the geographical variation in Sr-90 deposition density per unit precipitation as a function of latitude and longitude. This geographical variation was assumed to be independent of time.

c) The deposition density of Sr-90 per unit precipitation (specific activity) in the NE U.S. for each month from 1952 through 1971 was estimated from available monitoring data. The deposition for other areas of the U.S. was then estimated from the model described in b) and the measured monthly precipitation.

d) The ratio of the deposition of each nuclide listed in Table 2 to the deposition of Sr-90 for each month for the period 1953-1972 was estimated using actual data if data were available. If no data were available for a particular period for a particular radionuclide, an atmospheric model was used to estimate the ratio of the deposition density of that nuclide that of a nuclide of similar half-life for which data was available. For the purposes of this preliminary feasibility study, the deposition-density ratios of one nuclide to another were assumed to be independent of location.

e) The monthly deposition density of each radionuclide was then calculated by multiplying its estimated ratio to Sr-90 for that month by the estimated Sr-90 deposition density for that month to obtain an estimate of the nuclide deposition density.

f) The cumulative amount of each radionuclide present in the soil in each county was calculated from the estimated monthly depositions and nuclide half-life, correcting for decay during the month of deposition and decay from one month to another as well as ingrowth of daughter activity (e.g., Nb-95 from Zr-95).

g) The exposure rate in air and dose to a typically-exposed adult produced by each radionuclide present in the soil was calculated from its cumulative deposition density using conversion factors from (Beck, 1980). The dose contributions from each radionuclide were summed to estimate the total monthly dose, the annual dose from external radiation and the total dose for an individual resident in the same county throughout the period 1953-2000. Population doses (per capita doses) were also calculated by weighting the individual county estimates by the county population during the time of testing.

h) An electronic data base with the estimated deposition densities of Sr-90 by month and county, the estimated isotopic ratios by month, the estimated external doses to a typically exposed individual for each county, month and radionuclide was prepared.

In the following paragraphs, each of the steps above is described in more detail.

<u>Precipitation estimates</u>

Monthly precipitation has been measured at over 8000 U.S. Weather Service cooperative monitoring sites and data is available for most sites beginning in about 1900. This data is available on the world wide web (http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html). Not all sites were in operation at all times and even for sites in operation continuously, data was often missing for some or all months during a given year. Since there are about 3,000 counties in the continental U.S., the average number of monitoring sites per county was about 3. However, some counties had a large number of sites (10 or more) while precipitation was not measured at all in other counties.

For this preliminary feasibility study a single estimate of monthly precipitation was obtained for each county for each month from 1953-1972 by averaging the available reported monthly data for each site in operation during that month. If no data were available for a county for any particular month the value for the nearest county was used (the nearest county was defined as the smallest distance between county centroids).

The crude estimates of monthly precipitation thus obtained are subject to a certain level of bias. First, for many counties, particularly large counties with large variation in topography, there were large variations in monthly precipitation from one monitoring site to another as shown in Table 3. Thus the average for that county may not be representative of the precipitation in the areas where most of the population reside (e.g., Seattle or Salt Lake City). Furthermore, the average precipitation may be much less than the maximum in the county. As will be discussed later, the exposure to individuals living in these higher precipitation regions may be considerably higher than the average exposure estimated for the county. Also, the substitution of missing values with values for the nearest county may not be the most appropriate for areas of the country with rapidly varying topology. Suggestions for improving the estimates of precipitation are discussed later in this report.

The estimates of average precipitation for each county used for the calculations in this report are contained in the electronic database accompanying this report.

Table 3: Variation of monthly precipitation within selected counties during Dec., 1962

Clallam County, WA		King County, WA		Salt Lake County, UT	
Site	(cm)	Site	(cm)	Site	(cm)
Clallam Bay	32	Cedar Lake	25	Alta	4.0
Elwha	22	Grotto	34	City Creek	1.1
Forks	48	Landburg	19	Cottonwd. W.	0.8
Lake Suther.	23	Mod Mt. Dam	17	Gorfield	0.15
Neah Bay	45	Palmer	34	Midvale	0.4
Port Angelos	9	Scenic	27	Mt. Dell Dam	1.4
Suppho	34	Seattle	10	Salt Lake	0.23
Sequim	4	SeTac AP	13	SLC AP	0.71
Tatoosh Is.	33	Snaqual. Falls	15	Silver Lake	3.2
		Snaqual. Pass	34	Univ. Utah	0.8

Variation in specific activity of Sr-90 with latitude and longitude

Previous studies have demonstrated that the deposition of Sr-90 or Cs-137 from "global" fallout was generally proportional to the amount of precipitation over any particular localized area (Krey and Beck, 1981; Beck and Krey, 1983; Collins and Hallden, 1958; Martell, 1959; Alexander et al., 1961; Hardy et al.,1962, 1968). However, the slope of the regression (Bq per cm of rain) was known to vary significantly with both latitude and longitude across the continental U.S. Fig 3 from Alexander et al., (1964) shows the variation of cumulative Sr-90 deposition with latitude at sites with the same average annual precipitation in the central U.S. as determined from soil sampling at various times as shown. There is a clear variation with latitude with a maximum in the 35-40 degree latitude band. The deposition at low latitudes is less than the maximum by about a factor of two. Furthermore, based on the different sampling times, the variation with latitude did not appear to vary significantly over time.

A similar variation with longitude is illustrated by Fig 4. Here the cumulative activity per cm of rain for cumulative Sr-90 measured in soil samples at sites in the latitude band 35-45 degrees is shown. Data from the cumulative deposition of Sr-90 from 1958-65 as measured in deposition in the HASL pot and column sites are also plotted. These data indicate a clear trend of a relatively constant specific activity in the eastern U.S. and then a steep increase as one approaches the mountainous area of western Colorado, Utah and Wyoming. The specific activity reaches a peak of about a factor of two at approximately the longitude of Salt Lake City but drops precipitously to less than northeastern U.S.

levels as one reaches the West Coast. The result of this increase in specific activity is that sites such as Salt Lake City, where the average annual rainfall is about ½ that of New York City, received about the same total Sr-90 deposition as New York City. The exact reason for apparent steep gradient with longitude is not known but may be due to a combination of factors including the relatively high latitudes and increased thunderstorm activity during the months of peak stratosphere to troposphere air transfer (Hardy et al., 1968).

As described below, the results shown in Figures 3 and 4 were used to create a crude time-independent model of the variation of Sr-90 specific activity as a function of latitude and longitude that was used to estimate Sr-90 deposition density for each county of the continental U.S.

Specific activity of Sr-90 at NE U.S. sites

As discussed earlier, monitoring of fallout deposition was carried out at only a limited number of sites in the U.S., mostly in the late 1950's and 1960's. Many of these monitoring sites were in the northeastern U.S. (Fig 2). Thus it was decided to use the average of the measured data for sites in the latitude band 38-45 degrees and longitude band 70-85 degrees as the benchmark for estimating the specific activity in other regions of the continental U.S. This choice was made for several reasons. First, as shown in Fig 4, the variation in specific activity in this longitude band was relatively constant. Second, for years beginning in 1958 and for several months in 1956, data were available for at least 2-3 or more sites that could be used to obtain a reasonable estimate of the mean for the region. Finally, for periods prior to 1956, data are available only for NYC.

The benchmark specific activity values thus obtained are shown in Fig 5 for the years through 1965. It should be noted that there were often large variations in measured monthly values at sites relatively near to each other (e.g., New York City and Westwood, NJ) as well as occasional large differences in duplicate samples taken at the same site. This suggests that significant measurement errors were possible in either the Sr-90 measurement or the local precipitation measurement that was reported by the HASL. Thus in calculating the average specific activity for any particular month, the author's judgment was used to discard apparent anomalous measurements in order to obtain a set of specific activity measurements that were consistent with the time of year and previous and subsequent months data. The data from other sites in the U.S., along with Figures 3 and 4, was also used to identify clearly anomalous data. Note that the monthly variations in specific activity do not track the fission yields shown in Fig 1. This reflects the fact that most of the fallout in the U.S. was from debris injected into the stratosphere resulting in a relatively long delay between its creation and subsequent deposition. Note also the annual spring peaks in deposition that reflect the greater transfer of debris from the stratosphere to the troposphere during the late winter and early spring (Bennett, 1978; UNSCEAR, 1982).

Prior to 1954, there were no reported measurements of Sr-90 from which to make specific activity measurements. However, soil sample data were available for a few sites in the eastern U.S. These provided a crude estimate of the total deposition of Sr-90 from “global” fallout up to 1954. Almost all of this deposition was assumed to have occurred in 1953, primarily as a result of the high-yield U.S. tests carried out in the Pacific in late 1952. The monthly variation in specific activity during the year was assumed to be the same as that measured in NYC during 1954.

For each month from 1953 through 1972, an estimate of the baseline specific activity of Sr-90 in precipitation was thus obtained for use in estimating the specific activity in other regions of the country as described in the next section. These specific activity estimates are contained in the electronic database supplied with this report. The section later in this report on possible improvements to the crude estimates in this report discusses improvements that might be made in these estimates.

Deposition density of Sr-90 in the continental U.S.A.

In order to estimate the deposition density of Sr-90 in each county of the continental U.S.A. a monthly basis a number of assumptions have been made.

First, it was assumed that the deposition in any particular county was proportional to the precipitation that occurred in that county during that month. Since the specific activity has been shown to vary significantly with latitude and longitude, it was thus necessary to develop a model describing this variation. Because of the sparse available data, it was not feasible to develop a detailed continuously varying model of the variation with latitude and longitude for this preliminary feasibility study. Thus a relatively crude model consistent with the data shown on Fig 3 and 4 was adopted. The Continental U.S. was divided into 25 latitude-longitude quadrangles and the average specific activity for each quadrangle relative to the default specific activity discussed in the previous section was estimated from the data shown in Figs 3 and 4. These default specific activities are given in Table 4. For this study, it is assumed that the variation was independent of time. This may not be strictly true, as discussed later in the section on possible methodology improvements, particularly for months of testing when some of the fallout may have been from debris injected into the troposphere instead of the stratosphere.

Table 4 :Sr/cm:default ratios (relative to NE U.S. baseline values)

Lat \ lon:(degrees):	60-90	90-100	100-110	110-120	>120
25-30	0.45	0.45	0.6	0.5	0.5
30-35	0.6	0.65	1.2	1.0	0.7
35-40	0.8	0.9	1.5	2.0	0.8
45-45	1.0	1.1	1.6	1.9	0.6
45-50	0.8	0.85	0.9	1.0	0.5

Because the variation with longitude and latitude is not uniform, counties near the boundary of quadrangles where the default specific activity estimates differ significantly will have larger uncertainties in Sr-90 deposition estimates than counties in sections of the U.S. where the gradations from quad to quad are smaller. Clearly, as discussed later, a more sophisticated model might be developed, particularly if additional data can be located to better define the actual variations with latitude and longitude and with time. However, it is likely that the variations in precipitation within a county discussed earlier are a larger contributor to the total uncertainty in deposition in these areas than the crude estimates of geographical variation in specific activity.

Finally, the present model does not account for dry fallout. For most areas of the U.S. dry fallout was probably less than 10% of the total deposition. However, for any particular month where the precipitation was very low the dry deposition may have been more significant. The impact of not accounting for dry deposition is most significant for the more arid regions of the U.S. Thus, as discussed in the section on possible improvements, the estimates for fallout for those areas are likely underestimated in this report. It should be noted, however, that even, accounting for more dry fallout in such counties, the total fallout in these counties would still have been relatively low compared to counties with even average amounts of precipitation.

The deposition density of Sr-90 was thus estimated for each county for each month from 1953-1972 by multiplying the average precipitation for that county for that month by the benchmark specific activity and the assumed relative specific activity for that particular latitude-longitude band. The resultant deposition density estimates for each county and month are provided in the electronic database accompanying this report.[1]

Although the model used to estimate the Sr-90 deposition is fairly crude, a comparison with the available data for a number of sites where sufficient data is available indicates that the agreement is fairly good. This is true even on a monthly basis when one considers the measurement errors and variations in monthly precipitation within a given county. Figures 6a-6f compare the model estimates of Sr-90 deposition for six different cities in various parts of the U.S. with the actual measured Sr-90 in rain. Although there are sometimes large differences for a particular month, the overall agreement is quite good. Keep in mind that the model results are based on the average precipitation for the entire county while the measurement results are for a single location.

For this preliminary study, any NTS Sr-90 deposition density in precipitation at the northeastern benchmark sites was not subtracted. As shown in Beck (1999), the deposition density of Sr-90 in the N.E. U.S.A. was fairly low compared to areas closer to the NTS and to “global” fallout. Thus the resultant slight bias in the estimates of “global” fallout for months of NTS testing based on using uncorrected benchmark data did not have any significant impact on the annual or total estimates of “global” fallout.

In addition to the comparisons shown in Figs. 6a-6f, the annual depositions for the years 1958-65 predicted by the model were compared to those at the measured sites for about 30 measurement sites with a significant amount of measured data. On average, the agreement in annual Sr-90 deposition was better than ∀10% although for some sites,

[1] Note that even for counties where an actual measurement exists at one or more sites for a particular month, the model estimates appear in the database. A subsequent analysis might decide to substitute measured values if available.

there were differences in the calculated and measured total deposition density estimates of as much as ∀50% for some years.

An additional test of the validity of the model estimates can be obtained by comparing the calculated cumulative Sr-90 deposition density for a given county with the results of soil samples taken at a site in that county. Comparisons with soil samples from 1964-66 are shown in Table 5. As seen, the model estimates of cumulative Sr-90 deposition agree reasonably well with the soil data. The largest differences occur in counties in mountainous regions of the country. The average precipitation for these counties may not be representative of the rainfall at the measurement site. In addition, the soil samples include both “global” and NTS fallout while the model estimates exclude most of the NTS fallout. Thus one would expect the soil data to be somewhat higher than the model estimates for areas immediately downwind of the NTS. There are also large differences for counties in very arid locales where the model’s neglect of dry fallout resulted in a significant underestimate in Sr-90 deposition density. Additional soil data are available beginning in 1953 and further comparisons, subtracting the contributions from NTS fallout, might be useful for refining the deposition model.

The comparisons discussed above suggest that the model estimates of total Sr-90 deposition density for any given year and over a longer period are probably quite reasonable although estimates for any particular month may be quite uncertain. Possible improvements are discussed later in this report.

Table 5: Comparison of Model Sr-90 Cumulative Deposition Density Estimates with Soil Sample Measurements

Site	Soil Sample Date	Cumulative Deposition Density (Bq.m2)	
		Soil Sample	Model
Clallam County, WA	9/64	1150-4200 (6 sites)	2290
	9/65	1300-6440	2440
Puyallup, WA	9/64	2110	1850
	9/65	2180	2110
Mandan, ND	10/64	3000	1440
Bozeman, MT	9/64	2780	1630
Orono, ME	6/64	2110	2410
	7/65	2180	2480
St. Paul. MN	10/64	2740	1890
Corvalis, OR	9/64	1630	1920
	9/65	1920	2070
Burlington, VT	6/64	1960	2440
	7/65	2220	2590
Rapid City, SD	9/64	3590	3150
	9/65	3590	3480

Boise, ID	9/64	2150	1630
	9/65	2550	1810
Ithaca, NY	9/64	2040	2440
	10/65	2110	2590
Amherst, MA	6/64	2000	2660
	7/65	2330	2890
S. Wellflect, MA	6/64	2780	2920
	7/65	2890	3030
Logan, UT	9/64	1520	2590
	9/65	1810	2740
Des Moines. IO	9/64	2780	2960
	8/65	3030	3180
Kingston, RI	6/64	2780	3030
	7/65	3330	3180
Brigham City, UT	9/64	3440	2370
	9/65	3370	2550
New York City	12/64	2590	2590
Salt lake City, UT	9/64	3740	3260
	9/65	3850	3550
Heber, UT	9/64	2330	2740
	9/65	2550	2960
Rosemont, NB	9/64	2890	2370
	9/65	3110	2850
Columbus, OH	8/64	2890	2180
	8/65	2960	2370
Derby, CO	9/64	2180	1700
	9/65	2290	1920
Healdsburg, CA	9/64	1920	2070
	9/65	1920	2220
Cedar City, UT	9/64	1260	1330
	9/65	1410	1550
Norfolk, VA	2/64	2110	2220
	2/65	2740	2290
	2/66	2810	2370
Tulsa, OK	10/64	1850	2330
Florence, SC	2/65	2890	2220
	3/66	2810	2220
Los Angeles, CA	9/64	810	1000
	9/65	850	1110
Atlanta, GA	2/64	2000	2510
	3/65	2740	2590
	3/66	2110	2660
El Centro, CA	9/64	570	110
	9/65	670	110

Newton, MS	3/65	1890	2260
Tifton, GA	3/65	2000	2290
Jacksonville, FL	2/65	2260	2370
	3/66	2150	2520
New Orleans, LA	3/65	2260	2520
	3/66	1890	2630
Ft. Lauderdale, FL	2/65	1850	2070
	3/66	2370	2070

Soil data from Meyer et al., 1968.

Ratios of deposition to Sr-90, Sr-89

The previous sections discussed the estimates of Sr-90 deposition density. Only two radionuclides were monitored fairly continuously for global fallout, Sr-90 and for fewer sites and times, Sr-89. The reason for this was that Sr-90 at that time was considered to be the most significant health hazard from "global" fallout due to its incorporation in bone via ingestion of contaminated foodstuffs and its long physical and biological half life. Thus other radionuclides were monitored infrequently and only at a few sites in the U.S. Because short-lived nuclides such as Zr-Nb-95 and others listed in Table 2 contributed significantly to external exposure rates, it is necessary to estimate the deposition density of these nuclides as well in order to estimate the exposure of the U.S. population to external gamma radiation.

Because of the sparseness of actual data, a critical assumption was required for this preliminary study, i.e., that the ratios of the various radionuclide deposition densities for any given month did not vary significantly across the U.S. Considering that most of the fallout deposited in the continental U.S. was from debris originally injected into the stratosphere where it had time to mix and equilibrate, this assumption is probably reasonable for the nuclides with half-lives greater than about a month. However, it may not be reasonable for nuclides with shorter half-lives for several reasons. First, some significant fraction of the fallout during months of testing, particularly for tests held at latitudes comparable to the U.S., may be from debris injected into the troposphere. The fallout would then vary across the U.S. because of decay in transit as the debris traversed the country. If debris from the stratosphere was transferred preferentially to the troposphere at specific longitudes, as indicated by Figure 4, again one might expect a variation with longitude in deposition. Debris injected into the troposphere tends to remain in a band close to the latitude of injection. However, some of the debris injected into the troposphere from U.S. tests in the Pacific at low latitudes might have diffused to higher latitudes and impacted the southern latitudes of the U.S. more than the more northerly latitudes. Unfortunately, except for Sr-89 with a half-life of 50 d, there is insufficient data upon which to base a geographical variation in deposition for these nuclides. In general, the Sr-89 to Sr-90 ratios do not indicate any significant geographical variation. Measurements of short-lived nuclides have been reported in precipitation and in air at only a few scattered sites across the U.S. and only during years after 1957.

Scattered data on individual nuclide activities in precipitation samples are available for Pittsburgh, Westwood, NJ, Houston TX (HASL, 1958-72, USAEC, 1958), New York City (Collins et al., 1961) and Fayetteville AK (Kuroda et al., 1965). There is also some data on short-lived and long-lived radionuclides in air for Miami and Sterling, VA (Lockhart et al., 1965), Richland, WA (Perkins et al., 1965), and Argonne, IL (Gustafson et al., 1965). Data for Ce-144 are also available from England for 1955 and 1956 (Stewart et al., 1957). Although these data do indicate a possible geographical variation during some of the months of testing, the data are often inconsistent and ambiguous. Further study is required along with a search for additional data in order to develop a credible model for the variation with location for these radionuclides. Thus, the deposition density estimates for nuclides shorted than about 1 month are highly uncertain and should be used with discretion.

Because of the sparseness of available data, even for Sr-89, a global circulation model developed by Bennett (1978) was used as an aid in estimating ratios of radionuclide deposition. This model was developed to describe atmospheric dispersion and deposition of radioactive debris produced in atmospheric nuclear testing (Bennett, 1978; UNSCEAR, 1982). The atmosphere is divided into a number of equatorial and polar regions from 0 to 30 and 30 to 90 degrees latitude, respectively. The troposphere height is variable with latitude and season, but for modeling purposes it is assumed to be at an average of 9 km altitude in the polar region and 17 km in the equatorial region. The lower stratosphere is assumed to extend to 17 km or 24 km in the two regions and the upper stratosphere to 50 km in both regions. The model requires certain assumptions regarding the fraction of fission products injected into the stratosphere versus the troposphere from each test. It also requires information on the yield and height of burst and estimates of the residence time and transfer rates of air from various regions of the stratosphere to other regions, from the stratosphere to the troposphere, and from the troposphere to deposition. Apportionment of debris to various compartments in the atmosphere is based on the reported stabilization heights of cloud formation following the explosion. Empirical values derived from a number of observations are used (Bennett, 1980, UNSCEAR 1982). The model tends to predict the temporal variation of Sr-90 deposition quite well (UNSCEAR, 1982). However, the estimates of the deposition of the shorter-lived nuclides are much more uncertain due to uncertainties in the exact fission yields for any particular test and the fractions of activity injected into the stratosphere versus the troposphere. The latter estimates are much more important for the short-lived nuclides than for the longer-lived nuclides.

Although the model is not able to accurately predict the actual deposition density of a particular short-lived nuclide, it served as a useful guide to the expected ratio of depositions for nuclides of about the same half life. Thus, for example, for periods when no measurements of Zr-95 were reported anywhere in the U.S., but measurements of Sr-89 were available, the model estimates of the ratio of Zr-95 to Sr-89 as a function of time were used to estimate the Zr-95/Sr-90 deposition density ratio from the average measured

Sr-89/Sr-90 ratio. Similarly, where Ce-144 data were available, but not Ru-106 data, the model deposition-density ratios of Ru-106/Ce-144 and the measured ratios of Ce-144/Sr-90 were used to estimate the Ru-106/Sr-90 ratio. A similar procedure was used to estimate I-131 deposition density from the sparse Ba-140 measurements. Ratios of Nb-95 to Zr-95 were estimated based on the estimated age of the Zr-95 being deposited and the relative half-lives of Zr-95 and Nb-95[2]. Since the half lives of Cs-137 and Sr-90 are similar (Table 2), the ratios of deposition were assumed to be equal to the production ratio for this report.[3] For periods where no data were available for a particular radionuclide the author made rough estimates using the production ratios shown in Table 2, and the model calculations as a guide. In all cases, where actual credible data was available, the actual data was used.

Again, the author's judgement was used to evaluate available data and thus the final estimates of the isotopic ratios presented in Appendix 1 of this report are a synthesis if the available data, the model predictions, and the author's professional judgement. Recommendations for estimating the uncertainty in and improving the estimates of isotopic ratios are discussed later in this report. The estimated ratios of Zr-95 to Sr-90 deposition density versus time are shown in Figure 7. Note that the ratio approaches the ratio of production rates given in Table 2 during the fall of 1961. This is expected since the stratospheric reservoir of Sr-90 was relatively depleted due to the moratorium on atmospheric testing from 1959 through most of 1961. At other times, the large inventory of Sr-90 in the stratosphere from earlier tests reduces the ratio below the production ratio even during months of heavy testing.

Deposition densities of radionuclides contributing to external radiation exposure

The deposition density of each of the radionuclides listed in Table 2 was thus estimated for each county and month by multiplying the estimated Sr-90 deposition density for that county and month by the monthly isotopic ratio estimates in given in Appendix 1. The estimates for the more important contributors to external dose, Zr-Nb-95 and Cs-137 are probably quite reasonable since Zr-95 was measured in precipitation or air at several sites in 1958 and 1961-62 and Sr-89 was measured at a relatively large number of sites (HASL, 1958-72). Furthermore, the model Sr-89/Zr-95 ratios agree reasonably well with the measurements for periods where both were measured simultaneously, supporting the use of the model ratios at other times. Similarly, the estimates for Ce-144 and Ru-106 are also considered reasonably valid. The deposition of Cs-137 as estimated from the production ratios is in reasonable agreement with available data. Ru-103 was not generally measured but Ce-141 measurements were occasionally reported. The use of the model and available Ce-141 data to infer Ru-103 deposition is probably reasonably valid. The most uncertain estimates are for Ba-140 and I-131, both for reasons discussed above

---

[2] Nb-95 is not produced during fission but grows in as Zr-95 decays. The ratio of Zr-95 to Nb-95 at any time thus depends on the time since the Zr-95 was produced. Nb-95 reaches about 97 % of secular equilibrium (Nb/Zr=2.2) in about 12 months.

[3] Since the half life of Cs-137 is actually slightly greater than that of Sr-90, this ratio probably increased very slightly with time since injection of debris into the stratosphere. Thus the total Cs-137 deposition may have been very slightly underestimated.

regarding geographical variations and due to the sparseness of available data. No actual data on I-131 deposition density was available for this report and thus I-131 deposition densities were estimated from available Ba-140 data. Scattered Ba-140 measurements in precipitation are available for Pittsburgh, Westwood, NJ, Houston, Richmond, CA, and Fayetteville, Arkansas at various times and a rough ratio to Sr-89 could be inferred from these measurements that was consistent with the ratio suggested by the Bennett model.

External radiation exposure

For the author's previous report on external exposure from NTS fallout, conversion factors from Beck (1980) were used to convert cumulative deposition density[4] to exposure rate in air assuming the radioactivity was distributed in the soil with a relaxation length of about 0.1 cm for the first 20 days. From 20 d to 200 d, a relaxation length of 1 cm was used, while for times greater than 200 days, a relaxation length of 3 cm was used. This report uses a similar model, multiplying the deposition on the ground less than 1 month by the conversion factor corresponding to a relaxation length of 0.1 cm. A relaxation length of 1 cm is used for the activity remaining in the soil that was deposited within the period 1-6 months while a relaxation length of 3 cm was used to calculate the exposure rate from the activity that had been present for greater than 6 months. The corresponding deposition-density to exposure conversion factor for each of these relaxation lengths is from Beck (1980). Since the penetration into the soil would be slower in more arid regions, maintaining the 0.1-cm relaxation length for the first 30 d provides a slightly conservative estimate of the exposure for sites with greater precipitation. Table 6 illustrates the dependence of the exposure rate in air on the various relaxation lengths. Note that the exposure rate is reduced by about 1/3 as the activity penetrates to a relaxation length of 1 cm and about ½ as the activity penetrates to a relaxation length of 3 cm from 0.1 cm. This accentuates the importance of the first few weeks after deposition with respect to total external radiation exposure to an even greater degree than previous calculations based only on radionuclide decay. For a discussion of available data on nuclide penetration with depth on the soil see Beck (1999).

[4] Again the ingrowth of Nb-95 from the decay of deposited Zr-95 was accounted for in the calculation of the cumulative deposition density of Nb-95. The buildup of Nb-95 activity relative to Zr-95 at any time is given by Nb = Zr * 2.17 * (1- exp (-0.00914 * t)) where t is in d.

Table 6: Exposure rate (: R/h per mCi/km^2) versus relaxation length for selected fission products (Beck, 1980)

Nuclide	Relaxation length (cm)		
	0.1	1	3
Zr-95	1.20E-02	7.94E-03	5.63E-03
Nb-95	1.24E-02	8.20E-03	5.82E-03
Mn-54	1.34E-02	8.82E-03	6.28E-03
Ba-La-140	3.57E-02	2.44E-02	1.71E-02
Sb-125	6.91E-03	4.61E-03	3.17E-03
Ru-103	7.85E-03	5.25E-03	3.58E-03
Rh-106	3.37E-03	2.25E-03	1.56E-03
I-131	6.32E-03	4.34E-03	2.89E-03
Cs-137	9.29E-03	6.15E-03	4.32E-03
Ce-141	1.09E-03	7.25E-04	4.92E-04
Ce-Pr-144	7.04E-04	4.80E-04	3.37E-04

Whole-body effective dose

In order to calculate the whole body dose from the free-in-air exposure data, one must first convert exposure to dose in air by multiplying by a factor of 0.875 rad/R. Then, to convert to dose in tissue and account for shielding by the body, one must convert from rads in air to rem (or in S.I. units, Gy to Sv). In this report, as was the case for NTS fallout (Beck, 1999, we chose to follow the ICRP guidelines (ICRP, 1991) and estimate the effective whole body dose that weights the effects on various organs in a proscribed manner. The UNSCEAR (1993) recommends a factor of 0.75 ± 0.05 to convert from Gy to Sv for adults. This is similar to average values recommended by the ICRP and others (NCRP, 1999). This factor of course varies with the energy of the radiation and the orientation with respect to radiation incidence (NCRP, 1999, Eckerman and Ryman, 1993), However, a value of 0.75 is a reasonable average for fission products (NCRP, 1999). The net conversion from exposure in air to effective dose is thus about 0.875 * 0.75 = 0.66 for adults. Calculations using computer phantoms have indicated that the effective dose to young children is about 30% higher (NCRP, 1999).

Thus the dose to adults exposed outdoors is about 2/3 the outdoor exposure. However, most people spend most of their time indoors and thus their exposure is reduced greatly due to attenuation of the radiation by building materials. The amount of shielding (i.e. the shielding factor) will depend on the type of structure. In general, based on a review of the available literature, it is estimated that heavily constructed buildings made of brick or concrete will provide a shielding factor of about 0.2 ± 20% (1 s,d,) while lightly constructed buildings will provide a shielding factor of about 0.4. ±20% (NCRP, 1999). These estimates are fairly conservative and allow for a small amount of radioactivity that may be tracked into the home from contamination of shoes, etc. Assuming that on average most persons spend about 80% of their time indoors (UNSCEAR, 1993; NCRP, 1999) with an average shielding factor of 0.3, their whole body effective dose would be 0.66 * (0.2 + 0.8 * 0.3) = 0.29 x Outdoor exposure. However, the UNSCEAR estimated that persons who work outdoor spend on average only 40% of their time indoors and the most exposed outdoor worker spends only about 30% of his/her time indoors. The NRC (1977) made a similar estimate of 40% of time spent indoors for the maximum exposed individual. Assuming only 30% indoors in a lightly shielded structure for the maximum exposed outdoor worker, the dose to the most exposed individuals would be 0.66 * (0.7 + 0.3 * 0.4) = 0.54 x Outdoor exposure or almost twice that of the average exposure. Conversely, the UNSCEAR (1993) estimated indoor workers spend only about 10% of their time outdoors while other estimates indicate some individuals spend even less time outdoors. Assuming 5% as a reasonable estimate for the least exposed individual living in a well shielded house and/or working in a well-shielded building, the minimum exposed individual would receive a dose of about 0.66 * (0.05 + 0.95 * 0.2) = 0.16 x outdoor exposure, or about ½ that of the average dose.

Thus the actual dose to any individual can range by about a factor of four depending on the amount of time spent outdoors and the type of structure the individual lives and works in. The dose to children could be about 30% higher than that for adults for the same fraction of time outdoors. In this report, all calculations of dose are based on the average exposure given above and estimates for any individual should be adjusted up or down based on the above discussion.

As discussed previously, the dose in a particularly individual in some counties may be considerably higher than estimated in this report. This is due to the use of an average precipitation for the county. Conversely, the use of the average precipitation for the county may have resulted in the estimated dose for most of the population being somewhat overestimated if most of the population resides at lower altitude, lower precipitation regions of the county. It should also be noted that the rate of penetration of radionuclides into the soil will also vary from site to site depending on the amount of rainfall and type of soil. Thus the relaxation lengths used for estimating the free-in-air exposure rates may also not correctly reflect the actual depth distribution at any particular locale and thus the dose to any particular individual.

Beta-ray skin dose

All of the exposures and doses discussed above refer to exposure to gamma radiation from the fission products deposited onto the ground. However almost all of the gamma emitting radionuclides also emit beta rays and a number of fission products emit beta rays but no gamma rays. Because of their low penetrating power, beta rays are attenuated rapidly in soil and even in air and thus contribute little to whole body radiation exposure (Eckerman and Ryman, 1993; NCRP, 1999). However, beta rays can contribute to the dose to skin, particularly in the days immediately following fallout before the activity has penetrated more deeply into the soil. Because the beta radiation is so sensitive to the actual depth distribution in the soil, only a very crude estimate can be made of the dose.

Besides the beta radiation itself, the beta rays produce a small amount of gamma radiation via bremsstrahlung (Eckerman and Ryman, 1993). This gamma radiation, although only a small fraction of the energy of the beta ray itself, can produce a small whole body exposure and add to skin dose. Furthermore, it is generally the only way a beta emitter can irradiate body organs other than the skin. The calculation of doses from beta radiation from fission products in the soil was discussed in the previous report by this author on NTS fallout exposure rates. Because of the fact that most of the short-lived beta ray emitters decayed prior to the deposition of "global" fallout, the relative impact of beta radiation compared to gamma radiation is expected to be have been even more minor than was estimated for NTS fallout.

Discussion of Results

Fallout deposition

The total deposition density of Cs-137 from "global" fallout through 1972 is shown in Figure 8. The total deposition Density of Zr-95+Nb-95 is shown in Fig. 9. The small differences in geographical variations for Cs-137 as compared to Zr-Nb-95 reflect the fact that Zr-Nb-95 was deposited only during and within a few months after testing while Cs-137, due to its long half-life and long stratospheric-residence time, was deposited essentially continuously. Thus areas with more frequent precipitation during periods of testing received relatively higher Zr-Nb-95 (as well as other short-lived radionuclides) deposition. Figs. 10 and 11 illustrate the variation with time of the annual population-weighted deposition density of Cs-137 and Zr-95, respectively. Also shown for Cs-137 is the cumulative deposition density. The latter illustrates the gradual build-up of activity in the soil that occurs for the longer-lived radionuclides. This buildup results in a gradually increasing exposure rate with time as shown later. Fig. 10 indicates that the deposition of Zr-95 in 1954 was less than that in 1958 and much less than the relative fission yields shown in Table 1. This is not exactly unexpected, however, since all of the tests conducted in 1954 were surface shots compared to only about 2/3 of the yield in 1958 being from surface shots in 1958 and ¾ in 1956 (USDOE, 1994). Surface shots would result in a much larger proportion of the debris being deposited locally and regionally as opposed to globally.

Table 7 gives the calculated total deposition (1953-1972) of each radionuclide and the population-weighted deposition density, and compares these with the estimates for NTS fallout from Beck (1999) and estimates for the Northern Hemisphere from UNSCEAR (1993).

As can be seen from Table 7, the deposition density of long-lived radionuclides from "global" fallout is about a factor of 10-15 greater than that from NTS fallout. However, the total deposition of short-lived nuclides such as I-131 was much less for "global" fallout than for NTS fallout. The "global" to NTS fallout ratios of population-weighted deposition density differ from the total deposition ratios reflecting the more uniform deposition of "global" fallout across the country. As shown in Beck (1999), the deposition of NTS fallout generally declined as the distance from NTS increased. The higher relative proportion of "global" fallout in the more populous (and higher rainfall) eastern U.S. resulted in a relatively higher per capita exposure from "global" fallout for the same total continental U.S. deposition.

Table 7: Total deposition and population-weighted mean deposition density of selected radionuclides for NTS fallout and "global" fallout. Bq/m^2

Nuclide	Total Deposition (10^{15} Bq)		Population weighted Deposition density (kBq / m^2)		
	NTS	"Global	NTS	Global (this study)	"global"**
Cs-137	2.3	28	0.26	4.4	5.2
Sr-90	1.8	19	0.11	2.9	3.2
Zr-95	218	313	25	50	38
Nb-95	0	400	0	65	64
Ru-103	426	212	46	35	28
Ba-140	1390	290	144	46	23
Ce-141	500	223	54	37	21
Ce-144	40	302	4.6	47	48
Ru-106	24	157	2.6	24	24
Sr-89	333	170	36	28	20
I-131	1484	112	192	18	19
Pu-239+240	0.13	~0.4	~0.015	~0.06	0.06

** for 40-50 degree latitude band (UNSCEAR, 1993)

The deposition of course varied from year to year. The annual per capita deposition density for each nuclide for "global" fallout is shown in Table 8. Because of the delay that resulted due to the injection of debris into the stratosphere, the deposition of long-lived nuclides continued for many years after the cessation of testing.

Table 8: Annual per capita deposition density for "global" fallout. Bq/m^2

Year	Cs-137	Zr-95	Nb-95	Ru-103	Ru-106	I-131	Ba-140	Ce-141	Ce-144	Sb-125	Mn-54	Sr-89	Sr-90
1953	55	920	1549	740	475	210	614	737	671	39	40	895	37
1954	96	2424	2458	3077	873	1408	4273	2540	1095	67	58	1815	64
1955	191	296	390	129	1218	47	153	144	1261	117	58	308	127
1956	181	3738	4510	3503	935	2241	5606	3313	1367	106	132	2103	121
1957	138	3890	6978	2760	922	2120	5323	3712	1737	84	128	2139	92
1958	269	5401	6026	7442	2243	3977	10477	8337	4209	184	348	3851	180
1959	379	6685	12933	3171	2416	5	166	2870	4585	246	514	3060	252
1960	95	0	0	0	250	0	0	0	374	48	55	0	64
1961	115	4265	3257	2870	598	1463	4247	4028	1284	77	104	2279	77
1962	549	13813	14253	5307	4524	6009	15020	7327	10245	560	2125	6852	366
1963	921	8920	12477	6216	5958	62	308	3901	12954	910	2197	4526	614
1964	647	108	227	5	2660	0	0	0	5007	505	818	0	431
1965	288	0	0	0	818	0	0	0	1151	184	201	0	192
1966	109	0	0	0	220	0	0	0	314	62	52	0	73
1967	57	0	0	0	82	0	0	0	118	29	18	0	38
1968	58	0	0	0	59	0	0	0	86	26	12	0	39
1969	54	0	0	0	39	0	0	0	58	22	8	0	36
1970	67	0	0	0	34	0	0	0	51	24	6	0	45
1971	57	0	0	0	21	0	0	0	31	18	4	0	38
1972	23	0	0	0	6	0	0	0	0	7	1	0	15

Exposure and dose

The geographical distribution of total whole-body effective dose from all “global” fallout through 1972 for a typically exposed individual (80% indoors, 0.3 shielding factor) is shown in Figure 12. As can be seen, the variation across the continental U.S. is relatively small, about a factor of four for most counties, reflecting primarily variations in precipitation. The specific mean doses for each county for each month, year, and total are included in the database that accompanies this report. The interested reader can estimate his/her exposure and dose by multiplying by the appropriate indoor/outdoor and shielding factor correction factor as discussed in the previous section. The distribution of doses for 1962 is shown in Fig. 13 to illustrate the variation during a period of heavy testing when short-lived radionuclides contributed most of the exposure.

The relative impact as a function of time was investigated by calculating the population exposure for each county (the product of the average exposure for a given county multiplied by its population) and then summing over all counties. The annual population exposure versus year of exposure is given in Table 9. The per capita dose (population exposure divided by total population) is also shown. The corresponding estimates for NTS fallout from Beck (1999) are also shown for comparison.

From Table 9, one sees that the total and per capita population dose from external radiation through 2000 was about 50% higher than that from NTS fallout. The per capita dose to an average-exposed individual was 0.73 mSv. The UNSCEAR, 1993 estimate a population-weighted dose from “global” fallout in the latitude band 40-50 degrees to be about 1 mSv. Considering the variations in fallout with latitude discussed earlier in this report, the present doses estimate and the UNSCEAR estimate agree well. The highest annual per capita doses occurred in 1962 and 1963 and are comparable to the annual per capita doses from NTS fallout in 1952, 1953, 1955 and 1957. In fact the total population dose from “global” fallout through 1972 was comparable to that from the NTS for the same period.

Table 9: Population dose and per capita dose to typically-exposed individuals versus year of exposure

Year	"Global" Fallout		NTS Fallout *	
	Pop. dose (10^3 person-Sv)	Per cap. dose (mSv)	Pop. dose (10^3 person-Sv)	Per cap. dose (mSv)
1951			6.5	0.039
1952			15	0.093
1953	7.7	0.007	19	0.12
1954*	2.8	0.017	0.2	0.001
1955	1.0	0.006	12	0.072
1956*	4.1	0.025	0.1	0.001
1957	4.9	0.030	20	0.12
1958*	6.8	0.042	0.8	0.005
1959	7.7	0.047		-
1960	1.6	0.010		-
1961	3.3	0.020		
1962	14.5	0.089	4.7	0.029
1963	12.6	0.077		
1964	5.9	0.036		
1965	3.7	0.023		
1966	2.8	0.019		
1967	2.4	0.015		
1968	2.3	0.014		
1969	2.1	0.013		
1970	2.0	0.012		
1971	1.8	0.011		
1972	1.8	0.011		
1973-2000	34.4	0.211	0.45 (1963-2000)	
Total	119	0.73	80	0.49

*From Beck (1999). Based on 1960 population of 1.63 x 10^8

A large number of fission products are produced in a nuclear explosion. However, only a relatively few account for most of the external exposure. Table 10 shows the largest contributors to total integrated exposure (% of total integrated exposure from nuclide and decay products). The global fallout percentages vary only slightly with location but vary significantly from year to year as shown in Figure 14. Figure 15 shows the per capita dose that resulted from each radionuclide as a function of time. The short-lived radionuclides have been grouped. As can be seen, during periods of testing the shorter-lived isotopes contribute relatively more to the dose while for years with no testing the longer-lived radionuclides are dominant. In contrast to the doses from NTS fallout, very short-lived radionuclides such as Te-I-132 and I-131 were insignificant contributors to exposure rates while Zr-Nb-95 accounted for a large portion of the exposure. For NTS fallout, Zr-Nb-95 was significant only at large distances from the NTS (Beck, 1999). Most of the cumulative dose from "global" fallout was due to Zr-Nb-95 and the longer-lived nuclides. Cs-137 and Zr-Nb-95 accounted for about 70% of the cumulative population exposure (see Table 9). In contrast, Cs-137 contributed only a small amount of (about 2%) of the integral dose from NTS fallout (Beck, 1999).

Table 10: Percentage of total integral exposure contributed by various fission products

Nuclide	Global Fallout (1953-2000) (%)	NTS* (%)
Te-I-132	<1	20-30
Ba-La-140	7	20-50
I-133	<<1	<1-10
Np-239	<<1	3-6
Zr-Nb-95	26	5-20
Zr-Nb-97, 97m	<<1	<1-6
I-135	<<1	<1-5
Ru-103	3	3-10
I-131	<1	3-4
Cs-137	45	1-3
Ru-106	6	<<1
Sb-125	4	<<1
Ce-Pr-144	2	<<1
Mn-54	6	0
Ce-141	<1	<1

*Depends on distance from NTS (see Beck, 1999)

Since, as discussed earlier, the estimates in this report are based on a relatively crude model(s) and there are large uncertainties, particularly, in the ratios of deposition for the short-lived radionuclides. The average monthly exposure rates calculated for various counties across the U.S. agreed quite well with actual measurements of fallout exposure rates made at sites in those counties using in situ gamma ray spectrometry, at least during 1962 and 1963 when the "global" fallout exposure rates were the highest. These comparisons are shown in Table 11. Since again the model results are an average for the entire county and the entire month of sampling while the measurements are instantaneous point measurements at a single location, the agreement is quite satisfying and lends confidence that the estimates for other periods of high fallout are also reasonably valid. Even though most of the exposure rate is due to Zr-95-Nb-95 and Cs-137, one can assume that the contributions to dose from other nuclides have not been drastically under- or over-estimated.

Table 11: Comparison of Measured Fallout Exposure Rates with Model Estimates

Location	Date	Measurement (: R/h)*	Model estimate (: R/h)*
Butte, MT	9/27/62	2.3	1.2
Missoula, MT	9/27/62	1.6	1.6
Ellensburg, WA	9/29/62	0.5	1.4
Seattle, WA	9/29/62	2.2	1.8
Clallam City, WA	10/1-2/62	2.0 (avg. of 5 sites)	1.8
Corvalis, OR	10/3/62	1.0	2.3
Crater Lk, OR	10/4/62	2.9	1.9
Richmond, CA	10/5/62	0.7	0.5
	10/12/63	1.4	1.2
Felton, CA	10/6/62	1.1	0.9
Santa Cruz, CA	10/6/62	1.0	0.9
Sunnyvale, CA	10/6/62	0.7	0.7
	10/12/63	0.4	1.4
Reno, NV	10/7/63	1.0	2.4
Winnemucca, NV	10/8/62	1.2	0.9
Elko, NV	10/8/62	1.8	2.2
	10/8/63	2.5	2.6
Wendover, UT	10/8/62	1.9	2.2
Salt Flats nr. Wend.	10/9/62	3.1	2.2
	10/16/63	1.7	1.8
Rawlins, WY	10/10/63	1.6	1.5
Laramie, WY	10/10/62	4.1	2.5
	10/8/63	3.6	1.8
Ft. Collins, CO	10/10/62	2.1	2.6
Denver, CO	10/10/62	1.6 (avg. of 5 sites)	2.2
	10/19/63	1.0 (avg. of 6 sites)	1.8
Colo. Springs, CO	10/11/62	2.7 (avg. of 2 sites)	2.3
	10/20/63	1.6 (avg. of 4 sites)	2.2
La Junta, CO	10/11/62	2.0	1.7
Dodge City, KS	10/12/62	3.1	2.4
	10/21/63	2.2	1.8
Wichita, KS	10/12/62	3.6	3.5
Kansas City, MO	10/13/62	4.1	3.6
Hannibal, MO	10/13/62	4.1	4.5
Springfield, IL	10/14/63	3.8	2.3
Franklin Pk., IL	10/22/63	2.5	2.5
Argonne Lab	10/15/62	2.5	2.8
	10/3/63	3.1 (2 sites)	2.8
Somerset, PA	10/16/62	3.6	3.6
	10/1/63	6.8	2.3

Location Date Measurement (: R/h)* Model estimate (: R/h)*

Carlisle, PA	4/5/63	4.4	3.8
	10/1/63	1.9	1.8
Decatur, AL	4/7/63	6.0	6.0
Memphis, TN	4/8/63	5.0	5.3
Little Rock, AR	4/9/63	6.6	3.9
Houston, TX	4/10/63	5.6	1.8
Galveston, TX	4/10/63	0.5	1.2
Lake Chas., LA	4/14/63	5.2	3.1
Bay Minette, LA	4/13/63	4.6	3.2
Macon, GA	4/16/63	4.3	4.4
Aiken, SC	4/17/63	6.6	4.7
US25&SC19, SC	4/17/63	4.2 (5 sites)	4.7
Nr. Warrenton, NC	4/18/63	4.1	3.8
Madison, WI	9/22/62	2.6	3.0
Spring Valley, MN	9/22/62	2.6	3.8
	10/3/63	2.4	3.4
Sioux Falls, SD	9/23/62	5.1 (2 sites0	4.0
	10/5/63	3.6	2.6
Chamberlain, SD	9/23/62	4.6	4.2
	10/6/63	3.6	2.9
Murdo, SD	9/24/62	3.6	5.0
	10/6/63	3.7	3.0
Rapid City, SD	9/24/62	3.8 (2 sites)	5.3
	10/17/63	2.8	3.8
Spearfish, SD	9/24/62	3.7	6.6
Sundance, WY	9/25/62	2.3	5.2
	10/7/63	2.7	3.1
Moorecroft, WY	9/25/62	2.3	5.2
	10/7/63	2.7	3.1
Pelham, NY	8/63	3-5 (multiple measurements)	3.9

*Measurement results from Beck et al, (1963, 1966).
The model results are the average for the county and for the month of sampling. The measurement results are for a specific date and place(s). Measurement error was on the order of 0.2-0.4 :R/hr. Thus the lack of agreement for any individual measurement-model pair could just reflect changes in deposition density during the month, the site precipitation not being representative of the county average, or the site itself not being representative of the general area.

The doses discussed above are from gamma irradiation. As discussed in Beck (1999), the ICRU (1997) estimated the beta skin dose rate from a plane source of fission products to be about 8-16 times the total effective dose. In Beck (1999), the ratio of dose rates for a 0.1-cm relaxation length for early arrival times was estimated to be about 3-5. The age (arrival time) of “global” fallout compared to NTS fallout was very long and most of the dose was delivered over a long period of time during which the longer-lived radionuclides penetrated further into the soil. It can thus be assumed that the beta skin dose from “global” fallout was even less significant than that estimated for NTS fallout. This is particularly true since most of the global fallout was deposited during rain and the assumption of a 0.1-cm relaxation length for the first 30 days is thus probably conservative. Only a relatively few longer-lived nuclides emitting higher energy beta rays such as Y-90, the daughter of Sr-90, contribute significantly to the dose.

The actual impact of beta exposure is of course even less than estimated by the ICRU. The average individual would be exposed to beta radiation only for the 20% of time spent outdoors, resulting in an actual beta skin dose to gamma whole body dose ratio of about 0.2-0.4. Furthermore, since the radio-sensitivity of the skin is generally accepted to be much lower than for other organs, even the beta dose to the most exposed individuals who spend up to 70% of their time outdoors can be considered insignificant compared to their whole-body gamma exposure.

One source of beta radiation exposure that might be significant for “global” fallout in some cases is contamination to the skin from children playing in contaminated soil, both from soil adhering to the skin as well as due to a closer proximity to the source. The dose to a child playing on the ground would probably be about a factor of two higher than that to a standing adult due to the closer proximity to the source plane. However, this would still probably not constitute a significant exposure. A more significant exposure route would likely be direct ingestion of soil (NCRP, 1999).

Recommendations for Future Work and for Improving the Preliminary Estimates of This Feasibility Study

As is evident from the discussions above, the models used to estimate exposure rates and deposition densities are quite crude and monthly and individual county estimates may have large uncertainties particularly estimates for short-lived radionuclides such as I-131. Comparisons with soil sample analyses and in situ gamma spectrometric estimates of exposure rates suggest that the overall geographical distribution of external dose to the U.S. population, and the per capita or population dose, are probably quite reasonable. The per capita dose is also consistent with previous estimates made for residents of the mid latitudes of the Northern Hemisphere by the UNSCEAR (1993). Because most of the external dose was delivered after 1956, at least some data was available for the more important contributors to dose upon which to base the estimates.

However, the analysis carried out for this preliminary study suggests that considerable improvement could be made. This might allow more accurate estimates of deposition densities and doses for particular months to be made, particularly for years prior to 1958, as well as more accurate predictions of the geographical variation for any particular time. For example, by weighting the various precipitation measurements in a given county by the population one might be able to calculate a population-weighted Sr-90 deposition density that in turn would allow a better estimate of the dose to a typical resident of that county than the present estimate. An analysis of the gummed-film data for the years prior to 1958, in a manner similar to that carried out for NTS fallout, might also allow better estimates of deposition as a function of location for years prior to 1958. A further assessment of the variations in precipitation within counties might identify some populations that were exposed to much higher doses than presently estimated ("hotspots"). Areas with large amounts of thunderstorm activity during months of testing could be identified since this was believed to be one mechanism that resulted in high fallout of short-lived radionuclides such as I-131.

By assigning reasonable estimates of uncertainty and variability to critical parameters for each of the steps used in this preliminary study, one could estimate a confidence limit for the estimated monthly doses for each county in a manner similar to that provided by NCI (1997). Without such a systematic analysis it is difficult to assess the validity of any particular county's monthly dose estimate.

In addition to estimating the uncertainties in the various deposition and exposure estimates, the estimates themselves might be improved if additional data can be located, particularly data on the ratios of the deposition of the various nuclides as a function of location in the U.S. Additional data could also be used to develop a more sophisticated, higher resolution, model of the distribution of Sr-90 specific activity with latitude and longitude. This might be accomplished using a technique such as kriging to provide estimates of specific activity that vary smoothly across the country. A more sophisticated model would also attempt to account for the impact of "dry" deposition at arid locations. A thorough review and assessment of the vast amount of other scattered sources of data might also allow the estimates of isotopic ratios for particular months to be improved. It may also allow improvements to the atmospheric model, which would then allow one to more confidently utilize the model for periods with no data. Because the current effort was limited in scope and resources, only a small subset of the vast literature could be evaluated and utilized.

I-131 may have been a significant contributor to ingestion dose. The present preliminary results suggest I-131 deposition was comparable to that from the NTS in many areas of the country. However, due to the lack of actual data, a much more comprehensive effort will be necessary to provide estimates of I-131 deposition density and associated uncertainty comparable to those estimated for NTS fallout. This effort would include development of a model for the likely geographical variation in the deposition of short-lived radionuclides across the U.S.

The estimates in this report do not include the impact from tests conducted after 1963 by China and France. The atmospheric tests by China in particular, although the total fission yield was only about 20 MT, were conducted at mid latitudes in the Northern Hemisphere and did result in additional exposures to the continental U.S. population during the 1970s and early 1980s.

A number of minor contributors to external exposure were not considered in this preliminary assessment. Small quantities of Co-60, an activation product, were measured in fallout at some sites during 1962-63, as were small quantities of Sb-124 and Cs-134. Small quantities of radioactive tracers were also released during tests in 1958 (W-185) and 1962 (Rh-102). None of these nuclides are believed to have contributed significantly to population doses. Also not considered in this study was the deposition of a few radionuclides that may contribute in a minor way to ingestion exposure such as Fe-55, Pu-239+240, Pu-241, Am-241 and Tc-99.

An additional possibility for further study would be to also estimate the doses to the populations of Alaska and Hawaii. These states were not included in the present analysis since they represent special unique situations: Hawaii due to its proximity to the Pacific weapons testing area and Alaska due to its proximity to Soviet testing sites.

The scope of work for this project requested an estimate of the time (resources) that would be required for each of the suggested improvements discussed above. It is difficult to make such an estimate at the present time. It should be noted that the NCI project to estimate the exposure of the U.S. population from I-131 required a large number of person-years of effort. An effort at least as comprehensive would be required to provide estimates of equal quality for “global” fallout along with credible estimates of uncertainty. A thorough search for additional data might require the assessment of data provided in a large subset of the thousands of publications and reports that have been published on aspects of “global” fallout. Development of more sophisticated models and assignment of realistic uncertainty estimates would be dependent on such on assessment of all retrievable data. A critical question that must be answered first is how fine a spatial and temporal resolution is desired. The present study indicates that a temporal resolution on the order of a month is reasonable and feasible but that for some counties, the spatial variation across the county may be very large and difficult to quantity.

Summary and Conclusions

Fallout from atmospheric tests resulted in a per capita external radiation exposure of about 0.7 mSv to the population of the U.S. through the year 2000, about 1½ times that incurred from NTS fallout. However, residents in the states immediately downwind from the NTS received much higher than average exposures from NTS fallout while the exposures in the western and northwestern U.S. and some areas of the Midwest and SE were much less than the average. The doses from "global" fallout were more uniformly distributed across the U.S. with differences from place to place reflecting differences in average precipitation.

Annual per capita doses from "global" fallout were comparable to annual doses from NTS fallout during the years of testing. However, most of the exposure from the NTS tests occurred with the first 3 weeks of each test and was due to relatively short-lived radionuclides. In contrast, the exposure from "global" fallout occurred over a much greater span of time and was primarily from Zr-Nb-95 and a few long-lived radionuclides. Thus the dose rate was more uniform with time. Almost the entire whole-body effective dose to the population was from gamma rays emitted by fission products deposited on the ground. The actual dose received by any individual depended on the fraction of time he/she spent outdoors and the degree of shielding provided by his/her dwelling. The most exposed individuals at any particular location would have been outdoor workers or others who spent most of their day outdoors. The locations with the highest dose rates were those areas with high average annual precipitation. Beta radiation from fission products in the surface soil did result in additional dose to the skin when outdoors. However, this contribution was not large enough to be considered an important component of total fallout radiation and for "global" fallout was probably even less significant than it was for NTS fallout exposure. The only significant possible impact might have been for children who played in the soil for significant intervals of time.

The deposition of fission products contributed to internal radiation exposure via ingestion as well as external exposure. The deposition densities of several nuclides that could contribute significantly to ingestion doses were calculated for this study although the internal doses via ingestion will be treated in a separate report.

Comparisons with soil sample data and exposure rate measurements at a large number of sites in the U.S. during 1963-65 indicate that the model predictions reliably represent the overall pattern of total fallout and resultant population doses. Due to the sparseness of data prior to 1956, estimates of deposition and doses for 1953-56 are more uncertain than for years where fallout was monitored more extensively. However, the contribution to the total population dose from fallout in those years was relatively small.

This report has demonstrated that it is feasible to grossly estimate the external exposure of the population of the U.S. as a function of location and time. However, the monthly estimates for any particular county are probably quite uncertain and the exposure rate probably varied significantly from place to place within a county, particularly for counties with large variations in topography. If more precise estimates of exposure are required for particular times and places, a more exhaustive study will be required. Such a study would need to carry out an intensive investigation to locate and evaluate additional measurement data, particularly for the shorter-lived radionuclides. A more sophisticated model would need to be developed those accounts for variations in the specific activity of Sr-90 deposition with latitude and longitude and accounts for any variations in this quantity with time. Geographic variations in isotopic ratios need to be investigated in greater detail, especially for the shorter-lived radionuclides such as I-131 that likely contributed significantly to ingestion doses to children. Variations in precipitation across a given county will also need to be considered in much more detail in order to obtain a better estimate of dose rates to an individual living in any particular county. Finally, uncertainty estimates need to be incorporated into the various components of the dose assessment model used here in order to allow reasonable estimates to be made of the relative uncertainties in the estimates as a function of location and time.

The database annex to this report, in the form of Excel spreadsheet files, gives the calculated deposition densities of all the radionuclides considered for each test for each county of the U.S. The whole-body effective dose to a typically exposed adult for each month is also tabulated for each county. By accessing the data for their particular county of residence for any given year(s), and applying the appropriate correction factor to adjust the tabulated doses for the actual fraction of time spent outdoors, the interested reader can estimate his/her whole body dose for any particular time interval and location.

List of Figures

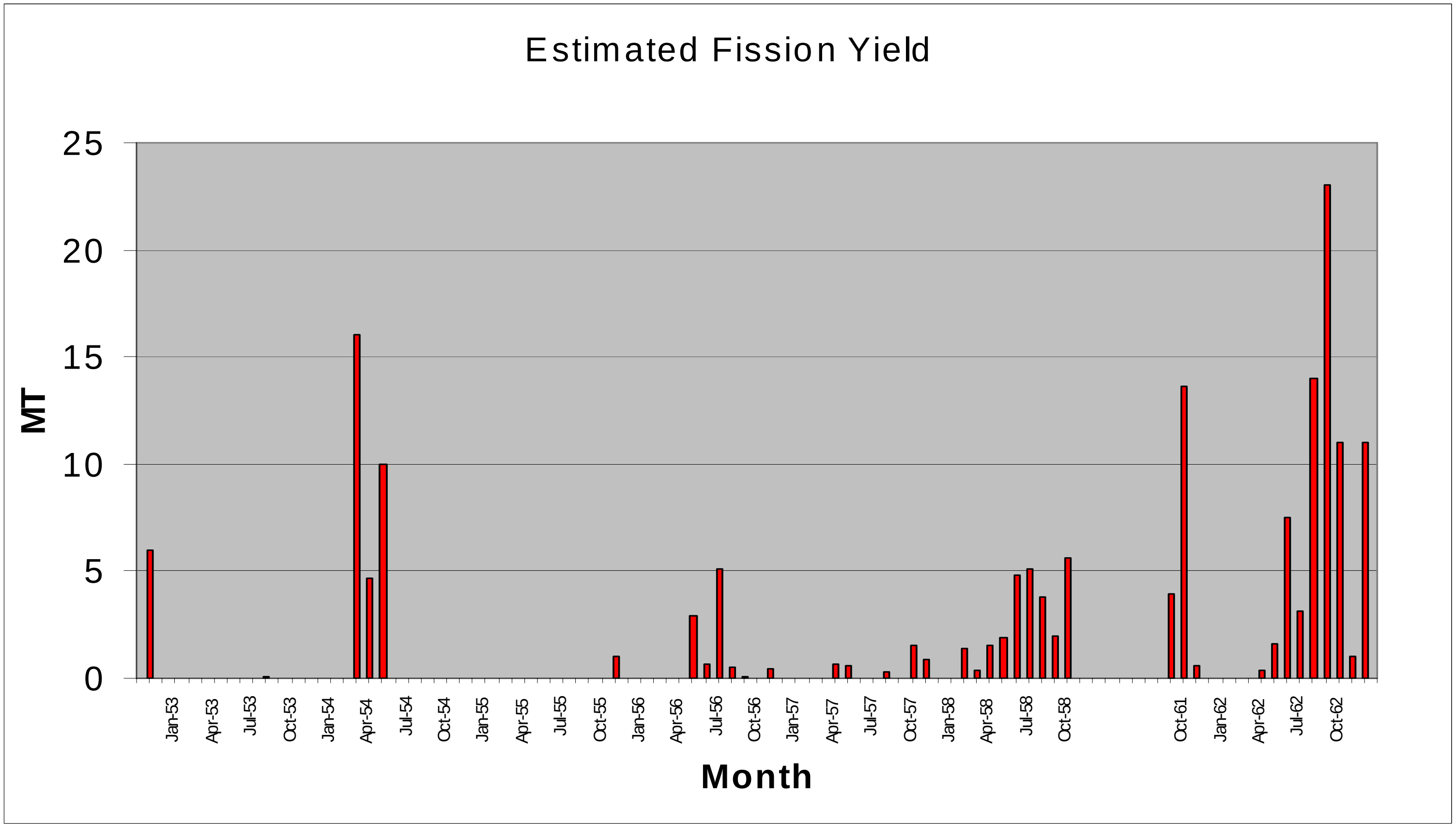


Figure 1: Estimated fission yield of tests conducted by the U.S., U.K. and U.S.S.R. for each month from 1952 through 1962.

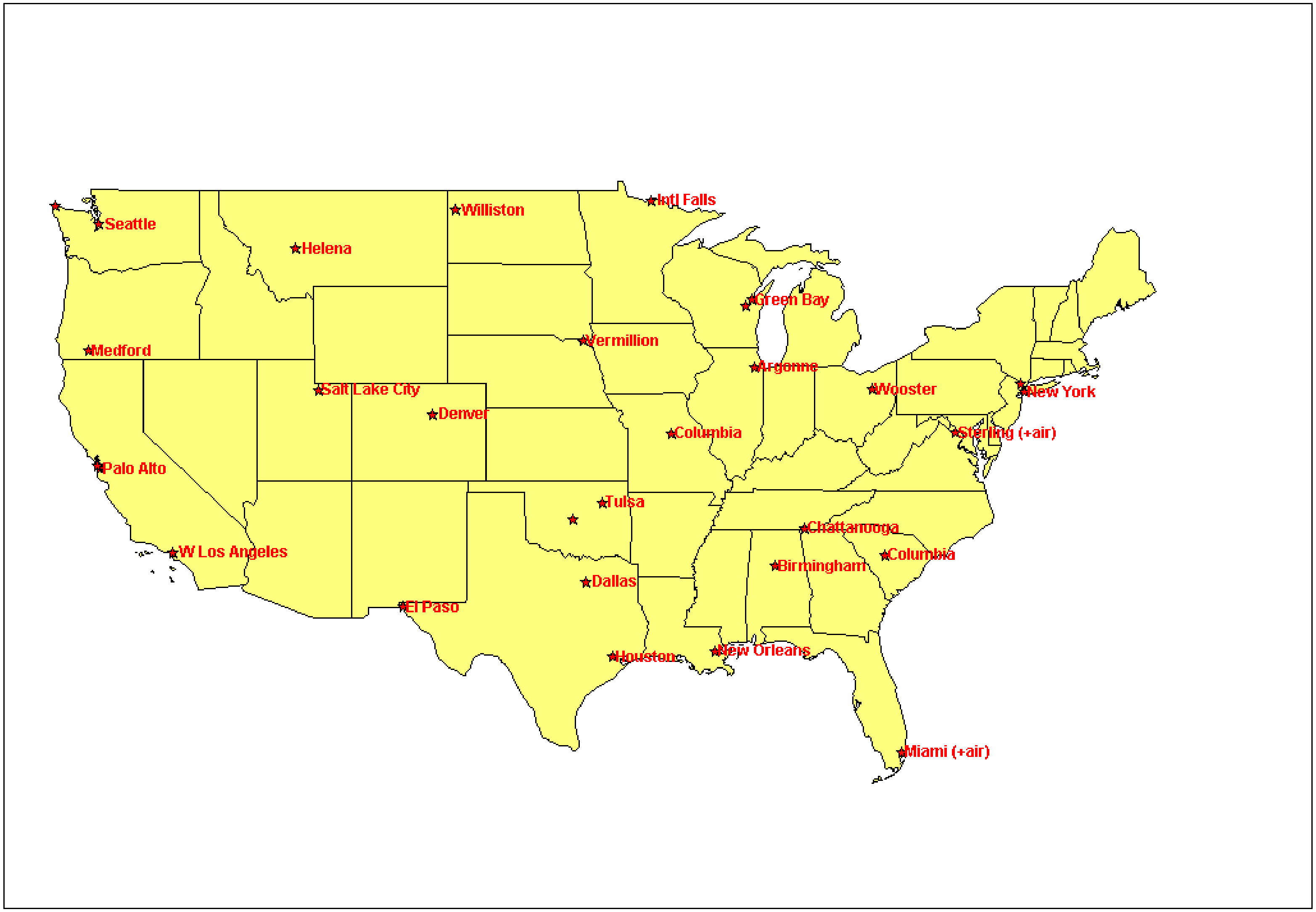
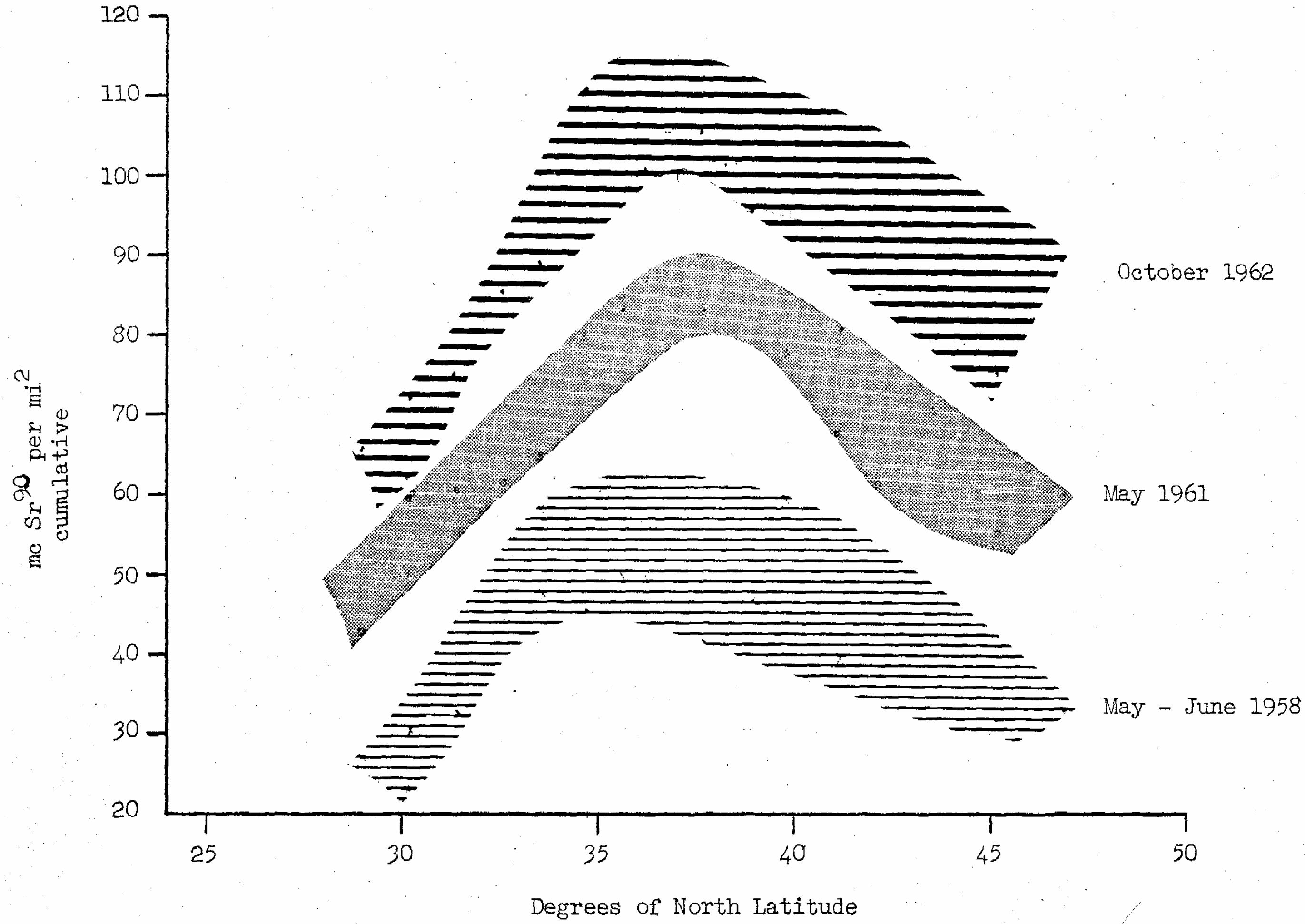


Figure 2: HASL and NRL Precipitation and Air Sampling Sites in 1962.

Figure 3 - Cumulative Deposition of Strontium-90 Along a Mid-United States Constant Precipitation Transect



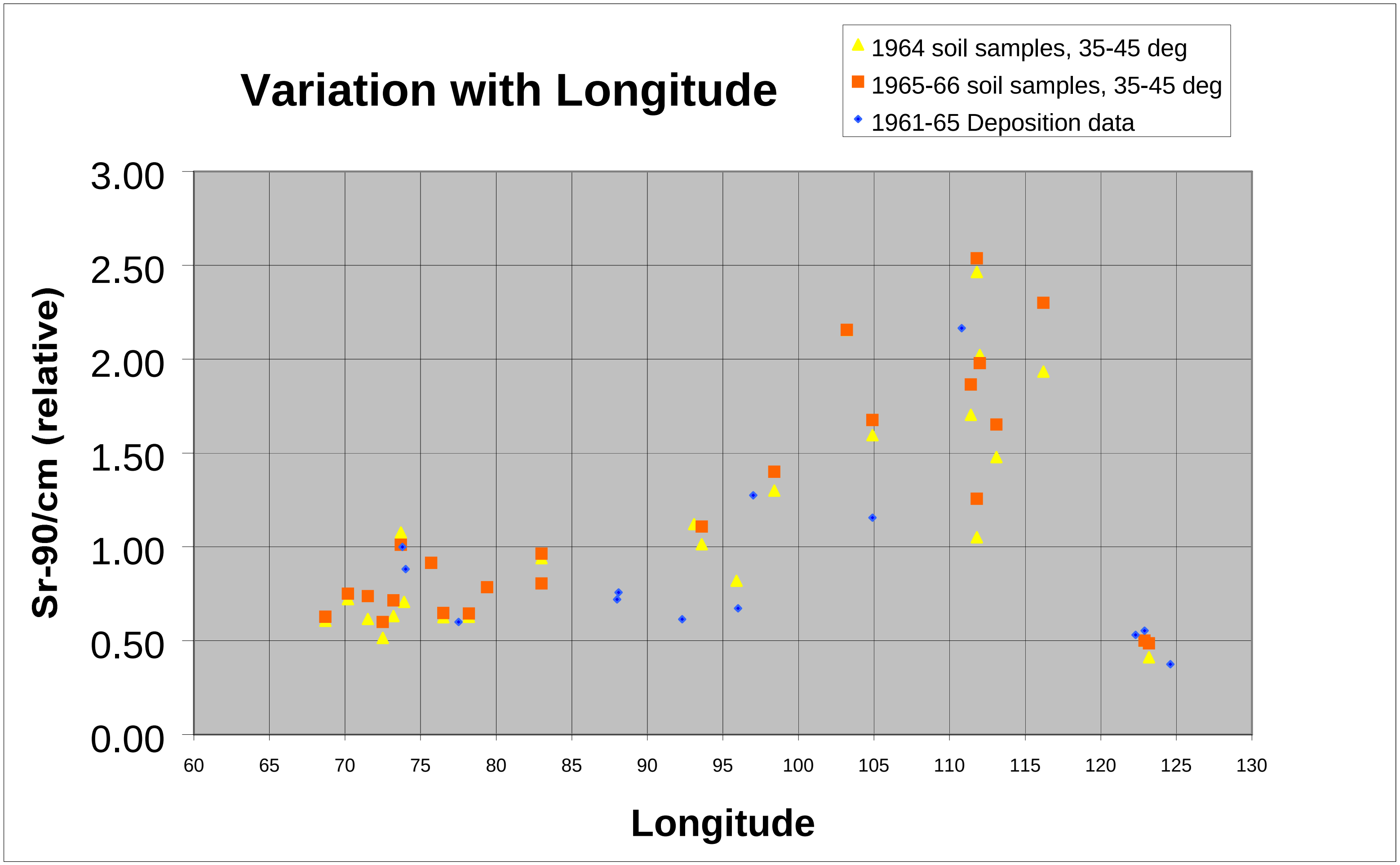


Figure 4: Variation of Sr-90 Deposition Density per cm of rain with longitude. The ordinate values for the deposition data have been normalized to those for the soil data since the soil data represent cumulate deposition at the time of sampling.

.

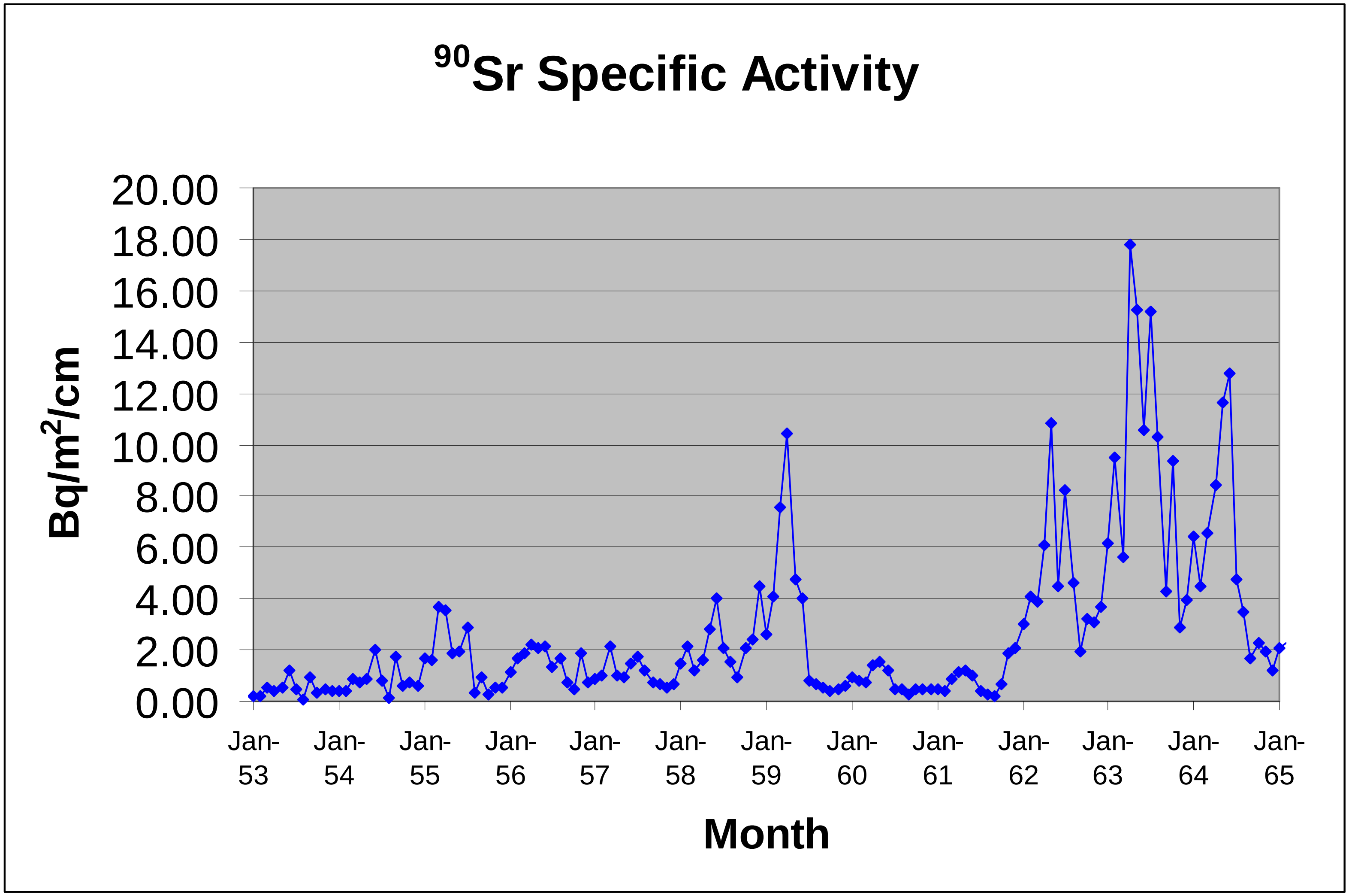


Figure 5: Specific activity of Sr-90 in precipitation (deposition density per cm of rain) for N.E. U.S. baseline sites for each month from 1953-1965.

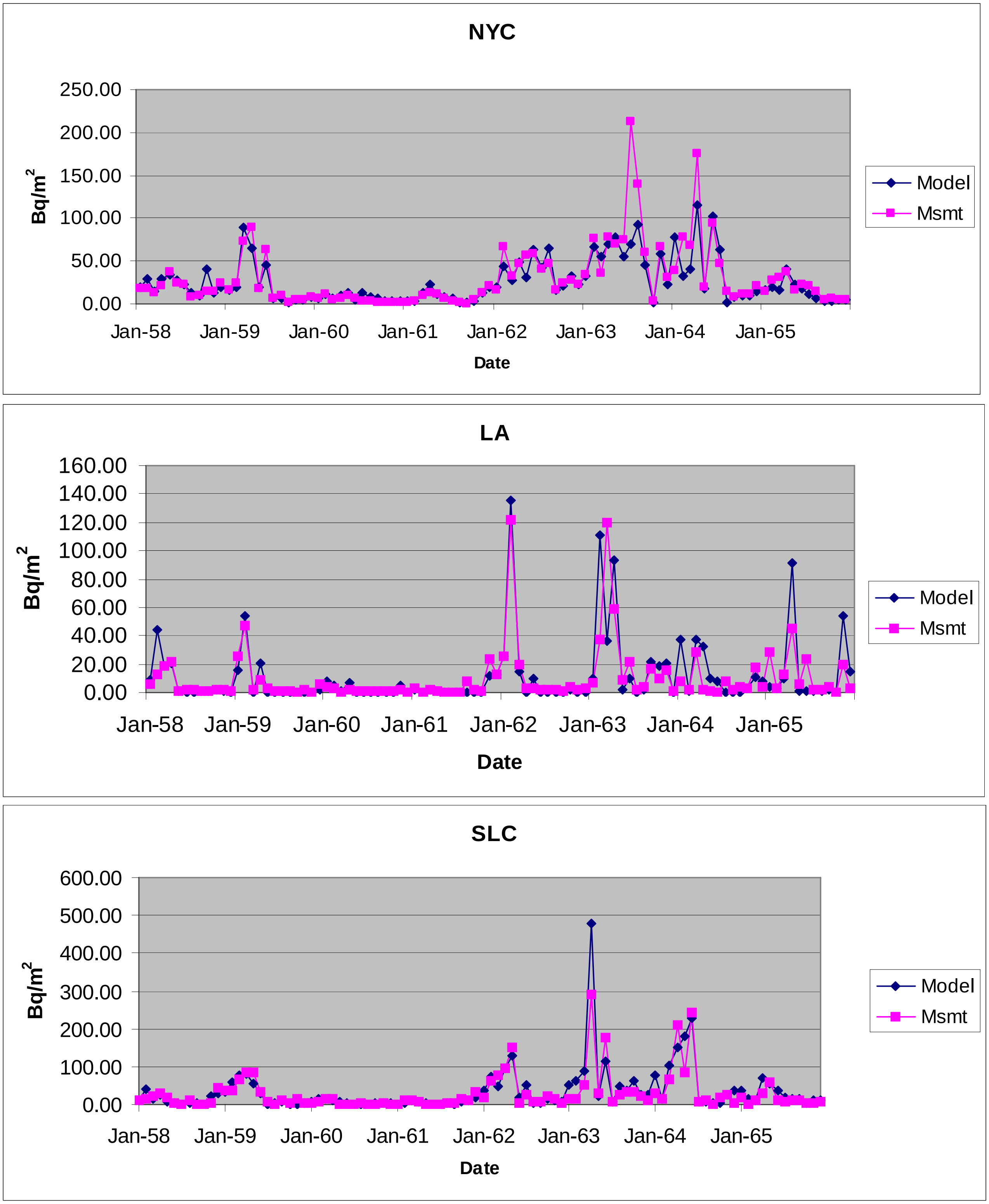
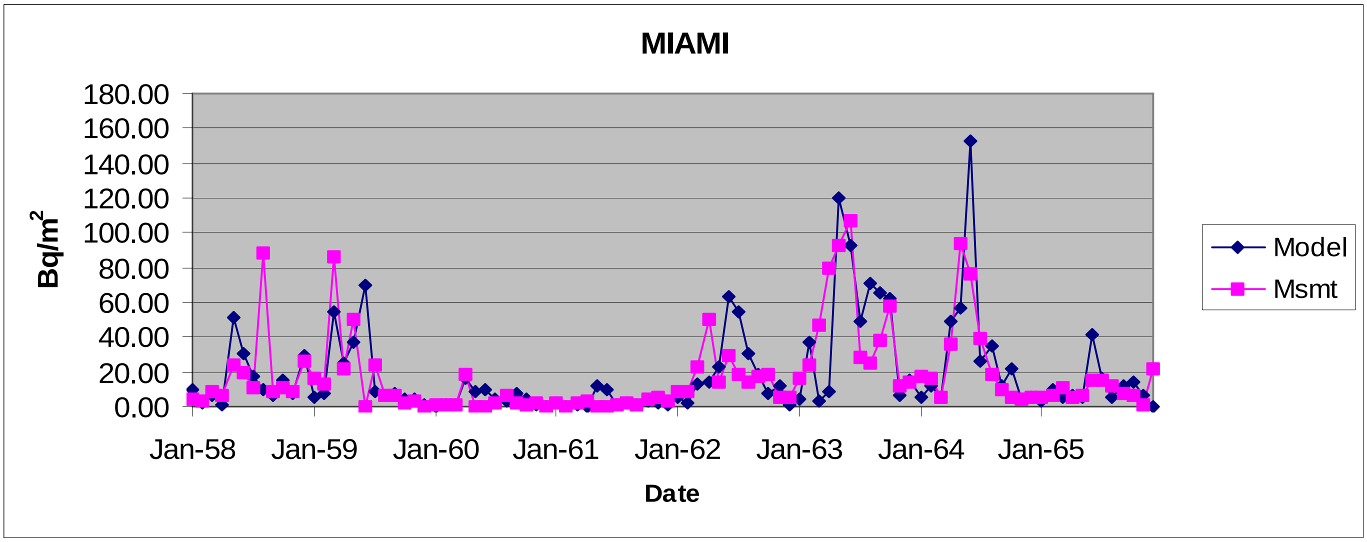
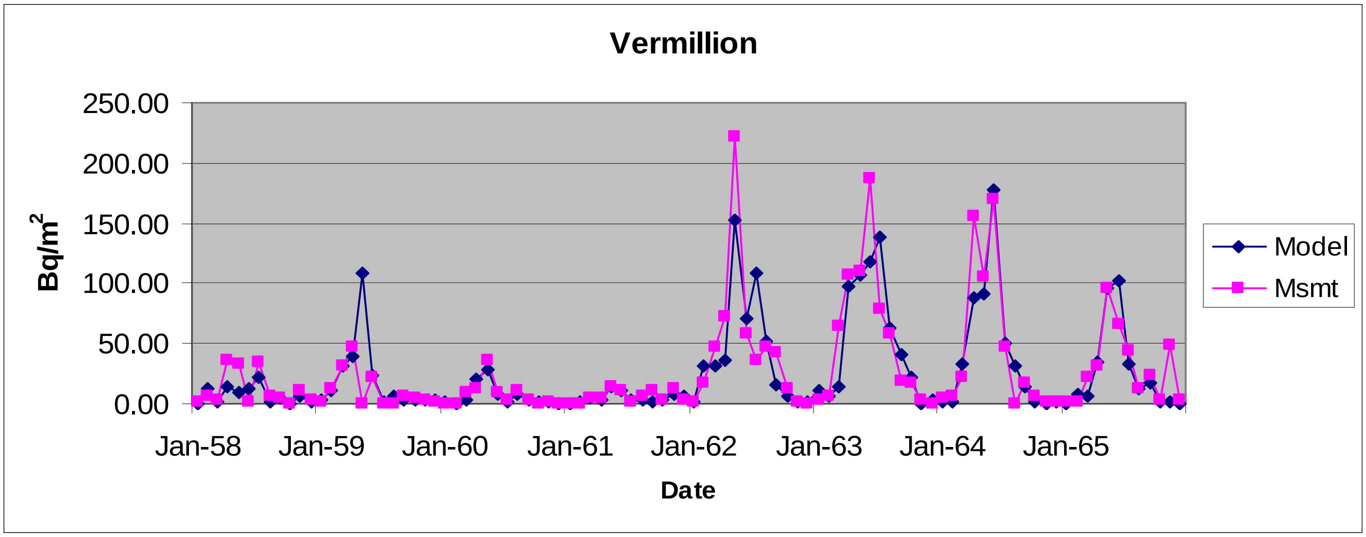
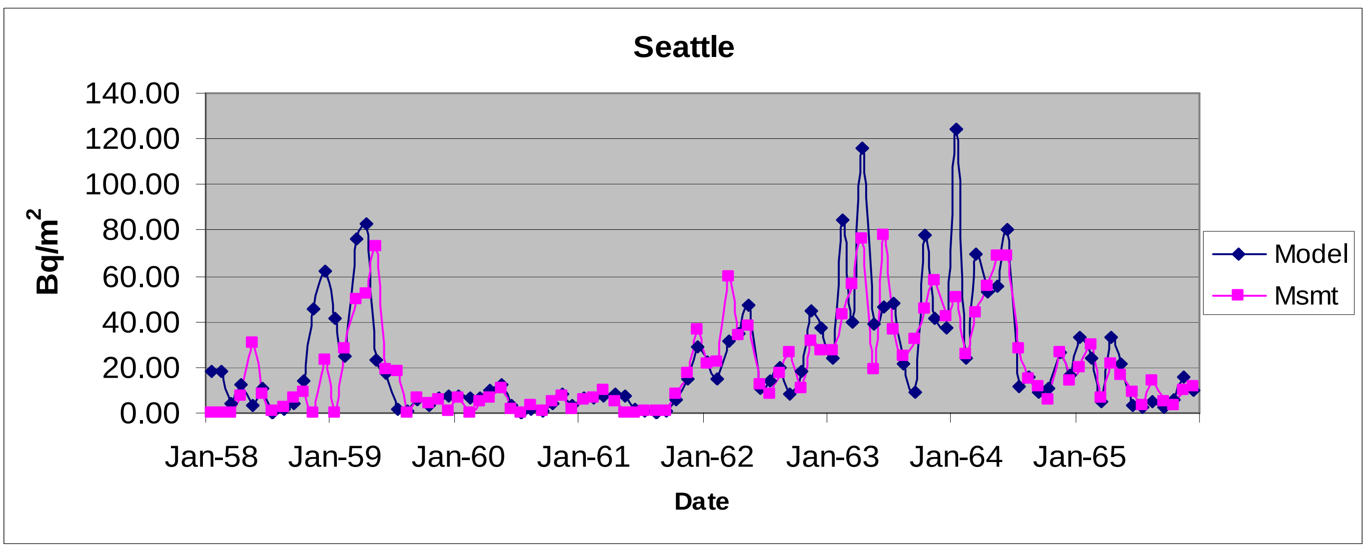


Figure 6a-6f. Comparisons of monthly model estimates of Sr-90 deposition density with measurements for selected cities. The model estimate is the average for the entire county in which the measurement site is located.


MIAMI
Bq/m2
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Jan-58
Jan-59
Jan-60
Jan-61
Jan-62
Jan-63
Jan-64
Jan-65
Date
Model
Msmt


Vermillion
Bq/m2
250.00
200.00
150.00
100.00
50.00
0.00
Jan-58
Jan-59
Jan-60
Jan-61
Jan-62
Jan-63
Jan-64
Jan-65
Date
Model
Msmt


Seattle
Bq/m2
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Jan-58
Jan-59
Jan-60
Jan-61
Jan-62
Jan-63
Jan-64
Jan-65
Date
Model
Msmt

.

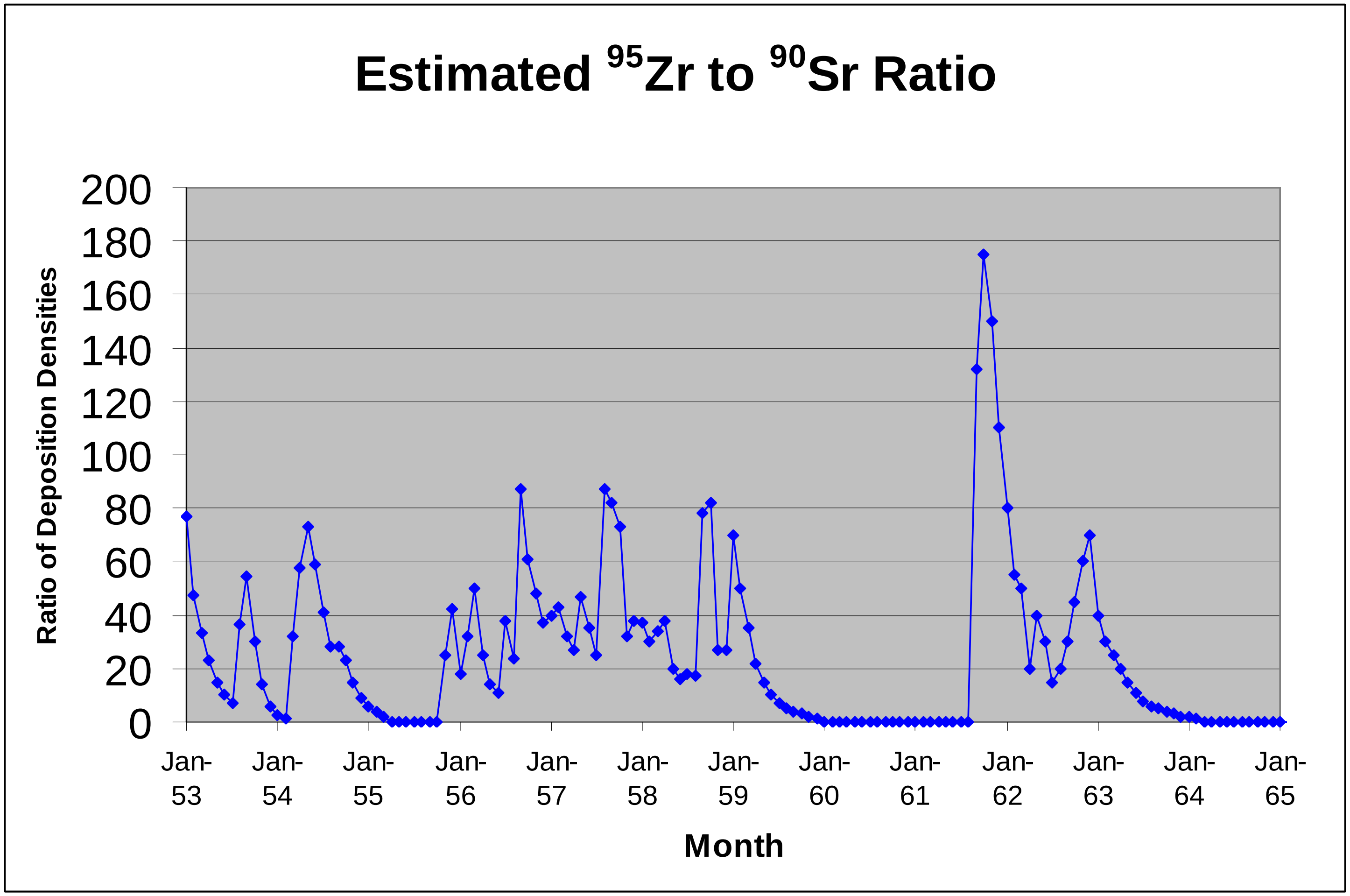


Figure 7: Estimated deposition density ratio of Zr-95 to Sr-90 for each month from 1953-1965.

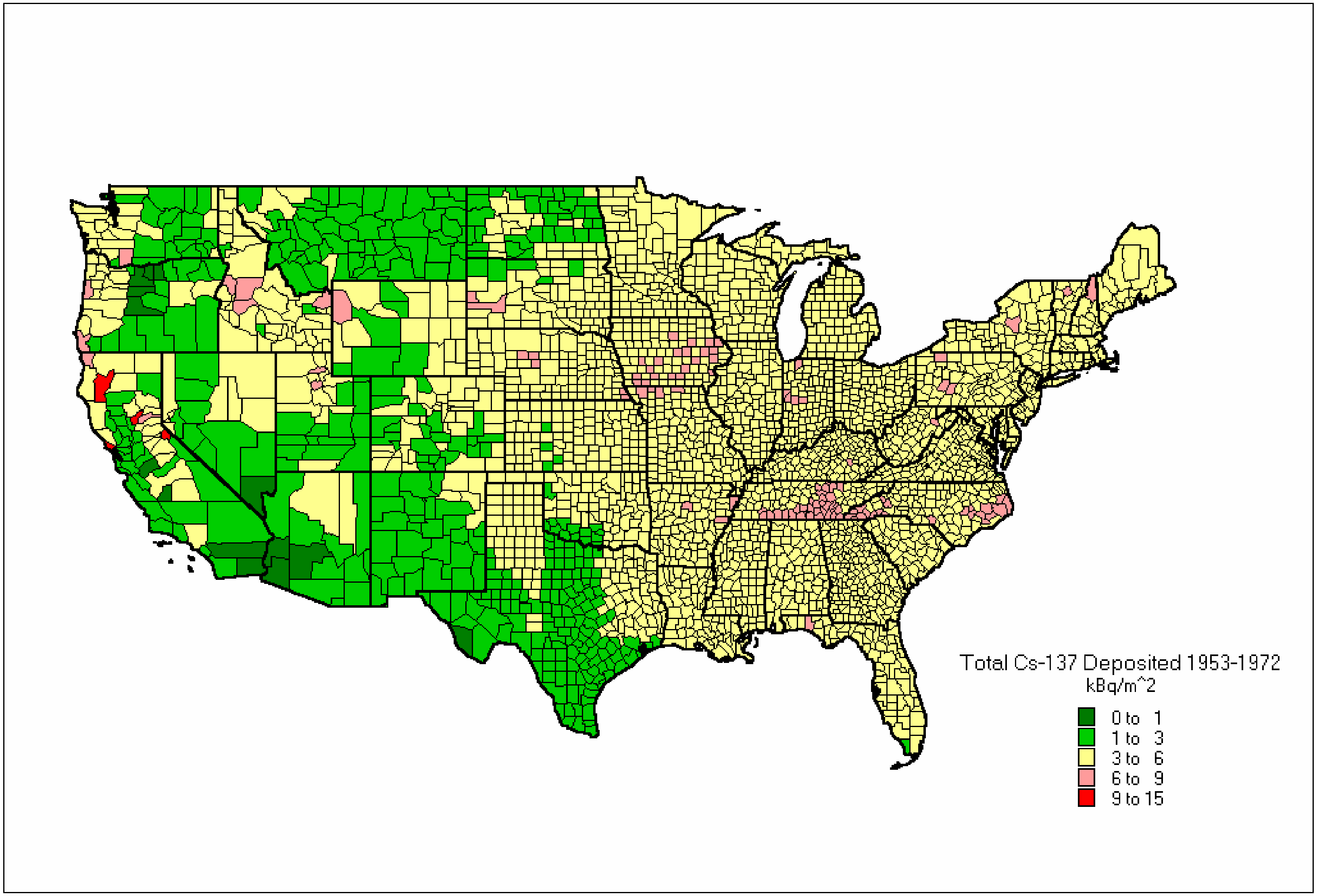


Figure 8: Total Cs-137 deposited from 1953-72 in each county.

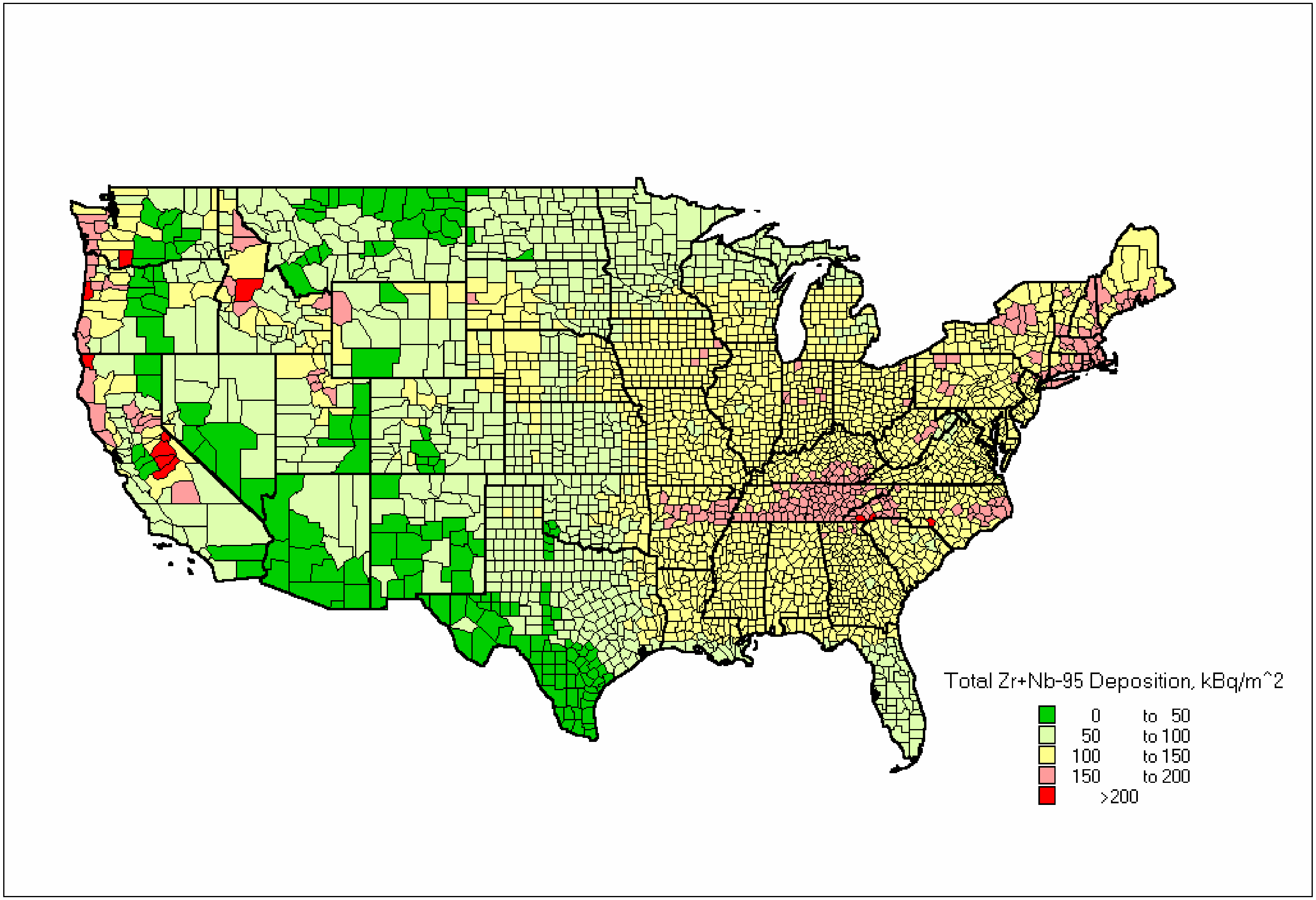


Figure 9: Total deposition of Zr-95+Nb-95 from 1953-1965 for each county.

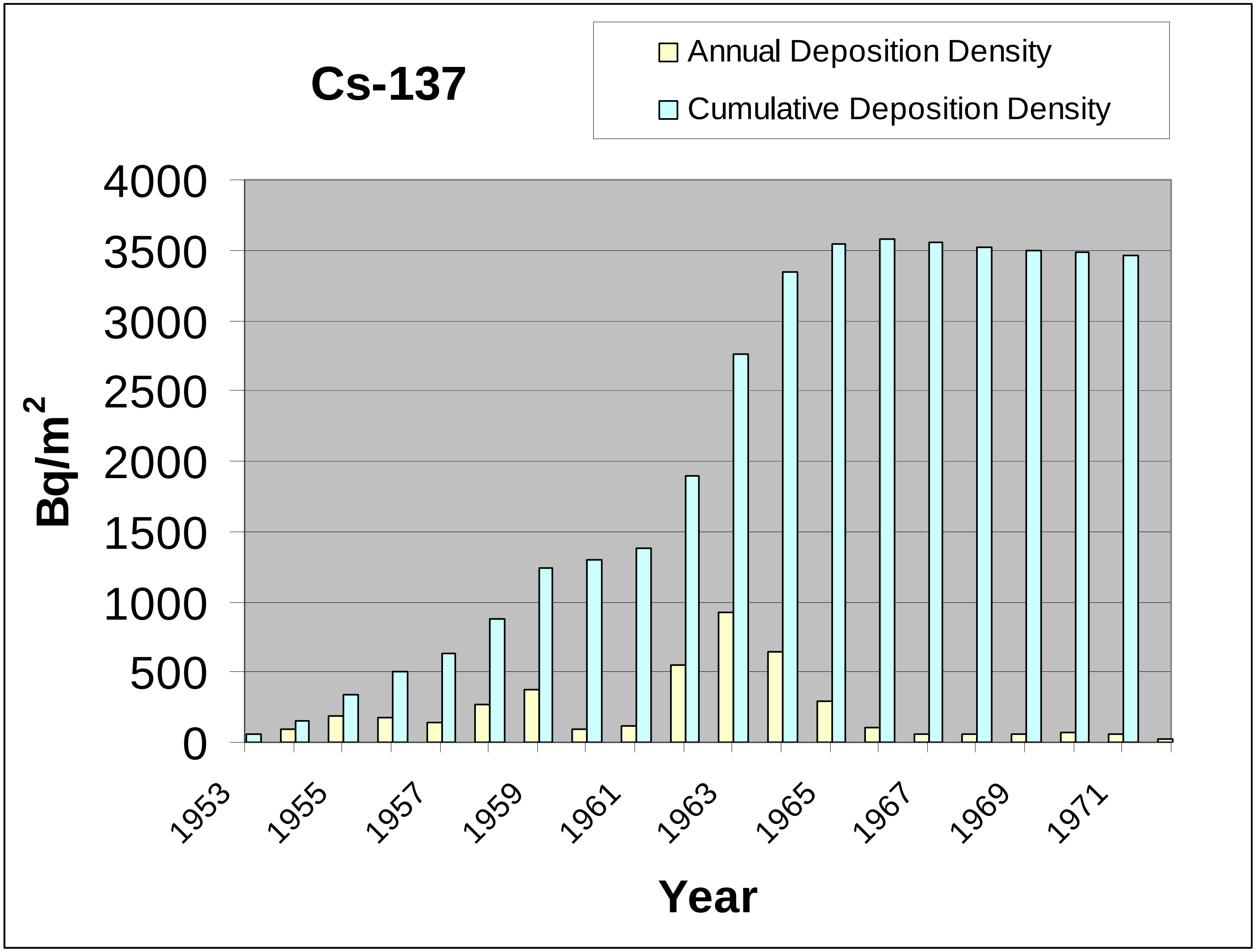


Figure 10: Annual population-weighted deposition density of Cs-137 and cumulative activity in soil at the end of each year.

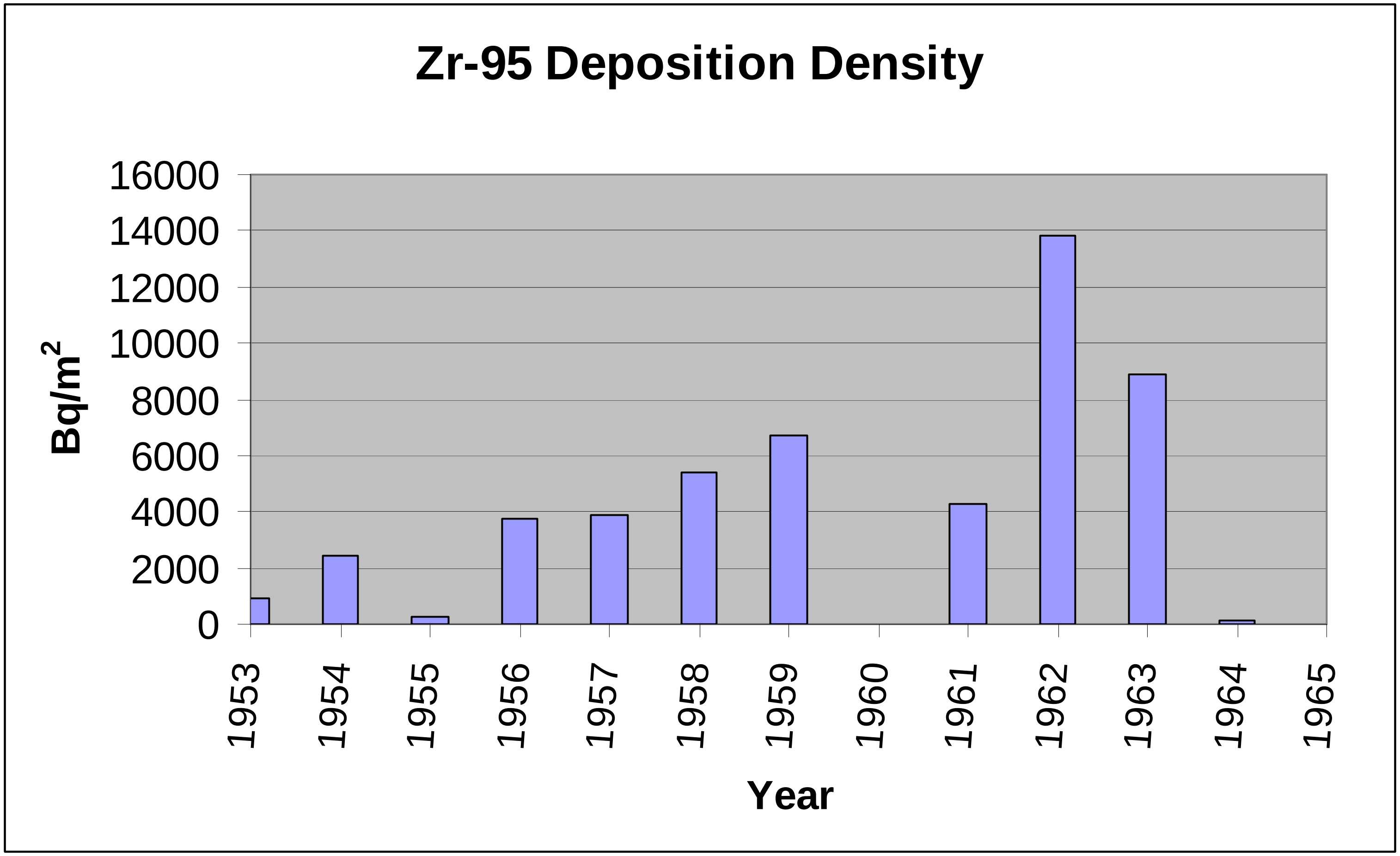


Figure 11: Annual population-weighted deposition density of Zr-95.

.

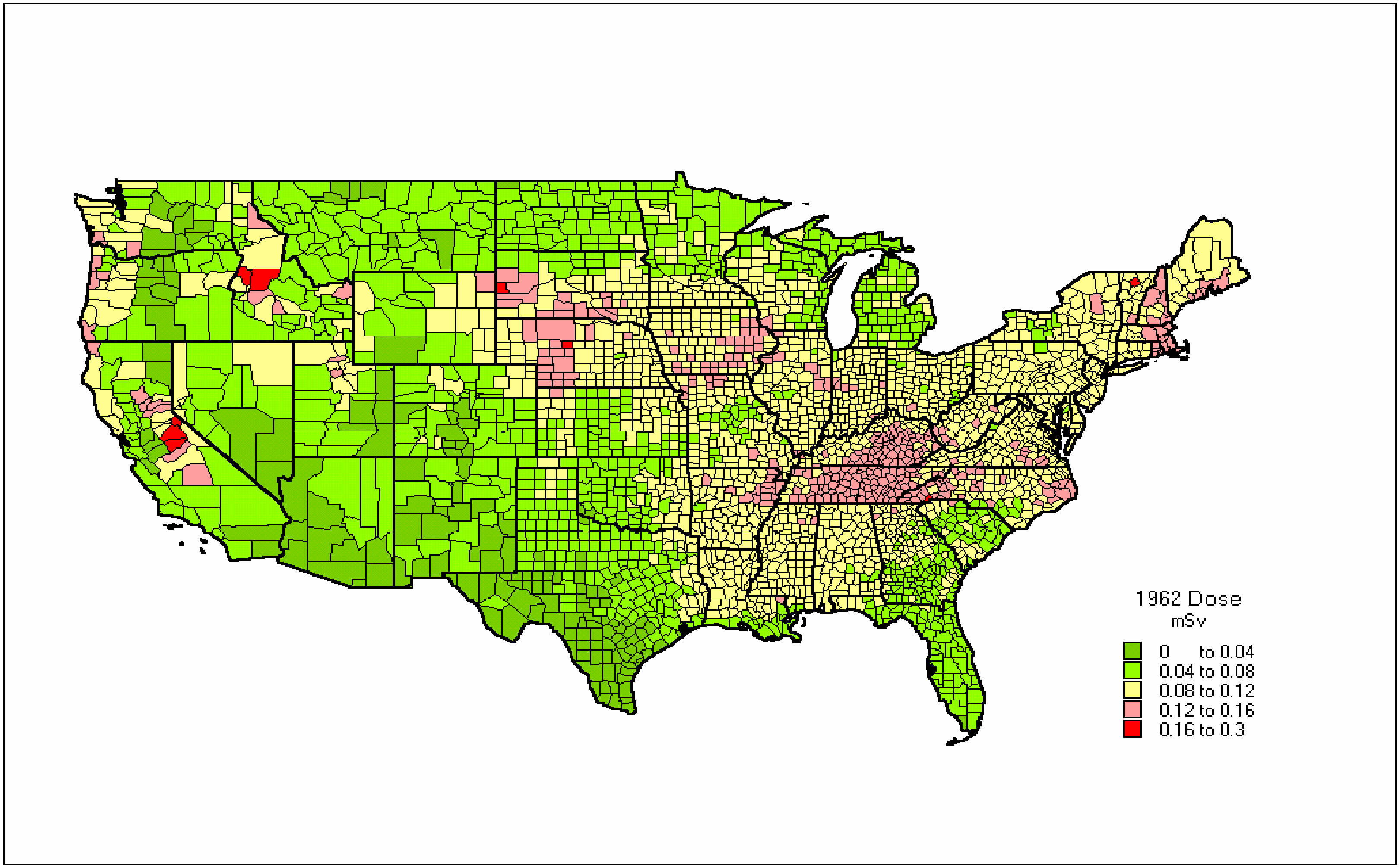


Figure 12: Dose received by typically exposed adults for each county during 1962.

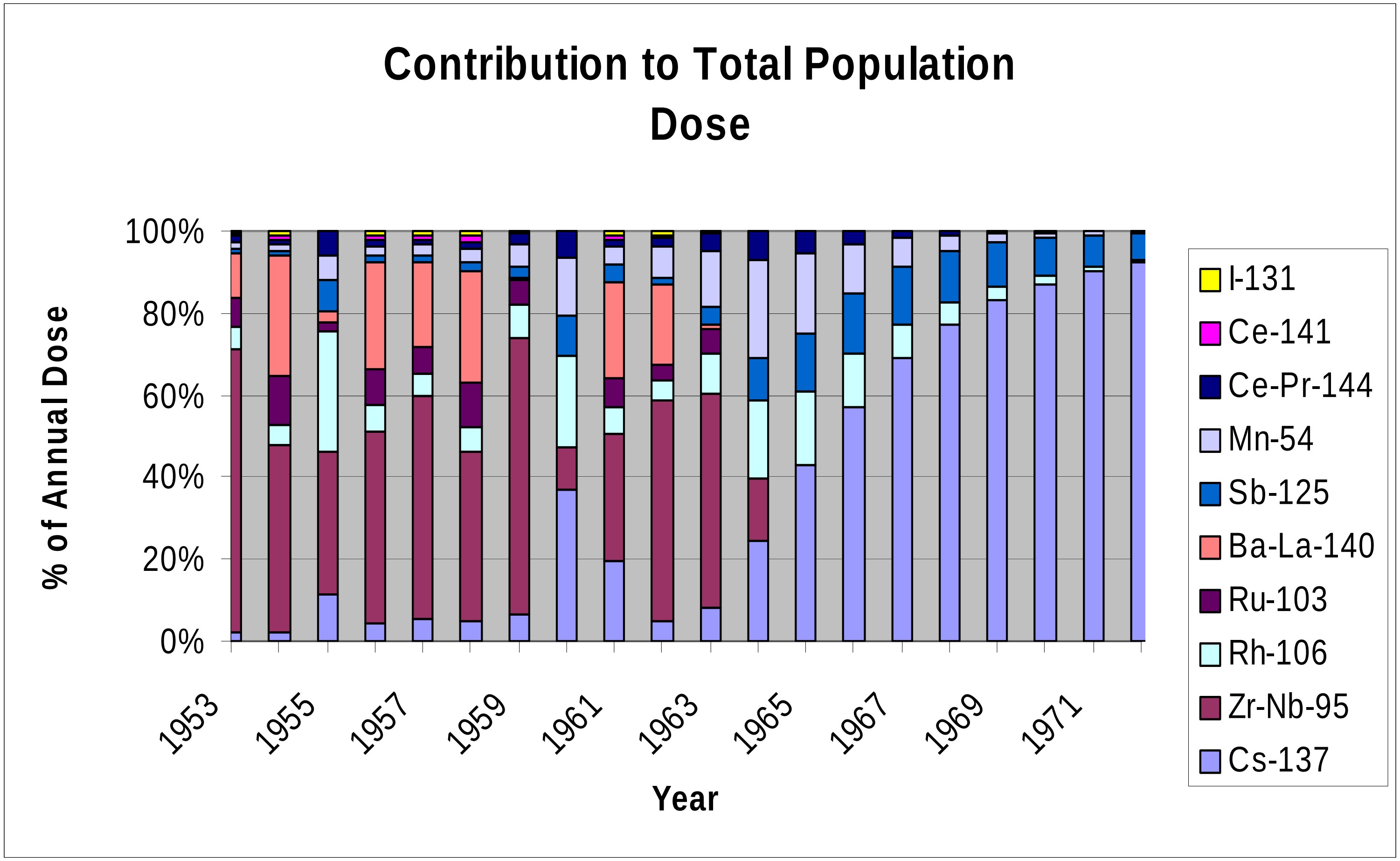


Figure 13: Fraction (%) of total annual population dose from each radionuclide; 1953-1972.

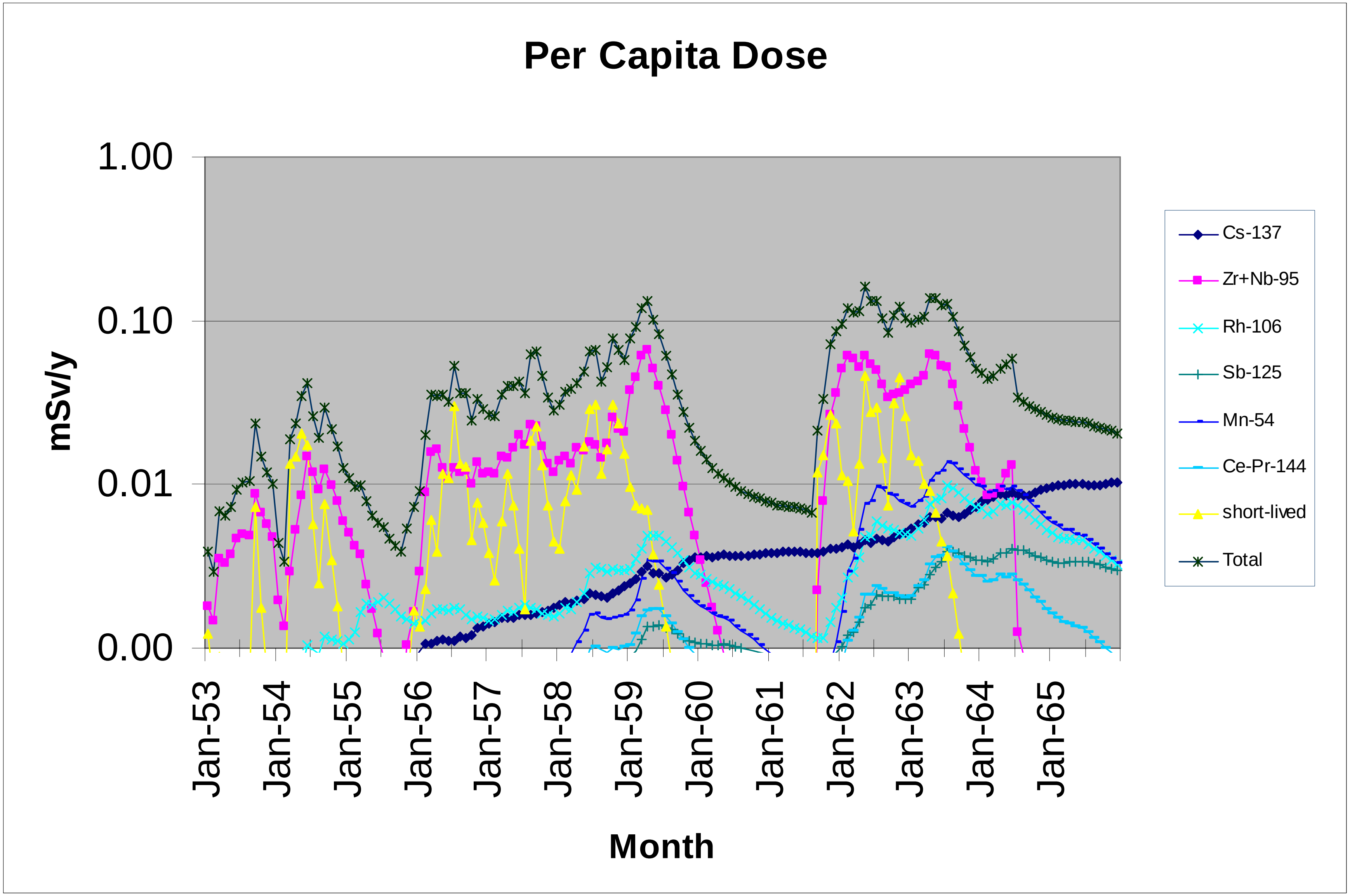


Figure 14: Monthly variations in Per Capita Dose from specific radionuclides. The short-lived radionuclides (I-131, Ba-La-140, Ru-103, and Ce-141) are grouped together.

References

Alexander, L.T., R.N. Jordan, R.F. Dever, E.P. Hardy, G.H. Hamada, L. Machta, and R.J.List; Sr-90 on the Earth's Surface, USAEC rept. TID-6567, Feb, 1961

Alexander, L., M. Meyer, J.S. Allen, and E.P.Hardy. "Cumulative Deposition of Strontium-90 Along a Mid-United States Constant Precipitation Transect", in USAEC rept. HASL-149, Oct. 1, 1964.

Beck, H.L., W.J. Condon and W,M. Lowder. Environmental Radiation Measurements in the Southeastern, Central and Western United States. USAEC report HASL-145, April, 1964.

Beck, H. L. , W.M. Lowder, B.G. Bennett, and W.J. Condon, Further Studies of External Environmental Radiation. USAEC report HASL-170, March, 1966.

Beck, H.L. Exposure rate conversion factors for radionuclides deposited on the ground. US Dept. of Energy report EML-378. NTIS, Springfield, VA, 1980.

Beck, H.L.; Krey, P.W. "Radiation exposure in Utah from Nevada nuclear tests". Science **220**:18-24; 1983.

Beck, H.L., I.K. Helfer, A. Bouville, and M. Dreicer. "Estimates of fallout in the western U.S. from Nevada weapons testing based on gummed-film monitoring data". Health Phys. **59**(5): 565-570; 1990.

Beck, Harold L. External Radiation Exposure to the Population of the Continental U.S. from Nevada Weapons Tests and Estimates of Deposition Density of Radionuclides That Could Significantly Contribute to Internal Radiation Exposure via Ingestion. Report to the National Cancer Institute, Nov. 1, 1999.

Bennett, B.G., Environmental Aspects of Americium. USDOE report EML-348, 1978.

Collins, W.R. and N.A. Hallden, "A Study of Fallout in Rainfall Collectors from March through July 1956", USAEC rept. NYO-4889 in USAEC rept. HASL-42, "Environmental Contamination from Weapons Tests", Oct. 1958.

Collins, W.R., G.W. Welford and R.S. Morse, "Fallout from 1957 and 1958 Nuclear Test Series", Science 134, #1484, 989-986, Oct. 6, 1961.

Eckerman, K. and Ryman, J.C. Dose Coefficients for external exposure to radionuclides distributed in air, water and soil, Federal Guidance report 12. USEPA, Washington; 1993.

Gustafson, P.F., S.S. Brar and S.E. Muniac, "Variation of fission products and natural radioactivity in surface air", in Radioactive Fallout from Nuclear Weapons Tests, A. Klement ed., USAEC Symposium Proc. Of Second Conference, Nov., 1964, pp. 497-506, USAEC TID, Nov. 1965.

Hardy, E.P. and L.T. Alexander, “Rainfall and Deposition of Sr-90 in Clallam County, WA”, Science 136, #3519, June, 1962.

Hardy, E., M.W. Mayer, J.S. Allen, L.T. Alexander, “Sr-90 on the Earth’s Surface”, Nature 219, #514, pp 584-587, Aug., 1968.

Harley, John H., “A Brief History of Long-Range Fallout”, in Health and Safety Laboratory report HASL-306, Environmental Quarterly, July 1, 1976, pp I-3 to I-1.

HASL. USAEC Health and Safety Laboratory (HASL) Fallout Quarterly Reports, 1958-1972, Reports HASL-55, 65, 69, 77, 84. Available from NTIS. Fallout data available at www.eml.doe.gov.

Hicks, H.G. Results of calculations of external radiation exposure rates from fallout and the related radionuclide composition of selected U.S. pacific events. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-53505; 1984.

ICRP. International Commission on Radiological Protection., 1990 Recommendations of the International Commission on Radiological Protection, ICRP Pub. 60, Annals of the ICRP **21**, Pergamon Press, Elmsford, NY; 1991.

ICRU. Dosimetry of External Beta Rays for Radiation Protection. Report of the International Commission on Radiation Units and Measurements, ICRU-56. ICRU, Bethesda, MD;1997.

Krey, P.W. and Beck, H.L., The Distribution Throughout Utah of 137Cs and 239+240Pu from Nevada Test Site Detonations, USDOE rept EML-400. NTIS; 1981.

Kuroda, P.K., P. Kauranen, B.D. Palmer, K.K. Menon, and L.M. Fry, “Fission Products in the Atmosphere and in Rain”, In Radioactive Fallout from Nuclear Weapons Tests, USAEC Symposium Proc. Of Second Conference, A. Klement ed., Nov., 1964, pp. 602-615, USAEC TID, 1965.

Lockhart, L.B., Jr., R.L. Patterson, Jr., A.W. Saunders, Jr. and R.W. Black. “Atmospheric Radioactivity Along the 80^{th} Meridian West”, in Radioactive Fallout from Nuclear Weapons Tests, USAEC Symposium Proc. Of Second Conference, A. Klement ed., Nov., 1964, pp. 477-496, USAEC TID, 1965. (See also data reports cited in this paper).

Lowder, W.M., H.L. Beck and W.J. Condon, “The spectrometric determination of dose Rates from natural and Fallout Gamma radiation in the United States, 1962-63”, Nature 202, 745-749. (1964).

Martell, E., Science **129**, p 1197, 1959.

Meyer, M.W., J.S. Allen, E. Hardy and L.T. Alexander, Strontium-90 on the Earth’s surface, IV. ,USAEC rept. TID-24341., 1968.

NCI. National Cancer Institute. Estimated Exposures and Thyroid Doses Received by the American people from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests; October 1997.

NCRP. Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies. National Council on Radiation Protection and Measurements rept. #129. NCRP, Bethesda, MD; 1999.

Perkins, R.W., C.W. Thomas and J.M. Nielson, "Measurements of Airborne Radionuclides and Determination of their Physical Characteristics", in Radioactive Fallout from Nuclear Weapons Tests, USAEC Symposium Proc. Of Second Conference, A. Klement ed., Nov., 1964, pp198-221, USAEC TID, 1965.

PHS. Public Health Service. Tabulation of findings, Radiation Surveilance Network, available from CIC, Las Vegas. 1958-.

Radiological Health Data. U.S. Dept of Health, Education, and Welfare, Public Health Service. Monthly reports, 1958+

Stewart, N.G., R.G.D. Osmond, R.N. Crooks, and E.M. Fisher. The worldwide deposition of long-lived fission products from nuclear test explosions. Atomic Energy research establishment rept. AERE HP/R 2354, Oct. 1957. Reproduced in USAEC, 1958.

USAEC. Environmental Contamination from Weapons Tests. USAEC rept. HASL-42; 1958.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly. United Nations rept. E.82.IX.8. United Nations. New York; 1982.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. 1993 Report to the General Assembly, with scientific annexes. UN pub. E.94.IX.2. United Nations, New York; 1993.

U.S. Dept. of Energy. United States Nuclear Tests. DOE/NV-209, Rev. 14 (1994)

USDOE. Drawing back the Curtain of Secrecy. Restricted data Declassification policy- 1946 to the Present (RDD-5), 1/1/99. USDOE, Washington. (Available on the internet at (http://www.Osti.doe.gov).

USERDA. Final Tabulation of Monthly Sr-90 Fallout Data: 1954-1976. USERDA report HASL-329, 1977.

VNIEF. Ministry of the Russian Federation for Atomic Energy, Ministry of Defence of the Russian Federation. USSR Nuclear Weapons Tests and Peacefful Nuclear Explosions, 1949 through 1990. Russian Federal Nuclear center-VNIEF, 1996.

Appendix 1: Nuclide Ratios Used in This Preliminary Assessment

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
Jan-53	77.08	76.33	17.09	1.14	2.56	31.03	68.45	28.00	2.18	0.90
2	47.69	42.94	16.19	1.12	0.14	5.11	29.80	23.00	1.73	1.20
3	33.54	31.61	15.66	1.10	0.00	0.00	19.37	20.00	1.39	1.50
4	23.00	12.58	15.13	1.09	0.00	0.00	10.00	19.00	1.12	1.60
5	15.00	5.99	13.64	1.08	0.00	0.00	6.00	18.00	0.93	1.80
6	10.00	2.31	10.94	1.08	0.00	0.00	3.00	17.00	0.73	1.90
7	7.00	1.69	10.07	1.06	0.00	0.00	2.00	15.00	0.72	1.90
8	36.65	34.31	8.93	1.04	40.13	83.03	40.40	13.00	1.33	2.00
9	54.51	51.84	13.50	1.04	43.64	116.39	70.46	22.00	1.23	2.10
10	30.20	23.45	12.24	1.01	3.47	20.19	28.90	18.00	1.06	2.10
11	13.88	13.94	10.83	0.97	0.14	2.26	15.00	14.00	0.94	2.10
12	5.59	8.78	9.67	0.94	0.01	0.21	8.00	11.00	0.84	2.10
Jan-54	2.40	5.54	8.60	0.91	0.00	0.02	4.00	9.00	0.77	2.10
2	1.29	3.62	8.99	0.89	0.00	0.00	2.00	9.00	0.72	2.10
3	32.00	62.01	11.67	0.98	52.12	146.42	46.12	13.00	0.87	0.50
4	58.00	92.87	14.18	1.06	50.69	158.86	75.84	18.00	0.93	0.70
5	73.00	102.77	15.88	1.10	68.87	186.57	93.41	22.00	1.25	0.70
6	59.00	74.14	15.58	1.10	12.01	63.15	60.24	21.00	1.18	0.90
7	41.00	43.47	14.85	1.08	0.82	11.81	29.83	19.00	1.03	1.20
8	28.00	25.16	13.97	1.06	0.05	2.11	14.55	17.00	0.90	1.50
9	28.00	24.12	13.63	1.05	16.60	35.28	22.48	17.00	0.76	1.60
10	23.00	18.06	13.00	1.04	6.63	19.77	17.08	16.00	0.68	1.80
11	15.00	10.65	12.90	1.02	3.44	9.72	8.20	15.00	0.64	1.90
12	9.00	4.39	11.78	1.00	0.00	0.00	2.38	13.00	0.61	1.90
Jan-55	6.00	2.58	11.24	0.98	0.00	0.00	1.00	12.00	0.57	2.00
2	4.00	1.41	10.52	0.96	0.00	0.00	0.64	11.00	0.54	2.10
3	2.00	0.41	10.63	0.95	0.00	0.00	0.30	11.00	0.49	2.10
4	0.00	0.00	9.79	0.93	0.00	0.00	0.00	10.00	0.46	2.20
5	0.00	0.00	9.91	0.92	0.00	0.00	0.00	10.00	0.43	2.20
6	0.00	0.00	9.09	0.90	0.00	0.00	0.00	9.00	0.40	2.20
7	0.00	0.00	8.26	0.88	0.00	0.00	0.00	8.00	0.38	2.20

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
8	0.00	0.00	8.37	0.87	0.00	0.00	0.00	8.00	0.36	2.20
9	0.00	0.00	7.49	0.85	0.00	0.00	0.00	7.00	0.34	2.20
10	0.00	0.79	6.55	0.83	0.31	1.00	0.53	6.00	0.32	2.20
11	25.00	4.02	9.32	0.90	5.86	13.00	6.16	15.00	0.68	0.50
12	42.00	37.01	8.89	0.88	14.12	56.00	52.50	14.00	0.77	0.90
Jan-56	18.00	13.34	8.14	0.85	0.87	8.00	17.20	12.00	0.75	1.20
2	32.00	19.41	7.08	0.83	0.17	4.00	22.57	10.00	0.70	1.50
3	50.00	29.90	11.27	0.82	10.54	23.00	27.34	16.00	0.72	1.60
4	25.00	13.14	8.49	0.81	2.10	7.00	10.32	12.00	0.71	1.80
5	14.00	14.77	6.13	0.82	23.04	47.00	16.64	9.00	0.87	0.50
6	11.00	15.54	3.93	0.89	18.42	43.00	15.06	6.00	1.38	0.70
7	38.00	65.95	8.75	0.99	70.94	171.00	52.12	12.00	1.49	0.70
8	24.00	35.51	6.61	0.98	11.47	45.00	25.89	9.00	1.45	0.90
9	87.00	96.78	7.48	0.98	66.07	167.00	103.44	12.00	1.40	0.90
10	61.00	54.72	7.52	0.96	6.18	35.00	53.10	12.00	1.48	1.00
11	48.00	37.19	8.78	0.94	17.21	40.00	37.84	14.00	1.62	1.20
12	37.00	29.27	12.47	0.94	20.69	52.00	36.61	21.00	1.66	1.50
Jan-57	40.00	27.04	8.44	0.92	8.49	28.00	31.88	14.00	1.60	1.60
2	43.00	23.91	13.70	0.90	3.01	13.00	25.32	22.00	1.54	1.80
3	32.00	18.00	9.35	0.89	11.40	26.00	20.96	15.00	1.47	1.90
4	27.00	20.57	11.89	0.91	31.29	68.00	36.67	23.00	1.39	1.90
5	47.00	18.33	8.63	0.89	11.50	44.00	33.00	17.00	1.39	2.00
6	35.00	11.05	8.58	0.87	4.16	10.00	17.00	16.00	1.27	2.10
7	25.00	6.13	10.67	0.90	0.85	2.00	9.00	21.00	1.03	2.10
8	87.00	56.57	10.56	0.90	85.03	195.00	80.00	21.00	1.08	2.20
9	82.00	141.01	12.00	0.96	102.38	243.00	170.00	23.00	1.10	2.20
10	73.00	75.83	9.11	0.97	47.28	141.00	95.00	18.00	1.14	0.60
11	32.00	28.36	9.60	1.01	27.00	66.00	40.00	21.00	2.12	0.60
12	38.00	27.03	9.23	0.97	4.76	25.00	35.00	20.00	2.13	0.80
Jan-58	37.00	36.39	9.50	0.93	1.10	7.00	42.00	20.00	1.95	0.90
2	30.00	15.38	10.08	0.91	16.01	30.00	19.00	21.00	1.85	1.20
3	34.00	32.04	9.76	0.99	32.48	78.00	47.00	22.00	2.08	1.00
4	38.00	30.93	11.15	0.98	6.66	25.00	42.00	25.00	2.17	1.00
5	20.00	15.82	11.17	1.01	23.95	54.00	16.00	22.00	2.11	1.00
6	16.00	24.36	13.53	1.04	22.08	53.00	20.00	23.00	1.80	1.00

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
7	18.00	49.59	14.13	1.07	28.33	70.00	36.00	21.00	1.59	1.00
8	17.00	44.24	14.97	1.06	5.97	20.00	31.00	22.00	1.58	1.00
9	78.00	55.23	11.71	1.06	50.12	118.00	66.00	21.00	2.14	1.00
10	82.00	64.11	15.48	1.08	69.12	160.00	90.00	32.00	2.00	1.20
11	27.00	109.30	10.66	1.09	18.96	65.00	150.00	23.00	2.13	1.50
12	27.00	60.40	14.80	1.06	3.59	33.00	74.00	31.00	2.30	1.60
Jan-59	70.00	44.16	11.85	1.03	0.28	7.00	48.00	24.00	2.31	1.80
2	50.00	23.72	14.19	1.01	0.03	2.00	23.00	28.00	2.23	1.90
3	35.00	16.01	9.00	0.99	0.00	0.00	14.00	22.00	2.18	1.90
4	22.00	11.43	9.00	0.98	0.00	0.00	9.00	13.00	2.09	2.00
5	15.00	2.83	10.00	0.96	0.00	0.00	2.00	19.00	1.97	2.10
6	10.00	3.16	9.56	0.94	0.00	0.00	2.00	18.00	1.85	2.10
7	7.00	1.76	8.06	0.93	0.00	0.00	1.00	15.00	1.75	2.20
8	5.00	1.97	5.99	0.91	0.00	0.00	1.00	11.00	1.64	2.20
9	4.00	0.00	6.12	0.89	0.00	0.00	0.00	11.00	1.54	2.20
10	3.00	0.00	4.58	0.87	0.00	0.00	0.00	8.00	1.43	2.20
11	2.00	0.00	4.71	0.86	0.00	0.00	0.00	8.00	1.33	2.20
12	1.00	0.00	3.05	0.84	0.00	0.00	0.00	5.00	1.22	2.20
Jan-60	0.00	0.00	5.65	0.82	0.00	0.00	0.00	9.00	1.13	2.20
2	0.00	0.00	5.25	0.82	0.00	0.00	0.00	8.00	1.02	2.20
3	0.00	0.00	4.62	0.80	0.00	0.00	0.00	7.00	0.97	2.20
4	0.00	0.00	3.96	0.78	0.00	0.00	0.00	6.00	0.93	2.20
5	0.00	0.00	4.01	0.76	0.00	0.00	0.00	6.00	0.88	2.20
6	0.00	0.00	3.39	0.75	0.00	0.00	0.00	5.00	0.83	2.20
7	0.00	0.00	3.43	0.74	0.00	0.00	0.00	5.00	0.78	2.20
8	0.00	0.00	2.78	0.72	0.00	0.00	0.00	4.00	0.74	2.20
9	0.00	0.00	2.83	0.71	0.00	0.00	0.00	4.00	0.69	2.20
10	0.00	0.00	2.89	0.69	0.00	0.00	0.00	4.00	0.65	2.20
11	0.00	0.00	2.21	0.68	0.00	0.00	0.00	3.00	0.60	2.20
12	0.00	0.00	3.01	0.67	0.00	0.00	0.00	4.00	0.56	2.20
Jan-61	0.00	0.00	3.07	0.65	0.00	0.00	0.00	4.00	0.52	2.20
2	0.00	0.00	3.12	0.64	0.00	0.00	0.00	4.00	0.49	2.20
3	0.00	0.00	2.37	0.63	0.00	0.00	0.00	3.00	0.46	2.20
4	0.00	0.00	2.40	0.62	0.00	0.00	0.00	3.00	0.44	2.20
5	0.00	0.00	2.44	0.61	0.00	0.00	0.00	3.00	0.41	2.20

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
6	0.00	0.00	3.30	0.60	0.00	0.00	0.00	4.00	0.38	2.20
7	0.00	0.00	4.19	0.58	0.00	0.00	0.00	5.00	0.36	2.20
8	0.00	0.00	4.00	0.57	0.00	0.00	0.00	4.10	0.34	2.20
9	132.00	138.55	10.00	0.97	240.03	500.00	215.00	25.00	1.25	0.50
10	175.00	188.93	14.00	1.60	96.10	250.00	280.00	33.00	1.89	0.70
11	150.00	76.09	13.00	1.60	46.45	120.00	110.00	32.00	2.30	0.70
12	110.00	73.83	17.00	1.60	11.16	75.00	95.00	40.00	3.29	0.90
Jan-62	80.00	31.00	12.00	1.40	0.62	12.00	32.00	35.00	4.46	1.20
2	55.00	31.45	13.00	1.50	0.07	4.00	32.00	29.00	5.36	1.50
3	50.00	7.68	13.00	1.50	0.01	1.00	7.00	37.00	6.67	1.60
4	20.00	2.90	13.00	1.60	11.88	22.00	3.00	28.00	7.25	1.80
5	40.00	5.49	13.00	1.60	24.78	56.00	8.00	31.00	6.55	0.70
6	30.00	9.61	12.00	1.70	17.32	41.00	14.00	26.00	6.18	0.90
7	15.00	2.82	13.00	1.50	12.21	32.00	4.00	22.00	5.86	1.00
8	20.00	3.68	11.00	1.50	8.92	24.00	5.00	21.00	5.87	0.70
9	30.00	14.39	11.00	1.60	7.49	22.00	20.00	26.00	5.43	0.70
10	45.00	27.00	11.00	1.40	43.78	100.00	66.00	28.00	4.59	0.70
11	60.00	50.00	11.00	1.30	58.53	156.00	73.00	30.00	3.91	0.70
12	70.00	45.00	12.00	1.50	23.91	72.00	61.00	32.00	3.93	0.70
Jan-63	40.00	62.00	11.00	1.40	1.99	7.00	34.00	30.00	3.87	0.70
2	30.00	41.00	12.00	2.40	0.22	2.00	22.00	30.00	3.89	0.90
3	25.00	18.00	13.00	1.40	0.04	1.00	9.00	27.00	3.98	1.20
4	20.00	9.89	11.00	1.20	0.00	0.00	8.96	24.00	3.92	1.50
5	15.00	5.92	9.00	1.40	0.00	0.00	4.84	22.00	3.77	1.60
6	11.00	3.53	8.00	1.60	0.00	0.00	2.60	20.00	3.60	1.80
7	8.00	2.60	10.00	1.50	0.00	0.00	1.72	19.00	3.44	1.90
8	6.00	1.40	9.00	1.50	0.00	0.00	0.83	15.00	3.29	1.90
9	5.00	0.62	8.00	1.70	0.00	0.00	0.33	16.00	3.11	2.00
10	4.00	0.30	8.00	1.30	0.00	0.00	0.00	13.00	2.92	2.10
11	3.00	0.15	6.00	1.10	0.00	0.00	0.00	13.00	2.74	2.10
12	2.00	0.08	6.00	1.30	0.00	0.00	0.00	14.00	2.55	2.10
Jan-64	2.00	0.05	7.00	1.27	0.00	0.00	0.00	16.00	2.36	2.10
2	1.00	0.03	6.00	1.25	0.00	0.00	0.00	14.00	2.21	2.10
3	0.00	0.02	7.00	1.22	0.00	0.00	0.00	13.00	2.11	
4	0.00	0.01	7.00	1.19	0.00	0.00	0.00	12.00	2.00	

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
5	0.00	0.00	6.00	1.17	0.00	0.00	0.00	11.00	1.89	
6	0.00	0.00	6.00	1.15	0.00	0.00	0.00	11.00	1.77	
7	0.00	0.00	6.00	1.12	0.00	0.00	0.00	10.00	1.67	
8	0.00	0.00	5.00	1.10	0.00	0.00	0.00	9.00	1.58	
9	0.00	0.00	5.00	1.08	0.00	0.00	0.00	9.00	1.48	
10	0.00	0.00	5.00	1.05	0.00	0.00	0.00	8.00	1.37	
11	0.00	0.00	5.00	1.03	0.00	0.00	0.00	7.00	1.28	
12			5.00	1.00				7.00	1.25	
Jan-65			4.73	1.01				6.63	1.20	
2			4.72	0.98				6.63	1.17	
3			4.47	0.99				6.28	1.12	
4			4.46	0.96				6.28	1.10	
5			4.23	0.97				5.94	1.05	
6			4.22	0.94				5.94	1.03	
7			3.99	0.95				5.63	0.98	
8			3.99	0.93				5.63	0.96	
9			3.77	0.94				5.33	0.92	
10			3.77	0.91				5.33	0.90	
11			3.57	0.92				5.04	0.86	
12			3.56	0.89				5.04	0.84	
Jan-66			3.37	0.90				4.78	0.81	
2			3.36	0.87				4.78	0.79	
3			3.18	0.88				4.52	0.76	
4			3.18	0.86				4.52	0.74	
5			3.01	0.87				4.28	0.71	
6			3.00	0.84				4.28	0.69	
7			2.84	0.85				4.06	0.66	
8			2.84	0.83				4.06	0.65	
9			2.69	0.84				3.84	0.62	
10			2.68	0.81				3.84	0.61	
11			2.54	0.82				3.64	0.58	
12			2.53	0.80				3.64	0.57	
Jan-67			2.40	0.80				3.44	0.55	
2			2.39	0.78				3.44	0.54	
3			2.27	0.79				3.26	0.51	

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
4			2.26	0.77				3.26	0.50	
5			2.14	0.77				3.09	0.48	
6			2.14	0.75				3.09	0.47	
7			2.02	0.76				2.92	0.45	
8			2.02	0.74				2.92	0.44	
9			1.91	0.75				2.77	0.42	
10			1.91	0.72				2.77	0.41	
11			1.81	0.73				2.62	0.39	
12			1.80	0.71				2.62	0.39	
Jan-68			1.71	0.72				2.48	0.37	
2			1.70	0.70				2.48	0.36	
3			1.61	0.70				2.35	0.35	
4			1.61	0.68				2.35	0.34	
5			1.53	0.69				2.22	0.32	
6			1.52	0.67				2.22	0.32	
7			1.44	0.68				2.11	0.30	
8			1.44	0.66				2.11	0.30	
9			1.36	0.66				1.99	0.28	
10			1.36	0.64				1.99	0.28	
11			1.29	0.65				1.89	0.27	
12			1.28	0.63				1.89	0.26	
Jan-69			1.22	0.64				1.79	0.25	
2			1.21	0.62				1.79	0.24	
3			1.15	0.63				1.69	0.23	
4			1.15	0.61				1.69	0.23	
5			1.09	0.62				1.60	0.22	
6			1.08	0.60				1.60	0.21	
7			1.03	0.60				1.52	0.21	
8			1.02	0.59				1.52	0.20	
9			0.97	0.59				1.44	0.19	
10			0.97	0.57				1.44	0.19	
11			0.92	0.58				1.36	0.18	
12			0.91	0.56				1.36	0.18	
Jan-70			0.87	0.57				1.29	0.17	
2			0.86	0.55				1.29	0.17	

Month	95/90	103/90	106/90	125/90	131/90	140/90	141/90	144/90	54/90	Nb/Zr
3			0.82	0.56				1.22	0.16	
4			0.82	0.54				1.22	0.15	
5			0.77	0.55				1.16	0.15	
6			0.77	0.53				1.16	0.15	
7			0.73	0.54				1.09	0.14	
8			0.73	0.52				1.09	0.14	
9			0.69	0.53				1.04	0.13	
10			0.69	0.51				1.04	0.13	
11			0.65	0.52				0.98	0.12	
12			0.65	0.50				0.98	0.12	
Jan-71			0.62	0.51				0.93	0.11	
2			0.62	0.49				0.93	0.11	
3			0.58	0.50				0.88	0.11	
4			0.58	0.48				0.88	0.10	
5			0.55	0.49				0.83	0.10	
6			0.55	0.47				0.83	0.10	
7			0.52	0.48				0.79	0.09	
8			0.52	0.47				0.79	0.09	
9			0.49	0.47				0.75	0.09	
10			0.49	0.46				0.75	0.09	
11			0.46	0.46				0.71	0.08	
12			0.46	0.45				0.71	0.08	
Jan-72			0.44	0.45				0.67	0.08	
2			0.44	0.44				0.67	0.08	
3			0.41	0.44				0.63	0.07	
4			0.41	0.43				0.63	0.07	
5			0.39	0.44				0.60	0.07	
6			0.39	0.42				0.60	0.07	
7			0.37	0.43				0.57	0.06	
8			0.37	0.42				0.57	0.06	
9			0.35	0.42				0.54	0.06	
10			0.35	0.41				0.54	0.06	
11			0.33	0.41				0.51	0.06	
12			0.33	0.40				0.51	0.05	

Appendix 2: Classified Data That Could be of Use in Assessing Fallout Impact on U.S. Population

The ability to estimate fallout deposition from NTS shots was made possible by the calculations of Hicks based on cloud measurements of the relative production of the various fission products from each test. The composition of debris is very dependent on the spectrum of neutrons produced in the device and the composition of the fuel. Similar data for test carried out by the U.S. and U.K. in the Pacific as well as for tests carried out in the Soviet Union would be useful for making comparable estimates of fallout deposition for tests carried out outside the U.S. Such data, if available, is classified.

Also classified is the fraction of the total yield of individual shots that resulted from fission versus fusion. Again, this information is needed to make reasonable estimates of deposition and resultant doses from tests held outside the U.S. The atmospheric model developed by Bennett (1980) described in this report requires estimates of the fission yield to estimate the amount of debris injected into various compartments of the atmosphere. This model in turn is useful for estimating nuclide deposition ratios as described in this report.

Appendix H

Internal Dose Estimates from Global Fallout

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from High-yield Weapons Tests Conducted by the U.S., U.K., and U.S.S.R. between 1952 and 1963

Final Report

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-008090

September 30, 2000

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from Nuclear Tests at the Nevada Test Site

Part I. Estimates of Dose

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-912901

TABLE OF CONTENTS

ABSTRACT

According to a Congressional request to the Department of Health and Human Services, a feasibility study is being conducted to study the health consequences to the American peoples of nuclear weapons tests. This report concerns calculations of the dose from the consumption of food contaminated by radionuclides deposited or distributed with global fallout, which originated from high-yield tests conducted in the Northern Hemisphere by the U.S., the U.K. and the U.S.S.R. Such tests were conducted in 1952–1958 and 1961–1962. Results of this part of the feasibility study indicate that such doses can be calculated, as have similar doses from the tests conducted at the Nevada Test Site. The methods of calculation for ^{90}Sr, ^{131}I, and ^{137}Cs are based upon the methods developed and used earlier by the Off-Site Radiation Exposure Review Project; these methods employed seasonally adjusted values of radioecological transfer of radionuclides to humans.

For ^{90}Sr and ^{137}Cs, doses were calculated on a yearly basis for 1953 through 1972 for each county in the contiguous U.S. for adults and for persons born on 1 January 1951; doses during the latter years were well beyond the time period of the actual tests, but these long-lived radionuclides were still being deposited from the reservoir in the stratosphere. Doses from ^{131}I were estimated only on a country-average basis, as county-by-county deposition levels were not available; doses from ^{131}I were estimated for the 1953–1963 years. Doses from ^{3}H and ^{14}C were calculated with the use of specific activity models, and calculations were carried out for the actual doses received in 1952–2000. Detailed results are provided in a CD that accompanies this report. Summary results in the form of coded maps are provided for ^{90}Sr and ^{137}Cs. The total estimated collective effective dose from the five radionuclides considered is estimated to be 66,000 person Sv; the collective dose to the thyroid is 210,000 person Sv. The estimated per caput effective dose is 400 μSv. These doses are somewhat smaller than the doses previously estimated to have occurred in the contiguous U.S. from the atmospheric tests conducted at the Nevada Test Site. The more important radionuclides in global fallout (on an effective dose basis) were ^{14}C and ^{137}Cs, whereas the dose from the Nevada tests is dominated by ^{131}I.

A comparison is made of the doses calculated with the current method with doses that can be derived from measurements of global fallout radionuclides in milk as reported by the U.S. Public Health Service's Pasteurized Milk Network for the time period of 1960–1963 first quarter. The results are in good agreement for ^{90}Sr and ^{131}I; calculated results for ^{137}Cs are higher than those based upon the milk measurements, but this is expected as a substantial fraction of dose from ^{137}Cs arises from the consumption of meat.

A list is provided of major references concerning the occurrence of global fallout and calculations of dose from these radionuclides.

The presently available calculations of dose from ^{131}I in global fallout are limited and are not available on a county-by-county basis. Recommendations are provided on how to improve this situation by the use of measured values of global fallout in milk, other foods, cattle thyroids, and air.

PREFACE

Congress has asked the Department of Health and Human Services (HHS) to study the health consequences to the American people of nuclear weapons tests. Within that framework a purchase order has been received to assist in the determination of radiation dose to the American people from large atmospheric nuclear weapons tests conducted by the U.S. and the U.K. in the Pacific and by the former U.S.S.R., primarily near the Arctic Circle. Such doses are commonly referred to as resulting from “global fallout.”

The tasks to be performed under the terms of the purchase order are:

1. “The primary work to be performed is to prepare crude estimates of the doses of internal radiation received by the American people as a result of the aboveground tests carried out at sites outside the continental U.S. including the Marshall Islands, Kazakhstan, and Russia. These estimates would be:

   – “Based on a review of the readily available literature and information found in scientific journals and published reports; it is not expected that sophisticated computer models should be developed or used for this purpose. For the purposes of this assessment, an electronic database of fallout deposition will be provided by NCI;

   – “Averaged over states or latitudinal bands of the continental U.S., with indications on how the high-risk populations could be identified. However, if feasible, primary calculations should be carried out on a county by county basis, and averaged only for presentation purposes;

   – “Calculated separately for the most important radionuclides produced in nuclear weapons tests. These would include, but would not be limited to H-3, C-14, Sr-90, Cs-137, and I-131. Estimates of dose from Sr-90 and Cs-137 will use the deposition databases provided by NCI while estimates of dose from H-3 and C-14 will use methods published by other investigators and by UNSCEAR in its 1993 report as well as in previous reports. Estimates of dose from I-131 will also use the data provided by NCI, though the dose estimates to be reported will be limited to a nationwide collective dose estimate.

   – “Provided in terms of absorbed doses for some of the most radiosensitive organs and tissues (red bone marrow, gastro-intestinal tract, and thyroid).

   – “Calculated by year of testing in the 1950s and 1960s, and summed over the most significant tests worldwide (other than those tests conducted at the Nevada Test Site), with a comparison to the published UNSCEAR latitudinal averages for all tests.

   – “Calculated for persons born on 1 January 1951 and residing continuously in the counties of birth. This calculation will use age-corrected coefficients.

2. “For selected areas of the continental U.S. and for selected years of fallout, compare the internal dose estimates calculated in item 1 for Sr-90, Cs-137, and I-131 with those derived from the measurements of fallout radionuclides in foodstuffs.

3. “Provide a list of the most significant references regarding: (1) the networks of measurements of fallout radionuclides in air and foodstuffs, and (2) the assessment of the doses from internal radiation.

4. “The report to be provided shall discuss limitations on presently calculating county-specific dose estimates from global sources of I-131 and shall discuss feasibility for future work and methods that might be implemented in such work.”

The funds made available to accomplish this work consisted of $24,900. Thus, it was necessary to find very efficient means to accomplish this complex task.

INTRODUCTION

In previous reports (Anspaugh 2000; Beck 1999) doses were estimated for the 48 contiguous states from fallout derived from the tests of nuclear weapons-related devices at the Nevada Test Site (NTS). Results in Beck (1999) were for external exposure and dose, and results in Anspaugh (2000) were for doses from the ingestion of contaminated foods. The latter report was based upon estimates of deposition density as calculated by Beck (1999) for 19 radionuclides. These radionuclides were selected for analysis on the basis of screening calculations that had been performed previously by Ng et al. (1990) for the Off-Site Radiation Exposure Review Project (ORERP); these screening calculations indicated that 21 radionuclides were estimated to be responsible for about 95% of the total dose from the ingestion pathway for the radionuclides released at the NTS. Doses were not calculated in Anspaugh (2000) for two (^{135}I and ^{239}Np) of the 21 radionuclides, as estimates of deposition density were not available[*] at the time when the calculations were made. Most of the 19 radionuclides had relatively short half lives, but were more important in a dosimetric sense than the long-lived radionuclides due to the rapid entry of local and regional fallout into food chains.

For global fallout the radionuclides of concern are different for several reasons. The first is that global fallout by definition consists of radioactive debris that is globally dispersed due to its injection into the high atmosphere by large explosions. Due to its injection at high altitudes, global fallout typically does not return to earth for one or more years. During this time the short-lived fission products decay to small levels, and, except for unusual occurrences, the short-lived radionuclides of interest for NTS fallout are not of concern. Two radionuclides, ^{90}Sr and ^{137}Cs, have long half lives (about 30 y each) and do not decay appreciably before they return to earth. Historically, these radionuclides have been studied extensively due to their presence in global fallout and due to concern about adverse health effects from the ingestion of these two radionuclides.

Another factor of importance is that global fallout originates from high-yield weapons that typically derive much of their yield from fusion reactions. These explosions produce or “spill” large amounts of ^{3}H, and the intense neutron flux also produces large amounts of ^{14}C through the reaction ^{14}N(n,p)^{14}C. Because ^{3}H and ^{14}C enter their respective hydrogen and carbon cycles and do not deposit in the same manner as do radionuclides associated with particulate matter, the usual methods of calculating deposition and dose are not appropriate; rather the

[*] Estimates of deposition density for ^{239}Np are now available from Beck (personal communication). If more detailed studies are to follow the current feasibility studies, the dose from ^{239}Np should be included.

specific activity approach has been used (UNSCEAR 1993). In order to calculate the dose from ^{3}H and ^{14}C, it is necessary to derive source terms (the activity created per unit fusion-explosion energy) and to estimate the fusion yields as a function of time. In general there is little movement of radionuclides across the hemispheric boundary, so it is also important to know the fusion yield in the northern hemisphere for this assessment. Most of the fusion yields occurred in the northern hemisphere, but with substantial amounts near the equator. The conservative assumption is made here that the resulting radionuclides remained in the northern hemisphere.

The fusion yields estimated to have occurred in the northern hemisphere as a function of time are indicated in Table 1. These values were derived from total yield values reported in UNSCEAR (1993), DOE (1994), and Mikhailov et al. (1996); and with subtraction of the fission yields derived by Beck (2000).

Due to widespread concern about global fallout and its effects on man, scientists from many countries have studied fallout beginning in the 1950s. Such concern was a primary reason that led to the formation of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which has studied global fallout over many years and has issued a number of assessments of dose with primary interest on calculating global averages of dose. In its most recent assessment of global-fallout dose the UNSCEAR (1993) provided the estimates indicated in Table 2 of the doses from the ingestion of food contaminated by global fallout.

Table 1. Estimated fusion yields exploded in the northern hemisphere as a function of time. Values are estimated from total yields in UNSCEAR (1993), DOE (1994), and Mikhailov et al. (1996); minus the fission yields estimated by Beck (2000). Explosions close to the equator are conservatively considered to have injected their debris into the northern hemisphere only.

Year	Fusion yield, megatons
1952	5.0
1953	0.36
1954	17
1955	0.88
1956	13
1957	3.9
1958	31
1959	0
1960	0
1961	69
1962	99
Total	240

Table 2. Effective dose commitments estimated by UNSCEAR (1993) for the northern temperate zone (40°–50° latitude) from radionuclides produced by the testing in the atmosphere of large nuclear weapons. Estimates below are for "global" fallout and arise primarily from the injection of radionuclides into the upper atmosphere of the northern hemisphere.

Radionuclide	Dose commitment, μSv
^{3}H	48
^{14}C	78[a]
^{55}Fe	14
^{89}Sr	2.3
^{90}Sr	170
^{131}I	79
^{137}Cs	280
^{140}Ba	0.42
^{238}Pu	0.0009
$^{239+240}Pu$	0.50
^{241}Pu	0.004
^{241}Am	1.5
Sum	670

[a] The UNSCEAR (1993) value of 2600 μSv over all time was multiplied by a factor of 0.03, the portion estimated to be delivered in 50–70 y.

On the basis of the data in Table 2, and in accordance with the requirements for the purchase order, the radionuclides selected for examination during this feasibility study include ^{3}H, ^{14}C, ^{90}Sr, ^{131}I, and ^{137}Cs. These radionuclides account for all but a small fraction of the estimated dose to man from global fallout. The prominence of ^{131}I on the list may be surprising, as its half life is only eight days. The appearance of ^{131}I in global fallout has tended to be sporadic, but contaminated milk in the U.S. had been observed on a number of occasions (e.g., Dahl et al. 1963; Terrill et al. 1963). Possible mechanisms for these sporadic occurrences have been suggested by Machta (1963) and include

- The subsidence of large air masses contaminated with debris from U.S.S.R. tests at its Novaya Zemlya site near the Arctic Circle, and
- The penetration of large thunder storms into the upper troposphere and stratosphere that resulted in the scavenging of fresh debris from the U.S. tests in the Pacific.

The assessment of dose from ^{14}C is particularly difficult, due to its long half life of 5730 y. The UNSCEAR (1993) has assessed the intergenerational dose due to this radionuclide, and under such considerations it is the most significant radionuclide in global fallout. The relative importance of ^{14}C is much less, if the dose during the first 50–70 y is considered. Further, the carbon cycle is complex (as evidenced by the current controversy over global warming due to the release of carbon dioxide), and dose assessments must rely on complicated models. Thus, the projections of dose into the future for this radionuclide are only approximate, but estimates of dose through the present time are firmly based upon measurements of ^{14}C in food, water, and humans.

Estimates of dose from ^{3}H are considered to be more reliable, as this radionuclide has a much shorter half life of 12 y, and the hydrogen cycle is not as complicated as that of carbon. As for ^{14}C, estimates of dose through the present time are firmly based upon measurements of ^{3}H in food, water, and humans.

The purpose of this report is to fulfill the requirements of the purchase order referenced in the Preface. The estimates of dose (Task 1) from global fallout for the radionuclides indicated above are summarized in Part I of this report, as are the methods used to perform the calculations. An accompanying CD-ROM contains the detailed results of the calculations on a county-by-county basis for ^{90}Sr and ^{137}Cs; more details of the results for ^{3}H, ^{14}C, and ^{131}I are also provided on the CD, but results for these radionuclides are available only as averages over the continental U.S. Part II of this report contains all other information requested (Tasks 2, 3, and 4).

METHODS

The methods of dose calculation used in this report for ^{90}Sr, ^{131}I, and ^{137}Cs are similar to those used previously for the calculations of dose from tests at the NTS (Anspaugh 2000). The specific activity approach is used to calculate doses from ^{3}H and ^{14}C; the methods used for ^{3}H and ^{14}C are similar to those used by the UNSCEAR (1993).

Nuclear events of interest

This report includes doses from all high-yield nuclear events that took place within the northern hemisphere during the years from 1952 through 1963; such tests were stopped in 1963 by the U.S., the U.K., and the U.S.S.R. Tests at the NTS are not included in this report, as such tests were not high-yield, and doses from the ingestion of contaminated foods from NTS tests have been included in a previous assessment (Anspaugh 2000).

Because tests of high-yield weapons inject much of their debris into the stratosphere from which it devolves slowly over time, it is not generally possible to identify global fallout with a particular test. Rather, doses have been calculated on a monthly basis for ^{90}Sr, ^{131}I, and ^{137}Cs and on a yearly basis for ^{3}H and ^{14}C.

Internal dose from ^{90}Sr and ^{137}Cs

Doses from ^{90}Sr and ^{137}Cs were estimated by a process similar to that used for radionuclides from NTS fallout (Anspaugh 2000). The basic calculation is shown in equation (1):

$$D = P \times I \times F_g \,, \qquad (1)$$

where D = Absorbed dose, Gy, or equivalent/effective dose, Sv;
P = Deposition density of the radionuclide of interest at time of fallout arrival, Bq m^{-2};

I = Integrated intake by ingestion of the radionuclide per unit deposition, Bq per Bq m^{-2}; and

F_g = Ingestion-dose coefficient for the radionuclide, Gy Bq^{-1} or Sv Bq^{-1}.

Deposition density. Values of deposition density, *P*, for ^{90}Sr were furnished by Beck (2000) on behalf of the National Cancer Institute (NCI) on a county-by-county basis averaged over each month for the years of 1953 through 1972.† Values for the deposition density for ^{137}Cs were derived from those of ^{90}Sr by multiplying the ^{90}Sr results by a factor of 1.5, as recommended by Beck (2000) [a similar relationship has been used by UNSCEAR (1993)].

Integrated intake. Monthly average values of integrated intake, *I*, were derived from Whicker and Kirchner (1987) by interpolation of the date-specific values in that publication. The age-related values used in this study are shown in Figs. 1 and 2 for ^{90}Sr and ^{137}Cs, respectively.

Values of integrated intake are complex functions of age- and season-dependent intake rates of different foods and the season-dependent radioecological movement of radionuclides through food chains. Whicker and Kirchner (1987) developed the PATHWAY model to estimate integrated intake for the ORERP studies. The food-consumption rates used in the

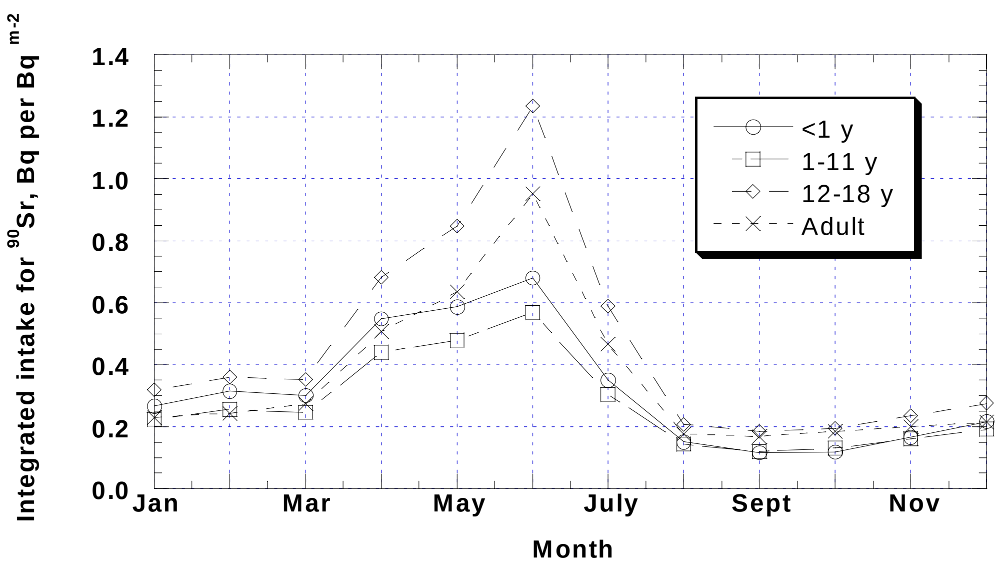


Fig. 1. Monthly average values of integrated intake of ^{90}S for four age groups. Data were derived from Whicker and Kirchner (1987).

† These years do not match the years of testing indicated on the previous page. Fallout from the 1952 tests occurred mainly in 1953 and afterward; fallout from the tests in the early 1960's was still measurable in 1972.

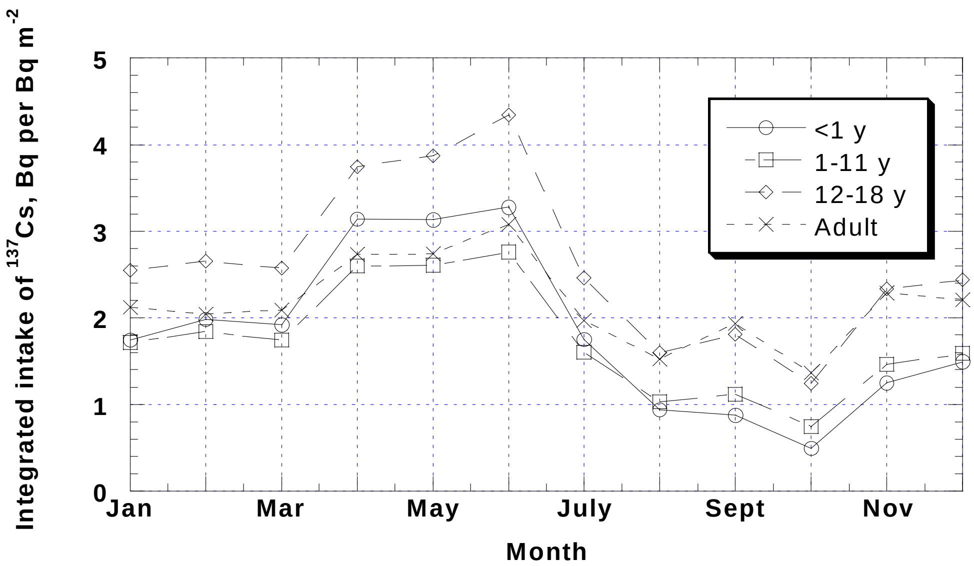


Fig. 2. Monthly average values of integrated intake of ^{137}Cs for four age groups. Data were derived from Whicker and Kirchner (1987).

PATHWAY model are shown in Table 3. The fractions of different food types that are assumed to be locally produced are indicated in Fig. 3, and the consumed fraction of non-leafy vegetables and fruits assumed to be freshly produced is shown in Fig. 4.

The radioecological component of PATHWAY is complex and includes many factors:

- Initial retention of radionuclides by vegetation;
- Loss of radionuclides from vegetation as a function of time;

Table 3. Food-consumption rates used in the PATHWAY code (Whicker and Kirchner 1987). Estimates are based primarily on data summarized by Rupp (1980) for rural families.

Food type	Food-consumption rates by age group, fresh kg day^{-1}			
	<1 y	1–11 y	12–18 y	≥19 y
Milk	0.800	0.623	0.635	0.360
Milk products	0.144	0.074	0.143	0.062
Beef	0.044	0.113	0.210	0.277
Poultry	0.003	0.017	0.028	0.030
Eggs	0.017	0.026	0.036	0.053
Leafy vegetables	0.002	0.021	0.036	0.062
Stored fruits and vegetables	0.207	0.266	0.356	0.360
Grains	0.025	0.025	0.151	0.137

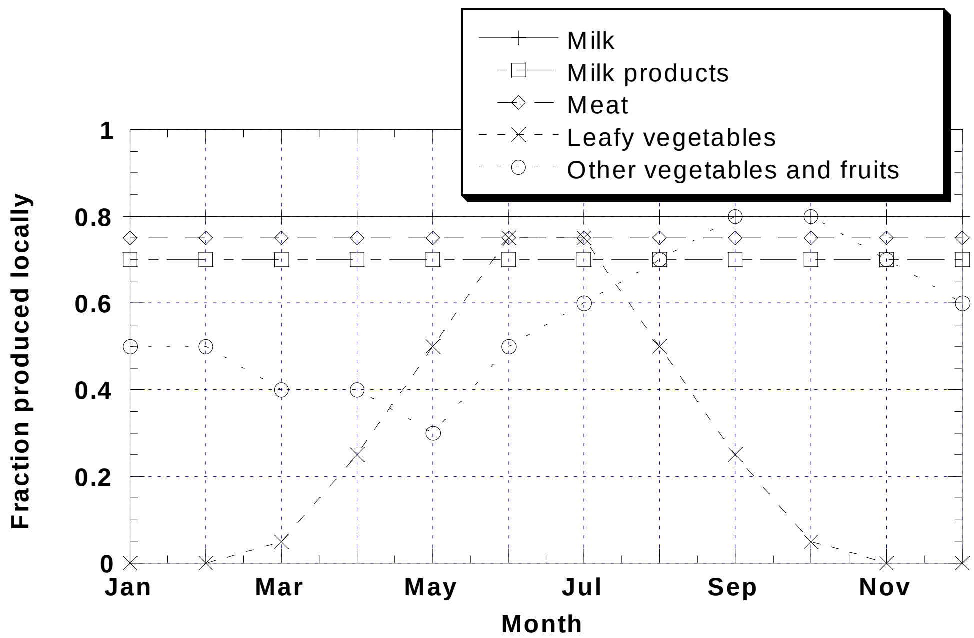


Fig. 3. Fraction of food that is assumed to be locally produced for several different food categories. Values for eggs are the same as those for milk. From Whicker and Kirchner (1987).

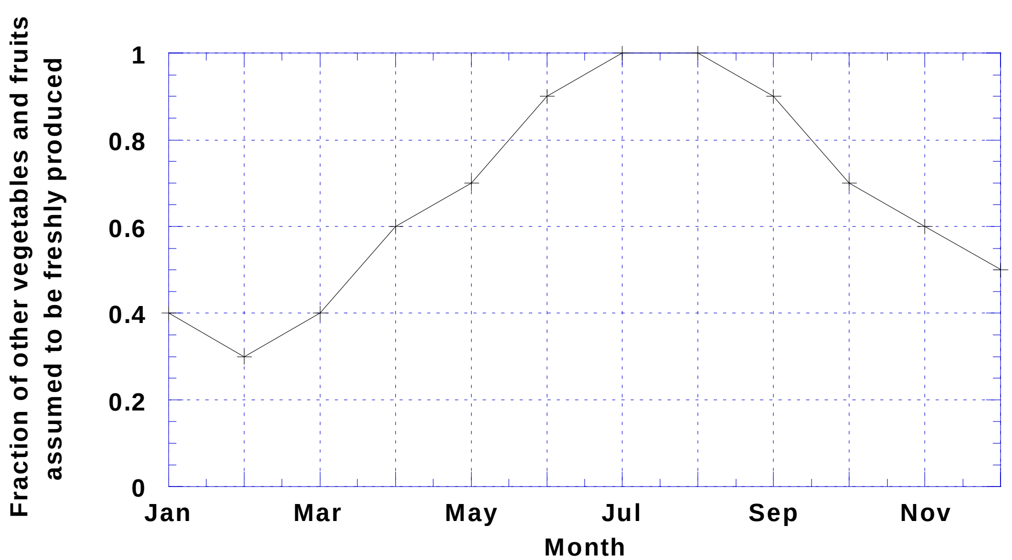


Fig. 4. Consumed fraction of non-leafy vegetables and fruits assumed to be freshly produced. From Whicker and Kirchner (1987).

- Dilution of radionuclide concentration in fresh vegetation by plant growth;

- Movement of radionuclides through several soil compartments;
- Uptake of a radionuclide through the soil-root system; and
- Recontamination of plant surfaces by resuspension and redeposition and by rain splash.

One of the critical factors that is known to vary substantially is the initial retention of fallout by fresh vegetation, particularly when deposition occurs with precipitation (Anspaugh 1987; NCI 1997). The value used for this parameter in PATHWAY is 0.39 m^2 kg^{-1}. Its value is known to vary with particle size (and distance from the site of detonation) for dry deposition and with rainfall rate for wet deposition. In addition, values vary substantially for reasons that are not yet explicable. Thus, uncertainty in this parameter contributes substantially to the uncertainty in the estimates of internal dose.

Although the values of integrated intake were originally derived for dry deposition in the semi-arid western areas of the U.S. nearby the NTS, this same value has been used for the entire study performed here. Based upon the experimental data reported by Hoffman et al. (1989), the value of 0.39 m^2 kg^{-1} is actually a reasonable value for retention of radionuclides in rainfall, except during conditions of very light rain when higher values have been observed.

Dose coefficients. The ICRP (1989, 1993, 1995, 1996) has provided compilations of dose coefficients, F_g, for ingestion of radionuclides by members of the general public. These published values, however, are incomplete in the sense that dose coefficients are not listed for all organs for all age groups. Recently, the ICRP (1998) has made available a CD-ROM system that allows the calculation of equivalent and effective doses for all organs for the six age groups[‡] considered by the ICRP. The dose-coefficient values provided by the ICRP represent the dose from a given intake that will occur over the next 50 years for adults or until age 70 y for the younger age groups; such values are commonly referred to as coefficients of committed dose.

ICRP (1998) is the source of dose coefficients used for this dose assessment. As for previously performed assessments (Ng et al. 1990), the ICRP dose coefficients have been considered to be average values (or arithmetic means). For the assessment for doses from tests at the NTS (Anspaugh 2000), the ICRP coefficients were converted to geometric means, so that uncertainties could be propagated in a consistent manner. As the deposition-density values provided by Beck (2000) for global fallout do not have attached uncertainty values, the dose coefficients used for this assessment have been used directly from ICRP (1998). The dose coefficients used in this study are indicated in Table 4.

For ^{90}Sr, dose coefficients for the unlisted organs are essentially the same as the dose coefficient for the thyroid; as ^{90}Sr (and its progeny) is a "pure" beta-emitting radionuclide that localizes in the bone, the higher doses are to the bone marrow and to the bone surface. The dose coefficient for ^{90}Sr is also somewhat higher for the colon, due to the transit of the beta emitter. On the other hand, ^{137}Cs is distributed throughout the body and delivers most of its dose from the emission of a gamma ray by its short-lived progeny ^{137m}Ba. Thus, while dose coefficients for

[‡] The six age groups considered by the ICRP are 1) "three months" [0 to 12 months], 2) "one y" [from 1 y to 2 y], 3) "five y" [>2 y to 7 y], 4) "10 y" [>7 y to 12 y], 5) "15 y" [>12 y to 17 y], and 6) "adult" [>17 y].

^{137}Cs for the colon are nearly twice as high as the effective dose coefficient, the dose coefficients for the unlisted organs are approximately the same as the effective dose coefficient.

Table 4. Age-dependent dose coefficients for members of the public used in this study for ^{90}Sr and ^{131}I. Values are from ICRP (1998)

ICRP age category	Dose coefficient for the indicated radionuclide and organ, Sv Bq^{-1}						
	^{90}Sr Bone Sur[a]	^{90}Sr Colon[b]	^{90}Sr Red marr[c]	^{90}Sr Thyroid	^{90}Sr Effective	^{137}Cs Colon	^{137}Cs Effective
3 mo	2.3×10^{-6}	1.2×10^{-7}	1.5×10^{-6}	1.2×10^{-8}	2.3×10^{-7}	3.8×10^{-8}	2.1×10^{-8}
1 y	7.3×10^{-7}	8.9×10^{-8}	4.2×10^{-7}	5.5×10^{-9}	7.3×10^{-8}	2.3×10^{-8}	1.2×10^{-8}
5 y	6.3×10^{-7}	4.5×10^{-8}	2.7×10^{-7}	2.9×10^{-9}	4.7×10^{-8}	1.5×10^{-8}	9.6×10^{-9}
10 y	1.0×10^{-6}	2.6×10^{-8}	3.7×10^{-7}	1.8×10^{-9}	6.0×10^{-8}	1.3×10^{-8}	1.0×10^{-8}
15 y	1.8×10^{-6}	1.5×10^{-8}	4.9×10^{-7}	1.1×10^{-9}	8.0×10^{-8}	1.5×10^{-8}	1.3×10^{-8}
Adult	4.1×10^{-7}	1.3×10^{-8}	1.8×10^{-7}	6.6×10^{-10}	2.8×10^{-8}	1.5×10^{-8}	1.3×10^{-8}

[a] Bone surface
[b] Weighted mass average of dose coefficients for the lower and upper large intestine
[c] Red bone marrow

Age groups. Doses were calculated on a county-by-county basis for adults and for an individual who was born on 1 January 1951.

Dose from ^{131}I

For ^{131}I calculations were also based on eqn (1). Beck (2000) did not provide county-by-county estimates of deposition density for ^{131}I, as more analysis would be required beyond that possible for this feasibility study. Rather, rough estimates of deposition density were provided on a population-weighted basis for the entire country. As for ^{90}Sr and ^{137}Cs, monthly averages of age-dependent integrated intake values were derived from Whicker and Kirchner (1987). The values used in this study are shown in Fig. 5. Dose coefficients were taken from the ICRP (1998); the values used are listed in Table 5. Calculations were made for adults and for individuals born on 1 January in each of the years from 1951 through 1963. In addition, because the dose from ingestion of ^{131}I varies strongly with age, per caput values of dose were calculating by considering the age distribution of the population in 1960 and by calculating a population-weighted average value of dose. For the latter calculation, age-dependent values of integrated intake and dose coefficients were used.

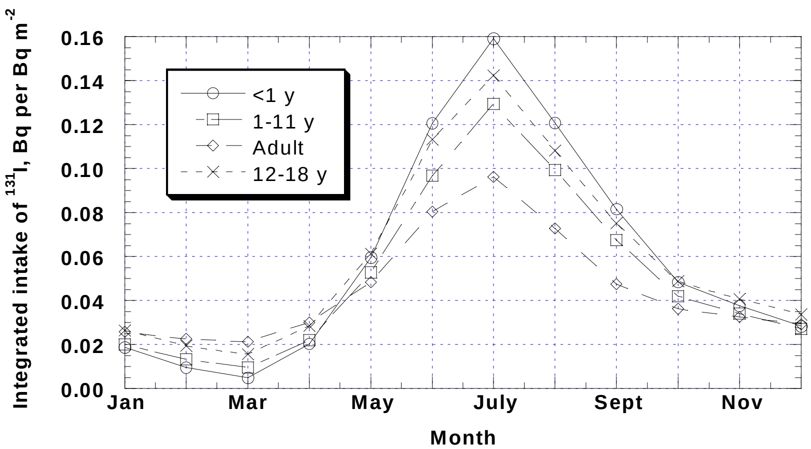


Fig. 5. Monthly average values of integrated intake for four age groups for ^{131}I. Data were derived from Whicker and Kirchner (1987).

Table 5. Age-dependent dose coefficients for ^{131}I used in this study for members of the public. Values are from ICRP (1998)

ICRP age category	Dose coefficient for ^{131}I for the indicated organ, Sv Bq^{-1}				
	Bone surface	Colon	Red marrow	Thyroid	Effective
3 mo	6.1×10^{-10}	2.6×10^{-9}	5.2×10^{-10}	3.7×10^{-6}	1.8×10^{-7}
1 y	4.4×10^{-10}	1.5×10^{-9}	3.7×10^{-10}	3.6×10^{-6}	1.8×10^{-7}
5 y	2.8×10^{-10}	6.5×10^{-10}	2.2×10^{-10}	2.1×10^{-6}	1.0×10^{-7}
10 y	1.9×10^{-10}	2.8×10^{-10}	1.6×10^{-10}	1.0×10^{-6}	5.2×10^{-8}
15 y	1.4×10^{-10}	1.5×10^{-10}	1.2×10^{-10}	6.8×10^{-7}	3.4×10^{-8}
Adult	1.3×10^{-10}	1.2×10^{-10}	1.0×10^{-10}	4.3×10^{-7}	2.2×10^{-8}

Dose from ^{3}H and ^{14}C

Doses for these two globally dispersed radionuclides were calculated on the basis of the specific activity approach. As the fusion yield in the northern hemisphere is an important input to the calculation for both radionuclides, the data shown in Table 1 were used as input values. Another important input is the amount of ^{3}H and ^{14}C created per Mt of fusion. UNSCEAR (1993) gives a value of 740 PBq Mt^{-1} for ^{3}H; a reasonable estimate for ^{14}C is 0.85 PBq Mt^{-1}.

Doses from ^{3}H were calculated with use of the NCRP (1979) model; a rough estimate can also be made on the basis of the estimated natural production rate of 37 PBq per y per hemisphere and the measured concentrations of ^{3}H in surface waters. The annual absorbed dose in tissue from naturally occurring ^{3}H was derived in UNSCEAR (1982) to be 10 nSv. Based upon these values a rough estimate of the average dose commitment from ^{3}H is

$$240\,\text{Mt} \times 740\,\frac{\text{PBq}}{\text{Mt}} \times 10\,\frac{\text{nSv}}{\text{y}} \times \frac{1}{37}\,\frac{\text{y}}{\text{PBq}} = 48{,}000\,\text{nSv} \quad . \tag{2}$$

However, this result does not provide any information on how this dose might be delivered over time. Use of the NCRP (1979) model provides a more sophisticated approach that simulates the world's hydrological cycle through the use of seven compartments, which consist of atmospheric water, surface soil water, deep groundwater, surface streams and fresh water lakes, saline lakes and inland seas, ocean surface, and the deep ocean. The use of the hydrological cycle is appropriate, as most of the ^{3}H released is in the form of tritiated water or is soon converted to that form (from HT) in soil. Calculations are then made by considering the specific activity of ^{3}H in the various water compartments and the rate of change among the compartments.

Example results from the NCRP (1976) model of the dose over time from the release of 1 PBq of ^{3}H to the northern hemisphere are shown in Fig. 6. The annual dose falls off rapidly with time due to the mixing of the released ^{3}H into the larger compartments. The summary result of the data shown in Fig. 6 is that the release of 1 PBq of ^{3}H to the atmosphere in the northern hemisphere would result in a dose of 0.38 nSv to each person living in the hemisphere. The latter result is consistent with the value computed from eqn (2) of 0.27 nSv with consideration of the substantial uncertainty in both results.

The dose from the release of ^{14}C can be assessed in a rather similar way, although the carbon cycle is much more complicated. From UNSCEAR (1982, 1993) the natural production rate of ^{14}C is roughly 1 PBq y^{-1}, and the resulting equilibrium specific activity produces an annual effective dose of about 12 μSv. A calculation similar to that of eqn (2) could be made, but it would be potentially misleading due to the very long half life of ^{14}C and the very long time (more than one individual's life time) to achieve equilibrium. Thus, in order to calculate doses over the first 50 y from the release of ^{14}C, a compartment model for the global circulation of carbon was used. The model chosen is that of Titley et al. (1995), which is the latest model that has been widely accepted and which builds upon previously accepted models. The Titley et al. model is complicated and contains 23 compartments with separate compartments of two to four layers in each ocean. Carbon is considered to be in the form of CO_2, which is the form that enters the food chain. The model takes into account temperature changes, photosynthesis in the surface layers of the oceans, and transfer of carbon down the water column.

Example results of model calculations are shown in Fig. 7, which is a plot showing the annual doses from the release of 1 PBq of ^{14}C to the northern hemisphere. The summary result of the data shown in Fig. 7 is that the release of 1 PBq of ^{14}C to the atmosphere of the northern hemisphere would result in a dose of 0.7 μSv to each person living in the hemisphere over the following 50 y.

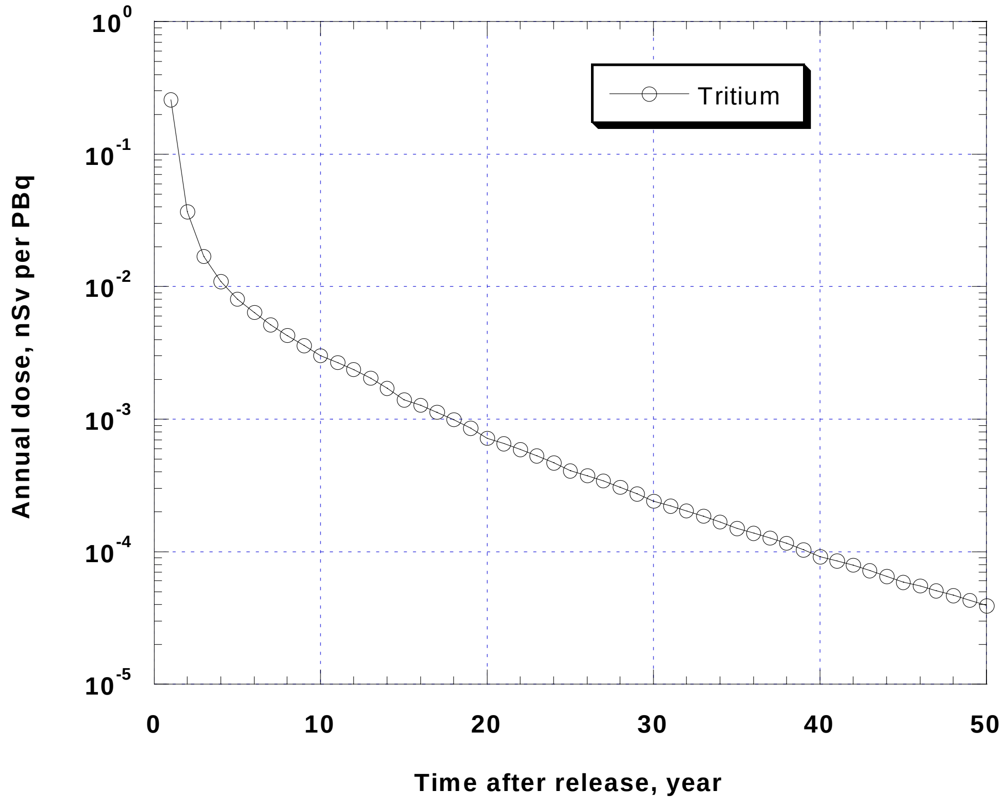


Fig. 6. Annual dose as a function of time following the release of 1 PBq of ^{3}H to the atmosphere of the northern hemisphere. Results are based upon the NCRP (1979) model of tritium in the hydrological cycle.

These model results for ^{3}H and ^{14}C are approximate, and no attempt has been made to derive age-dependent values. This is broadly appropriate for these two radionuclides and any other beta-emitting radionuclide that can be assessed using a specific activity approach. Also, as both radionuclides are distributed throughout the body, all organ and effective dose coefficients are presumed to be numerically equal.

Collective dose

Collective doses were also calculated. For ^{90}Sr and ^{137}Cs for which results were available on a county-by-county basis, the adult dose for each county was multiplied by its 1954 population with data supplied by Beck (2000) to give a county specific collective dose for each year (1953–1972). The use of adult doses for this calculation tends to underestimate the true collective dose; however, for ^{90}Sr and ^{137}Cs this effect is not as significant as it is for ^{131}I. Collective doses for each county were also summed to give a collective dose for each year. Finally, doses for all years were also summed to give the total collective dose to the 48 contiguous states.

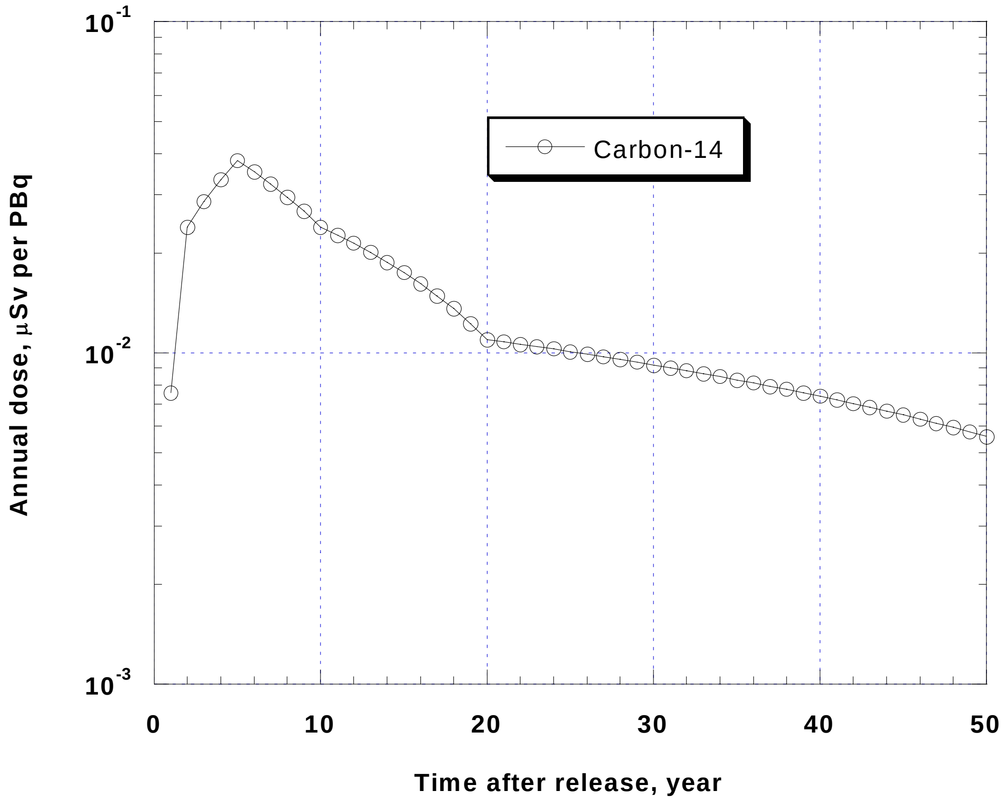


Fig. 7. Annual effective dose following the release of 1 PBq of ^{14}C to the atmosphere of the northern hemisphere. Results are based upon the model of Titley et al. (1995).

For ^{131}I deposition values were not available on a county-by-county basis, but on a population-weighted basis for the entire country. Collective doses were calculated by using the same procedure as mentioned in a previous section for per caput doses. That is, calculations were made with consideration of the age distribution of the population and appropriate values of age-dependent integrated intake and dose coefficient.

For ^{3}H and ^{14}C rough estimates of individual doses were calculated on a country-average basis; such values do not have an age dependence. Collective doses were calculated by simply multiplying the individual doses for the country by the country population in 1954.

RESULTS AND DISCUSSION

The results of the calculations made for this project are provided on a CD that accompanies this report. Information on the CD is organized as follows:

- There is one folder labeled "SrCs" that contains 21 workbooks; 20 are labeled GB1953 through GB1972 and one is labeled GB53-72, which is a summary of the doses for the 20-y period. Each of the 20 workbooks for individual years contains two spreadsheets; the first is labeled "Sheet1" and contains county-by-county data for estimates of committed dose from ^{90}Sr and ^{137}Cs. Values are provided both for "adults" and for a person born on 1 January 1951. For ^{90}Sr estimates are provided for bone surface, colon, red marrow, thyroid, and effective dose; for ^{137}Cs estimates are provided for colon and effective doses. The second spreadsheet is labeled "Collective" and contains calculated values for collective dose on a county-by-county basis. In addition to data for the parameters indicated above, the sum of collective effective dose from both ^{90}Sr and ^{137}Cs is calculated. The summary workbook "GB53-72" contains similar data in two spreadsheets, but summarized over the entire period of the calculation.

- There is one spreadsheet labeled "GBLI131" that contains all calculations for dose from global fallout due to ^{131}I. Calculations are provided for bone surface, colon, red marrow, thyroid, and effective dose for adults and for persons born on 1 January in the years 1951 through 1963. Collective doses and per caput doses are provided on the same spreadsheet; such calculations were made using the fraction of the population falling into various age groups and appropriate values of age-dependent integrated intake and dose coefficient.
- A final spreadsheet is labeled "TritCarb" and contains estimates of dose for ^{3}H and ^{14}C. Doses are estimated on the basis of the inputs of fission yield from Table 1 and the time dependent annual dose factors from Figs. 6 and 7. Each year's input is tracked separately and summed for each individual year. The calculations extend through the year 2000.

The intent of the following material is to summarize the data contained on the CD in the files mentioned above.

Doses for individuals

^{90}Sr and ^{137}Cs. Estimates of committed dose are available on the CD-ROM for each county in the contiguous U.S.; values are provided for adults and for a person born on 1 January 1951. For ^{90}Sr estimates are given for dose to the bone surface, colon, red marrow, and thyroid and for effective dose. For ^{137}Cs estimates are given for dose to the colon and for effective dose. Reasons for the selections of these organs are discussed in the Methods Section. Such large amounts of data are more easily summarized graphically. Figs. 8–23 provide representative results for three years[§] and the sum of committed doses for the entire 1953–1972 period. Figs. 8–11 are results for the 1955 year. Figs. 8 and 9 present doses to the red bone marrow from ^{90}Sr for an adult and for a person born on 1 January 1951. Figs. 10 and 11 present effective doses from ^{137}Cs for an adult and for a person born on 1 January 1951. This pattern is repeated for the years of 1959 and 1963; the doses were the highest for the latter year. Finally, Figs. 20–23 present doses for the two age groups to the red bone marrow from ^{90}Sr and effective dose from ^{137}Cs that are summed over the entire period of calculation (1953–1972).

The appearance of the maps in Figs. 8–23 is influenced by the choice of the dose ranges used for the display. There are five dose ranges used for each map, and these dose ranges were selected in the following way with Figs. 8 and 9 used as illustrations. First, all of the data for the committed dose to the selected organ (or effective dose) for the selected radionuclide for the

[§] The 1955, 1959, and 1963 years that are plotted represent local maxima in dose; the committed dose in 1963 (resulting largely from explosions in 1962) was the highest.

3071 counties for both the adult and the person born on 1 January 1951 were combined into a single file and sorted. For Figs. 8 and 9 this combined file represented the committed doses to the red bone marrow from ^{90}Sr for the adult and for the person born on 1 January 1951 for all 3071 counties. Then, 10% of the 6142 combined sorted doses were assigned the color blue (lower doses) for each map, 25% green, 30% yellow, 25% orange, and 10% red (higher doses). Examination of Figs 8 and 9 indicates several features.

First, it is clear that the higher committed doses from ^{90}Sr occurred to persons living in the eastern third of the country, although there are also “hot spots” in the Midwest, and in parts of California, Idaho, Oregon, and Washington. These areas of higher committed dose are related primarily to the amounts of rainfall that occurred in these locations. Second, comparison of the two figures indicates that a person born on 1 January 1951 received higher committed doses than a person who was an adult, although these doses are not greatly different. For Figs. 10 and 11 the same technique was used, except that committed effective doses due to ^{137}Cs are plotted. The same geographical pattern is evident, but in this case the dose to the person born on 1 January 1951 is lower than to the adult. Whether doses are higher or lower for a particular age group depends upon 1) the time of year when the fallout occurred, which in turn affects 2) the relative values of the age-dependent integrated intakes [see Figs. 1 and 2], and 3) the values of the age-dependent dose coefficients [Table 4].

The per caput doses over the entire period of analysis are summarized in Table 6 for adults and for a person born on 1 January 1951. In general, the doses calculated for a person born in 1951 from ^{90}Sr are two-three times higher than for the adult, but the doses from ^{137}Cs are essentially the same for the two age groups. The sum of effective doses from ^{90}Sr and ^{137}Cs is 170 μSv for the adult and 210 μSv for the person born in 1951.

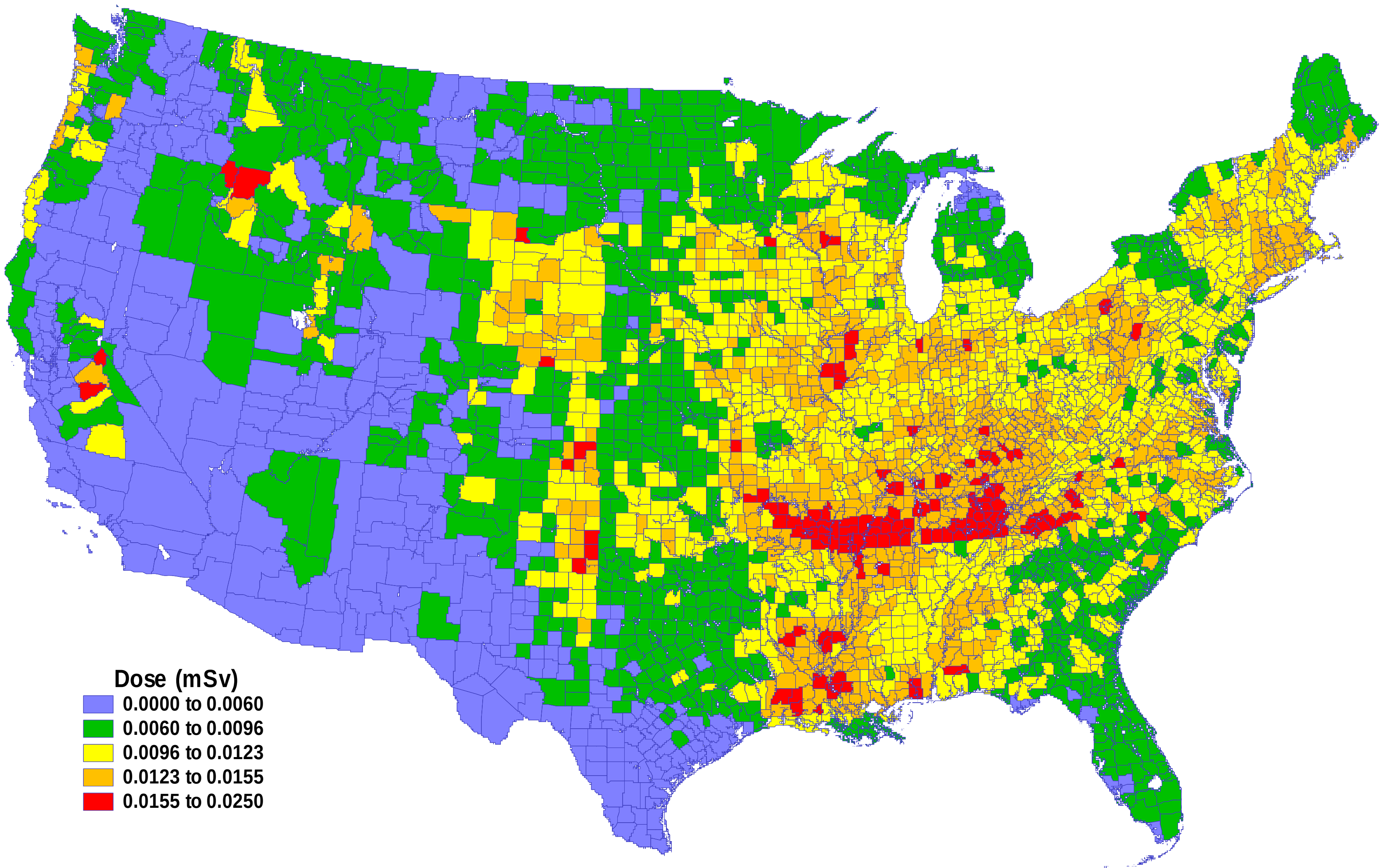


Fig. 8. Map of the committed dose (mSv) for an adult to the red bone marrow from ^{90}Sr deposited during 1955

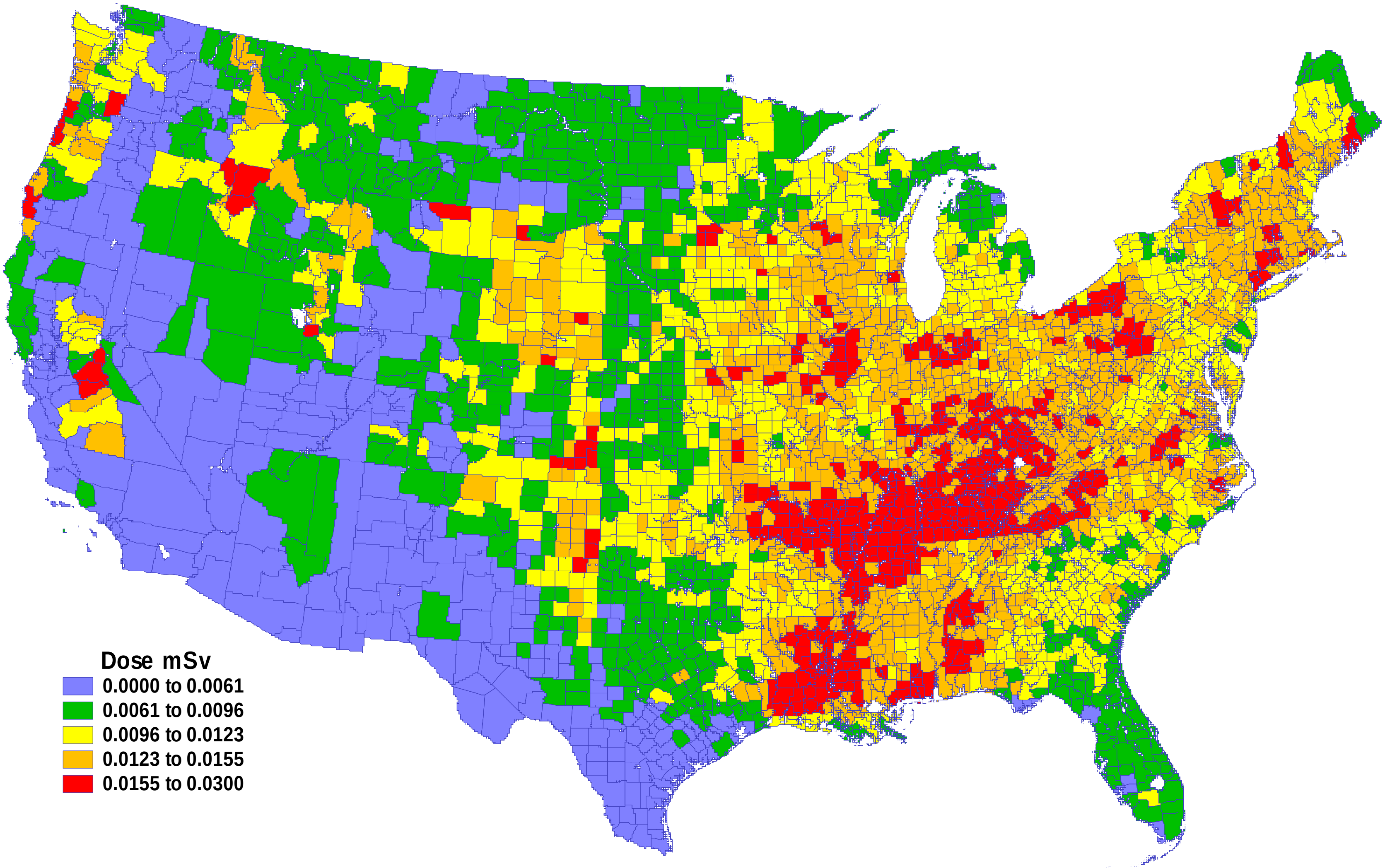


Fig. 9. Map of the committed dose (mSv) for a person born in 1951 to the red bone marrow from ^{90}Sr deposited during 1955.

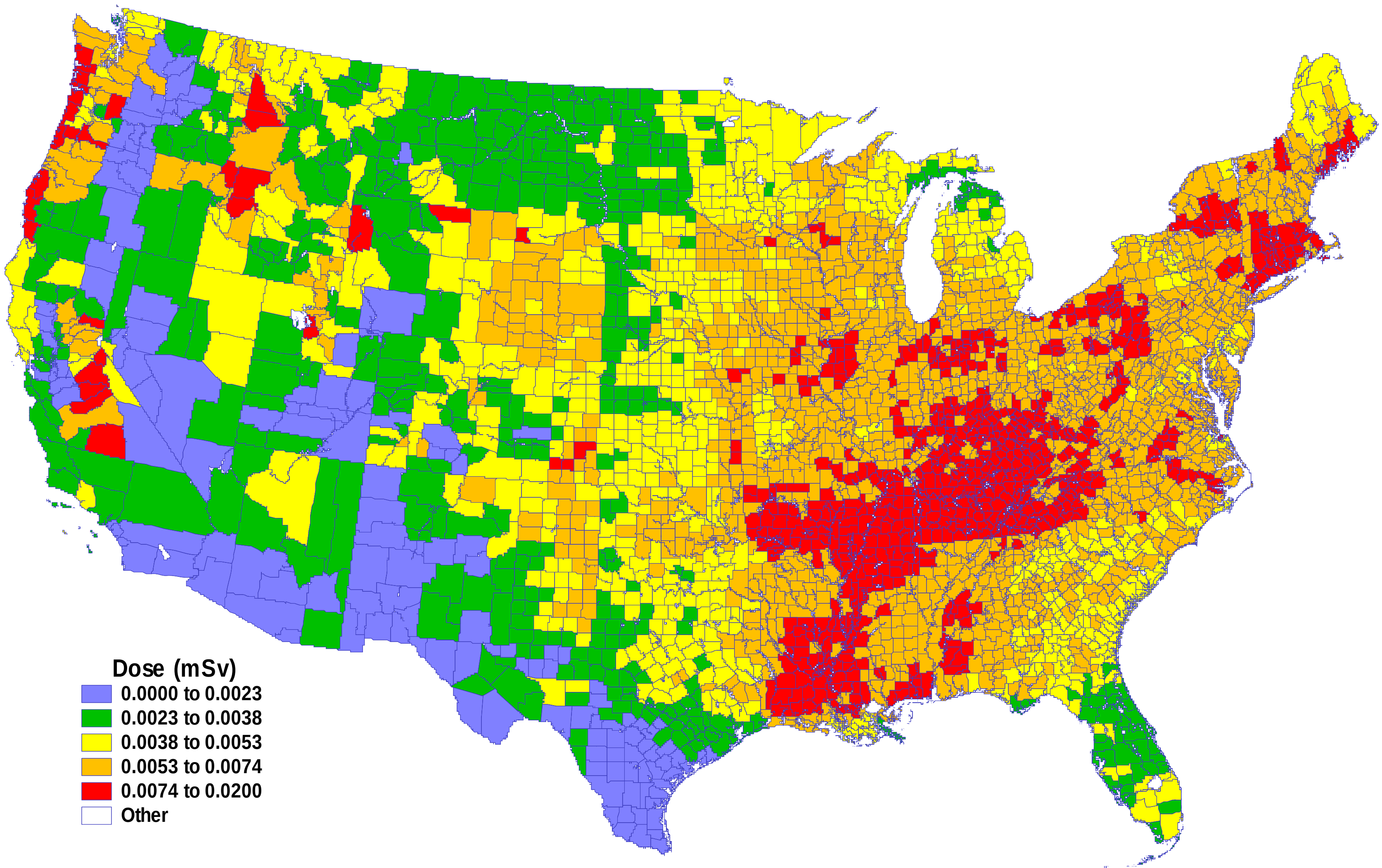


Fig. 10. Map of the committed effective dose (mSv) for an adult from ^{137}Cs deposited during 1955.

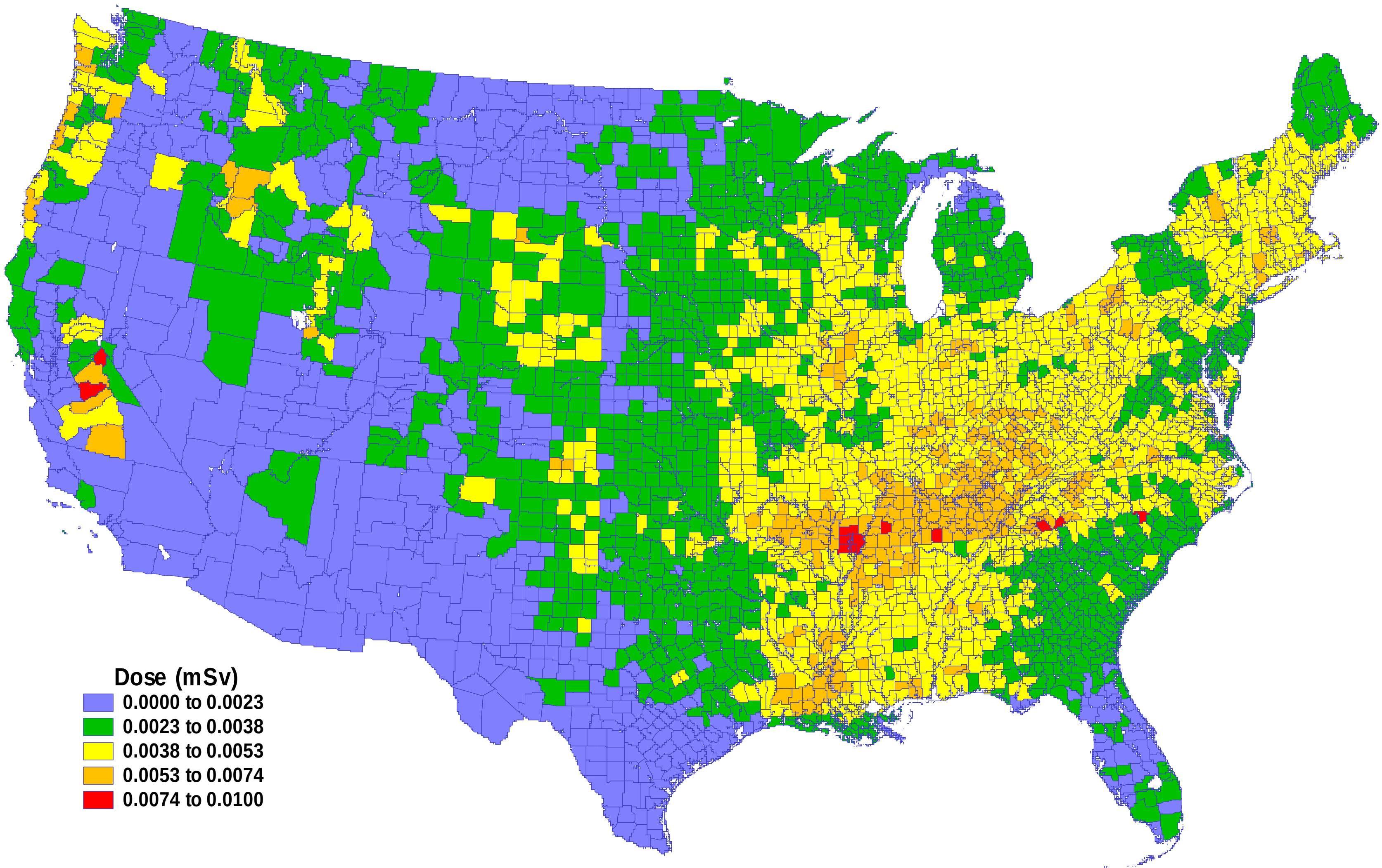


Fig. 11. Map of the committed effective dose (mSv) for a person born in 1951 from ^{137}Cs deposited during 1955.

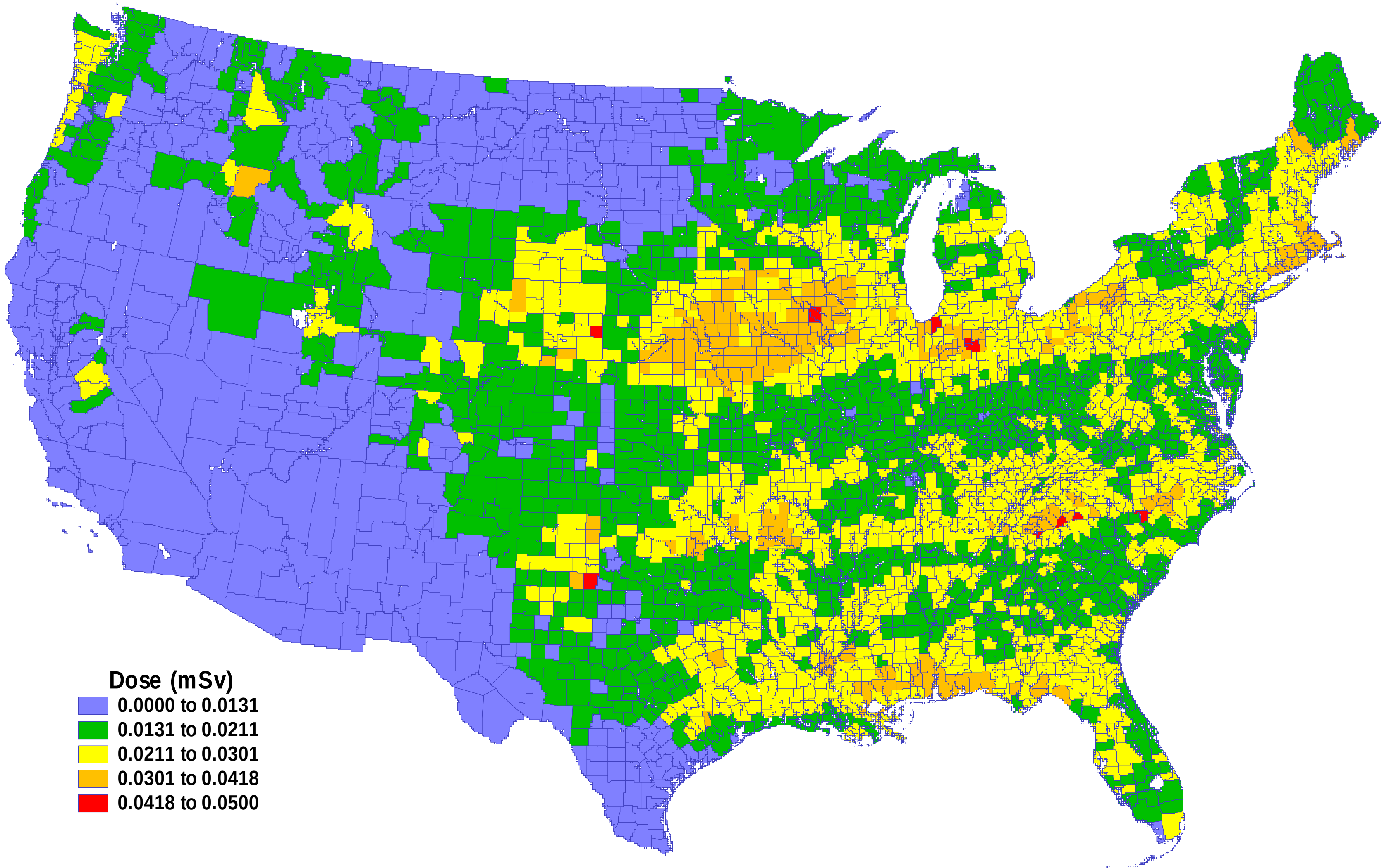


Fig. 12. Map of the committed dose (mSv) for an adult to the red bone marrow from ^{90}Sr deposited during 1959.

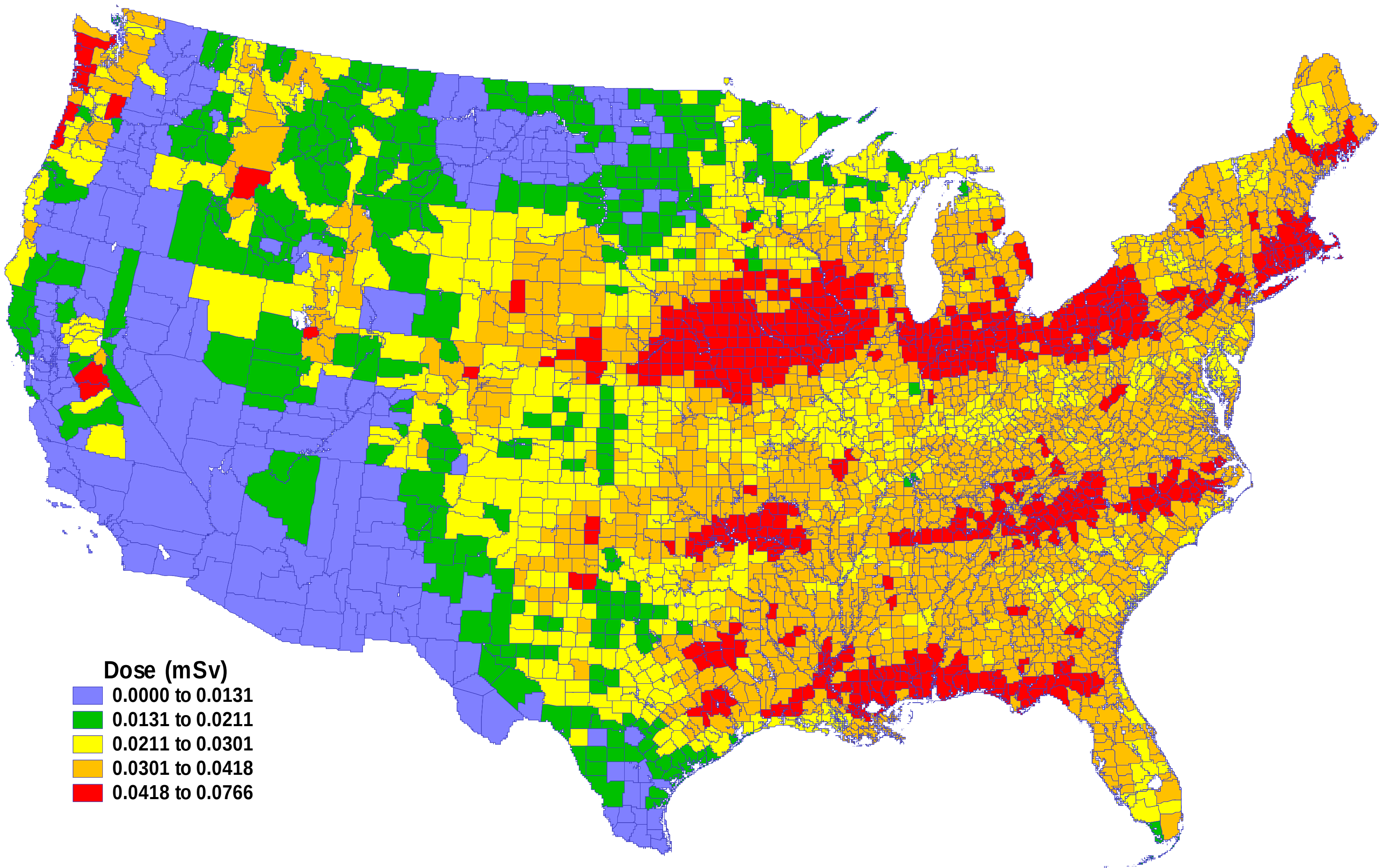


Fig. 13. Map of the committed dose (mSv) for a person born in 1951 to the red bone marrow from ^{90}Sr deposited during 1959.

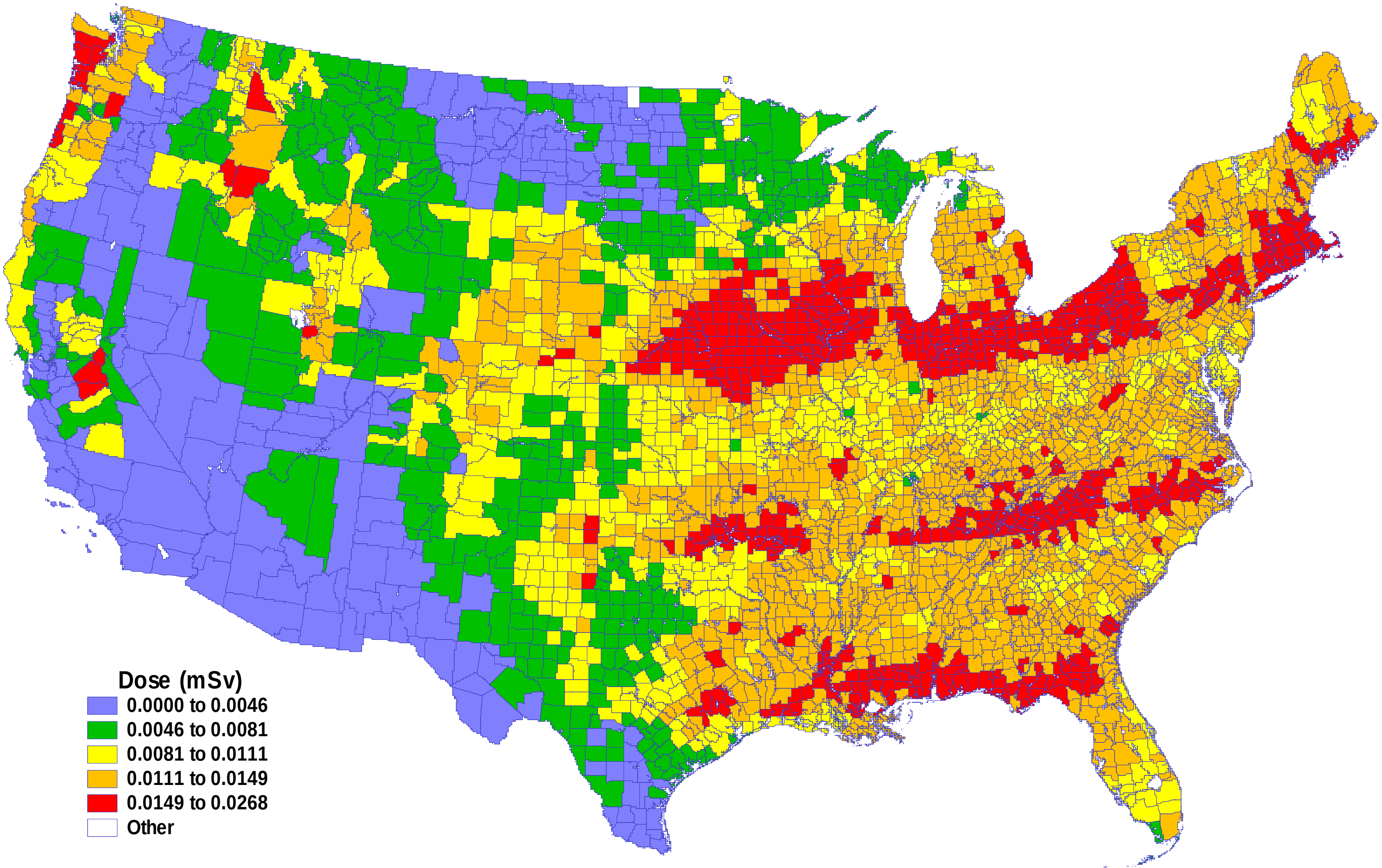


Fig. 14. Map of the committed effective dose (mSv) for an adult from ^{137}Cs deposited during 1959.

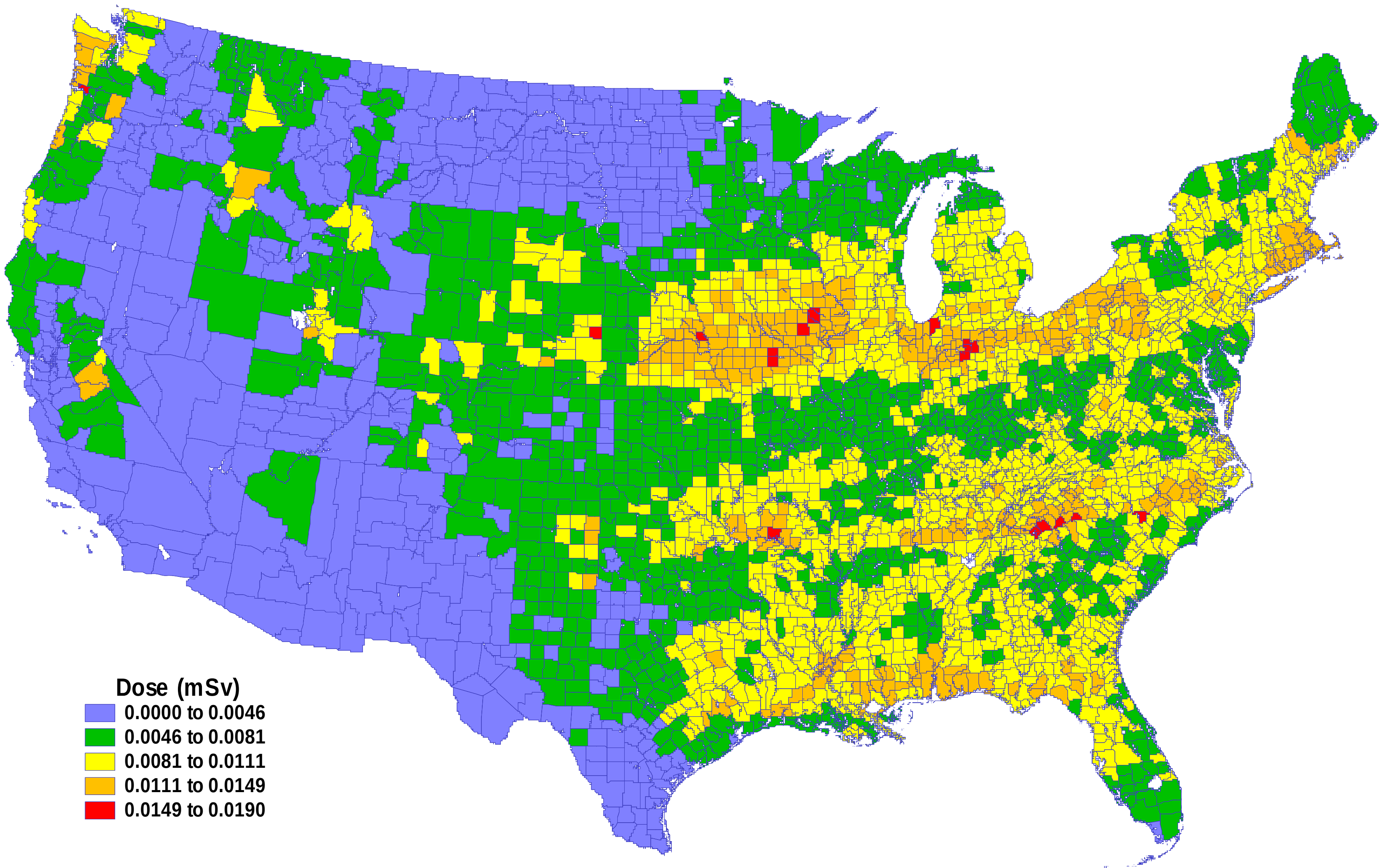


Fig. 15. Map of the committed effective dose (mSv) for a person born in 1951 from ^{137}Cs deposited during 1959.

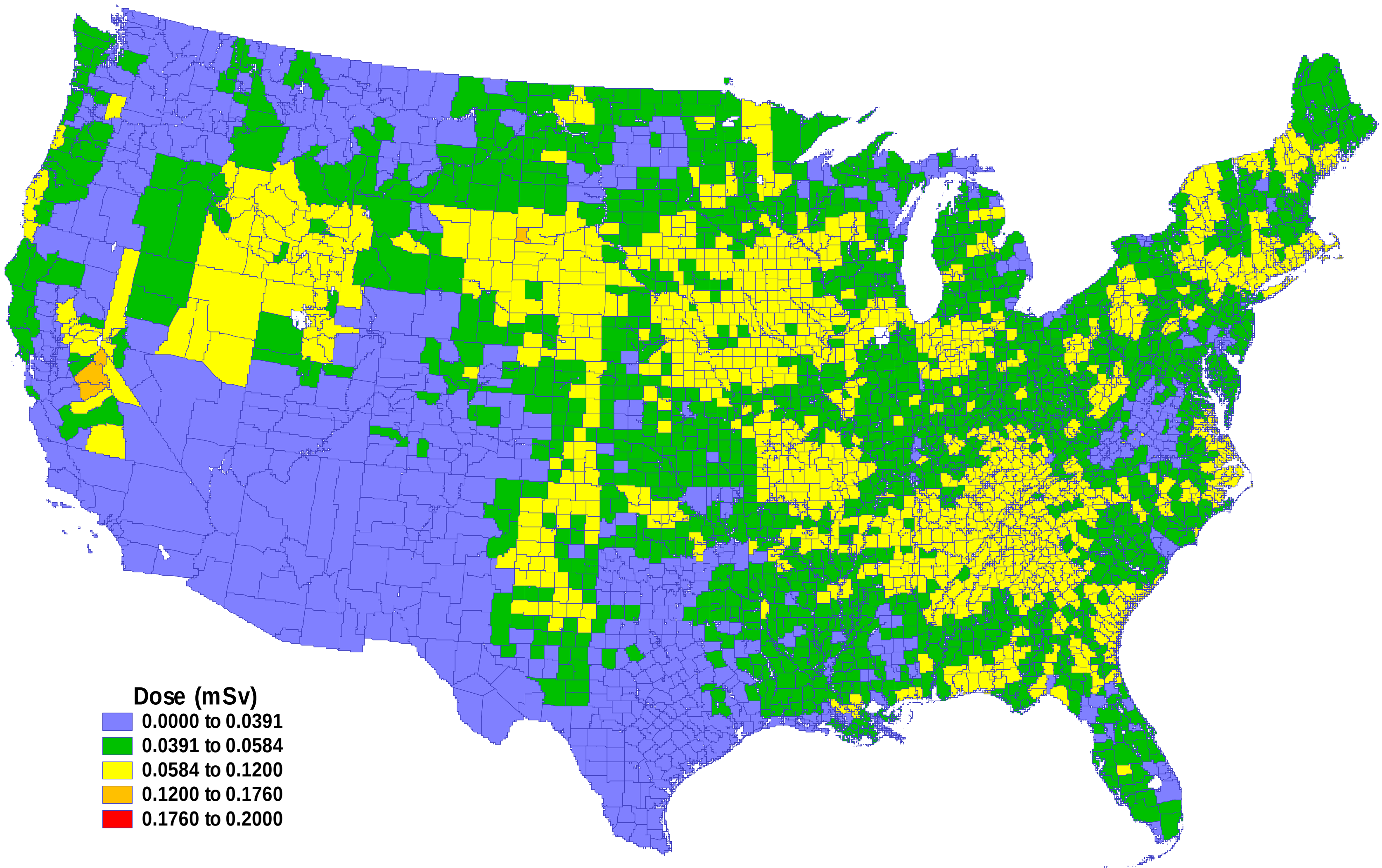


Fig. 16. Map of the committed dose (mSv) for an adult to the red bone marrow from ^{90}Sr deposited during 1963.

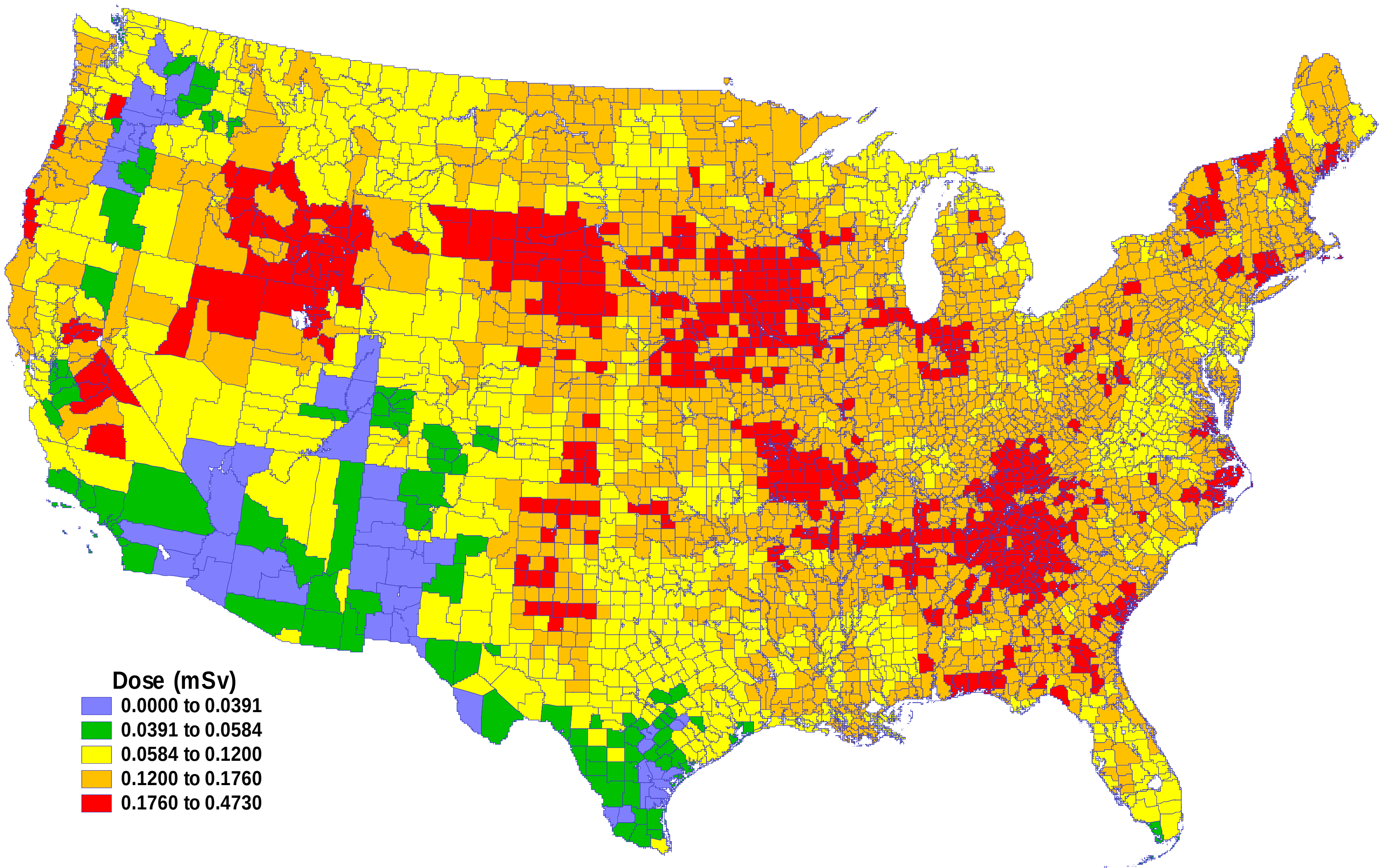


Fig. 17. Map of the committed dose (mSv) for a person born in 1951 to the red bone marrow from ^{90}Sr deposited during 1963.

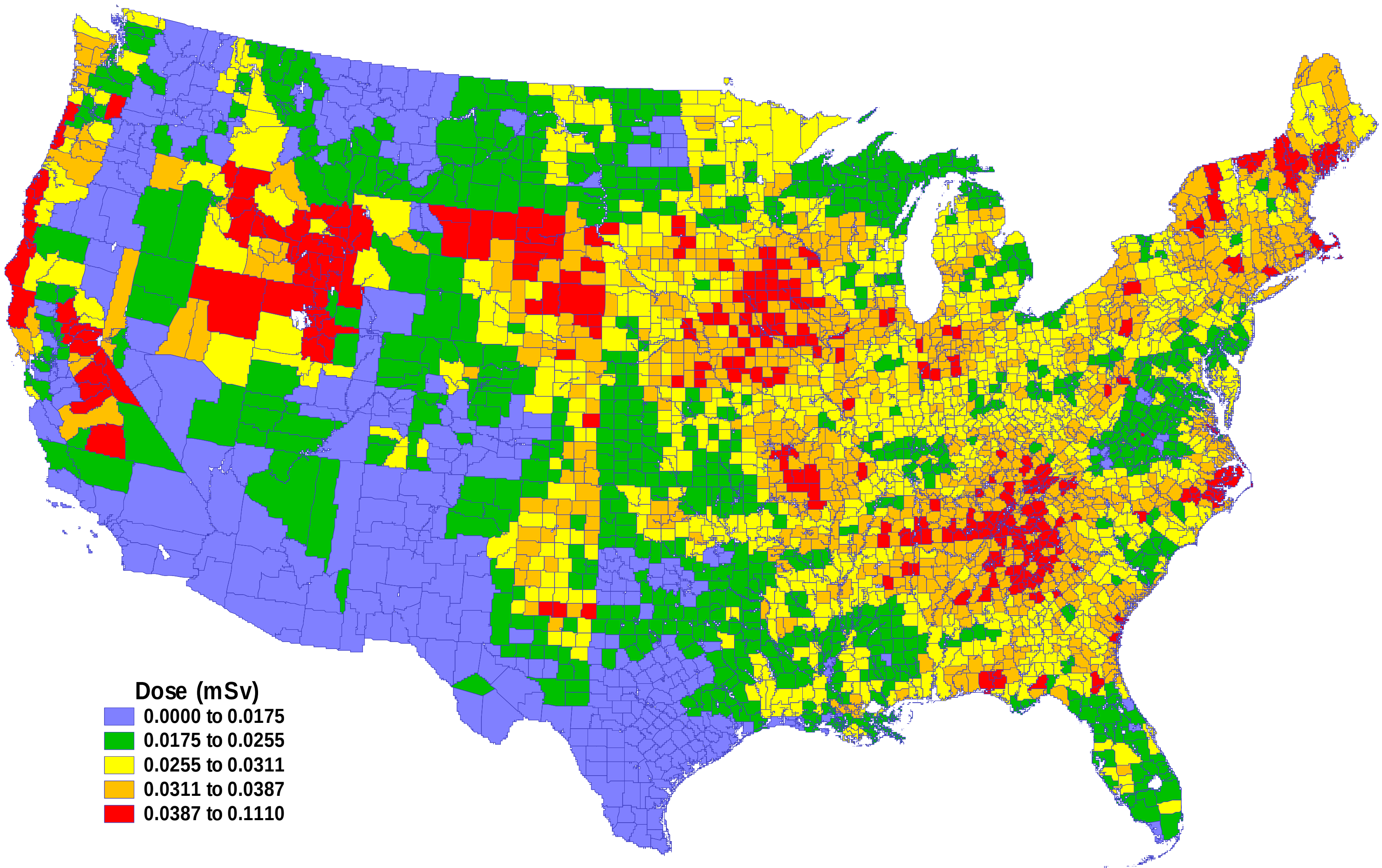


Fig. 18. Map of the committed effective dose (mSv) for an adult from ^{137}Cs deposited during 1963.

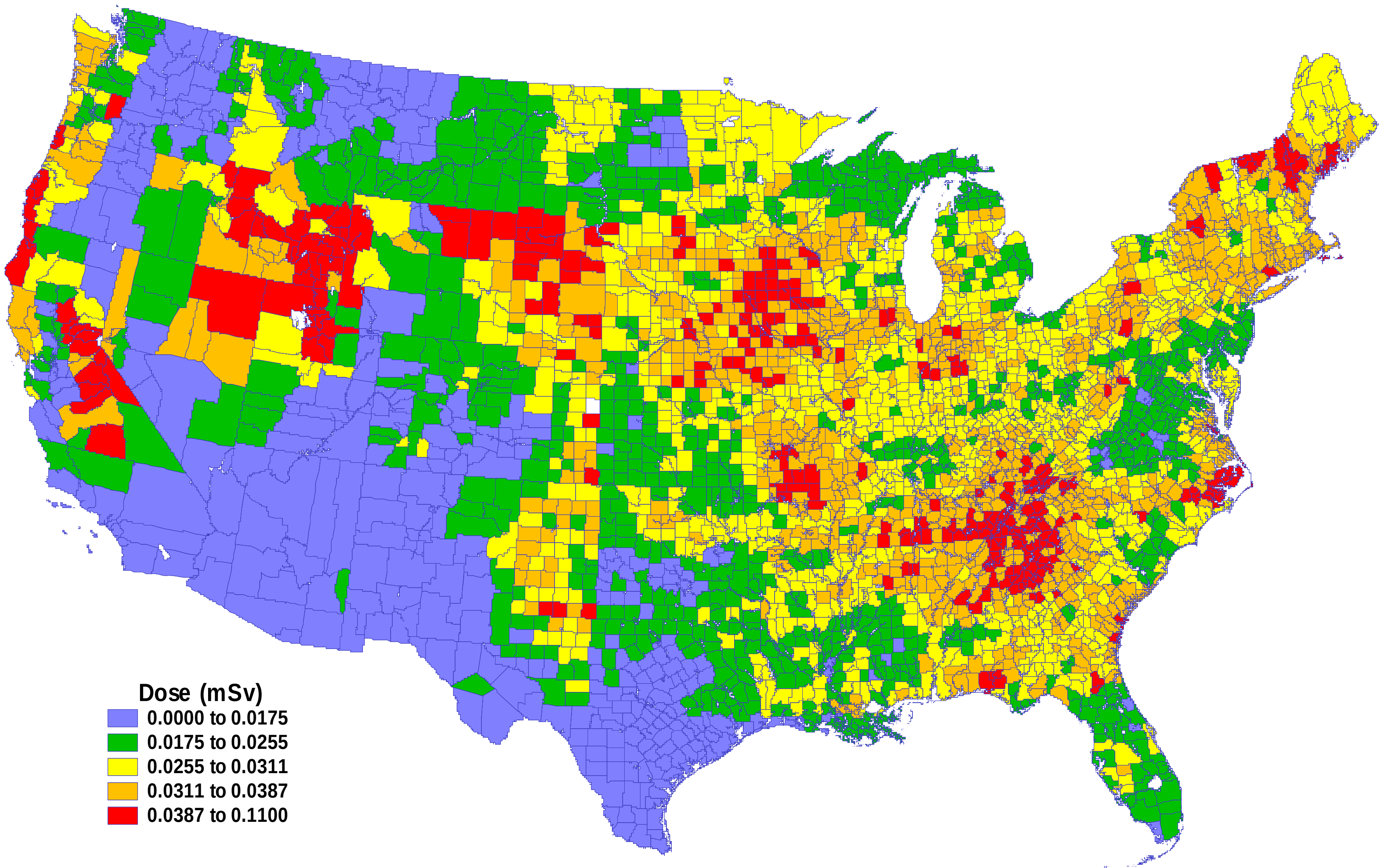


Fig. 19. Map of the committed effective dose (mSv) for a person born in 1951 from ^{137}Cs deposited during 1963.

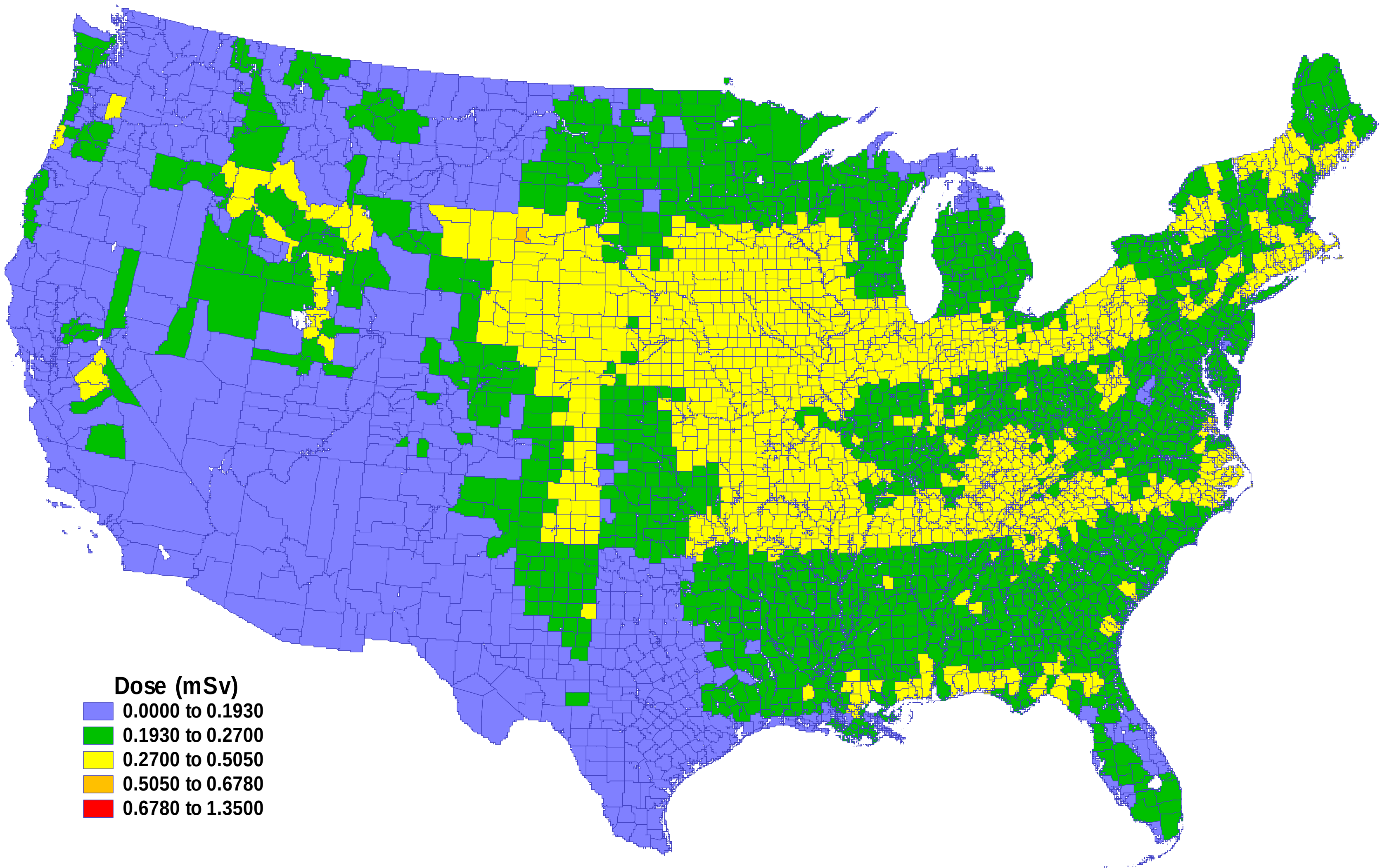


Fig. 20. Map of the committed dose (mSv) for an adult to the red bone marrow from ^{90}Sr deposited during 1953-1972.

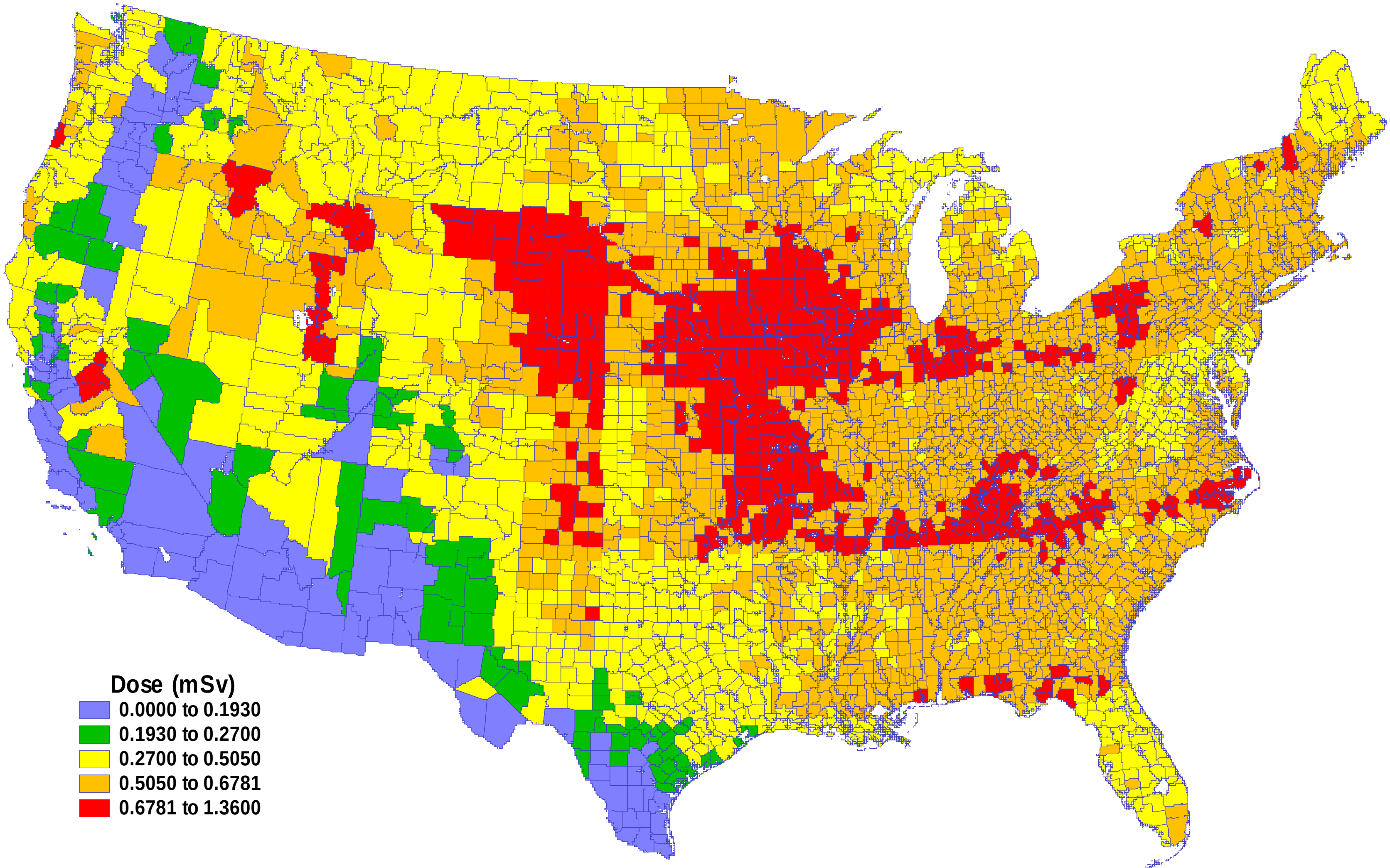


Fig. 21. Map of the committed dose (mSv) for a person born in 1951 to the red bone marrow from ^{90}Sr deposited during 1953-1972.

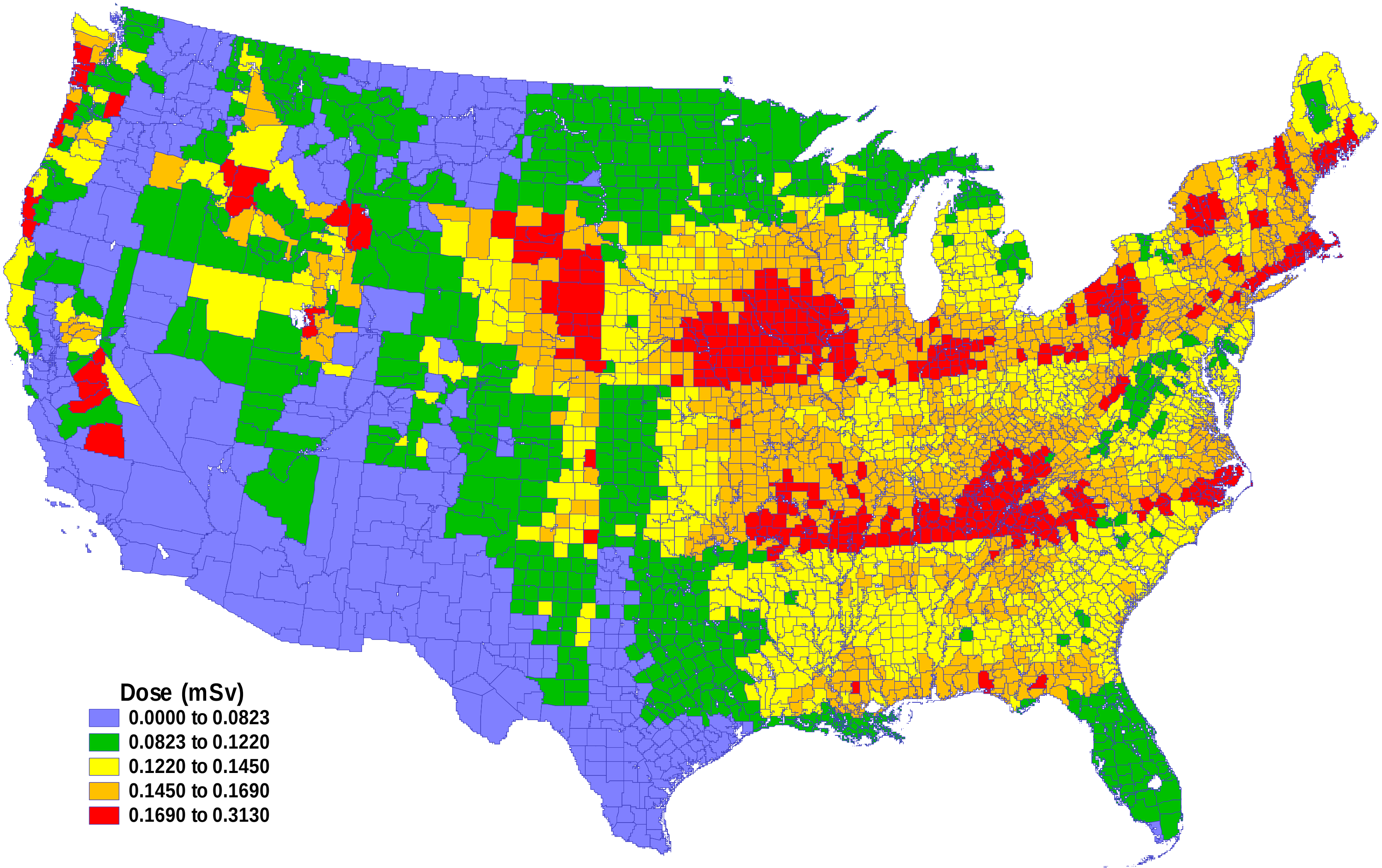


Fig. 22. Map of the committed effective dose (mSv) for an adult from ^{137}Cs deposited during 1953-1972.

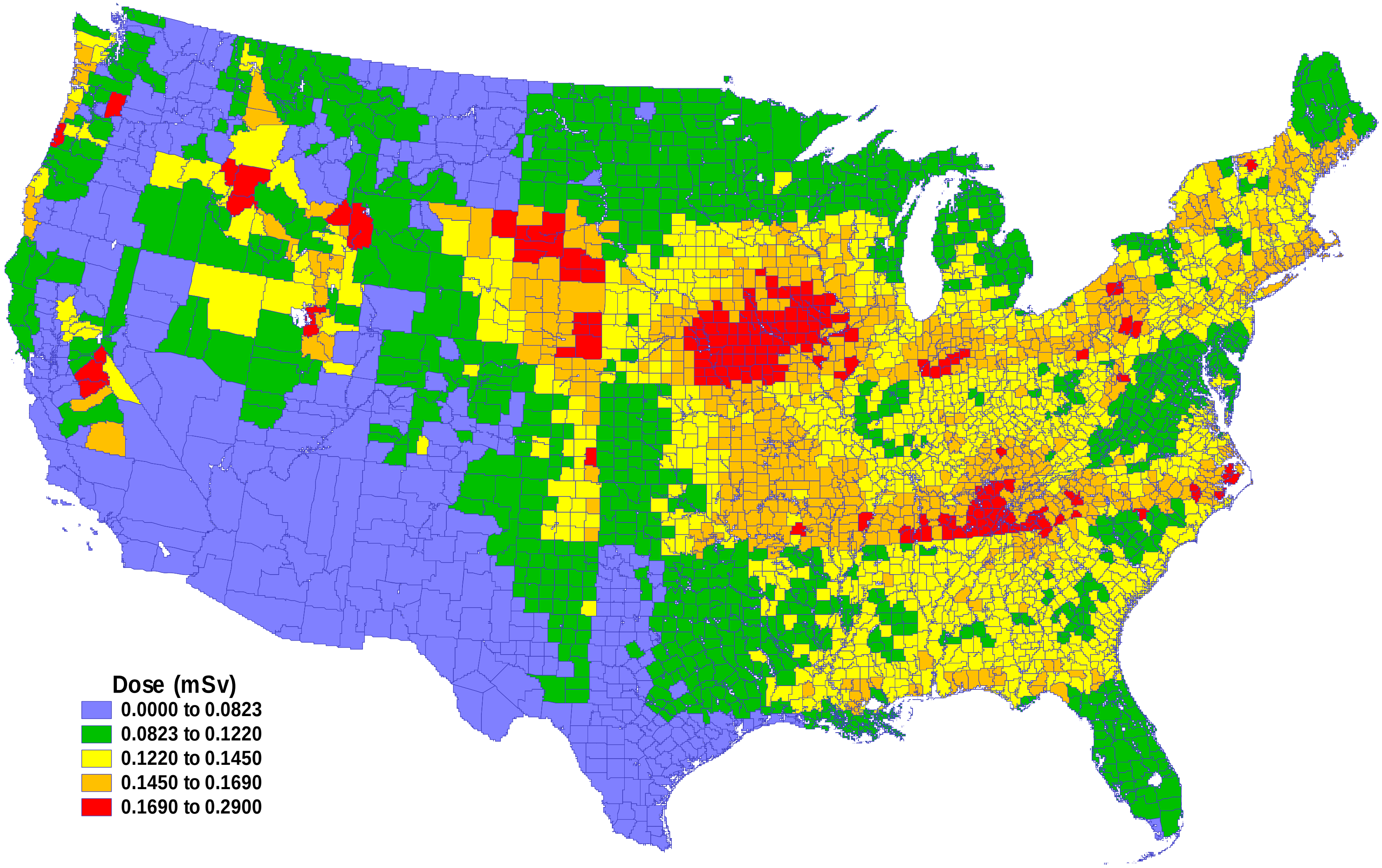


Fig. 23. Map of the committed effective dose (mSv) for a person born in 1951 from ^{137}Cs deposited during 1953-1972.

Table 6. Total per caput doses calculated for the 1953–1972 period from the deposition of ^{90}Sr and ^{137}Cs in global fallout. Upper values are for adults; lower values are for a person born on 1 January 1951. Values are averaged over the entire U.S.

Radionuclide	Individual organ or effective committed dose, μSv				
	Bone surface	Colon	Red marrow	Thyroid	Effective
	Adult				
^{90}Sr	540	17	240	0.86	37
^{137}Cs		160			130
	Person born on 1 January 1951				
^{90}Sr	1600	34	530	2.3	87
^{137}Cs		160			120

Another way of examining the committed doses for individuals is to look at the sum of effective doses from ^{90}Sr and ^{137}Cs on a county-by-county basis. Such values can be summed for each county over the entire period of 1953–1972. When this is done, the resulting highest dose of 380 μSv is found in Alpine County, California, and the lowest dose of 6.8 μSv occurred in Imperial County, California, a range of a factor of nearly 60. It is rather surprising that both the lowest and the highest doses occurred in the same state; however, the two counties differ markedly. Alpine County is in the Sierra Nevada Mountains and experiences a high amount of precipitation. Imperial County borders on Mexico and is shadowed by the mountains east of San Diego. Thus, it receives very little precipitation. A list of the 80 counties with the higher estimates of summed committed effective doses is given in Table 7.

One of the interesting features of Table 7 is that there are many counties with essentially the same estimated dose—this is to be expected given that global fallout is rather evenly dispersed and that the amount of annual precipitation is the most important factor in determining the amount of global fallout deposited in any one county. Another interesting feature is that the state with the highest number of counties in Table 7 is Iowa (22) followed by Tennessee (14) and North Carolina (11).

Counties with the lower estimates of dose are listed in Table 8. Again, it is noted that there is a large number of counties with essentially equal doses, which are lower than those in Table 7 due primarily to the low amounts of annual precipitation in these counties. The state with the highest number of occurrences in Table 8 is Texas (29) followed by California (12) and Washington (9). Three states–California, Oregon, and Utah–contain counties that occur on both lists. This is due to the highly diverse climatic conditions found in these three states.

Fig. 24 is a plot of the country-average sum of committed effective dose from ^{90}Sr and ^{137}Cs as a function of time for two age cohorts: adults in 1951 and those born on 1 January 1951. The influence of changing intake rates and dose coefficients with age is seen. The relative position of the two curves changes as the person born in 1951 ages and is assigned different intake rates and dose coefficients.

^{131}I. As mentioned above, it was not possible for Beck (2000) to provide estimates of ^{131}I deposition on a county-by-county basis for this feasibility study. Rather, estimates of deposition through time were provided as country-average values. Because the dose from ingestion of ^{131}I is strongly age dependent, dose estimates were calculated for adults and for persons born on 1 January of each of the years 1951 through 1963. The calculations of dose from ^{131}I were not extended through 1972, as was done for ^{90}Sr and ^{137}Cs; this is because testing ended in 1963, and ^{131}I is too short-lived to contribute to doses in the later years. All doses from the ingestion of ^{131}I were estimated on the basis of age- and season-dependent intake factors and age-dependent dose coefficients.

Table 7. Counties with higher estimates of total individual effective dose from ^{90}Sr and ^{137}Cs.

State	County	Dose, μSv	State	County	Dose, μSv
CA	Alpine	380	TN	Bradley	260
SD	Lawrence	350	IA	Black Hawk	260
CA	Tuolumne	350	IA	Linn	250
NC	Transylvania	320	SD	Custer	250
ID	Valley	310	NE	McPherson	250
CA	Mariposa	310	IA	Dallas	250
NC	Richmond	290	UT	Weber	250
NC	Polk	280	NC	Yancey	250
ID	Adams	280	IA	Marshall	250
NC	Macon	280	IA	Delaware	250
NC	Clay	280	IA	Lucas	250
SD	Pennington	270	IA	Story	250
ID	Fremont	270	IA	Audubon	250
NE	Logan	270	IN	Montgomery	250
NE	Thomas	270	MO	Harrison	250
ID	Boise	270	IN	Fountain	250
TN	Sequatchie	270	IN	Warren	250
IA	Taylor	270	IA	Dubuque	250
IA	Iowa	270	IA	Louisa	250
NC	Cherokee	270	IA	Tama	250
NC	Graham	260	WY	Teton	250
TN	Marion	260	IA	Mahaska	250
TN	Grundy	260	TN	Hamilton	250
VT	Lamoille	260	MO	Atchison	250
MO	Worth	260	TN	Mcminn	250
MO	Nodaway	260	MO	Gentry	250
NE	Hooker	260	NE	Pawnee	250
NE	Nemaha	260	NC	Greene	250
NE	Richardson	260	NC	Lenoir	250
IA	Montgomery	260	IA	Franklin	250
UT	Salt Lake	260	IA	Shelby	250
IA	Page	260	MO	Holt	250
NC	Swain	260	MO	Putnam	250
TN	Bledsoe	260	IA	Benton	250
OR	Lincoln	260	TN	Scott	250
TN	Meigs	260	IA	Monroe	250
TN	Rhea	260	WY	Crook	250
TN	Van Buren	260	TN	Chester	250
IA	Jones	260	TN	McNairy	250
IA	Adair	260	TN	Hardin	240

Table 8. Counties with lower estimates of total individual effective dose from ^{90}Sr and ^{137}Cs.

State	County	Dose, μSv	State	County	Dose, μSv
CA	Imperial	6.8	WA	Franklin	52
AZ	Yuma	14	TX	Hudspeth	52
OR	Sherman	31	NM	Hidalgo	52
AZ	Maricopa	31	WA	Adams	52
OR	Gilliam	31	TX	Hidalgo	52
OR	Wasco	33	UT	Grand	52
TX	Presidio	35	NM	San Juan	53
NV	Clark	36	TX	Culberson	53
WA	Yakima	37	NM	Sierra	53
TX	El Paso	38	TX	Zavala	54
OR	Jefferson	38	CA	Orange	54
OR	Deschutes	38	TX	Live Oak	54
CA	Riverside	40	TX	Kleberg	54
NM	Dona Ana	40	NV	Esmeralda	55
CA	Merced	40	WA	Island	55
TX	Zapata	41	CO	Costilla	55
WA	Benton	42	CA	Santa Barbara	56
NM	Valencia	43	TX	Brooks	56
WA	Grant	44	TX	Kenedy	56
NM	Luna	44	AZ	Graham	56
AZ	Pinal	44	WA	Douglas	57
CA	Lassen	44	TX	Val Verde	57
TX	Brewster	45	TX	Jim Wells	57
TX	Jim Hogg	47	TX	Cameron	57
OR	Crook	47	TX	Nueces	57
WA	Klickitat	48	CO	Rio Grande	57
AZ	Pima	48	TX	Atascosa	58
CA	San Joaquin	48	TX	Willacy	58
TX	Webb	48	TX	Uvalde	59
TX	Starr	48	NM	Catron	59
TX	Duval	49	TX	Loving	59
OR	Wheeler	50	CA	San Diego	60
OR	Lake	50	UT	Wayne	60
CA	San Benito	50	CO	Conejos	60
NM	Socorro	50	TX	Frio	60
CA	Stanislaus	50	CA	Modoc	61
TX	Dimmit	51	UT	San Juan	61
WA	Chelan	51	CA	Inyo	61
TX	Mcmullen	51	AZ	Santa Cruz	62
TX	La Salle	51	TX	San Patricio	63

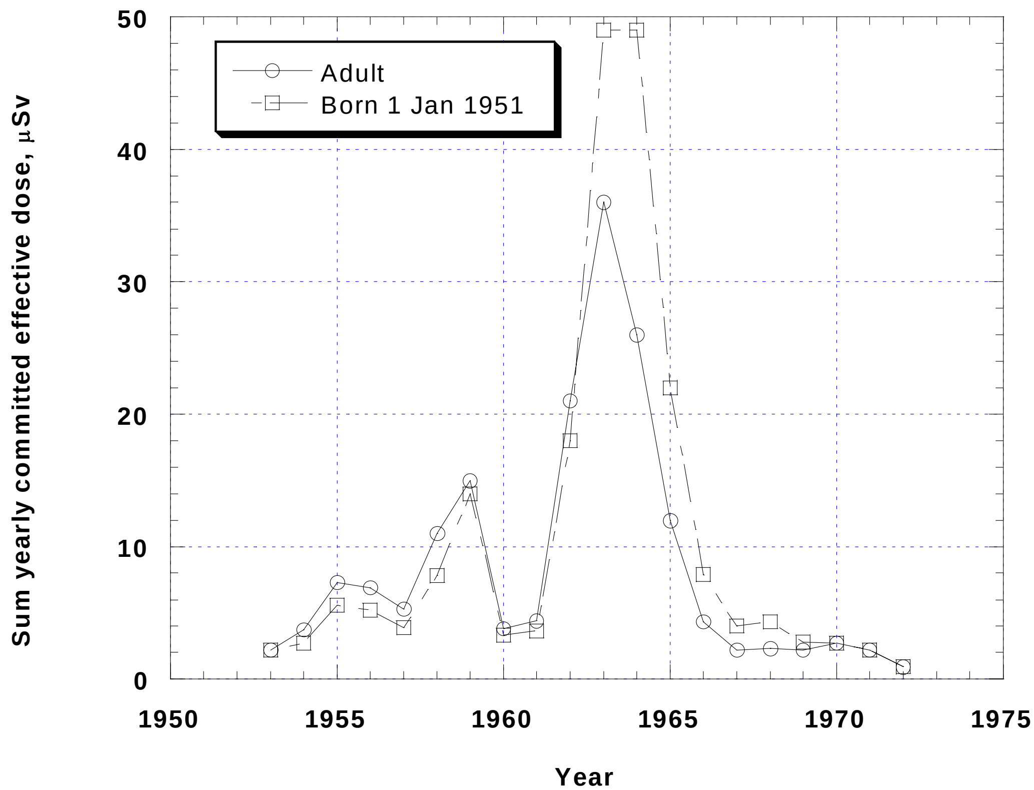


Fig. 24. Plot of the sum of committed effective doses from ^{90}Sr and ^{137}Cs as a function of time for two cohorts: those who were adults in 1951 and those born on 1 January 1951. Most of the variation in the doses between the two cohorts is due to changes in intake rates and in strontium metabolism as the young person ages.

The complete set of calculations of dose from the ingestion of ^{131}I is available on the CD-ROM in the workbook entitled "GBLI131." The year-by-year estimates of per caput bone surface, colon, red marrow, thyroid, and effective dose are summarized in Table 9. As expected, due to the accumulation of iodine in the thyroid, the dose to this organ is the highest at 960 μSv and the effective dose is less by a factor of 20.

The estimates of yearly per caput thyroid dose, along with thyroid doses to the adult and a person born on 1 January 1951, are plotted in Fig. 25. As the person born on 1 January 1951 ages, s/he was assigned the appropriate age-dependent intakes and dose coefficients with time. As indicated, the dose to the young person is substantially higher than the per caput dose and the dose to the adult is substantially lower than the per caput dose. The combined effects on cumulative dose of birth year and of the amount of fallout experienced during a particular year are illustrated in Fig. 26 for persons born on 1 January in the years 1951 through 1963. The highest dose was received by a person born on 1 January 1956. Such a person would have received a substantial dose at a young age from the relative peak of fallout in 1957 and would have still been young enough to have both a high intake and a high dose coefficient for the highest yearly amount of ^{131}I in fallout in

1962. The person born on 1 January 1951 received less dose, because by the time of the fallout peak in 1962 s/he was older and would have experienced less intake and had a lower dose coefficient.

Table 9. Year-by-year estimates of per caput dose from the ingestion of ^{131}I in fallout from high-yield weapons tests in the atmosphere. The estimates below are country averages, as reliable estimates of deposition on a county-by-county basis are not yet available.

Year	Per caput organ or effective dose, μSv				
	Bone surface	Colon	Red marrow	Thyroid	Effective
1953	0.0023	0.0045	0.0019	12	0.62
1954	0.011	0.020	0.0088	56	2.8
1955	0.00026	0.00046	0.00021	1.3	0.066
1956	0.031	0.059	0.025	170	8.2
1957	0.021	0.040	0.017	110	5.6
1958	0.044	0.083	0.036	230	12
1959	0.000021	0.000035	0.000017	0.10	0.0051
1960	0	0	0	0	0
1961	0.011	0.020	0.0088	58	2.9
1962	0.062	0.11	0.050	320	16
1963	0.00024	0.00040	0.00019	1.2	0.059
Sum	0.18	0.34	0.15	960	48

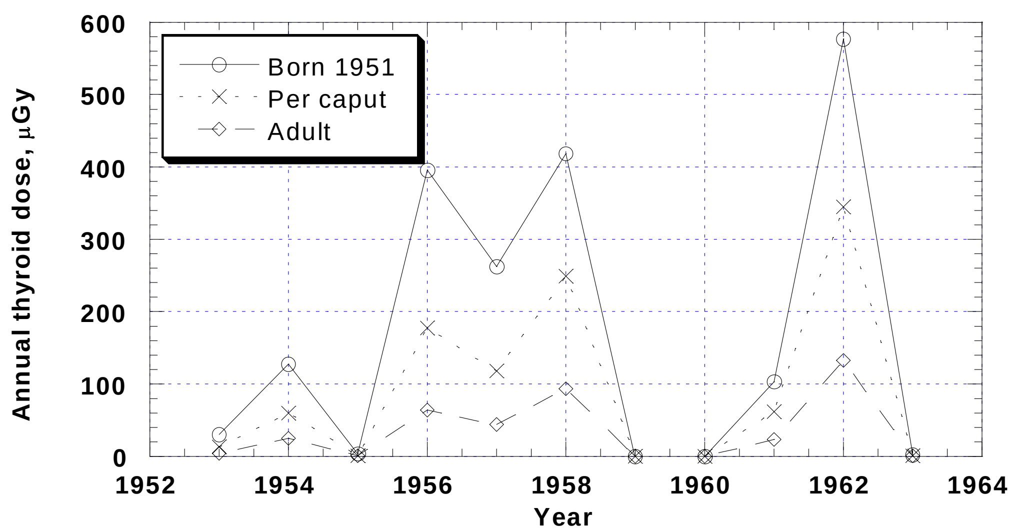


Fig. 25. Annual thyroid dose due to the ingestion of ^{131}I from global fallout as a function of year. Data are for three cohorts: those who were adults (≥18 y in 1953), the per caput value (population-weighted by age), and those born on 1 January 1951.

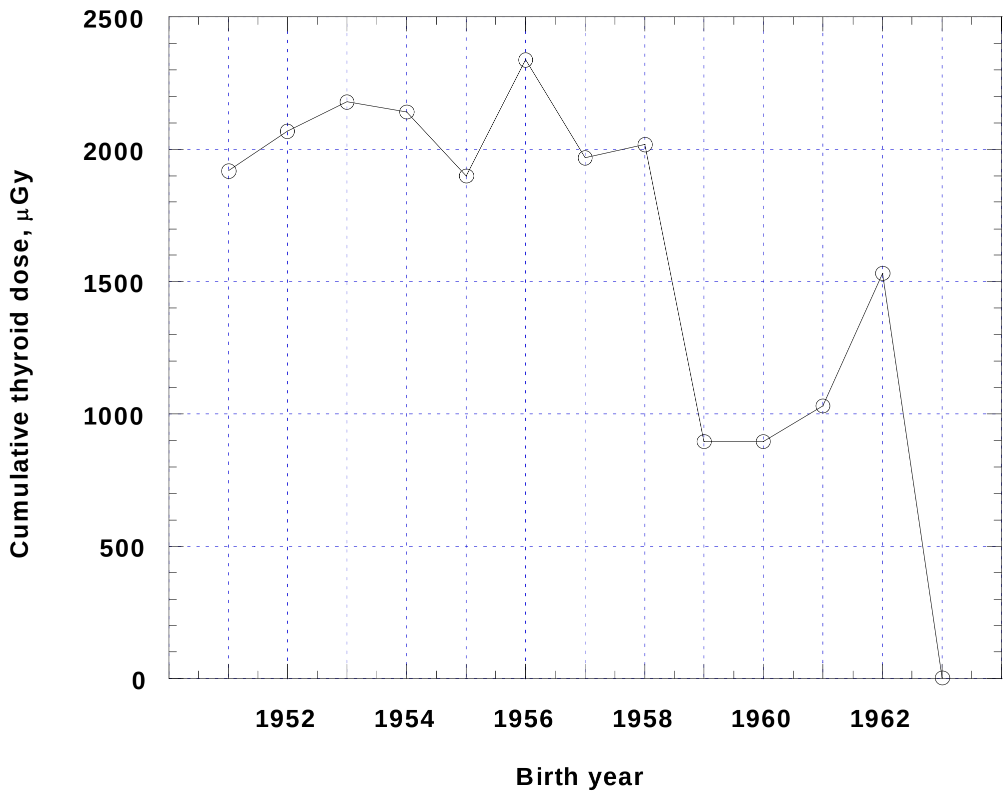


Fig. 26. Cumulative (1953 through 1963) thyroid dose as a function of birth year.

Tritium and ^{14}C. The calculated results for the individual effective doses from ^{3}H (tritium) and ^{14}C are given in Table 10. In contrast to the results for ^{90}Sr and ^{137}Cs the values in Table 10 are doses calculated to be actually received in the indicated year, whereas for ^{90}Sr and ^{137}Cs the computed values are for committed doses. The disparate treatments arise from the markedly different behavior of the two groups of radionuclides. Most of the intake of ^{90}Sr and ^{137}Cs will occur in the same year that the radionuclides are deposited in fallout and/or during the next year. However, ^{3}H and ^{14}C are in vapor or gaseous form and do not deposit with particulate matter. Rather, they take substantial time to be distributed throughout the world and their compartments of distribution are very large. Carbon-14 is also very long lived and will contribute to yearly dose for tens of thousands of years. In that regard it does not make sense within the framework of the present project goals to calculate a dose "commitment" that would be intergenerational. Therefore, the yearly doses for ^{3}H and ^{14}C have been calculated and summed only through the year 2000.

As indicated in Table 10, the calculated sums of effective doses through the year 2000 are 66 µSv for ^{3}H and 120 µSv for ^{14}C. The time dependencies of the doses from ^{3}H and ^{14}C are also plotted in Fig. 27, which is on a semi-logarithmic scale. Here, the effects of global distribution, size of compartments, and exchange rates are clearly evident; ^{3}H also has a much, much shorter half life. It is evident that the yearly dose from ^{3}H tracks more closely the amounts injected into the atmosphere, and the yearly dose from ^{3}H subsequently decreases fairly rapidly due to its half life. In contrast, ^{14}C takes a long time to be distributed throughout its compartments, the yearly doses track the injection rates only slowly, and the yearly doses decrease with time much more slowly.

Table 10. Dose to an individual in the Northern Hemisphere from the creation or release of ^{3}H and ^{14}C from the testing of large fusion weapons in the atmosphere.

Year	Effective dose, μSv		Year	Effective dose, μSv	
	^{3}H	^{14}C		^{3}H	^{14}C
1952	0.95	0.032	1977	0.18	2.6
1953	0.20	0.10	1978	0.16	2.4
1954	3.4	0.24	1979	0.14	2.3
1955	0.69	0.51	1980	0.12	2.1
1956	2.8	0.68	1981	0.11	2.0
1957	1.3	0.95	1982	0.097	2.0
1958	6.3	1.3	1983	0.087	1.9
1959	1.1	1.7	1984	0.078	1.9
1960	0.58	1.9	1985	0.069	1.9
1961	14	2.4	1986	0.061	1.8
1962	21	4.0	1987	0.056	1.8
1963	3.8	5.4	1988	0.051	1.7
1964	2.0	5.6	1989	0.046	1.7
1965	1.4	6.2	1990	0.040	1.7
1966	1.1	6.3	1991	0.036	1.6
1967	0.86	5.8	1992	0.033	1.6
1968	0.71	5.3	1993	0.031	1.5
1969	0.59	4.8	1994	0.028	1.5
1970	0.50	4.4	1995	0.025	1.5
1971	0.43	4.1	1996	0.023	1.4
1972	0.38	3.8	1997	0.021	1.4
1973	0.33	3.5	1998	0.019	1.4
1974	0.28	3.2	1999	0.017	1.4
1975	0.24	3.0	2000	0.015	1.3
1976	0.20	2.8	Sum	66	120

Collective dose

The collective doses that can be calculated from the data contained in the CD-ROM accompanying this document are summarized in Table 11. The total collective effective dose is estimated to be 66,000 person Sv, and the total collective thyroid dose is estimated to be 210,000 "thyroid Sv." In calculating the sum of the dose to the thyroid, it was assumed that the dose to the thyroid from ^{3}H, ^{14}C, and ^{137}Cs was equal to the effective dose. This is a reasonable assumption, as these three radionuclides are distributed uniformly throughout the body.

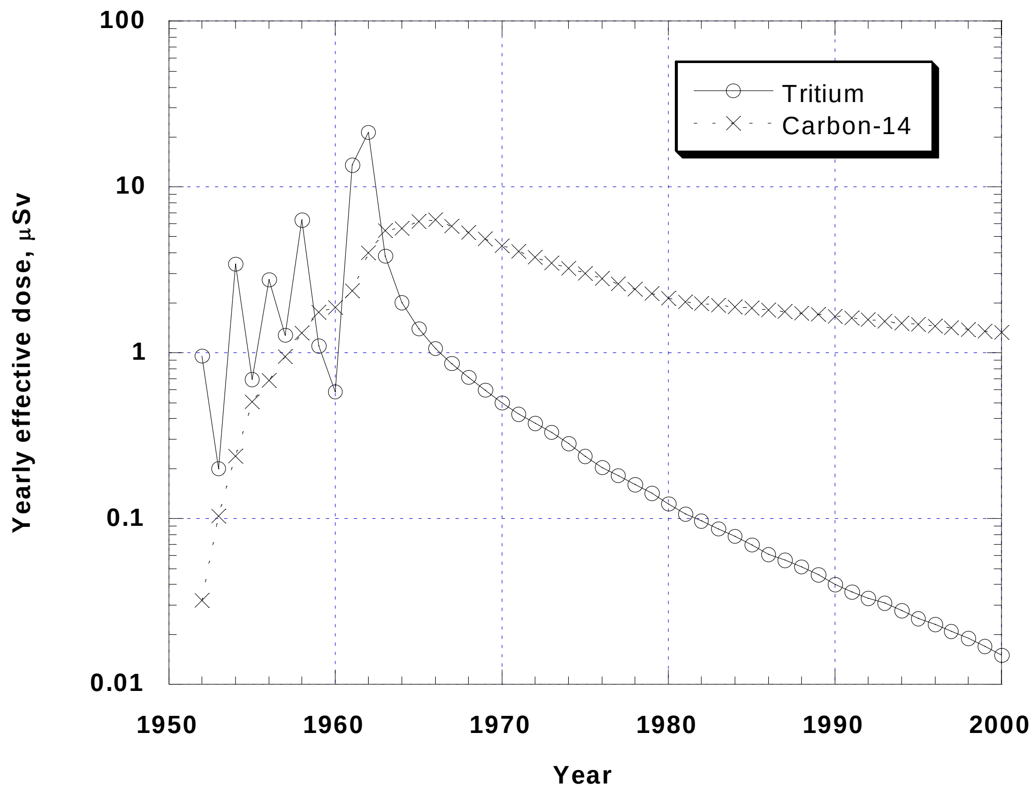


Fig. 27. Plot of the yearly doses from ^{3}H and ^{14}C calculated on the basis of specific activity models. Due to its large compartments that exchange carbon slowly and its long half life, the dose from ^{14}C tracks the injections more slowly than does the dose from ^{3}H.

Table 11. Total collective doses calculated for the 1953–1972 period from the deposition of ^{90}Sr, ^{131}I, and ^{137}Cs in global fallout and for the 1952–2000 period from ^{3}H and ^{14}C distributed throughout the Northern Hemisphere. Values are calculated for the 48 contiguous states in the U.S. The sum collective thyroid dose is estimated by summing the specifically calculated thyroid doses and adding the effective doses for ^{3}H, ^{14}C, and ^{137}Cs.

Radionuclide	Collective organ or effective committed dose, person Sv				
	Bone surface	Colon	Red marrow	Thyroid	Effective
^{3}H					11,000
^{14}C					20,000
^{90}Sr	87,000	2,800	38,000	140	5,900
^{131}I	30	56	24	160,000	7,800
^{137}Cs		25,000			22,000
Sum				210,000	66,000

Comparison of per caput effective doses

In Table 12 the doses calculated in this report are compared to similar estimates of dose from global fallout reported in UNSCEAR (1993) as doses averaged over the north temperate zone (40°–50°) of the globe and to values reported previously in Anspaugh (2000) for doses averaged over the contiguous U.S. from atmospheric tests conducted at the Nevada Test Site. Examination of Table 12 indicates that the global fallout doses reported in UNSCEAR (1993) are higher than those reported here for ^{90}Sr, ^{131}I, and ^{137}Cs, whereas the UNSCEAR reported doses are lower for ^{3}H and ^{14}C. There are several primary reasons for this: 1) the models used in this study are somewhat different from those used by the UNSCEAR and 2) the assessment domains are different, as the U.S. covers approximately 30°–50°. In general, the agreement between the two studies is reasonable given the relatively large amount of uncertainty in both studies. The UNSCEAR will report on a revised assessment this year that has been made possible by revised information on fission and fusion yields reported for the large yield tests; the UNSCEAR assessment models have also been revised.

Comparison of the doses reported here for the high-yield tests versus those estimated previously for tests conducted at the NTS indicates that the sums of the per caput doses are roughly similar, although the importance of ^{131}I is much greater for the doses from the NTS tests. Also, other short-lived radionuclides are relatively more important for the NTS tests, notably ^{89}Sr and ^{140}Ba.

Uncertainty

It was not possible for this feasibility study for Beck (2000) to estimate uncertainty in the amounts of monthly depositions of ^{90}Sr and ^{137}Cs on a county-by-county basis or for the country-average values for the monthly deposition of ^{131}I. Thus, no attempt was made to estimate analytically the uncertainty in the estimates of internal dose reported here. Also, the models used to calculate doses from ^{3}H and ^{14}C do not at present allow for the analytical estimation of uncertainty. Based upon the author's subjective judgment, the uncertainty in doses for any individual county is a factor of three or more. The estimates of country-average per caput dose and the estimates of collective dose are likely uncertain by a factor of two or more. It is believed that a substantial amount of uncertainty is associated with estimating the amount of fallout retained by vegetation.

CONCLUSIONS

The results reported here are part of a feasibility study to determine if the external and internal doses from fallout from atmospheric tests conducted at the Nevada Test Site and from high-yield tests conducted at other locations can be estimated. Previously reported studies have determined that the internal dose from ^{131}I (NCI 1997) and other radionuclides (Anspaugh 2000) can be determined for tests at the NTS. Similarly, it has been demonstrated that it is feasible to estimate external doses from the tests at the Nevada Test Site (Beck 1999) and from the high-yield tests (Beck 2000). This report completes the individual components of this feasibility study with the demonstration that internal doses from the high-yield weapons tests can be calculated.

Except for the dose from ^{131}I and in very general terms, the dose from global fallout (or the dose from high-yield weapons) is more important than the dose from weapons tests at the Nevada Test Site. Also, the external dose tends to be higher than the dose from the ingestion of food contaminated with radionuclides. However, for ^{131}I and in particular the dose to the thyroid, the tests conducted at the Nevada Test Site were more important contributors to dose. In fact, for the Nevada tests, ^{131}I contributed about 90% of the total effective dose. Because the variations in dose on a county-by-county basis are very large for the Nevada tests, however, there can be major local variations in this general conclusion.

Table 12. Summary of the estimates reported in this paper for per caput doses resulting from the ingestion of contaminated foods in the 48 contiguous states in the United States from fallout from high-yield tests in the atmosphere ("global fallout"). The current estimates are compared with those reported in UNSCEAR (1993) and with those previously reported for per caput doses from atmospheric tests in Nevada (Anspaugh 2000). Values in the table do not include external doses, which are reported separately by Beck (1999, 2000).

Radionuclide	Per caput effective dose commitment, μSv		
	This project		UNSCEAR (1993)
	Nevada Test Site	Global fallout[a]	Global fallout[b]
^{3}H	-	66[c]	48
^{14}C	-	120[c]	78[d]
^{55}Fe			14
^{89}Sr	17		2.3
^{90}Sr	3.7	37	170
^{91}Sr	0.0065		
^{97}Zr	0.15		
^{99}Mo	1.0		
^{103}Ru	3.8		
^{106}Ru	7.2		
^{105}Rh	0.086		
^{132}Te	7.8		
^{131}I	610[e]	48	79
^{133}I	1.9		
^{136}Cs	3.6		
^{137}Cs	10	130	280
^{140}Ba	12		0.42
^{143}Ce	0.40		
^{144}Ce	5.3		
^{147}Nd	1.1		
^{238}Pu			0.0009
$^{239+240}$Pu	1.2		0.50
^{241}Pu	0.087		0.004
^{241}Am			1.5
Sum	680[e]	400[f]	670[d]

[a] Averaged over the U.S.
[b] North temperate zone (40°–50°).
[c] To the year 2000.
[d] The UNSCEAR (1993) value of 2600 μSv was multiplied by a factor of 0.03, the portion estimated to be delivered in 50 y.
[e] Age corrected.
[f] Incomplete sum for the radionuclides considered.

REFERENCES

Anspaugh, L. R. Retention by vegetation of radionuclides deposited in rainfall—A literature summary. Livermore: Lawrence Livermore National Laboratory, Livermore; UCRL-53810; 1987.

Anspaugh, L. R. Radiation dose to the population of the continental United States from the ingestion of food contaminated with radionuclides from nuclear tests at the Nevada Test Site. Salt Lake City: L.R. Anspaugh; Report to the National Cancer Institute; P.O. #263-MQ-912901; 2000.

Beck, H. L. External radiation exposure to the population of the continental U.S. from Nevada weapons tests and estimates of deposition density of radionuclides that could significantly contribute to internal radiation exposure via ingestion. New York: H.L. Beck; Report to the National Cancer Institute, P.O. #263-MQ-909853; 1999.

Beck, H. L. External radiation exposure to the population of the continental U.S. from high-yield weapons tests conducted by the U.S., U.K. and U.S.S.R. between 1952 and 1963. New York: H.L. Beck; Report to the National Cancer Institute, P.O. #263-MQ-003539; 2000.

Dahl, A. H.; Bostrum, R.; Patzer, R. C.; Villforth, J. C. Patterns of I^{131} levels in pasteurized milk network. Health Phys. 9:1179–1185; 1963.

Department of Energy. United States nuclear tests. July 1945 through September 1992. Las Vegas: U.S. DOE Nevada Operations Office; Report DOE/NV-209 (Rev. 14); 1994.

Hoffman, F. O.; Frank, M. L.; Blaylock, B. G.; von Bernuth, R. D.; Deming, E. J.; Graham, R. V.; Mohrbacher, D. A.; Water, A. E. Pasture grass interception and retention of ^{131}I, ^{7}Be, and insoluble microspheres deposited in rain. Oak Ridge: Oak Ridge National Laboratory; ORNL-6542; 1989.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 1. Annals ICRP 20(2). Oxford: Pergamon Press; Publication 56; 1989.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 2: Ingestion dose coefficients. Annals ICRP 23(3/4). Oxford: Pergamon Press; Publication 67; 1993.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 3: Ingestion dose coefficients. Annals ICRP 25(1). Oxford: Pergamon Press; Publication 69; 1995.

International Commission on Radiological Protection. Age-dependent doses to members of the public from intake of radionuclides: Part 5: Compilation of ingestion and inhalation dose coefficients. Annals ICRP 26(1). Oxford: Pergamon Press; Publication 72; 1996.

International Commission on Radiological Protection. The ICRP database of dose coefficients: Workers and members of the public. Oxford: Pergamon Press; Version 1.0 on CD-ROM; 1998.

Machta, L. Meteorological processes in the transport of weapon radioiodine. Health Phys. 9:1123–1132; 1963.

Mikhailov, V. N.; Andryshin, I. A.; Bogdan, V. V.; Vashchinkin, S. A.; Zelentsov, S. A.; Zolotukhin, G. E.; Karimov, V. M.; Kirichenko, V. V.; Matushchenko, A. M.; Silkin, Yu. S.; Strukov, V. G.; Kharitonov, K. V.; Tcdhernyshev, A. K.; Tsrykov, G. A.; Shumaev, M. P. USSR nuclear weapons tests and peaceful nuclear explosions. 1949 through 1990. Moscow: Ministry of the Russian Federation for Atomic Energy and Ministry of Defense of the Russian Federation; 1996.

National Cancer Institute. Estimated exposures and thyroid doses received by the American people from Iodine-131 in fallout following Nevada atmospheric nuclear bomb tests. Washington: NCI Report; 1997.

National Council on Radiation Protection and Measurements. Tritium in the environment. Bethesda: NCRP; Report No. 62; 1979.

Ng, Y. C.; Anspaugh, L. R.; Cederwall, R. T. ORERP internal dose estimates for individuals. Health Phys. 59:693–713; 1990.

Rupp, E. M. Age dependent values of dietary intake for assessing human exposures to environmental pollutants. Health Phys. 39:151–163; 1980.

Terrill, J. G., Jr. Review of radionuclides in the food chain. In: Fallout, radiation standards, and countermeasures. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy; 88th Congress; 1963; Vol. 1:71–201.

Titley, J. G.; Cabianca, T.; Lawson, G.; Mobbs, S. F.; Simmonds, J. Improved global dispersion models for iodine-129 and carbon-14. Luxembourg: Commission of European Communities; Report EUR-15880; 1995.

United Nations Scientific Committee on the Effects of Atomic Radiation. Ionizing radiation: Sources and biological effects. New York: United Nations; Sales No. E.82.IX.8; 1982.

United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York: United Nations; Sales No. E.94.IX.2; 1993.

Whicker, F. W.; Kirchner, T. B. PATHWAY: A dynamic food-chain model to predict radionuclide ingestion after fallout deposition. Health Phys. 52:717–737; 1987.

Radiation Dose to the Population of the Continental United States from the Ingestion of Food Contaminated with Radionuclides from High-yield Weapons Tests Conducted by the U.S., U.K., and U.S.S.R. between 1952 and 1963

Part II. Reference and Subsidiary Information

Lynn R. Anspaugh
Lynn R. Anspaugh, Consulting
Salt Lake City, UT

Report to the National Cancer Institute
Purchase Order No. 263-MQ-912901

COMPARISON OF CALCULATED DOSES WITH THOSE DERIVED FROM MEASUREMENTS IN FOODSTUFFS

One of the specified tasks was to compare the internal dose estimates calculated for ^{90}Sr, ^{131}I, and ^{137}Cs with those derived from the measurements of fallout radionuclides in foods. Extensive measurements of fallout radionuclides in foods started in 1960 with the establishment of the Pasteurized Milk Network (PMN) of the Public Health Service. Additional data were also taken on a limited and/or sporadic basis by many organizations [see PHS (1960)[5] for a summary of early measurement efforts], but many of the more sophisticated measurements were not well organized until after the end of the period of testing of high-yield weapons in the atmosphere.

A full-scale comparison of the measurements with the dose estimates provided in Part I of this report would be a major undertaking well beyond the limited funds made available for the present study.

One of the key issues, of course, is whether the model used in Part I of this study is a reasonable qualitative and quantitative description of the movement of fallout radionuclides to man. The model used for Part I of this study is the PATHWAY model of Whicker and Kirchner (1987).[6] During the development of this model it was extensively tested against several data sets, including the measured amounts of global fallout radionuclides in foodstuffs; in addition other data sets were used such as concentrations measured following tests at the Nevada Test Site and following the reactor accident at Windscale, UK. A major report on this subject was published (Kirchner and Whicker 1984).[7] This article gives several graphs of long-term comparisons of ^{90}Sr and ^{137}Cs from global fallout in beef and milk. Many additional data sets are provided. The following is an excerpt from the abstract in Kirchner and Whicker (1984):

> "The statistical tests used to compare the predictions of PATHWAY to the observations include a correlation analysis, a paired t-test, and a binomial test. We use the correlation coefficient between observations and predictions through time to compare the dynamics of the simulated and real world system. Plots of the residuals from regression are then examined for bias between the predictions and observations. The significance of any trends in the residuals is evaluated using a runs test. The paired t-test and the binomial test are used to evaluate the accuracy of PATHWAY's predictions. The hypothesis for the paired t-test is that the ratio of predictions to observations is 1. The paired t-test can be used to test hypotheses about ratios because the distributions of observations and predictions appear to be lognormal. However, the paired t-test does not consider uncertainty in the predictions of the model. We use a binomial test to compare the observed

[5] Public Health Service. Radiological Health Data Vol. 1, No. 1; April 1960.
[6] See Part I References for citation.
[7] Kirchner, T. B.; Whicker, F. W. Validation of PATHWAY, a simulation model of the transport of radionuclides through agroecosystems. Ecological Modeling 22:21–44; 1984.

data to an interval estimate from PATHWAY. The interval corresponds to a 95% confidence interval on the prediction, and is derived from uncertainty analyses that have been conducted on PATHWAY.

"PATHWAY's predictions are significantly correlated with observed levels of ^{137}Cs and ^{90}Sr in pasture and alfalfa. PATHWAY also simulates the dynamics of ^{131}I, ^{140}Ba, and ^{137}Cs in milk well, but fails to predict what appears to be a long term accumulation of ^{90}Sr in the agro-ecosystem. PATHWAY predicts the absolute concentrations of ^{131}I in milk quite well, but tends to predict levels of ^{140}Ba, ^{90}Sr, ^{137}Cs in milk that are different from those observed by factors of 2 to 7. PATHWAY predicts levels of ^{137}Cs and ^{90}Sr in pasture and beef within a factor of 2 of those observed."

Thus, while the PATHWAY model has been tested extensively and performs quite well, it is not perfect and has been noted to both underpredict and overpredict real world situations. In order to examine some important data sets that pertain directly to global fallout, the data presented to the U.S. Congress by Terrill (1963)[8] are used here. The data pertain to the PMN mentioned above. Although data from 62 different locations are available, it is not easy to associate these milkshed data with counties. In addition deposition values for ^{131}I and dose estimates are not available on a county-by-county basis. Therefore, a comparison has been made only for the population-weighted average dose calculated for the 48 states with network-average concentrations, C_m, measured in milk. The relevant milk data are shown in Table 1.

The reported concentrations for ^{90}Sr, ^{131}I, and ^{137}Cs have been used as the starting point to calculate effective doses for adults according to the following equation:

$$E = C_m \times L \times T \times F_g \times \mathrm{K}$$

where E = Effective dose, Sv;
L = Consumption rate of milk, L day^{-1};
T = Number of days in time period, days period^{-1};
F_g = Ingestion-dose coefficient for the radionuclide, Sv Bq^{-1}; and
K = Units conversion constant, 0.037 Bq pCi^{-1}.

Values of F_g are the same as those used in Part I of this report. A value for L was taken to be 0.42 L day^{-1}, which is consistent with the PATHWAY model values (Whicker and Kirchner 1987). T is either 365 days per year or one fourth of that per quarter. The results of these calculations and the comparisons to the values estimated and reported in Part I of this report are shown in Table 2. A comparison of the values indicates that the dose values for ^{90}Sr and ^{131}I agree quite well, certainly within the expected uncertainties of the values. Dose values for ^{137}Cs do not agree as well, with the model results from Part I being substantially higher. However, a significant amount of the calculated dose from ^{137}Cs would be expected to have occurred from the consumption of contaminated meat; thus, the difference is reasonable.

[8] See following list of documents for citation.

Table 1. Daily average concentration of radionuclides in milk from the 62 stations in the U.S. Public Health Service's Pasteurized Milk Network, 1960 through the first quarter of 1963. From Terrill (1963).

Time period or parameter	Concentration in milk, pCi L^{-1}				
	^{89}Sr	^{90}Sr	^{131}I	^{137}Cs	^{140}Ba
1960					
12-month average level	<5	8	0	10	0
12-month low station	<5	4	0	<5	0
12-month high station	<5	13	0	75	0
1961					
12-month average level	10	8	20	10	<10
12-month low station	<5	4	<10	<5	<10
12-month high station	30	16	70	65	10
1962					
12-month average level	50	13	32	45	12
12-month low station	17	3	<10	12	<10
12-month high station	170	30	104	108	29
1st Quarter 1963					
3-month average level	35	16	<10	70	<10
3-month low station	<5	4	<10	20	<10
3-month high station	265	37	20	135	30

Table 2. Calculated doses according to the measured concentrations of global fallout radionuclides in milk from Table 1 compared to the estimates of dose reported in Part I of this report. Estimates in the last three columns include doses calculated to arise from additional pathways.

Time period	Effective dose to adults, μSv					
	From milk concentration			From results in Part I		
	^{90}Sr	^{131}I	^{137}Cs	^{90}Sr	^{131}I	^{137}Cs
1960	1.3	0	0.74	0.81	0	3.0
1961	1.3	2.5	0.74	0.84	1.2	3.6
1962	2.1	4.0	3.3	4.4	6.8	17
1963, first quarter	0.64	<0.31	1.3	0.69	0.034	0.48

In general the results of this comparison are considered to be satisfactory and indicate that there are no gross errors in the assumptions used in the modeling process. Comparisons such as this can never be perfect and agreement within a factor or two or so is considered excellent.

LIST OF SIGNIFICANT REFERENCES

Congressional Hearings

Over the years Congress has held several hearings on fallout, and the records of the major hearings listed below are major sources of information on fallout. Most of the material is concerned with global fallout, but significant amounts of information pertaining to the Nevada Test Site are also included, particularly in the 1957, 1959, and 1963 hearings.

U.S. Congress. The nature of radioactive fallout and its effects on man. Washington: U.S. Government Printing Office; Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy; 85th Congress; 1957.

U.S. Congress. Fallout from nuclear weapons tests. Washington: U.S. Government Printing Office; Hearings before the Special Subcommittee on Radiation, Joint Committee on Atomic Energy; 86th Congress; 1959.

U.S. Congress. Radiation standards, including fallout. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy; 87th Congress; 1962.

U.S. Congress. Fallout, radiation standards, and countermeasures. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy; 88th Congress; 1963.

U.S. Congress. Low-level radiation effects on health. Washington: U.S. Government Printing Office; Hearings before the Subcommittee on Oversight and Investigations, Committee on Interstate and Foreign Commerce, House of Representatives; 96th Congress; 1979.

Major sources of information on radioactive contamination

Health and Safety Laboratory. Fallout quarterly reports. New York: U.S. Department of Energy; 1958+.

Mikhailov, V. N.; Andryshin, I. A.; Bogdan, V. V.; Vashchinkin, S. A.; Zelentsov, S. A.; Zolotukhin, G. E.; Karimov, V. M.; Kirichenko, V. V.; Matushchenko, A. M.; Silkin, Yu. S.; Strukov, V. G.; Kharitonov, K. V.; Tcdhernyshev, A. K.; Tsrykov, G. A.; Shumaev, M. P. USSR nuclear weapons tests and peaceful nuclear explosions. 1949 through 1990. Moscow: Ministry of the Russian Federation for Atomic Energy and Ministry of Defense of the Russian Federation; 1996.

Terrill, J. G., Jr. Review of radionuclides in the food chain. In: U.S. Congress (1963), Vol. 1:71–201.

U.S. Department of Energy. United States nuclear tests. Las Vegas: Nevada Operations Office; DOE/NV-209, Rev. 14; 1994.

U.S. Public Health Service. Radiological health data. A series of monthly reports published from April 1960 through December 1974. Washington: U.S. Government Printing

Office. (Later names of this journal were “Radiological Health Data and Reports” and “Radiation Data and Reports.”)

Publications related primarily to dose or data directly relevant to dose reconstruction

Åberg, B.; Hungate, F. P. Radioecological concentration processes. Proceedings of an international symposium held in Stockholm 25–29 April 1966. New York: Pergamon Press; 1967.

Anspaugh, L. R. Retention by vegetation of radionuclides deposited in rainfall: A literature summary. Livermore: Lawrence Livermore National Laboratory; UCRL-53810; 1972.

Barry, P. J.; Chamberlain, A. C. Deposition of iodine onto plant leaves from air. Health Phys. 9:1149–1157; 1963.

Beierwaltes, W. H.; Crane, H. R.; Wegst, A.; Spafford, N. R.; Carr, E. A., Jr. Radioactive iodine concentration in the fetal human thyroid gland from fall-out. J. Am. Med. Assoc. 173:1895–1902; 1960.

Beierwaltes, W. H.; Hilger, M. T. J.; Wegst, A. Radioiodine concentration in fetal human thyroid from fallout. Health Phys. 9:1263–1266; 1963.

Cohn, S. H.; Gusmano, E. A. Uptake and transfer of fallout I^{131} in pregnant women. Heath Phys. 9:1267–1269; 1963.

Dunning, G. M. Two ways to estimate thyroid dose from radioiodine in fallout. Nucleonics 14(2):38–44; 1956.

Dunning, G. M. Criteria for evaluating gamma radiation exposures from fallout following nuclear detonations. Radiology 66:585–594; 1956.

Dunning, G. M. Criteria for establishing short term permissible ingestion of fallout material. Am. Ind. Hyg. Assoc. J. 19:111–120; 1958.

Eisenbud, M.; Mochizuki, Y.; Goldin, A. S.; Laurer, G. R. Iodine-131 dose from Soviet nuclear tests. Science 136:370–374; 1962.

Eisenbud, M.; Pasternack, B.; Laurer, G.; Block, L. Variability of the I^{131} concentrations in the milk distribution system of large city. Health Phys. 9:1303–1305; 1963.

Eisenbud, M.; Pasternack, B.; Laurer, G.; Mochizuki, Y.; Wrenn, M. E.; Block, L.; Mowafy, R. Estimation of the distribution of thyroid doses in a population exposed to I^{131} from weapons tests. Health Phys. 9:1281–1289; 1963.

Eisenbud, M.; Mochizuki, Y.; Laurer, G. I^{131} dose to human thyroids in New York City from nuclear tests in 1962. Health Phys. 9:1291–1298; 1963.

Garner, R. J. A mathematical analysis of the transfer of fission products to cows’ milk. Health Phys. 13:205–212; 1967.

Koranda, J. J. Agricultural factors affecting the daily intake of fresh fallout by dairy cows. Livermore: Lawrence Livermore National Laboratory; UCRL-12479; 1965.

Lewis, E. B. Leukemia and ionizing radiation. Science 125:965–972; 1957.

Lewis, E. B. Thyroid radiation dose from fallout. Proc. Natl. Acad. Sci. 45:894–897; 1959.

Libby, W. F. Dosages from natural radiation and cosmic rays. Science 122:57–58; 1955.

Pauling, L. Genetic and somatic effects of carbon-14. Science 128:1183–1186; 1958.

Rupp, E. M. Age dependent values of dietary intake for assessing human exposure to environmental pollutants. Health Phys. 39:151–163;1980.

Stannard, J. N. Radioactivity and health. A history. Springfield, VA: National Technical Information Service; 1988.

Totter, J. R.; Zelle, M. R.; Hollister, H. Hazard to man of carbon-14. Science 128:1490–1495; 1958.

UNSCEAR. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations General Assembly; Official Records: Thirteenth Session, Supplement No. 17 (A/3838); 1958.

UNSCEAR. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations General Assembly; Official Records: Seventeenth Session, Supplement No. 16 (A/5216); 1962.

UNSCEAR. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations General Assembly; Official Records: Nineteenth Session, Supplement No. 14 (A/5814); 1964.

UNSCEAR. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations General Assembly; Official Records: Twenty-First Session, Supplement No. 14 (A/6314); 1966.

UNSCEAR. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations General Assembly; Official Records: Twenty-Fourth Session, Supplement No. 13 (A/7613); 1969.

UNSCEAR. Ionizing radiation: Levels and effects. A report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, with annexes. New York: United Nations; Sales No. E.72.IX.17; 1972.

UNSCEAR. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation 1977 report to the General Assembly, with annexes. New York: United Nations; Sales No. E.77.IX.1; 1977.

UNSCEAR. Ionizing radiation: Sources and biological effects. United Nations Scientific Committee on the Effects of Atomic Radiation 1982 report to the General Assembly, with annexes. New York: United Nations; Sales No. E.82.IX.8; 1982.

UNSCEAR. Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation 1988 report to the General Assembly, with annexes. New York: United Nations; Sales No. E.88.IX.7; 1988.

UNSCEAR. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation 1993 report to the General Assembly, with annexes. New York: United Nations; Sales No. E.94.IX.2; 1993.

Visalli, F. I.; Goldin, A. S. Fallout I^{131} in children—in vivo measurements. Health Phys. 9:1271–1277; 1963.

Publications related primarily to the detection or monitoring of fallout materials

Anderson, E. C. Part II. Scintillation counters. The Los Alamos human counter. Brit. J. Radiol. Suppl. 7:27–32; 1957.

Anderson, E. C. Radioactivity of people and milk: 1957. Science 128:882–886; 1958.

Anderson, E. C.; Schuch, R. L.; Fisher, W. R.; Langham, W. Radioactivity of people and foods. Science 125:1273–1278; 1957.

Anderson, E. C.; Schuch, R. L.; Fisher, W. R.; Van Dilla, M. A. Barium-140 radioactivity in foods. Science 127:283–284; 1958.

Arnalds, O.; Cutshall, N. H.; Nielsen, G. A. Cesium-137 in Montana soils. Health Phys. 57:955–958; 1989.

Begemann, F.; Libby, W. F. Continental water balance, ground water inventory and storage times, surface ocean mixing rates and worldwide water circulation patterns from cosmic-ray and bomb tritium. Geochim. Cosmochim. Acta 12:277–296; 1957.

Black, S. C.; Potter, G. D. Historical perspectives on selected health and safety aspects of nuclear weapons testing. Health Phys. 51:17–33; 1986.

Blincoe, C.; Bohman, V. R.; Fountain, E. L. Iodine-131 in bovine thyroid glands from 1957 through 1961. J. Agr. Food Chem. 12:414–418; 1964.

Blincoe, C.; Bohman, V. R. Bovine thyroid iodine-131 concentrations subsequent to Soviet nuclear weapons tests. Science 137:690–691; 1962.

Bohman, V. R.; Blincoe, C.; Wade, M. A.; Lesperance, A. L.; Fountain, E. L. Accumulation of strontium in bovine bones. J. Agr. Food Chem. 14:413–415; 1966.

Broecker, W. S.; Walton, A. Radiocarbon from nuclear tests. Science 130:309–314; 1959.

Bryant, F. J.; Chamberlain, A. C.; Morgan, A.; Spicer, G. S. Radiostrontium in soil, grass, milk and bone in UK: 1956 results. Harwell: Atomic Energy Research Establishment; AERE HP/R 2353; 1957.

Bustad, L. K., Ed. Biology of radioiodine. Oxford: Pergamon Press; 1964.

Caldecott, R. S.; Snyder, L. A., Eds. Radioisotopes in the biosphere. Minneapolis: University of Minnesota; 1960.

Campbell, J. E.; Murphy, G. K.; Goldin, A. S.; Robinson, H. B.; Straub, C. P.; Weber, F. J.; Lewis, K. H. The occurrence of strontium-90, iodine-131, and other radionuclides in milk—May, 1957, through April, 1958. Am. J. Pub. Health 49:225–235; 1959.

Carter, M. W.; Moghissi, A. A. Three decades of nuclear testing. Health Phys. 33:55–71; 1977.

Comar, C. L.; Trum, B. F.; Kuhn III, U. S. G.; Wasserman, R. H.; Nold, M. M.; Schooley, J. C. Thyroid radioactivity after nuclear weapons tests. Science 126:16–18; 1957.

Dahl, A. H.; Bostrum, R.; Patzer, R. C.; Villforth, J. C. Patterns of I^{131} levels in pasteurized milk network. Health Phys. 9:1179–1185; 1963.

Dunning, G. M.; Hilcken, J. A., Eds. Shorter term hazards of a fallout field. Washington: U.S. Government Printing Office; 1958.

Eckelmann, W. R.; Kulp, J. L.; Schulert, A. R. Strontium-90 in man, II. Science 127:266–274; 1958.

Eisenbud, M. Environmental radioactivity. New York: Academic Press; 3rd edition; 1987.

Eisenbud, M.; Harley, J. H. Radioactive dust from nuclear detonations. Science 117:141–147; 1953.

Eisenbud, M.; Harley, J. H. Radioactive fallout in the United States. Science 121:677–680; 1955.

Eisenbud, M.; Harley, J. H. Radioactive fallout through September 1955. Science 124:251–255; 1956.

Eriksson, E. An account of the major pulses of tritium and effects in the atmosphere. Tellus 17:118–130; 1965.

Evans, R. B.; Snelling, R. N.; Buck, F. N. Assessment of thyroid inhalation doses in the western United States from the Chinese nuclear test of November 1971. Radiat. Data Repts. 14:9–15; 1973.

Feely, H. W.; Friend, J. P.; Krey, P. W.; Russell, B. A. Project Star Dust flight data and results of radiochemical analyses of filter samples collected during 1961 and 1962. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-153; 1965.

Feely, H. W.; Katzman, D.; Biscaye, P. E.; Panaccione, J. B.; French, E. R. Flight data and results of radiochemical analyses of filter samples collected during 1965. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-176; 1966.

Fountain, E. L.; Seal, M. S. Strontium-90 in the bones of big game in the western United States. Health Phys. 13:1205–1209; 1967.

Fowler, E. B., ed. Radioactive fallout, soils, plants, man. New York: Elsevier; 1965.

Freiling, E. C., ed. Radionuclides in the environment. Washington: American Chemical Society; 1970.

Fry, L.; Kuroda, P. K. Stratospheric fallout of strontium-89 and barium-140. Science 129:1742–1743; 1959.

Fry, L. M.; Jew, F. A.; Kuroda, P. K. On the stratospheric fallout of strontium-90: The spring peak of 1959. J. Geophys. Res. 65:2061–2066; 1960.

Gunther, R. L.; Jones, H. B. Confirmation of radioactivity in thyroids of various animals. Berkeley: Lawrence Berkeley National Laboratory; UCRL-2689 and Addendum; 1954.

Gustafson, P. F. ^{137}Cs in the U.S. diet 1961–1968 and the influence of climatic and agricultural factors. In: Environmental contamination by radioactive materials. Vienna: International Atomic Energy Agency; 1967:135–143.

Hagemann, F.; Gray, J., Jr.; Machta, L.; Turkevich, A. Stratospheric carbon-14, carbon dioxide and tritium. Science 130:542–543; 1959.

Hagemann, F.; Gray, J., Jr.; Machta, L. Carbon-14 measurements in the atmosphere – 1953 to 1964. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-159; 1964.

Hanson, W. C. Cesium-137 in Alaskan lichens, caribou and Eskimos. Health Phys. 13:383–389; 1967.

Hanson, W. C.; Dahl, A. H.; Whicker, F. W.; Longhurst, W. M.; Flyger, V.; Davey, S. P.; Greer, K. R. Thyroidal radioiodine concentrations in North American deer following 1961–1963 nuclear weapons tests. Health Phys. 9:1235–1239; 1963.

Hardy, E. P., Jr.; Harley, J.; Lough, S. A. Environmental contamination from weapons tests. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-42; 1958.

Hardy, E. P., Jr.; Klein, S. Strontium program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-51; 1958.

Hardy, E. P., Jr.; Klein, S. Strontium program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-55; 1959.

Hardy, E. P., Jr.; Klein, S. Strontium program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-65; 1959.

Hardy, E. P., Jr.; Klein, S. Strontium program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-69; 1959.

Hardy, E. P., Jr.; Klein, S. Strontium program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-77; 1960.

Hardy, E. P., Jr.; Klein, S. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-84; 1960.

Hardy, E. P., Jr.; Klein, S.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-88; 1960.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-95; 1960.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-105; 1961.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-111; 1961.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-113; 1961.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-115; 1961.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-117; 1961.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-122; 1962.

Hardy, E. P., Jr.; Rivera, J.; Frankel, R. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-127; 1962.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-131; 1962.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-132; 1963.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-135; 1963.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-138; 1963.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-140; 1963.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-142; 1964.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-144; 1964.

Hardy, E. P., Jr.; Rivera, J.; Collins, W. R., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-146; 1964.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-149; 1964.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-155; 1965.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-158; 1965.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-161; 1965.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-164; 1965.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-165; 1966.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-171; 1966.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-172; 1966.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-173; 1966.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-174; 1967.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-181; 1967.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-182; 1967.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-183; 1967.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-184; 1968.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-193; 1968.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-197; 1968.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-200; 1968.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-204; 1969.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-207; 1969.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-210; 1969.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-214; 1969.

Hardy, E. P., Jr.; Rivera, J. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-217; 1970.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-224; 1970.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-227; 1970.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-237; 1970.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-239; 1971.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-242; 1971.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-243; 1971.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-245; 1971.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-246; 1972.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-249; 1972.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-257; 1972.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-259; 1972.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-268; 1973.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-273; 1973.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-274; 1973.

Hardy, E. P., Jr. Fallout program quarterly summary report. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-276; 1973.

Hardy, E. P. Plutonium in soil northeast of the Nevada Test Site. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-306; 1976.

Harley, J. H.; Hardy, E. P., Jr.; Welford, G. A.; Whitney, I. B.; Eisenbud, M. Summary of analytical results from the HASL strontium program to June 1956. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4751 (Rev.); 1956.

Harley, J. H.; Rivera, J. Summary of available data on the strontium-90 content of food and of total diets in the United States. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-90; 1960.

Harley, J. H.; Hallden, N. A.; Ong, L. D. Y. Summary of gummed film results through December, 1959. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-93; 1960.

Hartgering, J. B.; Schrodt, A. G.; Knoblock, E. C.; Burstein, A. G.; McIver, R. D.; Roberts, J. E. Recovery of radioactive iodine and strontium from human urine—Operation Teapot. Washington: Walter Reed Army Institute of Research; AFSWP-893; 1955.

Health and Safety Laboratory. Project Sunshine, progress from September 1953 to January 4, 1954. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4571; 1954.

Health and Safety Laboratory. Worldwide fallout from Operation Castle. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4621; 1955.

Health and Safety Laboratory Staff Report. Preliminary data on fallout from the Fall 1961 USSR test series. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-121; 1962.

Health and Safety Laboratory Staff Report. Major catalogue of what is being measured. Survey of fallout operations. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-128; 1962.

Hoard, A. G.; Eisenbud, M.; Harley, J. H. Annotated bibliography on fall-out resulting from nuclear explosions. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4753; 1956.

Hoard, A. G.; Eisenbud, M.; Harley, J. H. Annotated bibliography on fall-out resulting from nuclear explosions. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4753; Supplement 1; 1956.

Hoard, A. G. Annotated bibliography on fall-out resulting from nuclear explosions. New York: U.S. Department of Energy Environmental Measurements Laboratory; NYO-4753; Supplement 3; 1957.

Holland, J. Z. Physical origin and dispersion of radioiodine. Health Phys. 9:1095–1103; 1963.

Hull, A. P. Vegetation retention and vegetation-milk ratios of fallout I^{131}. Health Phys. 9:1173–1177; 1963.

Johnson, J. E.; Wilson, D. W.; Lindsay, W. L. Transfer of fallout ^{137}Cs from soil to dairy cattle feeds. Proc. Soil Sci. Soc. Amer. 30:416–xxx; 1966.

Joyet, G.; Joyet, M.-L. The exponential decrease of ^{137}Cs in man from mid-1954 through mid-1968 and its significance. Health Phys. 18:455–465; 1970.

Kahn, B.; Straub, C. P.; Jones, I. R. Radioiodine in milk of cows consuming stored feed and of cows on pasture. Science 138:1334–1335; 1962.

Klement, A. W., Jr., Ed. Radioactive fallout from nuclear weapons tests. Washington: U.S. Department of Energy; AEC Symposium Series No. 5; 1965.

Kulp, J. L.; Eckelmann, W. R.; Schulert, A. R. Strontium-90 in man. Science 125:219–225; 1957.

Kulp, J. L.; Schulert, A. R. Strontium-90 in man. V. Science 136:619–632; 1962.

Kulp, J. L.; Schulert, A. R.; Hodges, E. J. Strontium-90 in man III. Science 129:1249–1255; 1959.

Kulp, J. L.; Schulert, A. R.; Hodges, E. J Strontium-90 in man IV. Science 132:448–454; 1960.

Kulp, J. L.; Slakter, R. Current strontium-90 level in diet in United States. Science 128:85–86; 1958.

Kulp, J. L.; Slakter, R.; Schulert, A. R. Strontium-90 in food. J. Agricul. Food Chem. 7:466–469; 1959.

Kuroda, P. K.; Hodges, H. L.; Fry, L. M. Spring peak of strontium-90 fallout. Science 132:742–743; 1960.

Langham, W. H.; Anderson, E. C. Strontium-90 and skeletal formation. Science 125:205–206; 1957.

Langham, W. H.; Anderson, E. C. Cs^{137} biospheric contamination from nuclear weapons tests. Health Phys. 2:30–48; 1959.

Libby, W. F. Radioactive fallout and radioactive strontium. Science 123:657–660; 1956.

Libby, W. F. Radioactive strontium fallout. Proc. Natl. Acad. Sci. 42:365–390; 1956.

Libby, W. F. Current research findings on radioactive fallout. Proc. Natl. Acad. Sci. 42:945–962; 1956.

Libby, W. F. Radioactive fallout. Proc. Natl. Acad. Sci. 43:758–775; 1957.

Libby, W. F. Radioactive fallout. Proc. Natl. Acad. Sci. 44:800–820; 1958.

Libby, W. F. Radioactive fallout particularly from the Russian October series. Proc. Natl. Acad. Sci. 45:959–976; 1959.

Libby, W. F. Moratorium tritium geophysics. J. Geophys. Res. 68:4485–4499; 1963.

Machta, L. Meteorological processes in the transport of weapon radioiodine. Health Phys. 9:1123–1132; 1963.

Machta, L. Carbon-14 measurements in the atmosphere. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-166; 1966.

Machta, L.; List, R. J.; Hubert, L. F. Worldwide travel of atomic debris. Science 124:474–477; 1956.

Machta, L.; List, R. J.; Telegadas, K. A survey of radioactive fallout from nuclear tests. J. Geophys. Res. 67:1389–1400; 1962.

Makhon'ko, K. P.; Malakhov, S. G., eds. Nuclear meteorology. Jerusalem: Israel Program of Scientific Translations; 1974.

Martell, E. A. Atmospheric aspects of strontium-90 fallout. Science 129:1197–1206; 1959.

Martell, E. A. On the inventory of artificial tritium and its occurrence in atmospheric methane. J. Geophys. Res. 68:3759–3769; 1963.

Martell, E. A. Iodine-131 fallout from underground tests. Science 143:126–129; 1964.

Medical Research Council. The hazards to man of nuclear and allied radiations. A second report to the Medical Research Council. London: Her Majesty's Stationery Office; 1960.

Menon, M. P.; Menon, K. K.; Kuroda, P. K. On the stratospheric fallout of bomb-produced cerium isotopes. J. Geophys. Res. 68:4495–4499; 1963.

Miller, C. E.; Marinelli, L. D. Gamma-ray activity of contemporary man. Science 124:122–123; 1956.

National Academy of Sciences. The biological effects of radiation. Washington: U.S. National Academy of Sciences; 1956.

National Academy of Sciences. Meteorological aspects of atomic radiation. Science 124:105–112; 1956.

Nordyke, M. D.; Williamson, M. M. The Sedan Event. Livermore: Lawrence Livermore National Laboratory; PNE-242F; 1965.

Perkins, R. W. Physical and chemical form of I^{131} in fallout. Health Phys. 9:1113–1122; 1963.

Perkins, R. W.; Thomas, C. W. Worldwide fallout. In: Hanson, W. C., ed., Transuranic elements in the environment. Springfield, VA: National Technical Information Service; DOE/TIC-22800; 1980:53–82.

Rand Corporation. World-wide effects of atomic weapons, Project Sunshine. Santa Monica: Rand Corporation; R-251-AEC; 1953.

Rand Corporation. Close-in fallout. Santa Monica: Rand Corporation; 1958.

Rivera, J. Index to interpretive articles and notes published in the Health and Safety Laboratory fallout program quarterly summary report from 1958 through 1969. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-218; 1970.

Rivera, J.; Harley, J. H. HASL contributions to the study of fallout in food chains. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-147; 1964.

Rivera, J.; Harley, J. H. The HASL bone program. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-163; 1965.

Roessler, G. S.; Dunavant, B. G.; Roessler, C. E. Cesium-137 body burdens in Florida residents. Health Phys. 16:673–679; 1969.

Roessler, C. E.; Williams, E. G.; Nettles, E. D. Cesium-137 and strontium-90 in Florida milk—A five-year study of distribution and levels. Health Phys. 16:681–689; 1969.

Rundo, J. Measurements of 137Cs in human beings in the United Kingdom. Harwell: Atomic Energy Research Establishment; AERE HP/M 126; 1958.

Russell, R. S. Radioactivity and human diet. Oxford: Pergamon Press; 1966.

Shore, B. W.; Hatch, F. C., Eds. Biological implications of the nuclear age. Washington: U.S. Department of Energy; AEC Symposium Series No. 16; 1969.

Soldat, J. K. The relationship between I^{131} concentrations in various environmental samples. Health Phys. 9:1167–1171; 1963.

Solon, L. R.; Lowder, W. M.; Zila, A. V.; DeVine, H. D.; Blatz, H.; Eisenbud, M. Measurements of external environmental radiation in the United States. Science 129:1183–1184; 1958.

Stewart, N. G.; Osmond, R. G. D.; Crooks, R. N.; Fisher, E. M. The world-wide deposition of long-lived fission products from nuclear test explosions. Harwell: Atomic Energy Research Establishment; AERE HP/R 2354; 1957.

Straub, C. P.; Fooks, J. H. Cooperative field studies on environmental factors influencing I^{131} levels in milk. Health Phys. 9:1187–1195; 1963.

Toonkel, L. E. Final tabulation of monthly ^{90}Sr fallout data. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-329; 1977.

Toonkel, L. E. Worldwide deposition of ^{90}Sr through 1979. In: Environmental Quarterly. New York: U.S. Department of Energy Environmental Measurements Laboratory; EML-381; 1980:I153–I165.

Van Middlesworth, L. Radioactivity in animal thyroids from various areas. Nucleonics 12(9):56–57; 1954.

Van Middlesworth, L. Radioactivity in thyroid glands following nuclear weapons tests. Science 123:982–983; 1956.

Van Middlesworth, L. Iodine-131 fallout in bovine fetus. Science 128:597–598; 1958.

Van Middlesworth, L. World-wide distribution of iodine-131 in animal thyroids following announcements of isolated nuclear weapons tests in North Africa. Nature 188(4752):748–749; 1960.

Van Middlesworth, L. Factors influencing the thyroid uptake of iodine isotopes from nuclear fission—A review. Health Phys. 9:1197–1211; 1963.

Volchok, H. L. The HASL surface air sampling program. Summary report for 1963. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-156; 1965.

Volchok, H. L. Index to interpretive articles and notes published in the Health and Safety Laboratory fallout program quarterly summary report from 1958 through April 1972. New York: U.S. Department of Energy Environmental Measurements Laboratory; HASL-266; 1972.

Weaver, J. C.; Kamm, M. L.; Dobson, R. L. Excretion of radioiodine in human milk. J. Am. Med. Assoc. 173:872–875; 1960.

White, M. R. Human and cattle thyroid radioactivity associated with fallout. Berkeley: Lawrence Berkeley National Laboratory; UCRL-3703; 1956.

White, M. R.; Dobson, E. L. California cattle thyroid activity associated with fallout. Berkeley: Lawrence Berkeley National Laboratory, UCRL-3355; 1956.

LIMITATIONS OF PRESENT CALCULATIONS OF DOSE FROM ^{131}I IN GLOBAL FALLOUT

Problems in calculating doses from ^{131}I contained in global fallout were mentioned in Part I. It is instructive to remember that by definition global fallout consists of debris that is injected into the upper regions of the atmosphere, from which it devolves slowly with time. A normal expectation would be that this material comes down so slowly that all of the ^{131}I contained in the debris would have decayed before it reached the earth. However, it was noted on many occasions that ^{131}I from global fallout did occur in milk, but mainly through the occurrence of uncommon atmospheric events such as the large-scale subsidence of air masses and from the penetration of large thunder storms into the upper troposphere and even into the stratosphere (Machta 1963).

In general these unusual occurrences were not predictable. Also, the networks that were established to monitor global fallout were not generally designed and equipped to monitor the presence of radionuclides as short-lived as ^{131}I. Thus, although some data exist and have been used by Beck (2000) to calculate country-average values of deposition of ^{131}I, it has not yet been possible to use such data to provide county-by-county estimates of the deposition of ^{131}I.

An alternate method of improving the estimates of dose from ^{131}I and in achieving much better resolution is to use the actual data on the measurements of the concentration of ^{131}I in milk. A summary of such measurements for the 1960–1963 (first quarter only) were presented earlier. Briefly, the history of such measurements is that the Public Health Service established the Raw Milk Network in 1957 to develop sampling and radiochemical analytical proficiencies (Terrill 1963). The Pasteurized Milk Network was established later and was used to monitor and report levels of radionuclides in milk from 1960 through 1974. The milksheds sampled through the PMN covered essentially all of the contiguous U.S. plus Alaska and Hawaii.

A proposed method to reconstruct radiation dose from ^{131}I in global fallout is to use the actual data reported from the PMN. This could cover at least the major periods of fallout from 1960 through 1963. Monthly summaries of such data are available in *Radiological Health Data,* a publication of the U.S. Public Health Service. It is hoped that the unsummarized data can be located and used for dose-reconstruction purposes.

An improved dose reconstruction for the important 1956–1958 years is more problematic, as very few measurements of radionuclides in milk were made. Perhaps additional work with the gummed-film data (Beck 2000) could be useful, and additional work could be done with the cattle-thyroid data collected by Van Middlesworth (1954, 1956, 1958,1960, 1963). There are also many measurements of concentrations of radionuclides in air that might be processed to derive useful information on the occurrence of ^{131}I in air; the deposition to ground and vegetation could then be estimated.

Appendix I

Communications Materials

Contents: This appendix provides the communications plan for the 131I/NCI Communications Project (I.1) , information pertaining to the January 2000 NCI/CDC workshop entitled "I-131 Fallout from NTS: Informing the Public" (I.2–I.5), a description of tools typically utilized for communications planning materials (I.6), and a description of the campaign implementation and evaluation (I.7). Although the campaign is ongoing, these materials are provided for historical reference.

I.1 Outline for I-131 Communications Plan

I.1.1 Situation Analysis

- In the 1950s and early 1960s, the United States Government conducted almost 100 atmospheric nuclear bomb tests in the Nevada Test Site (NTS), releasing iodine-131 (I-131) and other radionuclides into the atmosphere. In the same period, there were about a dozen underground tests where some atmospheric release of radioactive material was possible. Most of the current scientific information on the subject relates to I-131, which concentrates in the thyroid gland and may be linked to thyroid cancer and other thyroid disorders. Although I-131 released from the NTS has decayed and is no longer present in the environment, at the time of testing, radioactivity was deposited on soil and vegetation throughout the country. Doses of radiation varied widely according to geographic area based on wind and rainfall patterns. Some areas received minimal exposure, while others, sometimes far from the test sites, received higher radiation exposures. After cows and goats consumed the contaminated vegetation, I-131 appeared in the milk produced by those animals.
- Exposure to I-131 may increase the risk of thyroid cancer and other thyroid disorders. People who drank milk, particularly children, are estimated to have received higher

than average doses of I-131 from the contaminated milk which have been associated with a higher risk for thyroid cancer and other thyroid diseases. Those who were or may have been exposed to I-131 should be informed of their exposure and the potential health effects so that they can consult with a health care provider for monitoring of their thyroid and possible screening. Those who do not have a health care provider should be informed about existing resources that may be able to assist them. Although a diagnosis of thyroid cancer and other non-cancerous conditions must be treated seriously, thyroid cancer is relatively uncommon and is not normally fatal, particularly with early detection and proper treatment.

- Congress mandated that the National Cancer Institute (NCI) assess the public health impact of the NTS on the American people. Since the publication of NCI's report on estimated exposures and thyroid doses in 1997, an Institute of Medicine committee reviewed and assessed the validity of the report and made recommendations to the government on how to communicate with the public aboutI-131 exposure from the NTS.

- NCI has taken the lead role for the Federal Government in the development of a communications plan related to I-131 fallout exposure from NTS. In January 2000, a communications workshop – sponsored by NCI and the Centers for Disease Control (CDC) – was held to gather input from citizens, consumer advocates, physicians, scientists, health department representatives, and other government officials on the best ways to inform the public and health professionals about I-131 exposure. One outcome of the workshop was the formation of a Communications Development Group (CDG), made up of representatives from community groups, health professionals, and concerned citizens, to offer guidance to NCI staff with the development of an NTS I-131 communications plan.

- Although the current communications plan focuses on I-131 exposure from NTS, there are other sources of I-131 exposures in specific areas around the country. There are four additional nuclear reactor sites in the United States that released I-131 into the atmosphere that may have resulted in multiple I-131 exposures to nearby communities. These sites include the following: Hanford Nuclear Reservation in

Richmond, Washington; Idaho National Engineering and Environmental Laboratory in Idaho Falls, Idaho; Oak Ridge National Laboratory in Oak Ridge, Tennessee; and Savannah River Site in Aiken, South Carolina. There is a level of uncertainty associated with the health effects from multiple exposures to I-131, although it is likely that the health impact of multiple exposures may be more significant than a single dose exposure. In order to address this issue, the current plan will include messages that individuals who lived in and around the aforementioned areas may have received exposure to I-131 from NTS as well as from other sources, and that these multiple I-131 exposures may pose resultant health risks.

- ♦ The feasibility of collecting scientific information about the health effects from global fallout and the levels of exposure from other radionuclides is currently being assessed. If there is agreement on public health outreach concerning multiple I-131 exposures and the levels of exposure from other radionuclides, this communications planning process may be used as a blueprint for future communications efforts.

I.1.2 Challenges and Opportunities

Challenges

- ♦ The credibility of the Federal Government, as a whole, has been compromised on the radiation issue. Therefore, the Federal Government should work with third parties in providing informational messages. In addition, credibility issues vary across government agencies and according to individuals' experiences with particular agencies on issues related to radiation. The general public is largely unaware of radiation exposure that occurred nearly 50 years ago and may experience a variety of emotions when they learn about potential exposure risks. Some people may be justifiably concerned about their exposure and the risks that result from it; others may be unnecessarily frightened; some may question why the government conducted the tests, exposing the public to I-131, while others may not have any interest in the issue. For those who have suffered from thyroid illness or have loved ones who have suffered, the new information may also create a sense of closure and provide some answers. Balancing the need to inform people while creating an appropriate level of concern with the possibility of creating a significant level of unwarranted anxiety will be an ethical and communications challenge.

- The I-131 issue is competing with many other health issues that may be perceived to be more current and pressing among health care providers and members of the general public.
- I-131 exposure and the potential health implications are complex issues marked by scientific and medical uncertainties, and are difficult to communicate to the public in non-scientific terms. Communications about this issue must include honest descriptions of the uncertainties about exposure and potential doses, and honest descriptions of uncertainties related to assessing past exposure and potential doses received. Such communication can help build trust or may exacerbate a lack of trust if it appears to “waffle” on the uncertainties. In addition, because these exposures were *involuntary* and not fully disclosed for many years, reactions to related information will likely be more negative. Therefore, risk communication principles should be employed throughout the program.
- Communications efforts involving American Indian audiences will have to be sensitive to a heightened distrust of governmental messages and must be coordinated with other government agencies based on the unique government-to-government relationship with American Indian tribes.

Opportunities

- There are strong citizen networks and health professional organizations in the communities that may support implementation of specific strategies in a comprehensive communications plan. These networks include advocacy groups, public health networks, and Internet communications networks.
- CDG involvement will ensure that the communications plan is thorough and directed to the most appropriate audiences. The CDG can also help brainstorm possible organizational structures through which the messages can be disseminated.

- NCI has received a positive response to its efforts to involve the advocacy and the health professional communities at the earliest possible stages in the development of communications surrounding I-131.
- Other agencies and organizations are involved in addressing I-131 exposure issues. For example, ACERER (Advisory Committee for Energy-Related Epidemiological Research) held a meeting to hear public input on the need for thyroid screening for those exposed to I-131 from the NTS in June 2000.
- The research group led by Annette O'Connor has expressed an interest in developing a screening decision aid that may be one tool in the implementation of this communications plan. One activity of the plan, therefore, could be to work with this group to create and review such a tool. The feasibility will be explored for developing a decision tree that could help those without health insurance find existing programs that might assist them.

I.1.3 Communication Goals

- Individuals who may have been exposed to I-131 radiation from the NTS will seek the appropriate guidance of health care providers about the potential health effects of exposure and what can be done to address these effects.
- Healthcare providers will understand the risk of I-131 exposure and the potential health effects and will be able to advise patients regarding their individual health status, potential risks, and options.

I.1.4 Communication Objectives

- To communicate to the intended audiences understandable information about the release of I-131 from the NTS, the potential health effects of exposure, and what exposed individuals can do about those effects.
- To engage intended audiences in the issue and encourage individuals who are concerned about I-131 exposure to consult with a health care provider or other sources of health services.

- To inform health care professionals about the possible health effects of I-131 exposure and to provide information to assist them in working with patients who are concerned about exposure.

I.1.5 Intended Audiences

The Public

- Individuals aged 40 and older, particularly those who lived in areas of highest exposure and consumed milk, with special emphasis on underserved populations, including minority groups and those with limited access to the health care delivery system.

Health Care Providers

- Primary care providers
- Thyroidologists
- Obstetricians and gynecologists
- Managed care organizations
- Nurses and nurse practitioners
- Providers in community health centers, migrant health clinics, and the Indian Health Service
- Psychologists and psychiatrists

Others

- Social workers
- Advocacy and support groups
- Community-based networks
- Schools of Public Health

I.1.6 Channels

Members of the public, including those who may be at higher risk, may be reached through a variety of channels, including:

- Intermediary organizations such as environmental advocacy groups and downwinders
- Community groups (especially in high-risk locations)
- Health care providers (especially in high-risk locations)
- State and local health departments, sliding scale clinics, community health centers, and migrant health clinics
- Bureau of Primary Care, Health Resources and Services Administration (HRSA)
- Internet (NCI Web site and primary Internet health portals)
- NCI's Cancer Information Service (CIS)
- Health-related federal agencies, e.g., Public Health Service, Indian Health Service, CDC, Veterans Administration
- American Indian Tribal Governments through collaboration and support of the Indian Health Service and other federal agencies
- Churches and other religious organizations

How Health Care Providers May be Reached

- Intermediary groups such as professional associations and their media (newsletters, journals, etc.)
- Professional meetings and continuing education
- Internet
- Health-related federal agencies, e.g., Public Health Service, Indian Health Service, CDC, Veterans Administration, Health Care Financing Administration

I.1.7 Core Messages

The Public

- Brief explanation that everyone in the United States during the time of the tests was exposed to some level of I-131 and depending on individual risk factors, is at varying health risk; description of potential health effects and their symptoms; and how to determine exposure. Messages should also acknowledge that multiple I-131 exposures and exposure from other radionuclides were possible, although less is understood about these other exposures.
- Recommendation to consult with a health care provider to determine if any steps should be taken to monitor and protect their health. (Information will be available to guide people without health insurance to existing programs that may assist them.)

Healthcare Providers and Others

- Brief explanation that everyone in the United States during the time of the tests was exposed to some level of I-131 and depending on individual risk factors, is at varying health risk; description of health effects and their symptoms; and how to determine exposure.
- Suggestions for counseling patients with concerns about the health effects associated with I-131 exposure.
- Suggestions for assessing appropriate health precautions/monitoring.
- Resources and references.

I.1.8 Message Tone

- Compelling, motivating; not frightening
- Empowering audiences to address their concerns
- Credible, truthful, engaging
- Not paternalistic
- Compassionate

I.1.9 Message Development Process

Message concepts were developed and tested with members of the intended audiences to determine *how* to deliver the messages in the most useful way (after it is determined *what* to say). Concept testing* is the type of research recommended in communications planning after exploratory focus groups and before material pretesting. A creative team then analyzed the responses to determine how messages would be crafted so that audiences would understand and act upon them.

Once materials were created, they were pretested with appropriate audiences, including underserved individuals without access to health providers.

I.1.10 Strategies and Tactics

Create and activate existing community and grassroots networks, along with state and local health departments, to deliver program messages to identified audiences.

The NCI completed the following:

- Identified and created a contact list of potential organizations to include as a network for program implementation.
- Developed informational materials to be used at the local level by organizations already involved with radiation exposure issues and those committed to public health, including local health departments. By creating turnkey materials and kits, messages were controlled and consistent. Community groups were encouraged to refer individuals to the Cancer Information Service (CIS) for additional information, answers to questions, and referrals to health provider services and other community services for assistance. Final materials included:
    - **Get the Facts About Exposure to I-131 Radiation--**This general information brochure provides information about the Nevada tests and identifies individuals at particular risk.

* Message concepts, also called creative concepts, are simple graphics paired with headlines and taglines designed to elicit responses from audience groups and get them talking about the issue in very concrete terms.

- **Making Choices: Screening for Thyroid Disease*--**This decision aid workbook/brochure is for individuals concerned about their exposure to I-131 from fallout (This is based on decision support format of the Ottawa Health Decision Center at the University of Ottawa and Ottawa Health Research Institute, Ontario, Canada)
- **Radioactive Iodine (I-131) and Thyroid Cancer*--**This flip chart, designed for use in small groups of up to 10 people, addresses concerns specific to Native Americans.
- I-131 Website (www.cancer.gov/i131)
- Tools for partners* ("swiss cheese" press release, promotional brochure, web blurb)

Provided technical assistance in communicating information about I-131 and the potential health effects to public health departments in areas of highest exposure.

Developed materials to enable health professionals to respond to patient concerns about potential I-131 exposure and to address the issue with patients who may have received higher exposure**.** These materials are noted with a * above**.**

♦ Worked with health professional organizations and their members to provide information to patients who may be concerned about their exposure or who may be unaware, yet subject to health complications from their exposure.

Worked with health care providers through their professional organizations (such as medical societies) to raise their awareness of the issue and inform them about materials available for their use. 1-800 phone numbers and Web addresses were highlighted to help health care providers ask for or obtain materials.

Enable audiences to access materials through multiple channels so that information is presented to them proactively but is also accessible upon demand.

- Developed an “I-131 web page” on the NCI Web site (www.cancer.gov/i131). The page offers sections for consumers and health professionals. The decision aid and the dose/risk calculator are also on the website.
- Worked with key health information portals targeting health professionals and consumers so that they can either provide a link to the NCI website or post the I-131 materials on their own site.
- Provided information and training on the topic to the CIS regional offices, which respond to telephone inquiries from consumers and professionals and conduct community outreach on specific cancer-related issues. (Note: Individuals who do not have easy access to the Internet are directed to the CIS which can provide them with information about the tests at the NTS and the potential exposures and possible subsequent health effects. The CIS is also a resource for referrals to other services, such as counseling, for people who learn that they have cancer or other specified health conditions, such as problems caused by exposure to I-131.)

Collaborate with other federal agencies, components of the government and other organizations to achieve consistent communication about I-131 and the potential health effects and demonstrate the effectiveness of the planning process model.

- NCI worked with key federal partners, including the Centers for Disease Control and Prevention, the Agency for Toxic Substances and Disease Registry, the Department of Defense, the Veterans Administration, the Department of Energy, the Environmental Protection Agency, the Indian Health Service, Bureau of Primary Health Care, and others. This effort was made to ensure consistent, inter-agency communication and actions on related radiation issues and facilitate more information sharing across agencies. (It is not foreseen that these agencies will help facilitate the specific activities described in this plan.)
- Coordinated and collaborated with Canadian organizations on the decision aid.

Use a phased approach to build momentum around the message and an opportunity for on-going evaluation.

The campaign implementation and evaluation is outlined on Page I-124.

Addendum A

Cancer Information Service's Role in I-131 Communication Plan

Materials Distribution

- The I-131 materials are available from the Publication Ordering Service and on the Publications Locator on the Web.
- Callers to the CIS are offered appropriate materials.

Information Calls to 1-800-4-CANCER

- CIS is now using information prepared by NCI to answer inquiries form the public.
- CIS makes referrals to health care professionals according to its current referral policy. (Note: CIS does not make referrals to individual physicians, only to NCI sponsored programs.)
- CIS does not use any of the modeling techniques to perform risk assessments for callers.

Referrals to Other Services

- CIS has referral information for cancer screening, treatment, pain, and indigent care. CIS refers to other community/national organizations for support services; CIS does not maintain referrals for support groups or other local counseling services. If other specific referrals are necessary for this project, they would need to be provided to CIS.

Outreach

- The CIS Partnership Program distributes I-131 materials to the state, regional, and community/local organizations it routinely works with.

Addendum B

Other Suggestions from the CDG

This document includes issues that cannot be addressed within the scope of the NTS I-131 Communications Plan, but will be shared with other governmental agencies.

- Develop a pilot project for addressing multiple exposures to I-131 as well as exposure to other radionuclides. This communications plan focuses on exposure to I-131 from NTS, but may be used as a model for future efforts, if deemed scientifically feasible and appropriate.
- Provide cost reimbursement for screening and/or medical costs associated with exposure to I-131 from the NTS, exposure to other radionuclides from NTS, and exposures to I-131 and other radionuclides from multiple sources, including "global" nuclear testing and radiation releases from United States nuclear facilities.
- Develop an Information Resource Center similar to the Hanford Health Information Center with a 1-800 number, Health Information Network, and On-line Exposure Health Database. This would enable people to get information, get connected, and get help accessing ancillary services, such as support and counseling.
- Develop an NTS Fallout Health Effects Subcommittee and an NTS Fallout Health Information Network originally proposed in Utah House Concurrent Resolution 10.
- Provide training or "train the trainer" sessions on exposure and screening to enhance community-based efforts.
- Provide counseling/support services (or cost reimbursement) for people who learn that their health has been affected by I-131 from NTS.
- Incorporate new ACERER recommendations into the plan once they are formally recommended and approved by the Department of Health and Human Services.

I.2 Workshop Agenda

(see next page)

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

NATIONAL CANCER INSTITUTE

Workshop Agenda

January 19-21, 2000

Wednesday, January 19 – Briefing Day

9:00 a.m. – 9:30 a.m.	Arrival and Check-In	
Session A		
9:30 a.m. – 10:00 a.m.	Opening Session	
	Welcome and Charge to Group	Alan Rabson, M.D. Mike Sage, M.P.H.
	Ground Rules and Introductions	Denise Cavanaugh, Facilitator
Session B		
10:00 a.m. – 10:45 a.m.	Broad Overview and History	Mark Epstein, Moderator
	Brief NTS History	Mark Epstein
	A Citizen's Perspective	Trisha Pritikin, Esq., M.D., O.T.R
	IOM Report	Robert Lawrence, M.D.
10:45 a.m. – 11:00 a.m.	Break	
Session C		
11:00 a.m. – 12:30 p.m.	The Science of I-131 Exposure and Health	
	1. What Can Science Tell Us About the Health Risks of I131?	Charles Land, Ph.D.
	2. What I-131 Doses Did People Receive From NTS Fallout?	Steve Simon, Ph.D.
	3. Reflections From and Independent Scientist on the Science of I-131.	Owen Hoffman, Ph.D.
12:30 p.m. – 1:45 p.m.	Lunch	
Session D		
1:45 p.m. – 2:15 p.m.	Public Health Communications Challenge	Elaine Arkin
Session E		
2:15 p.m. – 3:00 p.m.	Table Discussions	Denise Cavanaugh
3:00 p.m. – 3:15 p.m.	Break	

Wednesday, January 19 – Briefing Day (Continued)

Session F

3:15 p.m. – 5:15 p.m.	Communications Challenge: Group Discussions		
	1. Interest Group Perspectives		
		Moderator	Seth Tuler
		State/Local Advocacy Organization	J. Truman
		National Advocacy Organization	Maureen Eldredge
		Physician Advocate	Tim Takaro, M.D.
		Native American	Robert Holden
		Ground Zero	Lincoln Grahlfs, Ph.D.
		Consumer Organization	Jean Halloran
	2. Health Provider: Channels and Gatekeepers		
		Moderator	Kevin Teale, M.A.
		Practitioner	R. Michael Tuttle, M.D.
		Sliding Scale Clinic	Delvin Little, M.D.
		Medical Specialty Group	Henry Royal, M.D.
		Risk Communicator	Jim Flynn, Ph.D.
		Medical Ethicist	Kristin Shrader-Frechette, Ph.D.

Session G

5:15 p.m. – 5:45 p.m.	Wrap-Up	Denise Cavanaugh
5:45 p.m. – 6:30 p.m.	Break	

Session H

6:30 p.m. – 9:00 p.m. Networking Reception and Dinner

Thursday, January 20 – Discussion Day

7:30 a.m. – 8:30 a.m.	Continental Breakfast	
Session I		
8:30 a.m. – 8:45 a.m.	Summary of Day 1 and Charge for Day 2	Denise Cavanaugh
Session J		
8:45 a.m. – 10:15 a.m.	Screening/Medical Monitoring	Denise Cavanaugh Mark Epstein Moderators
	1. What Recommendations and Current Programs Exist for Screening and Monitoring?	Robert Spengler, Sc.D. R. Michael Tuttle, M.D.
	2. Assessing Individual Risk	Keith Baverstock, Ph.D. Owen Hoffman, Ph.D.
	3. A Model for Individual Decisionmaking	Valerie Fiset, R.N., M.Sc.N.
10:15 a.m. – 10:30 a.m.	Break	
Session K		
10:30 a.m. – 12:00 noon	Table Discussions: What do we know that we can use to begin developing messages and defining populations? What do we need to know to develop and effective campaign? What questions should be forward for April screening forum?	
12:00 noon – 1:15 p.m.	Lunch	
Session L		
1:15 p.m. – 3:30 p.m.	Developing Model Outreach	
	1. Strategies for Message Development An approach to identifying Target audiences	Peter Sandman, Ph.D.
	Considerations for developing Science-based messages	Neil Weinstein, Ph.D.
	2. Audiences Research Results Presentation of preworkshop research	Ed Maibach, Ph.D.
3:30 p.m. – 3:45 p.m.	Break	

Thursday, January 20 – Discussion Day (Continued)

Session M

3:45 p.m. – 5:15 p.m.	Developing Model Outreach (Continued) 3. Table Discussions What additional audience research Is needed?	Ed Maibach, Ph.D., Facilitator

Session N

5:15 p.m. –5:45 p.m.	Wrap-Up Identify agreements and outstanding issues. Move forward on a communications plan.	Denise Cavanaugh

Friday, January 21 – Input Day

7:30 a.m. – 8:30 a.m.	Continental Breakfast	

Session O

8:30 a.m. – 9:00 a.m.	Summary of Day 2 and Charge for Day 3 Review Operating Principles	Denise Cavanaugh

Session P

9:00 a.m. – 11:00	Breakout Session Topic Decided on Thursday Afternoon	
10:00 a.m. – 10:15 a.m.	Break	

Session Q

11:00 a.m. – 12:00 noon	Reports From Breakout Session Group Reporters	
12:00 noon – 1:00 p.m.	Lunch	

Session R

1:00 p.m. – 2:00 p.m.	Summary	James Mathews/Kellie Marciel Joan Morrissey
	Next Steps	Nelvis Castro Owen Devine

Session T

2:00 p.m. – 2:15 p.m.	Closings Comments and Thank You to Participants	Alan Rabson, M.D.

I.3 Workshop Summary

I-131 Fallout from NTS: Informing the Public
January 19-21, 2000

Workshop Summary

On January 19-21, 2000, a workshop titled "I-131 Fallout from NTS: Informing the Public" was held in Rockville, Maryland. It was sponsored by the National Cancer Institute (NCI) and the Centers for Disease Control and Prevention (CDC) and planned in consultation with a working group of citizen representatives and state health department staff. This report summarizes the workshop proceedings for the benefit of participants and other interested individuals and organizations.

- Section I.3.1 - Workshop Proceedings
- Section I.3.2 - List of Working Group members and government staff
- Section I.3.3 - Workshop Participants
- Section I.3.4 - Proposed Campaign Operating Principles
- Section I.3.5 - List of Other Resources

The working group designed the workshop with five outcomes in mind:

1. Obtain input for the ongoing process of campaign development and implementation, including the structure for continued public participation in the process.
2. Get input on target audiences and a process for developing messages.
3. Get suggestions for additional audience research.
4. List the scientific questions that still need to be addressed, including suggestions for an April workshop on screening to be hosted by the Advisory Committee for Energy-

Related Epidemiologic Research (ACERER), which advises the Department of Health and Human Services (DHHS) on radiation research[1].

5. Identify ways to leverage this model process to benefit subsequent efforts on the full range of health effects from radionuclides released from the Nevada Test Site (NTS).

The workshop brought together affected citizens, consumer advocates, physicians, scientists, health department representatives, risk communicators, and government officials. Some had a long history with radiation fallout issues; others were new to the field but experienced in communications or reaching specific at-risk populations.

By the end of the three-day workshop, participants agreed on a set of campaign goals, provided organized feedback on four areas of campaign development, and developed a "wish list" of outcomes they would like to see in the near and distant future.

[1] At the time of the workshop, it was anticipated that the ACERER meeting to address screening issues would be held in April 2000. The meeting has since been scheduled for June, 2000.

I.3.1 Workshop Proceedings

I.3.1.1 Day One

Opening and Introductions

The workshop was opened by Alan Rabson, M.D., Deputy Director of the NCI, and Mike Sage, M.P.H., Acting Deputy Director of the National Center for Environmental Health at the CDC. They charged the group with providing input to NCI and CDC in the development of a communications program that will 1) inform the public, and more particularly, the members of the public who are at high risk for health problems because of their exposure to radioactive iodine-131, and 2) educate health providers so they can provide appropriate care. The challenge will be to figure out how best to communicate the history, the science, and the possible health risks from exposure to radioactive iodine-131 from the Nevada Test Site. Dr. Rabson noted the active interest of the Department of Health and Human Services (DHHS), acknowledging the presence of Dr. William Raub, representing DHHS Secretary Donna Shalala.

Denise Cavanaugh, the workshop facilitator, reviewed the ground rules and desired outcomes for the workshop. She reiterated the desire to identify some common ground, to provide scientific background, history on the issue, and to discuss the communications challenges and strategies that might be employed in the campaign. Ms. Cavanaugh encouraged participants to use the listserv set up by NCI to interact and give additional feedback after the workshop. A handout was provided with directions on how to subscribe to the listserv. Ms. Cavanaugh also pointed out the Operating Principles drafted by the working group.

Overview and History

Mark Epstein of Porter Novelli, Washington, D.C., gave a brief overview of the history of the Nevada Test Site, referring participants to the Institute of Medicine (IOM) Report[2] and working group member Trisha Pritikin's document[3] for further details.

Robert Lawrence, MD, of Johns Hopkins University, and chair of the IOM Committee that reviewed NCI's report[4] on I-131 dose estimates, offered a brief presentation of the IOM Report. He focused on the factors that contribute to individual dose estimates and the problems in making estimates due to geographic variation, dietary patterns, and individual susceptibility. He agreed that excess cases of thyroid disease were caused by radioactive fallout, but he asked whether trying to identify individuals who are at greatest risk and screening them would lead to greater harm than good. And so, the IOM committee took the approach "first, do no harm," in recommending against mass screening for thyroid cancer. He encouraged the group to work toward a communications program that focuses on shared decision-making between individuals and their health care providers.

Trisha Pritikin, a member of the working group, brought the perspective of a citizen exposed to NTS fallout and environmental ionizing radiation emissions, including I-131, from the Hanford nuclear weapons facility. She noted that radioiodine is only one of a host of biologically significant radionuclides released during the NTS nuclear bomb tests. She asked that this I-131-focused campaign be followed by similar campaigns on other NTS radionuclides. She called for an appropriate government response to these involuntary environmental exposures. She also encouraged a discussion of government-sponsored screening for those at highest risk from their childhood exposures, as is anticipated to occur at an upcoming ACERER meeting.

Ms. Pritikin detailed the impact of radioactive fallout on her family, describing her illness and the death of both of her parents. She grew up in Richland, Washington, adjacent to the

---

[2] *Exposure of the American People to Iodine-131 from Nevada Nuclear Bomb Tests: Review of the National Cancer Institute Report and Public Health Implications.* 1999. National Academy Press: Washington, DC

[3] Ms. Pritikin was a Working Group member who prepared a document, "NTS History," which was included in the packet of materials for workshop participants.

Hanford nuclear weapons facility. She called for estimates of cumulative exposures and risk, based on multiple radioactive exposures such as NTS, Hanford, and global fallout. She also called for discussion of all potential health outcomes, including thyroid cancer, autoimmune thyroiditis, hypothyroidism, hyperthyroidism, hyperparathyroidism, and other related diseases. She noted that screening for non-cancer outcomes involves a simple blood test, which has a different benefit/risk ratio than thyroid cancer screening.

At the completion of her presentation, Ms. Pritikin read from the written and oral transcripts of the Hearing before the Senate Permanent Subcommittee on Investigations of the Committee on Governmental affairs, citing Senator Tom Harkin's support for medical screening for those at highest risk from NTS I-131 exposures, and citing his disagreement with the recommendations against screening made by the IOM committee that reviewed the NCI I-131 report. Dr. Lawrence, chair of the IOM committee, responded by stating that he had spoken with senior members of Senator Harkin's staff regarding these IOM recommendations, and that those staff members then indicated that they understood why the IOM made the recommendations it did.

The Science of I-131 Exposure and Health

Charles Land, Ph.D., of NCI's Division of Cancer Epidemiology and Genetics, explained how NCI developed its estimates of exposure and explained why children were at higher risk than adults: children are more sensitive to radiation; their thyroid glands receive higher doses from ingested or inhaled I-131. They have a higher intake of milk (the main pathway of ingestion), and higher metabolism.

Steve Simon, Ph.D., of the National Research Council's Radiation Effects Research Board, described dose estimates. He explained how dose is calculated and described how uncertainty is factored in. He also showed a number of maps that showed the high exposure areas, or "hot spots," by birth year.

---

[4] *Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests.* 1997. U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute.

Both speakers described the complexity of estimating exposure and doses and the limitations of the sources of I-131 exposure information from the 1950s and 1960s, based on the time of year, weather patterns, cow grazing patterns, dairy management practices, etc. Dr. Simon explained the difficulties in coming to individual dose estimates, which rely on the accuracy of the person's memory of where they were and what they were doing during the testing. County-specific estimates already carry a high degree of uncertainty. Individual estimates are more uncertain, still.

F. Owen Hoffman, Ph.D., from SENES Oak Ridge, Inc., shared his perspective. He stated that, although the risk from exposure to iodine-131 is uncertain, it does not prevent us from estimating risk. The uncertainty can be quantified, allowing an estimated range of 8,000 to 208,000 excess cases of thyroid cancer due to NTS fallout. He suggested that most of the excess cases would occur in females who were children at the time of the testing and who resided in the eastern United States because that was where the population was most dense and where the most milk was produced.

Age, gender, and diet are more important determinants of risk than is location, said Dr. Hoffman. He also noted the need to bring together dose reconstructions from various sources of fallout to estimate cumulative doses. He also called for work to extend discussion beyond iodine-131 to other radionuclides in both NTS and global fallout.

Dr. Hoffman argued that health risk evaluations with regard to fallout should include more health effects than thyroid cancer, such as benign nodules and autoimmune thyroiditis. He also urged that other I-131 exposure sources and time periods beyond 1962 be investigated, including the underground testing era.

Dr. Hoffman also reported that there is now a more sophisticated method of calculating the uncertainty associated with dose estimates than what was used in the NCI online dose calculator. Calculations using the "Monte Carlo" method take into account the adding of uncertainties from disparate time periods, and result in smaller uncertainty ranges.

Public Health Communications Challenge

Elaine Bratic Arkin, a health communications consultant, defined health communications and social marketing, using a CDC definition: "the crafting and delivery of messages and strategies based on consumer research to promote the health of individuals and communities." Communications can prompt people to take simple actions, like call a toll-free number or make an appointment with a doctor. It can correct misconceptions, and it can coalesce relationships. She said that the campaign's challenges include the public's complacency (since these exposures happened decades ago), a media environment cluttered with health messages, and a very complex topic to convey to the public.

To be successful, the communications campaign needs to be planned, budgeted and supported over time, Ms. Arkin stated. It needs to be tracked and evaluated in case adjustments are needed. It may need to be part of a multifaceted program, coupled with provision of services and physician education, for example. She also described the components of a communications plan.

Table Discussions

Small group discussions following Ms. Arkin's presentation focused on two questions: what is the issue, and what one change might advance the effort? Some of the issues and actions discussed:

- Lack of trust in the government
- The government must accept accountability for past events and future actions.
- The program should be comprehensive instead of separating nuclear fallout from mining, milling, production, waste, and weapons use. In other words, the public wants to know about isotopes beyond I-131 and exposures beyond Nevada Test Site.
- There are two public health issues here: the actual physical impact of exposure and the psychological stress induced in people by the exposure.
- How will we help people who are mobile and speak a language other than English understand the risk?
- We've got to make clear there was an impact, even if we are uncertain about the magnitude.

- There is a need to educate physicians so they will take patients' complaints and concerns seriously. If a doctor is honest and up-front, the patient will have less fear and uncertainty.
- Physicians must be contacted before a public campaign is launched. We need to get the attention of primary care physicians and get health care providers, such as HMOs, on board.
- It may be difficult to identify a credible source for the information, due to issues of mistrust.
- There are two components: a notification piece, to educate and reduce fear, and a call to action so that high-risk individuals will seek medical advice, which would include educating physicians to be prepared to respond. There also may need to be some kind of direct help for the affected citizens from the government.
- Give people a full view of their risk from a combination of sources.
- Give people the information they need about risk factors so they can determine their own risk level and then give them information on obtaining follow-up consultation or care, if needed.

Panel 1: Interest Group Perspectives

Working group member Seth Tuler, Ph.D., of the Childhood Cancer Research Institute and Clark University, moderated the workshop's first panel discussion. Dennis Nelson, Ph.D., of Support and Education for Radiation Victims (SERV), described the lifestyle of the downwinder population near the Nevada Test Site to give a sense of the downwinder's exposure. He argued against focusing exclusively on I-131 and cancer and called for a national plan to notify people throughout the country so that they could look into their own exposures and seek early detection.

Maureen Eldredge of the Alliance for Nuclear Accountability described her organization's relationship with the government on nuclear weapons issues as a pattern of deceptions and cover-ups. She stated that the government has an obligation to tell the public that they were involuntarily and unknowingly exposed, regardless of how low the exposure or how minimal the health risk. She suggested also looking at all thyroid disease, not just cancer, and helping people figure out their cumulative doses so they have the full picture of their exposures. It is not up to the government to decide what information people should or shouldn't have because they might make a bad decision with all the information. People should make their own decisions about their health care. Lastly, she said that we should be aware of the impact of money. She said the government might be fearful of providing information out, as people who were exposed may sue the government, whether or not they suffered any ill consequences of exposure. She said the government should pay for the communications, the training and education of health providers, and perhaps even for treatment.

Tim Takaro, MD, of the University of Washington, represented Physicians for Social Responsibility. In his experience with Hanford, the people in the Northwest want to know about their families' illnesses. They want to know if they are at risk, whether they should be tested, and whether their children may be affected. He noted the importance of cumulative doses and called for looking at exposure from mining through weapons disposal. At the same time, physicians don't need to get an accurate dose on a patient to address concerns about risk for certain diseases based on their exposure from Hanford, NTS, and others. He noted that screening large populations with no restrictions is not cost effective, but that screening should not be denied a person who is concerned about his health and the impact of radiation exposure. Physicians will need to address patient anxiety, which in itself is a psychological and physiologic burden.

Robert Holden, of the National Congress of American Indians, discussed the history of the relationship between the federal government and native peoples, stating that the government has a responsibility, based on treaties, to provide for Indian health and welfare. Many Native Americans had multiple exposures. For example, uranium was mined on Navajo land and a national laboratory sits on Pueblo land. He noted that there are certain protocols to communicate with tribal officials. He stated that he hopes that the Native American community can continue a relationship with those planning this campaign to help them better understand Native Americans. He suggested a Native American caucus to work on these issues.

F. Lincoln Grahlfs, Ph.D., is an atomic veteran representing the National Association of Radiation Survivors. He described his experience educating Congress that nuclear radiation is hazardous and getting the word out about the NCI report. His group's media work got tremendous response in areas like St. Louis, Missouri, and Idaho Falls, two "hot spot" areas identified in the report. He warned that special interest groups might try to sabotage efforts to educate the public on issues of radiation exposure and health risks.

Mike Hansen, Ph.D. represented Jean Halloran from Consumer's Union. From his background working on advocacy issues on pesticides and genetically engineered foods, he stated that the government will have to do a few things to gain credibility: 1) take a comprehensive view, broader than I-131 and all potential health effects, 2) provide as much information as possible, and 3) admit the government was wrong. Even if the risk is small, the public will get upset at risks that were involuntary, that they had no control over, and that were done to them without their knowledge. The government will need to be upfront about what happened and how much they don't know. They'll need to work with grassroots organizations and those advocacy organizations that are critical of the government in order to make the campaign successful. The process will be difficult, but important. He suggested working with *Consumer Reports* magazine to write an article on this topic. Dissemination would be widespread, with a readership of 4.8 million subscribers in their 50s and 60s.

Seth Tuler ended the panel by discussing the findings of the ACERER's subcommittee for community affairs. 1) Federal efforts to address the public health consequences of NTS fallout are still inadequate. 2) Difficulty identifying specific fallout injuries does not absolve the federal government of its responsibility to shape a meaningful public health response. 3) Research is not a public health response and is not a substitute for the assistance that many exposed people believe that the government has a responsibility to provide. 4) Delays in sharing important public health information about fallout exposures have reinforced public cynicism toward federal officials.

He then reviewed the ACERER's recommendations: 1) Fulfill the legislative intent of Public Law 97-414, which mandated NCI's study of I-131 NTS fallout; 2) Complete a comprehensive dose reconstruction project for NTS fallout, with an oversight committee created to keep things on track; 3) Notify Americans of the factors that might help them determine if they received significant radiation doses from NTS fallout, targeting high-risk groups; 4) Create a public and health care provider information service; 5) Support an archival project to document the experiences of exposed people; 6) Further evaluate screening opportunities for thyroid disease.

He finished by summarizing the common themes heard during the panel discussion.

- The legacy of mistrust
- Identifying who is at high risk and providing more to them than mere notification
- Empowering people to make informed decisions about their health care
- Addressing fears versus creating fears
- Covering multiple exposures and contaminants
- Overcoming political resistance to implementing programs

Panel 2: Health Provider Channels and Gatekeepers

The final panel on the first day of the workshop included health professionals and gatekeepers. Kevin Teale, of the Iowa State Health Department, moderated. He began by pointing out the challenge the group faces in trying to get a message about this complex topic out to the broadcast media, which relies on four-second sound bites. He also raised the issue of getting the public to pay attention to the risk, when they already don't pay attention to some of the big health risks like smoking or weight control.

R. Michael Tuttle, M.D., from Memorial Sloan-Kettering Cancer Center, is a practicing thyroid specialist. He treats patients with thyroid disease, many of whom already ask him about radiation exposure and their disease. He sees a big challenge in translating excess relative risk, radiation dosage, and other relevant technical jargon into something meaningful to tell a patient. The program will have to help physicians define who is high-risk and help them discuss risk in a way that makes sense to their patients, which may vary by geographic location and cultural background. It must give physicians a strong scientific rationale for determining whether a patient is at risk or not.

Henry Royal, M.D., of the Washington University School of Medicine, was a member of the committee that wrote the IOM Report. He contrasted the public health perspective, which shows that thyroid cancer accounts for just 3% of all cancer deaths, with the personal, devastating perspective of a family member dying of thyroid cancer. He advocated allocating limited health care resources where they can have the greatest impact to reduce premature deaths. He acknowledged the difficulty in taking this view when individuals are dying of thyroid cancer, but shifting public health resources to a program that would have a small public health impact would cause others to needlessly suffer the tragedy of premature death.

Delvin Littell, M.D., of the Morgan County Medical Center, adjacent to Oak Ridge, Tennessee, encouraged the group to work with the organizations of community health centers, clinics that reach low-income individuals. In particular, he noted that the migrant labor movement might offer a resource of particular use with people who don't trust "the system." He also advised that communicators keep in mind how they would like to be treated when developing messages and strategies to reach the public.

James Flynn, Ph.D. Decision Research, talked about risk communications, explaining that the messages developed for this campaign will be going to people who will receive them within the context of suspicion of nuclear technology as well as their personal experiences and preformed judgments. These factors will affect the way they receive and respond to the messages.

Kristin Shrader-Frechette, Ph.D., of the University of Notre Dame, provided a medical ethicist's perspective. Two things she says have gone wrong with risk communication about radiological hazards are: the tendency to present scientific opinion as if it were fact and the tendency to make covert ethical judgments as if they were scientific judgments. She used the example of the IOM report recommending against mass screening because of the benefit to harm ratio. That's a value judgment that takes away individual rights. In a democracy, people have the right to know, the right to compensation, to due process, and to selfdetermination. People have the right to make mistakes for themselves. Lastly, she stated that, to communicate in a credible way, the government will have to state that this will not be repeated. People are willing to forget the past if we can assure them that what they went through in the past is not going to happen again. Deciding about screening is not just a scientific issue, it is an ethical issue and several members of the public should be involved in the decision-making. She recommended using the 1996 National Research Council report, *Understanding Risk: Informing Decisions in a Democratic Society*, as a way to improve risk communication and involve the public in a meaningful way. She also argued that the government is obligated to take responsibility and spend health care dollars on this issue, even if it involves diseases with small public impact because the government is accountable for the radiation fallout and its impact.

I.3.1.2 Day Two

Screening/Medical Monitoring

Day Two began with a session on Screening and Medical Monitoring. Robert Spengler, Sc.D., of the Agency for Toxic Substances and Disease Registry, and R. Michael Tuttle, M.D., reviewed existing recommendations and programs for screening and monitoring. They provided a handout that described the recommendations of various interested organizations and studies. Dr. Spengler also presented the proposed Hanford Medical Monitoring Program, which is not yet funded. He discussed recent revisions to the proposed program that address and reduce the potential harms of thyroid cancer screening expressed in the IOM report. In addition, he submitted documents on the proposal and revisions to NCI as handouts for the participants.

Keith Baverstock, Ph.D., of the World Health Organization, Helsinki, Finland, and Owen Hoffman, Ph.D., talked about assessing individual risk. Dr. Baverstock discussed the value of estimating individual risk, and the limitations of such estimates. He presented the NAS/IOM scheme for describing individuals' risk as falling into three non-numerical categories. Individuals born after the cessation of testing are not at risk; individuals over 18 at the time of testing are at very low risk. For other age categories, the NAS/IOM recommends that DHHS develop a method for calculating an individual "score"—for purposes of categorizing only, not as a numerical expression of risk—that takes into account location, milk consumption, milk source, and gender differences. The resulting scores would then be linked to recommendations for appropriate actions for individuals in each category.

Dr. Hoffman discussed the identification of high-risk sub-groups. He suggested the following criteria be used to determine high-risk status: those in childhood at the time of atmospheric testing, goat's milk drinkers, those with a family history of thyroid cancer or other thyroid abnormalities, and those with estimated doses above a given decision level. Dr. Hoffman emphasized that for the case of goat's milk drinkers who were children during the testing period, enough is known already to classify them as high-risk, without further dose refinement. He highlighted the inherent uncertainty of individual dose estimates and proposed that decisions be based on either the upper or lower bound of confidence on the dose estimates, and suggested a detailed framework for doing this.

Valerie Fiset, R.N., M.Sc.N., of the Sisters of Charity Ottawa Health Service, Ontario, Canada, presented a model for helping people make difficult health-related decisions. Decision aids walk patients, with their health care provider, through steps that help them look at options available, the potential outcomes of those options, then help the patient consider their values in relation to those options. Decision aids are used when the outcomes of the options are not very well known and the patient needs to judge the value of the benefits and risks. They are also useful when there is practice variation around a screening or treatment option. Her group has developed decision aids around chemotherapy for advanced lung cancer, hormone replacement therapy, and lumpectomy versus mastectomy for breast cancer treatment.

At this point, participant discussion began. Audience members were looking for clarification of the scope and goals of the campaign. Some expressed frustration with the government's past record on radiation issues and skepticism that things would change. Denise Cavanaugh, the workshop facilitator, asked the group to make recommendations and to develop a "wish list" of outcomes for the campaign. They are listed below.

General Recommendations

- Move forward with a campaign. Do not wait until all of the science is in. Talk about what you know and explain that more information on dose and associated risks will be provided when feasible.
- Educate the "publics" about the basics of radiation fallout, exposure (from individual facilities, and globally), and health impacts, while giving a sense of the complexity of the information.
- Keep public representatives involved as partners.

- The participants agreed on a framework to discuss I-131 first and then additional radionuclides, as information becomes available. That framework was called: "Public Health Legacy of Nuclear Production, Research, and Testing."

"Wish List" of Activities

Near Future (3 months)

- A communications plan with financial support.
- A decision about access to federally sponsored screening for uninsured and underinsured populations.
- Inclusion of state health departments in campaign development and implementation.
- Partnership with Native American tribal governments in developing the campaign.
- Use of the listserv as an interactive communications tool for discussion and review of draft planning documents.
- Consideration of a resource center with a toll-free number, i.e., an entity responsible for delivery of information.
- Development of an archive (or expansion of existing archives around the country) of documents and resources pertaining to the NTS and resulting exposures, in keeping with the ACERER recommendation.
- Continuation of relationships built at the January 2000 Workshop.
- Government acknowledgment of the legacy of nuclear production, research, and testing and commitment to prevention in the future.
- A clear set of recommended actions for the public to take with regard to exposure.
- Study of the ongoing health effects of existing nuclear action.

Distant Future (36 months)

- Outreach to communities.
- Outreach to federal agencies.
- Physician education implementation.

- Evaluation of campaign implementation.
- Benchmarks for physician education, etc.
- Development of cultural- and language-appropriate messages/materials for special populations.
- Addressing additional radionuclides.
- American public understanding fallout and health legacy.

Developing Model Outreach

Peter Sandman, Ph.D., a risk communications consultant, explained the difference between hazard (how dangerous something is) and outrage (how much it upsets people) and the fact that they are often poorly correlated. He suggested a two-pronged campaign. One audience is people who are significantly endangered by NTS fallout and deserve a warning. The second audience is the larger public whose hazard is low. He offered five options for messages to them, ranging from doing what you can to keep them from becoming outraged to getting them outraged to organize them politically. He suggested that the diverse interests in the room could work together on a campaign to reach those who are high risk, but would probably need to work separately to communicate to the larger public, since their goals would likely vary.

Regardless of how hazardous the fallout is to the public's health, Dr. Sandman noted that public outrage over nuclear fallout should be expected and is justified based on a list of twelve factors, including the involuntary nature of the exposure and the government's unresponsiveness to public concern. He said that in order to be credible, the government must acknowledge the outrage and admit that it is justified. He ended by saying that the government should apologize a lot; overestimate, rather than underestimate the risk; show concern, feeling and humanity; and acknowledge the moral relevance of the situation.

Neil Weinstein, Ph.D., of Rutgers University, discussed the challenges involved in communicating about risk, based on his experience with radon and other programs. He talked about the public's difficulty in understanding numbers and probabilities and the likelihood that people will be apathetic to the message that a health risk has occurred. He also warned against providing too much information in an effort to enable people to make their own informed decisions. He advocated giving recommendations for action with sufficient background information, without flooding people with all the details on dosing, probabilities, and the science of I-131 exposure.

Ed Maibach, Ph.D., of Porter Novelli, presented the results of six focus groups held with consumers and physicians to begin getting a sense of their knowledge and attitudes about radiation fallout and health risks, to understand their perceived risk, their degree of concern, and to understand their needs for information on these issues. The participants were drawn from two cities with a high exposure to I-131 and one with a lower exposure. The preliminary report was provided at the meeting.

- The consumers in both areas showed little concern about radiation fallout, had little interest in something that occurred in the past, and were more concerned by health issues they face today. But there was great passion for securing assurances that the tests never happen again. People wanted to know the big picture about the consequences of NTS testing rather than just about I-131.
- The physicians knew very little about nuclear testing and its health impacts. They called for a permanent ban on nuclear testing. They asked that a public education campaign not be mounted because it would create a mess without helping the public. They said a physician campaign might be a good idea, though they weren't convinced it would change their clinical practice at all.

Dr. Maibach ended by reminding the workshop participants that this was just the beginning of the audience research needed to develop a campaign. During the question and answer period following the presentation, workshop participants noted the likelihood that focus group responses were tied to the source and format of the information stimulus they received. It was pointed out that this should be taken into account in locating appropriate "messengers" for delivering exposure information to the public. Later in the workshop, the participants spent time discussing additional audience research needs.

Campaign Goals

Following the audience research presentation, workshop participants developed four goals for the communication campaign, which received wide support:

1. Acknowledge/explain what happened as a result of nuclear weapons production, research, and testing and what is happening now. Engage or encourage the public in a policy discussion on this issue.
2. Educate the public on the potential health consequences of I-131 and other radiation exposures so they can make good decisions. Provide mechanisms for follow-up (e.g. toll-free number) for people without a health care provider.
3. Educate health care providers about the health consequences of I-131 fallout and other radiation exposures as well as the pros and cons of thyroid evaluation so they can help their patients make good decisions.
4. Facilitate diagnosis, screening, and if necessary, treatment, for those with cancer and non-cancer radiation-related illnesses.

A number of organization representatives committed to working on specific campaign goals:

- ♦ Physicians for Social Responsibility, Alliance for Nuclear Accountability, and the National Indian Council on Aging expressed interest in working on goal #1 and bringing the topic to their organizations' meetings in May (PSR and ANA), and August (National Indian Council on Aging).

- ♦ Physicians for Social Responsibility, Alliance for Nuclear Accountability, National Association for the Advancement of Colored People (NAACP), and the National Association of Radiation Survivors offered to work with the federal government on goal #2.

I.3.1.3 Day Three

Organized Feedback

In small working groups, participants gave feedback regarding:

- ♦ Design of an ongoing campaign development workgroup.[5]
- ♦ Recommendations for issues to be addressed at the April 2000 ACERER workshop on screening.
- ♦ Additional audience research needs.
- ♦ Preparation for audience messaging: What key information needs to be communicated?

Each small group's recommendations and comments are presented below.

1. Campaign Development Workgroup

The workgroup that worked with NCI and CDC to plan the January workshop included individuals familiar with the following perspectives, groups, or organizations:

- ♦ Hanford downwinders
- ♦ Alliance for Nuclear Accountability
- ♦ ACERER Subcommittee for Community Affairs
- ♦ Hanford Health Information Network
- ♦ NAACP
- ♦ Physicians for Social Responsibility
- ♦ A Physician
- ♦ State Public Health Department (Radiological Health Section)
- ♦ NCI/CDC/ATSDR staff

---

[5] During the Workshop, this group was frequently referred to as the "Campaign Development Group" or "CDG." Since then, NCI staff have elected instead to call the group a "Communications Development Group" to be more encompassing of all the efforts involved in communications planning.

Workshop participants in the small group that discussed this topic proposed that the new "Campaign Development Group" include the following types of representation (this is a list of perspectives to be represented—not specific organizations):

- Activists (2)
- Downwinders (2)
- African American
- Health educator
- Health professional organization
- Hispanic from community and migrant health center
- Native American
- Physician
- State Public Health Department: health education and radiation control (2)
- Local health department
- Thyroid Foundation

Criteria for inclusion in workgroup:

- Long-term view
- A view broader than I-131 and thyroid cancer
- Ability and willingness to make necessary time commitment
- Ability to do outreach to their communities
- Work toward geographic diversity

It was also agreed that workgroup members need to be reimbursed equitably for the work they do on this project, and that the federal agencies involved must commit adequate staffing to this effort.

2. Recommendations for topics to be addressed at the ACERER meeting to address screening issues

- Feasibility of identifying higher- and lower-risk groups
- Basis for decisions regarding policies on screening—scientific analyses alone, versus incorporation of social justice considerations
- Risks and benefits of screening for cancer and non-cancer thyroid illness
- Incidence of false positives from most recent Hanford Thyroid Disease Study thyroid cancer medical evaluation
- Review of science regarding noncancer thyroid outcomes of I-131 exposure
- Cumulative effects: how do multiple exposures change a person's risk classification?
- Progress report on research into other radionuclides
- Examination of other screening programs around the world
- Potential funding mechanisms for screening programs; comparison of other screening programs
- Case study of affected citizens
- Operating principles

A workgroup will help plan the ACERER workshop. Individuals working on this list offered to participate. They were: John Bagby, Trisha Pritikin, Henry Royal, Robert Spengler, Oscar Tarrago, J.B. Hill, David Becker, and Steve Simon. Tim Takaro, Keith Baverstock, Owen Hoffman, and Kristin Shrader-Frechette also expressed interest in participating in the planning process.

3. Recommendations for Additional Audience Research

Who are we trying to reach? This must be determined before audience research begins. Once this is determined, the research would address:

- Demographic research on language, culture, education, and literacy levels.
- Preferred sources of information.

- Psychographic data -- beliefs/attitudes, epidemiologic data, role of the media.
- Message and strategy testing -- look at research and campaigns that have already been done. Do a meta-analysis to transform and digest that data to determine audience needs.
- Process evaluation: Was the campaign done on time, within budget?
- Outcome evaluation: What were the campaign's effects? What was the reach, frequency, and duration of communications? How many were exposed over a period of time? What were the effects on knowledge, attitudes, and behaviors? What were the long-term effects on behaviors?

4. Preparation for Audience Messaging: What key information needs to be communicated?

- The general United States population should receive information to improve their awareness.
  - Give historical context, discuss research, production, and testing. Discuss I-131 and other radionuclides. Discuss local testing, global fallout, associated social and ethical issues, and general risk factors (e.g., milk, and gender) so that people can self-identify. Give history of government action and where there is still work to be done. Describe the work that continues on outstanding issues to ensure that exposures from testing won't happen again.
- "Hot spot" audiences should receive:
  - All the information that the general United States population is receiving (see above).
  - Information on general risk factors plus multiple exposures so they can self-identify.
  - Assurance that health care providers and other agencies (e.g., managers at DOE/contractor facilities) are being told about this.
- Self-identified as at-risk or other concerned people should receive:
  - Information that the above audiences receive.

    - Information on what to do if you don't have a health care provider.
    - Details on the ongoing work regarding outstanding issues (screening, compensation, etc.)
    - A fact sheet from an official organization to bring to a clinic or physician's office.

- Health care providers should receive:
    - Everything the above two audiences receive and additionally, resources on screening for all thyroid disease.
- Payers of Healthcare (HMOs, government programs) and insurance commissioners should receive:
    - Clinical practice guidelines or Standards of Care.
- Workers (research, production, mining, etc.) should receive:
    - All information that "hot spot" and self-identified at-risk people receive.
- State Health Departments should receive:
    - All information that health care providers receive so they know they will also be disseminators, and must be kept informed as campaign progresses.
- State Regulators should receive:
    - All the same information that health care providers and state health departments receive.

We still need to determine the right organizations to communicate messages to various target audiences.

Summary Comments

Anne Lubenow, Acting Co-chief of the Health Promotion Branch in the Office of Cancer Communications, NCI, thanked all of the participants and expressed NCI's appreciation for everyone sharing their views. She encouraged participants to contact the NCI staff as needed. She also stressed that although we don't yet have all of the answers, we are on the road to developing a campaign, and have identified some common ground, as well as areas that need further discussion.

Joan Morrissey, Health Communicator with the Radiation Studies Branch, CDC, followed by thanking the workgroup for the tremendous amount of work they put in to planning this successful workshop. She specifically noted her desire to put together a Native American caucus, as suggested by Robert Holden. She reiterated the agencies' commitment to developing and implementing this program and doing it right.

A sampling of participants' closing remarks

"It's been really heartening for me as a person from a significantly impacted community to feel that all these people actually care about people like me, finally, because there are a whole lot of times when I don't feel that way. And I want to thank the agencies involved for never telling us that we couldn't discuss something. We were able to put all the issues on the table and discuss everything that I think people wanted to talk about. I feel very good about this process."

"I see an incredible variety of talent, knowledge, and goodwill in this room, and I see a huge opportunity to make a truly positive impact on all of society."

"A grave concern in all of this is that these issues have the ability to divide people in this country rather than unite them. If the same spirit of bringing different people together here could be the spirit of whatever moves out of it, I think we can go very far."

Next Steps

Nelvis Castro, Acting Associate Director for Cancer Communications at the NCI, thanked the participants for their candor and their dedication to this effort. She stated that the summary of the meeting would be posted on the listserv for a 2-week comment period, then finalized and distributed to interested parties. Dr. William Raub has committed to bringing the report to Secretary Shalala's attention. A Campaign Development Group will be formed and will review the draft communications plan and help with future activities. She estimated that the plan will take about six months to draft. The plan will be refined and modified as necessary based on feedback received from this group. She also hopes to learn about the communications channels that participants use to reach their constituents to expand the reach of the messages that are developed for this campaign.

Owen Devine, Ph.D., chief of the Risk Assessment and Communication Section, Radiation Studies Branch, CDC, talked about future plans to study other radionuclides and global fallout. A feasibility assessment will be presented to ACERER in June 2000 and to Congress in July 2000. It will be an assessment of the scientific feasibility of estimating dose and risk to the United States population from global fallout, including NTS. There will be a large discussion of communications in the report as well. He thanked all of the participants.

Dr. Alan Rabson closed the meeting by repeating the apology for NCI's delay in finishing the Nevada Test Site Fallout report. Processes have been put in place at the Institute so that such an "unconscionable delay" will never happen again. He called the workshop an "historic meeting" that has given NCI a new understanding and commitment to working with community representatives. He assured participants that NCI intends to follow through.

I.3.2 List of Working Group Members and Government Staff

I.3.2.1 Community Representatives

H. Jack Geiger, M.D. - (Departed group 11/99)

James B. Hill, Jr. - President, NAACP, Oak Ridge Branch

Yvette Joseph-Fox - National Indian Health Board (Departed group 10/99)

Bea Kelleigh - Executive Director, Hanford Health Information Network Resource Center

Stan Marshall - Radiological Health Section, Nevada State Health Division

Robert Musil - Executive Director, Physicians for Social Responsibility

Trisha Pritikin, Esq., M.Ed., O.T.R. - Downwinder

Robert Tiller - Physicians for Social Responsibility (Departed group12/99)

Seth Tuler, Ph.D. - Childhood Cancer Research Institute and Clark University

I.3.2.2 Government Staff

National Cancer Institute

Nelvis Castro - Acting Associate Director for Cancer Communications

Betsy Duane - Communications Coordinator, Division of Cancer Epidemiology and Genetics

Mark Epstein - Porter Novelli (Consultant)

Anne Lubenow - Acting Chief, Health Promotion Branch

Kelli Marciel - Presidential Management Intern, Health Promotion Branch

Jim Mathews - Senior Science Writer, Health Promotion Branch

Alan Rabson, M.D. - Deputy Director, National Cancer Institute

Paul Van Nevel - Van Nevel Communications, (Consultant - then Associate Director for Cancer Communications - retired as of 12/31/99)

Cori Vanchieri - Vanchieri Communications (Consultant)

Centers for Disease Control, National Center for Environmental Health

Owen Devine, Ph.D. - Chief, Risk Assessment and Communication Section, Radiation Studies Branch (moved to another division 2/1/00)

Christie Eheman - Epidemiologist

Joan Morrissey - Health Communicator, Radiation Studies Branch

Judith Qualters, Ph.D. - Acting Chief, Risk Analysis and Communication Section, Radiation Studies Branch

Agency for Toxic Substances and Disease Registry

Oscar Tarrago, M.D., M.P.H. - Fellow, Office of the Director, Division of Health Education and Promotion

I.3.3 Workshop Participants

(In alphabetical order by last name)

Elaine Bratic Arkin, Health Communication Consultant

John Bagby, Ph.D., Chairman, Advisory Committee for Energy Related Epidemiologic Research

Wayne Ball, Ph.D., Toxicologist, Utah Department of Health, Bureau of Epidemiology

Keith Frederick Baverstock, Ph.D., Regional Advisor, Public Health and Environmental Radiation, World Health Organization

David V. Becker, M.A., M.D., Professor of Radiology, Professor of Medicine, New York Presbyterian Hospital, Weill Medical College of Cornell University

Marco Beltran, M.P.H., Program Specialist, Migrant Head Start Quality Improvement Center

Joni Berardino, M.S., National Center for Farmworker Health

Luis Buen Abad, M.Ed., Environmental Specialist, Hanford Health Information Network

John Burklow, Deputy Director for Communications, Office of Communications and Public Liaison, NIH

Leticia Camacho, J.D., M.A., Director of Policy and Advocacy, Migrant Clinicians Network

Nelvis Castro, Acting Associate Director, Office of Cancer Communications, National Cancer Institute

David Cooper, M.D., Director, Division of Endocrinology, Sinai Hospital of Baltimore

Sharon Cowdrey, R.N., President, Miamisburg Environmental Safety and Health

Owen Devine, Ph.D., Chief, Risk Assessment and Communication Section, Radiation Studies Branch, CDC

Betsy Duane, Communications Coordinator, Division of Cancer Epidemiology and Genetics, National Cancer Institute

Christie Eheman, Ph.D., Epidemiologist, Centers for Disease Control and Prevention

Maureen Eldredge, Program Director, Alliance for Nuclear Accountability

Mark Epstein, Communications Consultant, Porter Novelli

Valerie Fiset, R.N., M.Sc.N., Clinical Nurse Specialist, Palliative Care, Sisters of Charity of Ottawa Health Service

James Flynn, Ph.D., Senior Research Associate, Decision Research

Patricia George, Community Research Coordinator, Nuclear Risk Management for Native Communities Project

Thomas M. Gerusky, Certified Public Health Physicist, Retired Director, Pennsylvania Bureau of Radiation Protection, Conference of Radiation Control Program Directors

Hossein Gharib, M.D., Professor of Medicine, Mayo Medical School, Mayo Clinic

F. Lincoln Grahlfs, Ph.D., M.A., President, National Association of Radiation Survivors

Michael Hansen, representing Jean Halloran, Director, Consumer Policy Institute, Consumers Union

James B. Hill, Jr., President, NAACP Oak Ridge Branch

Felicia Hodge, Dr.P.H., Director, Center for American Indian Research and Education

F. Owen Hoffman, Ph.D., President, SENES Oak Ridge, Inc.

Robert Holden, Director, Nuclear Waste Program, National Congress of American Indians

Bea Kelleigh, M.P.A., Executive Director, Hanford Health Information Network Resource Center

Gary Kodaseet, Vice Chairman, National Indian Council on Aging

Susan Koppi, Director, Public Affairs, The Endocrine Society

Gary L. Kreps, Ph.D., Chief, Health Communication and Informatics Research Branch, National Cancer Institute

Charles Land, Ph.D., Division of Cancer Epidemiology and Genetics, National Cancer Institute

Robert Lawrence, M.D., Associate Dean for Professional Education and Programs, School of Hygiene and Public Health, Johns Hopkins University

Lisa Ledwidge, M.P.A., M.S.E.S., Outreach Coordinator and Editor, SDA, Institute for Energy and Environmental Research

Delvin Littell, M.D., Medical Director, Morgan County Medical Center

Paul A. Locke, M.P.H., Dr.P.H., Deputy Director, Pew Environmental Health Commission

Anne Lubenow, M.P.H., Acting Chief, Health Promotion Branch, National Cancer Institute

Roger Macklin, M.S., Health Physicist, Tennessee Department of Environment and Conservation, Director of Radiological Health

Kelli Marciel, M.P.A., Presidential Management Intern, Health Promotion Branch, National Cancer Institute

Stan Marshall, Radiological Health Section, Nevada State Health Division

James Mathews, Senior Science Writer, Office of Cancer Communications, National Cancer Institute

Normie C. Morin, Ph.D., M.P.H., Project Director, Rocky Flats Health Studies, Disease Control and Environmental Epidemiology Division

Joan Morrissey, Health Communicator, Radiation Studies Branch, Centers for Disease Control and Prevention

Robert Musil, Executive Director, Physicians for Social Responsibility

Dennis Nelson, Ph.D., Director of Research, Support and Education for Radiation Victims

Nancy Nelson, Mass Media Branch, Office of Cancer Communications, National Cancer Institute

Claudia Parvanta, Ph.D., Director, Division of Health Communication, Office of Cancer Communications, Centers for Disease Control and Prevention

Judy Patt, Cancer Information Service, National Cancer Institute

Devon Payne-Sturges, M.P.H., Assistant Commissioner for Environmental Health, Baltimore City Health Department

Stacye Poer, Program Analyst, Office of Legislation and Congressional Activities, National Cancer Institute

Trisha T. Pritikin, Esq., M.Ed., O.T.R., Downwinder/Community Representative

Idaho J. Purce, Project Director, HIV/AIDS Education, NAACP; INEEL Health Effects

Judith R. Qualters, Ph.D., Acting Chief, Risk Analysis and Communication Section, NCEH, Centers for Disease Control and Prevention

Alan S. Rabson, M.D., Deputy Director, National Cancer Institute

William Raub, Deputy Assistant Secretary for Science Policy, Department of Health and Human Services

Karim Rimawi, Ph.D., Director, Bureau of Environmental Radiation Protection, New York State Department of Health

Jacob Robbins, M.D., Scientist Emeritus, National Institute of Diabetes and Digestive and Kidney Diseases

Henry D. Royal, M.D., Professor of Radiology, Division of Nuclear Medicine, Mallinckrodt Institute of Radiology, Washington University School of Medicine

Michael Sage, Acting Deputy Director, National Center for Environmental Health, Centers for Disease Control and Prevention

Peter Sandman, Ph.D., Risk Communication Consultant

Elke Shaw-Tulloch, Manager, Environmental Health Education Program, Idaho Division of Health

Kristin Shrader-Frechette, Ph.D., Medical Ethicist, Department of Philosophy and Department of Biological Sciences

Steven L. Simon, Ph.D., Senior Staff Officer, National Academy of Sciences, Board on Radiation Effects Research

Robert F. Spengler, Sc.D., Associate Administrator for Science, Agency for Toxic Substances and Disease Registry

Patrice Sutton, M.P.H., Western States Legal Foundation

Diana Swindel, Associate Director, Communications Office, National Center for Environmental Health

Tim K. Takaro, M.D., M.P.H., M.S., Acting Assistant Professor, University of Washington School of Medicine

Oscar Tarragó, M.D., M.P.H., Fellow, Office of the Director, Agency for Toxic Substances and Disease Registry, Division of Health Education and Promotion

Kevin Teale, M.A., Communications Director, Iowa Department of Public Health

Stephen Thomas, Ph.D., Associate Professor, Director, Institute of Minority Health Research, Rollins School of Public Health, Emory University

Tim L. Tinker, Dr.P.H., M.P.H., Chief, Communications and Research, Agency for Toxic Substances and Disease Registry

Seth Tuler, Ph.D., Childhood Cancer Research Institute and Clark University

R. Michael Tuttle, M.D., Assistant Attending, Memorial Sloan-Kettering Cancer Center

J. Paul Van Nevel, Van Nevel Communications, Consultant to the National Cancer Institute

Cori Vanchieri, Vanchieri Communications, Consultant to the National Cancer Institute

Neil Weinstein, Ph.D., Professor, Department of Human Ecology, Rutgers University

I.3.4 Proposed Campaign Operating Principles

- Honesty, openness to differing points of view, and a willingness to answer questions will characterize the ongoing planning, operation, and evaluation of the campaign.
- Trust and credibility will be earned and maintained by providing accurate and comprehensive information.
- The campaign will be respectful of human rights and the dignity of affected people.
- Persons who may have been exposed to radiation released from the Nevada Test Site will be involved in the development, implementation, and guidance of the campaign.
- Campaign information will be accurate, scientifically sound, and will explain the uncertainties of current knowledge.
- Information will be supportive, reflecting compassion and an understanding of scientific, medical, psychological, and ethical issues involved.
- The campaign will consider the needs of underserved populations and will strive for social equity.
- Efforts will be outcome-oriented.

I.3.5 List of Other Resources

- The NCI Fallout Report and all Campaign materials, including an individual dose/risk calculator can be found online at www.cancer.gov/I-131.
- The IOM's review of the NCI report can be viewed online as well. Visit www.nap.edu and enter 'Exposure of the American*' in the "search all titles" field.
- The National Research Council report referenced by Kristin Shrader-Frechette in her remarks, *Understanding Risk: Informing Decisions in a Democratic Society*, is also available at www.nap.edu using the title search feature.

- The Agency for Toxic Substances and Disease Registry Continuing Education Course for health care professionals, ***Case Studies in Environmental Medicine: Radiation Exposure from Iodine-131,*** is available on the ATSDR website.

Other valuable websites:

- CDC's National Center for Environmental Health, Radiation Studies Branch homepage (includes links to Hanford Thyroid Disease Study): www.cdc.gov/nceh/programs/radiation

- Hanford Community Health Project, an outreach and education initiative sponsored by ATSDR, provides educational information and materials about potential health risks to individuals who were exposed as young children to past releases of radioactive iodine (I-131) between 1944 and 1951 from the Hanford Nuclear reservation, in Washington State: http://www.atsdr.cdc.gov/hanford/

The NCI publication *Making Health Communication Programs Work: A Planner's Guide, a resource for health communicators*, first published in 1989 and widely known as the "Pink Book." The 2002 updated version reflects recent advances in knowledge and technology, such as the Internet, that can affect the communications process. This handbook presents key principles and steps in developing and evaluating health communications program for the public, patients, and health professionals. It can be viewed online at www.cancer.gov/pinkbook. Print or CD-ROM copies can be ordered by calling 1-800-4-CANCER (1-800-422-6237) or online at http://cancer.gov/publications.

I.4 Report of Key Findings: In-depth Interviews with Experts About I-131 Exposure from the Nevada Test Site

Prepared by:

Office of Cancer Communications
National Cancer Institute
31 Center Drive MSC-2580
Building 31, Room 10A03
Bethesda, MD 20892-2580

January 2000

I. INTRODUCTION AND METHOD

The National Cancer Institute (NCI) and Centers for Disease Control and Prevention (CDC) are designing a national campaign to implement Institute of Medicine (IOM) recommendations to communicate to Americans the potential health effects of Iodine-131 (I-131) radiation released during atmospheric testing in Nevada during the 1950s and 1960s. To inform this effort, NCI conducted 19 in-depth interviews with individuals who have expertise in areas related to the issue of nuclear fallout. The main objectives of this research were to measure awareness level, concern, familiarity with, and evaluation of the NCI Report and IOM recommendations about I-131 from the Nevada Test Site, and to obtain recommendations about how to conduct a communication campaign.

A working group consisting of NCI staff, CDC staff, and a panel of community representatives generated a list of potential interviewees. Individuals were suggested in a number of categories, including state and local public health officials, community advocates (including environmental, health, and pro-nuclear groups), scientific experts (e.g., radiation scientists), health-oriented professional organizations, veterans, health care providers (e.g., thyroid specialists), and health educators.

The selection of interviewees was based on the following criteria: 1) level of expertise; 2) an effort to obtain representation from all the categories listed above; and 3) geographic diversity. The original interviewee list was comprised of 29 contact names collectively agreed upon by working group members. Interviews were completed with 19 interviewees. When an effort to contact a particular interviewee was not successful, an alternate name was generally provided by working group members. Alternates were selected from the same type of background as the originally proposed interviewee.

In order to report the interview results in a way that incorporates the contextual background of individuals, interviewees were separated into three major reporting categories:

> **Public Health Officials:** Six government officials were interviewed in this category. Participants included those employed in public health departments in states with varying degrees of I-131 exposure from the Nevada Test Site and other representatives involved in radiation issues at the state level.
>
> **Advocacy Groups:** Seven individuals were interviewed in this category. Participants held a variety of positions in organizations dedicated to different issues associated with nuclear or radiation issues. Organizations were selected to represent a broad range of opinion. Included in this category were representatives of groups dedicated to radiation-exposed populations, the environment, and the advancement of nuclear science.
>
> **Scientific Experts:** Six individuals were interviewed in this category. Participants included both radiation and thyroid experts associated with a variety of institutions.

Interview questions were designed to measure awareness, concern and opinions about what constitutes an appropriate outreach response (See Attachment H-4-A for a copy of the interview instrument). It should be noted that the interview guide was not followed verbatim, and language was altered in some cases to be sensitive to the background and expertise level of each respondent. Each interview lasted approximately 30 minutes.

It should also be noted that in-depth interviewing is a qualitative research technique. Although the findings from this research can provide useful detailed insights into the perceptions and views of different organizations and experts involved with the I-131 fallout issue, they cannot represent the views of all such groups or persons.

II. KEY FINDINGS

This section outlines the key/preliminary findings from the interviews. Differences in responses between reporting groups are outlined separately.

A. Awareness and Concern

- **For public health officials, the NCI report frames the boundaries of awareness.**

When asked what they knew about the potential health effects of the Nevada Test Site, the majority of public health officials cited the NCI study as their primary reference point. All agreed that thyroid cancer or "the thyroid problem" was the main potential health outcome to be concerned about. Although two officials mentioned other possible conditions, like autoimmune illnesses and damage to other organs, they qualified these statements indicating that the data and science were only available on the thyroid cancer link. Only one official could name other radioactive substances released from the site in addition to I-131.

On a scale of one to ten, with one indicating "not at all severe" and ten indicating "very severe," most officials gave the potential health effects from the Nevada Test Site a fairly low severity rating of two or three. Only one official gave it a relatively high rating of six.

None of the officials said their organization had a formal position on I-131 exposure from the Nevada Test Site. One official, in a state with some highly exposed counties, said they were "struggling" to determine whether or not the potential risks justify a public outreach effort.

- **Advocacy groups have a far broader scope of concern.**

Fewer advocacy group participants mentioned the NCI report when asked about their knowledge of the potential health effects of the Nevada Test Site. Although most mentioned thyroid cancer and other non-cancerous thyroid abnormalities as possible outcomes, a few participants also mentioned leukemia. One representative said genetic mutations and birth defects were also a possibility.

In addition to being concerned about more health effects, advocacy group representatives were also more aware of other radioactive materials emitted from the tests. The most frequently cited substances after I-131 were cesium, strontium, and plutonium. When asked which substances they worried about the most, advocates said that all the substances posed significant reasons for concern, but for different reasons. Some pointed out the varying half-lives of the substances; several, for example, talked about plutonium's ability to persist in the environment for long periods of time. One representative took the opportunity to say that the NCI report was "too narrowly and conveniently" focused on thyroid cancer instead of on other more lethal cancers like leukemia, breast and bone cancer that may be caused by other materials like strontium and cesium.

Advocates rated the severity of the health effects from the Nevada Test Site much higher than did the public health officials. Most gave a rating somewhere in the range of eight to ten. Only one respondent thought differently. This participant, who refused to use the rating scale, characterized the potential health effects from Nevada Test Site exposure as 100 times more severe than an accident like Three Mile Island or waste disposal sites, but much less severe than radiation received from medical diagnostic tests.

All but two representatives said their organization had a position on exposure from the Nevada Test Site. One representative said there needed to be more education and research on the association between exposure and non-thyroid disorders, particularly parathyroid disorders. Another said the government needed to be more "forthright" and "conscientious" in its efforts to inform the public. Others called for health care provider education efforts and clinical screening and monitoring. Although two representatives said their organization did not have a formal or official position, they did say their organization generally supports the cause of research and educational efforts conducted for the benefit of exposed populations.

- **Concerns of scientific experts are defined by their evaluation of "the evidence."**

Scientific experts chose to focus primarily on the thyroid-cancer link when asked what they knew about the health consequences of the Nevada Test Site. Most made evaluative comments about the findings. The level of detail provided about the relationship between I-131 and thyroid cancer varied by the type of expert. Radiation experts provided much more detailed information and critiques of the NCI data. One such expert said, "I am aware that 10,000 to 75,000 new thyroid cancers will result from these tests." Another radiation expert characterized the findings as "statistically suggestive rather than significant." Strontium, cesium, and plutonium were most frequently mentioned by radiation experts as some of the other key radionuclides that were emitted from the tests. One expert said I-131 should be paid the most attention because it was the "main fallout product."

Thyroid experts had less detailed knowledge and seemed to retain only the facts they felt were relevant to their concerns and practice areas. These specialists were primarily concerned about the relationship between I-131 and thyroid disorders and less interested in other health effects. They were aware of the Nevada Test Site solely because of its relationship to I-131 (an issue thyroid specialists are quite knowledgeable about), since the site presents another potential avenue of iodine exposure. These specialists expressed limited concern, stating that exposure was found to be minimal for the most part and that thyroid cancer is highly treatable.

Expert ratings of the severity of potential health effects were more mixed than the other two interviewee groups. One radiation expert rated the severity of the health effects as a one or a two, while another rated it as an eight or nine. Many had difficulty providing unqualified responses, probably due to their high knowledge levels. For example, one radiation expert said the severity rating is dependent on geography, giving a one for a person living in New York City and a four for a person living in Utah. Thyroid specialists shared more commonality in their ratings with most giving it a low rating of a one or two. One specialist said the rating is dependent on age of exposure, giving it a rating of five for a child and only a rating of one for an adult.

B. Familiarity and Evaluation of NCI Report and IOM Action Recommendations

- **<u>Public health officials are in agreement with findings and recommendations.</u>**

All public health officials were quite familiar with the reports, and most had a good working knowledge of risk factors and other specifics. Officials in states with heavily exposed populations were more informed than officials from states with less exposure. One official of a state with areas of high exposure reported using the NCI data to conduct their own state-level investigation. Two officials in less exposed states had a more general level of knowledge about the NCI findings.

Overall, public health officials found the reports useful. Two officials said the most useful information was the county-level exposure information. Two others said the reports serve as good background pieces about the relationship between I-131 and thyroid cancer and will be a useful framework for thinking about other exposure sites throughout the country. There were few suggestions for additional information. One official said more definitive information on the risk associated with I-131 exposure was needed to determine what the exposures really mean from a health perspective. Another official thought information on the relationship between I-131 exposure and non-cancerous thyroid disorders would be important to have since there was a lot of “talk” about this issue.

All officials agreed with the IOM position that screening would cause more harm than good, due to the number of false positives. One individual said screening was also not advisable because the exposure findings were uncertain, and individuals would be better served if their own doctor decided whether or not screening was appropriate for them.

Most public health officials thought the proposed strategy of educating the general public and providing physicians with information to respond to inquiries would be very effective. Some said this was important because health care providers lack knowledge about the association between iodine and thyroid disease. One individual said it would be effective because people listen to and trust their doctors. Another official thought that the strategy made sense but that the nature of the information would be difficult for the public to understand.

- **<u>Advocacy groups disagree more with findings and recommendations.</u>**

Approximately two-thirds of the advocates said they were very familiar with the NCI and IOM reports. The remaining one-third recalled major pieces of information but without specifics. Advocacy group opinion about the information in the reports was considerably more divided than among public health officials. One representative said that some of the exposure information was inaccurate and that there were more areas listed as low-exposure areas than should be. Another representative held the opposite view, saying that there were more high-exposure areas than should be. A couple of representatives said the reports were useful in the sense that there was an “admittance” of responsibility, and some information was at least “out there.” And another representative took credit for pushing Congress to get the report “done in the first place.”

Advocacy representatives were far less supportive of the IOM screening recommendations than public health officials. Half thought screening for thyroid cancer was necessary, and half agreed that it was not a beneficial course of action. One individual supported the notion that screening for thyroid cancer would result in too many false positives, but felt screening for other disorders like hypothyroidism and hyperparathyroidism should be conducted.

When asked how effective the IOM strategy of educating physicians and the public would be, most advocates characterized the strategy as one that would be “helpful.” Two participants focused on the need to educate physicians so patients will be “taken seriously” and will not have to “educate their physicians.” Only one participant felt the action would be unnecessary and expressed doubt about the ability to educate physicians who are “essentially lay people when it comes to nuclear and radiation issues and lack technical knowledge and background.”

- **<u>Thyroid experts are in agreement, while radiation experts are more divided.</u>**

While the radiation experts were very familiar with the NCI and IOM reports and had examined them in detail, the thyroid specialists were only vaguely familiar with the actual reports. Despite their uncertainty about having read the reports, however, the thyroid specialists felt certain that they understood the overall findings from other sources like professional journals, newspapers, and presentations. In general, they recalled that the exposure did not pose a very significant health threat.

Those radiation experts who had read the reports found some information useful and some not. While one expert said the reports were “most inclusive and helpful,” another said they were “inconclusive” because the findings were “extrapolated from only 100 sites.” Another expert felt the information was useful, but needed to be translated in a way that would make it possible for the lay public to understand. The lack of “risk information” was “curiously avoided,” according to another expert.

The radiation experts were also divided on the issue of screening. One agreed with the argument that "screening will do more harm than good." Another agreed that it made no sense to screen the general population, but did think the issue of screening high-risk populations needed to be addressed. Another expressed agreement with not screening for thyroid cancer, but thought looking into screening for other non-cancerous thyroid disease was essential. The thyroid specialists were less divided, all indicating that wide-scale screening for thyroid cancer would result in too many false positives and could result in harm to the patient in terms of unnecessary surgical procedures.

Most experts thought the action recommended by the IOM would be very effective. Their reasons for thinking this strategy would be effective were similar to those of the other groups. Explanations provided were that physicians lack knowledge and have direct patient contact, while patients for the most part feel comfortable with their doctors. One expert said the strategy would be only "moderately effective" because physicians may not take the time to review the information provided and because not everyone has health insurance and/or is under the care of a physician.

C. Educational Efforts: What's Needed?

- **<u>Public health officials think risk factors should determine the focus and scope of the campaign.</u>**

When asked if the entire U.S. needs to be the target of an educational effort or if the effort should be confined only to those most heavily exposed, officials answered in accordance with their understanding of the risk factors and exposure patterns. One official thought the campaign could be focused on those who were children at the time and drank milk from a backyard goat or cow since these individuals were most at risk. Another official thought everyone should be given information, but the campaign should be more aggressively focused on those at higher risk. Those who thought a campaign would need to target the whole population grounded their opinions on the premise that it would be difficult to "find" everyone at high risk due to factors like mobility and storm and wind patterns.

By far, the most important information that officials thought needed to be provided to people is a profile of the risk factors. One official thought such a profile, along with an 800 number for those who need more information, would be a good idea since it is so difficult to separate out those who need to be concerned from those who don't.

- **<u>Advocacy groups say a "right to know" argument prevails.</u>**

A majority of advocates said a national campaign was needed because citizens have "a right to know" about the actions of their government. For example, one advocate said, "Everyone should know that this was done without our knowledge" because "the government has no right to contaminate us." Another said information should not be "denied to people," but qualified the response by saying it would be difficult to really get the information to everyone because a "large portion of the public is apathetic," especially when something seems so "far away." Some thought a general public information campaign was needed along with a more targeted and aggressive effort to ensure that high-risk groups are reached. Only one advocacy group representative thought that little needed to be done; this individual expressed the view that something "had to be done" because the issue had become "so political," but thought that the campaign should be very targeted to those at highest risk.

In addition to providing information on risk factors, advocates often mentioned a need to translate the information into a format that people can understand. One said people need to be provided with a listing of symptoms that may signal a thyroid problem so they can ask their doctor for a blood test or ultrasound. Another said people needed all the information required to calculate their own dose.

- **<u>Scientific experts propose solutions mixed with some worry about invoking "unnecessary" fear.</u>**

Although solutions proposed by scientific experts varied, more participants in this group than others expressed concern about the need to present information in a way that does not provoke anxiety or panic on the part of the public. The thyroid specialists frequently made this argument and expressed a preference for a targeted "talk to your doctor" type approach, especially aimed at those who were children at the time of exposure. One specialist thought it would be important to assure people that the NCI study was a "very carefully run study so they should not be afraid."

Radiation experts were more divided. One expert thought the "right to know" demanded a national campaign. This individual characterized the notion of a targeted campaign as a scientific impossibility because it would be too difficult to "find" the people most heavily affected. Another felt the information was already "out there" for people who needed to find it. He said that "the advocates do a good job of letting people know who need to know" and any further effort will start a public panic."

D. Participant Recommendations for How to Conduct a Campaign

- **<u>The majority of participants are in consensus about campaign "how-to's."</u>**

Although there was much disagreement about the appropriate scope and focus of a potential educational information campaign, a high degree of consensus emerged on how a campaign would be best implemented.

  - Most participants said that such a campaign would need to be conducted at a national level with significant use of mass media. Even many of those who thought more targeted campaigns were appropriate "back-tracked" a little here, realizing that a national effort may be needed in order to "find" everyone.

  - Providing information about exposure and risk was seen as important; dose information, as less so. A substantial amount of concern was expressed about the use of risk comparisons because they may tend to trivialize the issue.

- By far, participants across all three groups thought a coalition of different types of organizations (government, advocacy groups, and non-profits) should implement the campaign.

- The belief that a coalition was needed to counteract a lack of public trust in government and lend credibility to the campaign was expressed far more often by advocates than by public health officials and scientific experts.

- State public health officials thought their departments could play valuable coordinating roles at the state and local levels.

- In terms of federal government participation, there was little preference for which agency(ies) should lead the effort. It became apparent throughout many of the interviews, particularly with advocates, that individuals do not make distinctions between various federal agencies -- for example, CDC, NCI, the Department of Energy (DOE), or the Environmental Protection Agency (EPA). Many think of the "government" as an all-encompassing entity. When participants did make agency recommendations, NCI and CDC were the most frequently mentioned.

- Participants thought a variety of materials and resources would be helpful to their organizations: fact sheets, information kits, videos, in-person meetings, conferences and web-based materials. Web-based information was very appealing; videos and in-person meetings, somewhat less so.

Attachment I-4-A

OMB #0925-0046
Exp. Date: 8/31/00

INTERVIEW GUIDE FOR IN-DEPTH INTERVIEWS ABOUT I-131 EXPOSURE FROM THE NEVADA TEST SITE

November 1999

I. INTRODUCTION (3 MINUTES)

Hello, my name is __________ from Porter Novelli, and I'm calling on behalf of the National Cancer Institute and the Centers for Disease Control and Prevention. These organizations are currently working to develop educational efforts to address health effects that may be related to nuclear fallout from an atomic weapons testing program conducted in Nevada in the 1950s and 1960s. Do you have approximately 30 minutes so that I can talk with you about health issues related to the Nevada nuclear tests?

[IF YES, CONTINUE. OTHERWISE, TRY TO RESCHEDULE FOR ANOTHER DAY AND TIME.]

If it is alright with you, I would like to audio-record this discussion because everything you say is important. All of your comments will be kept confidential, and your responses will never be connected to your name or organization.

IA. ORGANIZATIONAL DEMOGRAPHICS (4 MINUTES)

First of all, I'd like to understand more about your organization.

1. What is your organization's mission and goals?

2. Who or what does your organization represent?

3. Does your organization have membership? Approximately how many members do you have?

4. Does your organization have any other core audiences or stakeholders?

5. How do you typically communicate with your audiences?

II. AWARENESS AND CONCERN (5-10 MINUTES)

1. What nuclear or radiation issues are you involved with or concerned about?

   PROBE for both locations (e.g., Hanford, etc.) as well as different types of radiation.

2. I'd like to talk specifically about the Nevada nuclear bomb tests now. What knowledge do you have about the Nevada tests and their consequences? What about health effects specifically?

   PROBE: Potential cancer-related health effects?
   Non-cancer-related effects?

3. Overall, on a scale of 1 to 10 (with 1 meaning not severe at all and 10 meaning very severe), how severe do you think the possible health effects of the Nevada nuclear bomb tests are? (INTERVIEWER NOTE: Collect professional/organizational perspective rather than personal.)

4. How would you rate the severity of these effects in relation to other nuclear or radiation issues that you are concerned about on a scale of 1 to 10? (INTERVIEWER NOTE: Collect professional/organizational perspective rather than personal.)

5. About 100 nuclear bomb tests were carried out in Nevada in the 1950s and 1960s. These tests released different types of radioactive material into the atmosphere. Which of these radioactive materials are you aware of?

   IF AWARE OF MORE THAN ONE MATERIAL: Are you concerned about some of these radioactive substances more than others? Why?

   Before proceeding, I'd like to provide you with some additional background. One of the radioactive materials released from the Nevada tests was Iodine 131, commonly referred to as I-131. As you are probably aware, some epidemiological studies have found an association between exposure to I-131 and the risk of thyroid cancer. In addition, I-131 may also be related to other types of thyroid disease, such as hypothyroidism or an underactive thyroid gland, hyperparathyroidism, a condition in which the parathyroid glands located next to the thyroid become overactive, and noncancerous thyroid growths. While everyone in the United States experienced some exposure to the I-131 fallout, those in areas adjacent to the Nevada Test Site, downwind, and in other areas of the country where wind patterns served to increase fallout were most heavily exposed. These risks may be highest for young children who drank milk and lived in high fallout areas during the time of the tests.

   [INTERVIEWER NOTE: Read high-exposure state list only if interview asks about the heavily affected region: Some adjacent states with high county exposure rates are

Colorado, Idaho, Kansas, Minnesota, Missouri, Montana, Nebraska, Nevada, South Dakota, Utah.]

In 1997 and 1999, two documents regarding the Nevada tests were released to the public. The National Cancer Institute or NCI released results of a study that assessed U.S. residents' possible exposure to radioactive Iodine-131 fallout during and shortly after the nuclear bomb tests.

In addition, the National Academy of Science's Institute of Medicine or IOM released a review of the NCI's methods and findings. This review also included recommendations on educating the general public about I-131 and advising physicians on how to approach patients who may have questions about I-131.

6. How familiar are you with the NCI and IOM reports, if at all?

7. If FAMILIAR: Do these reports provide your organization with the information you need to communicate with your key audiences about this issue?

   IF YES, PROBE: What information is useful?

   IF NO, PROBE: Why haven't the reports been useful?

8. Aside from what is provided by the NCI and IOM reports, what else does your organization know about this issue?

   PROBE: Where has your organization gotten that information?

      How has that information been useful?

9. What additional information do you need to understand the issues involved with I-131?

10. Does your organization have a position on the issues surrounding I-131 exposure from the Nevada Test Site?

   IF YES: What is that position?

      What specific concerns about I-131 exposure does your organization have?

III. EDUCATIONAL EFFORTS (10-15 minutes)

1. Residents of the U.S. were not uniformly exposed to I-131 fallout. In addition to factors such as geography and residential history, the dose of radiation individuals may have received varies by other factors, like age and dietary patterns.

In your opinion, who needs to be informed about the possible risks of associated with the I-131 emitted by the nuclear tests? Should everyone in the U.S. be the focus, or should information be more targeted to those who may have been more heavily exposed?

[INTERVIEWER NOTE: Read high exposure state list only if interview asks about the heavily affected region: Some adjacent states with high county exposure levels are Colorado, Idaho, Kansas, Minnesota, Missouri, Montana, Nebraska, Nevada, South Dakota, Utah]

2. What information do you think people who were heavily exposed need about I-131?

   IF THEY BELIEVE GENERAL PUBLIC SHOULD BE INFORMED: Which of these types of information do you think the general public should know?

3. Now I'm going to read you a list of different types of educational information that could be provided. Please rate how helpful each would be on a scale from 1 to 5 with 1 meaning not helpful at all and 5 meaning very helpful.

   a. Potential exposure levels based on factors like geography and age
   b. Dose information, an estimate of the amount of radiation actually absorbed by the thyroid)
   c. Risk information about potential health effects
   d. Risk comparisons, which quantify risk levels in various contextual ways to aid understanding
   e. Information about scientific uncertainties surrounding the estimates and associations between cause and effect

4. What do you think would be the most effective way to reach these populations?

   PROBE: Should education be conducted on a national, regional or local level? Why?

5. The IOM report concludes that the available science does NOT warrant routine clinical screening for thyroid cancer in the general population or within subgroups of the population as an intervention strategy. Do you think that the general population or any groups within the population need to be screened? Why or Why not?

   The IOM report suggests that the general public be targeted with educational information about their possible exposure to I-131 from the nuclear bomb test fallout. It also suggests that information be provided to health care providers so they can answer any questions that members of the public may ask them about the fallout and potential health consequences such as thyroid cancer.

6. How effective do you think this approach would be in educating the general public about I-131 fallout from the nuclear tests at the Nevada Test Site? Why?

7. What else, if anything, do you think would need to be done to better educate the general public about the issue of I-131 exposure?

8. Overall, who do you think should implement these efforts? Who should NOT conduct them?

   PROBE: Government agencies, non-profit organizations, or advocacy groups? National, regional, state, or local level?

   IF FEDERAL GOVERNMENT AGENCIES: Which government agencies do you think should implement the efforts? (PROBE: CDC, EPA, NCI, DOE)

   (INTERVIEWER NOTE: If regional, state, or local organizations are suggested, collect information that would be useful for future contact.)

9. Would your organization want to play a role in efforts to educate the public about possible I-131 exposure from nuclear tests conducted at the Nevada Test Site?

   IF YES: Which publics or groups would your organization want to play a role in educating?

   What would that role be?

   How would that role fit in with your organization's mission, goals, values, and activities?

10. Now, I'm going to read you a list of materials. Please indicate on a scale from 1 to 5 how helpful each would be to your organization (with 1 meaning not helpful at all and 5 meaning very helpful).

    a. Stand-alone materials such as brochures and fact sheets
    b. Information kits
    c. Videos
    d. In-person meetings
    e. Conferences/group meetings
    f. Web-based materials
    g. Would any other types of materials be helpful?

IV. CLOSING (2 MINUTES)

Thank you very much for speaking with me today. NCI and CDC are working together on this project to provide information on this issue to the public and health care providers. If you have any questions or if you would like to receive materials about the Nevada tests and I-131 fallout, please call Kelli Marciel at the National Cancer Institute at 301-496-6667.

I.5 Key Focus Group Findings on I-131 Exposure from the Nevada Test Site: Preliminary Findings from Public and Physician Groups

Prepared by:

Office of Cancer Communications
National Cancer Institute
31 Center Drive MSC-2580
Building 31, Room 10A03
Bethesda, MD 20892-2580

January 2000

KEY FOCUS GROUP FINDINGS ON I-131 EXPOSURE FROM THE NEVADA TEST SITE: PRELIMINARY FINDINGS FROM PUBLIC AND PHYSICIAN GROUPS

Table of Contents

I. INTRODUCTION

The National Cancer Institute (NCI) and Centers for Disease Control and Prevention (CDC) are designing a national campaign to implement Institute of Medicine (IOM) recommendations to communicate to Americans the potential health effects of Iodine-131 (I-131) radiation released during atmospheric testing in Nevada during the 1950s and 1960s. To inform this effort, Office of Cancer Communication (OCC) conducted six focus groups during December 1999 with members of the higher-exposure public, the lower-exposure public, and primary care physicians. Primary objectives of this research were:

- To gauge participants' awareness and knowledge of I-131 radiation fallout from the Nevada Test Site (NTS), as well as the potential risk for thyroid cancer and other non-cancerous thyroid conditions resulting from this exposure;
- To determine whether participants perceive themselves or anyone else as being at-risk for health problems resulting from I-131 exposure and, if so, how concerned participants are about such risk;
- To evaluate participants' reactions to IOM recommendations which discourage mass screening for thyroid cancer, but advocate for an educational campaign to communicate to Americans the potential health effects of I-131; and
- To gain a better understanding of the information needs and wants of the general public and health care professionals.

Preliminary findings from the focus groups are presented in this report. These findings will be used to help determine the direction and scope of further research for the campaign.

II. Methodology

Audience Segments

A total of six focus groups were conducted with three audience segments, referred to as the "higher-exposure public," the "lower-exposure public," and "physicians." The higher-exposure public was defined as adults ages 39-64 who had lived in at least one of 18 states exposed to high levels of I-131 for at least 5 years from birth to age 15.[6] The lower-exposure public was defined as adults 34-64 years of age who had NOT lived in one of the 18 higher-exposure states from birth to age 15. Conducting

[6] The higher-exposure and lower exposure public definitions were extracted from NCI's report, "Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests: A Report from the National Cancer Institute" (NIH Pub #97-4264), which outlined the key risk factors due to I-131 exposure. Participants had to be ages 39 to 64 because that is the present age of the individuals who were ages 0 to 15 during the time of the Nevada testing. The 18 states designated as high exposure by the report were: Arkansas, Colorado, Idaho, Illinois, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, Nevada, North Dakota, Oklahoma, South Dakota, Utah, Vermont, Wisconsin, and Wyoming.

research with both the higher- and lower-exposure public was done to obtain a preliminary sense of how risk status might affect one's awareness, knowledge, and concerns about the Nevada Test Site and I-131 health implications.

Physicians were defined as general practitioners, family physicians, or general internists who had been practicing medicine for at least three years in a high-exposure state. The three-year criterion ensured that physician participants had been in practice long enough to have some chance of seeing patients with radiation issues or health effects, and that they had been practicing in the surrounding area long enough to be familiar with their communities. Research was conducted with primary care physicians, because past research has shown that they are the most trusted source of both health care and health information.

A total of 51 people participated in the focus groups: 33 were members of the higher-exposure or lower-exposure public and 18 were physicians. The six focus groups were structured as follows:

Location	Date and Time	Audience Segment	Number of Participants
Philadelphia, PA	December 7, 1999 6:00-7:30 PM	Lower-exposure public	9
Philadelphia, PA	December 7, 1999 8:00-9:30 PM	Lower-exposure public	7
Omaha, NE	December 13, 1999 5:30-7:00 PM	Higher-exposure public	9
Omaha, NE	December 13, 1999 7:30-9:00 PM	Physicians	9
Burlington, VT	December 14, 1999 5:30-7:00 PM	Higher-exposure public	8
Burlington, VT	December 14, 1999 7:30-9:00 PM	Physicians	9

Focus Group Sites

The higher-exposure public and physicians groups were conducted in two states exposed to higher levels of I-131 radiation. Omaha, NE, was chosen because of its close proximity to the Nevada Test Site, and Burlington, VT, was included because it is farther away from the site. These locations were selected to provide an initial reading of whether geographic proximity to the Nevada Test Site would affect focus group responses, particularly perceived risk to health problems due to I-131 exposure.

The lower-exposure public groups were held in Philadelphia, PA, a lower-exposure state.

Participant Recruiting Criteria

Higher-exposure and lower-exposure individuals were recruited in advance of the focus groups. The screening questionnaire was designed to separate out people with a personal history of thyroid cancer or disease, individuals having an immediate family member with a history of thyroid disease, or individuals who self-reported that they were familiar with the issue of radioactive fallout from nuclear testing. The reason for excluding these individuals was the desire to talk with people for whom the I-131 issue is not already salient because of personal knowledge or experience. Clearly, any information campaign which is developed will have to address those who are already concerned about the issue, but it will also need to address the concerns and information needs of a potentially much larger number of people who will become aware (through the campaign) they may have a health risk due to I-131 exposure. It is this latter group – those not already knowledgeable or savvy about their potential risk – that the focus groups sought to speak with[7].

In addition to the above criteria, the screening criteria ensured that the groups would contain a mix of women and men, a mix of races, and participants whose educational levels ranged from a high school graduate through college graduate. Copies of the recruitment screeners for the public and physician groups can be found in Attachment A.

	Number of Participants (Higher-exposure)	**Number of Participants (Lower-exposure)**	**Number of Participants (TOTAL)**
Gender			
Female	8	9	17
Male	9	7	16
Race or Ethnicity			
White	11	11	22
Black	4	5	9
American Indian	2	0	2
Education			
High school degree	3	5	8
Some college or technical school	8	8	16
College degree	5	3	8
Not specified	1	0	1

[7] It should be noted that earlier research, in the form of in-depth interviews, was conducted in November 1999 with advocates, scientific experts, and public health experts to obtain the viewpoint of those more cognizant of the I-131 health issue.

Topic Guide Development

The moderator's guides for the general public and physicians' groups were designed to: a) measure initial awareness, knowledge and concern about the Nevada nuclear testing in the 1950s and 1960s; b) assess reactions to information presented during the groups about the I-131 exposure and its possible relationship to thyroid cancer and other non-cancerous thyroid disease; and c) gather opinions about the IOM screening recommendations as well as suggestions about implementing a communication campaign.

After participants were asked about their general awareness, knowledge and concern, they were shown a newspaper article from the *Chicago Sun-Times* dated August 2, 1997, along with a fact sheet and map illustrating exposure patterns across the U.S. They were then asked questions to elicit their reaction to the information. The newspaper article was selected from a sample of press coverage appearing after the release of the NCI report, "Estimated Exposures and Thyroid Doses Received by the American Public from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests." Potential articles were judged on their objectivity in communicating basic facts about the I-131 exposure and its potential relationship to thyroid cancer.

Each focus group was two hours in length and was conducted by a male moderator in his forties. Participants were paid for their participation. A copy of the topic guide, as well as the stimulus materials, can be found in Appendices B and C.

Limitations

It should be noted that focus groups are a qualitative research technique which provide useful, detailed insights into the target audience's perceptions and motivations. Findings from qualitative research, however, cannot be projected to a larger audience. Rather, they are intended to provide guidance and direction in determining the best approach for communicating with key audiences about cancer risk research. In addition, findings from focus groups should be considered preliminary, laying the groundwork for further research with key target audiences.

III. KEY FINDINGS

The remainder of this report presents the main findings from the focus groups. Findings related to the lower-exposure public, the higher-exposure public, and the physicians' groups are presented separately in order to give the reader an overall profile of each audience. However, it should be noted that there were many similarities across the three audience segments, particularly between the lower- and higher-exposure groups.

A. Lower-Exposure Public

Awareness, Knowledge & Concern **Before** Reading Newspaper Article and Fact Sheet

- Participants were concerned about a broad range of environmental concerns, including noise and water pollution, trash disposal, power plants, power lines, exhaust from vehicles, and "radiation" from computers.

- Participants were generally aware or had some vague recollection of the tests conducted at the Nevada Test site. The tests in Nevada were brought up by a few participants and then seemed to "ring a bell" for others who indicated a vague awareness of them.

- Several participants in each group knew the tests were conducted around the time of the 1950s or 1960s, but one thought tests had continued throughout the 1980s.

- Although participants were aware of the Nevada Test Site, they had little specific information about where their knowledge came from. No one knew about the NCI or IOM reports, or any other government reports on the issue. A couple of participants recalled seeing a movie about the Nevada Test Site called "Black Rain." Other participants mentioned television, and one got more specific and mentioned documentaries on programs like *Nova* and *60 Minutes*.

- None of the participants had specific knowledge of different types of radiation or radiation-induced health effects. Most expressed health concerns about "deformities" or "genetic alterations." One participant said the tests left people "crippled." Another said it could cause skin problems similar to those that resulted from "Agent Orange." Participants were particularly concerned about radiation-related illnesses being "passed through the genes."

- Participants felt little or no concern that they would suffer any negative health effects from the Nevada tests. Most did not consider themselves to be at risk and felt it was more of a concern for other people. One participant said, "If I lived out there I'd be concerned." Another said it was a problem for "those military people who were there at the time."

Concerns & Perceptions of Risk **After** Reading Newspaper Article and Fact Sheet

- Participants were provided with a newspaper article and additional facts regarding the association between the Nevada tests and thyroid cancer, risk factors that increase the likelihood of exposure, examples of higher and lower exposure areas, and possible associations between I-131 and two other types of non-cancerous thyroid disease: hypothyroidism and hyperparathyroidism.

Questions were then asked to gauge their level of concern, perceptions of risk, and opinions about actions that should be taken.

- The newspaper article and fact sheet raised levels of suspicion among many respondents. When asked about their initial reaction to the materials, many made comments like "there must be a big lawsuit coming" or referred to the newspaper article as a "scare tactic" no different from what they usually see in the news.

- Responses to the actual content of the material varied and included responses such as "frightening," surprise about the fact that "everyone was exposed" or the problem was so "widespread" and feelings of "sadness because children were affected." Others said the information was just "another thing to worry about."

- Even after reading the newspaper article and fact sheet, participants still did not feel a high level of personal concern about their risk of thyroid cancer or other non-cancerous thyroid disease from the Nevada Test Site 1-131 exposure. A few said there were more important health risks to worry about like stroke and heart attack. One respondent who stated that she has hypothyroidism said the information made her wonder about the possible connection to the Nevada Site, but even she did not seem overly concerned. Another said that the radiation had a "short half life" and no longer posed a risk because it was "long gone."

- When asked who is most at risk, participants thought the exposure posed a significant problem primarily to people living closer to the site. One said it was just not "plausible" that the radiation could cause problems in people thousands of miles away, and the rest of the group agreed. One person emphasized that she was still concerned about "other people being sacrificed."

- Few participants seemed to make the connection that *they* are the people who were children at the time of the tests and therefore at some level of risk. The length of time that has passed since the tests occurred and the aging of those who may be at greater risk seemed to make this a difficult concept for people to comprehend.

<u>Actions Needed</u>

- While some participants said they would like more information about I-131 exposure from the Nevada Tests, few seemed to want it out of concern for their own health. Most wanted more information in order to clear up what they perceived as discrepancies in the newspaper article. More participants in the first group wanted additional information than did those in the second group. A few participants said they didn't want more information because the issue "does not affect me" or "it is someone else's problem." One participant said it was like “AIDS” in the sense that “sometimes you just don’t want to know if you have a problem or not.”

- Among the few who wanted more information, interest focused primarily on more conclusive information on the association between I-131 and development of thyroid cancer, why the study took 14 years, and why it was still going to take more time to know whether people are “going to get cancer from the tests or not.”

- In general, thyroid screening and the false positives associated with screening were difficult concepts for people to understand.

- Reactions to the IOM recommendation not to conduct screening were mixed. Reasons for not supporting the IOM recommendation included statements like “If there is anything the government can do, it should be done” or “It sounds like the government is copping out.” Participants who supported screening stressed the individual’s right to choose, rather than concern about whether they themselves should (or might elect to) be screened.

- Proponents of the IOM recommendation expressed other views. One participant said screening would just cause a “panic.” Another suggested screening in “limited areas.” And one, who inaccurately thought cancer could be detected by a blood test, kept asserting that blood tests should be conducted because they would not cause anyone any harm.

- Regardless of whether or not they agreed with the IOM screening recommendation, many thought each individual should have the final say in whether or not to be screened.

<u>Educational Effort: Who Should Conduct It?</u>

- Most participants thought government should be involved in an educational effort because the government was “responsible” for what happened. Many individuals thought the American Cancer Society would be appropriate. Other groups mentioned included the Red Cross, Greenpeace, local and city health centers and other medical groups. A few thought a combination of government and non-government groups would be best.

- When asked what organizations should not be involved, some said the federal government because it “caused the problem” and therefore would not be trusted. A few said that only the part of government which caused the problem (i.e., “the military”) should not be involved. One participant expressed distrust of the Environmental Protection Agency (EPA) and said that agency should not take part.

- When probed about the appropriateness of the National Cancer Institute's involvement in an educational effort, participants said they had never heard of the institute. One participant said he thought the National Cancer Institute might be part of the National Institutes of Health, which may be associated with Johns Hopkins. Another participant then said the National Institutes of Health was a "research organization" that might be affiliated with that "group out of Atlanta," prompting another respondent to mention the "CDC."

Ethical Considerations

- Participants were generally divided over whether there was good reason for conducting the Nevada bomb tests during the 1950s and 1960s. Some said the tests were necessary to ensure the safety of Americans during the Cold War. Others said that it is "never right to sacrifice anyone" and that the nuclear testing "should not have been done because of the problems it caused." One participant also mentioned that the public could have been better protected from the radiation fallout at the time of the nuclear testing.

- Several participants expressed the opinion that "the government" (no agency specified) will always keep secrets and will never disclose the "full story" about nuclear testing pertaining to the past, present, or future.

- A couple of participants said that, in addition to being informed about the Nevada bomb testing and its resultant health effects, they would want assurance that nuclear testing would never happen again. Most of the other participants, however, took the viewpoint that the nuclear testing was over and that nothing could be done about it. In the words of one participant, "You can't right a wrong."

B. Higher-Exposure Public

Awareness, Knowledge & Concern **Before** Reading Article and Fact Sheet

- Participants expressed a broad range of general concerns about environmental hazards, from air and water pollution to lead paint, but provided few specifics. One participant said she was worried about "carcinogens...that are just everywhere nowadays."

- Participants had little knowledge about nuclear testing in general or the Nevada Test Site in particular. A few participants could name locations in the U.S. where nuclear testing has been conducted, including "the Pacific," "the West," and the state of Nevada. A couple of these participants thought testing was still going on in these locations. Only a few recalled specific dates of the nuclear testing, expressing a vague recollection that "there was some nuclear testing that went on in the 1950s and 1960s." Participants had no specific knowledge of different types of radiation or radiation-induced health effects from the

Nevada Test Site. Several expressed the view that the government has kept secrets about nuclear testing.

- Most participants could not recall the source of their information about the Nevada nuclear tests. A few vaguely recalled hearing something in "the news" or through "a documentary." One participant, for example, recalled seeing a program on the History Channel that "had something to do with radiation exposure and military men." Another said she thought the Discovery Channel might have run a documentary about the issue in the not too distant past. Another participant remembered some media coverage happening "when people were invited to watch some above-ground testing with special glasses." Although she couldn't recall the specifics, she characterized the event as "a real big deal."

- Participants initially expressed little concern about suffering any negative health effects from the Nevada tests. One participant, describing the tests as "underground tests," said he hoped the people conducting the tests now were protecting the environment to avoid any "contamination of the atmosphere or water supply." Another participant responded by saying it was more important to be concerned about the effects of such tests on people and animals than the environment. Another emphasized that people should worry more about the present than the past. One Vermont participant expressed little concern because of living far away from the Nevada Test Site (Note: this perception later changed when participants saw a map illustrating that radiation fallout had been carried from the West to the East).

<u>Perceptions of Personal Risks & Concerns **After** Reading Article and Fact Sheet</u>

- Prior to seeing the article and fact sheet, participants were asked whether they remembered hearing anything in the news about two years ago. None remembered anything too specific. A couple of participants said they remembered hearing something, but they either could not recount the details or mentioned other events such as the nuclear testing in India and Pakistan.

- The newspaper article and fact sheet initially evoked an emotional reaction from some participants. Some Nebraska and Vermont participants said they were "shocked" and that the information made them feel "unsafe." However, these emotional reactions dissipated quickly after the first few minutes of conversation.

- When asked who in the population is most at risk, most participants in Nebraska and Vermont immediately noted that people living in their own geographical areas were exposed, often referring to the color map of exposure levels. Comments like, "We are in the red" or "It is right over us" were fairly frequent during the course of the groups. Few participants, however, fully comprehended that they might also be at risk because they were children at the time of testing and may have consumed contaminated milk.

- Despite some initial surprise over seeing the "red spots," personal concern about developing cancer or non-cancerous thyroid disease was minimal. Most participants said they were not too concerned because:

  - They cannot change the past
  - They need to focus on the future
  - They question the credibility of some of the information in the article
  - They need more information to determine their true risk
  - It would be difficult to prove that any thyroid occurrence is actually caused by I-131 exposure
  - They have other more immediate health concerns such as heart disease, high blood pressure, prostate cancer, and breast cancer
  - They have other (non-health) concerns such as neighborhood violence
  - Thyroid problems have not surfaced thus far after routine checkups
  - The chances of getting thyroid cancer are small

  As one participant explained, "I'm sure we probably read about these nuclear tests at one time but then forgot about them. It's not the 'here and now.' The only reason we are thinking about it now is because you are making us think about it."

- The issue of whether or not their children or spouses could be affected resonated more with participants than their own personal risk. A few asked questions about whether or not the effects of the exposure could be "passed down." Another said, "If we were affected, that means someone in our family could be affected. How are offspring affected?" One person was worried that the exposure could have caused "a flaw in the [genetic] system that will keep getting passed down." Another participant, still misunderstanding the time period of exposure, said she was glad her children don't drink milk.

- A couple of participants said they would worry more about getting other types of cancers from the tests as opposed to developing thyroid problems. One participant asked, "Why does all this focus on the thyroid?" Another participant said he thought skin and bone cancer might be more likely problems based on what happened to the people who were bombed in Japan.

<u>Actions Needed</u>

- Throughout the discussions, participants raised more questions than personal concerns about the tests. Questions that have not already been mentioned include:

  -- Were all the tests underground?
  -- How long does the I-131 fallout last? What is the half-life?

- -- Can radiation sink into the ground? If so, can it rise back above the surface of the ground?
- -- Was the information on the fact sheet compiled during the time of the testing or now?
- -- Weren't the tests conducted in the desert so they wouldn't harm any people, plants or animals?

- The majority of participants agreed that a public information campaign would be appropriate. One participant said, "The more people know, the better." However, a couple individuals in the groups noted that it would be important to conduct the campaign carefully so people don't panic needlessly.

- The majority of participants were not supportive of the IOM recommendation against screening. Most thought people should have the option to decide whether or not they needed to be screened. As one participant put it, "If they think it is relevant for them and they want to have it done, this should override the recommendation."

- Several participants requested more information about how to get tested for thyroid disease, including where to go and what the test involves. One respondent suggested providing information about how to check one's own thyroid gland for lumps or problems.

- A couple of participants were concerned that mandatory screening might cause a panic. This prompted one participant to suggest a campaign to inform doctors, so doctors could then decide whether or not a patient needed screening. A few others agreed with this recommendation.

- A few participants focused on compensation issues related to screening. One thought the government needed to pay for the screening, particularly for people with no insurance, since it was the government that caused the problem. Another participant questioned the motive behind the IOM recommendation, saying insurance companies and medical doctors were probably trying to get out of paying for the screening. One participant said those who were hurt should get "a big check" from the government and then laughed.

- A few participants thought that additional research was needed to develop a less-invasive screening test for thyroid cancer so more people can get screened without being harmed. Several also wanted more conclusive evidence showing that I-131 does cause health problems.

<u>Educational Effort: Who Should Conduct It?</u>

- Participants had few suggestions about who should conduct an educational effort. When probed, a few said the federal government should head the effort since it was responsible for the exposure; several specifically said the Public

Health Service and Centers for Disease Control and Prevention. In addition, a few participants indicated that their local governments should be responsible. Another participant said that "public health organizations that do things like vaccines" would be appropriate. Other organizations mentioned were Blue Cross, EPA, and the American Cancer Society.

- A few participants thought that people would be best educated by their own personal doctor. One participant suggested using an article in a medical society journal to educate physicians.

- When asked if the federal government needed to stay out of the effort, only a few participants commented. One said yes because "they lied once and they'll do it again." Another participant thought it was okay for the government to conduct the effort "because the people in government today are not the same people as 40 years ago." Some participants felt that local government would be better, explaining that local government is more personal and less likely to withhold information.

<u>Ethical Considerations</u>:

- Ethical issues related to the Cold War were brought up at two different points during the focus groups -- at the very beginning when participants were asked for their concerns about consequences from the Nevada tests and then again after reading the article. A few participants said testing needed to be conducted for the U.S. to maintain the "balance of power."

- Only a couple of individuals commented when asked why it was or why it was not important to educate the public about what happened. One participant said it was important because people were "exposed without their knowledge." Another participant was unsure whether an educational effort was justified because "there was no real thyroid cancer outbreak."

C. Primary Care Physicians

<u>Awareness, Knowledge & Concern **Before** Reading Article and Fact Sheet</u>

- In general, physicians had vague memories but little actual knowledge about nuclear weapons tests conducted in the United States. A couple of participants said they had heard something about the issue in the last few years, but could not provide specifics. One participant said he remembered hearing that the government admitted to exposing people to radiation from some tests that were conducted in the 1950s and 1960s. Another said the government also admitted that workers at a test site in the 1950s were exposed to radiation. In addition, one participant recalled that soldiers were affected by tests conducted "when the atomic bombs were developed." Another physician recounted his father warning him as a child to refrain from eating snow, though he did not understand why. Only one participant in Vermont knew specific details about the Nevada testing, recalling that fallout resulted from tests conducted around 1946-1955, that one type of fallout was strontium 90, and that weather patterns carried fallout across the US.

- Participants mentioned the western United States, Nevada, Utah and New Mexico when asked about nuclear testing locations.

- Most participants could provide no details about specific types of radiation emitted from the tests or about specific health or non-health related consequences.

- Participants could not recall where they received information about the Nevada nuclear tests. One participant thought there might have been a program about the issue on the Discovery Channel at one time. Another recalled seeing a person on television who recounted watching atomic bomb tests and suffering health effects afterward.

- Participants expressed little concern about their patients having negative health consequences as a result of the Nevada Test Site exposures. One participant said, “I have no day-to-day concerns. It was many years ago.” Another participant thought that any serious consequences “would have shown up by now.”

- Only a few participants recalled having any patients ask them about negative health effects from exposure to nuclear fallout. One physician said that only a few of his patients have expressed concern, and he told them how to “watch for lumps on their thyroid and other symptoms.” Another participant said he had one patient with leukemia ask him if it might be related to the tests, but he couldn’t give the patient an answer. Another mentioned a patient with a brain tumor who once asked about the possible connection to radiation fallout. Other participants said their patients are concerned about and ask questions about cancer, but they don’t tend to relate it to the environment.

- Participants offered some explanations for why their patients are not concerned about radiation from the Nevada Test Site. One participant said patients are more concerned about negative health effects from nuclear power plants or disposal sites. A couple other participants said cellular telephones have recently become a big issue. Another physician noted that a majority of the population of Omaha, Nebraska, moved there from someplace else, thereby diluting the level of concern. Another said, “The testing was so long ago that people have forgotten about it; that’s what the government wants.”

Awareness, Knowledge & Concern **After** Reading Article and Fact Sheet

- When asked about their initial reaction to the news article and fact sheet, participants responded with questions such as:

  - How did they determine radiation exposure for various areas of the country?
  - How was the data on dosage collected?
  - How can there be areas in the Central US where there was no exposure in between areas in the West and East where there was high exposure?
  - Do thyroid cancer rates map out similar to the radiation dosages displayed on the fact sheet?
  - What type of thyroid cancer might result from exposure to I-131?
  - Is there any scientific evidence that shows a direct link between I-131 exposure and thyroid diseases of any kind?
  - What's happening in Canada?

- Physicians repeatedly expressed a desire for sound scientific data about radiation dosage and links to negative health effects. Some even questioned the validity of the data that currently exists. One participant said he remembered a talk given by a lecturer at the National Cancer Institute who said the NCI exposure data was inaccurate and excluded some people who had higher-exposure because they drank milk from cattle. Another participant said she assumed any exposure information provided by the government would be wrong.

- The majority of participants said they would only be concerned for their patients if they received appropriate risk information indicating that there is a substantial increase in thyroid cancer. One participant said physicians would need to know if there was some type of evidence pointing to a "10% to 15% increase in thyroid cancer." Another asked, "Is this a hypothetical or a *true* risk?"

- The majority of participants agreed that they would not change the way they practice medicine based on the information they had just received and the ensuing discussion. Reasons for not changing their practice were as follows:

  - Thyroid cancer is rare (particularly in Nebraska and Vermont). One participant said she has only seen one case of thyroid cancer in twelve years.
  - Thyroid cancer is very survivable.
  - Most patients have other, more pressing health concerns such as breast cancer.
  - People are already "dying off from something else" by the time they get thyroid cancer.
  - The issue of I-131 has "fallen off the radar screen."

- There is not enough scientific evidence to warrant a high degree of concern.
- They do not want to unnecessarily alarm their patients with information that, to date is scientifically unfounded.
- They already routinely check for cancerous and non-cancerous thyroid problems during regular physical exams.

Actions Needed

- When asked what should be done to address I-131 exposure from the Nevada bomb testing, participants mentioned that the environment (air, water, and soil) should be tested and that nuclear testing should be permanently banned.

- Most participants thought an educational campaign targeting the public would be unnecessary and would only serve to cause undue public alarm. One participant said, "Too many things have been done in medicine before all the facts are in; we often put education before science." Others agreed that nothing should be done until a meaningful increase in actual risk is demonstrated. A couple of participants said a public education campaign would cause "a mess." Another stated that physicians are sometimes pressured by media coverage to do things just to put their patients' concerns to rest.

- Nearly all participants agreed that a medical education campaign targeted at physicians would not be beneficial because, again, the information would not change the way they practice medicine. One participant thought some very basic information provided to physicians in higher-exposure areas may be useful just to put them "on alert."

- All participants agreed with the IOM recommendation that screening at this time is unwarranted. All agreed that thyroid cancer is rare, very survivable and that false positives would result in more harm than good being done to patients. A couple of participants said they were also uncertain about the real benefits associated with early detection of thyroid cancer. One participant stated that checking everyone's thyroid would be a "logistical public health nightmare."

Educational Effort: Who Should Conduct It?

- If any educational effort were to be conducted, some participants thought the National Cancer Institute or the National Institute of Health would be the most appropriate sponsor because they are science-oriented. Others mentioned medical societies like the American Medical Association or their professional membership organizations such as the American Association of Family Physicians (AAFP).

- A couple of participants expressed concerns about sponsorship by advocacy organizations because they are not research-based and could be motivated by self-interests. Some participants said the American Cancer Society should not be involved for this reason. When the Vermont participants were asked about the Society of Physicians for Responsible Medicine, all of them laughed and immediately discredited the group as being too politically extreme.

Ethical Considerations

- Ethical issues regarding why the nuclear tests were conducted and about individuals' right to know triggered little interest among physician participants.

- Most physicians thought it would be unethical to launch any type of educational effort before there is scientific data to support the necessity of such an effort. One participant said, "It would not be a public service announcement, it would be a public disservice announcement."

I-5 ATTACHMENTS

I-5-A. Participant Screening Questionnaires
I-5-B. Moderator's Topic Guides

ATTACHMENT I-5-A

OMB# 0925-0046
Exp. Date 8/31/00

Screener for Health Focus Groups with Public

Name: ____

Street Address: ____

City: ________________________________ **Zip Code**: _____________ __________

Home Phone: _____________________ **Work Phone**: __________________________

	City	Group	Facility	Date	Time
☐	Philadelphia, PA	Lower risk	Focus Pointe	Dec. 7	6:00 PM
☐	Philadelphia, PA	Lower risk	Focus Pointe	Dec. 7	8:00 PM
☐	Omaha, NE	Higher risk	Midwest Survey	Dec. 13	5:30 PM
☐	Burlington, VT	Higher risk	Action Research	Dec. 14	5:30 PM

INTRODUCTION

Hello, my name is ___________, and I'm calling on behalf of a national, non-profit organization concerned about the health and well-being of Americans. We're talking to people to learn their opinions about some important environmental and health issues.
I want to assure you that we're not selling anything and that your responses will be kept confidential.

May I speak to an adult in the household? (ONCE SPEAKING TO ADULT, REPEAT INTRODUCTION IF NECESSARY AND ASK:) Would you be willing to answer a few questions?

- ☐ Yes (CONTINUE)
- ☐ No (THANK AND TERMINATE)

1. What is your exact age? (RECORD EXACT RESPONSE AND CODE IN APPROPRIATE AGE SUBGROUP.)

   Age: _______________

   - ☐ Younger than 39 (THANK AND TERMINATE)
   - ☐ 39-47 (RECRUIT 4)
   - ☐ 48-56 (RECRUIT 4)
   - ☐ 57-64 (RECRUIT 4)
   - ☐ 65 or older (THANK AND TERMINATE)

2. I'm going to read you a list of statements. For each one, please tell me whether you agree, neither agree nor disagree, or disagree with that statement. (READ.)

	Agree	Neither Agree nor Disagree	Disagree	Don't Know/ Refused
To protect the environment, people need to make big changes in the way they live.	1 (CONTINUE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)
I am concerned about the environment because of the potential harm to myself and my family.	1 (CONTINUE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)

3. Different areas of the country are more or less concerned about environmental issues. Thus, where we have lived can affect our opinions about the environment.

   a. I'm going to read you a list of states, and please tell me if you lived in any of these states between the time you were born and age 15. (READ STATES IN COLUMN "a" AND CHECK ANY STATES WHERE RESPONDENT LIVED BETWEEN THE AGES OF 0-15. MULTIPLE RESPONSES ACCEPTED.

   IF NO CHECKS ARE MADE IN COLUMN "a," CLASSIFY AS "LOWER RISK" AND SKIP TO Q3.

   IF ONE ORE MORE STATES ARE CHECKED, ASK Q2b FOR EACH STATE MENTIONED.)

   b. Did you live in [STATE] for at least 5 years? (USE COLUMN "b" TO CHECK ANY STATE(S) WHERE RESPONDENT LIVED AT LEAST 5 YEARS.

   CLASSIFY AS "HIGHER RISK" ANY RESPONDENT WHO HAS LIVED IN AT LEAST ONE OF THE LISTED STATES FOR AT LEAST 5 YEARS BETWEEN THE AGES OF 0-15.)

	a. Lived in state from age 0-15	**b. At least 5 years (ASK HIGHER RISK ONLY)**
(1) Arkansas	☐	☐
(2) Colorado	☐	☐
(3) Idaho	☐	☐
(4) Illinois	☐	☐
(5) Iowa	☐	☐
(6) Kansas	☐	☐

(7) Minnesota	☐	☐
(8) Missouri	☐	☐
(9) Montana	☐	☐
(10) Nebraska	☐	☐
(11) Nevada	☐	☐
(12) North Dakota	☐	☐
(13) Oklahoma	☐	☐
(14) South Dakota	☐	☐
(15) Utah	☐	☐
(16) Vermont	☐	☐
(17) Wisconsin	☐	☐
(18) Wyoming	☐	☐

4. Currently there are many issues about the environment under public debate, and different people are more or less familiar with them. I'm going to read you a list of specific environmental issues. For each one, please tell me whether you are "familiar," "neither familiar nor unfamiliar," or "not at all familiar" with that issue.

	Familiar	**Neither Familiar Nor Unfamiliar**	**Not at All Familiar**	**Don't Know/ Refused**
Liquid waste from chemical plants.	1 (CONTINUE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)
Residual pesticides in the water supply.	1 (CONTINUE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)
Radioactive fallout from nuclear testing.	1 (THANK AND TERMINATE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)
Toxic air emissions from coal plants used to generate electricity.	1 (CONTINUE)	2 (CONTINUE)	3 (CONTINUE)	9 (CONTINUE)

5. Since this study is also about health, I'm going to ask you some health related questions. Have you have ever been diagnosed with any of the following diseases … (READ. DO **NOT** RECRUIT PARTICIPANTS WHO HAVE HAD THYROID DISEASE OR CANCER.)

☐ Respiratory disease	(CONTINUE)
☐ Heart disease	(CONTINUE)
☐ Thyroid disease	(THANK AND TERMINATE)
☐ Cancer of any kind	(THANK AND TERMINATE)

6. Have any of your immediate family members, that is, your parents, brothers or sisters, partner, or children, ever been diagnosed with any of the following diseases … (READ. DO **NOT** RECRUIT PARTICIPANTS WHO HAVE HAD IMMEDIATE FAMILY MEMBER DIAGNOSED WITH THYROID DISEASE.)

- ☐ Respiratory disease (CONTINUE)
- ☐ Heart disease (CONTINUE)
- ☐ Thyroid disease of any kind, including thyroid cancer (THANK AND TERMINATE)
- ☐ Cancer of any other kind (CONTINUE)

7. I have a few more questions to ask for classification purposes. Which of the following best describes your race? (READ. RECRUIT 8 WHITE AND 4 NON-WHITE. NEBRASKA FACILITY MUST RECRUIT AT LEAST 2 AMERICAN INDIAN/ALASKA NATIVE.)

- ☐ White
- ☐ Black or African American
- ☐ Hispanic or Latino
- ☐ Asian
- ☐ Native Hawaiian/Other Pacific Islander
- ☐ American Indian /Alaska Native

8. Which of the following best describes your highest level of education? (READ.)

- ☐ Less than high school degree (THANK AND TERMINATE)
- ☐ High school degree (RECRUIT AT LEAST 3)
- ☐ Some college/technical school/associates degree (RECRUIT AT LEAST 3)
- ☐ 4-year college degree (RECRUIT NO MORE THAN 3)
- ☐ Some graduate school or more (THANK AND TERMINATE)

9. (NOTE GENDER:)

- ☐ Male (RECRUIT 6)
- ☐ Female (RECRUIT 6)

10. Have you ever been employed in any of the following settings?

	Yes	**No**	**Don't Know/Refused**
Medical or health setting	(THANK AND TERMINATE)	(CONTINUE)	(THANK AND TERMINATE)
Advertising or market research setting	(THANK AND TERMINATE)	(CONTINUE)	(THANK AND TERMINATE)

11. Have you ever participated in a focus group discussion or been paid to be part of a discussion group?

☐ Yes (CONTINUE)
☐ No (SKIP TO INVITATION)

12. How recently did you participate in the focus group?

☐ 6 months ago or less (THANK AND TERMINATE)
☐ More than 6 months ago (CONTINUE)

13. What did you talk about during the groups? (RECORD VERBATIM. DO NOT RECRUIT IF TOPICS WERE ABOUT THE ENVIRONMENT, ATOMIC BOMBS, NUCLEAR RADIATION, THYROID DISEASE, OR CANCER.)

____

____

____

INVITATION

Thank you for answering our questions. We'd like to invite you to take part in a focus group discussion of 8-10 people. We're talking to adults across the U.S. so that we can better plan for a national program focusing on the environment and the health of Americans. Your participation is very important to us. The focus group will take place [FACILITY, DATE, TIME] and will last about 2 hours. Participants will be paid $_____ in cash for their time to take part. We'll also serve refreshments. Will you take part?

☐ Yes (CONTINUE)
☐ No (THANK AND TERMINATE)

Thanks for accepting our invitation. For contact purposes, may I get your name, address, and daytime and evening phone numbers? (RECORD INFORMATION ON FIRST PAGE)

We will send you a packet with a confirmation letter three to five days before the focus group is held. It will include directions to the location where the discussion will take place. It is very important that you arrive on time. If you need glasses for reading, please bring them to the discussion. If you have any questions or find out that you cannot attend the focus group, please call ___________ at __________ so that we can find someone to take your place. Thank you for agreeing to take part in our study. We look forward to meeting you. Goodbye.

(NOTE TO RECRUITER: If respondents have any questions or concerns about the focus group topic, please contact Memi Miscally at Porter Novelli at 202-973-5845. Do NOT give her name to respondents.)

Recruited by: ______________________________ **Date**: ________________________

Confirmed by: _____________________________ **Date**: _______________________

OMB# 0925-0046
Exp. Date 8/31/00

Screener for Health Focus Groups with Physicians

Name: ____

Street Address: ____

City: ______________________ **Zip Code:** __________________

Home Phone: ______________ **Work Phone:** __________________

	City	Group	Facility	Date	Time
☐	Omaha, NE	Physicians	Midwest Survey	Dec. 13	7:30 PM
☐	Burlington, VT	Physicians	Action Research	Dec. 14	7:30 PM

INTRODUCTION

Hello, my name is ___________, and I'm calling on behalf of a national, non-profit organization concerned about the health and well-being of Americans. We're talking to physicians to learn their opinions about some important health issues. I want to assure you that we're not selling anything and that your responses will be kept confidential. May I speak to a physician? (ONCE SPEAKING TO PHYSICIAN, REPEAT INTRODUCTION IF NECESSARY AND ASK:) Would you be willing to answer a few questions?

- ☐ Yes (CONTINUE)
- ☐ No (THANK AND TERMINATE)

1 Which of the following best describes the kind of medicine you practice? (READ.)

a. General practice (CONTINUE)
b. Family practice (CONTINUE)
c. General internist (CONTINUE)
d. Other (THANK AND TERMINATE)

2. Are you a practicing physician—that is, do you see patients on a regular basis?

a. Yes (CONTINUE)
b. No (THANK AND TERMINATE)

3. Which of the following best describes how old the majority of your patients are? Are they … (READ.)

   a. Younger than 18 (THANK AND TERMINATE)
   b. 18-64 (CONTINUE)
   c. 65 or older (THANK AND TERMINATE)

4. Do you see approximately equal numbers of males and females?

   a. Yes (CONTINUE)
   b. No (THANK AND TERMINATE)

5. How many years have you been practicing medicine?

   a. Less than 5 years (THANK AND TERMINATE)
   b. 5 years or more (CONTINUE)

6. How long have you been practicing in the state of Nebraska/Vermont?

   a. Less than 3 years (THANK AND TERMINATE)
   b. 3 years or more (CONTINUE)

7. Are you employed full-time by a managed care company such as Kaiser Permanente or Aetna?

   a. Yes (RECRUIT NO MORE THAN 2)
   b. No (CONTINUE)

8. Have you ever been employed in an advertising or market research setting?

   a. Yes (THANK AND TERMINATE)
   b. No (CONTINUE)

9. Have you ever participated in a focus group discussion or been paid to be part of a discussion group?

☐ Yes (CONTINUE)
☐ No (SKIP TO INVITATION)

10. How recently did you participate in the focus group?

☐ 6 months ago or less (THANK AND TERMINATE)
☐ More than 6 months ago (CONTINUE)

11. What did you talk about during the groups? (RECORD VERBATIM. DO NOT RECRUIT IF TOPICS WERE ABOUT THE ENVIRONMENT, ATOMIC BOMBS, NUCLEAR RADIATION, THYROID DISEASE, OR CANCER.)

____

____

____

INVITATION

Thank you for answering our questions. We'd like to invite you to take part in a focus group discussion of 8-10 people. We're talking to physicians across the U.S. so that we can better plan for a national program focusing on the health of Americans. Your participation is very important to us. The focus group will take place [FACILITY, DATE, TIME] and will last about 2 hours. Participants will be paid $_____ in cash for their time to take part. We'll also serve refreshments. Will you take part?

☐ Yes (CONTINUE)
☐ No (THANK AND TERMINATE)

Thanks for accepting our invitation. For contact purposes, may I get your name, address, and daytime and evening phone numbers? (RECORD INFORMATION ON FIRST PAGE)

We will send you a packet with a confirmation letter three to five days before the focus group is held. It will include directions to the location where the discussion will take place. It is very important that you arrive on time. If you need glasses for reading, please bring them to the discussion. If you have any questions or find out that you cannot attend the focus group, please call ___________ at __________ so that we can find someone to take your place. Thank you for agreeing to take part in our study. We look forward to meeting you. Goodbye.

(NOTE TO RECRUITER: If respondents have any questions or concerns about the focus group topic, please contact Memi Miscally at Porter Novelli at 202-973-5845. Do NOT give her name to respondents.)

Recruited by: ____________________________ **Date**: ______________________

Confirmed by: ___________________________ **Date**: ______________________

ATTACHMENT I-5-B

OMB# 0925-0046
Exp. Date 8/31/00

Moderator's Guide for I-131 Focus Groups with the General Public

I. EXPLANATION AND INTRODUCTIONS (10 minutes)

1. **Thanks** for coming today. Your participation is very important to us; your insights will help us develop a national public health program.

2. My name is ______ and I work for ______, an independent research company. I do not work with the sponsor of these groups, so please feel that you can give me your **honest** opinions**—positive and negative**.

3. What we're doing today is called a focus group. You may have guessed that all of you **live in the Philadelphia/Omaha/Burlington area**, and for the next 2 hours, we're going to talk about the **environment and your health**.

4. I'm interested in all of your ideas, comments, and suggestions. There are **no right or wrong answers**. It's important that I hear what everyone thinks, so please speak up, especially if your view is different from something someone else says.

5. We'll **audio-tape** and **video-tape** this discussion. In addition, program planners sitting behind this mirror will **observe**. We're taking these steps because everything you say is important to us, and we want to make sure we don't miss any comments.

6. Please **talk one at a time** and in a voice at least as **loud** as mine so that the recording equipment can pick up everything that is said.

7. Later, we'll go through all of your comments and use them to write a report. Remember that all of your comments are **confidential**. Your name will not be used in the report.

8. If you need to use the bathroom, please go **one at a time**.

9. Please turn off any **beepers, pagers, or cell phones** that you may have.

10. Before we begin the discussion, please **introduce** yourself. Please tell us your:

- First name
- Number of years you've been living in the Philadelphia/Omaha/Burlington area

II. GENERAL AWARENESS, KNOWLEDGE, AND CONCERN (25 minutes)

1. What are some of the environmental issues that you've heard about, if any at all? Where does nuclear radiation fit into the list of issues? (SPEND ONLY A MINUTE AND THEN MOVE ON)

2. What words, images, or feelings come to mind when I say the word nuclear radiation?

3. What, if anything, have you heard about nuclear weapons tests conducted in the United States? (TRY TO OBTAIN PLACES AND DATES OF ATOMIC BOMB TESTING AND TYPES OF NUCLEAR RADIATION RELEASED)

About 100 atomic bomb tests were conducted in the state of Nevada during the 1950s and 1960s. These tests released different types of radioactive material into the atmosphere. The rest of this discussion will pertain to these tests and the nuclear radiation fallout.

4. Have you heard anything about these tests? IF YES: What have you heard about these tests?

PROBE: Types of radiation released?
IF AWARE OF MORE THAN ONE MATERIAL: Are you concerned about some of the radioactive substances more than others? What makes you more concerned?

5. What, if any, questions do you have about these tests and the nuclear radiation released?

PROBE: How about health related consequences?
How about any non-health related consequences?

6. What, if any, concerns do you have about these tests and the nuclear radiation released?

PROBE: How about health-related consequences?
How about any non-health-related consequences?

7. From what sources have you gotten any information you might have? IF MEDIA: From what sources did the media get their information? For example, do you remember any specific individuals, experts or organizations that the media quoted or mentioned? (PROBE FOR AWARENESS OF NCI AND IOM REPORTS)

III. REACTIONS AFTER SEEING ARTICLE (30 minutes)

Now, I'm going to give you a newspaper article (or fact sheet) to read about the Nevada nuclear bomb tests. Some of this information you may already know. Please read all the information carefully as we will be discussing this material in detail next.

I'd like to mention one other thing. The newspaper article mentions that people were most likely to be exposed to I-131 radiation if they lived around Nevada, specifically in the states of Montana, Idaho, Utah, South Dakota, and Colorado. FOR NEBRASKA GROUPS: Please note that Nebraska is near this region and was also a highly exposed state. FOR VERMONT GROUPS: Please note that Vermont was another highly exposed state, because weather patterns carried the radiation north and east of Nevada.

1. What are your initial reactions to this article and the additional information I've given you? (LEAVE OPEN DISCUSSION AROUND EMOTIONS/FEELINGS OR THE INFORMATION ITSELF)

2. When might people living in the U.S. have been affected by I-131? During the 1950s and 1960s when the tests were conducted? Now, in the 1990s? In the future, when it's 2000 and beyond?

You may or may not have a thorough understanding of thyroid cancer. To ensure that all of us have the information we need to get through tonight's discussion, I'd like to give you some information about thyroid cancer. (SHOW BOARD)

Thyroid Cancer

This type accounts for 1% of all cancers.

Symptoms:
Lump in the neck (most common) ____________
Tight or full feeling in the neck______________
Difficulty breathing or swallowing ______________ (less common)
Hoarseness______________________________
Swollen lymph nodes______________________

3. Based on the information provided, who do you think is at risk for thyroid cancer from the Nevada tests? What are the major factors that make someone more at risk?

PROBE: Different geographical areas
Age
Milk consumption

4. How concerned are you personally about your risk for developing thyroid cancer as a result of these tests and exposure to the fallout? What makes you particularly concerned?

At the present time, there is no scientific evidence that the amount of I-131 exposure that people received from the Nevada Site is related to any other types of thyroid disease besides thyroid cancer. Research is being conducted to find out if the amount of I-131 exposure people received could be related to other thyroid disorders. Here are descriptions of SOME of the symptoms of two disorders that some people have claimed could be related to the I-131 exposure from the Nevada Test Site. (SHOW BOARD)

Hypothyroidism
A condition in which the thyroid gland becomes underactive. The thyroid gland is located in the neck and affects heart rate, blood pressure, body temperature, metabolism, and childhood growth and development.

Symptoms:
Lack of Energy, Tiredness
Depression
Feeling Cold
Dry, Coarse, Itchy Skin
Dry, Coarse, Thinning Hair
Muscle Cramps
Constipation
Weight Gain

Hyperparathyroidism
A condition in which the parathyroid glands become overactive. The parathyroid glands are located next to the thyroid and affect the body's supply of calcium.

Symptoms:
Calcium Deposits
Osteoporosis or Loss of Bone Density
Muscular Weakness
Nervousness
Irritability
Racing Heart
Increased Perspiration
Thinning of Skin
Fine, Brittle Hair
Frequent Bowel Movements
Weight Loss

5. How concerned are you personally about your risk of developing any of the non-cancerous thyroid diseases I mentioned as a result of the Nevada tests? What makes you concerned?

6. In comparison to other types of health risks like heart disease or stroke, how concerned are you about getting thyroid cancer? How about non-cancerous thyroid diseases?

7. Is the information I provided you with confusing or clear? What would need to be done to make it easier to understand?

8. Would you like more information to determine how important a health issue the I-131 fallout from the Nevada tests is for you? Why or why not? What information?

IV. EDUCATIONAL CAMPAIGN (40 minutes)

1. What, if anything, do you think should be done about I-131 and any potential health risks?

PROBE: Public Education
Screening
Compensation for Medical Expenses

2. Who should be responsible? (IF GOVERNMENT: PROBE FOR LOCAL, STATE OR FEDERAL, IF FEDERAL PROBE FOR AGENCIES) What about these entities makes them responsible?

3. What are your opinions about this recommendation?

In 1999, the Institute of Medicine (IOM), a panel of experts from the National Academy of Scientists congressionally mandated to advise the federal government on medical issues, released medical screening recommendations for people who may have been exposed to I-131 released from the Nevada Tests. The panel concluded that the available science does NOT warrant medical screening tests within the general population or within any subgroups of the population.

The reasoning behind this recommendation is that very few people get thyroid cancer and those that do are very likely to be cured. In addition, the current method of thyroid cancer screening can produce false positives, meaning that people may be inaccurately diagnosed with thyroid cancer and consequently subjected to unnecessary fear, medication and surgery.

For these reasons, the IOM felt that the evidence suggests that more harm to the public than good would be done with screening.

Do you think there is a need for a public information campaign to educate people about their possible exposure to I-131 and the potential risks associated with that exposure?

4. In your opinion, who needs to be informed about the possible risks associated with the I-131 emitted from the nuclear tests? Should everyone in the U.S. be the focus, or should information be targeted to those who may have been more exposed? Why?

5. IF GENERAL PUBLIC: What information do you think the general public needs to get? IF THOSE MORE EXPOSED: What information do you think people who were heavily exposed need to get?

6. What information do you think you personally need about the I-131 emitted from the Nevada tests and its possible health effects?

7. What do you think would be the most effective ways to get this information to people?

PROBE: Television/radio
Newspapers/magazines
Conferences/meetings
Interpersonal communication
Brochures
Internet

8. What health care professionals, if any, do you think should be involved in reaching out to people? What about these people makes them important?

9. If an educational effort is to be launched, some organization or organizations need to be responsible for implementing the effort. Are there any organizations or types of organizations that you particularly trust to implement these efforts? What about those organizations makes you trust them?

   (PROBE: Government agencies, non-profit organizations or advocacy groups?)

10. Are there any organizations or types of organizations that should NOT be involved in implementing these efforts? What makes them untrustworthy?

11. Do you think people will trust a public education campaign that is conducted by the federal government? Would it matter what specific federal agencies are involved? Why?

V. ADDITIONAL CONSIDERATIONS (10 minutes)

1. In your opinion, what are the **main** reasons why the public should be informed about the Nevada Test Site, I-131 exposure, and any potential health problems?

IF NECESSARY, PROBE: Some people think the government has an obligation to let people know about the exposure from the Nevada Test Site primarily because some people could have been harmed by the fallout. Other people think that regardless of the level of harm people experienced, the government has an obligation to inform the public because the public has a right to know about its government's actions. Which of these best represents your views? Why?

2. Based on everything you know now, what if anything, would justify the Nevada atomic bomb testing?

IF NECESSARY, PROBE: People were exposed to radioactive material while nuclear weapons were being tested for the purpose of defending our country. What do you think about this?

3. Do you think the government would have intentionally exposed people to radioactive material or do you think the government probably didn't know about the negative health effects that may be associated with the exposures until after the tests were already conducted?

4. What else do you think needs to be done to address the issue of I-131 fallout from the Nevada Test Site that we have not talked about?

5. How do these ethical considerations impact your trust in the government as a whole and different government agencies?

6. Is there anything else that you think needs to be done to address the issue of I-131 fallout from the Nevada Test Site that we have not talked about?

VI. CLOSING (5 minutes)

1. CHECK WITH OBSERVERS FOR ADDITIONAL QUESTIONS.

2. Those are all of the questions I have. Do you have any final comments?

3. Thanks for your participation today. I have some bookmarks that can provide you with current information about what we've discussed this evening. Feel free to take one before you leave.

OMB# 0925-0046
Exp. Date 8/31/00

Moderator's Guide for I-131 Focus Groups with Physicians

I. EXPLANATION AND INTRODUCTIONS (10 minutes)

1. **Thanks** for coming today. Your participation is very important to us; your insights will help us develop a national public health program.

2. My name is ______ and I work for ______, an independent research company. I do not work with the sponsor of these groups, so please feel that you can give me your **honest** opinions **– positive and negative.**

3. What we're doing today is called a focus group. You may have guessed that all of you are **primary care physicians**, and for the next 2 hours, we're going to talk about the **environment and the health of your patients**.

4. I'm interested in all of your ideas, comments, and suggestions. There are **no right or wrong answers**. It's important that I hear what everyone thinks, so please speak up, especially if your view is different from something someone else says.

5. We'll **audio-tape** and **video-tape** this discussion. In addition, program planners sitting behind this mirror will **observe**. We're taking these steps because everything you say is important to us, and we want to make sure we don't miss any comments.

6. Please **talk one at a time** and in a voice at least as **loud** as mine so that the recording equipment can pick up everything that is said.

7. Later, we'll go through all of your comments and use them to write a report. Remember that all of your comments are **confidential**. Your name will not be used in the report.

8. If you need to use the bathroom, please go **one at a time**.

9. Please turn off any **beepers, pagers, or cell phones** that you may have.

10. Before we begin the discussion, please **introduce** yourself. Please tell us your:

    - First name
    - Number of years you've been practicing in the Omaha/Burlington area

II GENERAL AWARENESS, KNOWLEDGE, AND CONCERN (25 minutes)

1. What are some of the environmental issues that you've heard about, if any at all? Where does nuclear radiation fit into the list of issues? (SPEND ONLY A MINUTE AND THEN MOVE ON)

2. What words, images, or feelings come to mind when I say the word nuclear radiation?

3. What, if anything, have you heard about nuclear weapons tests conducted in the United States? (TRY TO OBTAIN PLACES AND DATES OF ATOMIC BOMB TESTING AND TYPES OF NUCLEAR RADIATION RELEASED)

About 100 atomic bomb tests were conducted in the state of Nevada during the 1950s and 1960s. These tests released different types of radioactive material into the atmosphere. The rest of this discussion will pertain to these tests and the nuclear radiation fallout.

4. What, if anything, have you heard about these Nevada bomb tests conducted during the 1950s and 1960s and the resulting nuclear radiation fallout?

   PROBE: Types of radiation released?
   IF AWARE OF MORE THAN ONE MATERIAL: Are you concerned about some of the radioactive substances more than others? What makes you more concerned?

5. What, if any, questions do you have about these tests and the nuclear radiation released?

6. What, if any, concerns do you have about these tests and the nuclear radiation released?

   PROBE: Any concerns about health or non-health related consequences?

7. Have you and your patients discussed the Nevada bomb tests and health problems resulting from the I-131 fallout radiation? If so, how often? What have you talked about? Who typically initiates the conversation—you or your patients?

8. Relative to their other health concerns, how concerned are your patients about experiencing health problems as a result of being exposed to I-131?

9. How concerned about I-131 health effects is your community in general?

10. From what sources have you gotten any information you might have? IF MEDIA: From what sources did the media get their information? For example, do you remember any specific individuals, experts or organizations that the media quoted or mentioned? (PROBE FOR AWARENESS OF NCI AND IOM REPORTS)

III REACTIONS AFTER SEEING ARTICLE (30 minutes)

Now, I'm going to give you a newspaper article and fact sheet to read about the Nevada nuclear bomb tests. The article actually appeared in newspapers across the country, perhaps even in your area. Some of this information you may already know. Please read all the information carefully as we will be discussing this material in detail next. (SHOW ARTICLE)

> I'd like to mention one other thing. The newspaper article mentions that people were most likely to be exposed to I-131 radiation if they lived around Nevada, specifically the states of Montana, Idaho, Utah, South Dakota, and Colorado. FOR NEBRASKA GROUPS: Please note that Nebraska is near this region and was also a highly exposed state. FOR VERMONT GROUPS: Please note that Vermont was another highly exposed state, because weather patterns carried the radiation north and east of Nevada.

1. What are your initial reactions to this article and the additional information I've given you? (LEAVE OPEN DISCUSSION AROUND EMOTIONS/FEELINGS OR THE INFORMATION ITSELF)

2. When might people living in the U.S. have been affected by I-131? During the 1950s and 1960s when the tests were conducted? Now, in the 1990s? In the future, when it's 200 and beyond?

You may or may not have a thorough understanding of thyroid cancer. To ensure that all of us have the information we need to get through tonight's discussion, I'd like to give you some information about thyroid cancer. (SHOW BOARD)

> **Thyroid Cancer**
> This type accounts for 1% of all cancers.
>
> **Symptoms:**
> Lump in the neck (most common)
> Tight or full feeling in the neck
> Difficulty breathing or swallowing (less common)
> Hoarseness
> Swollen lymph nodes

PROBE: Different geographical areas
Age
Milk consumption

4. Given the identified risk factors, how concerned are you that any of your current patients may be at risk of developing thyroid cancer?

At the present time, there is no scientific evidence that the amount of I-131 exposure that people received from the Nevada Site is related to any other types of thyroid disease besides thyroid cancer. Research is being conducted to find out if the amount of I-131 exposure people received could be related to other thyroid disorders. Here are descriptions of SOME of the symptoms of two disorders that some people have claimed could be related to the I-131 exposure from the Nevada Test Site. (SHOW BOARD)

Hypothyroidism
A condition in which the thyroid gland becomes **underactive**. The thyroid gland is located in the neck and affects heart rate, blood pressure, body temperature, metabolism, and childhood growth and development.

Symptoms:
Lack of Energy, Tiredness
Depression
Feeling Cold
Dry, Coarse, Itchy Skin
Dry, Coarse, Thinning Hair
Muscle Cramps
Constipation
Weight Gain

Hyperparathyroidism
A condition in which the parathyroid glands become **overactive**. The parathyroid glands are located next to the thyroid and affect the body's supply of calcium.

Symptoms:
Calcium Deposits
Osteoporosis or Loss of Bone Density
Muscular Weakness
Nervousness
Irritability
Racing Heart
Increased Perspiration
Thinning of Skin
Fine, Brittle Hair
Frequent Bowel Movements
Weight Loss

5. Do you believe these concerns about non-cancerous thyroid conditions are warranted by available information on I-131 and its effects on human health? Or are these concerns needlessly raised?

6. Additional research into the non-cancerous thyroid conditions due to I-131 exposure is being conducted. How worthwhile do you think this effort is?

7. How concerned are you about your patients' risk of developing any of the non-cancerous thyroid disease I mentioned as a result of the Nevada tests? What makes you concerned?

8. In comparison to other types of health risks, how concerned are you about your patients' risk for thyroid cancer as a result of I-131 exposure? Non-cancerous thyroid diseases? (DETERMINE WHETHER PARTICIPANTS ARE MORE CONCERNED ABOUT THYROID CANCER OR NON-CANCEROUS THYROID DISEASES)

9. What other information would you need to make a good determination of whether you have patients that are at heightened risk for I-131 related problems?

IV. EDUCATION CAMPAIGN (45 minutes)

1. What, if anything, do you think should be done to educate the public about I-131 and potential health risks?

   PROBE: Public education
   Screening
   Compensation for medical expenses (RESERVE ANY DISCUSSION AROUND ADDITIONAL TYPES OF COMPENSATION FOR SECTION V)

2. Who should be responsible for implementing these efforts? (IF GOVERNMENT: PROBE FOR LOCAL, STATE OR FEDERAL, IF FEDERAL PROBE FOR AGENCIES) What about these entities makes them responsible?

In 1999, the Institute of Medicine (IOM), a panel of experts from the National Academy of Scientists congressionally mandated to advise the federal government on medical issues, released medical screening recommendations for people who may have been exposed to I-131 released from the Nevada Tests. The panel concluded that the available science does NOT warrant medical screening tests within the general population or within any subgroups of the population.

The reasoning behind this recommendation is that very few people get thyroid and those that do are very likely to be cured. In addition, the current method of thyroid cancer screening can produce false positives, meaning that people may be inaccurately diagnosed with thyroid cancer and consequently subjected to unnecessary fear, medication and surgery.

For these reasons, the IOM felt that the evidence suggests that more harm than good to the public would be done with screening.

3. What are your opinions about this recommendation? How important is it to educate the public about I-131 and the potential health risks?

4. In your opinion, who needs to be informed about the possible risks associated with the I-131 emitted from the nuclear tests? Should everyone in the U.S. be the focus, or should information be targeted to those who may have been more exposed? Why?

5. IF GENERAL PUBLIC: What information do you think the general public needs to get?

   IF THOSE MORE EXPOSED: What information do you think people who were heavily exposed need to get?

6. What role, if any, should physicians play in a campaign to educate the public about I-131 health implications?

7. Based on what you know now, is it important for you to inform your patients? Why or why not?

8. What barriers might you encounter? What support might you need?

   PROBE: Time
   Money
   Tips on how to talk to patients
   Materials (What types?)
   Further information

9. What other types of health care professionals should be involved in an educational effort?

10. If an educational effort is to be launched, some organization or organizations need to be responsible for implementing the effort. What organizations or types of organizations would you particularly trust to implement these efforts? What about those organizations makes you trust them?

    PROBE: Government agencies
    Non-profit organizations
    Advocacy groups
    Medical associations

11. What organizations or types of organizations should NOT be involved in implementing these efforts? What makes them untrustworthy?

12. How much do you think people will trust a public education campaign that is conducted by the federal government? What specific federal agencies should be involved? Why?

V. ADDITIONAL CONSIDERATIONS (5 minutes)

1. In your opinion, what are the **main** reasons why the public should be informed about the Nevada Test Site, I-131 exposure, and any potential health problems?

   IF NECESSARY, PROBE: Some people think the government has an obligation to let people know about the exposure from the Nevada Test Site primarily because some people could have been harmed by the fallout. Other people think that regardless of the level of harm people experienced the government has an obligation to inform the public because the public has a right to know about its government's actions. Which of these best represents your views? Why?

2. Based on everything you know now, what if anything, would justify the Nevada atomic bomb testing?

   IF NECESSARY, PROBE: People were exposed to radioactive material while nuclear weapons were being tested for the purpose of defending our country. What do you think about this?

3. Do you think the government would have intentionally exposed people to radioactive material or do you think the government probably didn't know about the negative health effects that may be associated with the exposures until after the tests were already conducted?

4. What else do you think needs to be done to address the issue of I-131 fallout from the Nevada Test Site that we have not talked about?

VI. CLOSING (5 minutes)

1. CHECK WITH OBSERVERS FOR ADDITIONAL QUESTIONS.

2. Those are all of the questions I have. Do you have any final comments?

3. Thanks for your participation today. I have some bookmarks that can provide you with current information about what we've discussed this evening. Feel free to take one before you leave.

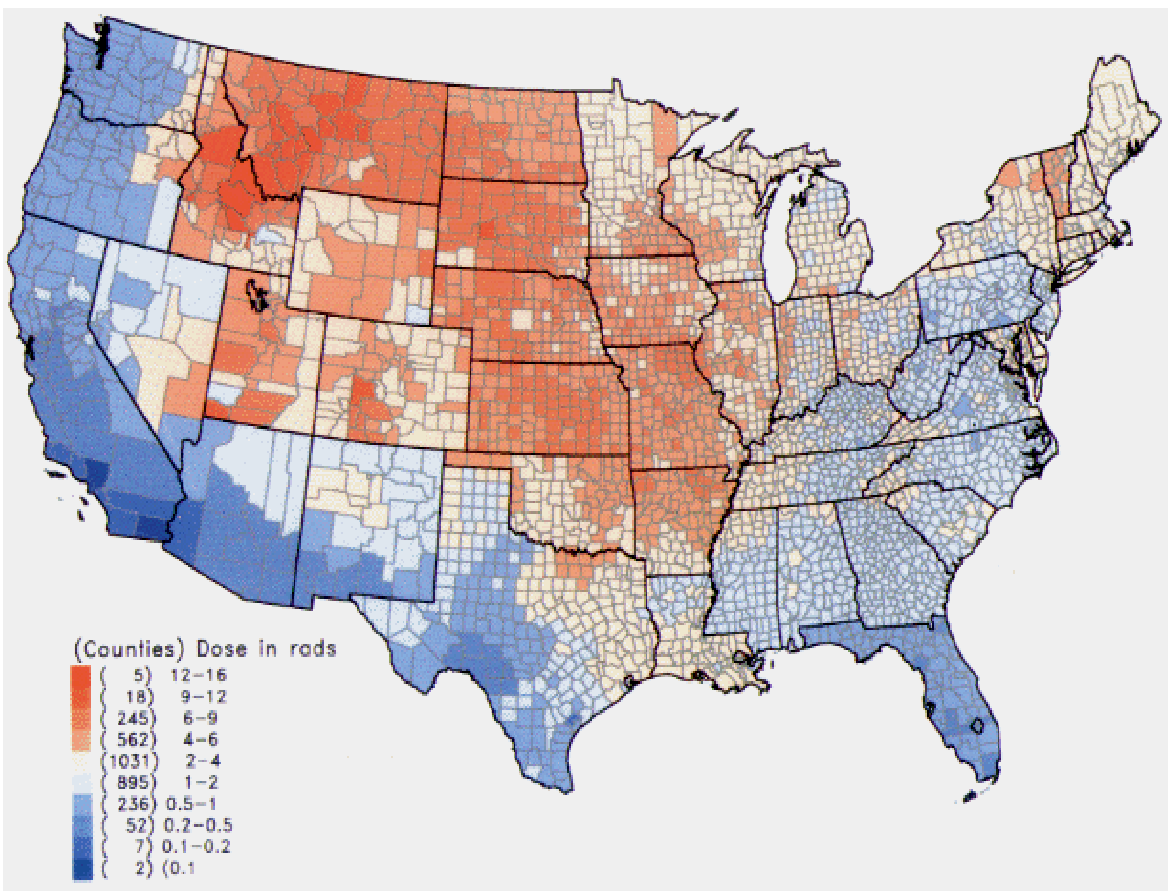
Additional Facts

- Thyroid cancer accounts for 1% of all cancers.

- Some areas near the Nevada Test Site were highly exposed to I-131 radiation. Other areas farther from Nevada also were highly exposed because weather patterns carried the radiation north and east of Nevada.

Study Estimating Thyroid Doses of I-131 Received by Americans from Nevada Atmospheric Nuclear Bomb Tests

Figure 1
Per capita thyroid doses resulting from all exposure routes from all tests



I.6 Tools for Research

(see next page)

Table I.6.1 "Tools" typically utilized for communications planning research.

Research Method	**Description**	**Pros**	**Cons**	**Common Uses**
Surveys/Questionnaires (self-administered)	Questionnaires or survey forms are filled out by the respondents themselves. Clarity in question design and instructions for completion are important.			
By mail	Questionnaires or survey forms are sent to potential subjects for them to complete on their own time and mail back to researcher.	• Generalizable results (if sufficiently large, probability sample with high response rate) • Can be anonymous (especially useful for highly sensitive topics) • Respondents can answer questions when most convenient for them • Can collect both program data and personal data (e.g., participant characteristics) • Does not require staff time to interact with target population • Can be used to access difficult-to-reach populations (e.g., the homebound, rural populations) • Can incorporate visual material (e.g., can pre-test prototype materials)	• Not appropriate for respondents who cannot read or write • Low response rate diminishes value of results. May require follow-up by mail or telephone to increase response rate (increases total costs). • Respondents may return incomplete questionnaires • Limited ability to probe answers • Respondents may self-select (potential bias) • May take long time to receive sufficient numbers of responses • Does not yield reliable assessments of attention-getting ability or recall of message • Postage may be very expensive if sample is large	• Obtain baseline data • Acquire self-reported information on behaviors, behavioral intentions, attitudes • Determine message's reach, attention-getting ability • Test knowledge, comprehension

Research Method	Description	Pros	Cons	Common Uses
By handout	Respondents are asked to complete survey at a location frequented by the target population (e.g., during a conference, in a classroom, after viewing an exhibit at a health fair).	• Can more readily improve response rate because there is an opportunity to use face-to- face persuasion tactics • Can collect both program data and personal data (e.g., participant characteristics)	• Not appropriate for respondents who cannot read or write • Must be able to reach respondents in person at a central location or a gathering	• Obtain baseline data • Acquire self-reported information on behaviors, behavioral intentions, attitudes • Test knowledge, comprehension
By Computerized Self-administered Questionnaires (CSAQ)	A questionnaire is programmed and displayed on a computer screen with respondents keying in their answers. Requires that respondents have access to programmed computers and that they be somewhat familiar and comfortable with using computers.	• Useful for complex questionnaires because complex "skip patterns" can be preprogrammed • Can control sequencing of questions • Can provide quick summary and/or analysis of results by eliminating the step of data entry from paper questionnaires or interviews	• Not appropriate for audiences who cannot read or those unfamiliar or uncomfortable with computers • Requires expensive technical equipment that may not be readily available or may be cumbersome in many settings	• Test knowledge, comprehension • Acquire self-reported information on behaviors, behavioral intentions, attitudes • Pre-test visual material • Determine if audience attends to, comprehends, and remembers contents of message.
Surveys/Questionnaires (administered by interviewer)	A trained interviewer asks survey questions of respondents. Allows respondent to ask for clarification and allows interviewer to control question sequence.			

Research Method	Description	Pros	Cons	Common Uses
By telephone	Respondents are contacted via telephone by trained interviewer. Respondents may be selected in advance from a list or contacted randomly (increases generalizability of results).	• Generalizable results (if sufficiently large, probability sample with high response rate) • Appropriate for those of lower literacy • Interviewer available to clarify questions for respondent and probe answers • Decreased likelihood of incomplete questionnaires	• Requires interviewer training • Low response rate diminishes value of results • Potential respondents who do not have a phone cannot participate • Respondents often hang up if they believe the survey is part of a solicitation call	• Obtain baseline data • Determine message's reach, attention-getting ability • Acquire self-reported information on behaviors, behavioral intentions, attitudes • Test knowledge, comprehension.
By computer-assisted telephone interviewing (CATI) technology	Respondents are contacted via telephone by a trained interviewer who has the questionnaire displayed on a computer terminal. The interviewer enters data directly into the computer.	• Generalizable results (if sufficiently large, probability sample with high response rate) • Can program allowable codes for responses which interviewer can use to correct mistakes during interview • Can program help menus to assist interviewer • Computer controls question sequence, allowing complex "skip patterns" • Provides a more efficient means of generating a probability sample	• Considerable development work and lead time are needed before survey implementation • Requires much interviewer training • Not useful for small samples because the workload costs of CATI exceed the benefits	• Obtain baseline data • Test knowledge and comprehension • Obtain self-reported information regarding attitudes and behaviors.

Research Method	Description	Pros	Cons	Common Uses
Face-to-face	One-on-one, in-person interview is used to collect information on knowledge, attitudes, and/or behaviors.	• Generalizable results (if sufficiently large, probability sample with high response rate) • Appropriate for those of lower literacy • Useful with difficult-to-reach populations (e.g., homeless, low-literacy) or when target audience cannot be sampled using other data collection methods • Interviewer available to clarify questions for respondent and probe answers • Decreased likelihood of incomplete questionnaires	• Can be more labor intensive than self-administered or telephone data collection • Less appropriate for sensitive or threatening questions (respondents may not answer truthfully in person)	• Obtain baseline data • Determine message's reach, attention-getting ability • Acquire self-reported information on behaviors, behavioral intentions, attitudes • Test knowledge, comprehension

Research Method	Description	Pros	Cons	Common Uses
Central location intercept interviews	Potential respondents are approached in a public area by a trained interviewer and invited to participate in the survey. Usually conducted in a high-traffic area (e.g., mall, student union) or other area frequented by target population. Requires highly structured, pre-determined questions that primarily use multiple-choice or close-ended questions.	• Can connect with harder-to-reach respondents in locations convenient and comfortable for them • Can be conducted quickly • Cost-effective means of gathering data in relatively short time • Increased number of respondents within intended population if appropriate location chosen • Larger sample size than focus groups • Eliminates group bias that is possible in focus groups	• Requires interviewer training • Quota sample, not probability sample • Not appropriate for sensitive issues or potentially threatening questions • Cannot easily probe for additional information (too time consuming)	• Test program messages, materials
Written responses to requests for information (e.g., diaries, activity logs, anecdotal accounts)	Information is requested in a specific format from individuals implementing a program or from participants themselves. Information may relate to such issues as quality of program components or how components are used by target population.	• Can allow respondents more flexibility in their replies • Can enable researchers to receive reports on behavior over time, rather than a "snapshot"	• Requires considerable effort on respondents' parts • Incoming data may be voluminous and challenging to code and compare • Not appropriate for respondents who have poor writing	• Track program implementation • Learn what questions program participants had • Learn what technical assistance was needed by program staff

Research Method	Description	Pros	Cons	Common Uses
Review of existing data (e.g., program registration rolls, grocery store receipt tapes, hospital discharge records)	A structured evaluation of information previously collected by local, state, or national agencies is undertaken. Existing sources of health data (statistics, tracking records, treatment patterns) may be available on the World Wide Web or through government agencies, local or university libraries, health departments, clinics or hospitals, police departments, schools, research or nonprofit organizations. Organizations may collect data not originally intended as health data, but useful nonetheless. Examples include grocery store receipts and event attendance records. Analysis of existing data is useful for all forms of evaluation	• Use of existing data means less effort in data collection • May be inexpensive if owner of data provides them at little or no cost • Possible sources of data are plentiful	• Diminished ability to control data points and data collection methods	• Conduct needs assessment • Track the number of people engaging in a behavior in a given locale (e.g., accessing free mammography screening services, purchasing sunscreen).

Research Method	Description	Pros	Cons	Common Uses
In-depth personal interviews	Qualitative data collection method involves less rigid question structure and interviewing style than quantitative methods.	• Can explore long or complex draft materials • Can be effective with those of lower literacy • Allows considerable opportunity to probe answers • Allows for intensive investigation of individual thought, opinions, and attitudes	• Time consuming • Requires level of trust between interviewer and respondent, especially when dealing with sensitive or threatening material • Interviewer must be highly skilled in active listening, probing, and other interviewing skills • Interviewer must be knowledgeable about and sensitive to a respondent's culture or frame of reference	• Develop concepts or messages • Test long or complex draft materials • Conduct a needs assessment.
Focus groups	This tool is a qualitative method of data collection wherein a skilled moderator facilitates discussion on a selected topic among 6 to 10 respondents, allowing them to respond spontaneously to the issues raised. Lasts for 60 to 90 minutes per session. For focus group research to be most valuable, the moderator must cover the research topics, establish an environment in which all points of view are welcome, and follow up on unexpected but potentially valuable topics that are raised.			

Research Method	Description	Pros	Cons	Common Uses
Face-to-face	When focus groups are conducted in person, participants and the moderator gather, usually around a table. Observers (members of the research team) sit behind a one-way mirror or unobtrusively back from the table and take notes. Groups may also be recorded by audio- or videotape.	• Interaction in the group can help elicit in-depth thought and discussion • Considerable opportunity to probe answers • Can yield richer data than surveys about the complexities of audience's thinking and behavior • In-person groups give moderator more opportunity to read nonverbal cues and use nonverbal cues to control the flow of discussion than in telephone focus groups • Rapport can be fostered more easily among in-person groups than telephone groups	• Findings not generalizable • Respondents may be concerned about lack of anonymity • Can be labor intensive and expensive, especially if groups are conducted in multiple locations	• Explore complex topics with target audience prior to program (e.g., what helps/hinders healthy eating) • Learn about feelings, motivators, past experiences related to a health topic • Test concepts, message, materials, and artwork • Can generate and test hypotheses.

Research Method	Description	Pros	Cons	Common Uses
By telephone	When focus groups are conducted by telephone, the moderator and participants speak by conference call with observers listening and taking notes. Telephone groups may be recorded by audiotape. Typically, 6 to 8 people participate.	• Interaction in group can help elicit in-depth thought and discussion • Considerable opportunity to probe answers • Can yield richer data than surveys about the complexities of audience's thinking and behavior • Telephone focus groups can be more easily convened than in-person groups when participants' occupations/lifestyles afford little free time (e.g., doctors, mayors); reduce travel burden on research staff; and can allow for broad geographic representation • Allow for project staff and partners to listen from their homes or offices	• Findings not generalizable • Respondents may be concerned about lack of anonymity • Telephone groups tend to work best when participants have tangible materials to which they can respond (e.g., pre-testing materials). • Long distance phone bills for groups can be expensive, especially if many people listen in • Productive sessions by phone cannot usually be sustained more than 1 to 1½ hours	• Explore complex topics with target audience prior to program (e.g., what helps/hinders healthy eating) • Learn about feelings, motivators, past experiences related to a health topic • Test concepts, message, materials, and artwork • Generate and test hypotheses.

Research Method	Description	Pros	Cons	Common Uses
Theater testing	Quantitative data is collected from a large group of respondents (generally 60-100 people per session) who respond to audio-visual materials (e.g., commercials, PSAs). Some messages shown are controls and others are being tested, allowing for a more "real life" assessment of message concepts. Respondents answer questionnaires or respond electronically means.	• Can gather quantitative data from large group at once • Data available immediately • Showing "actual" audiovisual materials allows more realism than storyboards • Using control messages allows more realism	• Significant production costs associated with making draft materials available to test • Limited ability to ask open-ended questions • Rely on technological equipment that may not be readily accessible	• Test audiovisual materials with many respondents at once
Observational studies	Individuals are observed in a natural setting with minimal observer interaction (e.g., observing shoppers in a grocery store to see if they are reading posted nutritional charts)	• Can observe behaviors or program implementation directly	• Can be labor intensive; requires site visits • Many behaviors and program activities not easily observed • Presence of observer can alter behavior of those being observed • Ethics of observing people without their knowledge may be questioned	• Counting people accessing a service • Assessing the consistency with which a service is delivered (e.g., whether registration desk clerks mention a program to all potential participants) • Observing whether skills (e.g., testing blood sugar) have been learned correctly • Useful for observing behavior at baseline, during a program, and after it ends.

Research Method	Description	Pros	Cons	Common Uses
Readability testing	Estimates the educational level required for target population to adequately comprehend written materials (i.e., if a pamphlet's readability level is sixth grade, readers need to read at about the sixth grade level in order to comprehend the pamphlet.. Readability tests are available on many standard word processing packages or a test can easily be computed by hand.	• Inexpensive • Test can be performed very quickly	• "Rule of thumb" only, not predictive of readers' ability to understand content • Must be interpreted with caution because many additional factors can enhance or diminish comprehension of written material (e.g., the conceptual context of the material, reader's motivation or interest in the material, layout of concepts in a passage, use of graphics and symbols)	• Increase likelihood that materials will be comprehensible for those with lower literacy levels
Expert review	An analysis of program material or approaches is performed by individuals who are particularly knowledgeable in a content area. Reviewers may check such issues as scientific and technical accuracy or cultural appropriateness. Reviewers may be individuals such as medical research scientists, social workers, law enforcement officials, teachers, or community leaders.	• Inexpensive • Can help obtain support or "buy in" for your program	• Risk of experts seeking to take over or radically change program plans • Can be challenging to reconcile differing viewpoints	• Obtain input prior to program design from experts in a health field or who have experience working with your target audience • Ensure that your messages are scientifically accurate • Test program materials (e.g., ensure materials are culturally appropriate).

Research Method	Description	Pros	Cons	Common Uses
Gatekeeper Review	The appropriateness of draft program material for a target audience is assessed by individuals who can facilitate, complicate, or deny access to target population (e.g., those who control distribution channels). Gatekeeper commitment may be necessary to ensure that a program will be implemented as planned.	• Inexpensive • Can help obtain support or "buy in" for your program • Can ensure and smooth access to target populations	• Can cause setbacks if major revisions are needed (project staff can plan ahead and use formative research to avoid this) • Obtaining cooperation and getting priority attention can be challenging if gatekeepers are not especially invested in the population	• Ensure that messages will be disseminated and program plans carried out by obtaining gatekeeper approval prior to program dissemination • Obtain "buy in" from influential people who control distribution channels • Ensure that products conform to gatekeeper agency policies and goals (e.g., television station regulations for PSAs)
Media tracking (print, audio, or audiovisual media)	Content communicated by mass media outlets (e.g., television, radio, billboard advertisements) is tracked and analyzed systematically. A professional service typically is hired to do the tracking if the range of media sources extends much beyond the local level.	• Allows tracking of media that can be influential for the target audience • Allows health communicators to better understand patterns of media attention given their topic	• Review of data is time consuming • May require training of readers or video viewers if automated tracking is not used • Print and video clipping services are expensive	• Conduct needs assessment • Track changes in media treatment of a topic in response to an event or program • Identify issues addressed by media channels that focus on program's target audience • Discern whether media outlets are disseminating program messages as hoped or planned
Source: CDCynergy: Your health communication planning and evaluation tool. Version 1.0. Centers for Disease Control and Prevention; Office of Communication. July 1998.				

I.7 NCI's ^{131}I/NTS Communications Campaign and Process Evaluation Plan

I.7.1 NCI's ^{131}I/NTS Communications Campaign

The goals of NCI's ^{131}I/NTS Communications Campaign were:

- To inform health care providers (via health provider organizations) who conduct thyroid screening and education about the availability of NCI's I-131 materials, especially those practicing in significant fallout areas

- To inform consumer organizations that focus on health education needs of people ages 40 and older, with particular emphasis on groups responsible for thyroid education, about the availability of NCI's I-131 materials

- To inform federal agencies about the availability of NCI's I-131 materials for incorporation into their communication channels

- To make information about I-131 materials easily accessible for use by interested consumers, the public at large and advocacy organizations for inclusion in their communication channels

In December 2002, the NCI released communication materials for the Project, developed with extensive input from advocacy groups, community representatives and health officials, as well as extensive focus group testing. Materials included:

- **Get the Facts About Exposure to I-131 Radiation--**This general information brochure provides information about the Nevada tests and identifies individuals at particular risk.
- **Making Choices: Screening for Thyroid Disease--** This decision aid workbook/brochure is for individuals concerned about their exposure to I-131 from fallout (Based on decision support format of the Ottawa Health Decision Center at the University of Ottawa and Ottawa Health Research Institute, Ontario, Canada)
- **Radioactive Iodine (I-131) and Thyroid Cancer--**This flip chart, designed for use in small groups of up to 10 people, addresses concerns specific to Native Americans.
- **I-131 Web Site** (www.cancer.gov/i131), which includes tools for partners ("swiss cheese" press release, promotional brochure, etc.)

In order to accomplish these goals, by June 2003, NCI had accomplished the following

- Held a national teleconference (Dec 2002), at which NCI staff and invited experts discussed pertinent I-131 issues and plans for public promotion and dissemination of the materials
- Disseminated materials to project partners
- Within key exposure areas[8], disseminated materials through email and US postal service. Efforts concentrated on reaching key intermediaries-- health provider associations, community health clinics, advocacy and support groups, community-based networks, state health agencies, schools of public health, social workers, and federal agencies (including local clinics of the Indian Health Service.) (Full list follows). These intermediaries were provided tools to reach secondary audiences, which include individual health care providers and the concerned public aged 40 and older, particularly those who lived in areas of highest exposure and who consumed milk during the testing period.
- Conducted follow up calls to key organizations to ascertain interest in additional activities

In sum, the NCI conducted direct outreach with over 1000 local, regional and national organizations (see attached list).

I.7.2 NCI's ^{131}I/NTS Process Evaluation Plan

In evaluating the promotion and dissemination efforts of the NCI's ^{131}I/NTS Communications Campaign, the NCI developed the following measurable objectives:

1. By January 31, 2003, NCI will send promotional materials and educational products to all organizations on the original recruitment list.

2. By January 31, 2003, NCI will send promotional materials and educational products to health professional, consumer health, advocacy, and federal organizations identified by key stakeholders[9].

3. NCI will send promotional materials to 100% of organizations who request information on the educational products.

4. By December 31, 2002, NCI will conduct a teleconference to launch the materials with the media and key stakeholders.

---

[8] Twenty states received the highest fallout and include: Montana, Nevada, Utah, Colorado, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Missouri, Arkansas, Minnesota, Iowa, Wisconsin, Illinois, Wyoming, Idaho, Indiana, Texas and Vermont. There are 7 states (Massachusetts, Tennessee, New York, Oregon, Ohio, Michigan and Louisiana) in which only a few counties within each state were affected.

[9] Group of key informants representing health professional, consumer health, advocacy and federal organization who are interested in I-131 issues and who were identified by NCI at the project's inception. Largely consists of members of NCI's I-131 listserv.

5. By February 3, 2003, NCI will send I-131 promotional materials to 100% of specified NIH and NCI-affiliated groups
6. By February 10, 2003, NCI will send I-131 promotional materials and educational products to 100% of specified core thyroid health groups
7. By February 17, 2003, NCI will send I-131 promotional materials and educational products to 100% of specified general medical societies and primary care institutions
8. By February 27, 2003, NCI will send I-131 promotional materials and educational products to 100% of specified consumer health organizations
9. By February 21, 2003, NCI will send I I-131 promotional materials and educational products to 100% of specified Federal agencies (see Appendix B. Promotion Plan).
10. By July 3, 2003, NCI will follow-up with 100% of specified core thyroid health specific groups

A Process Evaluation Template, which includes evaluation questions, indicators, measures, process objectives, data sources, and frequency of data collection was developed. Data is to be analyzed in 2003.

This list represents over 450 national organizations/groups who received I-131 promotional materials disseminated by the Office of Cancer Communications in December 2002 [in addition to 121 Members of Congress].

AARP
Agency for Toxic Substances and Disease Registry
Alliance for Nuclear Accountability
Alliance of Atomic Veterans
American College of Preventive Medicine
American Thyroid Association (1000)
Association of State and Territorial Health Officials
ATSDR (1000)
Baltimore City Department of Health
Center for American Indian Research and Education
Center for Global Security & Health, Physicians for Social Responsibility
CDC: State Radiation Directors (54)
CDC: Division of Health Communication-Childhood Cancer Research Institute and Clark University
Colorado Department of Public Health and Environment
Conference of Radiation Control Program Directors
Consumers Union
Council of State and Territorial Epidemiologists
Decision Research
US Department of Health and Human Services
Vanderbilt University-Department of Radiology
Dine Care Group
Downwinders, Inc.
Elder Voices, Inc.
Hanford Health Information Network Resource Center
HRSA: radiation education grantees (36)
HRSA: Bureau of Primary Health Care: Primary and community health centers in high-exposed counties (390)
Idaho Division of Health
Indigenous Environmental Network
Institute for Energy and Environmental Research
Institute for Energy and Environmental Research
Interpretive Consultations, Inc, Risk Communication and Environmental Education
Iowa Dept. of Public Health
Johns Hopkins University School of Hygiene and Public Health
Mallinckrodt Institute of Radiology-Washington University School of Medicine
Mayo Medical School-Mayo Clinic Rochester
Memorial Sloan-Kettering Cancer Center
Miamisburg Environmental Safety and Health
Migrant Clinicians Network
Migrant Head Start Quality Improvement Center
Morgan County Medical Center
Morgan County Medical Center
NAACP-Oak Ridge, TN
National Association of County and City Health Officials
National Association of Radiation Survivors
National Center for Environmental Health
National Center for Farmworker Health
National Committee for Radiation Victims
National Congress of American Indians
National Institute of Diabetes and Digestive and Kidney Diseases
National Medical Association
Natural Resources Defense Council
Navaho Uranium Radiation Victims Committee
Directors Consumer Liaison Group-National Cancer Institute
Nevada State Health Division
New England Journal of Medicine
New York Presbyterian Hospital- Weill Medical College of Cornell University
New York State Department of Health
Nuclear Information & Resource Service
Oak Ridge Environmental Justice Committee
Oregon Department of Human Services
Oregon Health Division Environmental and Occupational Epidemiology
Pew Environmental Health Commission
Physicians for Social Responsibility
Porter Novelli
Public Interest Research Group- United States
Radiation and Public Health Project
Radiation Health Effects Archives
Radiological Health Section, Nevada State Health Division
Redish & Associates, Inc.
Rutgers University
Scarboro Community Environmental Justice Council
SENES Oak Ridge, Inc.
Short Cressman & Burgess PLLC
Sinai Hospital of Baltimore
Sisters of Charity of Ottawa Health Services
Snake River Alliance
Social and Environmental Research Institute
Standing for the Truth About Radiation
Support and Education for Radiation Victims
Tennessee Department of Environment and Conservation
The Endocrine Society

The National Academies
Thyroid Disease Information Source
Tufts University, Editor in Chief, Medicine and Global Survival
U.S. Department of Health and Human Services
University of Colorado School of Medicine
University of North Carolina at Chapel Hill School of Public Health
UPMC News Bureau
Uranium Education Program
Utah Department of Health, Bureau of Epidemiology
Vanchieri Communications
Western States Legal Foundation
Women's Action for New Directions
World Health Organization-Regional Office for Europe

This list represents over 200 national organizations/groups and their affiliates or chapters who received I-131 promotional materials disseminated by the Office Education and Special Initiatives in Spring 2003.

Alaska Native Tribal Health Consortium
American Academy of Family Physicians (chapter heads in 20 states)
American Academy of Nurse Practitioners
American Academy of Physician Assistants
American Association of Cancer Education
American Association of Retired Persons (local chapters and clearinghouse)
American Board of Internal Medicine
American Cancer Society (divisional offices)
American College of Obstetricians and Gynecologists
American College of Preventative Medicine
American Indian Institute
American Medical Association
American Nurses Association (state/local chapters in priority regions)
American Public Health Association
Association of American Indian Physicians
Association of Community Cancer Centers
Center for Medicaid and Medicare Services
Centers for Disease Control and Prevention
Chronic Disease Directors (communications committee)
Environmental Protection Agency (American Indian Environmental Office)
Indian Health Service (American Indian Environmental Office)
National Association of Community Health Centers (20 risk states)
National Association of County and City Health Officials
National Association of Social Workers
National Association of State Directors of Migrant Education
National Black Nurses Association
National Center for Farmworker Health
National Council of La Raza
National Hispanic Medical Association
National Hispanic Nurses Association
National Indian Health Board
National Medical Association (local and state societies)
National Rural Health Association
Native American Cancer Initiative
Native American Health Issues
Office of Minority Health (HHS clearinghouse)
Office of Minority Health Affairs
Older Women's League
Oncology Nursing Society – Special interest committees: Cancer Program Development, Management: Patient Education and Prevention, Early Detection Special Interest Groups
Thyroid Cancer Survivors' Association (local chapters)
Veterans Administration